

## Introduction

This document describes how to boot Linux on a SAMA7G5 Series device from e.MMC using Buildroot.

The device can boot from any of the external non-volatile memories (NVM) available on the board, such as QSPI, e.MMC or SD Card. To boot from an e.MMC Flash memory, the `sdcard.img` file must be flashed into the e.MMC Flash memory.

The procedure described in this document is applicable to all SAMA7G5 Series MPUs. The detailed steps apply to SAMA7G54-EK evaluation kits that feature an e.MMC Flash memory on the board.

This technical brief comprises the main steps below:

- [Get Buildroot for AT91](#)
- [Configure at91bootstrap](#)
- [Customize at91bootstrap to boot from e.MMC](#)
- [Modify U-boot to boot from e.MMC](#)
- [Modify the uboot-env and genimage files to boot from e.MMC](#)
- [Configure the SAMA7G5 boot sequence to boot from e.MMC and flash the image file into the target](#)

## Reference Documents

The following reference documents are available on [www.microchip.com](http://www.microchip.com).

**Table 1.** Reference Documents

Type	Document Title	Literature No.
Data sheet	SAMA7G5 Series	DS60001765
User's Guide	SAMA7G54-EK	DS50003273

## 1. Prerequisites

- Hardware
  - PC running Linux (ubuntu OS)
  - SAMA7G54-EK evaluation kit (Part Number: EV21H18A)
  - Two micro-B USB cables (included in the SAMA7G54-EK box)

- Software

This demo runs on an AT91 Linux platform built by Buildroot.

## 2. Get Buildroot for AT91

To get the source code, the buildroot-at91 and buildroot-external-microchip repositories should be cloned. buildroot-at91 is a fork of Buildroot with a few specific patches. The external tree provides additional defconfigs and packages dedicated to our demos.

To clone buildroot-at91 from the repository:

```
$ git clone https://github.com/linux4sam/buildroot-at91
```

To clone buildroot-external-microchip from the repository:

```
$ git clone https://github.com/linux4microchip/buildroot-external-microchip
```

The source code should be pointing to the latest version of the buildroot-at91 and buildroot-external-microchip repositories.



**Tip:** We advise you to use the same linux4microchip tag for both repositories.

---

**Note:** The buildroot-external-microchip tree is now part of linux4microchip, hence the tags on this repository are named linux4microchip-\*\*\*. Tags on buildroot-at91 keep the old format linux4sam-\*\*\*. However, the version year month YYYY.MM are equivalent.

To check out the latest version of buildroot-at91:

1. Navigate to the buildroot-at91 directory:  

```
$ cd buildroot-at91
```
2. Enter the following command to display the versions available in 2023:  

```
$ git tag | grep 2023
```
3. Check out the latest version:  

```
$ git checkout linux4microchip-2023.10
```

To check out the latest version of buildroot-external-microchip:

1. Navigate to the buildroot-external-microchip directory:  

```
$ cd ..  
$ cd buildroot-external-microchip
```
2. Enter the following command to know the available versions in 2023:  

```
$ git tag | grep 2023
```
3. Check out the latest version:  

```
$ git checkout linux4microchip-2023.10
```

### 3. Configure at91bootstrap

1. Navigate to the buildroot-at91 directory:

```
$ cd buildroot-at91
```

2. Enter the following command to export the additional defconfigs and packages from the external tree (buildroot-external-microchip):

```
$ export BR2_EXTERNAL=../buildroot-external-microchip/
```

3. Navigate to the configs directory in the buildroot-external-microchip directory to find the SAMA7G54-EK defconfig files:

```
$ cd ..
```

```
$ cd buildroot-external-microchip/configs
```

```
$ ls
```



```
masters@masters-VirtualBox:~/buildroot-external-microchip/configs$ ls
at91sam9x5ek_headless_defconfig
icicle_amp_defconfig
icicle_defconfig
icicle_nand_defconfig
icicle_nor_defconfig
icicle_rootfs_defconfig
sam9x60_curiosity_graphics_defconfig
sam9x60_curiosity_headless_defconfig
sam9x60ek_graphics_defconfig
sam9x60ek_headless_defconfig
sama5d27_som1_ek_graphics_defconfig
sama5d27_som1_ek_headless_defconfig
sama5d27_som1_ek_headless_wilc_defconfig
sama5d27_som1_ek_nodered_defconfig
sama5d27_som1_ek_optee_graphics_defconfig
sama5d27_som1_ek_optee_headless_defconfig
sama5d27_wlsom1_ek_graphics_defconfig
sama5d27_wlsom1_ek_headless_defconfig
sama5d2_icp_headless_defconfig
sama5d2_ptc_ek_graphics_defconfig
sama5d2_ptc_ek_headless_defconfig
sama5d2_ptc_ek_nodered_defconfig
sama5d2_xplained_graphics_defconfig
sama5d2_xplained_headless_defconfig
sama5d2_xplained_nodered_defconfig
sama5d2_xplained_optee_graphics_defconfig
sama5d2_xplained_optee_headless_defconfig
sama5d3_eds_headless_defconfig
sama5d3_eds_nf_defconfig
sama5d3_xplained_graphics_defconfig
sama5d3_xplained_headless_defconfig
sama5d3_xplained_nodered_defconfig
sama5d4_xplained_graphics_defconfig
sama5d4_xplained_headless_defconfig
sama5d4_xplained_headless_wilc_defconfig
sama5d4_xplained_nodered_defconfig
sama7g5ek_headless_defconfig
```

4. From the list, note the configuration file name "sama7g5ek\_headless\_defconfig."
5. Navigate to the buildroot-at91 directory and make the configuration files:

```
$ cd ..
```

```
$ cd buildroot-at91
```

```
$ make sama7g5ek_headless_defconfig
```

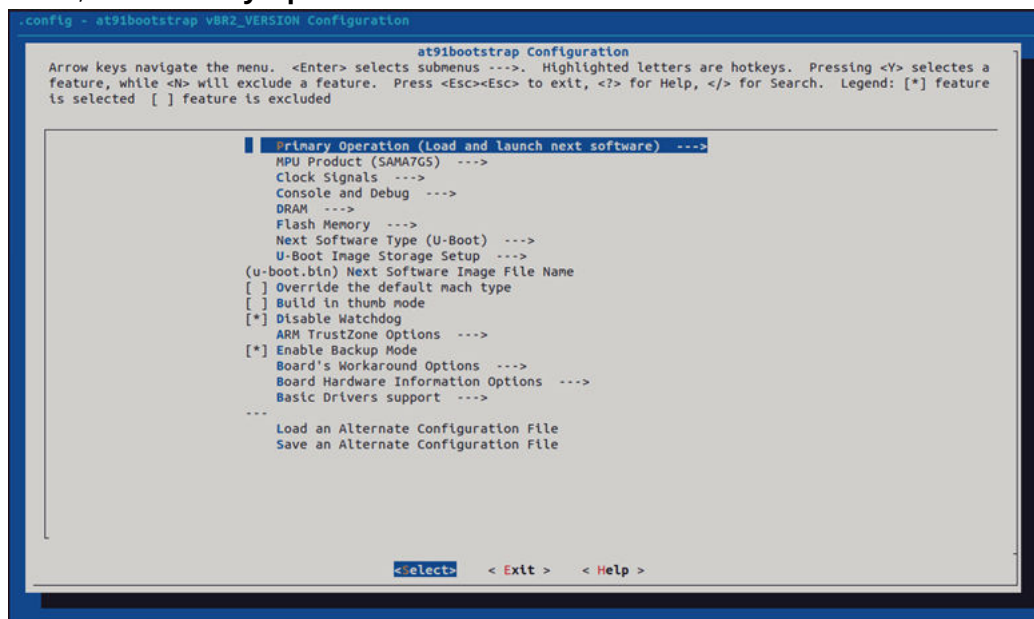
## 4. Customize at91bootstrap to boot from e.MMC

