

Renesas Synergy™ Platform

Low Power Modes V2 HAL Module Guide**Introduction**

This module guide will enable you to effectively use a module in your own design. Upon completion of this guide, you will be able to add this module to your own design, configure it correctly for the target application and write code, using the included application project code as a reference and efficient starting point. References to more detailed API descriptions and suggestions of other application projects that illustrate more advanced uses of the module are available in the Renesas Synergy Knowledge Base (as described in the References section at the end of this document), and should be valuable resources for creating more complex designs.

The Low Power Modes V2 HAL module is a high-level API for low-power mode applications and is implemented on r_lpm2. The Low Power Modes HAL module uses the low-power mode hardware peripheral on the Synergy MCU.

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1. Low Power Modes V2 HAL Module Features

The LPM V2 HAL module supports configuration of MCU operating power-control modes and MCU low-power modes using the low-power mode hardware peripheral.

The LPM V2 HAL module supports the following low power modes:

- Deep Software Standby mode
- Software Standby mode
- Sleep mode
- Snooze mode

The LPM V2 HAL module supports reducing power consumption when in deep stand-by mode through internal power-supply control and by resetting the states of I/O ports. The LPM V2 HAL module supports disabling and enabling of the MCU’s other hardware peripherals.

Note: Not all low-power V2 modes are available on all MCUs Groups.

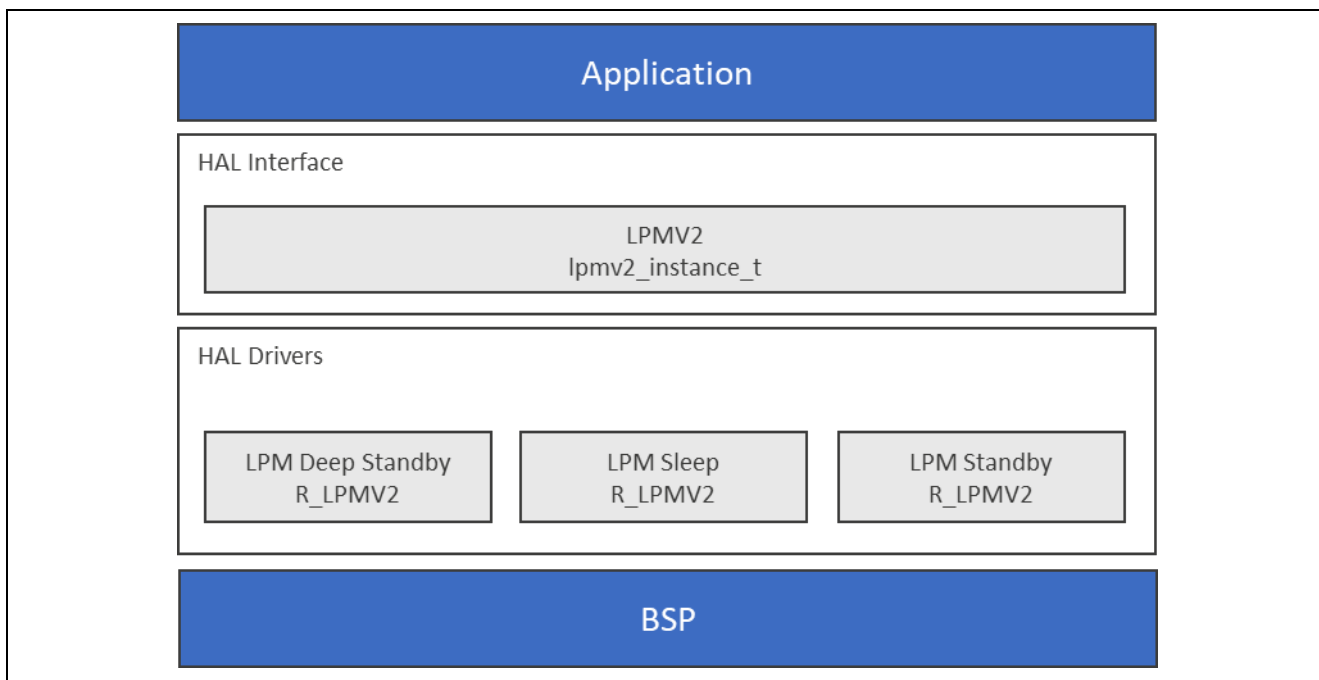


Figure 1. Low Power Modes V2 Module Block Diagram

2. Low Power Modes V2 HAL Module APIs Overview

The Low Power Modes V2 HAL module defines APIs for configuring operations and enabling and disabling low-power operations. A complete list of the available APIs, an example API call and a short description of each can be found in the following table. A table of return status values follows the API summary table.

Note: The Low Power Modes V2 HAL module will no longer handle operating power-control modes of the MCU, these are now handled by the CGC HAL module.

The following API examples illustrate sleep-mode use; “deep_standby” and “standby” can be substituted for “sleep” in the API examples to create examples for those modes.

Table 1. Low Power Modes V2 Module API Summary

Function Name	Example API Call and Description
.init	<code>g_lpmv2_sleep0.p_api->init(g_lpmv2_sleep0.p_cfg);</code> Open the LPM driver module Initialized the LPM block according to the passed in config structure.
.lowerPowerCfg	<code>g_lpmv2_sleep0.p_api->lowerPowerCfg(power_mode, output_port_enable, power_supply, io_port_state);</code> Configure a low power mode.
.lowPowerModeEnter	<code>g_lpmv2_sleep0.p_api->lowPowerModeEnter(void);</code> Enter low power mode (sleep/standby/deep standby) using WFI macro. Function will return after waking from low power mode.
.versionGet	<code>g_lpmv2_sleep0.p_api->versionGet(&version);</code> Get the driver version and place it at the pointer version.

Note: For details on operation and definitions for the function data structures, typedefs, defines, API data, API structures, and function variables, review the SSP User's Manual API References for the associated module.

Table 2. Status Return Values

Name	Description
SSP_SUCCESS	API Call Successful
SSP_ERR_INVALID_POINTER	Pointer is NULL
SSP_ERR_INVALID_MODE	Invalid settings for specified mode
SSP_ERR_INVALID_HW_CONDITION	OPCMTSF and SOPCMTSF flags are not cleared within internally set timeout.

Note: Lower-level drivers may return common error codes. Refer to the SSP User's Manual API References for the associated module for a definition of all relevant status return values.

3. Low Power Modes V2 HAL Module Operational Overview

LPM V2 Initialization

The LPM V2 API function `lpm_v2_api_t::init` should be called before calling any other LPM V2 function. The `init` function handles initialization of internal variables and locks.

