APPLICATION NOTE

Design Optimization for a Low-Power SAMA5D3-based System

Atmel | SMART SAMA5D3 Series

Introduction

The Atmel® | SMART SAMA5D3 series is a high-performance, power-efficient embedded MPU. It features reduced power consumption, making it an ideal platform for low-power applications, such as battery-powered devices.

This application note provides techniques to optimize the design of a SAMA5D3-based system in order to achieve the lowest power consumption possible.

The application note consists of three sections:

- Section 1 introduces the SAMA5D36 CPU Module Power Consumption (CMP) board and its Linux demo.
- Section 2 presents the overall power consumption of SAMA5D36 in different modes, including Low-power mode and Active mode.
- Section 3 explains how to optimize the power consumption for a SAMA5D3-based system.

This application note should be used in conjunction with the SAMA5D3 Series datasheet available on www.atmel.com.

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1. SAMA5D36-CMP Board and Linux Demo

1.1 SAMA5D36-CMP Board

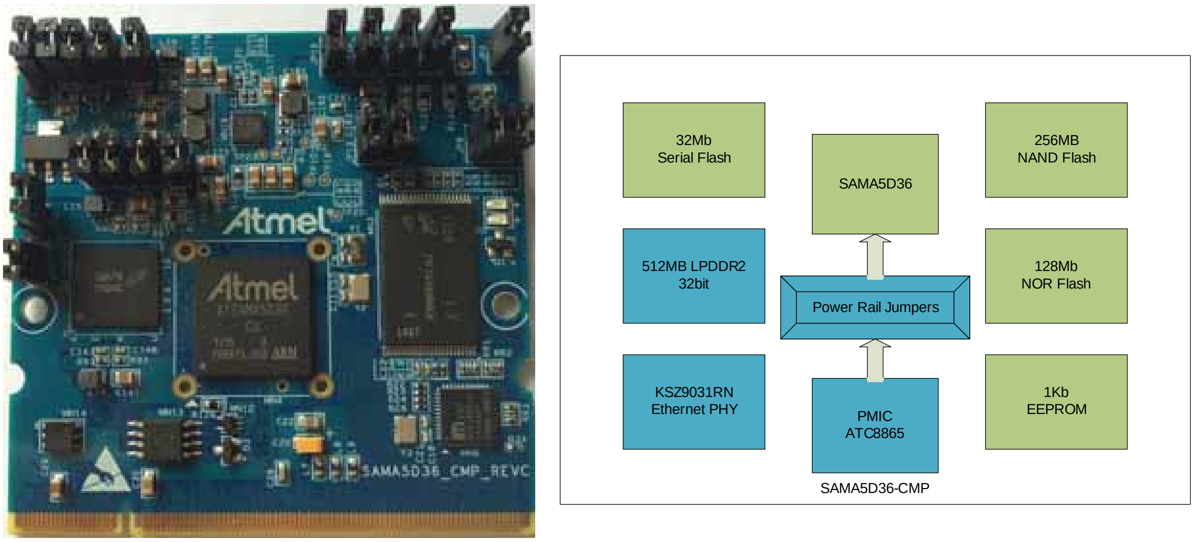
SAMA5D36-CMP board (see Figure 1-1) is a CPU module designed to measure the power consumption of the SAMA5D36 device.

For complete schematics of the SAMA5D36-CMP RevC, refer to the appendix.

Note: Before using the CMP board, check the settings of all jumpers to ensure that they are in the default state as illustrated in Figure 1-2.

The CMP board is a CPU module (CM) board to be used in conjunction with the SAMA5D3-EK main board (MB). The main differences between the CMP board and the CM board are the jumpers that measure the power consumption of each rail of the SAMA5D36 product, the use of LPDDR2 instead of DDR2, and the power management IC (PMIC).

Figure 1-1. SAMA5D36-CMP Overview



1.1.1 Jumper Settings

With one jumper on each power rail of the SAMA5D36 device, the CMP board features more jumpers than the CM board, thus offering more precise measurement capabilities than the CM. This makes it possible to measure the current of each power rail, thus facilitating the overall power consumption investigation/analysis of the SAMA5D36 and external devices. This is of particular importance for low-power applications.

For detailed jumper settings on the CMP board, please refer to Figure 1-2.

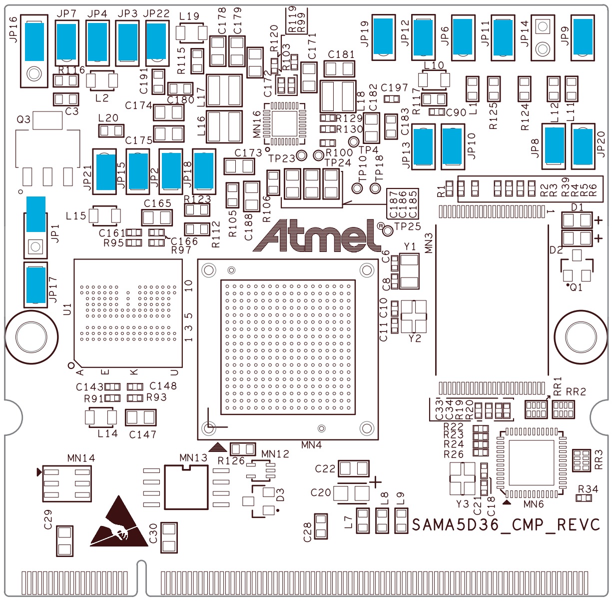
1.1.2 Low-Power DDR2 (LPDDR2)

Low-power DDR2 memory (MT42L128M32D1GU-25 WT) is used on the CMP board instead of DDR2, which is used on the CM board. Its low-power advantage makes LPDDR2 a good memory replacement in low-power system design.

1.1.3 Power Management IC (PMIC)

The Active-Semi ACT8865 is the power management IC (PMIC) implemented on the CMP board. It supplies all the on-board components including the CPU and the memories, making it a complete and highly-efficient power management solution.

Figure 1-2. CMP Default Jumper Settings

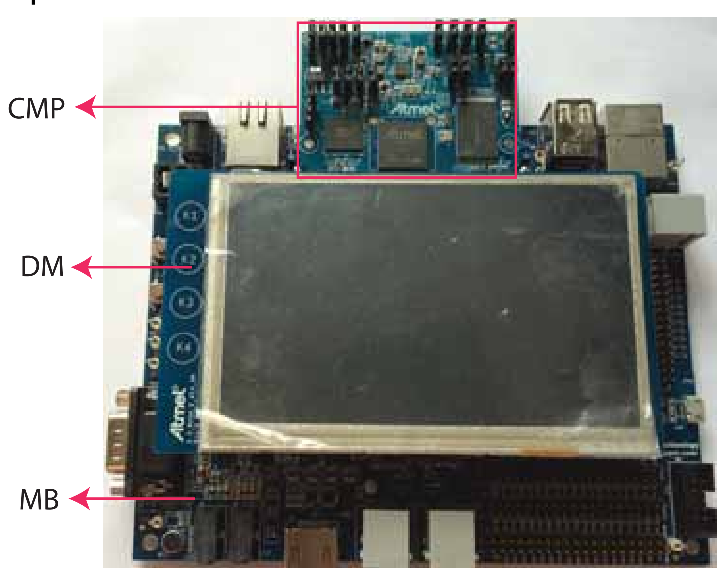


PAGE	REFERENCE	DEFAULT	FUNCTION
4	JP2	CLOSE	VDDCORE
4	JP3	CLOSE	VDDUTMIC
4	JP4	CLOSE	VDDPLLA
4	JP6	CLOSE	VDDIOM_MPU
4	JP7	CLOSE	VDDBU
4	JP8	CLOSE	VDDIOP1_MPU
4	JP9	CLOSE	VDDIOP0_MPU
4	JP10	CLOSE	FUSE_2V5
4	JP11	CLOSE	VDDUTMII
4	JP12	CLOSE	VDDOSC
4	JP13	CLOSE	VDDANA
4	JP14	OPEN	CM-3V3 to MB-3V3
4	JP15	CLOSE	VDDIODDR_MPU_1V2
4	JP17	CLOSE	VCC_5V
4	JP18	CLOSE	VCC_1V8
4	JP19	CLOSE	VCC_3V3
4	JP20	CLOSE	VDDIOP1_GPHY
4	JP21	CLOSE	VDDIODDR_1V2
4	JP22	CLOSE	VCC_1V2
7	JP1	OPEN	Disable SPI0_NPCS0 for Dataflash
9	JP16	2-1	GPHY 1V2 from VCC_1V2
		2-3	GPHY 1V2 from PMOS

The CMP board is fully compatible with the Atmel SAMA5D3-EK evaluation kit. It can be used as a seamless replacement for the CM board of the Atmel SAMA5D3-EK, and functions with the main board (MB) and display module (DM) board. In this application note, we develop a power consumption demonstration platform by replacing the CM with a CMP in the standard SAMA5D3-EK, as shown in Figure 1-3.

Note: The CMP board is not for public sale. It is intended only for internal engineering purposes. For more information on the CMP board, please contact your local Atmel representative or FAE.

Figure 1-3. Power Consumption Demo Platform



Note: For more details on the SAMA5D3-EK, refer to the SAMA5D3 Series Evaluation Kit User Guide available on www.atmel.com.

1.2 Linux Demo

The SAMA5D36-CMP board is delivered with a default Linux demo stored in the on-board NAND Flash. At power-up, in connection with the SAMA5D3x-MB and SAMA5D3x-DM boards, the demo starts running and plays a video.

The default Linux demo code together with this application note can be downloaded from:

ftp://ftp.linux4sam.org/pub/demo/sama5d36-cmp/

The demo archive contains:

- All component binaries:

  sama5d3xek-nandflashboot-uboot-3.6.1.bin, u-boot.bin, sama5d36ek_cmp.itb, rootfs-sama5d3xek.ubi
- A TCL/SAM-BA script that interfaces with the SAM-BA tool to flash the demo: sama5d3xek_demo_linux_nandflash.tcl
- A .bat script able to run the flashing script calling SAM-BA itself:

  sama5d3xek_demo_linux_nandflash.bat

The Atmel SAMA5D36 integrates the full peripheral set available for the SAMA5D3 series, including an LCD controller, touch screen interface, CMOS sensor interface, Gigabit EMAC, 10/100 EMAC and a high-speed USB host and device. The default Linux demo for the SAMA5D36-CMP is designed for the evaluation of these peripherals. In addition, the demo has been designed to support the MB RevC/D/E, and any of the display modules, either the 5" with resistive touchscreen, the TM4300 or the TM700 from PDA with capacitive touchscreen..

If the on-board NAND Flash has been erased, the user may need to re-flash the default demo. To do so, follow the procedure below:

1. Set up drivers/software environment by installing:
   – JLink (\tools\Jlink\Setup_JLinkARM_V450j.zip): SAM-ICE driver
   – JLinkCDC (\tools\Jlink OB DBGU\JLinkCDCInstaller_V1_2b.zip): USB serial port driver for debug information display
   – SAM-BA (\tools\SAM-BA2.12\sam-ba_2.12.zip): a tool used to program the on-board memory
   – SAM-BA patch (tools\SAM-BA2.12\sam-ba_2.12_patchsama5d3xcmp.zip)

(**Note:** SAM-BA 2.12 formal release is for SAMA5D3-EK with DDR2 on CM board. To support the CMP board with LPDDR2, a patch needs to be applied. Extract the .zip patch file and unzip it, run *sam-ba_2.12_patchsama5d3xcmp.exe* by double-clicking it to apply the SAM-BA patch.)

