AN3326

How to use the SAMA5D2 USB Mass Storage Gadget Under Linux®

Introduction

This application note describes how to get started using the SAMA5D2 USB Mass Storage Gadget under Linux.

The document shows how to simulate a USB Mass Storage Gadget (or “Device”) by using SAMA5D2. The simulation requires a UDC driver and a Gadget driver. The UDC driver is provided by the Microchip Linux Board Support Package (BSP); the Gadget driver is contained in the kernel.

Reference Documents

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

Prerequisites

- Hardware
  - PC
  - SAMA5D27 SOM1 Evaluation Kit (Part Number: ATSAMA5D27-SOM1-EK1)
  - SDCard
  - USB cable (Micro-USB to Type-A cable)
- 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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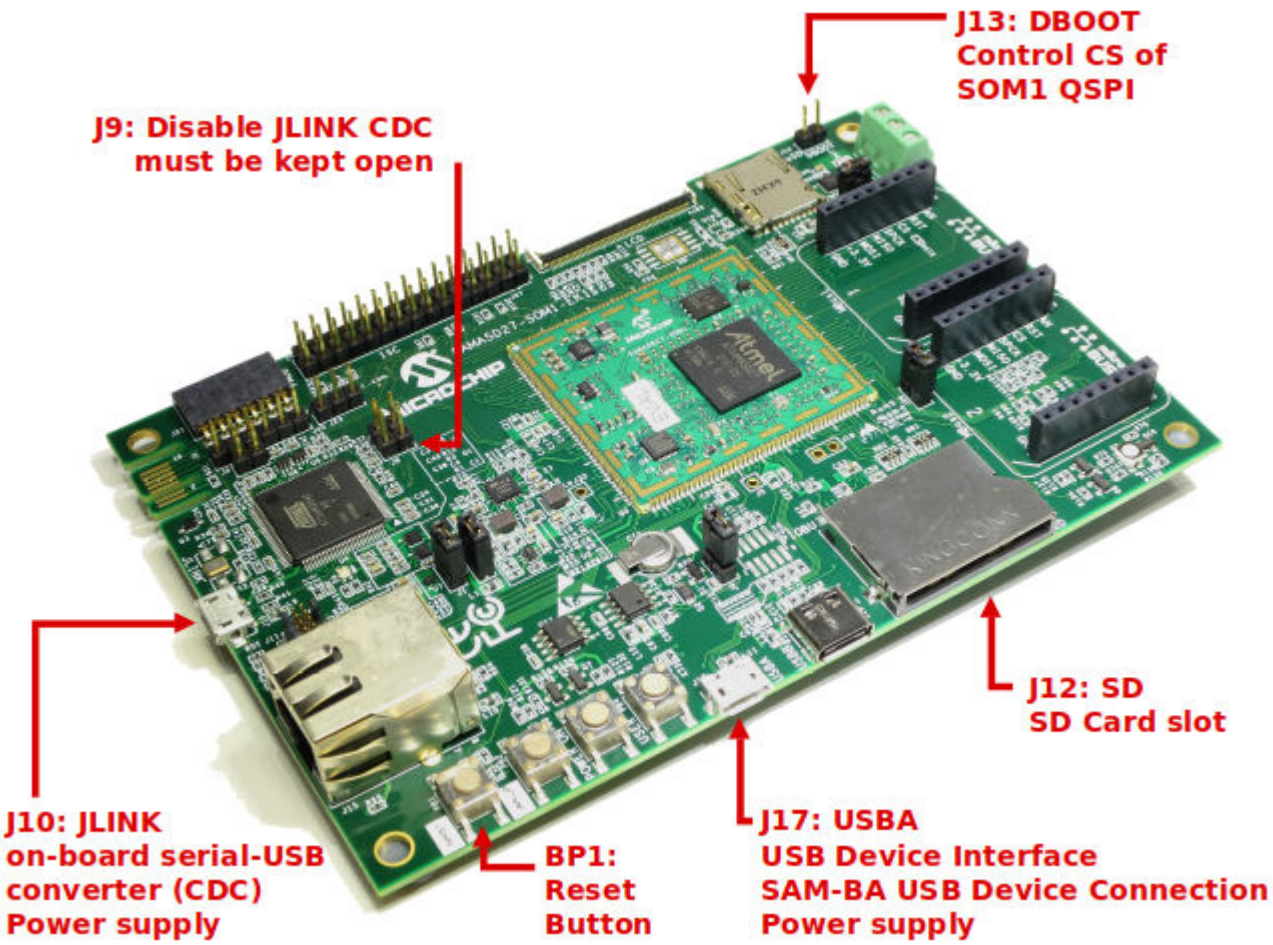
J13: DBOOT
Control CS of
SOM1 QSPI
J9: Disable JLINK CDC
must be kept open
J12: SD
SD Card slot
J10: JLINK
on-board serial-USB
converter (CDC)
Power supply
BP1:
Reset
Button
J17: USBA
USB Device Interface
SAM-BA USB Device Connection
Power supply