Sleep low-power mode

By default, at power on, sleep mode is enabled as the low-power mode. Sleep mode is the most convenient low-power mode available, as it does not require any special configuration (other than configuring and enabling a suitable interrupt or event to wake the MCU from sleep) to return to normal program-execution mode. Any interrupt wakes the MCU device from sleep low-power mode. The states of the SRAM, the processor registers, and the hardware peripherals are all maintained in sleep mode, and the time needed to enter and wake from sleep is minimal. Any interrupt causes the MCU device to wake from sleep mode, including the SysTick interrupt used by the ThreadX® thread scheduler. The LPM API function `lpm_v2_api_t::init` should be called before any other function. The LPM API function, `lpm_v2_api_t::lowerPowerCfg`, can be used to configure the MCU to use sleep as its low-power mode. The LPM API function `lpm_v2_api_t::lowPowerModeEnter` should be used to directly enter sleep mode.

An illustrative code example is available on the LPM_V2 Knowledge Base article, available as described in the Reference Information section at the end of this document.

Software Standby Mode for LPM V2

In software-standby mode, the CPU, as well as most of the on-chip peripheral functions and all of the internal oscillators, are stopped. Retained are the contents of the CPU internal registers and SRAM data, the states of on-chip peripheral functions and I/O Ports. Software-standby mode allows significant reduction in power consumption, because most of the oscillators are stopped in this mode. Like sleep mode, standby mode requires an interrupt or event be configured and enabled to wake from standby mode.

The possible triggers for waking from standby mode are enumerated in the Properties window for convenience; multiple triggers can be enabled.

An illustrative code example is available on the LPM_V2 Knowledge Base article, available as described in the Reference Information section at the end of this document.

Snooze Mode with Software Standby Mode for LPM V2

Snooze mode is available through the standby mode LPM V2 instance. Choose "Standby with Snooze Enabled" for "Choose the low power mode" in the Properties window. Snooze mode can be used with some MCU peripherals to execute basic tasks, while keeping the MCU in a low-power state. The snooze settings are below the standby settings in the Properties window. The ADC, DTC, and other peripherals can be enabled in snooze mode. All the settings for snooze are available through configuration properties for the standby instance, with the exception of the Event Link Controller settings for registers SELSR0 and IELSRn. Snooze is considered an advanced feature.

The "Snooze Mode Settings" are only used if the low-power mode choice is "Standby with Snooze Enabled," as shown in the following screen capture:

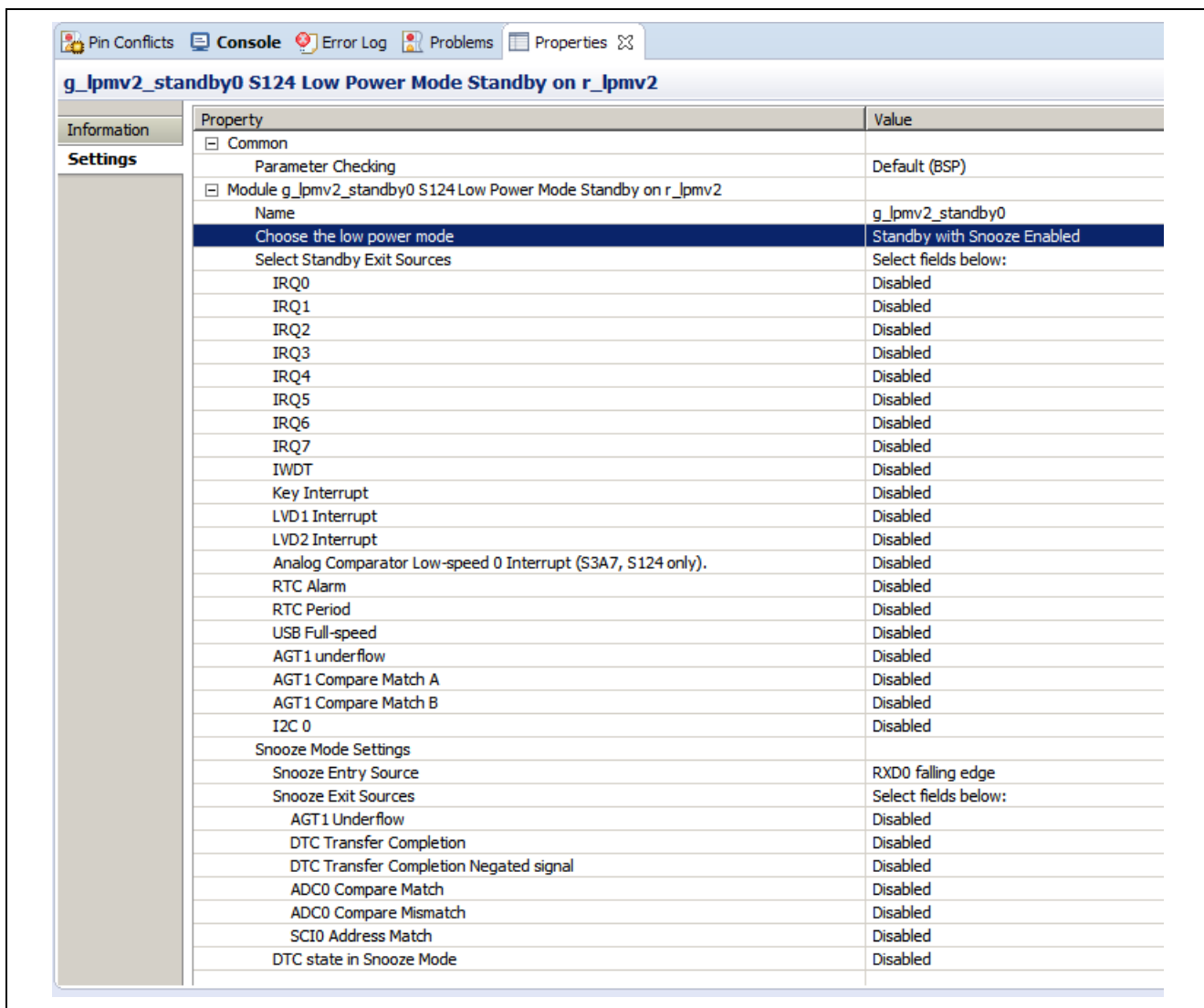


Figure 2. Standby mode with Snooze setting enabled

Snooze is a feature of standby mode that allows some peripherals to run even though the MCU core is not executing instructions. The low-power mode peripheral options related to snooze mode are shown in the following image. Only one snooze-entry source can be enabled, while multiple snooze-exit sources can be enabled; the DTC peripheral can be enabled in snooze mode as well.

