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## How to Use the SAMA5D2 ADC Under Linux®

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### Introduction

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This application note describes how to get started using the SAMA5D2 ADC under Linux.

With the introduction of the industrial I/O (IIO) subsystem into the kernel, it is easy to access the ADC device in user space via sysfs or a device node. The device driver of the ADC in the SAMA5D2 was implemented based on this subsystem. With the standard interface of IIO, it is easy to develop/port an application program into user space.

Because the features of the ADC are implemented in kernel space, this document explains how to use the ADC in user space.

### Reference Documents

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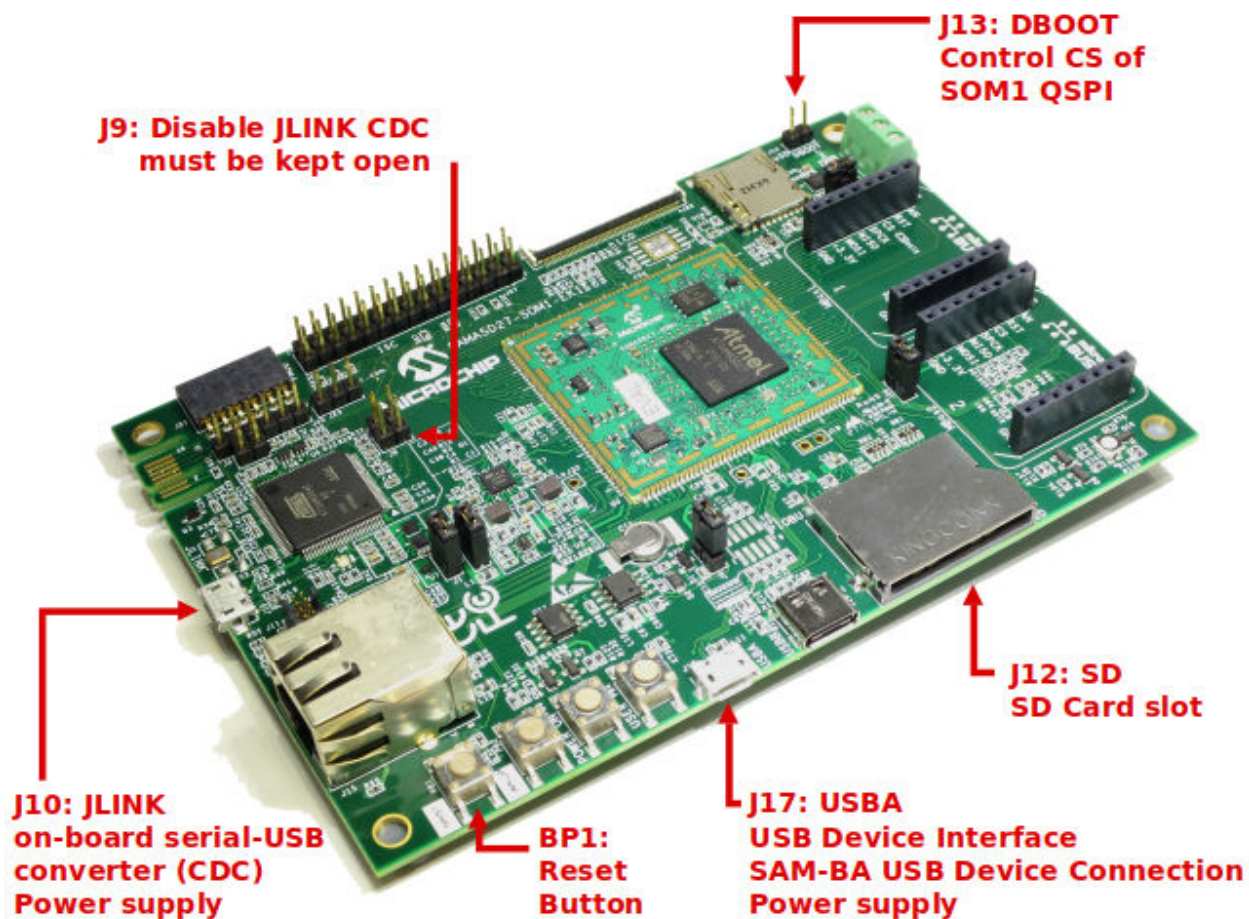
Title	Reference	Available
SAMA5D2 Series Datasheet	DS60001476	<a href="https://www.microchip.com/design-centers/32-bit-mpus">https://www.microchip.com/design-centers/32-bit-mpus</a>
SAMA5D27 SOM1 Kit1 User Guide	DS50002667	<a href="https://www.microchip.com/DevelopmentTools/ProductDetails/PartNO/ATSAMA5D27-SOM1-EK1">https://www.microchip.com/DevelopmentTools/ProductDetails/PartNO/ATSAMA5D27-SOM1-EK1</a>