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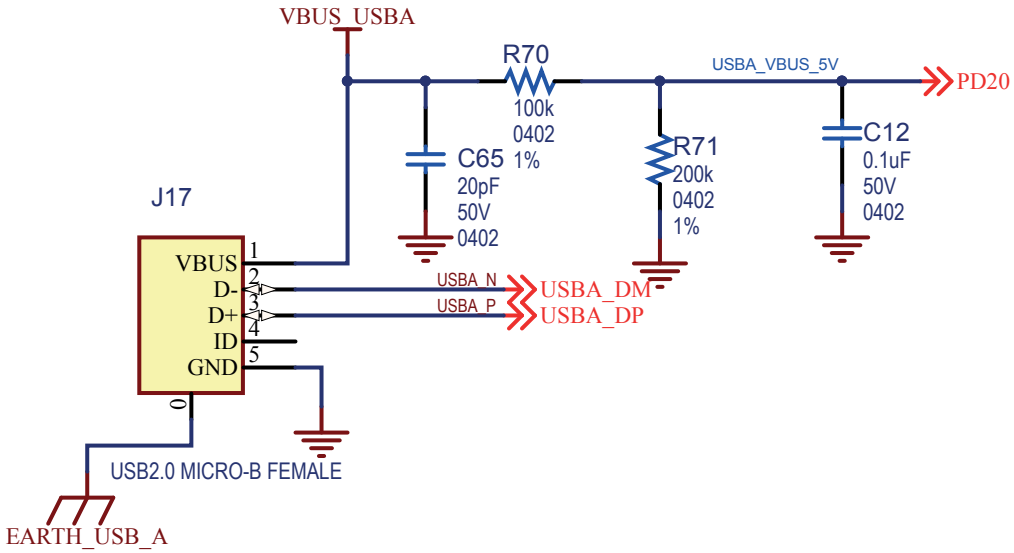
1. Hardware Design

1.1 Interface



USB-A J17 was used in this Mass Storage Gadget demo.

1.2 Connection

Connect USB-A J17 to the PC using the USB cable (see Prerequisites).

Refer to the following picture.


MICROCHIP
SAMA5D27-SOM1-EK1
microSD
microSDHC
microSDXC
ADAPTER

2. Software Design

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

`atmel_sama5d27_som1_ek_mmc_dev_defconfig`

The USB Mass Storage Gadget demo works under this default configuration without any adjustment.

The g_mass_storage target in kernel was used to provide a mass storage function and can be built in kernel image or as a driver module.

Note: As most of the important parameters are passed via module parameters, it is preferable to build the g_mass_storage target as a driver module; otherwise, bootargs in the U-Boot environment must be modified in order to pass parameters to g_mass_storage.

The following table describes the g_mass_storage module parameters (source: kernel_dir/Documentation/usb/massstorage.txt).