Snooze Mode Settings	
Snooze Entry Source	RXD0 falling edge
Snooze Exit Sources	Select fields below:
AGT1 Underflow	Disabled
DTC Transfer Completion	Disabled
DTC Transfer Completion Negated signal	Disabled
ADC0 Compare Match	Disabled
ADC0 Compare Mismatch	Disabled
SCIO Address Match	Disabled
DTC state in Snooze Mode	Disabled

Figure 3. Snooze Mode Settings

Deep Software Standby Mode for LPM V2

Deep Software Standby Mode is only available on some MCU devices. The MCU device always wakes from Deep Software Standby Mode by going through reset, either by the negation of the reset pin or by one of a set of wake-up events displayed in the configuration Properties window for the LPM deep standby instance.

The possible triggers for waking from deep standby mode are enumerated in the Properties window for convenience. Multiple triggers can be enabled. Some triggers have an associated edge type, falling or rising. These options are enumerated also as shown above and below.

An illustrative code example is available on the LPM_V2 Knowledge Base article, available as described in the Reference Information section at the end of this document.

3.1 Low Power Modes V2 HAL Module Important Operational Notes and Limitations

3.1.1 Low Power Modes V2 HAL Module Operational Notes

Using this driver to configure the LPM peripheral to wake the MCU from standby mode through interrupts requires the interrupt to be configured and enabled by the peripheral driver or framework that uses that interrupt. For example, to wake from standby through AGT1 underflow, that interrupt must be enabled through the configuration of the AGT timer module.

If the main oscillator or PLL with main-oscillator source is used for the system clock, the wake time from standby mode can be affected by the Main Oscillator Wait Time Setting in the MOSCWTCR register. This register setting is available to be changed through the Main Oscillator Wait Time setting in the CGC HAL module properties. See the Wakeup Timing and Duration table in Electrical Characteristics for more information.

Note: When a project uses ThreadX and the low-power mode standby, deep standby or standby with snooze enabled, the call to the `lpm_v2_api_t::lowPowerCfg` API function should occur immediately before the call to the `lpm_v2_api_t::lowPowerModeEnter` API function. This is necessary since ThreadX also uses low-power modes in its idle loop and `tx_thread_sleep` function; ThreadX expects the MCU device to be configured for the low-power mode sleep.

When a project uses ThreadX and the low-power mode standby or standby with snooze enabled, the low-power mode should be reverted to sleep after the MCU device wakes from standby after returning from the `lpm_v2_api_t::lowPowerModeEnter` function. This is necessary since ThreadX also uses low-power modes in its idle loop and `tx_thread_sleep` function; ThreadX expects the MCU device to be configured for the low-power mode sleep. The API function `lpm_v2_api_t::lowPowerCfg` needs to be called again before `lpm_v2_api_t::lowPowerModeEnter` to re-configure the low-power mode to sleep, if the `tx_thread_sleep` function is used in the project, or if there may not always be a thread ready to run.

Detailed information about the expected power consumption of the MCU device in operating states and in Low Power Modes V2 can be found in the Operating and Standby Current section within the Electrical Characteristics section of the MCU Synergy Hardware User’s Manual.

3.1.2 Low Power Modes V2 HAL Module Limitations

- Flash stop (code flash disable) is not supported. See the section “Flash Operation Control Register (FLSTOP)” of the S1/S3 Synergy Hardware User’s Manual.
- Reduced SRAM retention area in software standby mode is not supported. See the section “Power Save Memory Control Register (PSMCR)” of the S3 Synergy Hardware User’s Manual.
- The MCU may not enter or stay in Software Standby and Deep Software Standby modes with the debugger attached. Instead, the MCU may be woken from Software Standby and Deep Software Standby modes by the debugger. To properly test and verify Software Standby and Deep Software Standby modes, the debugger must not be attached.
(NOTE: Due to some issues, the Application project works only when connected to debugger for e² studio. So, while using e² studio, use the application project along with debugger connected to test the low power modes.)
- If the main oscillator or PLL with the main oscillator source is used for the system clock, the wake time from standby mode can be affected by the Main Oscillator Wait Time Setting in the MOSCWTCR register. This register setting can be changed through the Main Oscillator Wait Time setting in the CGC HAL module properties. See the “Wakeup Timing and Duration” table in Electrical Characteristics for more information.
- Refer to the latest SSP Release Notes for any additional operational limitations for this module.

4. Including the Low Power Modes V2 HAL Module in an Application

This section describes how to include the Low Power Modes V2 HAL module in an application using the SSP configurator.

Note: It is assumed you are familiar with creating a project, adding threads, adding a stack to a thread and configuring a block within the stack. If you are unfamiliar with any of these items, refer to the first few sections of the SSP User’s Manual to learn how to manage each of these important steps in creating SSP-based applications.

To add a Low Power Modes V2 Driver to an application, simply add it to a thread using the stacks selection sequence given in the following table. (The default name for the Low Power Modes Driver is g_lpmv2_<mode>0. This name can be changed in the associated Properties window.)

Table 3. Low Power Modes V2 Module Selection Sequence

Resource	ISDE Tab	Stacks Selection Sequence
g_lpmv2_deep_standby0 S7G2 Low Power Mode Sleep on r_lpmv2	Threads	New Stack> Driver> Power> Low Power Mode Deep Standby on r_lpmv2
g_lpmv2_sleep0 S7G2 Low Power Mode Sleep on r_lpmv2	Threads	New Stack> Driver> Power> Low Power Mode Sleep on r_lpmv2
g_lpmv2_standby0 S7G2 Low Power Mode Sleep on r_lpmv2	Threads	New Stack> Driver> Power> Low Power Mode Standby on r_lpmv2

Note: The selection sequences list modes available for the S7G2 Group. Other MCUs will have a different selection sequence available in the ISDE.

If you add the LPM V2 HAL module to more than one thread, or to a thread and to HAL/Common, give each instance of the LPM V2 Driver a unique name by highlighting the instance of the driver in the Modules window and changing the entry for name in the Properties view. The default settings for the LPM V2 HAL module configuration structure can also be changed using this view.

(The following figure shows the three available low power modes for the S7G2 MCU. These modules can be added individually or in groups. This figure shows all three for completeness; the configurator automatically adds any needed lower-level modules. Modules with a **Gray** band are individual modules that stand alone. Modules with a **Blue** band are shared or common and need only be added once and can be used by multiple stacks.