### Prerequisites

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- Hardware
  - PC
  - SAMA5D27 SOM1 Evaluation Kit (Part Number: ATSAMA5D27-SOM1-EK1)
  - SDCard
- Software

This demo runs on the AT91 Linux platform built by Buildroot. The first step is to set up the AT91 Buildroot development environment. Refer to the web site: <http://www.at91.com/linux4sam/bin/view/Linux4SAM/BuildRoot>



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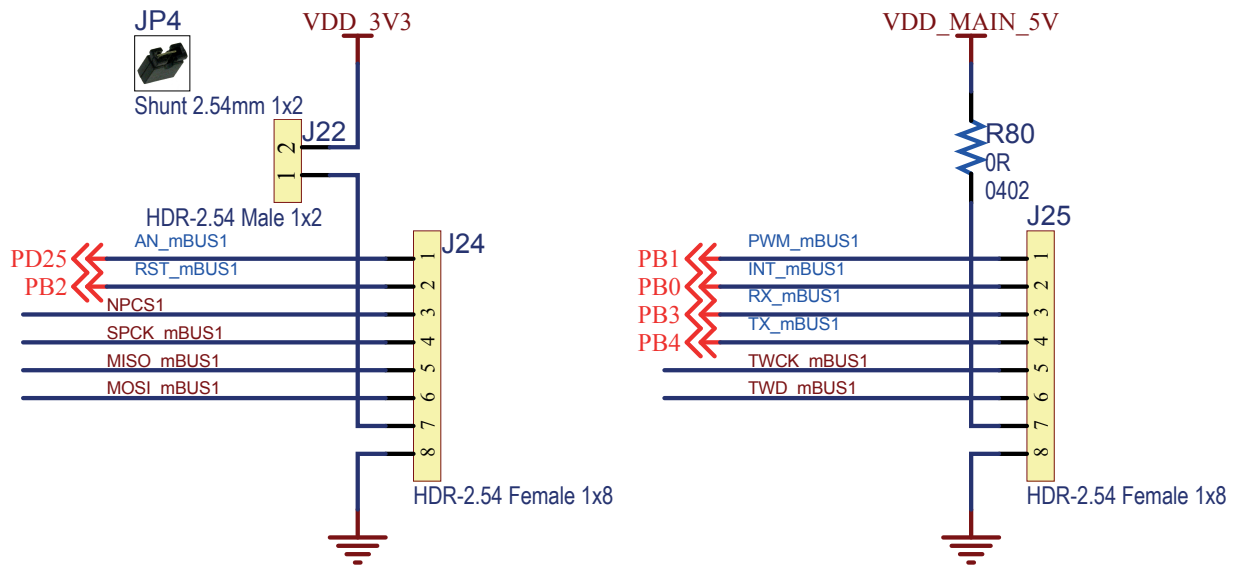
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## 1. Hardware Design

### 1.1 Interface



The mikroBUS1 connector is used for easy testing and monitoring. The analog input pin, AN\_mBUS1, of the mikroBUS1 interface is implemented on Linux.

The ADC channel AD6 is connected to the AN\_mBUS1 via GPIO PD25 on the SAMA5D27-SOM-EK1:

- AD6 → PD25 → AN\_mBUS1

For more details about the pin multiplexing of the SAMA5D2, refer to the table “Pin Description (all packages)” in the SAMA5D2 data sheet.

## 2. Software Design

The Microchip Linux platform was built using Buildroot with the following configuration:

`atmel_sama5d27_som1_ek_mmc_dev_defconfig`

An ADC device driver has been implemented based on the Industrial Input/Output (IIO) framework in the kernel space.

Most features are supported by this driver.

This section illustrates how to interact with an ADC driver via the standard IIO sysfs interface.

No C-code demo is included in this document because all steps in the section [Hands-On](#) can be done with sysfs or Linux commands.

