



DesignNews

BeagleBone Black Primer

Day 4: BeagleBone Black PRU Programming

Sponsored by



Webinar Logistics

- Turn on your system sound to hear the streaming presentation.
- If you have technical problems, click “Help” or submit a question asking for assistance.
- Participate in ‘Attendee Chat’ by maximizing the chat widget in your dock.



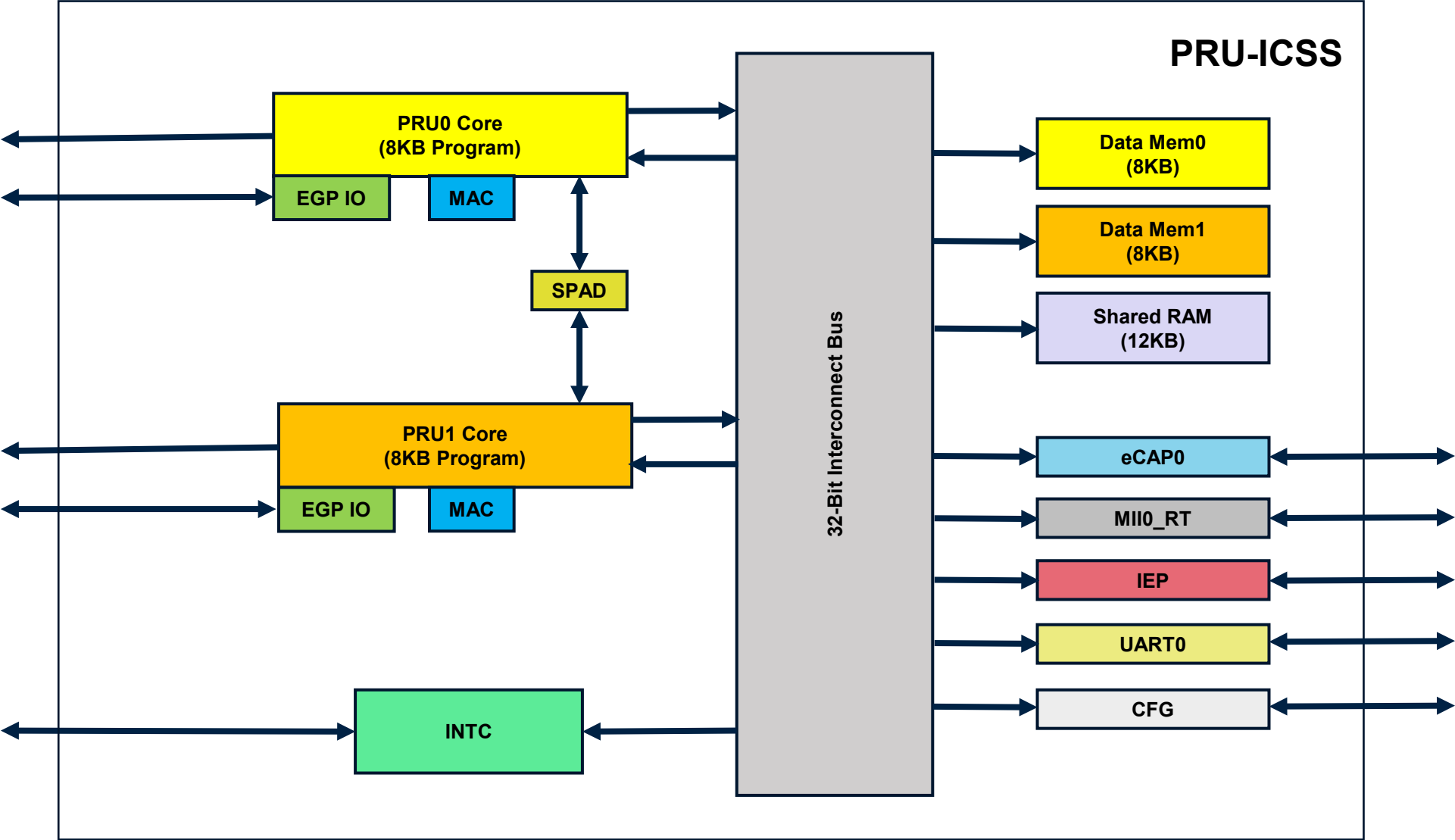
Fred Eady

Visit 'Lecturer Profile' in your console for more details.