Table 2-1. g_mass_storage Module Parameters

Parameter	Description
Mass Storage Gadget Specific Module Parameters	
file=filename[,filename...]	This parameter lists paths to files or block devices used for backing storage for each logical unit. There may be at most FSG_MAX_LUNS (8) LUNs set. If more files are specified, they will be silently ignored. See also “luns” parameter. *BEWARE* that if a file is used as a backing storage, it may not be modified by any other process. This is because the host assumes the data does not change without its knowledge. It may be read, but (if the logical unit is writable) due to buffering on the host side, the contents are not well defined. The size of the logical unit will be rounded down to a full logical block. The logical block size is 2048 bytes for LUNs simulating CD-ROM, block size of the device if the backing file is a block device, or 512 bytes otherwise.
removable=b[,b...]	This parameter specifies whether each logical unit should be removable. “b” here is either “y”, “Y” or “1” for true or “n”, “N” or “0” for false. If this option is set for a logical unit, gadget will accept an “eject” SCSI request (Start/Stop Unit). When it is sent, the backing file will be closed to simulate ejection and the logical unit will not be mountable by the host until a new backing file is specified by userspace on the device (see “sysfs entries” section). If a logical unit is not removable (the default), a backing file must be specified for it with the “file” parameter as the module is loaded. The same applies if the module is built in, no exceptions. The default value of the flag is false, *HOWEVER* it used to be true. This has been changed to better match File Storage Gadget and because it seems like a saner default after all. Thus to maintain compatibility with older kernels, it's best to specify the default values. Also, if one relied on old default, explicit “n” needs to be specified now. Note that “removable” means the logical unit's medium can be ejected or removed (as is true for a CD-ROM drive or a card reader). It does *not* mean that the entire gadget can be unplugged from the host; the proper term for that is “hot-unpluggable”.
cdrom=b[,b...]	This parameter specifies whether each logical unit should simulate CD-ROM. The default is false.
ro=b[,b...]	This parameter specifies whether each logical unit should be reported as read only. This will prevent host from modifying the backing files. Note that if this flag for given logical unit is false but the backing file could not be opened in read/write mode, the gadget will fall back to read only mode anyway. The default value for non-CD-ROM logical units is false; for logical units simulating CD-ROM it is forced to true.

.....continued	
Parameter	**Description**
nofua=b[,b...]	This parameter specifies whether FUA flag should be ignored in SCSI Write10 and Write12 commands sent to given logical units. MS Windows mounts removable storage in “Removal optimised mode” by default. All the writes to the media are synchronous, which is achieved by setting the FUA (Force Unit Access) bit in SCSI Write(10,12) commands. This forces each write to wait until the data has actually been written out and prevents I/O requests aggregation in block layer dramatically decreasing performance. Note that this may mean that if the device is powered from USB and the user unplugs the device without unmounting it first (which at least some Windows users do), the data may be lost. The default value is false.
luns=N	This parameter specifies the number of logical units the gadget will have. It is limited by FSG_MAX_LUNS (8) and higher values will be capped. If this parameter is provided, and the number of files specified in “file” argument is greater than the value of “luns”, all excess files will be ignored. If this parameter is not present, the number of logical units will be deduced from the number of files specified in the “file” parameter. If the file parameter is missing as well, one is assumed.
stall=b	Specifies whether the gadget is allowed to halt bulk endpoints. The default is determined according to the type of USB device controller, but usually true.
Composite Gadget Common Parameters	
idVendor	USB Vendor ID (16-bit integer)
idProduct	USB Product ID (16-bit integer)
bcdDevice	USB Device version (BCD) (16-bit integer)
iManufacturer	USB Manufacturer string (string)
iProduct	USB Product string (string)
iSerialNumber	Serial number string (sting)

2.1 Device Tree

- Action: no need to change
- Location: buildroot-at91/output/build/linux-linux4sam_6.0/arch/arm/boot/dts
- Sources:
  - sama5d2.dtsi
  - at91-sama5d27_som1_ek.dts

Device tree for UDPHS in sama5d2.dtsi:

```
usb0: gadget@300000 {
    #address-cells = <1>;
    #size-cells = <0>;
    compatible = "atmel,sama5d3-udc";

 // specify which driver will be used for this usb device


    reg = <0x00300000 0x100000

 // definition for fifo memory region, base address 0x300000, size 0x100000
```

```
         0xfc02c000 0x400>;
 // definition for ctrl memory region, base address 0xfc02c000, size 0x400


    interrupts = <42 IRQ_TYPE_LEVEL_HIGH 2>;
 // PID of usb0 is 42, high level triggered, priority is 2


    clocks = <&udphs_clk>, <&utmi>;
 // definition for usb0 clock


    clock-names = "pclk", "hclk";
    status = "disabled";
 // default disabled, and will be replaced with “okay”



    ep@0 {
 // definition for usb end point


        reg = <0>;
        atmel,fifo-size = <64>;
        atmel,nb-banks = <1>;
    };

    ep@1 {
        reg = <1>;
        atmel,fifo-size = <1024>;
        atmel,nb-banks = <3>;
        atmel,can-dma;
        atmel,can-isoc;
    };

    ...... // ep2 ~ ep15
```