1. Enter the following command to modify the configurations:

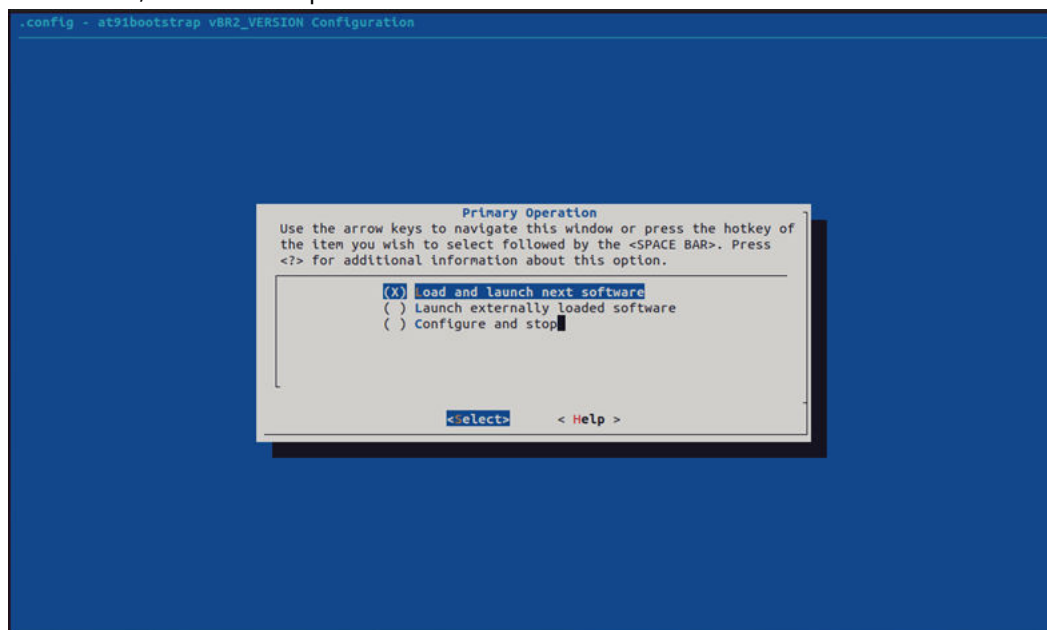
```
$ make at91bootstrap3-menuconfig
```

The **at91bootstrap Configuration** window opens.

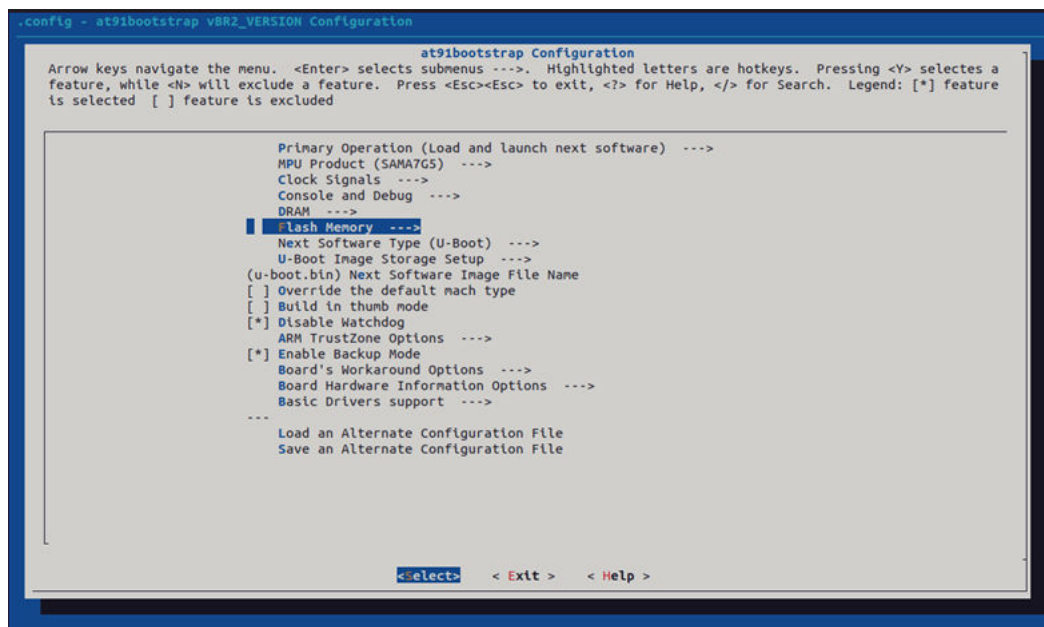
2. In the menu, click **Primary Operation**.



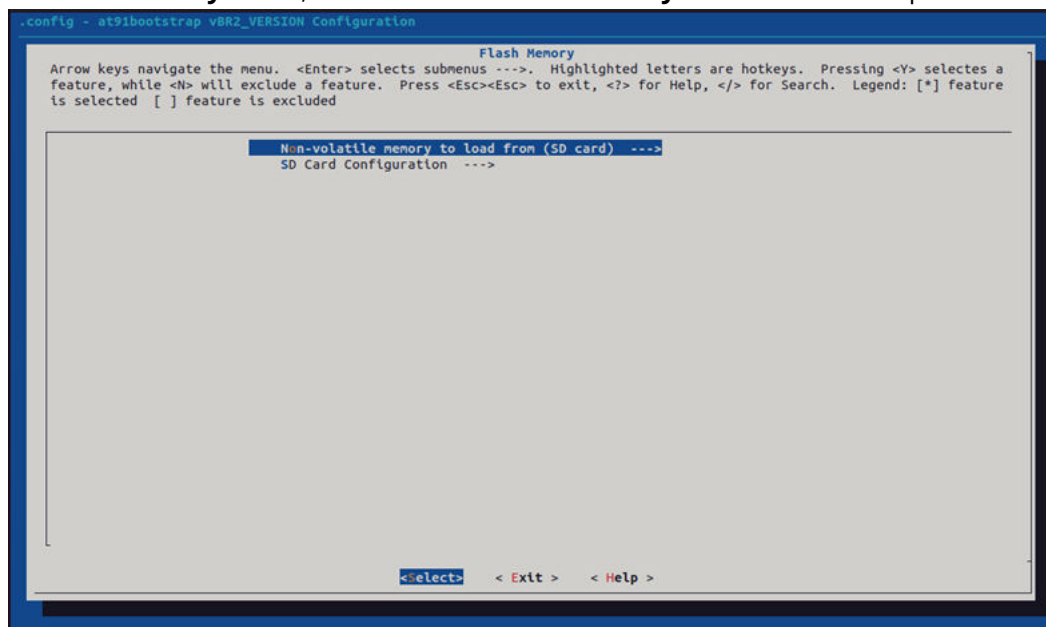
- a. In the Primary Operation menu, ensure the **Load and launch next software** check box is selected. If not, select it and press Enter.