AGENDA

- **BeagleBone Black PRU Primer**

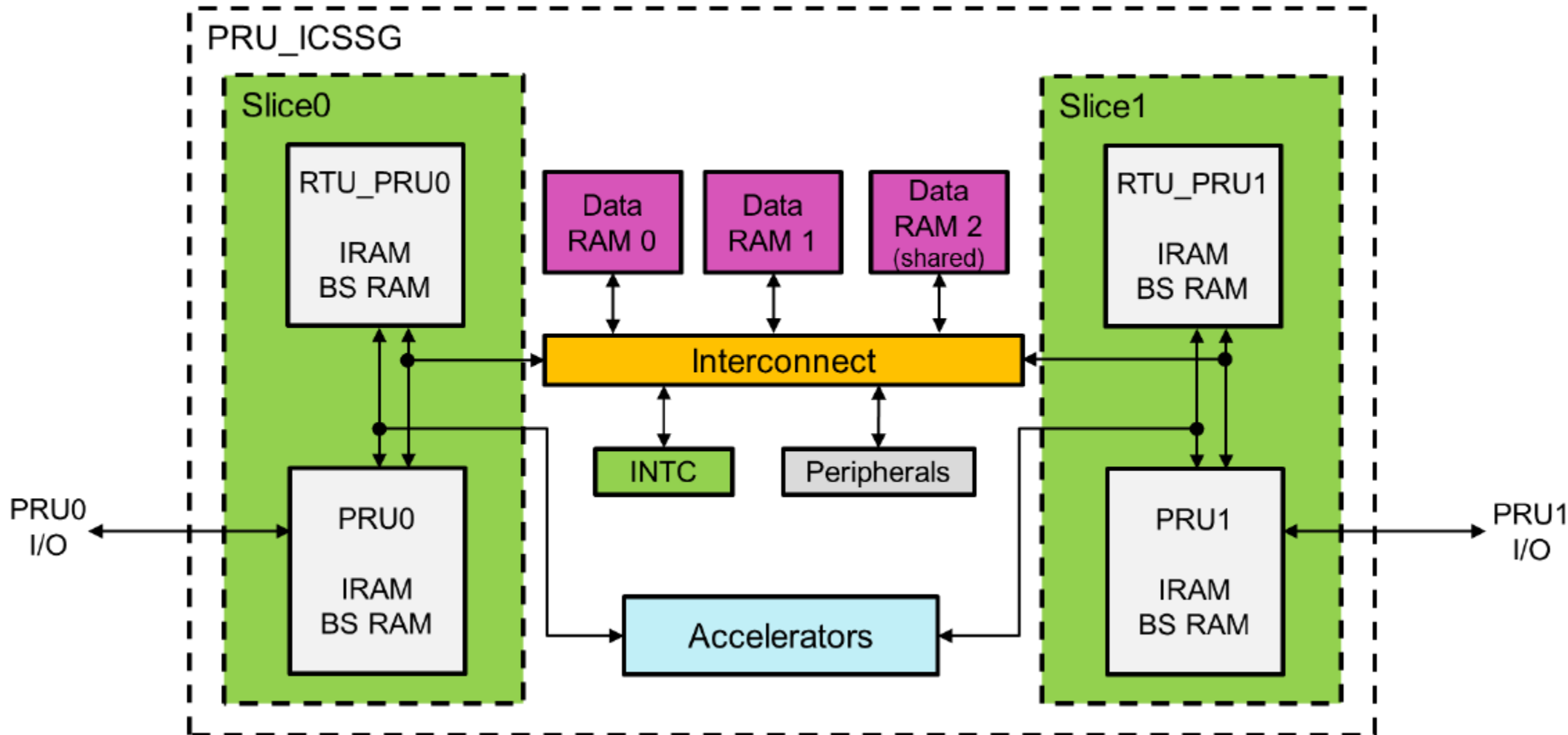




BeagleBone Black Primer
BeagleBone Black PRU Programming

BeagleBone Black PRU Primer

PRU Basics



BeagleBone Black PRU Primer
PRU Basics

P9			
DGND	1	2	DGND
VDD_3V3	3	4	VDD_3V3
VDD_5V	5	6	VDD_5V
SYS_5V	7	8	SYS_5V
PWR_BUT	9	10	SYS_RESETN
GPIO_30	11	12	GPIO_60
GPIO_31	13	14	GPIO_50
GPIO_48	15	16	GPIO_51
GPIO_5	17	18	GPIO_4
I2C2_SCL	19	20	I2C2_SDA
GPIO_3	21	22	GPIO_2
GPIO_49	23	24	GPIO_15
PRU0_7	25	26	PRU1_16 IN
PRU0_5	27	28	PRU0_3
PRU0_1	29	30	PRU0_2
PRU0_0	31	32	VDD_ADC
AIN4	33	34	GNDA_ADC
AIN6	35	36	AIN5
AIN2	37	38	AIN3
AIN0	39	40	AIN1
PRU0_6	41	42	PRU0_4
DGND	43	44	DGND
DGND	45	46	DGND

P8			
DGND	1	2	DGND
GPIO_38	3	4	GPIO_39
GPIO_34	5	6	GPIO_35
GPIO_66	7	8	GPIO_67
GPIO_69	9	10	GPIO_68
PRU0_15 OUT	11	12	PRU0_14 OUT
GPIO_23	13	14	GPIO_26
GPIO_47	15	16	GPIO_46
GPIO_27	17	18	GPIO_65
GPIO_22	19	20	PRU1_13
PRU1_12	21	22	GPIO_37
GPIO_36	23	24	GPIO_33
GPIO_32	25	26	GPIO_61
PRU1_8	27	28	PRU1_10
PRU1_9	29	30	PRU1_11
GPIO_10	31	32	GPIO_11
GPIO_9	33	34	GPIO_81
GPIO_8	35	36	GPIO_80
GPIO_78	37	38	GPIO_79
PRU1_6	39	40	PRU1_7
PRU1_4	41	42	PRU1_5
PRU1_2	43	44	PRU1_3
PRU1_0	45	46	PRU1_1

BeagleBone Black PRU Primer

BeagleBone Black versus Raspberry Pi 4B

Programmable Real-time Units (PRUs) are exclusive to the BeagleBone Black and are not found on the Raspberry Pi 4B.



