TB3183

What is SleepWalking? How it Helps to Reduce Power Consumption

Introduction

The SleepWalking feature is available in ARM® Cortex®-based Microchip's microcontrollers (MCUs). This feature allows temporary and asynchronous wake up of a peripheral to perform a task without waking up the CPU from Standby mode.

In MCU operation, the internal timer wakes up the CPU to check if certain conditions have occurred (i.e., battery voltage monitoring using the ADC), or the peripheral interrupts have woke up the CPU. The CPU and RAM traditionally consume the majority of the power in Active mode. Therefore, waking up the CPU from Low-Power mode to check for these conditions and start relevant actions in an Active state will consume a lot of power.

SleepWalking allows the CPU to remain in Low-Power mode until a relevant event occurs. When the CPU is in Low-Power mode, that is, Standby mode in Cortex-M0+ MCU, the peripheral can request the clock to perform its task. The CPU no longer needs to check whether or not a specific condition is present, such as an address match condition on the I^2C interface or a sensor connected to an ADC that has exceeded a specific threshold. With SleepWalking, this is done entirely by the peripherals with the help of an event system.

The following are basic implementation steps of SleepWalking:

- Main clocks and peripheral clocks are stopped in Sleep mode to save power
- Peripherals supporting SleepWalking (For example, peripherals supporting on-demand feature in Cortex-M0+ MCUs) individually request clocks in Sleep mode
- Clocks remain active until a specific peripheral operation is complete

The CPU and RAM will not wake up when sleepwalking supported peripherals perform the tasks, unless the CPU needs to perform an operation.

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1. SleepWalking Support in SAM MCUs

In Cortex-M0+ MCUs (AM D, SAM L and SAM C) and some of the Cortex-M4 MCUs (SAMD5x/ SAME5x), the SleepWalking feature is supported by many peripherals and these peripherals use the on-demand clock principle of the clock sources.

In the SAMD20/ D21 MCUs, the following peripherals support the SleepWalking feature.

- Real-Time Counter (RTC)
- External Interrupt Controller (ETC)
- SERCOMs (USART, SPI, I^2C)
- Timer/Counter (TC)
- Timer/Counter for Control Applications (TCC)
- Analog-to-Digital Converter (ADC)
- Analog Comparator (AC)
- Event System (EVSYS)

Note: All peripheral events do not support SleepWalking. Refer to the Event System sections of the relevant data sheets to know which event of the peripherals will support SleepWalking.

During Low-Power mode, the peripheral clocks are stopped. The SleepWalking supported peripheral that needs a clock will request it from the clock system (For example, Generic Clock Controller in Cortex-M0+ MCU).

In Cortex-M0+ MCUs, the following are the configurations and sequence of steps for an asynchronous path:

1. The Event System must be configured to use the asynchronous path causing the peripheral to request its clock asynchronously of the core clock.
2. The event generator triggers the event user which is based on the event system configuration.
3. The clock must be provided by the Generic Clock Generator, which is asynchronous from the MCU clock. The Generic Clock Controller will receive the request and then determine which generic clock generator is involved and which clock source needs to be awakened.
4. The clock source wakes up, enabling the generic clock generator and generic clock stages successively, and delivers the generic clock to the peripheral.
5. The peripheral that is associated with the event user must be able to run in Standby mode.

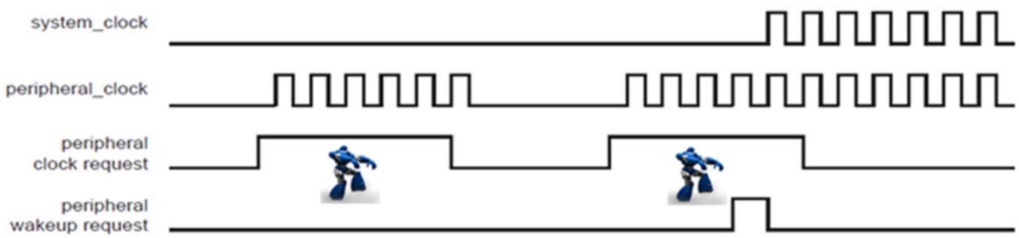
For additional information about event system paths, refer to the product data sheets or Event System Tech Brief, which is available for download at http://ww1.microchip.com/downloads/en/devicedoc/90003170a.pdf.