### 2.1 Device Tree

- Action: need to change
  - Change 1:
    - With the default setting, the ADC device was disabled in the device tree. The text in bold below shows how to enable the ADC in `at91-sama5d27_som1_ek.dts`.
- Location: `buildroot-at91/output/build/linux-linux4sam_6.0/arch/arm/boot/dts`
- Sources:
  - `sama5d2.dtsi`
  - `at91-sama5d27_som1_ek.dts`

**Device tree for ADC in `sama5d2.dtsi`:**

```
adc: adc@fc030000 {
    compatible = "atmel,sama5d2-adc"; // specify which driver is used for this ADC device
    reg = <0xfc030000 0x100>; // ADC base address is 0xfc030000, size is 0x100
    interrupts = <40 IRQ_TYPE_LEVEL_HIGH 7>; // PID of ADC is 40, high level triggered,
                                           // priority is 7
                                           // used to configure ADC interrupt in AIC
    clocks = <&adc_clk>; // definition of ADC clock source
    clock-names = "adc_clk";
    // one DMA channel was used by ADC
    dmas = <&dma0 (AT91_XDMAC_DT_MEM_IF(0) | AT91_XDMAC_DT_PER_IF(1) |
AT91_XDMAC_DT_PERID(25))>;
    dma-names = "rx";
    atmel,min-sample-rate-hz = <200000>; // define minimum sample rate
    atmel,max-sample-rate-hz = <2000000>; // define maxim sample rate
    atmel,startup-time-ms = <4>; // define startup time, 4ms
    atmel,trigger-edge-type = <IRQ_TYPE_EDGE_RISING>; // define trigger mode
    #io-channel-cells = <1>;
    status = "disabled"; // default disabled, and will be replaced with "okay" to enable
};

adc_clk: adc_clk {
    #clock-cells = <0>;
    reg = <40>; // PID of ADC is 28, this definition of offset will be used to enable
               // ADC clock in PMC
    atmel,clk-output-range = <0 83000000>; // ADC input clock, max frequency is 83 MHz
};
```

**Device tree for ADC in `at91-sama5d27_som1_ek.dts`:**

```
adc: adc@fc030000 {
    vddana-supply = <&vddana>; // Analog power supply for ADC
    vref-supply = <&advref>; // reference voltage for ADC

    status = "okay"; // This is change 1: The default setting is ADC disabled,
                     // it is enabled here.
};
```

## 2.2 Kernel

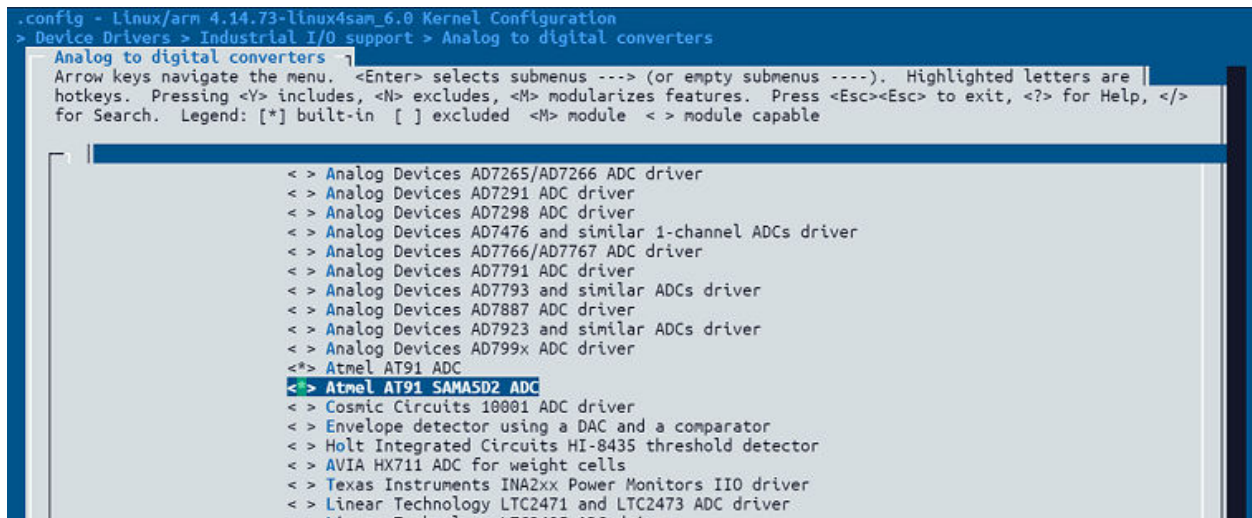
- Action: no need to change
- Location: buildroot-at91/output/build/linux-linux4sam\_6.0/
- Defconfig: sama5\_defconfig
- Driver files: drivers/iio/adc/at91-sama5d2\_adc.c