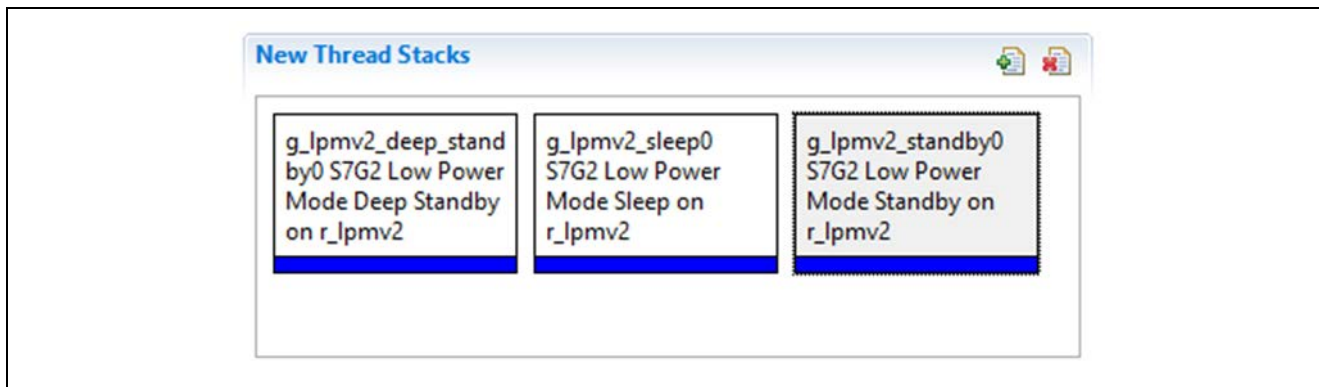


Figure 4. Low Power Modes V2 Module Stack

5. Configuring the Low Power Modes V2 HAL Module

The Low Power Modes V2 Driver module must be configured by the user for the desired operation. The SSP configuration window automatically identifies (by highlighting the block in red) any required configuration selections, such as interrupts or operating modes, which must be configured for lower-level modules for successful operation. Only those properties that can be changed without causing conflicts are available for modification. Other properties are 'locked' and are not available for changes, and are identified with a lock icon for the 'locked' property in the Properties window in the ISDE. This approach simplifies the configuration process and makes it much less error-prone than previous 'manual' approaches to configuration. The available configuration settings and defaults for all the user-accessible properties are given in the properties tab within the SSP configurator and are shown in the following tables for easy reference.

One of the properties most often identified as requiring a change is the interrupt priority; this configuration setting is available within the Properties window of the associated module. Simply select the indicated module and then view the Properties window; the interrupt settings are often toward the bottom of the properties list, so scroll down until they become available. Also note that the interrupt priorities listed in the Properties window in the ISDE includes an indication as to the validity of the setting based on the targeted MCU (CM4 or CM0+). This level of detail is not included in the following configuration properties tables, but is easily visible within the ISDE when configuring interrupt-priority levels.

Note: You may want to open your ISDE, create the module and explore the property settings in parallel with looking over the following configuration table settings. This helps orient you and can be a useful 'hands-on' approach to learning the ins and outs of developing with SSP.

Table 4. Configuration Settings for the Low Power Mode Deep Standby Module on r_lpmv2

ISDE Property	Value	Description
Parameter Checking	BSP, Enabled, Disabled (Default: BSP)	Enables or disables the parameter checking
Name	g_lpmv2_deep_standby0	Module name
Output port state in standby and deep standby, applies to address output, data output, and other bus control output pins	High impedance state, No change (Default: No change)	Output port state setting in Standby and Deep Standby
Maintain or reset the IO port states on exit from deep standby mode	Maintain the IO port states, Reset the IO port states (Default: Maintain the IO port states)	Output port state setting exit
Internal power supply control in deep standby mode	Maintain the internal power supply, Cut the power supply to standby RAM, low-speed on-chip oscillator, AGTn, and USBFS/HS resume detecting unit, Cut the power supply to LVDn, standby RAM, low-speed on-chip oscillator, AGTn, and USBFS/HS resume detecting unit (Default: Maintain the internal power supply)	Internal power supply control in deep standby mode setting

ISDE Property	Value	Description
Deep Standby Cancel Sources/Edges: Select Fields Below		
IRQ0	Enabled, Disabled (Default: Disabled)	IRQ0 selection
IRQ0 Edge	Disabled, Rising Edge, Falling Edge (Default: Disabled)	IRQ0 Edge selection
IRQ1	Enabled, Disabled (Default: Disabled)	IRQ1 selection
IRQ1 Edge	Disabled, Rising Edge, Falling Edge (Default: Disabled)	IRQ1 Edge selection
IRQ2	Enabled, Disabled (Default: Disabled)	IRQ2 selection
IRQ2 Edge	Disabled, Rising Edge, Falling Edge (Default: Disabled)	IRQ2 Edge selection
IRQ3	Enabled, Disabled (Default: Disabled)	IRQ3 selection
IRQ3 Edge	Disabled, Rising Edge, Falling Edge (Default: Disabled)	IRQ3 Edge selection
IRQ4	Enabled, Disabled (Default: Disabled)	IRQ4 selection
IRQ4 Edge	Disabled, Rising Edge, Falling Edge (Default: Disabled)	IRQ4 Edge selection
IRQ5	Enabled, Disabled (Default: Disabled)	IRQ5 selection
IRQ5 Edge	Disabled, Rising Edge, Falling Edge (Default: Disabled)	IRQ5 Edge selection
IRQ6	Enabled, Disabled (Default: Disabled)	IRQ6 selection
IRQ6 Edge	Disabled, Rising Edge, Falling Edge (Default: Disabled)	IRQ6 Edge selection
IRQ7	Enabled, Disabled (Default: Disabled)	IRQ7 selection
IRQ7 Edge	Disabled, Rising Edge, Falling Edge (Default: Disabled)	IRQ7 Edge selection
IRQ8	Enabled, Disabled (Default: Disabled)	IRQ8 selection
IRQ8 Edge	Disabled, Rising Edge, Falling Edge (Default: Disabled)	IRQ8 Edge selection
IRQ9	Enabled, Disabled (Default: Disabled)	IRQ9 selection
IRQ9 Edge	Disabled, Rising Edge, Falling Edge (Default: Disabled)	IRQ9 Edge selection
IRQ10	Enabled, Disabled (Default: Disabled)	IRQ10 selection
IRQ10 Edge	Disabled, Rising Edge, Falling Edge (Default: Disabled)	IRQ10 Edge selection
IRQ11	Enabled, Disabled (Default: Disabled)	IRQ11 selection
IRQ11 Edge	Disabled, Rising Edge, Falling Edge (Default: Disabled)	IRQ11 Edge selection
IRQ12	Enabled, Disabled (Default: Disabled)	IRQ12 selection
IRQ12 Edge	Disabled, Rising Edge, Falling Edge (Default: Disabled)	IRQ12 Edge selection
IRQ13	Enabled, Disabled (Default: Disabled)	IRQ13 selection
IRQ13 Edge	Disabled, Rising Edge, Falling Edge (Default: Disabled)	IRQ13 Edge selection
IRQ14	Enabled, Disabled (Default: Disabled)	IRQ14 selection
IRQ14 Edge	Disabled, Rising Edge, Falling Edge (Default: Disabled)	IRQ14 Edge selection
IRQ15	Enabled, Disabled (Default: Disabled)	IRQ15 selection
IRQ15 Edge	Disabled, Rising Edge, Falling Edge (Default: Disabled)	IRQ15 Edge selection
LVD1	Enabled, Disabled (Default: Disabled)	LVD1 selection