BeagleBone Black Primer
BeagleBone Black PRU Programming

BeagleBone Black PRU Primer

PRU Basics

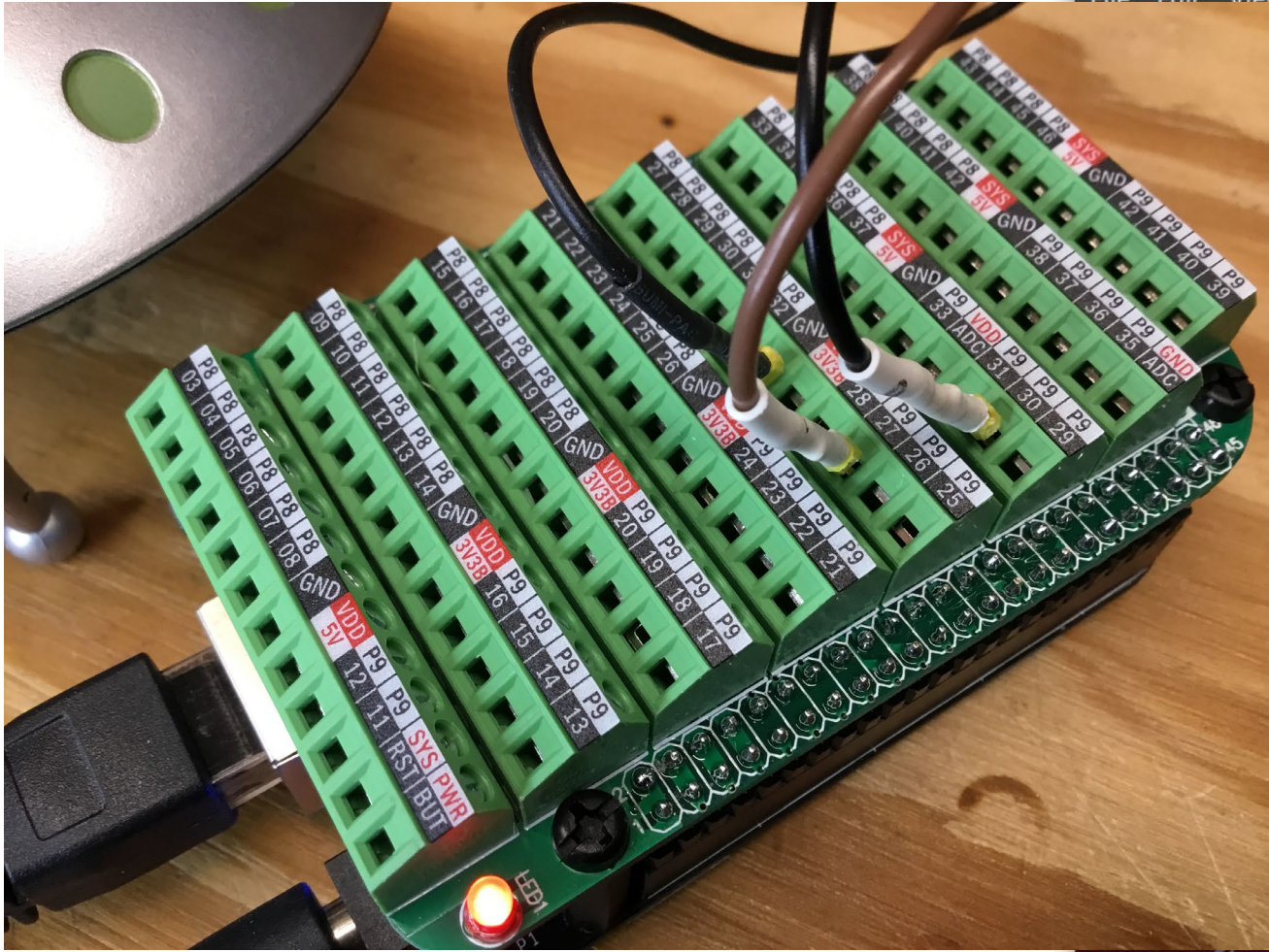


Uncomment to Disable



```
debian@beaglebone: ~  
File Edit View Search Terminal Help  
GNU nano 3.2 /boot/uEnv.txt  
  
#uboot_overlay_addr6=/lib/firmware/<file6>.dtbo  
#uboot_overlay_addr7=/lib/firmware/<file7>.dtbo  
###  
###Custom Cape  
#dtb_overlay=/lib/firmware/<file8>.dtbo  
###  
###Disable auto loading of virtual capes (emmc/video/wireless/adc)  
#disable_uboot_overlay_emmc=1  
#disable_uboot_overlay_video=1  
#disable_uboot_overlay_audio=1  
#disable_uboot_overlay_wireless=1  
#disable_uboot_overlay_adc=1  
###  
###PRUSS OPTIONS  
###pru_rproc (4.14.x-ti kernel)  
#uboot_overlay_pru=/lib/firmware/AM335X-PRU-RPROC-4-14-TI-00A0.dtbo  
###pru_rproc (4.19.x-ti kernel)  
uboot_overlay_pru=/lib/firmware/AM335X-PRU-RPROC-4-19-TI-00A0.dtbo  
###pru_uio (4.14.x-ti, 4.19.x-ti & mainline/bone kernel)  
  
^G Get Help ^O Write Out ^W Where Is ^K Cut Text ^J Justify ^C Cur Pos  
^X Exit ^R Read File ^\ Replace ^U Uncut Text ^T To Spell ^_ Go To Line
```

BeagleBone Black PRU Primer

PRU *toggle_led* Application – Available PRU GPIO Pins

```
debian@beaglebone: /sys/devices/platform/ocp
File Edit View Search Terminal Help

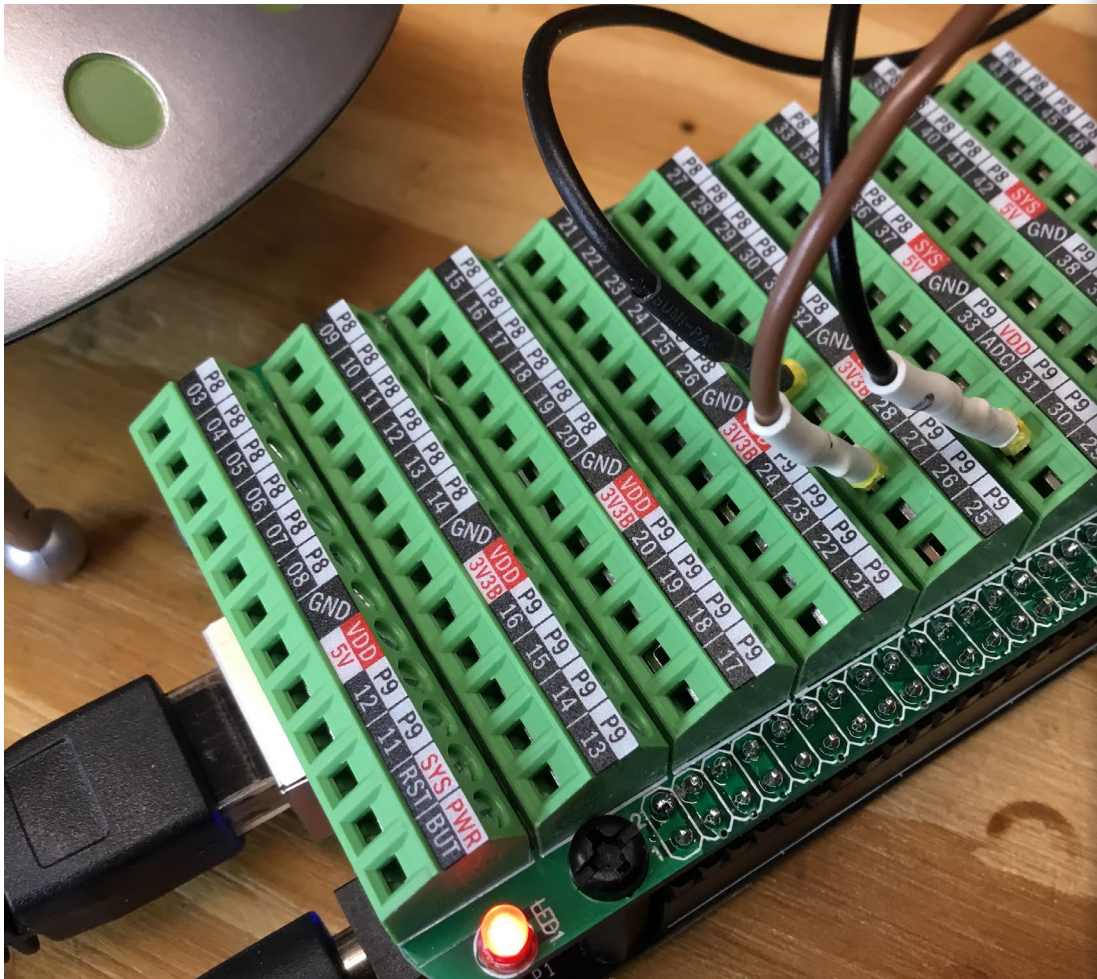
debian@beaglebone:/sys/devices/platform/ocp$ ls
481d8000.mmc                ocp:P8_17_pinmux
48300000.epwmss             ocp:P8_18_pinmux
48302000.epwmss             ocp:P8_19_pinmux
48304000.epwmss             ocp:P8_26_pinmux
4830e000.lcdc               ocp:P9_11_pinmux
48310000.rng                ocp:P9_12_pinmux
49000000.edma               ocp:P9_13_pinmux
49800000.tptc               ocp:P9_14_pinmux
49900000.tptc               ocp:P9_15_pinmux
49a00000.tptc               ocp:P9_16_pinmux
4a100000.ethernet           ocp:P9_17_pinmux
4a326004.pruss-soc-bus      ocp:P9_18_pinmux
4c000000.emif               ocp:P9_19_pinmux
53100000.sham               ocp:P9_20_pinmux
53500000.aes                ocp:P9_21_pinmux
56000000.sgx                ocp:P9_22_pinmux
driver_override             ocp:P9_23_pinmux
modalias                    ocp:P9_24_pinmux
ocp:cape-universal          ocp:P9_26_pinmux
ocp:clk_mcaspp0             ocp:P9_27_pinmux
ocp:l4_wkup@44c00000        ocp:P9_30_pinmux
ocp:P8_07_pinmux            ocp:P9_41_pinmux
ocp:P8_08_pinmux            ocp:P9_42_pinmux
ocp:P8_09_pinmux            ocp:P9_91_pinmux
ocp:P8_10_pinmux            ocp:P9_92_pinmux
ocp:P8_11_pinmux            of_node
ocp:P8_12_pinmux            power
ocp:P8_13_pinmux            subsystem
ocp:P8_14_pinmux            uevent
ocp:P8_15_pinmux
ocp:P8_16_pinmux
481cc000.can                ocp:P8_15_pinmux
481d0000.can                ocp:P8_16_pinmux
debian@beaglebone:/sys/devices/platform/ocp$
```