Device tree for UDPHS in at91-sama5d27_som1_ek.dts:

```
usb0: gadget@300000 {
    atmel,vbus-gpio = <&pioA PIN_PD20 GPIO_ACTIVE_HIGH>;
 // USB vbus pin definition


    pinctrl-names = "default";
    pinctrl-0 = <&pinctrl_usba_vbus>;
 // definition for usb0 pins


    status = "okay";
 // replace status’s property with “okay”, enable usb0 device


};
```

2.2 Kernel

- Action: no need to change
- Location: buildroot-at91/output/build/linux-linux4sam_6.0/
- Defconfig: sama5_defconfig
- Driver files:

– drivers/usb/gadget/udc/atmel_usba_udc.c
– drivers/usb/gadget/function/f_mass_storage.c
– drivers/usb/gadget/legacy/mass_storage.c

Check the kernel configuration for the USB mass storage gadget function:

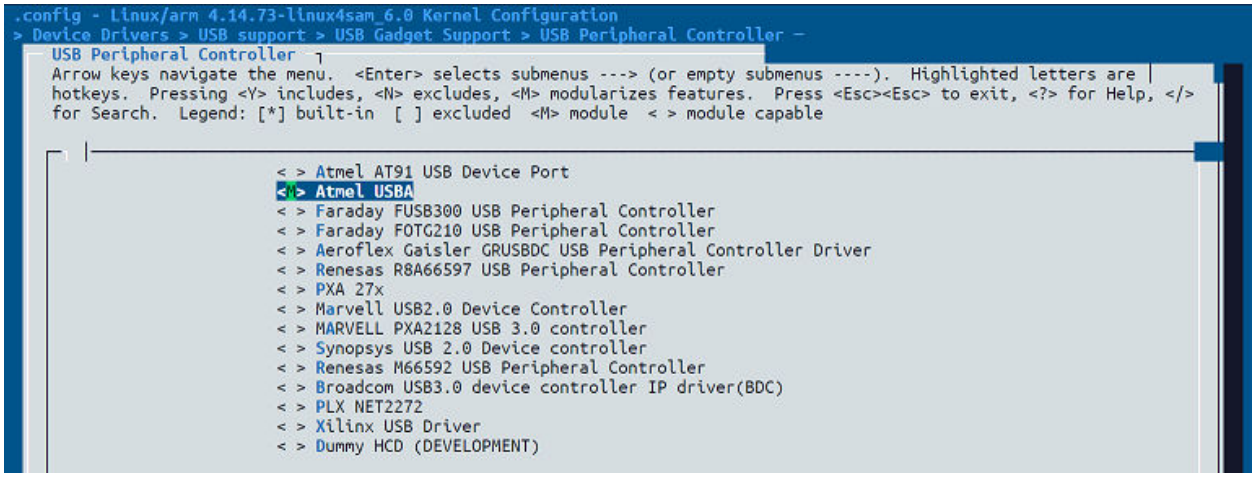
```
user@at91:~/buildroot-at91$ make linux-menuconfig
```

Device Drivers > USB support > USB Gadget Support > USB Peripheral Controller > Atmel USBA

Driver for the UDPHS (USB Device Port High Speed) controller.