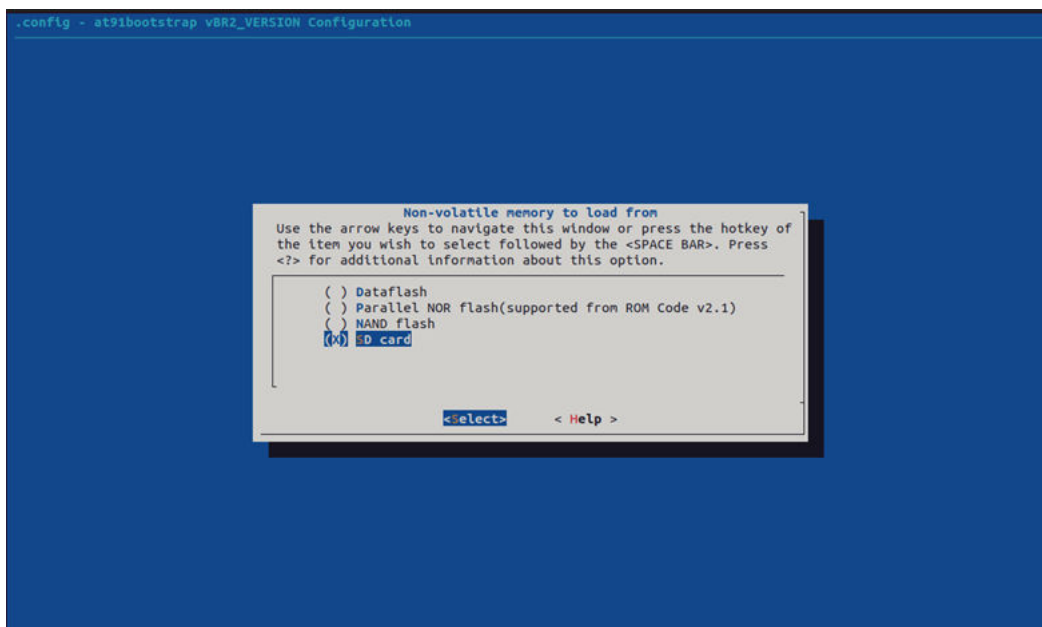
3. In the **at91bootstrap Configuration** window, select **Flash Memory** and press Enter.



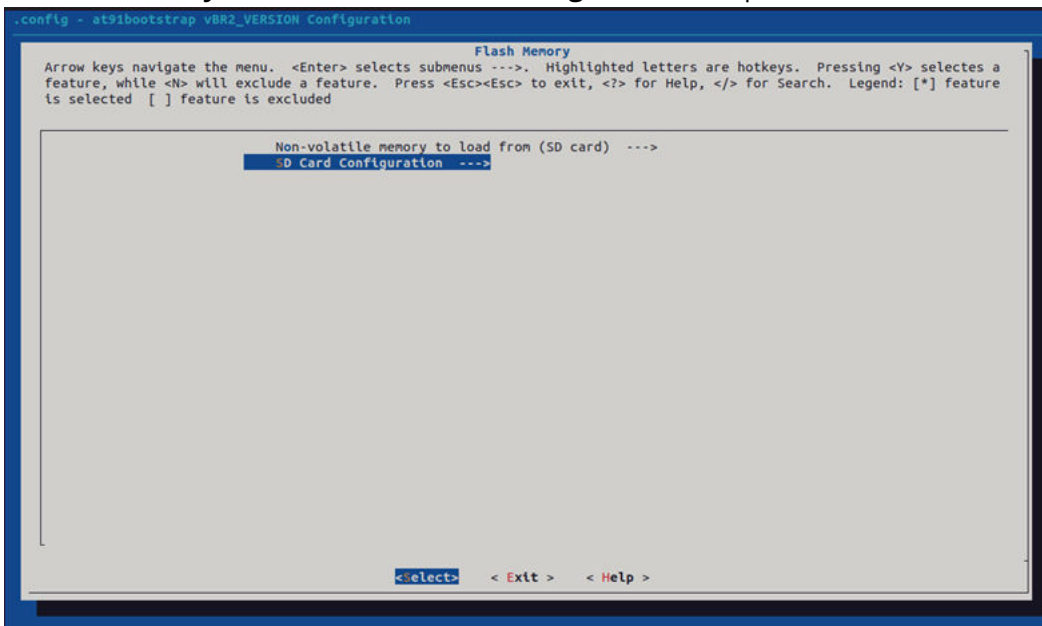
- a. In the **Flash Memory** menu, select **Non-volatile memory to load from** and press Enter.



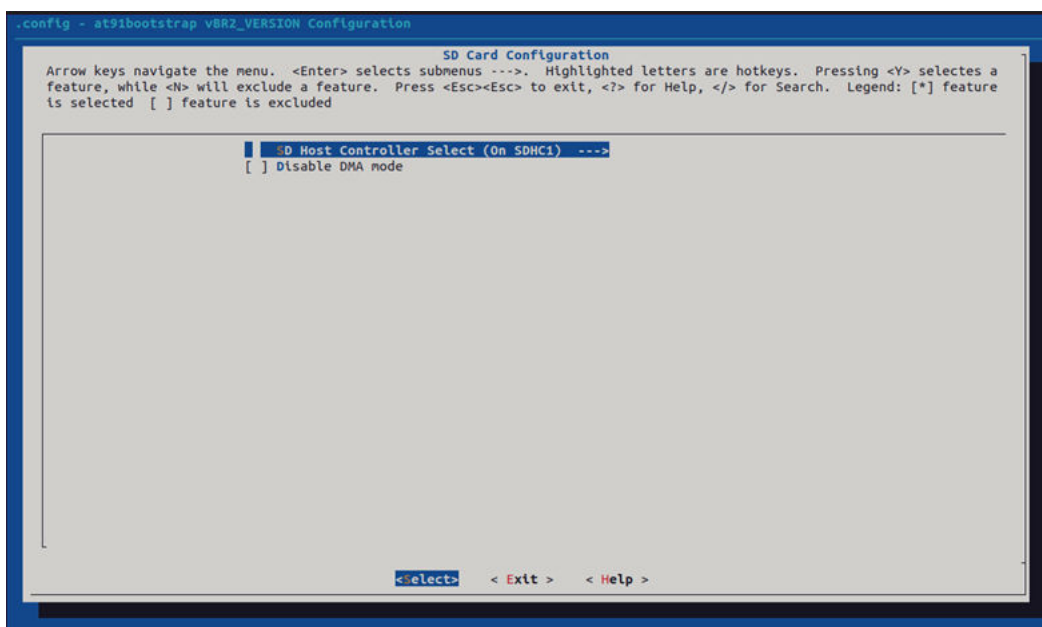
- b. In the **Non-volatile memory to load from** menu, ensure **SD card** is selected. If not, select it and press Enter.



