
AT11491: Peripheral Power Consumption in Standby Mode for SAM D Devices

Atmel SAM D

Introduction

This application note describes the usage of various peripherals in Standby Sleep mode for Atmel® | SMART microcontrollers in the SAM D family. The internal voltage regulator which powers VDDCORE on the SAM D21 device can be operated in Low Power mode when the device is in Standby Sleep. Since the current driving capacity of the regulator is lower in Low Power mode when compared to the Normal operating mode, the peripherals have to be configured so that the voltage regulator is not overloaded.

There are applications where the device have to consume substantially low power while keeping a few peripherals running. In such cases Standby Sleep mode can be used.

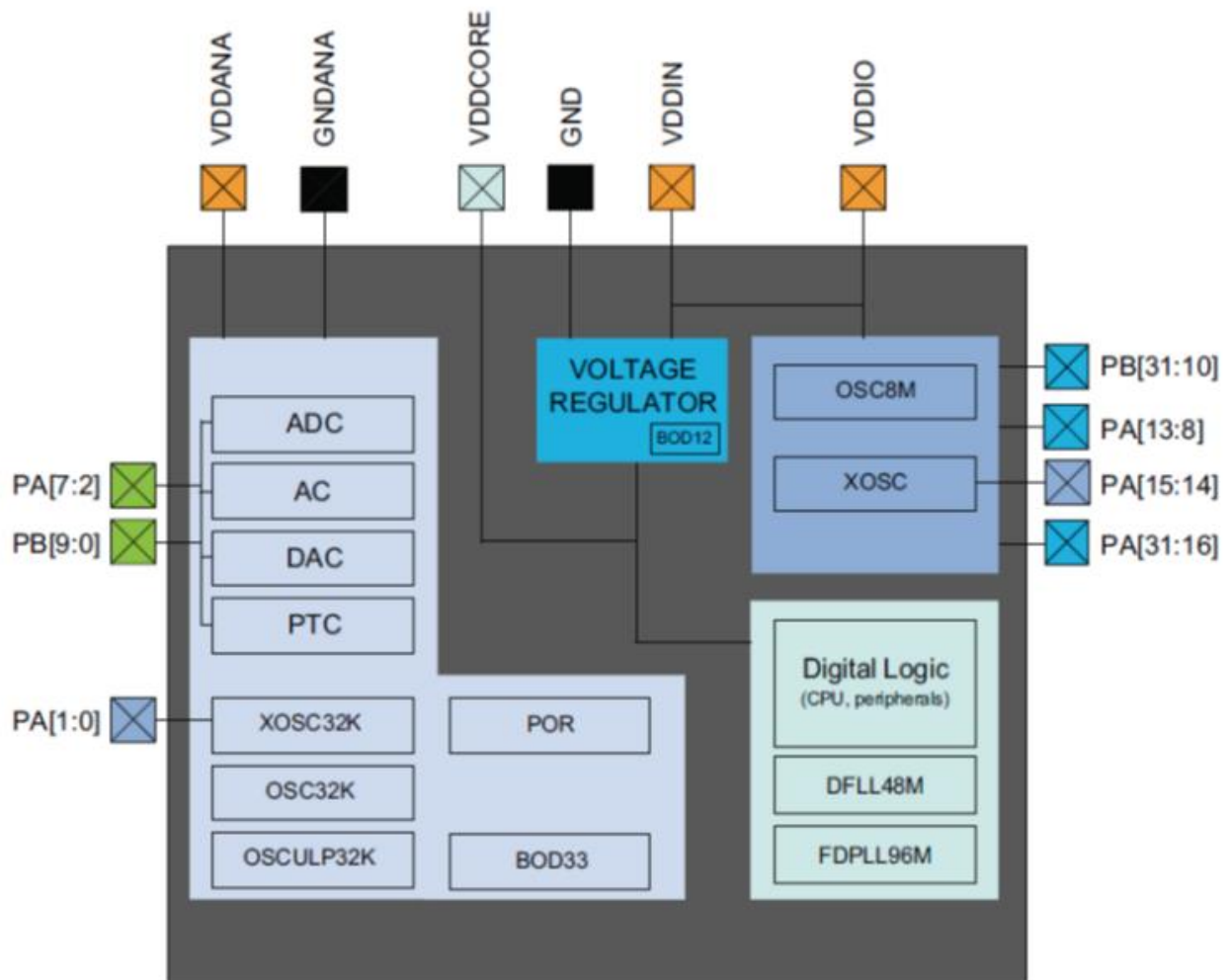
This application note will help estimating the current consumed by peripherals from the VDDCORE power domain when the voltage regulator is operated in Low Power mode. The measurements given in this application note are taken on the SAM D21 devices. The current consumption from the internal voltage regulator by peripheral on other SAM D devices such as SAM D10, D11, and D20; will be similar to the numbers provided in this document.