ISDE Property	Value	Description
LVD1 Edge	Disabled, Rising Edge, Falling Edge (Default: Disabled)	LVD1 Edge selection
LVD2	Enabled, Disabled (Default: Disabled)	LVD2 selection
LVD2 Edge	Disabled, Rising Edge, Falling Edge (Default: Disabled)	LVD2 Edge selection
RTC Interval	Enabled, Disabled (Default: Disabled)	RTC Interval selection
RTC Alarm	Enabled, Disabled (Default: Disabled)	RTC Alarm selection
NMI	Enabled, Disabled (Default: Disabled)	NMI selection
NMI Edge	Disabled, Rising Edge, Falling Edge (Default: Disabled)	NMI Edge selection
USBFS	Enabled, Disabled (Default: Disabled)	USBFS selection
UBSHS	Enabled, Disabled (Default: Disabled)	UBSHS selection
AGT1	Enabled, Disabled (Default: Disabled)	AGT1 selection

Note: The example values and defaults are for a project using the Synergy S7G2 MCU Family. Other MCUs may have different default values and available configuration settings.

Table 5. Configuration Settings for Low Power Mode Sleep Driver on r_lpmv2

ISDE Property	Value	Description
Parameter Checking	BSP, Enabled, Disabled (Default: BSP)	Enables or disables the parameter checking
Name	g_lpmv2_sleep0	Module name

Note: The example values and defaults are for a project using the Synergy S7G2. Other MCUs may have different default values and available configuration settings.

Table 6. Configuration Settings for Low Power Mode Standby Driver on r_lpmv2

ISDE Property	Value	Description
Parameter Checking	BSP, Enabled, Disabled (Default: BSP)	Enables or disables the parameter checking
Name	g_lpmv2_standby0	Module name
Choose the low power mode	Standby, Standby with Snooze enabled (Default: Standby)	Low power mode selection
Output port state in standby and deep standby, applies to address output, data output, and other bus control pins	No Change, High Impedance state (Default: No Change)	Output port state selection
Select Standby Exit Sources: Select Fields below		
IRQ0:15	Enabled, Disabled (Default: Disabled)	IRQ0:16 selection
IWDT	Enabled, Disabled (Default: Disabled)	IWDT selection
Key Interrupt	Enabled, Disabled (Default: Disabled)	Key Interrupt selection
LVD1 Interrupt	Enabled, Disabled (Default: Disabled)	LVD1 selection
LVD2 Interrupt	Enabled, Disabled (Default: Disabled)	LVD2 selection

ISDE Property	Value	Description
Analog Comparator High-speed 0 Interrupt	Enabled, Disabled (Default: Disabled)	Analog Comparator selection
RTC Period	Enabled, Disabled (Default: Disabled)	RTC Period selection
RTC Alarm	Enabled, Disabled (Default: Disabled)	RTC Alarm selection
USBFS	Enabled, Disabled (Default: Disabled)	USBFS selection
UBSHS	Enabled, Disabled (Default: Disabled)	UBSHS selection
AGT1 underflow	Enabled, Disabled (Default: Disabled)	AGT1 underflow selection
AGT1 Compare Match A	Enabled, Disabled (Default: Disabled)	AGT1 CMA selection
AGT1 Compare Match B	Enabled, Disabled (Default: Disabled)	AGT1 CMB selection
I2C 0	Enabled, Disabled (Default: Disabled)	I2C 0 selection
Snooze Mode Settings		
Snooze Entry Source	RXD0 falling edge, IRQ0:15, KINT (Key Interrupt), ACMPS0 (High-speed Analog Comparator 0), RTC Alarm, RTC Period, AGT1 Underflow, AGT1 Compare Match A, AGT1 Compare Match B (Default: RXD0 falling edge)	Source of Snooze mode entry
Snooze Exit Sources: Select fields below		
AGT1 Underflow	Enabled, Disabled (Default: Disabled)	AGT1 Underflow selection
DTC Transfer Completion	Enabled, Disabled (Default: Disabled)	DTC Transfer Completion selection
DTC Transfer Completion Negated signal	Enabled, Disabled (Default: Disabled)	DTC Transfer Completion Negated signal selection
ADC0 Compare Match	Enabled, Disabled (Default: Disabled)	ADC0 Compare Match selection
ADC0 Compare Mismatch	Enabled, Disabled (Default: Disabled)	ADC0 Compare Mismatch selection
ADC1 Compare Match	Enabled, Disabled (Default: Disabled)	ADC1 Compare Match selection
ADC1 Compare Mismatch	Enabled, Disabled (Default: Disabled)	ADC1 Compare Mismatch selection
SCI0 Address Match	Enabled, Disabled (Default: Disabled)	SCI0 Address Match selection
DTC State Selection		
DTC state in Snooze Mode	Enabled, Disabled (Default: Disabled)	DTC state in Snooze Mode selection

Note: The example values and defaults are for a project using the Synergy S7G2. Other MCUs may have different default values and available configuration settings.

In some cases, settings other than the defaults can be desirable. For example, it might be useful to select different states for entering or exiting low-power states.

5.1 Low Power Modes V2 HAL Module Clock Configuration

The Low Power Modes V2 peripheral module does not have any selectable clock sources.

5.2 Low Power Modes V2 HAL Module Pin Configuration

The Low Power Modes V2 peripheral module needs no pin assignments. Pin function selections are done in the properties configuration window.