Check the kernel configuration for the ADC function:

```
user@at91:~/buildroot-at91$ make linux-menuconfig
```

### Device Drivers > Industrial I/O support > Analog to digital converters > Atmel AT91 SAMA5D2 ADC

With this setting, the ADC driver for SAMA5D2 is built into the kernel.



## 2.3 Rootfs

- Action: no need to change
- Location: buildroot-at91/output/images/rootfs.tar

After Linux boot-up, two paths will be created to access the ADC driver:

- /sys/bus/iio/devices/iio:device0
  - This is the main entry of the IIO interface for the ADC device (iio:device0).
- /dev/iio:device0
  - IIO device node is used to read converted data from the ADC driver.

### 3. Hands-On

There are two ways to request an ADC conversion:

1. Software trigger – Internal synchronous trigger, by writing ADC\_CR.START.
2. Hardware trigger – Asynchronous trigger, asserted by an internal or external signal (pins or periodic event). Refer to ADC\_TRGR.TRGMOD for more information.

#### 3.1 Software Trigger

When reading the ADC channel raw file directly, a software trigger action is performed by the ADC driver:

```
# cat /sys/bus/iio/devices/iio:device0/in_voltage6_raw
16380

# cat /sys/bus/iio/devices/iio:device0/in_voltage_scale
0.201416015
```

The converted raw data is 16380 and the scaling ratio is 0.201416015.

Voltage value is:

$16380 \times 0.201416015 = 3.299 \text{ mV}$

#### 3.2 Hardware Triggers

Hardware triggers are an operating mode of the ADC where conversions are triggered directly by the hardware. In general, the ADTRG pin is used to receive the external hardware trigger signal.

In the SAMA5D2, the pin ADTRG is multiplexed with GPIO PD31.

In SAMA5D27-SOM1-EK1, GPIO PD31 was not exported to any connector and thus a workaround is used to handle this unexpected case.

```
# echo 1 &gt; /sys/bus/iio/devices/iio:device0/scan_elements/in_voltage6_en
# cat /sys/bus/iio/devices/trigger0/name
fc030000.adc-dev0-external_rising
# echo fc030000.adc-dev0-external_rising &gt; /sys/bus/iio/devices/iio:device0/trigger/
current_trigger
# echo 100 &gt; /sys/bus/iio/devices/iio:device0/buffer/length
# echo 1 &gt; /sys/bus/iio/devices/iio:device0/buffer/enable
# devmem2 0xfc0300C0 w 0xffff0005
// workaround here, use ADC internal periodic trigger instead of external trigger
...
Written 0xFFFF0005; readback 0xFFFF0005
# hexdump -e '/2 "%d\n"' -v /dev/iio:device0
16380
16380
16380
16380
16380
...
```

As stated in the section [Software Trigger](#) above, the converted raw data is 16380 and the scaling ratio is 0.201416015.

Voltage value is:

$16380 \times 0.201416015 = 3.299 \text{ mV}$

## 4. Microchip Peripheral I/O Python® (MPIO)

The Microchip Peripheral I/O (MPIO) Python package provides easy access to various hardware peripherals found on Microchip MPU processors and evaluation boards running Linux. The API is clean, consistent, flexible, documented, and well tested. It makes navigating and exercising even the most complex hardware peripherals a trivial task.

For more information, see <https://github.com/linux4sam/mpio>. Code examples showing how to work with the MPIO interface modules are provided in the folder `mpio/examples`.