BeagleBone Black PRU Primer

PRU *toggle_led* Application – Available PRU GPIO Pins

P9				P8			
DGND	1	2	DGND	DGND	1	2	DGND
VDD_3V3	3	4	VDD_3V3	GPIO_38	3	4	GPIO_39
VDD_5V	5	6	VDD_5V	GPIO_34	5	6	GPIO_35
SYS_5V	7	8	SYS_5V	GPIO_66	7	8	GPIO_67
PWR_BTN	9	10	SYS_RESETN	GPIO_69	9	10	GPIO_68
GPIO_30	11	12	GPIO_60	PRUO_15 OUT	11	12	PRUO_14 OUT
GPIO_31	13	14	GPIO_50	GPIO_23	13	14	GPIO_26
GPIO_48	15	16	GPIO_51	GPIO_47	15	16	GPIO_46
GPIO_5	17	18	GPIO_4	GPIO_27	17	18	GPIO_65
I2C2_SCL	19	20	I2C2_SDA	GPIO_22	19	20	PRU1_13
GPIO_3	21	22	GPIO_2	PRU1_12	21	22	GPIO_37
GPIO_49	23	24	GPIO_15	GPIO_36	23	24	GPIO_33
PRUO_7	25	26	PRU1_16 IN	GPIO_32	25	26	GPIO_61
PRUO_5	27	28	PRUO_3	PRU1_8	27	28	PRU1_10
PRUO_1	29	30	PRUO_2	PRU1_9	29	30	PRU1_11
PRUO_0	31	32	VDD_ADC	GPIO_10	31	32	GPIO_11
AIN4	33	34	GNDA_ADC	GPIO_9	33	34	GPIO_81
AIN6	35	36	AIN5	GPIO_8	35	36	GPIO_80
AIN2	37	38	AIN3	GPIO_78	37	38	GPIO_79
AIN0	39	40	AIN1	PRU1_6	39	40	PRU1_7
PRUO_6	41	42	PRUO_4	PRU1_4	41	42	PRU1_5
DGND	43	44	DGND	PRU1_2	43	44	PRU1_3
DGND	45	46	DGND	PRU1_0	45	46	PRU1_1

BeagleBone Black PRU Primer

PRU *toggle_led* Application – Configure PRU GPIO Pins

```
debian@beaglebone: /sys/devices/platform/ocp
File Edit View Search Terminal Help

debian@beaglebone:/sys/devices/platform/ocp$ config-pin P9_27 pruout
Current mode for P9_27 is:      pruout

debian@beaglebone:/sys/devices/platform/ocp$ config-pin P9_30 pruout
Current mode for P9_30 is:      pruout

debian@beaglebone:/sys/devices/platform/ocp$ config-pin -q P9_27
Current mode for P9_27 is:      pruout

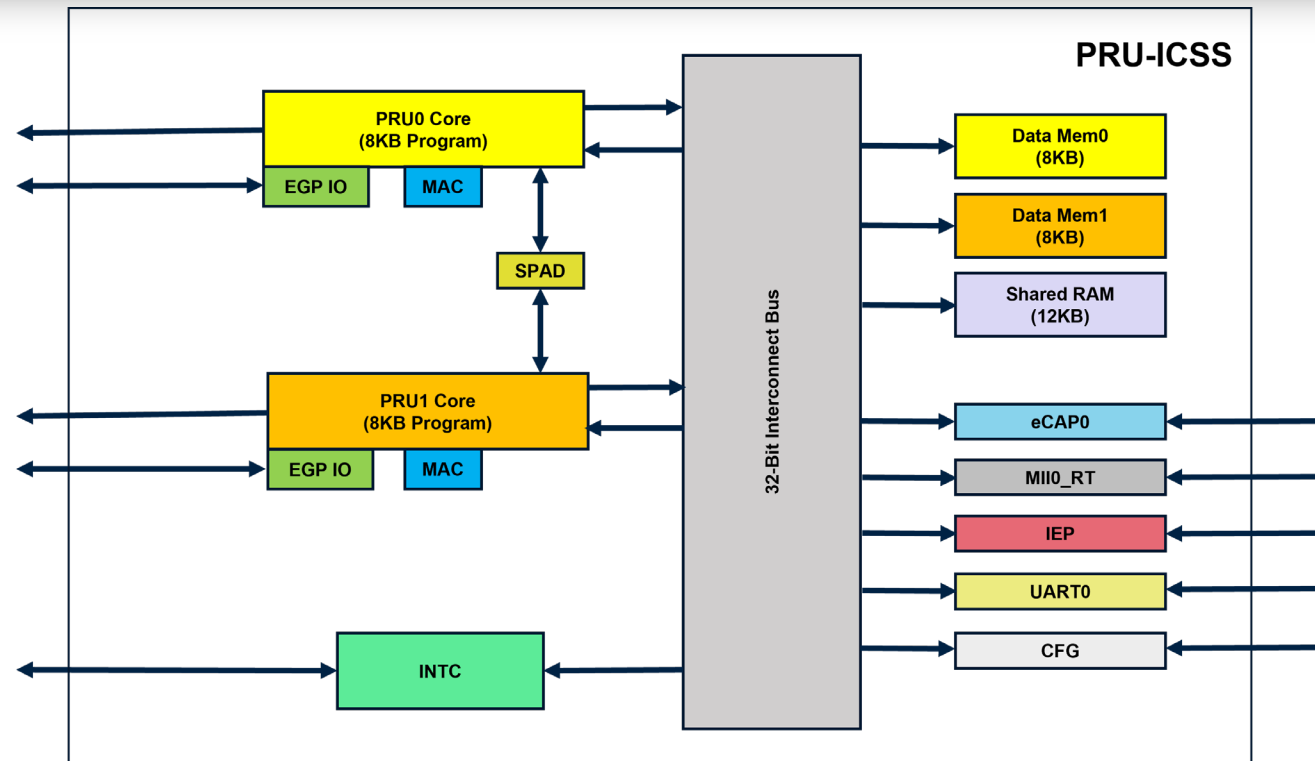
debian@beaglebone:/sys/devices/platform/ocp$ config-pin -q P9_30
Current mode for P9_30 is:      pruout

debian@beaglebone:/sys/devices/platform/ocp$
```

BeagleBone Black PRU Primer

PRU toggle_led Application – Get the Latest PRU Software Support Package

```
fred@shopUbuntu885: /  
File Edit View Search Terminal Help  
fred@shopUbuntu885:/$ git clone --depth=1 --branch v5.9.0 git://git.ti.com/  
pru-software-support-package/pru-software-support-package.git
```



BeagleBone Black PRU Primer

PRU *toggle_led* Application – Create PRU Project

New CCS Project
Create a new CCS Project.