6. Using the Low Power Modes V2 HAL Module in an Application

The typical steps in using the Low Power Modes V2 HAL module in an application are:

1. Initialize the Low Power Modes V2 HAL module using the `lpm_v2_api_t::init` API
2. Configure a low-power mode with the `lpm_v2_api_t::lowPowerCfg` API
3. Enter a low-power mode with the `lpm_v2_api_t::lowPowerModeEnter` API

These common steps are illustrated in a typical operational flow diagram in the following figure:

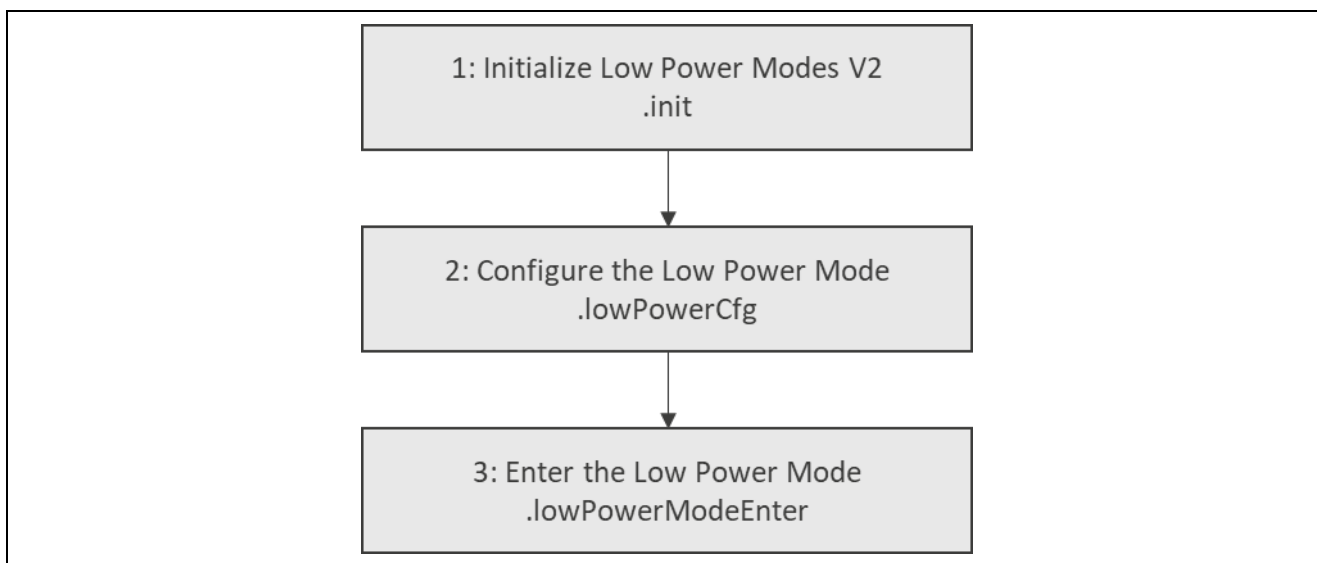


Figure 5. Flow Diagram of a Typical Low Power Modes V2 Module Application

7. The Low Power Modes V2 HAL Module Application Project

The application project associated with this module guide demonstrates the configuration steps in an example application. You may want to import and open the application project within the ISDE and view the configuration settings for the Low Power Modes V2 HAL module. You can also review the code (in `lpm_v2_hal_module_guide_project.c`) which demonstrates the Low Power Modes HAL module APIs in a complete design.

The application project demonstrates the typical use of the Low Power Modes HAL module APIs. The application project demonstration function initializes LEDs and the necessary lower-level modules: the External IRQ HAL module, RTC HAL module and selected Low Power Mode HAL module. When the Deep Software Standby Mode is chosen, there is an additional check, because leaving this mode causes the device to reset.

After the amber LED illuminates, the selected low-power mode is configured and the RTC counter is started. The green LED blinks and the device enters low-power mode. In sleep mode, the device generally wakes on any interrupt. Settings for Software Standby and Deep Software Standby modes specify interrupts from which low-power mode can exit. The application makes use of two interrupts: IRQ11 (S4 push button) and the RTC Period.

When the user presses the S4 button, the previously configured external interrupt is executed, and its service routine is called. The RTC HAL module is configured to emit a period interrupt every two seconds. When the device wakes up, due to the IRQ11 interrupt, the red LED illuminates; when it wakes from the RTC Period interrupt, the green LED blinks. The service routines for these interrupts do not execute when the device enters Deep Software Standby mode.

Table 7. Software and Hardware Resources Used by the Application Project

Resource	Revision	Description
e ² studio	6.2.1 or later	Integrated Solution Development Environment
SSP	1.5.0 or later	Synergy Software Platform
IAR EW for Renesas Synergy	8.23.1 or later	IAR Embedded Workbench® for Renesas Synergy™
SSC	6.2.1 or later	Synergy Standalone Configurator
SK-S7G2	v3.0 to v3.1	Starter Kit

The following two flow diagrams illustrate the modes available in a simple Application project.