Table of Contents

1	SAM D21 Power Domains and Low Power Models	3
2	Standby Mode and Voltage Regulator	4
2.2	Idle Mode	4
2.3	Standby Mode	4
3	Voltage Regulator Sourcing Limit	4
4	Core Power Consumption Results	5
4.1	Clock Conditions Used for Measurements	5
4.2	Measurements at 25°C.....	5
4.3	Measurements at 85°C.....	6
5	Usage Example for Standby Mode	6
6	Conclusion.....	6
7	FAQs	7
8	Recommended Reading	7
9	Revision History	8

1 SAM D21 Power Domains and Low Power Models

Figure 1-1. Power Domain Overview



The SAM D21 has power supply pins named VDDIN, VDDIO, and VDDANA. These pins should be connected together and fed with a voltage in the range 1.62V to 3.63V. This common voltage is referred to as VDD. Even though the device is powered through a single supply, the device internally operates in two voltage domains. The core, memories, peripherals to core interfaces, DFLL48M, and FDPLL96M are operated at 1.2V. I/Os are operated at the same voltage level as the VDD supply (1.62V to 3.63V). There is an internal voltage regulator on the SAM D21 device which gives 1.2V supply to the core.

To optimize for the Low Power applications, the SAM D21 device supports different sleep modes such as Idle and Standby. Please consult the SAM D21 Datasheet [1], Chapter 7, "Power Supply and Start-Up Considerations" for more details.

2 Standby Mode and Voltage Regulator

There are two main types of sleep modes available on the SAM D product family, Idle and Standby. There are also two different operating modes for the internal regulator, Normal mode, and Low Power mode.

Table 2-1. Sleep Mode Entry and Exit

Mode	Level	Mode Entry	Wake-up Sources
Idle	0	SCR.SLEEPDEEP = 0 SLEEP.IDLE=Level WFI	Synchronous ⁽²⁾ (APB, AHB), asynchronous ⁽¹⁾
	1		Synchronous (APB), asynchronous
	2		Asynchronous
Standby	None	SCR.SLEEPDEEP = 1 WFI	Asynchronous

Notes: 1. Asynchronous: Interrupt generated on generic clock, external clock, or external event.

2. Synchronous: Interrupt generated on the APB clock.

2.2 Idle Mode

The CPU is stopped. Depending on if IDLE0, IDLE1 or IDLE2 mode is selected, some of the synchronous clock domains are also stopped. The internal regulator for VDDCORE always operates in Normal mode when the device is configured to be in IDLE sleep mode.

2.3 Standby Mode

All clock sources are stopped, except those where the RUNSTDBY (Run in Standby) bit for the module is set or have the ONDEMAND bit set to zero. By default the regulator operates in Low Power mode when using STANDBY sleep mode. Before entering Standby mode it must be made sure that significant amount of clocks and peripherals are disabled, so that the voltage regulator is not overloaded. To avoid overloading, the peripherals should be configured so that the total power consumption supplied by the internal regulator in low power mode should be less than 50µA. If the peripherals required to run in STANDBY mode consumes more than 50uA, the regulator should be configured to operate in normal mode, and this can be done from software by setting the RUNSTDBY bit in SYSCTRL -> VREG.

3 Voltage Regulator Sourcing Limit

Voltage regulator in Low Power mode can source up to 50µA for peripherals. If two peripherals are going to be used in Standby mode, then the cumulative consumption should not exceed the limit.

Consumption details of various peripherals in Standby mode is given in the next section along with the measurement conditions.

In a situation where the power consumption is exceeding the power limits because of the combination of peripherals, the peripherals operating clock speed has to be reduced to reduce the power consumption within the power limits. See the question on GCLK frequency in Chapter 7 FAQs. If the total power consumption in the core domain exceeds what the regulator is able to support, the device will have a BOD reset.