Target: <select or type filter text> BeagleBone_Black

Connection: Verify...

PRU

Project name: toggle_led

☒ Use default location

Location: /home/fred/workspace_v11/toggle_led Browse...

Compiler version: TI v2.3.3 More...

Project type and tool-chain

Project templates and examples

type filter text

- Empty Project
- Empty Project (with main.c)**
- Empty Assembly-only Project
- Empty RTSC Project
- Basic Examples
 - Hello World

Creates an empty project initialized for the selected device. The project will contain an empty 'main.c' source-file.

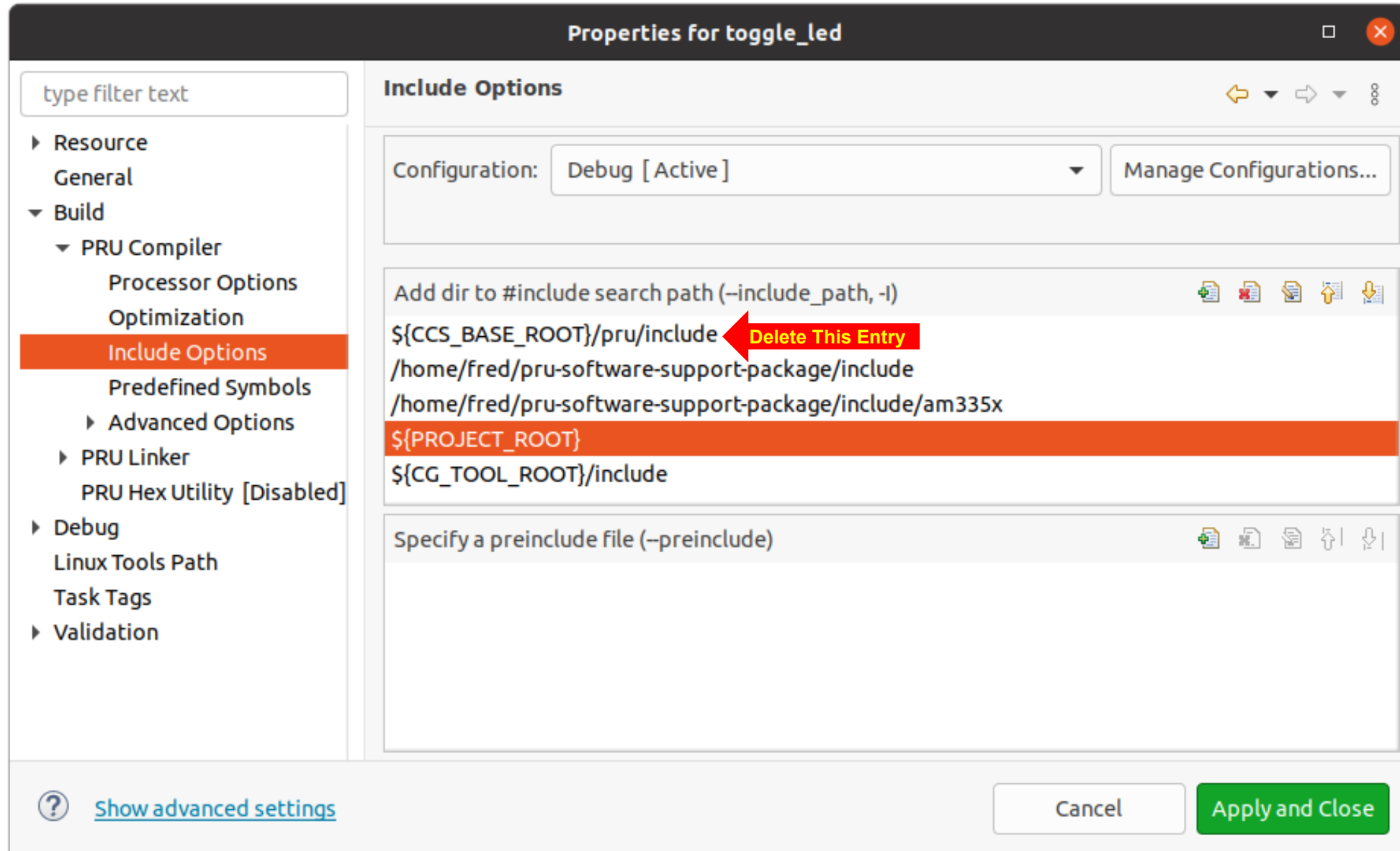
Open [Resource Explorer](#) to browse a wide selection of example projects...

Open [Import Wizard](#) to find local example projects for selected device...