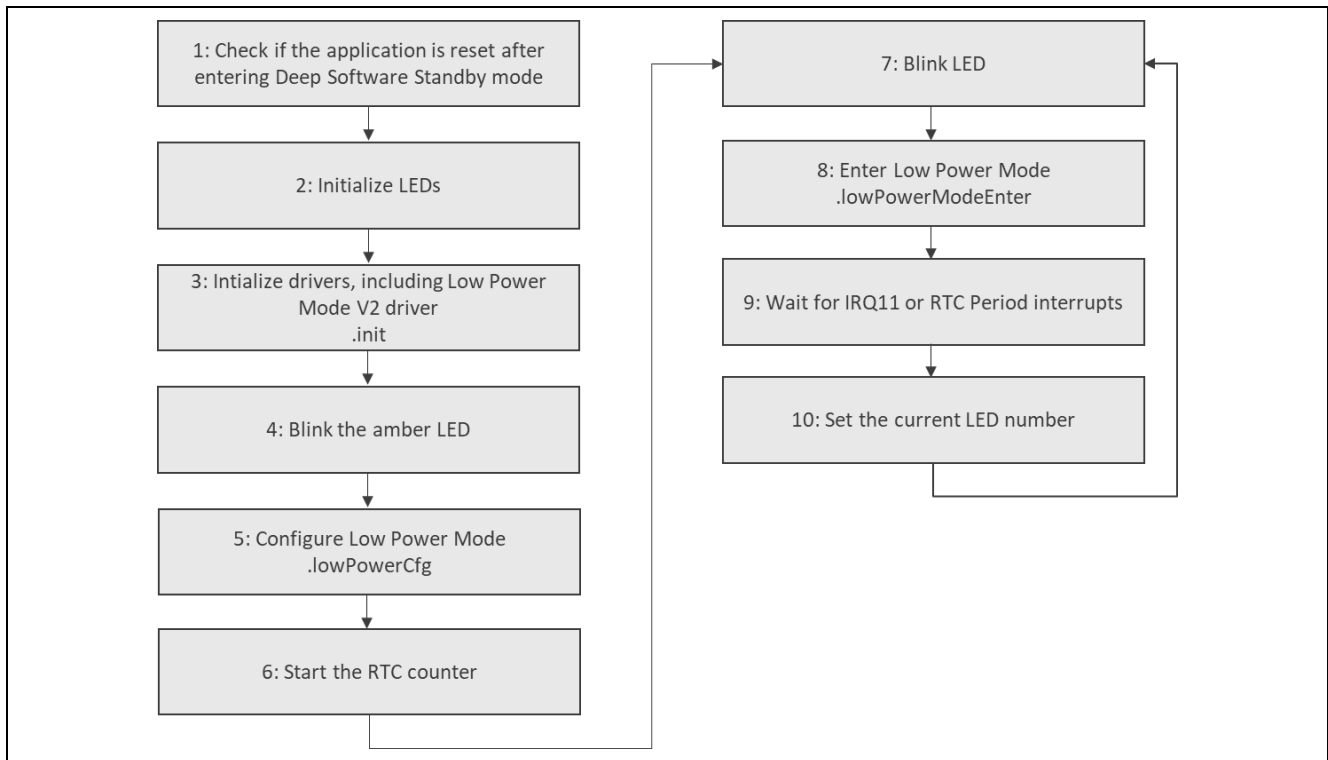


Figure 6. Low Power Modes V2 Module Application Project Flow Diagram (Sleep and Software Standby modes)

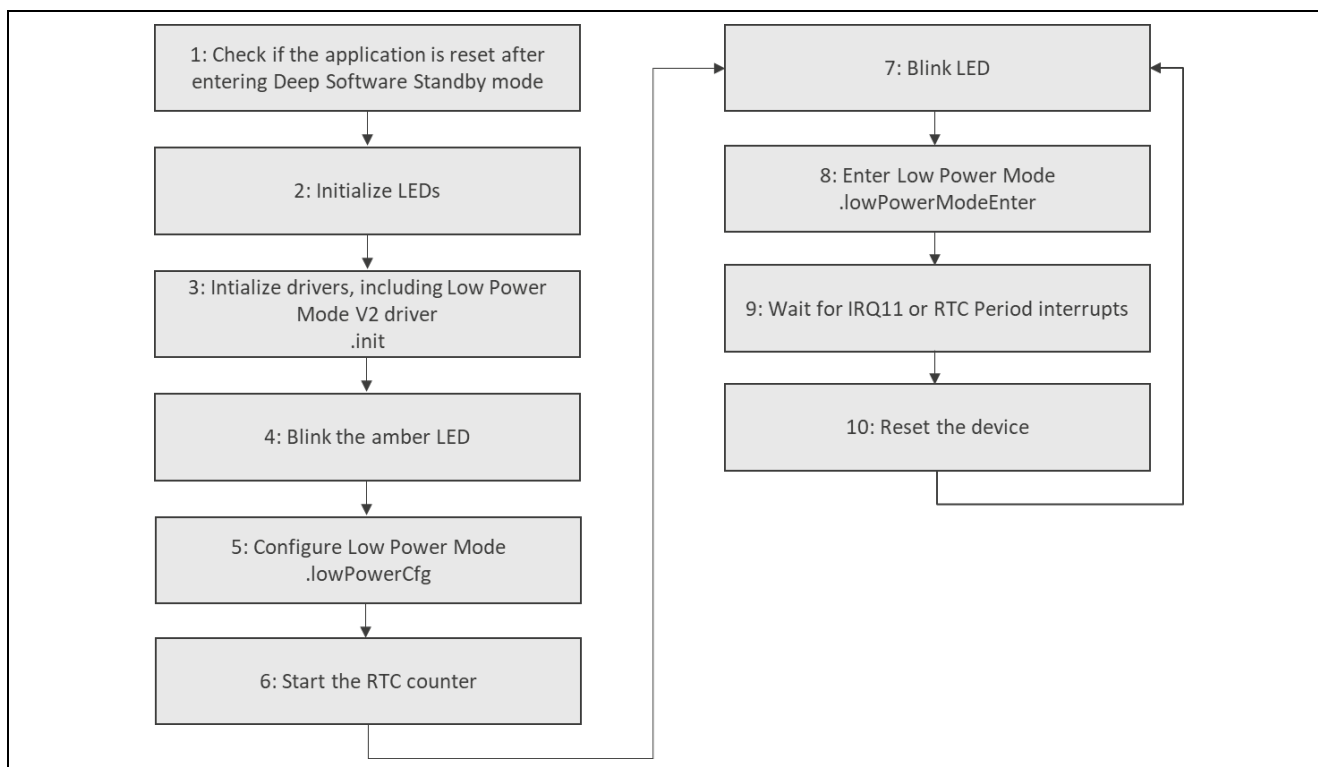


Figure 7. Low Power Modes V2 Module Application Project Flow Diagram (Deep Software Standby mode)

The `lpm_v2_hal_module_guide_project.c` file is located in the project once it has been imported into the ISDE. You can open this file within the ISDE and follow along with the description provided to help identify key uses of APIs.

The first section of `lpm_v2_hal_module_guide_project.c` has the header files which reference the LPM instance structure. Next, some macro constants are defined. The `LPM_MODE` definition should be used to select the low-power mode. After this definition, there are other macros which help to run the application project on other Synergy boards. The next section has function prototypes, and their bodies follow. The first one is used for LED initialization; it gets the BSP LED information and checks if there are at least two LEDs and turns off all the LEDs. The second function initializes the External IRQ HAL module (for S4 button handling), RTC HAL module, and Low Power Modes V2 HAL module. The third function checks if the device has just left Deep Software Standby mode and clears the flags in Deep Software Standby mode registers.

The next section is the entry function for the main program-control section. The necessary initialization is performed, and the selected Low Power Mode is configured. Inside the ‘forever’ while loop, the currently set LED blinks, and the low-power mode is entered and waits for an interrupt. After waking up, the while loop functions are repeated.

The last section contains callback functions for the IRQ11 and RTC Period interrupts; they change the current LED number. When the execution of this callback ends, the MCU is awake.

(Note that when Deep Software Standby mode is used and one of the configured interrupts occur, the device will be reset and hence the callback will not be called.)

Since the application project uses low-power modes, some options must be set in order to provide handling of these modes when debugging. Otherwise, the device will always enter sleep mode regardless of the selected mode, and after entering low-power mode, the debug connection can be lost.