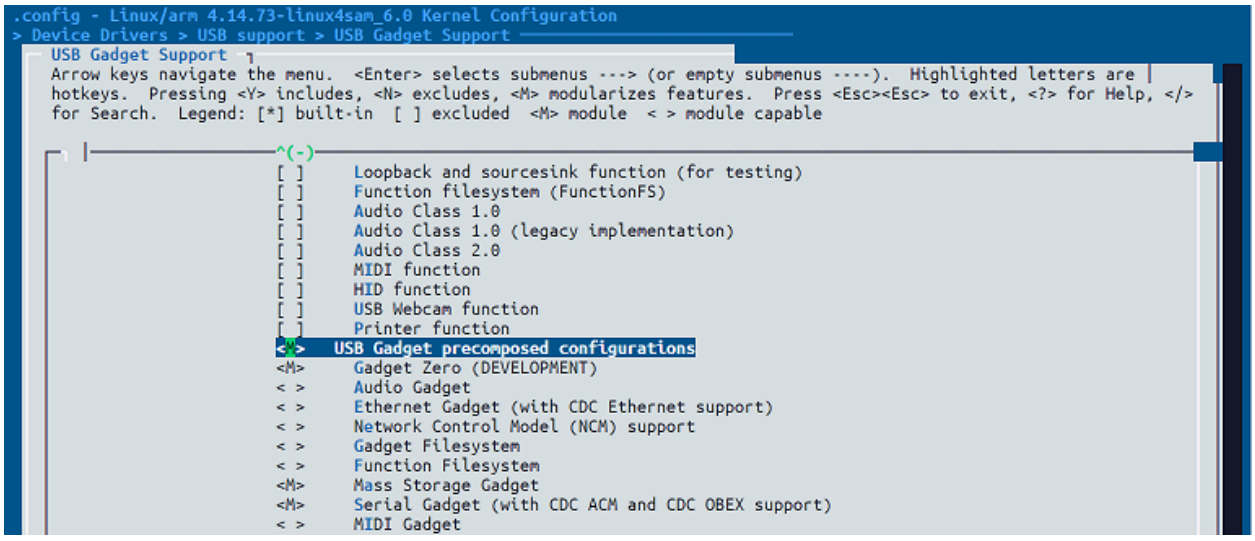
<M> was used for this driver, and this driver module will be inserted into the kernel automatically by udev once usb0, in the device tree, is registered.

With the default setting, this item has been selected.



Device Drivers > USB support > USB Gadget Support > USB Gadget precomposed configurations

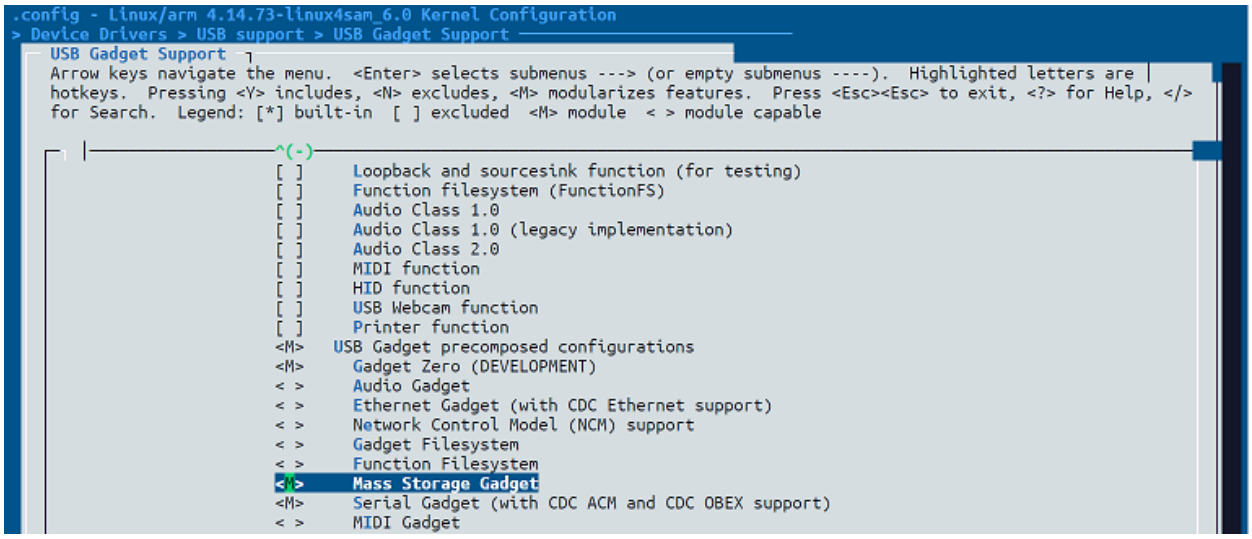
Select the “USB Gadget precomposed configurations” item. All supported gadget devices will be listed.



Device Drivers > USB support > USB Gadget Support > Mass Storage Gadget

Select “Mass Storage Gadget” with <M>. It will be built as a driver module.

It can be seen that some other gadget device drivers were selected with the default setting. After a successful build, all driver module files will be stored in rootfs and these modules can be dynamically inserted and removed at runtime according to the application requirements.



2.3 Rootfs

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

3. Hands-On

3.1 Hands-On with Module g_mass_storage.ko

3.1.1 Simplest Mass Storage Device

The “file” parameter lists paths to files or block devices used for backing storage for each LUN (logical unit). In this demo, a boot partition in the MMC card was used as a backing storage.