2. Build the demo platform:
   – Double-check the connection of the CM with the MB and the DM to make sure they are properly connected and all jumpers are correctly set.
   – Press **PB4 CS_BOOT** button to de-select the on-board serial Flash and the NAND Flash. Insert a 5V power supply to power-up the demo board.
   – Connect the demo board through **J20 USB-A** to the PC with a micro-USB cable.
   – Check “Device Manager->Ports (COM & LPT)”. If “AT91 USB to Serial Converter (COMx)” appears, then the USB connection between the demo board and PC is working.
3. Download and program:
   – Unzip the demo package (\demo\linux4sam-buildroot-sama5d3xek-cmp-demo-v1.0.1.zip). In the demo archive, run sama5d3xek_demo_linux_nandflash.bat by double-clicking it to flash the on-board memory.
   – A log file (logfile.log) will pop up upon completion of demo flashing.
4. Run the demo:
   – Re-plug the 5V power supply to run the Linux demo on the demo board.
   – Use a micro-USB cable to connect the demo board through **J14** to the PC, and open a hyperterminal console window as (115200-8-N-1).
   – On the console window, type “root” to log in:

```
Welcome to Buildroot
buildroot login: root
#
```

1.3 Source Code Extraction and Building

a) At91bootstrap:

Github: https://github.com/at91linux/at91bootstrap.git

Branch: wya/at91bootstrap-3.x-cmp

TAG: sama5d3x_cmp_v1.0

Commands to build binary:

```
# make sama5d3xeknf_cmp_uboot_defconfig
# make
```

Generated file:

sama5d3xek-nandflashboot-uboot-3.6.1.bin

b) u-boot:

Github: https://github.com/at91linux/u-boot-at91.git

Branch: u-boot-2013.07-at91-cmp

TAG: sama5d3x_cmp_v1.0

Commands to build binary:

```
# make sama5d3x_cmp_nandflash
```

Generated file:

u-boot.bin

c) Linux:

Github: git://github.com/at91linux/linux-at91.git

Branch: wya/linux-at91-cmp

TAG: sama5d3x_cmp_v1.0

Commands to build binary:

```
# ./build_cmp_all.sh
```

Generated file:

sama5d36ek_cmp.itb

d) buildroot (the same as SAMA5D3 series release):

Github: git://github.com/linux4sam/buildroot-at91.git

Branch: buildroot-2013.02-at91

Commands to build binary:

```
# make sama5d3ekdemo_defconfig
# make
```

Generated file:

rootfs-sama5d3ek.ubi

2. Power Consumption under Linux Scenarios

The SAMA5D3 series is based on the ARM® Cortex™-A5 processor and offers a good balance between performance and power consumption. Typical application scenarios have been selected to illustrate the high performance levels of the SAMA5D3, its rich connectivity and multimedia features and its low power consumption.

This section gives a detailed description of each scenario, as well as the typical power consumption data for each. All power consumption data were measured based on:

- HW demo board: default demo platform (RevD MB+5” LCD+RevC CMP)
- SW demo package: linux4sam-buildroot-sama5d3xek-cmp-demo-v1.0.1.zip
- Measurement equipment: Agilent 34410A 6(1/2) Digit Multimeter

The power consumption data may vary slightly depending on the revision of the MB, the LCD, the CMP and the measurement equipment used.

Note: In some cases, the “top” command is used to get the real-time CPU usage value (%), which is (1-CPU_idle%).

```
# top
Mem: 21008K used, 492708K free, 0K shrd, 0K buff, 6520K cached
CPU:  36% usr   0% sys   0% nic  63% idle   0% io   0% irq   0% sirq
```

For example, in the above log information, if the CPU idle percentage is 63%, then the CPU usage value is 37%.

2.1 Low-power Modes

In most cases, at least two low-power modes must be implemented in an operating system – Standby mode and Suspend mode.

In Standby mode, the SAMA5D3 is in Idle mode, and the core is in Wait for Interrupt mode. Most peripherals are still enabled and running. The internal bus is in High-speed mode for fast system restoration.

In Suspend mode, the SAMA5D3 is in Ultra-low-power mode with a 512 Hz MCK. The core is in Wait for Interrupt mode, and most peripherals are disabled and not running. The internal bus is set to Low-speed mode for further power savings.

To build this scenario, stop auto-boot in U-Boot and set loader options for this case:

```
U-Boot 2013.07-00054-gd757001 (Feb 25 2014 - 14:03:56)
CPU: SAMA5D36
Crystal frequency:       12 MHz
CPU clock        :      528 MHz
Master clock     :      132 MHz
DRAM:  512 MiB
NAND:  256 MiB
In:    serial
Out:   serial
Err:   serial
Net:   No ethernet found.
Hit any key to stop autoboot:  0
U-Boot>setenv bootcmd 'nand read 0x22000000 0x00200000 0x00400000; bootm
0x22000000#conf@sama5d36ek_pm'
U-Boot>boot
```

After the operating system starts up, log in and type commands to enter the system into the low-power modes separately:

```
Welcome to Buildroot
buildroot login: root
# echo standby >/sys/power/state
// echo mem >/sys/power/state
```

```
PM: Syncing filesystems ... done.
Freezing user space processes ... (elapsed 0.01 seconds) done.
Freezing remaining freezable tasks ... (elapsed 0.01 seconds) done.
LDO_REG7: No configuration
LDO_REG6: No configuration
FUSE_2V5: No configuration
VDDANA: No configuration
Suspending console(s) (use no_console_suspend to debug)
PM: suspend of devices complete after 218.937 msecs
PM: late suspend of devices complete after 0.407 msecs
PM: noirq suspend of devices complete after 0.391 msecs
```

The power consumption data for each power rail of the SAMA5D36 is listed below for reference.

Use Case: Low Power Modes (command: echo standby > /sys/power/state) (command: echo mem > /sys/power/state)						
Operation Setting: LPDDR2 in self-refresh mode						
Used Peripheral: NAND, DBGU, MPDDRC, GPIO						
			Standby (MCK=PCK=132MHz)		Suspend to Mem (MCK=PCK=512Hz=32768Hz(osc)/64)	
Power Rail	Voltage Range (V)	Voltage (V)	Current (mA)	Power Consumption (mW)	Current (mA)	Power Consumption (mW)
VDDCORE(JP2)	1.1 ~ 1.32	1.15	29.69	34.14	0.36	0.41
VDDIODDR(JP15)	1.7 ~ 1.9 1.14 ~ 1.30	1.15	0.0017	0.00	0.0016	0.00
VDDIOM(JP6)	1.65 ~ 1.9 3.0 ~ 3.6	3.3	0.0061	0.02	0.0061	0.02
VDDIOP0(JP9)	1.65 ~ 3.6	3.3	0.0076	0.03	0.0076	0.03
VDDIOP1(JP8)	1.65 ~ 3.6	3.3	0.0046	0.02	0.0046	0.02
VDDBU(JP7)	1.65 ~ 3.6	3.25	0.0022	0.01	0.0022	0.01
VDDUTMIC(JP3)	1.1 ~ 1.32	1.15	0.0095	0.01	0.0014	0.00
VDDUTMII(JP11)	3.0 ~ 3.6	3.3	0.0001	0.00	0.0001	0.00
VDDPLLA(JP4)	1.1 ~ 1.32	1.15	7.73	8.89	0.0002	0.00
VDDOSC(JP12)	1.65 ~ 3.6	3.3	0.43	1.42	0.0001	0.00
VDDANA(JP13)	3.0 ~ 3.6	3.32	0.0032	0.01	0.0032	0.01
VDDFUSE(JP10)	2.25 ~ 2.75	2.51	0.0001	0.00	0.0001	0.00
Total				45		0.50

Notes: 1. For Linux Standby mode, the SAMA5D36 is in Idle mode, while some peripherals such as the timer, DDR2 controller and DBGU serial port must be enabled.

2. For Linux Suspend mode, the SAMA5D36 is in ULP (Ultra-low-power) 512 Hz mode. In the SAMA5D3 series datasheet, the power consumption for ULP 512Hz is given as 1.2V × 0.40 mA. In this case, due to the lower supply voltage (1.15V), the actual power consumption is 1.15V × 0.36 mA.

Touch the keypads on the DM board to wake up the demo. The system will resume all the suspended drivers and print the wake-up time on the hyperterminal:

```
PM: noirq resume of devices complete after 0.315 msecs
PM: early resume of devices complete after 0.358 msecs
PM: resume of devices complete after 180.424 msecs
Restarting tasks ... done.
Vddcore suspend finish voltage 1250mV
#
```

2.2 Linux Idle

In this scenario, the Linux system is running without any workload (CPU usage is close to 0). Power consumption for this scenario is measured as the reference for other scenarios. By comparison, we can see how the current changes on each power rail when special features are enabled and in use.

To build up this scenario, stop auto-boot in U-Boot and set loader options for this case:

```
Hit any key to stop autoboot:  0
U-Boot>setenv bootcmd 'nand read 0x22000000 0x00200000 0x00400000; bootm
0x22000000#conf@sama5d36ek_pm'
U-Boot>boot
```

After the operating system starts up, log in:

```
Welcome to Buildroot
buildroot login: root
#
```

The power consumption data for each power rail of the SAMA5D36 is listed below for reference.

Use Case: Command prompt after login, No application running, no LCD display				
Operation Setting: MCK: 132MHz, PCK: 528MHz, LPDDR2: 132MHz				
Used Peripheral: NAND, DBGU, MPDDRC				
Power Rail	Voltage Range (V)	Voltage (V)	Current (mA)	Power Consumption (mW)
VDDCORE(JP2)	1.1 ~ 1.32	1.25	44.97	56.21
VDDIODDR(JP15)	1.7 ~ 1.9 1.14 ~ 1.30	1.25	4.46	5.58
VDDIOM(JP6)	1.65 ~ 1.9 3.0 ~ 3.6	3.3	0.053	0.17
VDDIOP0(JP9)	1.65 ~ 3.6	3.3	0.0079	0.03
VDDIOP1(JP8)	1.65 ~ 3.6	3.3	0.0046	0.02
VDDBU(JP7)	1.65 ~ 3.6	3.25	0.002	0.01
VDDUTMIC(JP3)	1.1 ~ 1.32	1.25	0.011	0.01
VDDUTMII(JP11)	3.0 ~ 3.6	3.3	0.0001	0.00
VDDPLLA(JP4)	1.1 ~ 1.32	1.25	8.06	10.08
VDDOSC(JP12)	1.65 ~ 3.6	3.3	0.43	1.42
VDDANA(JP13)	3.0 ~ 3.6	3.32	0.0031	0.01
VDDFUSE(JP10)	2.25 ~ 2.75	2.51	0.0001	0.00
Total				74

2.3 Dhrystone

In this scenario, Dhrystone, a typical computing benchmark program, is used to evaluate the contribution of the ARM core to power consumption figures. The Dhrystone program is compiled with the same toolchain as kernel building. The Dhrystone source code and binary can be extracted from APP\dhrystone\ at FTP: ftp://ftp.linux4sam.org/pub/demo/sama5d36-cmp/.

In this case, the CPU usage accounts for almost 99% of the overall power consumption.

To build this scenario, stop auto-boot in U-Boot and set loader options for this case:

```
Hit any key to stop autoboot:  0
U-Boot>setenv bootcmd 'nand read 0x22000000 0x00200000 0x00400000; bootm
0x22000000#conf@sama5d36ek_dhrystone'
U-Boot>boot
```

After the operating system starts up, log in:

```
Welcome to Buildroot
buildroot login: root
#
```

Insert an SD card containing Dhrystone and copy Dhrystone to NAND Flash:

```
# mount /dev/mmcblk0p1 /mnt
# cp /mnt/dhrystone ./
```

Unmount SD card and remove it from the demo board:

```
# umount /mnt
```

Run Dhrystone:

```
# ./dhrystone
```

The power consumption data for each power rail of the SAMA5D36 is listed below for reference.

Use Case: Active Power Consumption (running Dhrystone: 599DMIPS)				
Operation Setting: MCK: 132MHz, PCK: 528MHz, LPDDR2: 132MHz				
Used Peripheral: NAND, DBGU, MPDDRC, HSMCI				
Power Rail	Voltage Range (V)	Voltage (V)	Current (mA)	Power Consumption (mW)
VDDCORE(JP2)	1.1 ~ 1.32	1.25	130.63	163.29
VDDIODDR(JP15)	1.7 ~ 1.9 1.14 ~ 1.30	1.25	4.46	5.58
VDDIOM(JP6)	1.65 ~ 1.9 3.0 ~ 3.6	3.3	0.053	0.17
VDDIOP0(JP9)	1.65 ~ 3.6	3.3	0.0081	0.03
VDDIOP1(JP8)	1.65 ~ 3.6	3.3	0.0047	0.02
VDDBU(JP7)	1.65 ~ 3.6	3.25	0.0019	0.01
VDDUTMIC(JP3)	1.1 ~ 1.32	1.25	0.011	0.01
VDDUTMII(JP11)	3.0 ~ 3.6	3.3	0.0001	0.00
VDDPLLA(JP4)	1.1 ~ 1.32	1.25	8.05	10.06
VDDOSC(JP12)	1.65 ~ 3.6	3.3	0.43	1.42
VDDANA(JP13)	3.0 ~ 3.6	3.32	0.0032	0.01
VDDFUSE(JP10)	2.25 ~ 2.75	2.51	0.0001	0.00
Total				181

Note: By comparing this scenario with the "Linux Idle" scenario, we can see that the power consumption contribution of the ARM core lies only in VDDCORE.

2.4 Audio

Audio playback is an essential feature for smart devices. In this scenario, the SAMA5D36 is configured to perform MP3 decoding and playing function.

To build this scenario, stop auto-boot in U-Boot and set loader options for this case:

```
Hit any key to stop autoboot:  0
U-Boot>setenv bootcmd 'nand read 0x22000000 0x00200000 0x00400000; bootm
0x22000000#conf@sama5d36ek_audio'
```

-

Note: The DTB file in loader options differs for different revisions of the MB.