In Cortex-M7 MCUs (SAM E70/ S70), a few peripherals, such as UART, TWI support SleepWalking; however, in the SAMG5x family of MCUs, the UART, TWI, SPI and ADC all support the SleepWalking features.

In Cortex-M7 MCUs, the following are the configurations and sequence of steps:

1. The corresponding SleepWalking Activity Status register is checked to ensure that the peripheral has no activity in progress.
2. If the corresponding SleepWalking Activity Status register is set, SleepWalking must be disabled.
3. Asynchronous partial wakeup function of the peripheral is enabled.
4. The Event generator (UART) triggers to wake up the MCU from Wait mode.

Figure 1-1. Sleepwalking Activity



Note: The Cortex-M0+ event system has various configurable event generators and user options to operate various peripherals in low power. Comparatively, the SAM E70/S70 and SAM G5x MCUs have limited event system capability to operate in low power. For additional information, refer to the Table *Real-time Event Mapping List* in the SAME70 data sheet.

2. Sleepwalking Implementation

To explain SleepWalking, the SAML21 MCU is used in this reference. To understand the power consumption optimization using SleepWalking, the application code is implemented in the following two ways:

- Classical Interrupt-based implementation
- Sleepwalking implementation

Classical Interrupt-Based Implementation

In the Classical Interrupt-based implementation, the CPU is woke up every 125ms using an RTC interrupt, which is based on the OSCULP 32kHz oscillator to start the ADC conversion.

At the end of a 10-transfer frame, the CPU is woke up using a DMA interrupt to process the data to be plotted into the Data Visualizer of the Studio using the SPI DGI (Data Gateway Interface) connection.

In this implementation, the core is woke up every 125 ms to start the ADC and every 10 DMA transfers.

For both of these implementations, the ADC will convert the analog signal coming from the sensor and trigger a DMA data transfer to the Low-Power RAM (LPRAM) as soon as the result of the conversion is ready. This part is automatically done by an internal hardware trigger path present between the ADC and the DMA.

The power consumption for the interrupt-based sequence using the Data Visualizer of the Studio is shown in the following figure.