? < Back Next > Cancel Finish

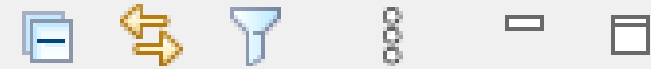
BeagleBone Black PRU Primer

PRU *toggle_led* Application – Create PRU Project



PRU *toggle_led* Application – Create PRU Project

Project Explorer

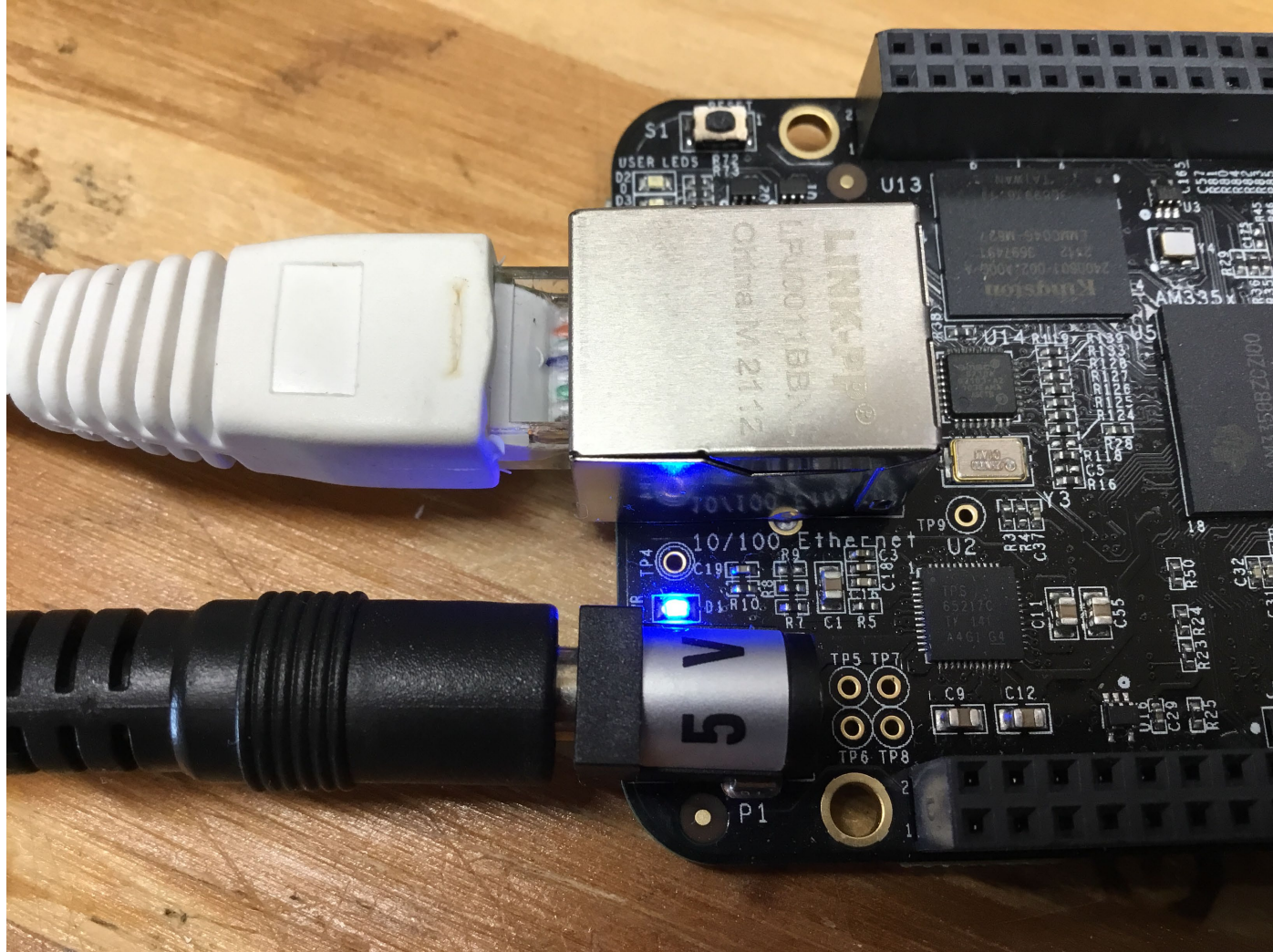
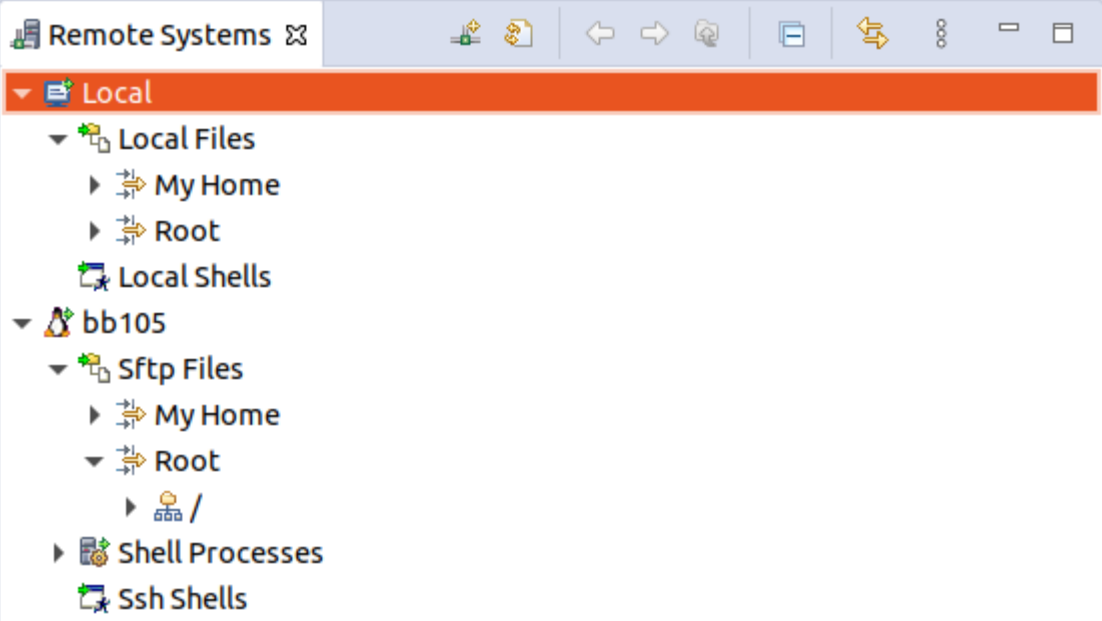


toggle_led [Active - Debug]

- ▶ Binaries
- ▶ Includes
 - ▶ /home/fred/pru-software-support-package/include
 - ▶ /home/fred/pru-software-support-package/include/am335x
 - ▶ /home/fred/ti/ccs1120/ccs/tools/compiler/ti-cgt-pru_2.3.3/include
 - ▶ toggle_led
- ▶ Debug
- ▶ AM335x_PRU.cmd
- ▶ main.c
- ▶ resource_table_empty.h 

BeagleBone Black PRU Primer

PRU *toggle_led* Application – Connect to the BBB



PRU *toggle_led* Application – Write the PRU0 Code

```
/**
*****
/* BEAGLEBONE PRU0 TOGGLE LED
/* WRITTEN BY FRED EADY
/* LAST UPDATED 05/01/2022
*****
#include <stdint.h>
#include <pru_cfg.h>
#include "resource_table_empty.h"

volatile register uint32_t __R30; //PRU0 GPIO Output Pins

int main(void)
{
    volatile uint32_t flipper;
    __R30 = 0x0000;

    while(1)
    {
        flipper = __R30; //load flipper with R30 bits
        flipper ^= 0x24; //flip P9_27 and P9_30
        __R30 = flipper; //push flipped bits to GPIO
        __delay_cycles(100000000); //PRU0 runs at 200MHz - 0.5s delay
    }
}
```