For RevC MB:

```
U-Boot>setenv bootcmd 'nand read 0x22000000 0x00200000 0x00400000; bootm
0x22000000#conf@sama5d36ek_revc_audio'
```

-

```
U-Boot>boot
```

After the operating system starts up, log in:

```
Welcome to Buildroot
buildroot login: root
#
```

Insert an SD card containing an MP3 file and launch the following commands:

```
# mount /dev/mmcblk0p1 /mnt
# cd /mnt
# ls
tellmewhy.mp3
# madplay tellmewhy.mp3

# cd ../
# umount /mnt
```

The power consumption data for each power rail of the SAMA5D36 is listed below for reference.

Use Case: MP3 Audio Playback (Mp3 file in SD card, 128Kbps, 44.1KHz sample rate, 2 channels)				
Operatino Setting: MCK: 132MHz, PCK: 528MHz, LPDDR2: 132MHz				
Used Peripheral: NAND, DBGU, MPDDRC, SSC, HSMCI				
Power Rail	Voltage Range (V)	Voltage (V)	Current (mA)	Power Consumption (mW)
VDDCORE(JP2)	1.1 ~ 1.32	1.25	55.53	69.41
VDDIODDR(JP15)	1.7 ~ 1.9 1.14 ~ 1.30	1.25	4.73	5.91
VDDIOM(JP6)	1.65 ~ 1.9 3.0 ~ 3.6	3.3	0.042	0.14
VDDIOP0(JP9)	1.65 ~ 3.6	3.3	0.19	0.63
VDDIOP1(JP8)	1.65 ~ 3.6	3.3	2.62	8.65
VDDBU(JP7)	1.65 ~ 3.6	3.25	0.0019	0.01
VDDUTMIC(JP3)	1.1 ~ 1.32	1.25	0.011	0.01
VDDUTMII(JP11)	3.0 ~ 3.6	3.3	0.0001	0.00
VDDPLLA(JP4)	1.1 ~ 1.32	1.25	8.07	10.09
VDDOSC(JP12)	1.65 ~ 3.6	3.3	0.43	1.42
VDDANA(JP13)	3.0 ~ 3.6	3.32	0.0086	0.03
VDDFUSE(JP10)	2.25 ~ 2.75	2.51	0.0001	0.00
Total				96

2.5 LCD Controller (LCDC)

This scenario is designed to evaluate the power consumption of the LCD controller, which is typically used for multimedia display. By default, the SAMA5D36-CMP demo launches a video. During video playing, the CPU usage is approximately 45%, mainly for video software decoding.

To build this scenario, stop auto-boot in U-Boot and set loader options for this case:

```
Hit any key to stop autoboot:  0
U-Boot>setenv bootcmd 'nand read 0x22000000 0x00200000 0x00400000; bootm
0x22000000#conf@sama5d36ek_lcd'
```

-

Note: The DTB file in loader options differs for different DM.

For PDA 4.3”:

```
U-Boot>setenv bootcmd 'nand read 0x22000000 0x00200000 0x00400000; bootm
0x22000000#conf@ sama5d36ek_pda4_lcd'
```

For PDA 7”:

```
U-Boot>setenv bootcmd 'nand read 0x22000000 0x00200000 0x00400000; bootm
0x22000000#conf@ sama5d36ek_pda7_lcd'
```


```
U-Boot>boot
```

After the operating system starts up, log in:

```
Welcome to Buildroot
buildroot login: root
#
```

The power consumption data for each power rail of the SAMA5D36 is listed below for reference.

Use Case: Video playback (LCDC: base layer, 800*480*24 bits, 45 fps; 480*272 MPEG2, software decoding)				
Operation Setting: MCK: 132MHz, PCK: 528MHz, LPDDR2: 132MHz				
Used Peripheral: NAND, DBGU, MPDDRC, LCDC, GPIO				
Power Rail	Voltage Range (V)	Voltage (V)	Current (mA)	Power Consumption (mW)
VDDCORE(JP2)	1.1 ~ 1.32	1.25	85.41	106.76
VDDIODDR(JP15)	1.7 ~ 1.9 1.14 ~ 1.30	1.25	6.44	8.05
VDDIOM(JP6)	1.65 ~ 1.9 3.0 ~ 3.6	3.3	0.14	0.46
VDDIOP0(JP9)	1.65 ~ 3.6	3.3	12.28	40.52
VDDIOP1(JP8)	1.65 ~ 3.6	3.3	0.0047	0.02
VDDBU(JP7)	1.65 ~ 3.6	3.25	0.0029	0.01
VDDUTMIC(JP3)	1.1 ~ 1.32	1.25	0.011	0.01
VDDUTMII(JP11)	3.0 ~ 3.6	3.3	0.0001	0.00
VDDPLLA(JP4)	1.1 ~ 1.32	1.25	8.05	10.06
VDDOSC(JP12)	1.65 ~ 3.6	3.3	0.42	1.39
VDDANA(JP13)	3.0 ~ 3.6	3.32	0.0032	0.01
VDDFUSE(JP10)	2.25 ~ 2.75	2.51	0.0001	0.00
Total				167

2.6 Image Sensor Interface (ISI)

This scenario is designed to evaluate the power consumption of the image sensor interface, which is used for image sensor preview. By default, the SAMA5D36-CMP demo supports several sensor modules including OV5640/OV2640/OV2643.

To build this scenario, stop auto-boot in U-Boot and set loader options for this case:

```
Hit any key to stop autoboot:  0
U-Boot>setenv bootcmd 'nand read 0x22000000 0x00200000 0x00400000; bootm 0x22000000#conf@sama5d36ek_isi'
```

Note: The DTB file in loader options differs for different revisions of the MB and the DM.

For PDA 4.3":

```
U-Boot>setenv bootcmd 'nand read 0x22000000 0x00200000 0x00400000; bootm 0x22000000#conf@sama5d36ek_pda4_isi'
```

For PDA 7":

```
U-Boot>setenv bootcmd 'nand read 0x22000000 0x00200000 0x00400000; bootm 0x22000000#conf@sama5d36ek_pda7_isi'
```

For RevC MB:

```
U-Boot>setenv bootcmd 'nand read 0x22000000 0x00200000 0x00400000; bootm 0x22000000#conf@sama5d36ek_revc_isi'
U-Boot>setenv bootcmd 'nand read 0x22000000 0x00200000 0x00400000; bootm 0x22000000#conf@sama5d36ek_revc_pda4_isi'
U-Boot>setenv bootcmd 'nand read 0x22000000 0x00200000 0x00400000; bootm 0x22000000#conf@sama5d36ek_revc_pda7_isi'
```

```
U-Boot>boot
```

After the operating system starts up, log in:

```
Welcome to Buildroot
buildroot login: root
#
```

Stop the default video playing:

```
# ps
PID   USER     COMMAND
    1 root     init
    …
  619 root     {go.sh} /bin/sh /root/go.sh
  620 root     -sh
  624 root     gst-launch-0.10 filesrc location=/root/MPEG2_480_272.avi ! avide
  629 root     ps
# kill -9 619      (The PID may differ  each time)
# kill -9 624      (The PID may differ each time)
```

Start the image sensor preview:

```
# ls /sys/class/video4linux
video0
# cat /sys/class/video4linux/video0/name
isi-camera
# gst-launch v4l2src device="/dev/video0" ! video/x-raw-yuv, width=640,height=480 ! ffmpegcolorspace ! fbdevsink
```

The power consumption data for each power rail of the SAMA5D36 is listed below for reference.

Use Case: Image Sensor preview (Image Sensor: OV5640, VGA 640*480, YUV422)				
Operation Setting: MCK: 132MHz, PCK: 528MHz, LPDDR2: 132MHz				
Used Peripheral: NAND, DBGU, MPDDRC, ISI, LCDC, GPIO				
Power Rail	Voltage Range (V)	Voltage (V)	Current (mA)	Power Consumption (mW)
VDDCORE(JP2)	1.1 ~ 1.32	1.25	79.67	99.59
VDDIODDR(JP15)	1.7 ~ 1.9 1.14 ~ 1.30	1.25	8.16	10.20
VDDIOM(JP6)	1.65 ~ 1.9 3.0 ~ 3.6	3.3	0.13	0.43
VDDIOP0(JP9)	1.65 ~ 3.6	3.3	14.74	48.64
VDDIOP1(JP8)	1.65 ~ 3.6	3.3	0.0045	0.01
VDDBU(JP7)	1.65 ~ 3.6	3.25	0.0075	0.02
VDDUTMIC(JP3)	1.1 ~ 1.32	1.25	0.011	0.01
VDDUTMII(JP11)	3.0 ~ 3.6	3.3	0.0001	0.00
VDDPLLA(JP4)	1.1 ~ 1.32	1.25	8.05	10.06
VDDOSC(JP12)	1.65 ~ 3.6	3.3	0.42	1.39
VDDANA(JP13)	3.0 ~ 3.6	3.32	4.06	13.48
VDDFUSE(JP10)	2.25 ~ 2.75	2.51	0.0001	0.00
Total				184

2.7 Gigabit EMAC (GMAC)

iPerf is a tool to measure the maximum bandwidth for TCP and UDP. By default, it is included in the SAMA5D36-CMP demo. To proceed, set up the Gigabit Ethernet network and start the measurement.

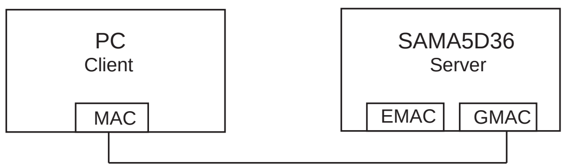
To build this scenario, stop auto-boot in U-Boot and set loader options for this case:

```
Hit any key to stop autoboot:  0
U-Boot>setenv bootcmd 'nand read 0x22000000 0x00200000 0x00400000; bootm
0x22000000#conf@sama5d36ek_gmac'
U-Boot>boot
```

After OS starts up, log in:

```
Welcome to Buildroot
buildroot login: root
#
```

Use an Ethernet cable to connect the Gigabit Ethernet ports of both the evaluation kit and the PC, as illustrated below:



Set up the evaluation kit as the server with the following commands:

```
# ifconfig eth0 192.168.3.2
# iperf -u –s
```

Set up the PC as the client and then start data transfer to the PC with the following commands:

```
# ifconfig eth0 192.168.3.3
# iperf -u -c 192.168.3.2 -t 120 -i 1 -b 300M
```

The power consumption data for each power rail of the SAMA5D36 is listed below for reference.

Use Case: Running as iPerf server				
Operatino Setting: MCK: 132MHz, PCK: 528MHz, LPDDR2: 132MHz				
Used Peripheral: NAND, DBGU, MPDDRC, GMAC				
Power Rail	Voltage Range (V)	Voltage (V)	Current (mA)	Power Consumption (mW)
VDDCORE(JP2)	1.1 ~ 1.32	1.25	95.24	119.05
VDDIODDR(JP15)	1.7 ~ 1.9 1.14 ~ 1.30	1.25	8.38	10.48
VDDIOM(JP6)	1.65 ~ 1.9 3.0 ~ 3.6	3.3	0.062	0.20
VDDIOP0(JP9)	1.65 ~ 3.6	3.3	0.0079	0.03
VDDIOP1(JP8)	1.65 ~ 3.6	3.3	10.37	34.22
VDDBU(JP7)	1.65 ~ 3.6	3.25	0.0019	0.01
VDDUTMIC(JP3)	1.1 ~ 1.32	1.25	0.011	0.01
VDDUTMII(JP11)	3.0 ~ 3.6	3.3	0.0001	0.00
VDDPLLA(JP4)	1.1 ~ 1.32	1.25	8.01	10.01
VDDOSC(JP12)	1.65 ~ 3.6	3.3	0.41	1.35
VDDANA(JP13)	3.0 ~ 3.6	3.32	0.0031	0.01
VDDFUSE(JP10)	2.25 ~ 2.75	2.51	0.0001	0.00
Total				175

2.8 USB Host

Bonnie++ is a benchmark tool to test hard drive and file system performance. The Bonnie++ source code can be downloaded for free from http://sourceforge.net/projects/bonnie/. In this case, Bonnie++ is compiled with the same tool-chain as kernel building. The Bonnie++ source code and binary can be extracted from APP\bonnie\ at FTP: ftp://ftp.linux4sam.org/pub/demo/sama5d36-cmp/.

To measure the typical power consumption of the USB peripheral, the test must be run from a USB disk. The test lasts about 30 minutes, depending on the speed of the USB disk. The maximum CPU usage may be as high as 90%.