Figure 2-1. Power Consumption for the Interrupt-Based Sequence Flow Diagram

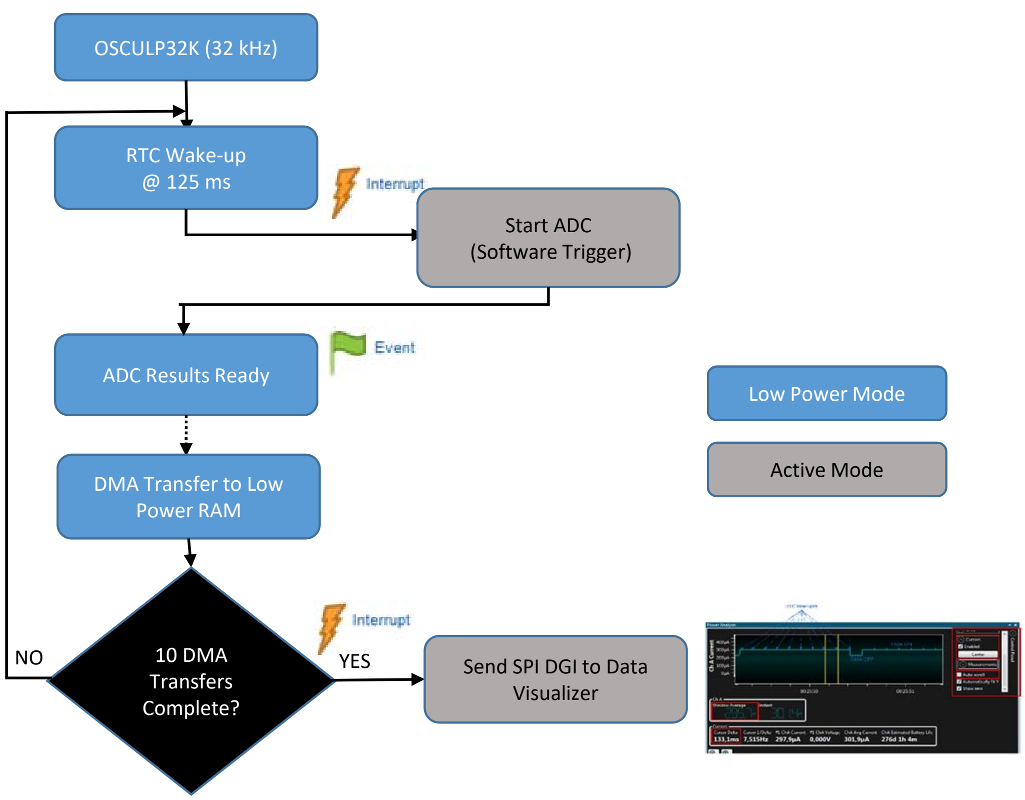
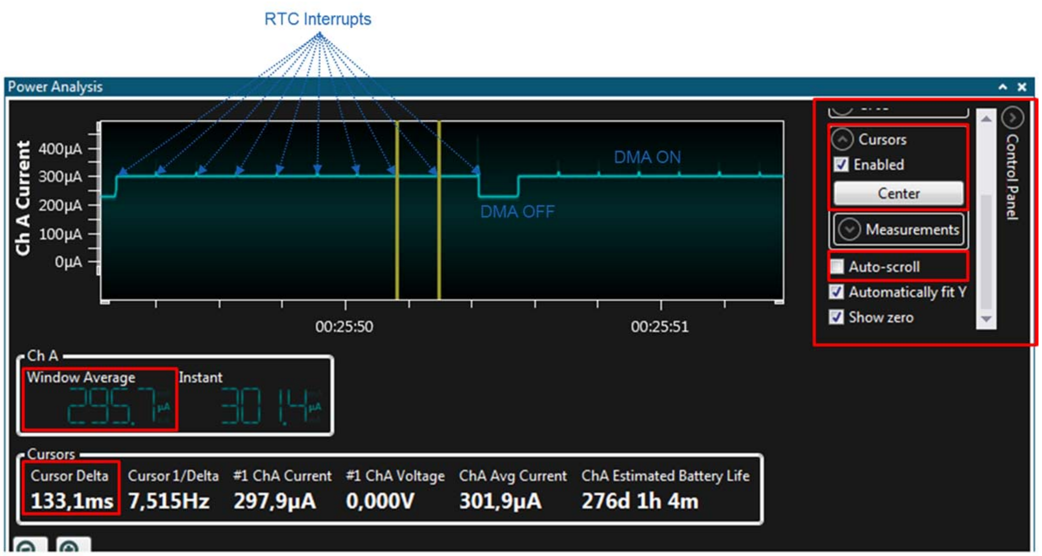