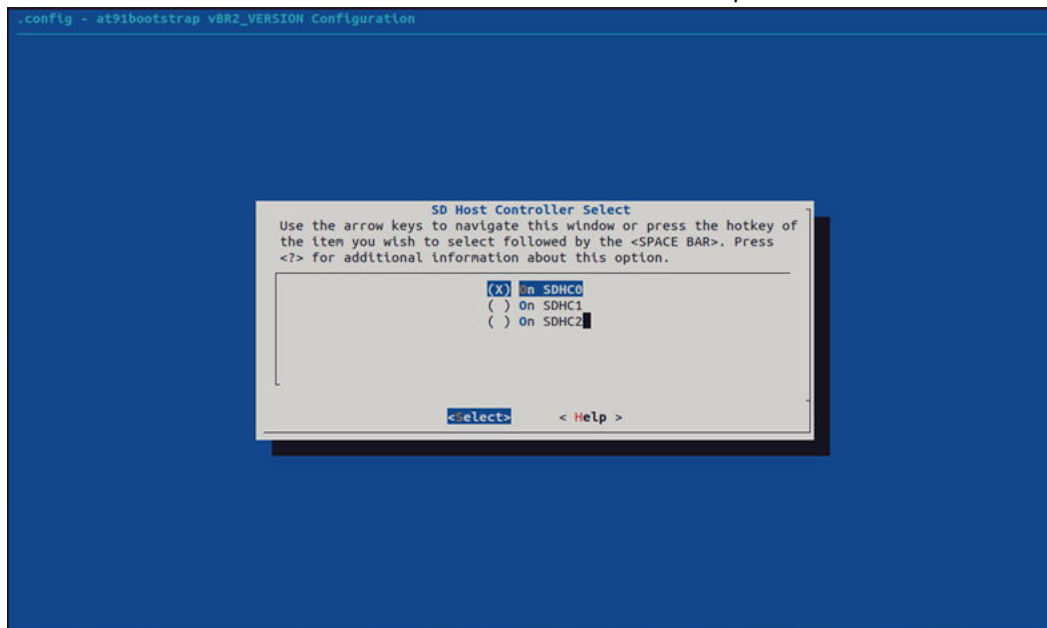
- c. In the **Flash Memory** menu, select **SD Card Configuration** and press Enter.



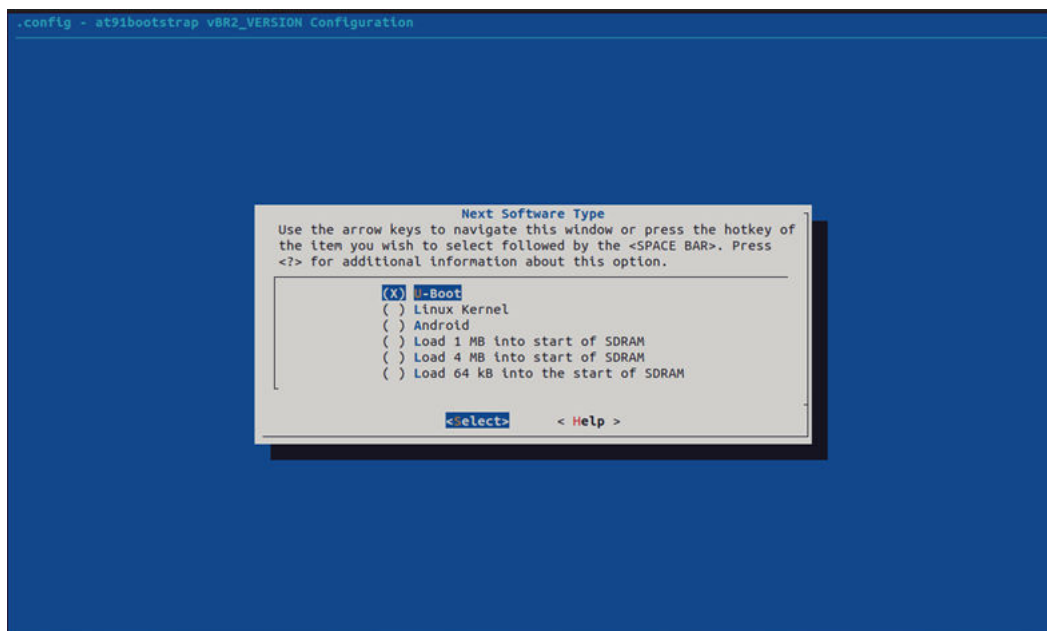
- d. In the **SD Card Configuration** menu, select **SD Host Controller Select** and press Enter.



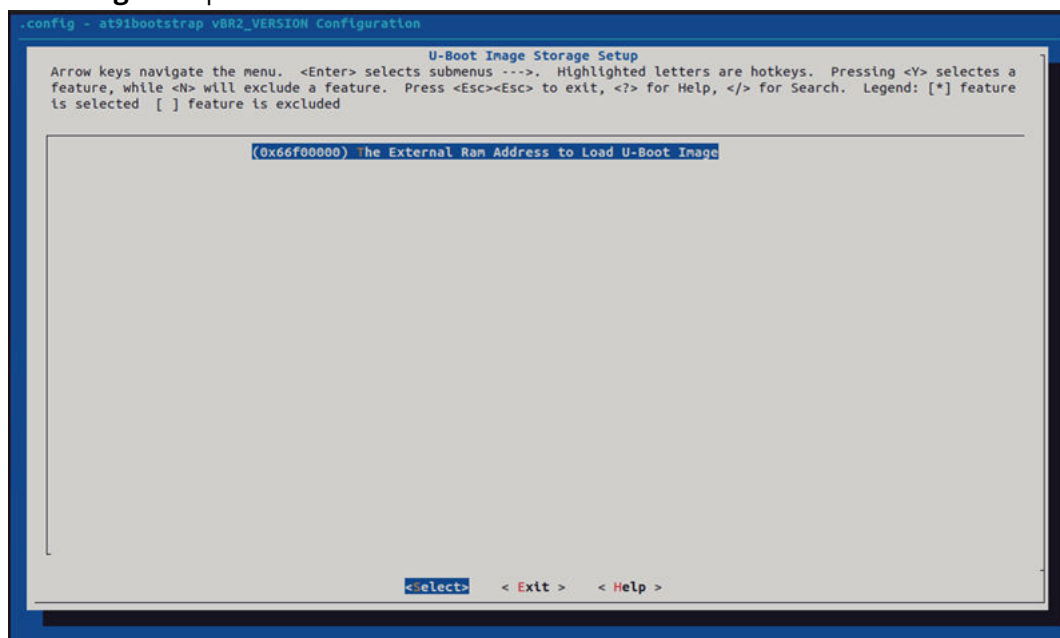
- e. In the **SD Host Controller Select** menu, select **On SDHC0** and press Enter.



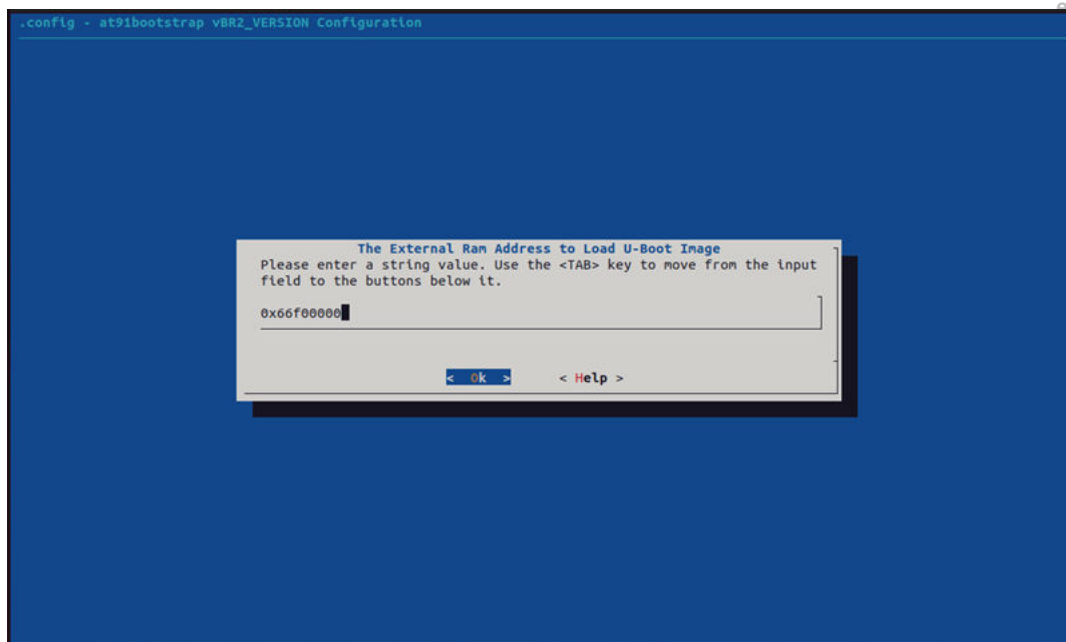
- f. Press ESC twice to exit the menu.
4. In the **at91bootstrap Configuration** window, select **Next Software Type** and press Enter.
- a. In the **Next Software Type** menu, ensure the **U-Boot** check box is selected. If not, select it and press Enter.