To build up this scenario, stop auto-boot in U-Boot and set loader options for this case:

```
Hit any key to stop autoboot:  0
U-Boot>setenv bootcmd 'nand read 0x22000000 0x00200000 0x00400000; bootm
0x22000000#conf@sama5d36ek_usb'
U-Boot>boot
```

After the operating system starts up, log in:

```
Welcome to Buildroot
buildroot login: root
#
```

Plug a USB disk containing the benchmark test (Bonnie++) and launch the following commands:

```
# mount -t vfat /dev/sda1 /mnt
# cd /mnt

# ls
bonnie++
# ./bonnie\+\+ -d ./test -s 1000 -u 0
Using uid:0, gid:0.
Writing with putc()...done
Writing intelligently...done
Rewriting...done
Reading with getc()...done
Reading intelligently...done
start 'em...done...done...done...
Create files in sequential order...done.
Stat files in sequential order...done.
Delete files in sequential order...done.
Create files in random order...done.
Stat files in random order...done.
Delete files in random order...done.
Version 1.03e       ------Sequential Output------ --Sequential Input- --Random-
                    -Per Chr- --Block-- -Rewrite- -Per Chr- --Block-- --Seeks--
Machine        Size K/sec %CP K/sec %CP K/sec %CP K/sec %CP K/sec %CP  /sec %CP
buildroot     1000M  3338  75  6674   1  4191   5  4354  95 21745  21  1318  27
                    ------Sequential Create------ --------Random Create--------
                    -Create-- --Read--- -Delete-- -Create-- --Read--- -Delete--
              files  /sec %CP  /sec %CP  /sec %CP  /sec %CP  /sec %CP  /sec %CP
                 16    13  95 +++++ +++   196  99    20  96 +++++ +++    45  59
buildroot,1000M,3338,75,6674,1,4191,5,4354,95,21745,21,1318.1,27,16,13,95,++++
+,+++,196,99,20,96,+++++,+++,45,59

# cd ../
# umount /mnt
```

The power consumption data for each power rail of the SAMA5D36 is listed below for reference.

Use Case: Run Bonnie++(Version: 1.03e command: ./bonnie++ -u 0) on USB disk				
Operatino Setting: MCK: 132MHz, PCK: 528MHz, LPDDR2: 132MHz				
Used Peripheral: NAND, DBGU, MPDDRC, USB Host				
Power Rail	Voltage Range (V)	Voltage (V)	Current (mA)	Power Consumption (mW)
VDDCORE(JP2)	1.1 ~ 1.32	1.25	116.01	145.01
VDDIODDR(JP15)	1.7 ~ 1.9 1.14 ~ 1.30	1.25	5.53	6.91
VDDIOM(JP6)	1.65 ~ 1.9 3.0 ~ 3.6	3.3	0.047	0.16
VDDIOP0(JP9)	1.65 ~ 3.6	3.3	0.0085	0.03
VDDIOP1(JP8)	1.65 ~ 3.6	3.3	0.0048	0.02
VDDBU(JP7)	1.65 ~ 3.6	3.25	0.0019	0.01
VDDUTMIC(JP3)	1.1 ~ 1.32	1.25	7.94	9.93
VDDUTMII(JP11)	3.0 ~ 3.6	3.3	22.95	75.74
VDDPLLA(JP4)	1.1 ~ 1.32	1.25	8.04	10.05
VDDOSC(JP12)	1.65 ~ 3.6	3.3	9.93	32.77
VDDANA(JP13)	3.0 ~ 3.6	3.32	0.0033	0.01
VDDFUSE(JP10)	2.25 ~ 2.75	2.51	0.0001	0.00
Total				281

3. Power Optimization

3.1 Optimizing Power Consumption of the SAMA5D36

In this section, we provide techniques to optimize the power consumption of the SAMA5D36 using power rails, clock settings, peripheral settings, working mode selection and I/O setting.

3.1.1 SAMA5D36 Power Rails

Table 3-1 lists the parts of the SAMA5D36 powered by different power rails. Understanding the power behavior of these power rails helps to optimize their use. Also, the power consumption parameters provided in the SAMA5D3 series datasheet help to estimate the power consumption of the SAMA5D36 in a real application.

Table 3-1. SAMA5D3 Power Supplies

Name	Voltage Range, Nominal	Associated Ground	Powers
VDDCORE	1.1–1.32V, 1.2V	GNDCORE	The core, including the processor, the embedded memories and the peripherals
VDDIODDR	1.7–1.9V, 1.8V 1.14–1.30, 1.2V	GNDIODDR	LPDDR/DDR2 Interface I/O lines LPDDR2 Interface I/O lines
VDDIOM	1.65–1.95V, 1.8V 3.0–3.6V, 3.3V	GNDIOM	NAND and HSMC Interface I/O lines
VDDIOP0	1.65–3.6V	GNDIOP	Peripheral I/O lines
VDDIOP1	1.65–3.6V	GNDIOP	Peripheral I/O lines
VDDBU	1.65–3.6V	GNDBU	The Slow Clock Oscillator, the internal 32 kHz RC Oscillator and a part of the System Controller
VDDUTMIC	1.1–1.32V, 1.2V	GNDUTMI	The USB device and host UTMI+ core The UTMI PLL
VDDUTMII	3.0–3.6V, 3.3V	GNDUTMI	The USB device and host UTMI+ interface
VDDPLLA	1.1–1.32V, 1.2V	GNDPLL	The PLLA cell
VDDOSC	1.65–3.6V	GNDOSC	Main Oscillator Cell and PLL UTMI. If PLL UTMI or USB is used, the range is to be 3.0V to 3.6V.
VDDANA	3.0–3.6V, 3.3V	GNDANA	Analog-to-Digital Converter
VDDFUSE	2.25–2.75V, 2.5V	GNDFUSE	Fuse box for programming. It can be tied to ground with a 100 Ω resistor for fuse reading only.

3.1.1.1 VDDCORE

VDDCORE powers the processor, embedded memories and all peripherals.

The SAMA5D3 features three low-power modes: Idle, Ultra-low-power and Backup. Depending on the mode implemented on the SAMA5D3, the power consumption on VDDCORE can be lowered to different levels (refer to the SAMA5D3 datasheet for detailed numbers).

When the processor goes into Ultra-low-power mode, power consumption and MCK frequency decrease. The lower the CPU MCK frequency, the less power it consumes, and the longer the wake-up time becomes.

Suggestion: Select the appropriate MCK frequency for Ultra-low-power mode depending on the requirements of application performance and wake-up speed.

Note: Put the core into Idle mode to save power when no tasks are in process.

3.1.1.2 VDDIODDR

The current into VDDIODDR depends on the external memory devices and speed. Its range can vary from almost 0 to a much higher value.

For the LPDDR2 on the CMP board, the voltage of the memory IOs is 1.25V and MCK is set to 132 MHz.

- After memory initialization, the current is about 4.5 mA with no data access. This current will increase with more data access (read and write), achieving up to 10.9 mA.
- For memory Self-refresh mode, the current is as low as 2~3 uA.

In comparison, for the DDR2 on the CM board, with voltage of memory IOs at 1.8V and the MCK set to 132 MHz,, the current into VDDIODDR ranges from 15 mA to 20 mA.

3.1.1.3 VDDIOM, VDDIOP0 and VDDIOP1

These three power rails power most I/Os of SAMA5D3 (refer to section 4 “Package and Pinout” in datasheet). Any peripheral activity may affect the current value on the corresponding power rail.

3.1.1.4 VDDBU

VDDBU powers the Slow Clock oscillator, the internal 32 kHz RC oscillator and a part of the System Controller.

Suggestion: To reduce power consumption on VDDBU, make sure that the unused oscillator is disabled when switching between the external and internal oscillators..

Note: The internal 32 kHz RC oscillator is used in ROM code for fast boot-up, though its frequency precision is lower than that of the external crystal oscillator.

3.1.1.5 VDDOSC, VDDUTMIC and VDDUTMII

VDDOSC powers the main oscillator cell and part of the PLL UTMI.

VDDUTMIC powers the USB device and host UTMI+ core.

Once the USB transceiver is enabled, approximately 5.5 mA will be consumed on this power rail. There will be an increase of approximately 2.5 mA for device or host transfer.

VDDUTMII powers the USB device and host UTMI+ interface.

There is a total of three USB ports. Each port causes an increase of about 18 mA of current in VDDUTMII after the USB connection is set up.

Suggestion: To reduce power consumption on these three power rails, disable the USB transceiver as well as the UTMI PLL if the USB is not necessary in the application.

3.1.1.6 VDDPLLA

The PLL output frequency ranges from 400 MHz to 1000 MHz. The higher the output frequen cy, the higer the power consumption. Thus it is important to define an appropriate clock tree for the system and then set up the oscillator and PLLs accordingly.

For example, if PCK = 400 MHz, more power is saved by setting PCK = PLL = 400 MHz instead of PLL = 800 MHz and PCK=PLL/2.

3.1.1.7 VDDANA

VDDANA supplies the Analog-to-Digital Converter and its IOs only. When the ADC is not in use or in Sleep mode, the current through this power rail is only several µA.

3.1.1.8 VDDFUSE

During FUSE programming, the maximum current through VDDFUSE may reach 40 mA. Under other conditions, such as FUSE reading or no action, power consumption is close to 0.

3.1.2 System Clock

Master clock (MCK) is the clock provided to memory controllers and all peripherals. When the processor and all peripherals are idle and no task is being processed, the base consumption on VDDCORE mainly depends on MCK frequency, whether the PCK is equal to 2 × MCK, 3 × MCK, or 4 × MCK. The PCK frequency only affects the CPU performance.

Table 3-2 shows the power consumption in Linux Idle mode with different MCK. We can see that the power consumption on VDDCORE in Idle mode is proportional to MCK frequency (~ 0.32 mA/MHz).

Table 3-2. VDDCORE Consumption Vs. MCK

		OS Idle MCK=132 MHz PCK=528 MHz, VDDCORE=1.25V		OS Idle MCK=132 MHz PCK=396 MHz		OS Idle MCK=88 MHz PCK=264 MHz		OS Idle MCK=50 MHz PCK=200 MHz	
Power Rail	**Voltage (V)**	**Current (mA)**	**Power Consumption (mW)**	**Current (mA)**	**Power Consumption (mW)**	**Current (mA)**	**Power Consumption (mW)**	**Current (mA)**	**Power Consumption (mW)**
VDDCORE(JP2)	1.2	42.18	52.73 41.89		50.27 28.09		33.71	18.38	22.06
VDDIODDR(JP15)	1.2	4.33	5.41 4.23		5.08 2.84		3.41 1.63		1.96
VDDIOM(JP6)	3.3	0.079	0.26	0.08	0.26 0.079		0.26 0.079		0.26
VDDIOP0(JP9)	3.3	0.083	0.27 0.083		0.27 0.083		0.27 0.082		0.27
VDDIOP1(JP8)	3.3	0.17	0.56 0.17		0.56 0.17		0.56 0.17		0.56
VDDBU(JP7)	3.25	0.0013	0.00 0.0013		0.00 0.0013		0.00 0.001	3	0.00
VDDUTMIC(JP3)	1.2	0.0099	0.01 0.0093		0.01 0.0086		0.01 0.008	3	0.01
VDDUTMII(JP11)	3.3	0.0002	0.00 0.0002		0.00 0.0002		0.00 0.000	2	0.00
VDDPLLA(JP4)	1.2	7.81	9.76 9.99		11.99	7.82	9.38	10.01	12.01
VDDOSC(JP12)	3.3	0.42	1.39 0.42		1.39 0.42		1.39 0.42		1.39
VDDANA(JP13)	3.32	0.0032	0.01 0.0032		0.01 0.0032		0.01 0.003	2	0.01
VDDFUSE(JP10)	2.51	0.0002	0.00 0.0002		0.00 0.0002		0.00 0.000	2	0.00
Total			70		70		49		39
VDDCORE Consumption Per MCK		0.32	0.40	0.32	0.38	0.32	0.38	0.37	0.44

Suggestion: Select the appropriate PCK depending on application requirements.

Then set MCK to 1/4 × PCK.

3.1.3 Peripherals

The peripherals can be divided into three categories depending on their behavior regarding power consumption (VDDCORE). Refer to the table "Power Consumption by Peripheral in Active Mode (TA 25°C, TA 85°C and TA 105°C)" in the Electrical Characteristics section in the SAMA5D3 datasheet.

3.1.3.1 Category I

Each peripheral in this category consumes a constant amount of power as long as it is enabled, with the power consumption value directly proportional to its working frequency.

For example, when the USART is enabled, its power consumption is:

$$3.0\ \mu A/MHz^{(1)} \times \text{working frequency}^{(2)}$$

Note (1): 3.0 uA/MHz is the USART consumption per MHz.

Note (2): The working frequency is not always equal to MCK.

The Soft Modem (SMD) is a special case, with its power consumption dependent on its clock source instead of its working frequency. Linear with the MCK, thus its power consumption is:

$$5.5\ \mu A/MHz^{(3)} \times MCK$$

Note (3): 5.5 uA/MHz is the SMD consumption per MHz.

3.1.3.2 Category II

The power consumption of the peripherals in this category is related to their transfer speed.