4 Core Power Consumption Results

4.1 Clock Conditions Used for Measurements

The Generic clock used by the peripheral are:

- RTC
32.768kHz from XOSC32K
- WDT
Clocked from OSCULP32K
- SERCOM
1MHz from OSC8M
- ADC
1MHz from OSC8M
- AC
500kHz from OSC8M
- TC
500kHz from OSC8M
- TCC
500kHz from OSC8M
- PTC
1MHz GCLK from OSC8M
- EIC
Clocked from OSCULP32K

4.2 Measurements at 25°C

Note: 'None' in the peripheral column indicates the consumption from the internal voltage regulator, when none of the peripherals are operated.

Table 4-1. Measurements at 25°C

Peripheral	Current Consumption [μ A]
None	5.00 ⁽¹⁾
RTC	5.056
TC	24.133
TCC	31.572
ADC	23.139
UART	28.637
SPI	4.987
I2C	4.987
WDT	5.007
AC	23.173
EIC	5.107
PTC	27.720

Note: Typical consumption will be less than this value, but for calculations, use this number.

4.3 Measurements at 85°C

Table 4-2. Measurements at 85°C

Peripheral	Current Consumption [μA]
None	51.718
RTC	51.898
TC	71.008
TCC	78.415
ADC	70.335
UART	75.686
SPI	52.221
I2C	52.261
WDT	52.548
AC	70.533
EIC	52.741
PTC	75.176

5 Usage Example for Standby Mode

An example for peripheral usage in Standby mode is described in this section. The application uses RTC and ADC. The ADC is used for periodically measuring the voltage on an input pin. The calculations below will help to decide whether the internal voltage regulator needs to be operated in Normal mode or in Low Power mode.

When measured at 25°C, the current consumption from the internal voltage regulator by RTC and ADC in Standby mode is:

- RTC -> 5.056μA
- ADC -> 23.139 μA

Here the total consumption by the two peripherals can be calculated as below.

Total current consumption from internal voltage regulator = Sum of consumption by each peripheral – (5.0 * [Total number of peripherals running in Standby mode – 1]).

Where 5.0 is the current taken from the internal voltage regulator when no peripherals are running.

Thus, the value is $(5.056 + 23.139) - (5.0 * [2-1]) = 23.195 \mu A$.

In this case, the RUNSTDBY bit for these two peripherals can be set, to let them run in Standby Sleep and the internal voltage regulator can be configured to operate Low Power mode.

6 Conclusion

- Multiple peripherals can run in Standby mode. Power budgeting can be done based on typical values given in this application note.
- When the GCLK frequency for a peripheral is higher than the clock conditions mentioned in [Section 4.1 Clock Conditions Used for Measurements](#), the peripheral may consume more current from the internal voltage regulator than what is given in this application note. In such cases, it is recommended to operate the core voltage regulator in Normal mode while the device is in Standby Sleep mode.

- If the device is operated at 85°C or more, operate the core voltage regulator in Normal mode by setting the RUNSTDBY bit in SYSCTRL->VREG as workaround for the Errata #12291 mentioned in SAM D21 Datasheet [1].

7 FAQs

1. **Is it possible to perform such measurement on a SAM D21 Xplained Pro? If not, why?**
This cannot be done on a SAM D21 Xplained Pro since the value measured across the current measurement header gives the total consumption by the device.
2. **The datasheet shows VDDCORE as an output pin. How is the current consumption from VDDCORE measured?**
The current consumption numbers mentioned in this document are measured using characterization setup, where the current sourced by the internal voltage regulator can be measured.
3. **Can I correlate the values given in SAM D21 Datasheet [1] in section “Typical Peripheral Current Consumption”, with the current consumption values given in this document?**
No. The values given in the datasheet section Typical Peripheral Current Consumption are measured, based on the total current taken by the device via its supply pins. The current consumption numbers given in this document show the current drawn from the internal voltage regulator by each peripheral.
4. **Will the measurements given in this document be applicable to other SAM D devices?**
The measurements given in this application note are measured with SAM D21 devices. The consumption numbers on SAM D20, D10 and D11 will be similar to or lower than the numbers given in this document.
5. **If the GCLK frequency for a peripheral is reduced by half, what will be the effect on current consumption from the internal voltage regulator?**
The resultant current consumption will be approximately half of the original value.

8 Recommended Reading

- [1] [SAM D21 Datasheet](#)
- [2] [AT04188: SAM D20/D21/D10 - How to Achieve Power Numbers](#)

9 Revision History

Doc Rev.	Date	Comments
42472A	07/2015	Initial document release.



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