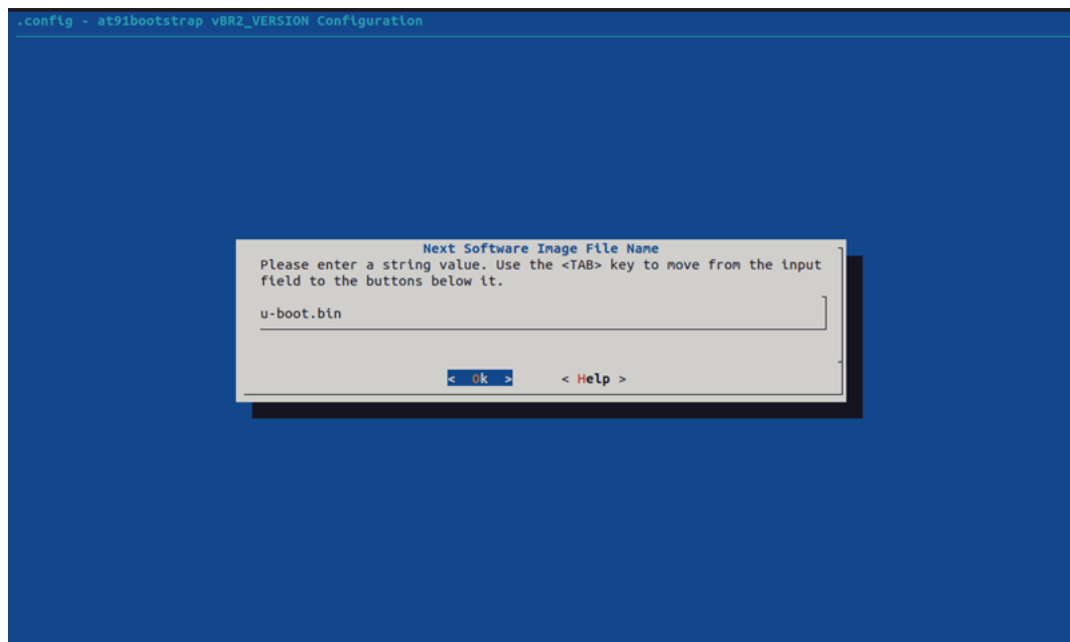
5. In the **at91bootstrap Configuration** window, select **U-boot Image Storage Setup** and press Enter.
  - a. In the **U-Boot Image Storage Setup** window, select **The External Ram Address to Load U-Boot Image** and press Enter.



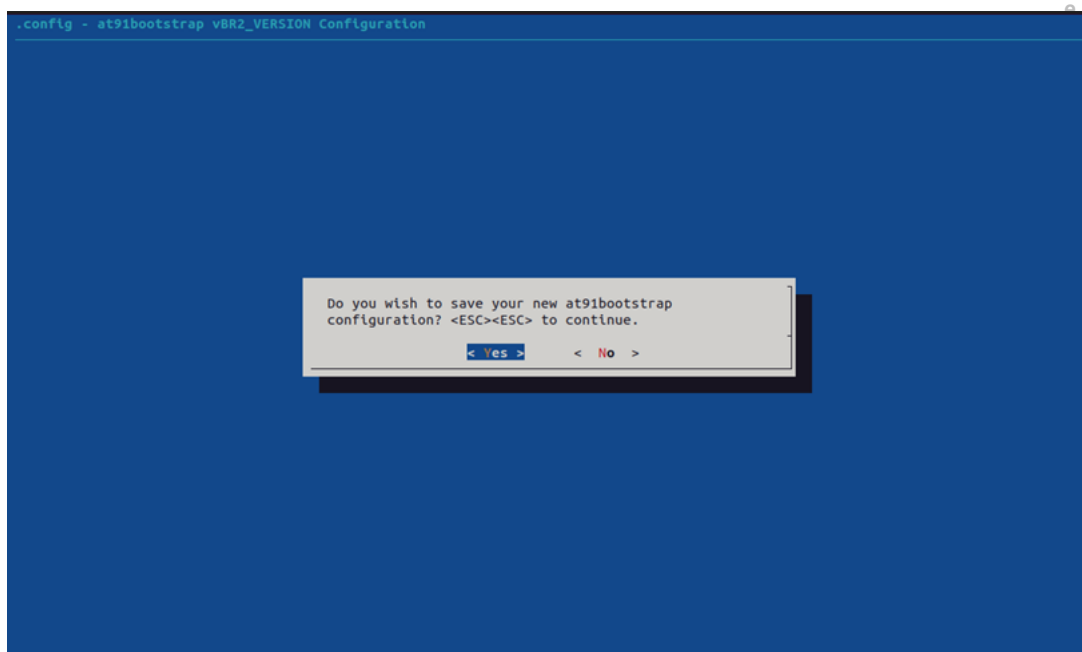
- b. In the **The External Ram Address to Load U-Boot Image** window, ensure that the RAM address displayed is **0x66f00000**. If not, update the address to **0x66f00000** and click **ok**.



- c. Press ESC twice to exit the menu.
6. In the **at91bootstrap Configuration** window, select **Next Software Image File Name** and press Enter.
  - a. In the **Next Software Image File Name** window, ensure the file name is **u-boot.bin**, if not update as **u-boot.bin** and click **ok**.



7. Select **Exit** and press Enter.
  - a. Click **Yes**.



## 5. Modify U-boot to boot from e.MMC

1. Enter the following command to modify the configurations:

```
$ make uboot-menuconfig
```

Note that building and opening the **U-Boot configuration** window will take a few minutes.