For example, for the high-speed USB Host, when CPU usage is 24%, the UHPHS power consumption is:

$$(9.6 \times \text{transfer speed (Mb/s)} + 12)\ \mu A/MHz \times MCK$$

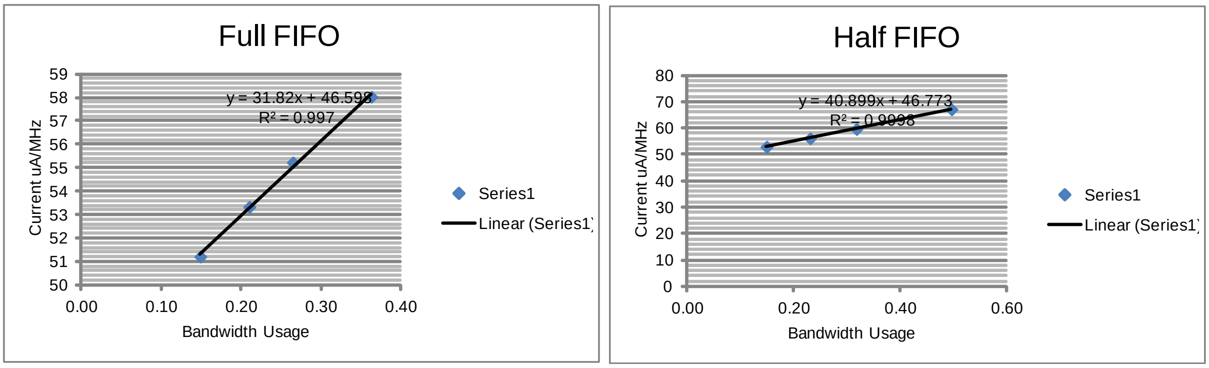
Note: For UHPHS/UDPHS, LCDC, EMAC/GMAC, the power consumption already includes the MPDDRC consumption on VDDCORE.

3.1.3.3 Category III

The power consumption of each peripheral in this category is related to its bandwidth usage.

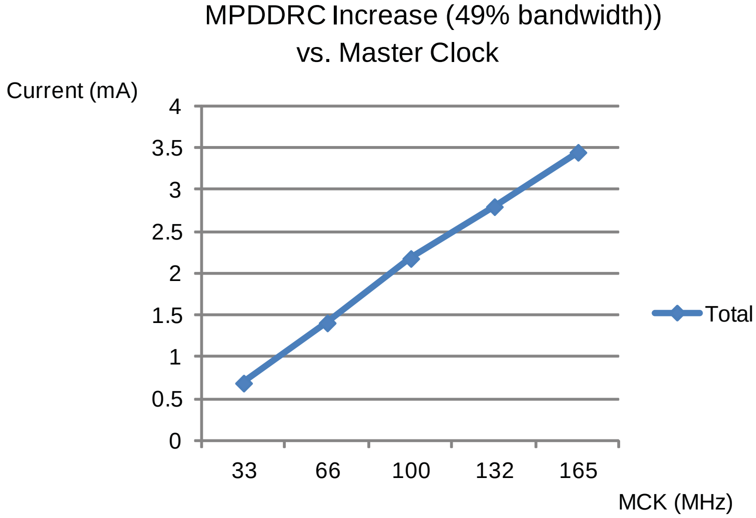
An example is the MPDDRC. Figure 3-1 shows the correlation between MPDDRC power consumption and its bandwidth.

Figure 3-1. Correlation between Consumption and Bandwidth



The increase in power consumption is linear with MCK (with the same bandwidth usage condition). Figure 3-2 shows the relation between power consumption increase and MCK (with the same bandwidth).

Figure 3-2. Linearity between Consumption Increase and MCK



3.1.4 VDDCORE Power Consumption Model

With the power consumption information extracted from the datasheet, we can estimate the overall consumption on each power rail.

Note: Compared to VDDCORE, other power rails do not contribute much to overall power consumption. For this reason, the focus in this section is on the power consumption model of VDDCORE.

The overall consumption on VDDCORE can be calculated by the formula:

$$I_{VDDCORE\_overall} = I_{VDDCORE\_idle} + (I_{VDDCORE\_dhrystone} - I_{VDDCORE\_idle}) \times CPU\_usage\ (\%) + I_{VDDCORE\_peripheral\_1} + \ldots + I_{VDDCORE\_peripheral\_n}$$

With the GMAC use case as an example:

- MCK is 132 MHz, PCK is 528 MHz.
- USART and GMAC are both enabled.
- CPU usage is 24%.
- GMAC transfer speed is 300 Mb/s.

Therefore the theoretical overall consumption on VDDCORE is:

$$I_{VDDCORE\_overall} = 24\text{ mA} + (117\text{ mA} - 24\text{ mA}) \times 24\% + (1.2\text{ uA} \times 300\text{ Mb/s} + 36\text{ uA}) \times 132\text{ MHz} / 1000 + 3.0\text{ uA} \times 132\text{ MHz} / 1000 = 99.02\text{ mA}$$

Note: $I_{VDDCORE\_idle}$: VDDCORE power consumption in Idle mode (24 mA, refer to the SAMA5D3 datasheet)

Note: $I_{VDDCORE\_dhrystone}$: VDDCORE Power Consumption in Active Mode running Dhrystone (117 mA, refer to the SAMA5D3 datasheet).

The calculated theoretical result is aligned with the measured value: 95.24 mA.

Note: The calculated theoretical value is only for reference. The final data should be based on the real measurement result.

Suggestions:

1. Disable any peripherals not implemented in the user application to avoid unnecessary power consumption.

Note: Disabling the USB is not sufficient to ensure that it consumes no power. In addition, the USB transceivers must also be disabled.

2. Use the minimum peripheral clock rate (MCK/8, /4, /2).

3.1.5 Power Supply

Set the power supply voltage to a minimum value depending on the corresponding working conditions:

- 1.15V ± 5% for VDDCORE in Linux Suspend-to-mem mode
- 1.2V ± 5% (PLL < 800 MHz) or 1.25 V ± 5% (PLL >= 800 MHz) in Active mode

The power management IC (Active-Semi PMIC)makes it possible to adjust the core voltage dynamically. Normally, core and PLL supply must be set to 1.25V to reach their maximum speed. If PCK ≤ 400 MHz, 1.15V is enough to save power.

3.1.6 Multi-port DDR-SDRAM Controller (MPDDRC)

For the Multi-port DDR-SDRAM Controller (MPDDRC), external impedance match resistors are not necessary because the MPDDRC already has internal impedance matched. Therefore, adding external resistors may lead to higher consumption.

Suggestions:

1. Do not add external impedance match resistors for MPDDRC.

2. Set the memory refresh cycle properly. Generating too many refresh commands will lower the memory bandwidth and SAMA5D3 performance.

3.1.7 GPIO

In Low-power modes, the I/O state of SAMA5D3 can influence the power consumption of the external devices.

For example, for some bidirectional I/Os with external pull-up/pull-down resistors, their states are uncertain when the CPU enters Low-power modes. This may lead to extra power consumption.

Suggestion: Correctly configure the PIO to pull-up/pull-down, input/output, output (0/1) state.

Using the Soft Modem as an example, set its two pads (DIBP to Pull-up state, DIBN to Pull-down state) to minimize power consumption.

3.2 Optimizing Power Consumption of External Devices

To minimize overall system-level power consumption, the power consumption of external devices must be taken into consideration.

3.2.1 General Guidelines

Check the specification of each external device for the correlation between power consumption and the different working modes, then configure the device to work in the appropriate power mode.

If the low-power requirement is still not met, shut down the external device by directly switching off its power supply when it is not used.

3.2.2 Examples on SAMA5D36-CMP Demo Board

3.2.2.1 LPDDR2

The SAMA5D3 supports DDR2 and LPDDR2, both of which can be set in Self-refresh mode when the Linux OS enters Standby/Suspend mode. It is recommended to use LPDDR2 instead of DDR2 in low-power applications because the power consumption level of LPDDR2 is only about 1/3 of that of DDR2 (refer to Table 3-3 for details), with both running at the same frequency. In addition, LPDDR2 can work at a much lower frequency thus saving more power, while there is a minimum frequency limitation for DDR2.

Table 3-3 provides the power consumption comparison between LPDDR2 (on CMP) and DDR2 (on CM).

Table 3-3. Power Consumption Comparison between LPDDR2 and DDR2

	Current (µA) from Datasheet	
	400 MHz	**Self-refresh Mode**
LPDDR2 MT42L128M32D1GU-25 WTA	122000	5683
DDR2 * 2 MT47H128M16RT-25E:C	324000	28800

Note: The LPDDR2 module on the CMP board is MT42L128M32D1GU-25 WTA (512 MB, 32-bit); the DDR2 module on the CM board is MT47H128M16RT-25 (256 MB, 16-bit).

3.2.2.2 Gigabit Ethernet PHY

The GMAC PHY chip (KSZ9031RNX) on the SAMA5D3 demo board has two power-down modes: software power-down and chip power-down. The consumption in chip power-down mode is lower than that in software power-down mode. However, it is important to note that once the GMAC PHY enters into chip power-down mode, the only way to exit is by hardware reset.

3.2.2.3 Device Shutdown

If the LCD is not used, ensure that the LCD backlight is turned off, as it has the highest power consumption of the system. Put the LCD control IC into Standby mode. Ensure that the LCDC is disabled in the SAMA5D36.

By implementating the suggestions for consumption optimization, the power consumption of the corresponding external devices can be reduced. Table 3-4 shows the change in power consumption figures after implementing the power-saving techniques on the SAMA5D36-CMP board.

Table 3-4. Power Consumption of External Devices

	Consumption in Active Mode 5V (mA)	Consumption in Low-Power Mode 5V (mA)	Consumption Optimization Solution	Expected Consumption 5V (mA)
LCD	260	50	Disconnect DM board	0
G-PHY	90	13	Set to power-down mode	13
E-PHY	32	2	Set to power-down mode	2
COM	20	0.6	Disconnect cable	0.6
HDMI	4.7	4.7	Set to power-down mode	0
JTAG	36	36	Disconnect its power supply	0
Audio	0.1	0.1	Keep in power-down mode (after reset)	0.1
Other ICs	15	15		15
Total	457.8	121.4		30.7

4. Conclusion

The SAMA5D3 series targets low-power applications. Its power consumption is significantly lower compared to some competitors' similar products in both low-power and in active modes, without reduced performance levels. The SAMA5D3 is suitable for low-power applications, such as portable devices that require long battery life and a rich set of connectivity interfaces.

The data provided in this application note may vary from board to board and from device to device, and depends on the measurement conditions and type of equipment used. The data is for reference only.

5. FAQ

1. When the demo board is powered on, why doesn't the default demo show up?

   Please check the following points:

   - Double check all the jumpers to make sure they are set correctly. If not, set them according to Figure 1-2.
   - The demo might not be successfully flashed, or the NAND Flash might be erased. If so, re-flash the default demo as described in Section 1.2.
   - If an amp meter is inserted for current measurement, the supply voltage might drop due to the impedance of the amp meter. Check the range selection of the meter.

2. Why does switching the test range of the amp meter cause the reset of the demo board?

   - On some low-end amp meters, the current loop is cut off during range switching.

3. Why are the consumption numbers I get in some cases not exactly the same as those provided in this application note?

   - The numbers provided in this application note are typical/average values. The actual values might vary slightly due to certain factors such as different ICs, PCB and temperature.
   - The default demo is with a full DTB, in which most peripherals and drivers have been enabled. If you use the default demo for other different cases (where specific DTBs instead of the full DTB should be used), the power consumption will increase.

4. How can I wake up the system from Standby/Suspend mode when no DM board is connected?

   - A push-button **PB3** on the MB can be used to wake up the kit from Standby/Suspend mode. But as the pin for push-button **PB3** is multiplexed as one LCD data line, for the default/LCD/ISI case, the push-button **PB3** does not work and you must reset the kit.

5. In the USB host scenario, why is the current through VDDUTMII and VDDOSC abnormal in Low-power mode?

   - In the current release, the USB transceiver and an internal bandgap for UTMI PHY cannot be stopped once they have been started or initialized.