See 4.1 How to Add a New Partition to an MMC Card in Buildroot.

```
# modprobe g_mass_storage file=/dev/mmcblk0p1 removable=1
Mass Storage Function, version: 2009/09/11
LUN: removable file: (no medium)
LUN: removable file: /dev/mmcblk0p1
Number of LUNs=1
g_mass_storage gadget: Mass Storage Gadget, version: 2009/09/11
g_mass_storage gadget: userspace failed to provide iSerialNumber
g_mass_storage gadget: g_mass_storage ready
# g_mass_storage gadget: high-speed config #1: Linux File-Backed Storage
```

3.1.2 Read-Only Mass Storage Device

```
# modprobe g_mass_storage file=/dev/mmcblk0p1 removable=1 ro=1
Mass Storage Function, version: 2009/09/11
LUN: removable file: (no medium)
LUN: removable read only file: /dev/mmcblk0p1
Number of LUNs=1
g_mass_storage gadget: Mass Storage Gadget, version: 2009/09/11
g_mass_storage gadget: userspace failed to provide iSerialNumber
g_mass_storage gadget: g_mass_storage ready
# g_mass_storage gadget: high-speed config #1: Linux File-Backed Storage
```

3.1.3 CD-ROM Mass Storage Device

Generate an ISO9660 filesystem image, then use the resulting *.iso file as LUN backing storage.

See 4.2 How to Install the genisoimage Command in Buildroot.

```
# mount /dev/mmcblk0p1 /mnt
# ls /mnt
System Volume Information  u-boot.bin
at91-sama5d27_som1_ek.dtb  zImage
boot.bin
# genisoimage -allow-lowercase -l -o image.iso /mnt
Warning: creating filesystem that does not conform to ISO-9660.
I: -input-charset not specified, using ascii (detected in locale settings)
Total translation table size: 0
Total rockridge attributes bytes: 0
Total directory bytes: 2048
Path table size(bytes): 44
Max brk space used 5000
2342 extents written (4 MB)
# ls
image.iso
# modprobe g_mass_storage file=/root/image.iso removable=1 cdrom=1
Mass Storage Function, version: 2009/09/11
LUN: removable file: (no medium)
LUN: removable read only CD-ROM file: /root/image.iso
Number of LUNs=1
g_mass_storage gadget: Mass Storage Gadget, version: 2009/09/11
g_mass_storage gadget: userspace failed to provide iSerialNumber
g_mass_storage gadget: g_mass_storage ready
# g_mass_storage gadget: high-speed config #1: Linux File-Backed Storage
```

3.1.4 Mass Storage Device with Multiple LUNs

Multiple LUNs (logical units) were supported by the Mass Storage Gadget driver. A new MMC partition was added for the demo.

“iSerialNumber” must be provided, otherwise only the first disk or drive will be detected in Windows (this differs from Ubuntu).

```
# modprobe g_mass_storage file=/root/image.iso,/dev/mmcblk0p1,/dev/mmcblk0p3 removable=1,1,1
cdrom=1,0,0 ro=1,1,0 iSerialNumber=0000000000000001,0000000000000002,0000000000000003
Mass Storage Function, version: 2009/09/11
LUN: removable file: (no medium)
LUN: removable read only CD-ROM file: /root/image.iso
LUN: removable read only file: /dev/mmcblk0p1
LUN: removable file: /dev/mmcblk0p3
Number of LUNs=3
g_mass_storage gadget: Mass Storage Gadget, version: 2009/09/11
g_mass_storage gadget: g_mass_storage ready
# g_mass_storage gadget: high-speed config #1: Linux File-Backed Storage
```

3.2 Hands-On with Built-In g_mass_storage

g_mass_storage can be built into the kernel image, but will result in the following error log when booting if the bootargs was not updated in uboot:

```
Mass Storage Function, version: 2009/09/11
LUN: removable file: (no medium)
no file given for LUN0
g_mass_storage 300000.gadget: failed to start g_mass_storage: -22
```

This error message is due to the following codes in f_mass_storage.c:

```
if (!cfg->filename && !cfg->removable) {
pr_err("no file given for LUN%d\n", id);
return -EINVAL;
}
```

Some important parameters must be passed during g_mass_storage initialization. The parameter “removable” must be passed by updating bootargs. See 3.2.1 Using sysfs to Interact with g_mass_storage.