2. From the menu, select **Boot options** and press Enter.

```
.config - U-Boot 2022.01-linux4sam-2023.04 Configuration
U-Boot 2022.01-linux4sam-2023.04 Configuration
Arrow keys navigate the menu. <Enter> selects submenus --- (or empty submenus ---). Highlighted letters are hotkeys.
Pressing <Y> includes, <N> excludes, <M> modularizes features. Press <Esc><Esc> to exit, <?> for Help, </> for Search.
Legend: [*] built-in [ ] excluded <M> module < > module capable

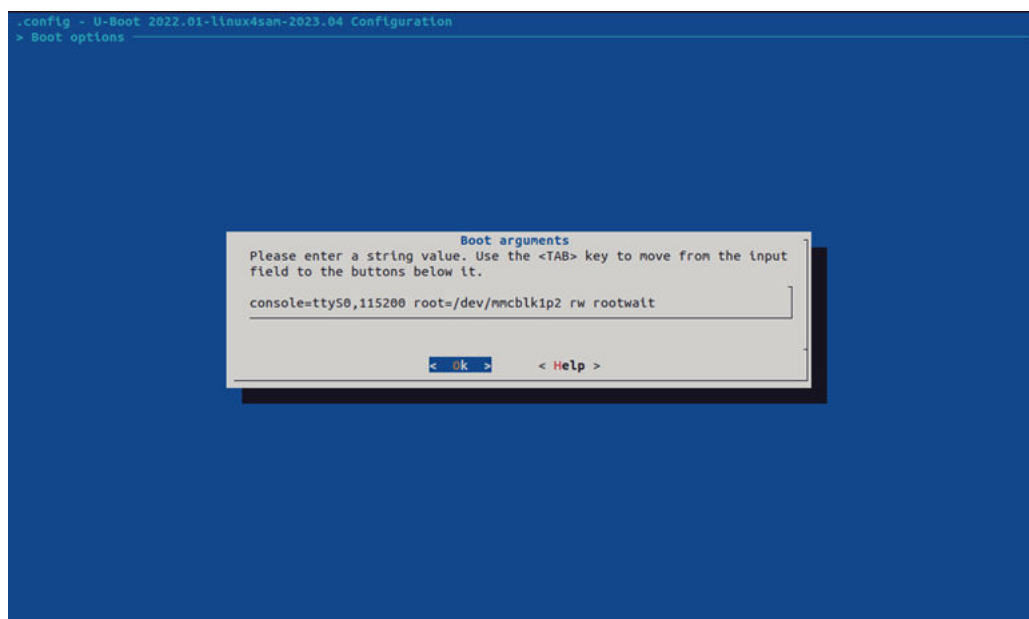
*** Compiler: arm-buildroot-linux-gnueabi-hf-gcc.br_real (Buildroot linux4microchip-2023.04)
Architecture select (ARM architecture) ---
[ ] Skip the calls to certain low level initialization functions
[ ] Skip the call to lowlevel_init during early boot ONLY
ARM architecture ---
General setup ---
API ---
[*] Boot options ---
Console ---
Logging ---
Init options ---
Security support ---
Update support ---
Blob list ---
SPL / TPL ---
Command line interface ---
Partition Types ---
Device Tree Control ---
Environment ---
[*] Networking support ---
Device Drivers ---
File systems ---
Library routines ---
[ ] Unit tests ---
[ ] Unit tests in SPL
v(+)
```

- a. In the **Boot options** window, select **Boot arguments** and press Enter.

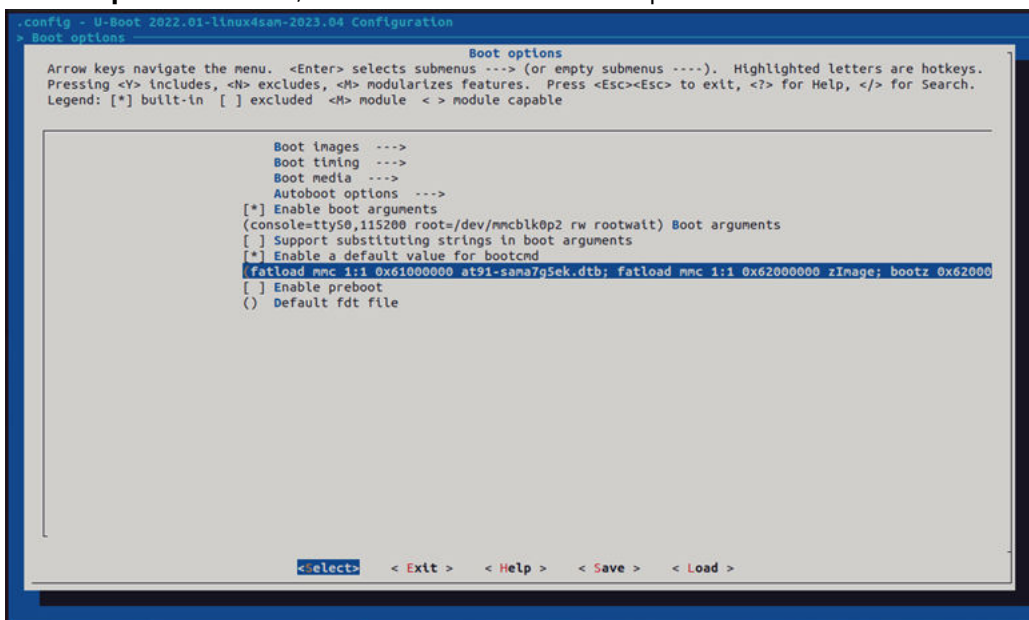
```
.config - U-Boot 2022.01-linux4sam-2023.04 Configuration
> Boot options
Boot options
Arrow keys navigate the menu. <Enter> selects submenus --- (or empty submenus ---). Highlighted letters are hotkeys.
Pressing <Y> includes, <N> excludes, <M> modularizes features. Press <Esc><Esc> to exit, <?> for Help, </> for Search.
Legend: [*] built-in [ ] excluded <M> module < > module capable

Boot images ---
Boot timing ---
Boot media ---
Autoboot options ---
[*] Enable boot arguments
[*] Enable boot arguments
[*] Enable boot arguments
[ ] Support substituting strings in boot arguments
[*] Enable a default value for bootcmd
(fatload mmc 1:1 0x61000000 at91-sama7g5ek.dtb; fatload mmc 1:1 0x62000000 zImage; bootz 0x62000)
[ ] Enable preboot
[ ] Default fdt file
```

- b. In the **Boot arguments** window, modify the string from “root=/dev/mmcblk1p2” to “root=/dev/mmcblk0p2”, select **ok** and then press Enter.  
**Note:** For SAMA7G54-EK, the e.MMC device is connected to SDMMC0 and the SD card is connected to SDMMC1. “p2” (“partition 2”) contains the root file system.



- c. In the **Boot options** window, select **Bootcmd value** and press Enter.



- d. In the **bootcmd value** window, update the string from:

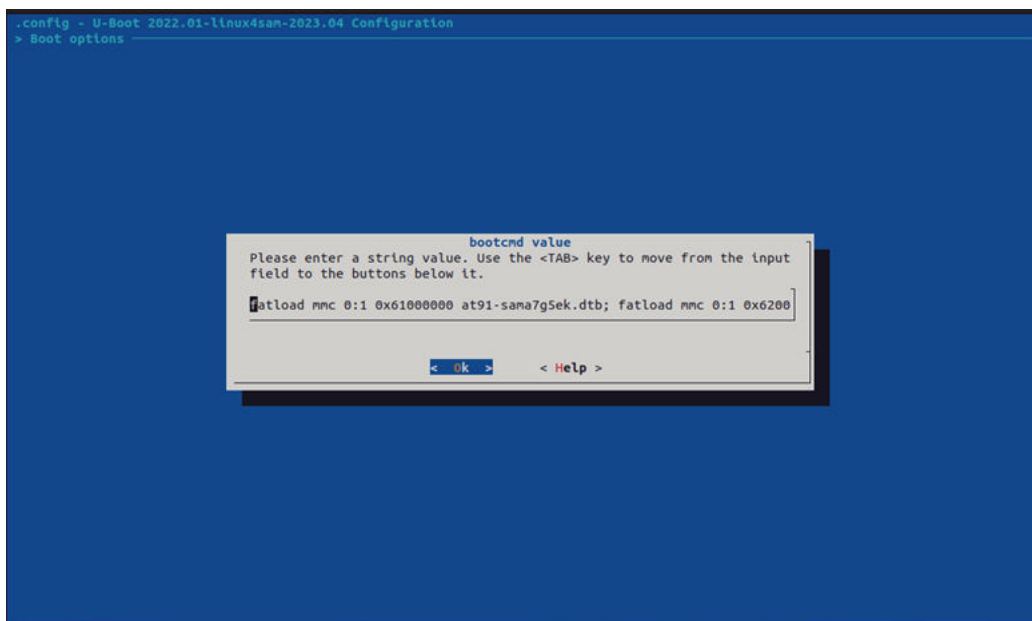
```
fatload mmc 1:1 0x61000000 at91-sama7g5ek.dtb; fatload mmc 1:1
0x62000000 zImage; bootz 0x62000000 - 0x61000000
```