### 4.1 MPIO in Buildroot

In order to benefit from MPIO in your Buildroot configuration, follow the steps below:

#### 1. Enable Python

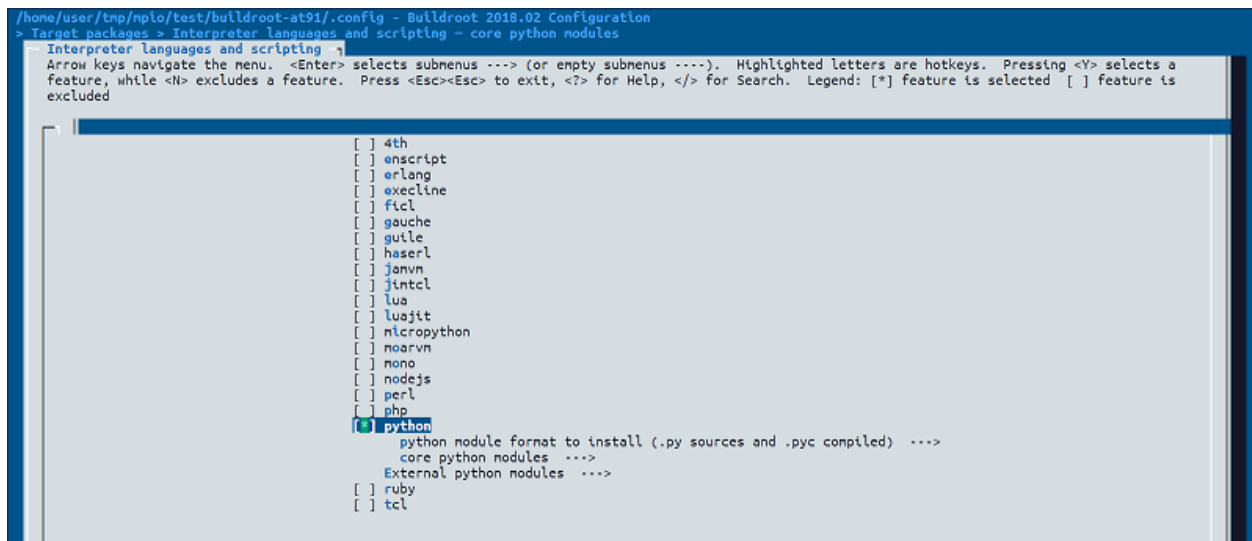
```
user@at91:~/buildroot-at91$ make menuconfig
```

Select “**python**” to enable python support:

- Target packages > Interpreter languages and scripting > [\*] **python**

Then enter “**python module format to install**” and select “**.py sources and .pyc compiled**”.

- Target packages > Interpreter languages and scripting > python > python module format to install > **.py sources and .pyc compiled**



Some additional python modules must be selected. Enter “**core python modules**” and select “**curses module**”, “**readline**” and “**hashlib module**”.

- Target packages > Interpreter languages and scripting > core python modules > [\*] **curses module**
- Target packages > Interpreter languages and scripting > core python modules > [\*] **readline**



- Target packages > Interpreter languages and scripting > core python modules > [\*] hashlib module

```

/home/user/tmp/mpio/test/buildroot-at91/.config - Buildroot 2018.02 Configuration
> Target packages > Interpreter languages and scripting > core python modules
core python modules
Arrow keys navigate the menu. <Enter> selects submenus ---> (or empty submenu ----). Highlighted letters are hotkeys. Pressing <Y> selects a feature, while <N> excludes a feature. Press <Esc><Esc> to exit, <?> for Help, </> for Search. Legend: [*] feature is selected [ ] feature is excluded

*** The following modules are unusual or require extra libraries ***
[ ] bzip2 module (NEW)
[ ] bsddb module (NEW)
[ ] codescjk module (NEW)
[*] curses module
[ ] ossaudiodev module (NEW)
[*] readline
[ ] ssl (NEW)
[ ] unicodedata module
[ ] sqlite module
[ ] xml module (NEW)
[ ] zlib module (NEW)
[*] hashlib module

```

Enter “External python modules” and select “python-setuptools”.