BeagleBone Black PRU Primer

PRU *toggle_led* Application – Compile the PRU0 Code

```

Console
CDT Build Console [toggle_led]

**** Build of configuration Debug for project toggle_led ****

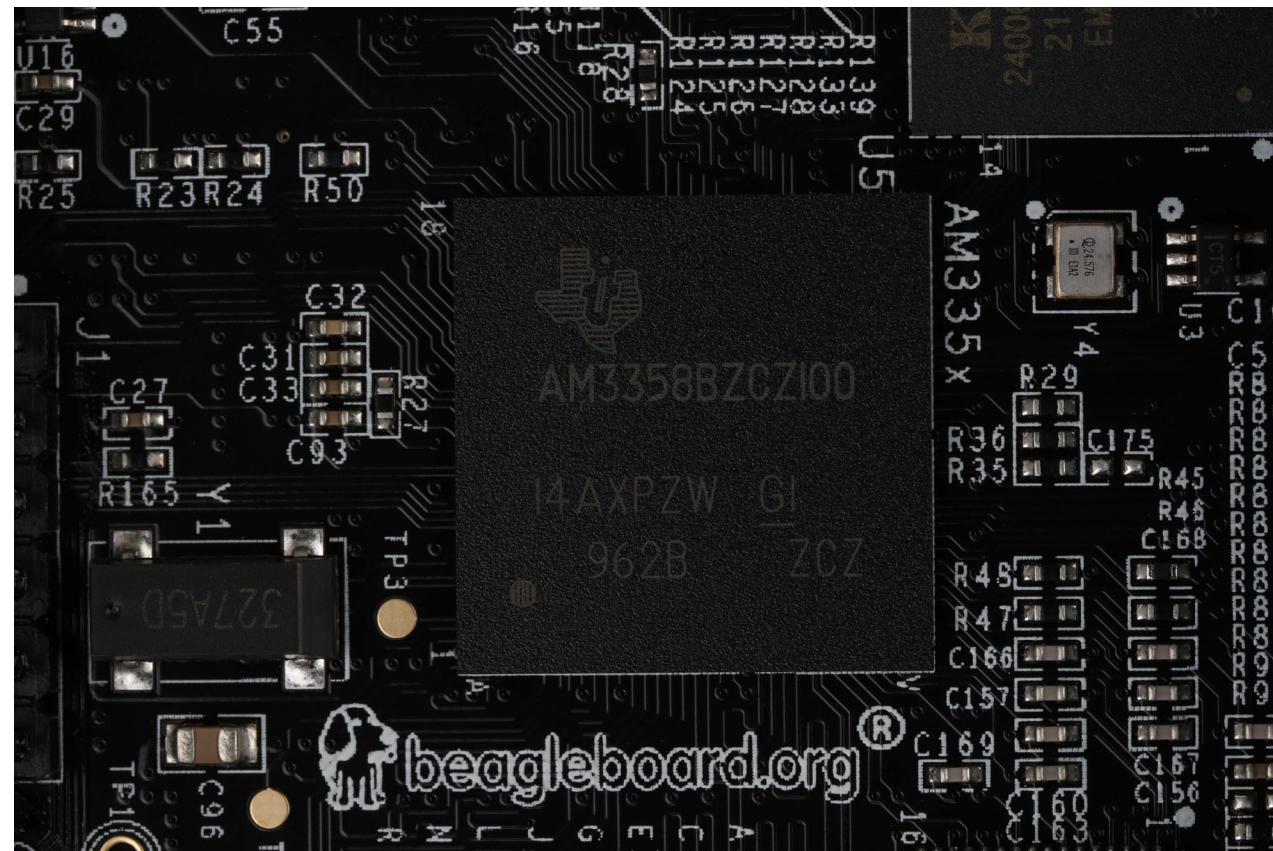
/home/fred/ti/ccs1120/ccs/utis/bin/gmake -k -j 4 all -o

Building file: "../main.c"
Invoking: PRU Compiler
"/home/fred/ti/ccs1120/ccs/tools/compiler/ti-cgt-pru_2.3.3/bin/clpru" -v3 --
include_path="/home/fred/pru-software-support-package/include" --
include_path="/home/fred/pru-software-support-package/include/am335x" --
include_path="/home/fred/workspace_v11/toggle_led" --include_path="/home/fred/
ti/ccs1120/ccs/tools/compiler/ti-cgt-pru_2.3.3/include" --define=am3359 --
define=pru0 -g --diag_warning=225 --diag_wrap=off --display_error_number --
endian=little --hardware_mac=on --preproc_with_compile --
preproc_dependency="main.d_raw" "../main.c"
Finished building: "../main.c"

Building target: "toggle_led.out"
Invoking: PRU Linker
"/home/fred/ti/ccs1120/ccs/tools/compiler/ti-cgt-pru_2.3.3/bin/clpru" -v3 --
define=am3359 --define=pru0 -g --diag_warning=225 --diag_wrap=off --
display_error_number --endian=little --hardware_mac=on -z -m"toggle_led.map" --
heap_size=0x100 --stack_size=0x100 -i"/home/fred/ti/ccs1120/ccs/tools/compiler/
ti-cgt-pru_2.3.3/lib" -i"/home/fred/ti/ccs1120/ccs/tools/compiler/ti-cgt-
pru_2.3.3/include" --reread_libs --diag_wrap=off --display_error_number --
warn_sections --xml_link_info="toggle_led_linkInfo.xml" --rom_model -o
"toggle_led.out" "../main.obj" "../AM335x_PRU.cmd" -llibc.a
<Linking>
Finished building target: "toggle_led.out"

**** Build Finished ****

```



PRU *toggle_led* Application – Copy Binary to BBB /bbbProjects

```
fred@shopUbuntu885: ~/workspace_v11/toggle_led/Debug
File Edit View Search Terminal Help

fred@shopUbuntu885:~/workspace_v11/toggle_led/Debug$ sudo scp toggle_led.out deb
ian@192.168.1.105:/home/debian/bbpruProjects
[sudo] password for fred:
Debian GNU/Linux 10

BeagleBoard.org Debian Buster IoT Image 2020-04-06

Support: http://elinux.org/Beagleboard:BeagleBoneBlack_Debian

default username:password is [debian:temppwd]

debian@192.168.1.105's password:
toggle_led.out                               100%  31KB 838.0KB/s   00:00
fred@shopUbuntu885:~/workspace_v11/toggle_led/Debug$
```