to

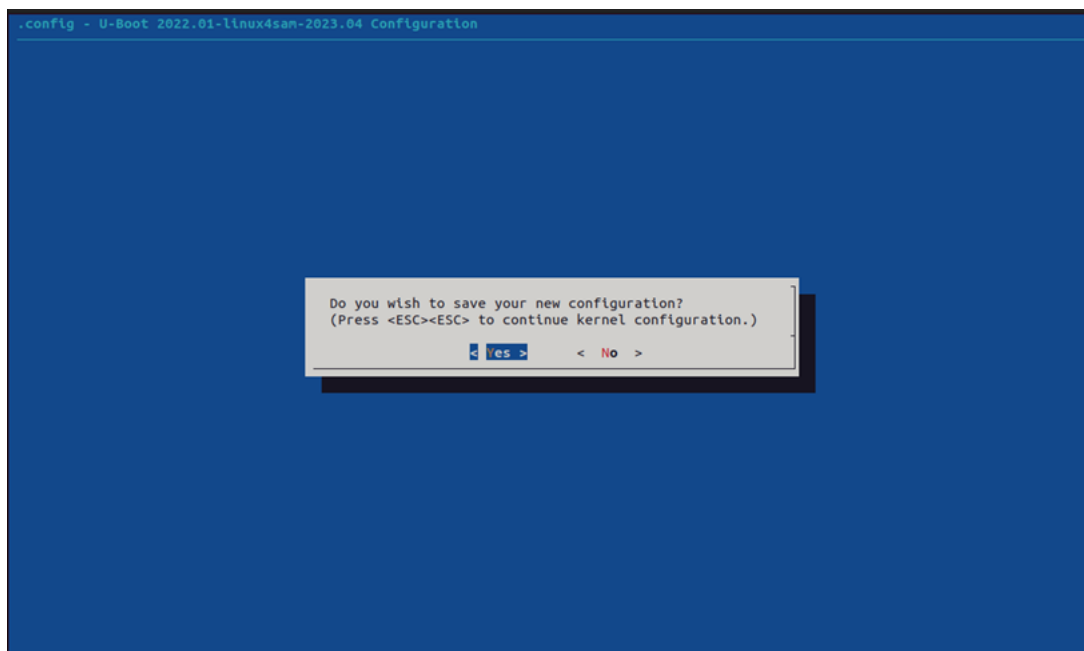
```
fatload mmc 0:1 0x61000000 at91-sama7g5ek.dtb; fatload mmc 0:1
0x62000000 zImage; bootz 0x62000000 - 0x61000000
```

and click **ok**.

**Note:** For SAMA7G54-EK, "fatload mmc 0:1" states that 0 (e.MMC device) is connected to SDMMC0 and 1 (partition 1) contains the kernel, the u-boot and the device tree.



- e. Press ESC twice to exit the menu.
3. Select **Exit** and press Enter.
    - a. Click **Yes**.



## 6. Modify the uboot-env and genimage files to boot from e.MMC

1. In the explorer, navigate to **buildroot-external-microchip > board > microchip > sama7g5ek**.

2. Open the **uboot-env.txt** file.

3. In the **bootargs** section, modify the **root** values as follows:

```
root=/dev/mmcblk0p2
```

4. Modify bootcmd as follows:

```
Bootcmd=fatload mmc 0:1 0x61000000 at91-sama7g5ek.dtb; fatload mmc 0:1  
0x62000000 zImage; bootz 0x62000000 - 0x61000000
```

5. Click **Save** and close the file.

6. In the same directory, open the **genimage.cfg** file.

7. Modify the **files** section as follows:

```
Files = {  
    zImage,  
    at91-sama7g5ek.dtb,  
    boot.bin,  
    u-boot.bin  
}
```

8. Click **Save** and close the file.

## 7. Final Build

After all required changes are made, the build can be performed.

1. Navigate to the buildroot-at91 directory:

```
$ cd buildroot-at91
```

2. Build the at91bootstrap with the following command:

```
$ make
```

The build will take a few hours to complete.

3. Once the build is complete, navigate to buildroot-at91/output/Images.
4. Verify that the sdcard.img file is generated.

## 8. Flash the image file into the target

1. Install the SAM-BA software on your PC:

Download and install SAM-BA from [www.linux4sam.org/bin/view/Linux4SAM/SoftwareTools#SAM\\_BA](http://www.linux4sam.org/bin/view/Linux4SAM/SoftwareTools#SAM_BA).

2. Configure the first stage bootloader to boot from the e.MMC Flash memory:

The boot sequence must be configured to boot from e.MMC using the Boot Configuration Packet (BCP). The BCP can be written to either the emulation SRAM or the OTPC.



**CAUTION** Once a packet has been written into the OTPC, Emulation mode can never be enabled again. Be careful before writing a packet in OTPC.

---

**Note:** If the user is programming BCP to the emulation SRAM, then in every power cycle (VDDBU power reset), BCP should be programmed to the emulation SRAM to boot from e.MMC. For more details, refer to the section “ Boot Strategies” in the SAMA7G5 Series Data Sheet (see [Reference Documents](#)).

To program the Boot Configuration Packet into the emulation SRAM:

1. Enable Emulation:  

```
$ sam-ba -p serial -b sama7g5-ek -a bootconfig -c writecfg:bscr:EMULATION_ENABLED
```
2. Read bscr and verify emulation is enabled:  

```
$ sam-ba -p serial -b sama7g5-ek -a bootconfig -c readcfg:bscr
```
3. Reset the emulation SRAM:  

```
$ sam-ba -p serial -b sama7g5-ek -a bootconfig -c resetemul
```
4. Refresh the emulation SRAM:  

```
$ sam-ba -p serial -b sama7g5-ek -a bootconfig -c refreshcfg:emul
```
5. Enable debug, SDMMC0 as external NVM:  

```
$ sam-ba -p serial -b sama7g5-ek -a bootconfig -c writecfg:bcp-emul:DBGU,SDMMC0_IOSET1
```
6. Read bcp\_emul and verify whether SDMMC0 is set as external NVM:  

```
$ sam-ba -p serial -b sama7g5-ek -a bootconfig -c readcfg:bcp-emul
```

```

@che-ld-~
@che-ld-~$ sam-ba -p serial -b sama7g5-ek -a bootconfig -c writecfg:bscr:EMULATION_ENABLED
Opening serial port 'ttyACM0'
Connection opened.
Buffer is 33279 bytes (Infinity pages) at address 0x00107e00.
Executing command 'writecfg:bscr:EMULATION_ENABLED'
Setting BSCR to EMULATION_ENABLED
Connection closed.
@che-ld-~$ sam-ba -p serial -b sama7g5-ek -a bootconfig -c readcfg:bscr
Opening serial port 'ttyACM0'
Connection opened.
Buffer is 33279 bytes (Infinity pages) at address 0x00107e00.
Executing command 'readcfg:bscr'
BSCR=0x00000001 / EMULATION_ENABLED
Connection closed.
@che-ld-~$ sam-ba -p serial -b sama7g5-ek -a bootconfig -c resetemul
Opening serial port 'ttyACM0'
Connection opened.
Buffer is 33279 bytes (Infinity pages) at address 0x00107e00.
Executing command 'resetemul'
Connection closed.
@che-ld-~$ sam-ba -p serial -b sama7g5-ek -a bootconfig -c refreshcfg:emul
Opening serial port 'ttyACM0'
Connection opened.
Buffer is 33279 bytes (Infinity pages) at address 0x00107e00.
Executing command 'refreshcfg:emul'
Connection closed.
@che-ld-~$ sam-ba -p serial -b sama7g5-ek -a bootconfig -c writecfg:bcp-emul:DBGU,SDMMC0_IOSET1
Opening serial port 'ttyACM0'
Connection opened.
Buffer is 33279 bytes (Infinity pages) at address 0x00107e00.
Executing command 'writecfg:bcp-emul:DBGU,SDMMC0_IOSET1'
Setting BCP-EMUL to FLEXCOM0_USART_IOSET1,SDMMC0_IOSET1
Connection closed.
@che-ld-~$ sam-ba -p serial -b sama7g5-ek -a bootconfig -c readcfg:bcp-emul
Opening serial port 'ttyACM0'
Connection opened.
Buffer is 33279 bytes (Infinity pages) at address 0x00107e00.
Executing command 'readcfg:bcp-emul'
BCP-EMUL=FLEXCOM0_USART_IOSET1,SDMMC0_IOSET1
Connection closed.
@che-ld-~$