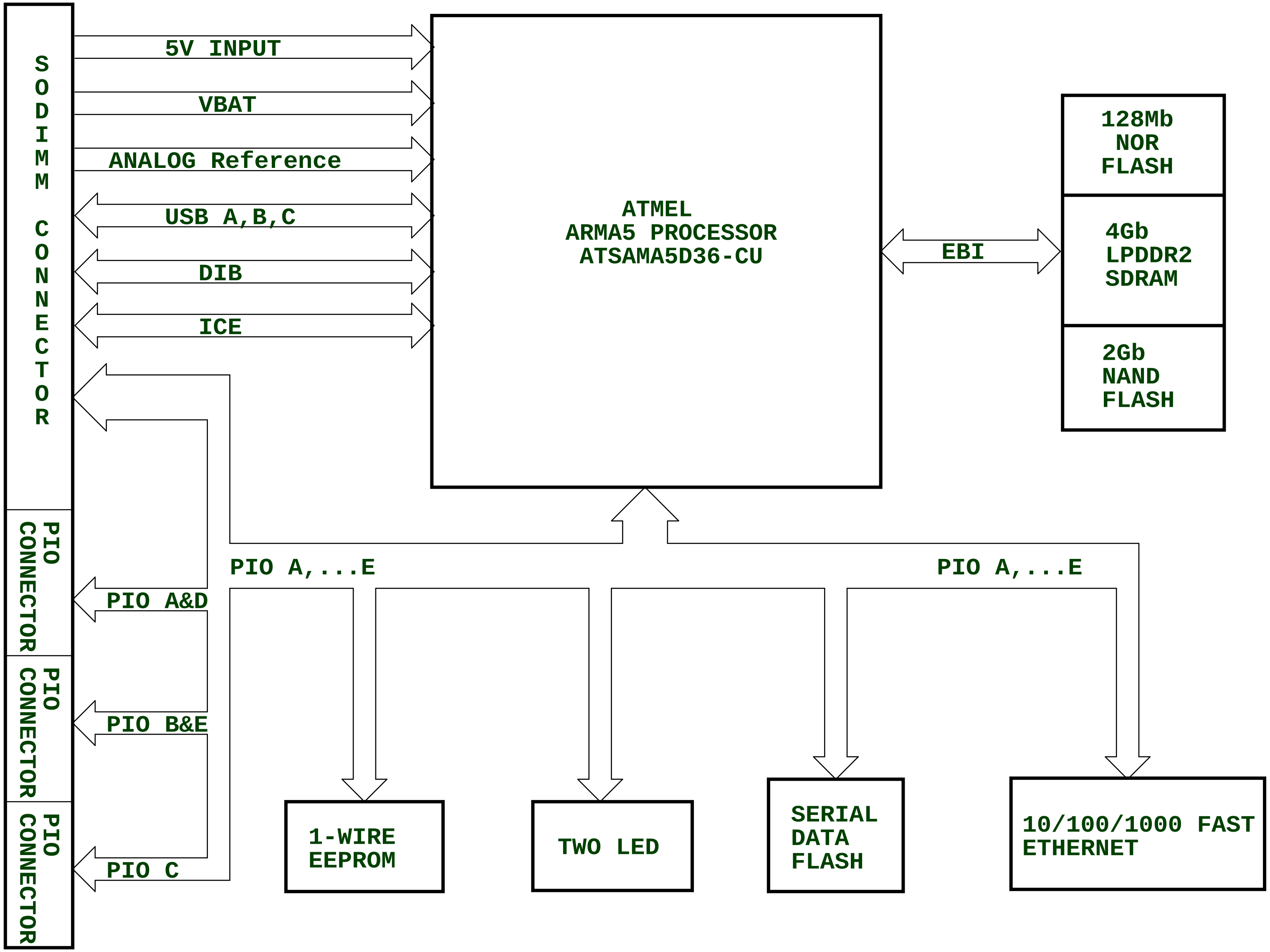
6. Why is the wake-up time printed on the hyperterminal in this demo longer than that in datasheet?

   - The wake-up time in the datasheet is the time from when the wake-up event occurs to when the core executes the first instruction.
   - The wake-up time printed on the hyperterminal in this demo is from the wake-up event occurrence to system recovery. The extra time is used to resume device drivers.

Appendix A. SAMA5D36-CMP Schematics

This section contains the following schematics:

- Block diagram
- PIO Muxing & Jumper
- SAMA5D3x power
- SAMA5D3x NOR and NAND Flash
- SAMA5D3x Data Flash, 1-wire, LED
- 4Gb LPDDR2
- Ethernet
- 200-pin SODIMM



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B		JH	27-Sep-13	X.X	XX-XXX-XX
A		JH	18-Jun-13	X.X	XX-XXX-XX

SAMA5D36-CMP

BLOCK DIAGRAM

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JUMPER and SOLDERDROP

PAGE	REFERENCE	DEFAULT	FUNCTION
4	JP2	CLOSE	VDDCORE
4	JP3	CLOSE	VDDUTMIC
4	JP4	CLOSE	VDDPLLA
4	JP6	CLOSE	VDDIOM_MPU
4	JP7	CLOSE	VDDBU
4	JP8	CLOSE	VDDIOP1_MPU
4	JP9	CLOSE	VDDIOP0_MPU
4	JP10	CLOSE	FUSE_2V5
4	JP11	CLOSE	VDDUTMII
4	JP12	CLOSE	VDDOSC
4	JP13	CLOSE	VDDANA
4	JP14	OPEN	CM-3V3 to MB-3V3
4	JP15	CLOSE	VDDIODDR_MPU_1V2
4	JP17	CLOSE	VCC_5V
4	JP18	CLOSE	VCC_1V8
4	JP19	CLOSE	VCC_3V3
4	JP20	CLOSE	VDDIOP1_GPHY
4	JP21	CLOSE	VDDIODDR_1V2
4	JP22	CLOSE	VCC_1V2
7	JP1	CLOSE	SPI0_NPCS0 for Dataflash
9	JP16	2-1	GPHY 1V2 from VCC_1V2
		2-3	GPHY 1V2 from PMOS

SAMA5D36 config

	SAMA5D31	SAMA5D33	SAMA5D34	SAMA5D35	SAMA5D36
CAN0			✓	✓	✓
CAN1			✓	✓	✓
GMAC		✓	✓	✓	✓
EMAC	✓			✓	✓
HSMCI2	✓		✓	✓	✓
LCDC	✓	✓	✓		✓
USART0	✓			✓	✓
USART1	✓			✓	✓
ISI	✓	✓	✓	✓	✓
TC1				✓	✓

DEFAULT NO POPULATE PARTS

PAGE	REFERENCE	FUNCTION
4	R130	Option for NRSTO from PMIC
4	C190	Option for SHDN pulse edge power on PMIC
4	Q4	Option for nPBIN from MB button
4	C195	Option for delay NRST_CMP
4	R133	Option for nPBSTAT to PD19
4	JP14	Option for VCC_3V3 to MB
5	R54	Option for pull up JTAGSEL
6	R1	Option for pull down WP of NAND flash
8	R82, R83	Option for terminal DDR_CLK
10	R81	Option for PB13 to Sodimm

SCHEMATICS CONVENTIONS

(1) Resistance Unit: "K" is "Kohm", "R" is "Ohm
(2) "DNP" means the component is not populated by default

TEST POINT

PAGE	REFERENCE	FUNCTION
4	TP4	NRST_CMP
4	TP10	WKUP
4	TP18	SHDN
4	TP23	Output 6 (LDO) of PMIC
4	TP24	Output 7 (LDO) of PMIC
5	TP25	PE0 (EBI_A0)
8	TP6	DDR_VREF

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SAMA5D36-CMP

PIO Muxing & Jumper

REV	MODIF.	DES.	DATE	VER.	DATE
C		JH	21-Jan-14	X.X	XX-XXX-XX
B		JH	27-Sep-13	X.X	XX-XXX-XX
A		JH	18-Jun-13	X.X	XX-XXX-XX

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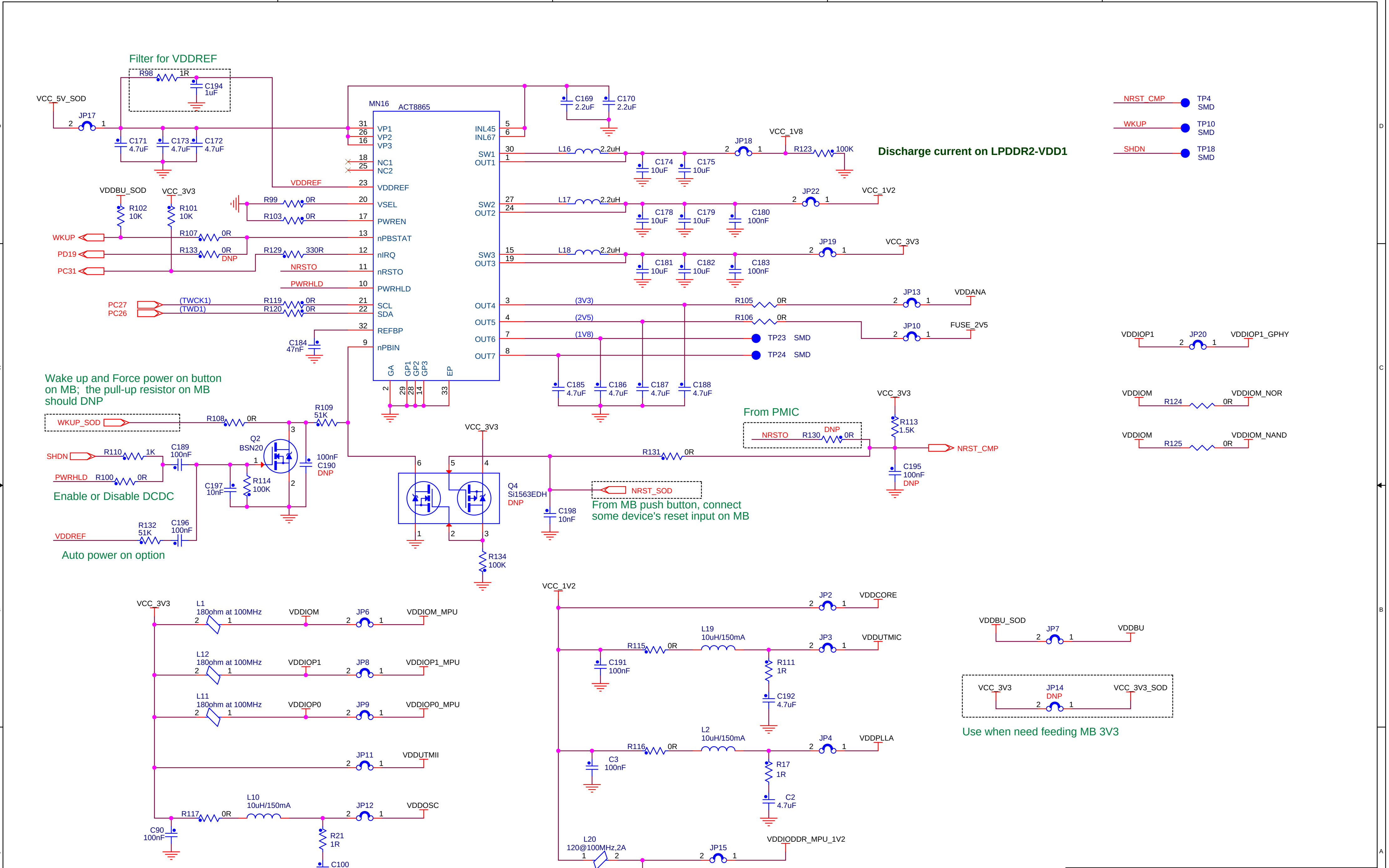

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A		JH	18-Jun-13	X.X	XX-XXX-XX