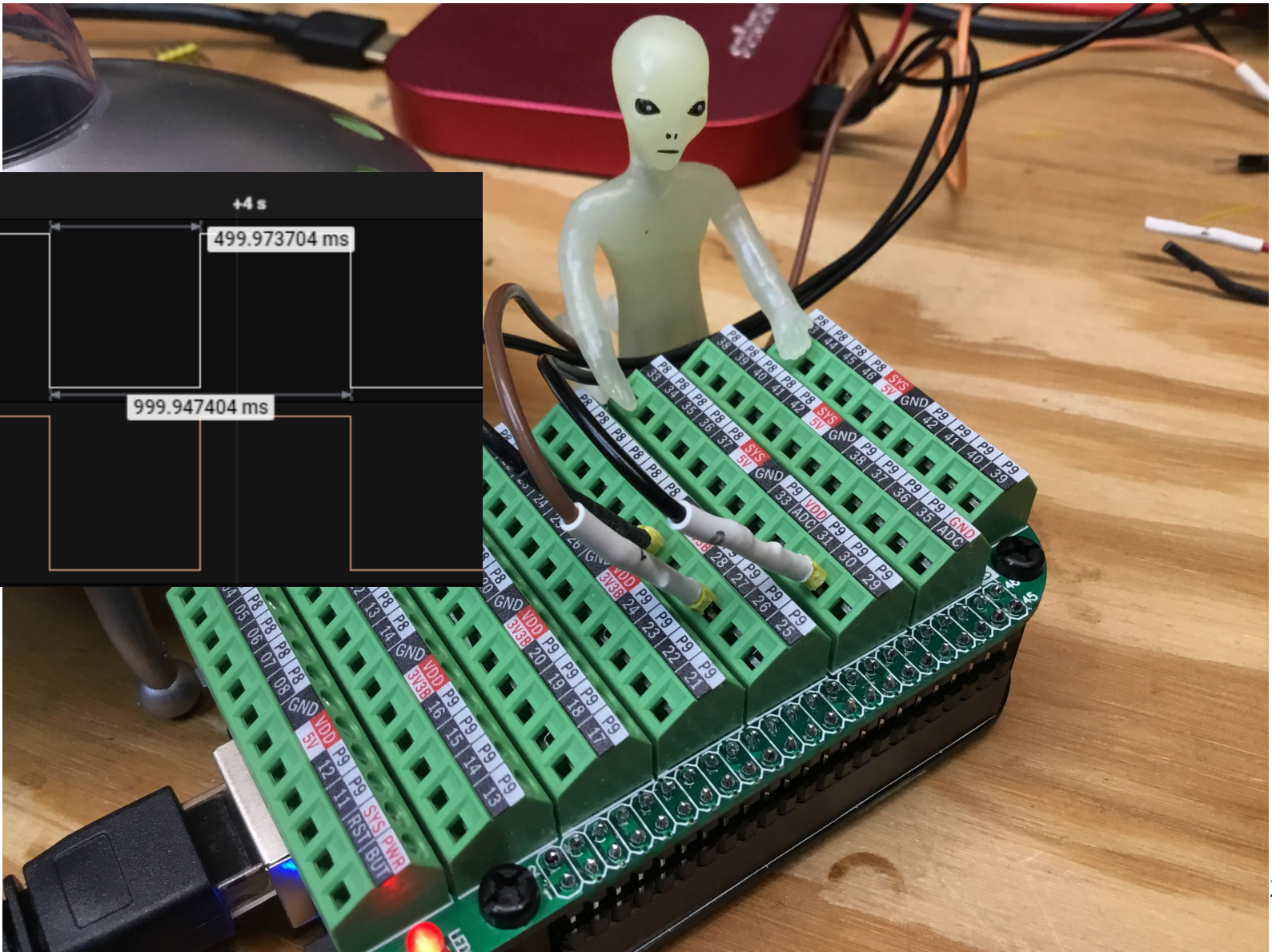
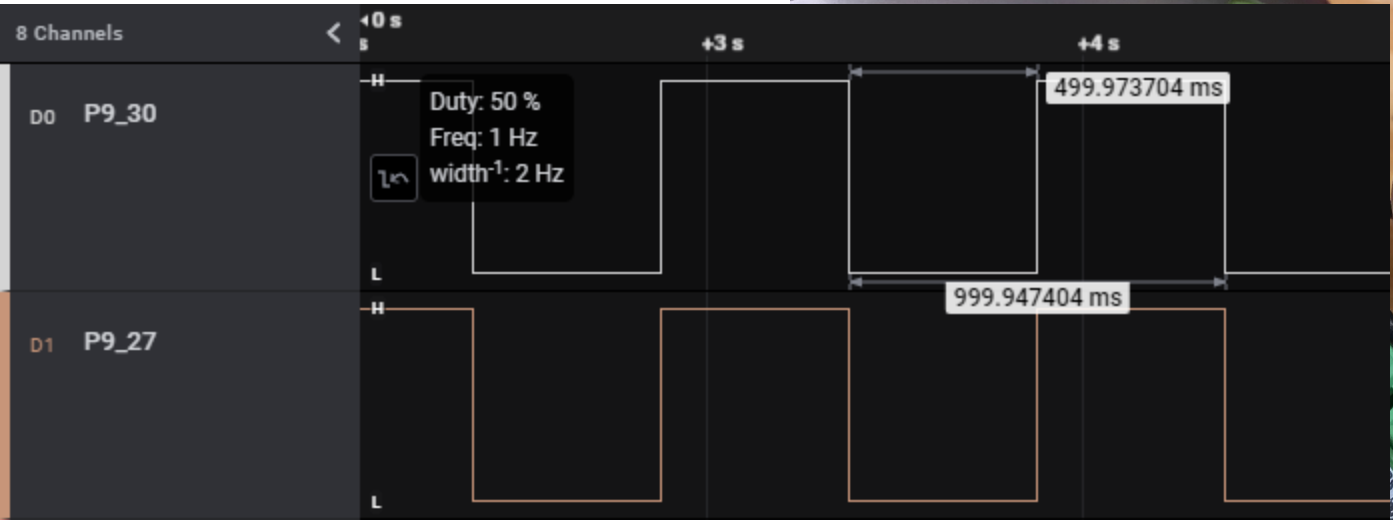
PRU *toggle_led* Application – Load the firmware and Let the Dog Out!

```
debian@beaglebone: /sys/class/remoteproc/remoteproc1
File Edit View Search Terminal Help

debian@beaglebone:~$ sudo scp /home/debian/bbpruProjects/toggle_led.out /lib/fir
mware/toggle_led
[sudo] password for debian:
debian@beaglebone:~$ cd /sys/class/remoteproc/remoteproc1
debian@beaglebone:/sys/class/remoteproc/remoteproc1$ echo toggle_led>firmware
debian@beaglebone:/sys/class/remoteproc/remoteproc1$ cat firmware
toggle_led
debian@beaglebone:/sys/class/remoteproc/remoteproc1$ echo start>state
debian@beaglebone:/sys/class/remoteproc/remoteproc1$ cat state
running
debian@beaglebone:/sys/class/remoteproc/remoteproc1$ echo stop>state
debian@beaglebone:/sys/class/remoteproc/remoteproc1$ cat state
offline
debian@beaglebone:/sys/class/remoteproc/remoteproc1$
```

BeagleBone Black PRU Primer

PRU *toggle_led* Application – Let the Dog Out!



Thank you for attending!!!

Please consider the resources below:

- [BeagleBone Black How-To PDF](#)
- [BeagleBone.org](#)

No download package today.

MORE TO COME..





DesignNews

Thank You

Sponsored by