```

### To program the Boot Configuration Packet into the OTPC:

1. Disable emulation:
 

```
sam-ba -p serial -b sama7g5-ek -a bootconfig -c writecfg:bscr:EMULATION_DISABLED
```
2. Read bscr and verify emulation is disabled:
 

```
sam-ba -p serial -b sama7g5-ek -a bootconfig -c readcfg:bscr
```
3. Refresh OTP:
 

```
sam-ba -p serial -b sama7g5-ek -a bootconfig -c refreshcfg:otp
```
4. Enable debug, SDMMC0 as external NVM:
 

```
sam-ba -p serial -b sama7g5-ek -a bootconfig -c writecfg:bcp-otp:DBGU,SDMMC0_IOSET1
```
5. Read bcp\_otp and verify whether SDMMC0 is set as external NVM:
 

```
sam-ba -p serial -b sama7g5-ek -a bootconfig -c readcfg:bcp-otp
```

**Note:** For more details, refer to SAM-BA installation directory/doc/sama7g5.html.

3. Flash the sdcard.img file into the e.MMC Flash memory:
  - a. In the terminal, navigate to the buildroot-at91/output/images directory:
 

```
$ cd buildroot-at91/output/Images
```
  - b. Program the sdcard.img file on the SAMA7G54-EK with the following command:
 

```
$ sam-ba -p serial -b sama7g5-ek -a sdmmc -c write:sdcard.img
```

 Flashing the sdcard.img file will take a few minutes.

```

@che-ld- : /buildroot-at91/output/images$ sam-ba -p serial -b sama7g5-ek -a sdmmc -c write:sdcard.img
Opening serial port 'ttyACM0'
Connection opened.
Detected memory size is 3909091328 bytes.
Page size is 512 bytes.
Buffer is 20480 bytes (40 pages) at address 0x0010afc0.
Executing command 'write:sdcard.img'
Wrote 20480 bytes at address 0x00000000 (0.00%)
Wrote 20480 bytes at address 0x00005000 (0.00%)
Wrote 20480 bytes at address 0x0000a000 (0.01%)
Wrote 20480 bytes at address 0x0000f000 (0.01%)
Wrote 20480 bytes at address 0x00014000 (0.01%)
Wrote 20480 bytes at address 0x00019000 (0.01%)
Wrote 20480 bytes at address 0x0001e000 (0.01%)
Wrote 20480 bytes at address 0x00023000 (0.02%)
Wrote 20480 bytes at address 0x00028000 (0.02%)

```

- c. Reset the board by pressing the reset(nRST) button.

Successful booting of a Linux image can be observed in the Linux serial debug console, as shown below:

```

MCK: mck domains initialization complete.
TZC400: Initialization complete.
PUBL: Training complete.
UMCTL2: Initialization complete.
Backup mode enabled

AT91Bootstrap 4.0.8 (2024-01-02 10:57:03)

SD/MMC: Image: Read file u-boot.bin to 0x66f00000
MMC: ADMA supported
MMC: Specification Version 4.0 or higher
MMC: v5.1 detected
MMC: highspeed supported
MMC: Dual Data Rate supported
MMC: detecting buswidth...
MMC: 8-bit bus width detected
SD/MMC: Done to load image

<debug_uart>

U-Boot 2023.07.02-linux4microchip-2023.10 (Jan 02 2024 - 10:55:48 +0530)

CPU: SAMA7G54
Crystal frequency: 24 MHz
CPU clock : 800 MHz
Master clock : 200 MHz

Model: Microchip SAMA7G5-EK
DRAM: 512 MiB
Core: 261 devices, 24 uclasses, devicetree: separate
MMC: mmc@e1204000: 0, mmc@e1208000: 1
Loading Environment from FAT... MMC: no card present
** Bad device specification mmc 1 **
In: serial@200
Out: serial@200
Err: serial@200
Net: eth0: ethernet@e2800000, eth1: ethernet@e2804000
Hit any key to stop autoboot: 0
44378 bytes read in 16 ms (2.6 MiB/s)
4880816 bytes read in 301 ms (15.5 MiB/s)
Kernel image @ 0x62000000 [ 0x00000000 - 0x4a79b0 ]
## Flattened Device Tree blob at 61000000
Booting using the fdt blob at 0x61000000
Working FDT set to 61000000
Loading Device Tree to 7eb35000, end 7eb42d59 ... OK
Working FDT set to 7eb35000

Starting kernel ...

Booting Linux on physical CPU 0x0

```

```
[ OK ] Reached target Login Prompts.  
Starting OpenSSH server daemon...  
[ OK ] Finished Save/Restore Sound Card State.  
[ OK ] Started OpenSSH server daemon.  
[ OK ] Started Network Time Service.  
[ OK ] Reached target Multi-User System.  
atmel_usart_serial atmel_usart_serial.0.auto: using dma1chan0 for  
atmel_usart_serial atmel_usart_serial.0.auto: using dma1chan1 for  
  
Welcome to the Microchip SAMA7G5 Demo  
sama? login:
```

## 9. Conclusion

This document describes, step by step, how to boot Linux from the e.MMC Flash memory. The tool used is Buildroot, which is available in [www.linux4sam.org/bin/view/Linux4SAM/BuildRoot](http://www.linux4sam.org/bin/view/Linux4SAM/BuildRoot).

## 10. Revision History

### 10.1 Rev. A - 03/2024

First issue.

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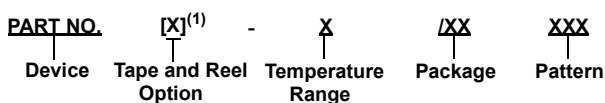
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Tape and Reel Option:	Blank	= Standard packaging (tube or tray)
	T	= Tape and Reel <sup>(1)</sup>
Temperature Range:	I	= -40°C to +85°C (Industrial)
	E	= -40°C to +125°C (Extended)
Package: <sup>(2)</sup>	JQ	= UQFN
	P	= PDIP
	ST	= TSSOP
	SL	= SOIC-14
	SN	= SOIC-8
	RF	= UDFN
Pattern:	QTP, SQTP, Code or Special Requirements (blank otherwise)	

Examples:

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