SAMA5D36-CMP

POWER

SCALE 1/1

REV. C

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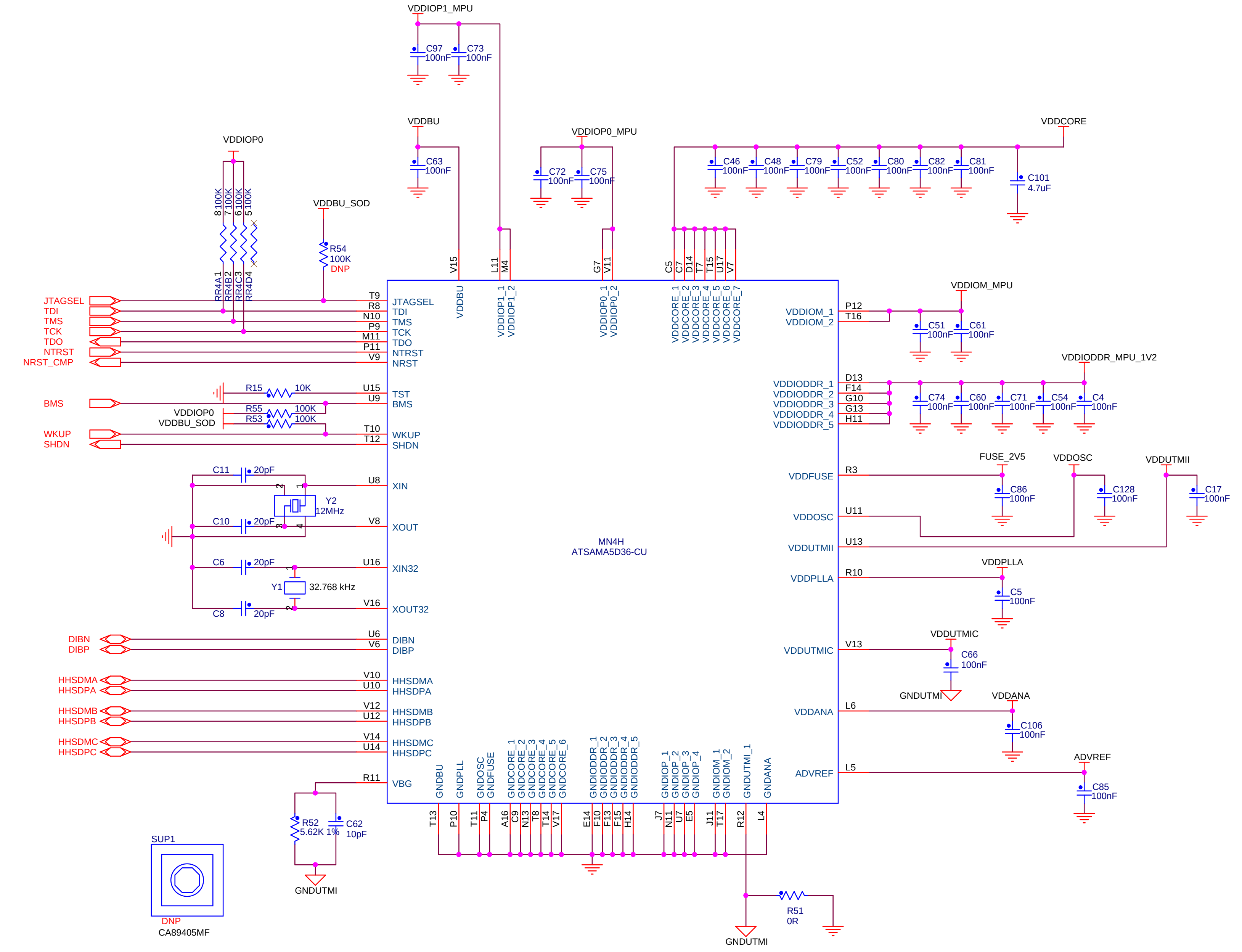

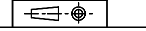

SAMA5D36-CMP

SAMA5D36-I&POWER

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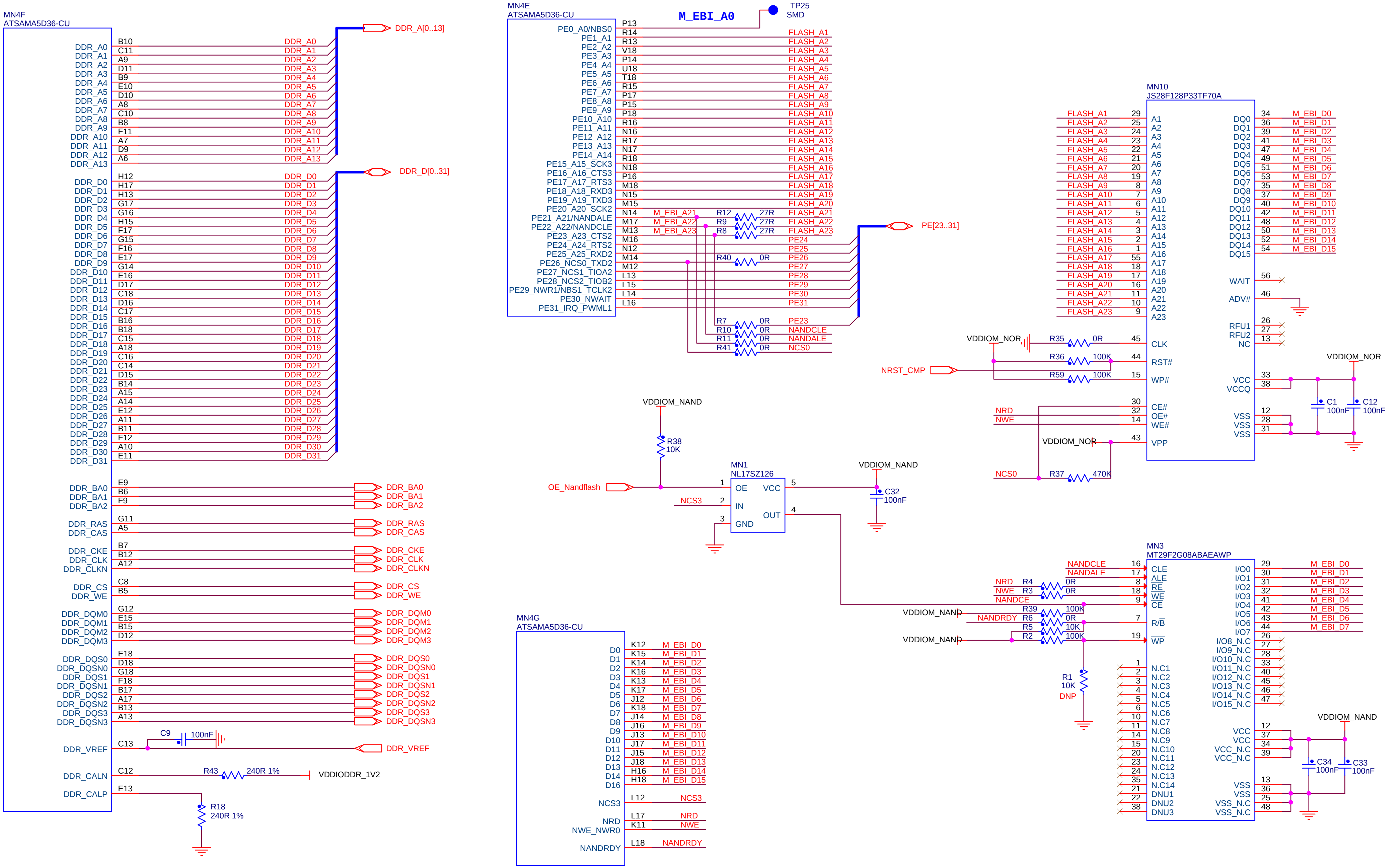

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A		JH	18-Jun-13	X.X	XX-XXX-XX
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SAMA5D36-II&NOR&NAND

SCALE 1/1

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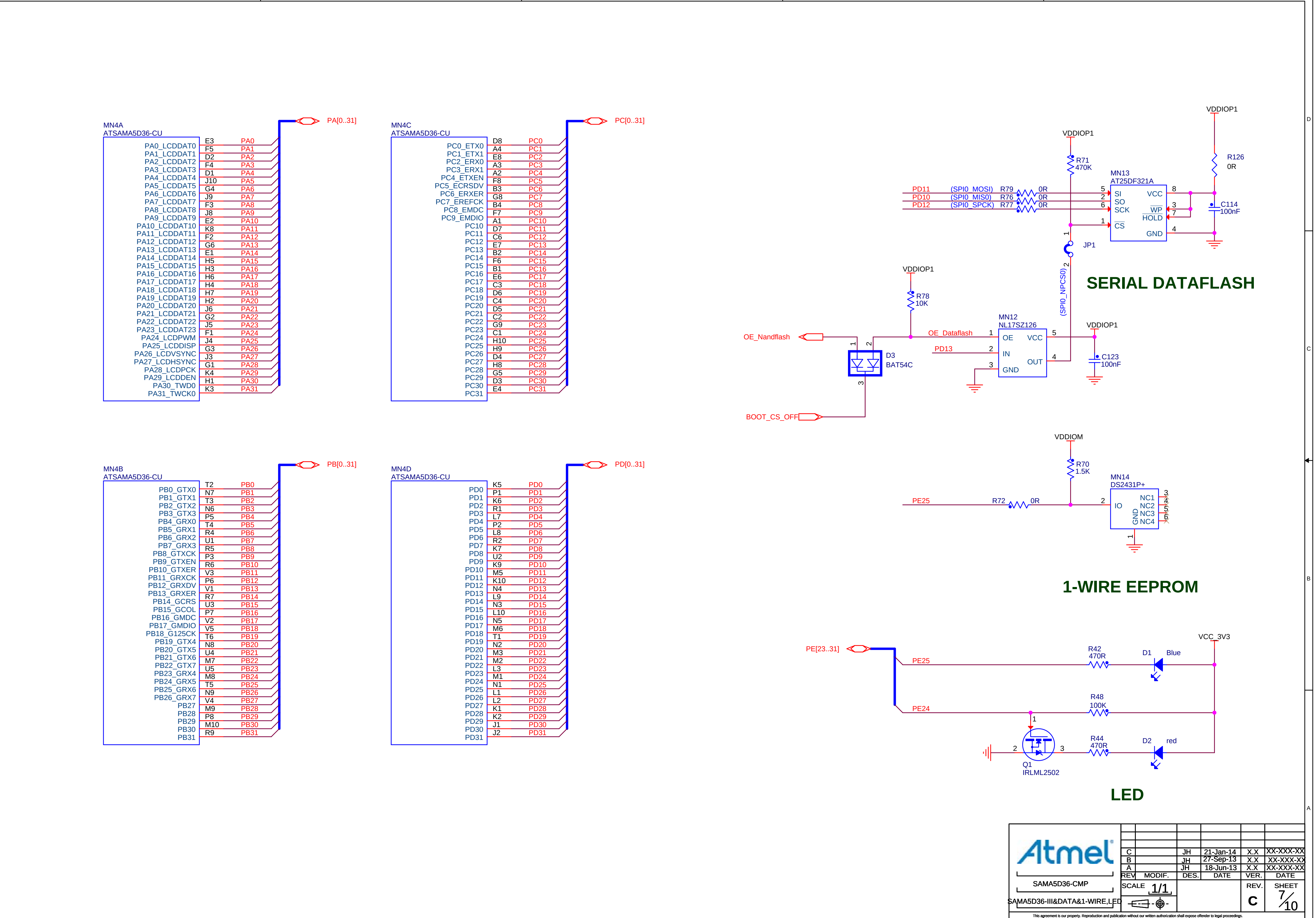

MN4A ATSAMA5D36-CU
PA[0..31]
MN4C ATSAMA5D36-CU
PC[0..31]
MN4B ATSAMA5D36-CU
PB[0..31]
MN4D ATSAMA5D36-CU
PD[0..31]
SERIAL DATAFLASH
MN13 AT25DF321A
VDDIOP1
R71 470K
R126 0R
C114 100nF
PD11 (SPI0_MOSI) R79 0R
PD10 (SPI0_MISO) R76 0R
PD12 (SPI0_SPCK) R77 0R
JP1
(SPI0_NPCS0)
MN12 NL17SZ126
OE_Nandflash
OE_Dataflash
PD13
D3 BAT54C
R78 10K
C123 100nF
BOOT_CS_OFF
1-WIRE EEPROM
VDDIOM
R70 1.5K
PE25
R72 0R
MN14 DS2431P+
LED
VCC_3V3
PE[23..31]
PE24
R42 470R
D1 Blue
R48 100K
R44 470R
D2 red
Q1 IRLML2502
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SAMA5D36-CMP
SAMA5D36-III&DATA&1-WIRE,LED
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B JH 27-Sep-13 X.X XX-XXX-XX
A JH 18-Jun-13 X.X XX-XXX-XX
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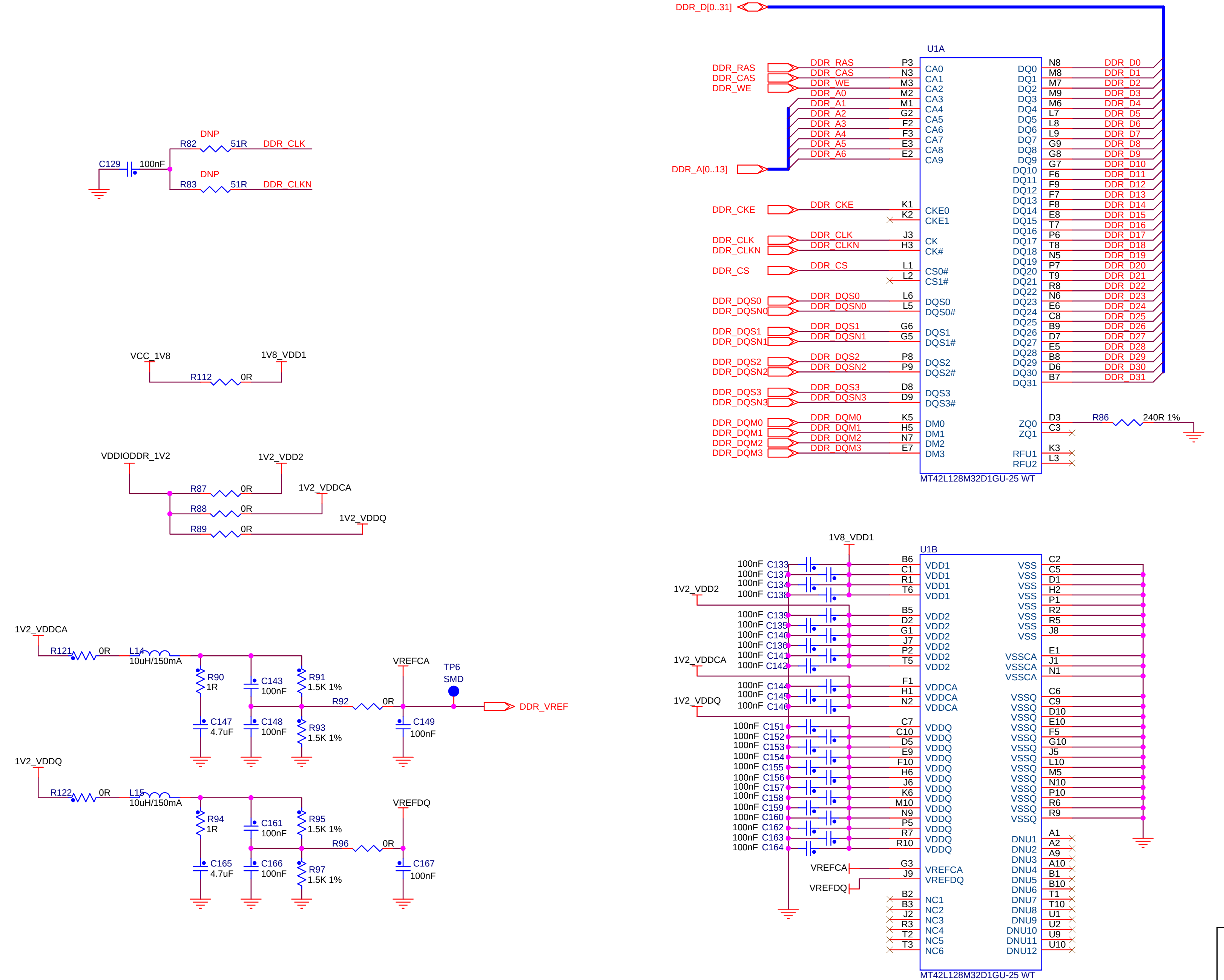
LPDDR2 SDRAM