- Target packages > Interpreter languages and scripting > External python modules > [\*] python-setuptools

```

/home/user/tmp/mpio/test/buildroot-at91/.config - Buildroot 2018.02 Configuration
> Target packages > Interpreter languages and scripting > External python modules
External python modules
Arrow keys navigate the menu. <Enter> selects submenus ---> (or empty submenu ----). Highlighted letters are hotkeys. Pressing <Y> selects a feature, while <N> excludes a feature. Press <Esc><Esc> to exit, <?> for Help, </> for Search. Legend: [*] feature is selected [ ] feature is excluded

^(-)=
[ ] python-pyudev (NEW)
[ ] python-pyusb (NEW)
[ ] python-pyxb (NEW)
[ ] python-pyxml (NEW)
[ ] python-pyzmq (NEW)
[ ] python-raven (NEW)
[ ] python-remi (NEW)
[ ] python-requests (NEW)
[ ] python-requests-oauthlib (NEW)
[ ] python-requests-toolbelt (NEW)
[ ] python-rpi-gpio (NEW)
[ ] python-rtplib-fb (NEW)
[ ] python-scandir (NEW)
[ ] python-schedule (NEW)
[ ] python-sdnotify (NEW)
[ ] python-secretstorage (NEW)
[ ] python-see (NEW)
[ ] python-serial (NEW)
[ ] python-service-identity (NEW)
[ ] python-setproctitle (NEW)
[*] python-setuptools
[ ] python-sh (NEW)
[ ] python-shutilwhich (NEW)

```

## 2. Enable the MPIO Module

Enter “External options” and select “python-mpio”.

- External options > [\*] python-mpio

```

/home/user/tmp/mpio/test/buildroot-at91/.config - Buildroot 2018.02 Configuration
> External options
External options
Arrow keys navigate the menu. <Enter> selects submenus ---> (or empty submenu ----). Highlighted letters are hotkeys. Pressing <Y> selects a feature, while <N> excludes a feature. Press <Esc><Esc> to exit, <?> for Help, </> for Search. Legend: [*] feature is selected [ ] feature is excluded

*** MCHP (in /home/user/tmp/mpio/test/buildroot-external-microchip) ***
[ ] gl-decoder
*** gst1-at91 needs a toolchain w/ glibc ***
*** libplanes depends on libdrm, cairo, lua, and cJSON ***
[ ] ptc_examples
*** python-iocontrol depends on pyqt5 and mpio ***
[*] python-mpio
[ ] dt-overlay-at91
Init configuration (none) ----

```

## 3. Finish the Buildroot Configuration and Build

Enter “Filesystem images” and set the exact size of rootfs to 120MB.

- Filesystem images > (120M) exact size

```

/home/user/tmp/mpio/test/buildroot-at91/.config - Buildroot 2018.02 Configuration
* Filesystem Images
Filesystem Images
Arrow keys navigate the menu. <Enter> selects submenus --- (or empty submenus ---). Highlighted letters are hotkeys. Pressing <Y> selects a
feature, while <N> excludes a feature. Press <Esc><Esc> to exit, <?> for Help, </> for Search. Legend: [*] feature is selected [ ] feature is
excluded

[ ] axfs root filesystem
[ ] cloop root filesystem for the target device
[ ] cpio the root filesystem (for use as an initial RAM filesystem)
[ ] cramfs root filesystem
[*] ext2/3/4 root filesystem
    ext2/3/4 variant (ext4) --->
    ( ) filesystem label
    (120M) exact size
    (0) exact number of inodes (leave at 0 for auto calculation)
    (5) reserved blocks percentage
    (-O ^64bit) additional mke2fs options
    Compression method (no compression) --->

```

After saving, the following new settings are added to the configuration file of Buildroot:

```

.....
BR2_PACKAGE_PYTHON=y
BR2_PACKAGE_PYTHON_PY_PYC=y
BR2_PACKAGE_PYTHON_CURSES=y
BR2_PACKAGE_PYTHON_READLINE=y
BR2_PACKAGE_PYTHON_HASHLIB=y
BR2_PACKAGE_PYTHON_SETUPTOOLS=y
BR2_PACKAGE_PYTHON_MPIO=y
BR2_TARGET_ROOTFS_EXT2_SIZE="120M"
.....

```

Then re-configure and build Buildroot:

```

user@at91:~/buildroot-at91$ make atmel_sama5d27_som1_ek_mmc_dev_defconfig
user@at91:~/buildroot-at91$ make

```

## 4.2 Examples

After building successfully, burn your SD card with buildroot-at91/output/images/sdcard.img.

Execute the python codes on the target board, for example:

```

# ./adc2.py DEVICE
# ./gpio1.py PIN
# ./pwm_led.py DEVICE CHANNEL
.....

```

**Note:** The python example code can be found in <https://github.com/linux4sam/mpio/examples>

## **5. Revision History**

### **5.1 Rev. A - 09/2019**

First issue.
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