3.2.1 Using sysfs to Interact with g_mass_storage

The updated bootargs displays as follows:

```
bootargs=console=ttyS0,115200 earlyprintk root=/dev/mmcblk0p2 rw rootwait
g_mass_storage.removable=1
```

In the uboot console, set bootargs as follows:

```
=> setenv bootargs “console=ttyS0,115200 earlyprintk root=/dev/mmcblk0p2 rw rootwait
g_mass_storage.removable=1”
=> saveenv
=> boot
```

After bootarg updated successfully, the following booting logs display:

```
Mass Storage Function, version: 2009/09/11
LUN: removable file: (no medium)
LUN: removable file: (no medium)
Number of LUNs=1
g_mass_storage gadget: Mass Storage Gadget, version: 2009/09/11
g_mass_storage gadget: userspace failed to provide iSerialNumber
g_mass_storage gadget: g_mass_storage ready
```

Other parameters can be passed to g_mass_storage via the sysfs interface. Use the following command to insert storage medium “/dev/mmcblk0p1” into the USB mass storage drive:

```
# cd /sys/devices/platform/ahb/300000.gadget/gadget/lun0
# ls
file    nofua   power   ro      uevent
# echo /dev/mmcblk0p1 > file
```

Use the following command to eject the storage medium:

```
# echo > file
```

4. Appendix

4.1 How to Add a New Partition to an MMC Card in Buildroot

In SAMA5D27-SOM1-EK1, modify the following file to add a new MMC partition:

`buildroot-at91/board/atmel/sama5d27_som1_ek_mmc/genimage.cfg`

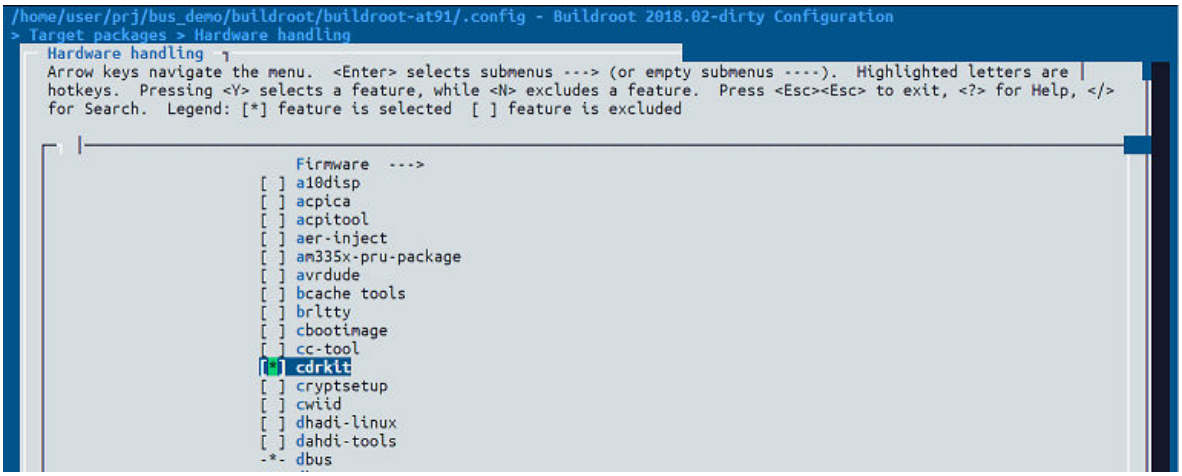
The following example code shows how to add a partition to an MMC card for mass storage function:

```
# Image for SD card boot on Atmel SAMA5D2 Xplained boards
#
image boot.vfat {
  vfat {
    files = {
      "zImage",
      "at91-sama5d27_som1_ek.dtb",
      "boot.bin",
      "u-boot.bin"
    }
  }
  size = 16M
}
image sdcard.img {
  hdimage {
  }
  partition boot {
    partition-type = 0xC
    bootable = "true"
    image = "boot.vfat"
    offset = 1M
  }
  partition rootfs {
    partition-type = 0x83
    image = "rootfs.ext4"
    size = 512M
  }
  partition mass-storage1 {
    partition-type = 0x83
    size = 32M
  }
}
```

4.2 How to Install the genisoimage Command in Buildroot

1. Add the cdrkit package support in Buildroot:

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



2. Rebuild Buildroot:

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

5. Revision History

5.1 Rev. A - 11/2019

First issue.

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