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4Gb LPDDR2

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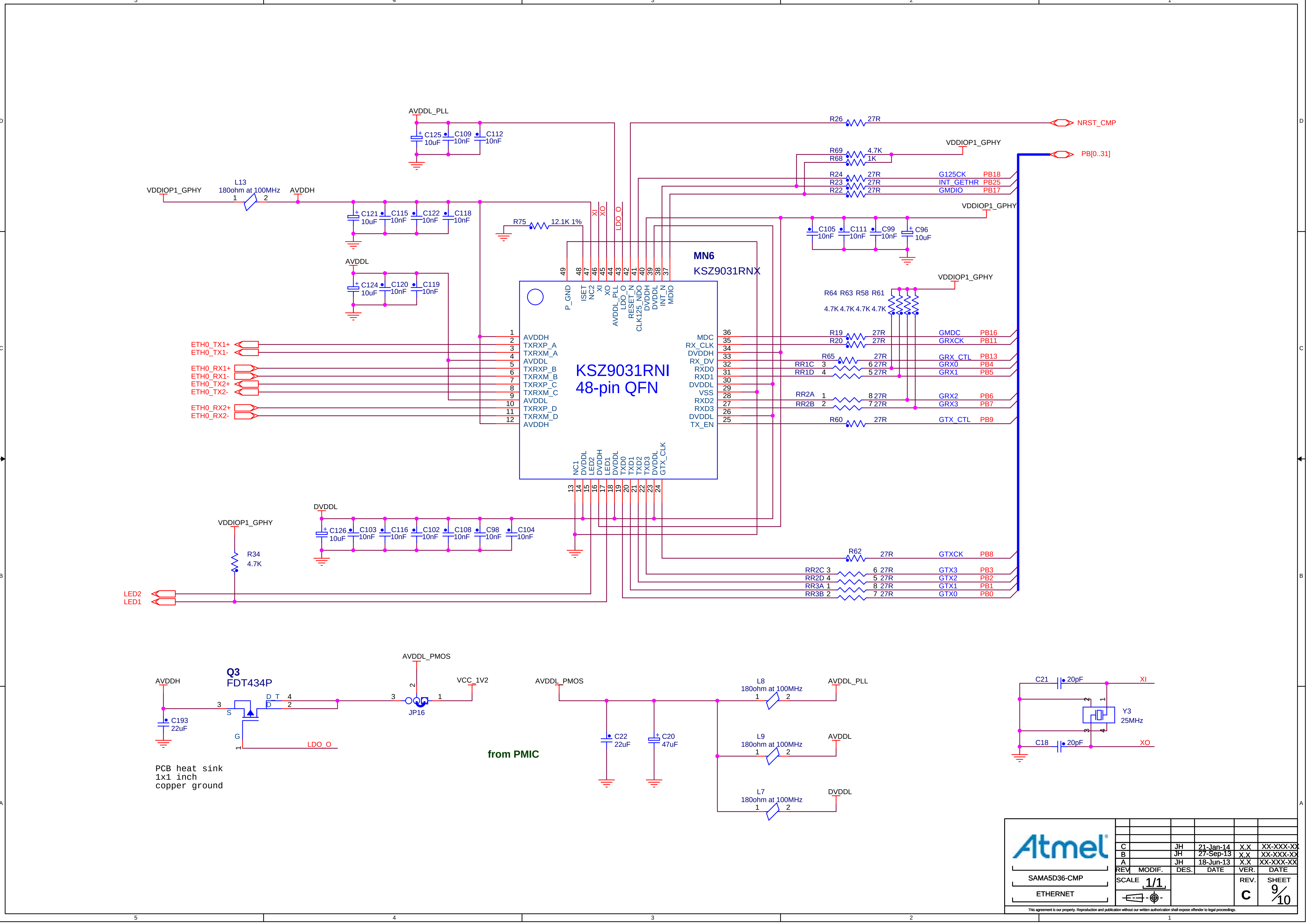

MN6
KSZ9031RNX
KSZ9031RNI
48-pin QFN
P_GND
ISET
NC2
XI
XO
AVDDL_PLL
LDO_O
RESET_N
CLK125_NDO
DVDDH
DVDDL
INT_N
MDIO
AVDDH
TXRXP_A
TXRXM_A
AVDDL
TXRXP_B
TXRXM_B
TXRXP_C
TXRXM_C
AVDDL
TXRXP_D
TXRXM_D
AVDDH
MDC
RX_CLK
DVDDH
RX_DV
RXD0
RXD1
DVDDL
VSS
RXD2
RXD3
DVDDL
TX_EN
NC1
DVDDL
LED2
DVDDH
LED1
DVDDL
TXD0
TXD1
TXD2
TXD3
DVDDL
GTX_CLK
AVDDL_PLL
C125 10uF
C109 10nF
C112 10nF
VDDIOP1_GPHY
L13
180ohm at 100MHz
AVDDH
C121 10uF
C115 10nF
C122 10nF
C118 10nF
AVDDL
C124 10uF
C120 10nF
C119 10nF
R75 12.1K 1%
ETH0_TX1+
ETH0_TX1-
ETH0_RX1+
ETH0_RX1-
ETH0_TX2+
ETH0_TX2-
ETH0_RX2+
ETH0_RX2-
R26 27R
NRST_CMP
PB[0..31]
R69 4.7K
R68 1K
R24 27R G125CK PB18
R23 27R INT_GETHR PB25
R22 27R GMDIO PB17
C105 10nF
C111 10nF
C99 10nF
C96 10uF
R64 R63 R58 R61
4.7K 4.7K 4.7K 4.7K
R19 27R GMDC PB16
R20 27R GRXCK PB11
R65 27R GRX_CTL PB13
RR1C 3 6 27R GRX0 PB4
RR1D 4 5 27R GRX1 PB5
RR2A 1 8 27R GRX2 PB6
RR2B 2 7 27R GRX3 PB7
R60 27R GTX_CTL PB9
DVDDL
C126 10uF
C103 10nF
C116 10nF
C102 10nF
C108 10nF
C98 10nF
C104 10nF
R34 4.7K
LED2
LED1
R62 27R GTXCK PB8
RR2C 3 6 27R GTX3 PB3
RR2D 4 5 27R GTX2 PB2
RR3A 1 8 27R GTX1 PB1
RR3B 2 7 27R GTX0 PB0
Q3
FDT434P
C193 22uF
LDO_O
AVDDL_PMOS
VCC_1V2
JP16
PCB heat sink
1x1 inch
copper ground
from PMIC
C22 22uF
C20 47uF
L8 180ohm at 100MHz
L9 180ohm at 100MHz
L7 180ohm at 100MHz
AVDDL_PLL
AVDDL
DVDDL
C21 20pF
C18 20pF
Y3 25MHz
XI
XO
Atmel
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B JH 27-Sep-13 X.X XX-XXX-XX
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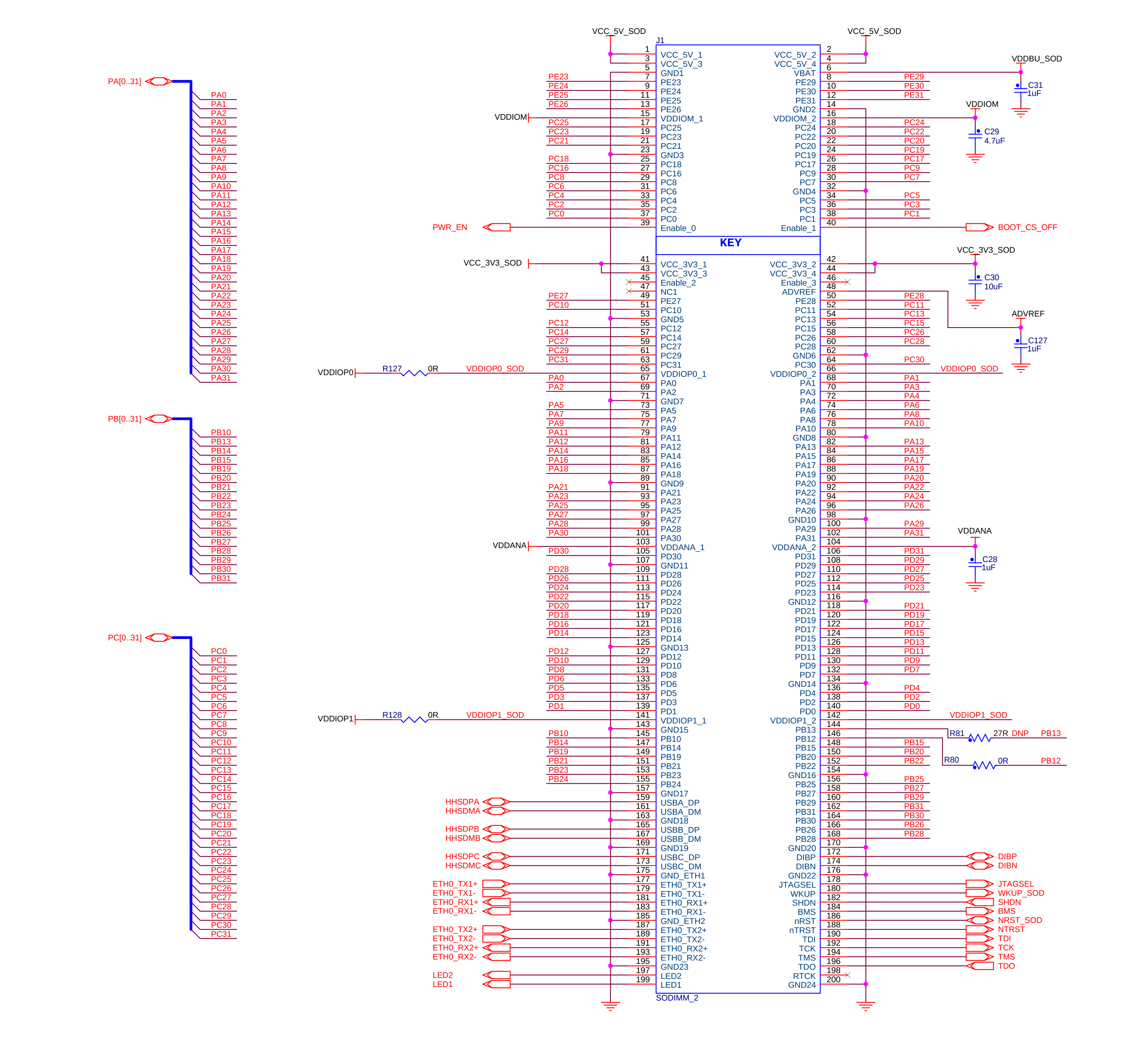

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200-PIN SODIMM

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6. Revision History

Table 6-1. Deisgn Optimization for Low-Power SAMA5D3-based Systems App Note Rev. 11291A Revision History

Doc. Rev. 11291A	Changes
23-Jun-14	First issue