Figure 2-2. Power Consumption



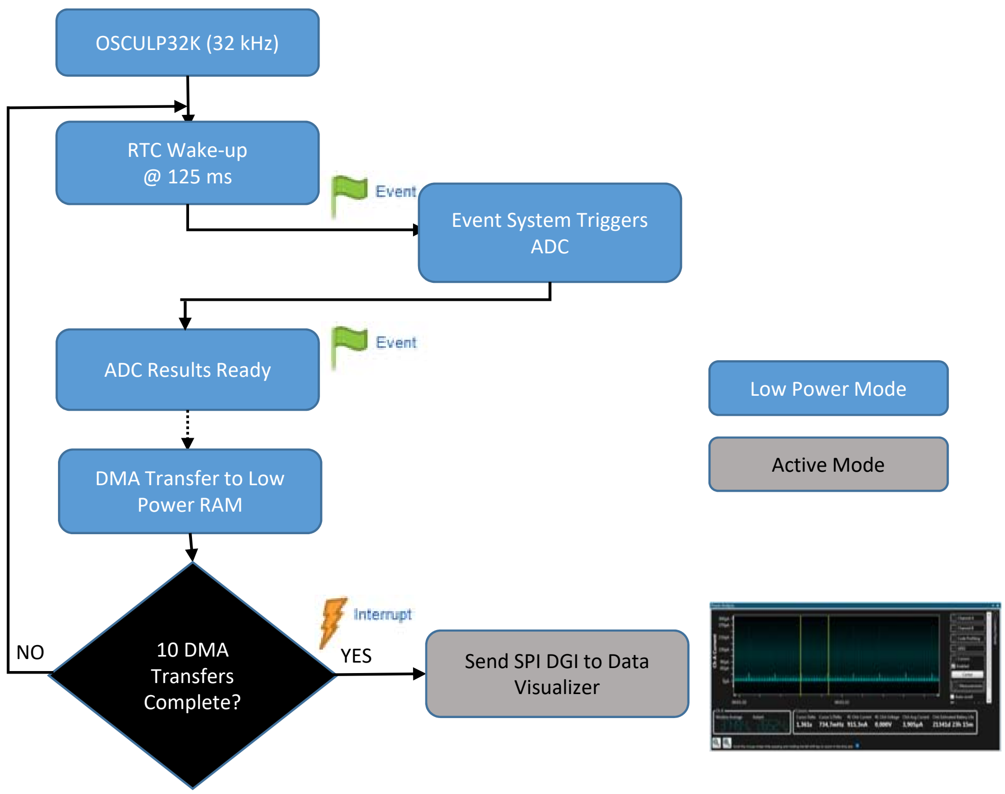
SleepWalking Implementation

In the SleepWalking implementation, the application takes advantage of the Event System. The RTC will automatically start the ADC conversion using the Event System of the chip without any CPU intervention.

The application scenario is explained in the following steps:

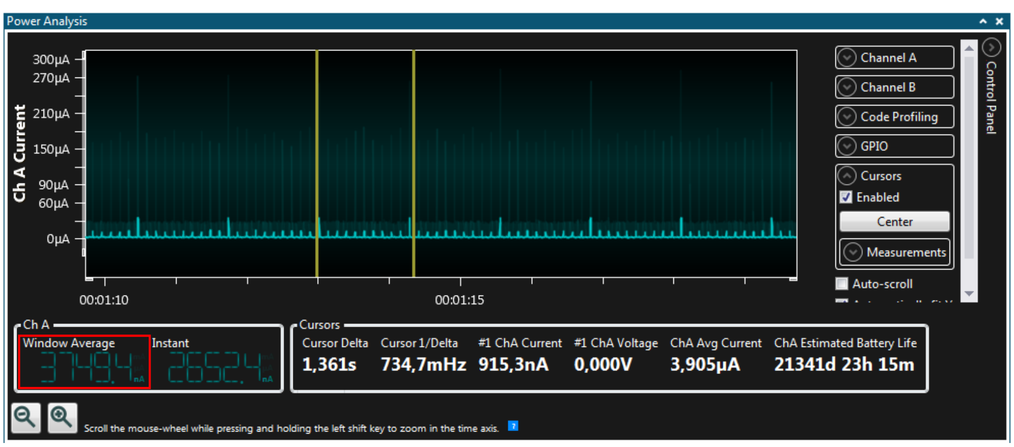
1. The RTC is configured as an Event Generator to generate a periodic event (every 125ms) to the ADC through the SAM L21 event system.
2. The ADC acknowledges the event from the RTC and starts a conversion.
3. The DMA moves the conversion from the ADC Result register to the low-power SRAM.
4. After 10 transfers, the DMA generates an interrupt to wake up the CPU to Active mode and process the data.
5. Data is then sent to the Data Visualizer using the SPI Data Gateway Interface (DGI).

Figure 2-3. SleepWalking Implementation Flow Chart



The power consumption for the SleepWalking sequence using the Data Visualizer is shown in the following figure.

Figure 2-4. Power Consumption for SleepWalking



Conclusion: As shown above, with the SleepWalking feature implementation the power consumption can be decreased.

3. Relevant Resources

For additional information on Sleepwalking features and other relevant information, refer to the following documents which are available for download from the Microchip web site.

- SAMD2x:
  - http://ww1.microchip.com/downloads/en/appnotes/atmel-42411-ultra-low-power-techniques-at06549_application-note.pdf
  - http://ww1.microchip.com/downloads/en/appnotes/atmel-42473-analog-comparator-application-examples_userguide_at11480.pdf
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  - http://ww1.microchip.com/downloads/en/appnotes/atmel-42411-ultra-low-power-techniques-at06549_application-note.pdf
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- SAM4L:
  - http://www.microchip.com/wwwappnotes/appnotes.aspx?appnote=en591380
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