In the e² studio Integrated Solution Development Environment (ISDE), perform the following steps to change settings:

1. Select the project as active and choose **Run > Debug Configurations**.
2. Mark a project-related debug configuration on the left and select the **Debugger** tab on the right.
3. Go to the **Connection Settings** tab.

4. In **Script File**, setting select the **CM_low_power_debug.JLinkScript** script attached with the application project. (It is important that the path to this script does not contain any space.)
5. Set **Yes** in the Low-Power Handling setting.

In IAR Embedded Workbench® for Renesas Synergy™ perform the following steps to change settings:

1. Select the project as active and choose **Project > Options**.
2. Select **Debugger** on the left sidebar and the **Setup** tab on the right.
3. Check **Use macro file(s)** and select the **low_power_debug.mac** file attached with the application project.
4. Open the **settings/LPM_V2_HAL_MG_AP_Debug.jlink** file.
If the file does not exist, attach the debugger to the device and disconnect. The file is created when attaching to the device for the first time.
5. Change the following line:
LowPowerHandlingMode = 0 to: **LowPowerHandlingMode = 1**
6. Save the file.

A few key properties configured in this application project support the required operations and the physical properties of the target board and MCU device. The following tables list properties with values set for this specific project. You can also open the application project and view these settings in the Properties window as a hands-on exercise.

Table 8. Low Power Mode V2 Sleep Module Configuration Settings for the Application Project

ISDE Property	Value Set
Parameter Checking	Default (BSP)
Name	g_lpmv2_sleep

Table 9. Low Power Mode V2 Standby Module Configuration Settings for the Application Project

ISDE Property	Value Set
Parameter Checking	Default (BSP)
Name	g_lpmv2_standby
Choose the low power mode	Standby
Output port state in standby and deep standby, applies to address output, data output, and other bus control output pins	No change
Select Standby Exit Sources: Select fields below	
IRQ0:10	Disabled
IRQ11	Enabled
IRQ12:15	Disabled
IWDT, Key Interrupt, LVD1:2 Interrupt, Analog Comparator High-speed 0 Interrupt, RTC Alarm	Disabled
RTC Period	Enabled
USB High-speed, USB Full-speed, AGT1 underflow, AGT 1 Compare Match A/B, I2C 0	Disabled
Snooze Mode Settings	
Snooze Entry Source	RXD0 falling edge
Snooze Exit Sources: Select fields below	
AGT1 Underflow, DTC Transfer Completion, DTC Transfer Completion Negated signal, ADC0 Compare Match, ADC0 Compare Mismatch, ADC1 Compare Match, ADC1 Compare Mismatch, SCIO Address Match	Disabled
DTC state in Snooze Mode	Disabled

Table 10. Low Power Mode V2 Deep Standby Module Configuration Settings for the Application Project

ISDE Property	Value Set
Parameter Checking	Default (BSP)
Name	g_lpmv2_deep_standby
Choose the low power mode	Standby
Output port state in standby and deep standby, applies to address output, data output, and other bus control output pins	No change
Maintain or reset the IO port states on exit from deep standby mode	Maintain the IO port states
Deep Standby Cancel Sources/Edges: Select fields below	
IRQ0:10	Disabled
IRQ11	Enabled
IRQ11 edge	Rising edge
IRQ12:15	Disabled
LVD1:2	Disabled
RTC Interval	Enabled
RTC Alarm, NMI, USBFS, USBHS, AGT1	Disabled

Table 11. RTC Driver Module Configuration Settings for the Application Project

ISDE Property	Value Set
Parameter Checking Enable	Default (BSP)
Name	g_rtc
Clock Source	LOCO
Error Adjustment Value [DEPRECATED]	0
Error Adjustment Type [DEPRECATED]	None
Callback	rtc_callback
Alarm Interrupt Priority	Disabled
Period Interrupt Priority	Priority 5 (CM4: valid, CM0+: invalid)
Carry Interrupt Priority	Disabled

Table 12. External IRQ Driver Module Configuration Settings for the Application Project

ISDE Property	Value Set
Parameter Checking	Default (BSP)
Name	g_external_irq11
Channel	11
Trigger	Rising
Digital Filtering	Enabled
Digital Filtering Sample Clock	PCLK / 64
Interrupt enabled after initialization	True
Callback	irq11_callback
Interrupt Priority	Priority 5 (CM4: valid, CM0+: invalid)

8. Customizing the Low Power Modes V2 HAL Module for a Target Application

Some configuration settings will normally be changed by the developer from those shown in the application project. For example, the user may configure different exit sources for Standby or Deep Standby modes.

To help with customization efforts, examples of specific low power applications are available on the LPM_V2 Knowledge Base article, available as described in the Reference Information section at the end of this document.

9. Running the Low Power Modes V2 HAL Module Application Project

To run the Low Power Modes V2 HAL module application project and to see it executed on a target kit, you can simply import it into your ISDE, compile and run debug. Refer to the Synergy Project Import Guide (r11an0023eu0121-synergy-ssp-import-guide.pdf), included in this package for instructions on importing the project into e² studio ISDE or the IAR EW for Synergy, and then building/running the application.

To implement the Low Power Modes application in a new project, use the following steps for defining, configuring, auto-generating files, adding code, compiling and debugging on the target kit. The steps offer a hands-on approach that helps to make the development process with SSP more practical.

Note: The tasks are given in sufficient detail for someone experienced with the basic flow through the Synergy development process. If these steps are not familiar, refer to the first few chapters of the SSP User's Manual for a description of how to accomplish these steps.

To create and run the Low Power Modes V2 HAL module application project, follow these steps:

1. Create a new Renesas Synergy project for the S7G2-SK called LPM_V2_HAL_MG_AP.
2. Select the **Threads** tab.
3. Add the External IRQ HAL module to the HAL/Common thread.
4. Add the S7G2 Low Power Mode Sleep Driver to the HAL/Common thread.
5. Configure the added blocks according to the preceding tables.
6. Click on the **Generate Project Content** button.
7. Add the code from supplied project files: `hal_entry.c`, `lpm_v2_hal_module_guide_project.c`, and `lpm_v2_hal_module_guide_project.h`. Alternatively, copy over the generated `hal_entry.c`, `lpm_v2_hal_module_guide_project.c`, and `lpm_v2_hal_module_guide_project.h` files.
8. Select low-power mode in the `lpm_v2_hal_module_guide_project.c` file using the `LPM_MODE` macro.
9. Enable low-power modes handling in the editor by following the preceding instructions.
10. Connect to the host PC using the USB cable (use J19 DEBUG_USB connector).
11. Start to debug the application.
12. The output can be viewed on onboard LEDs. Use S4 button to blink an LED.

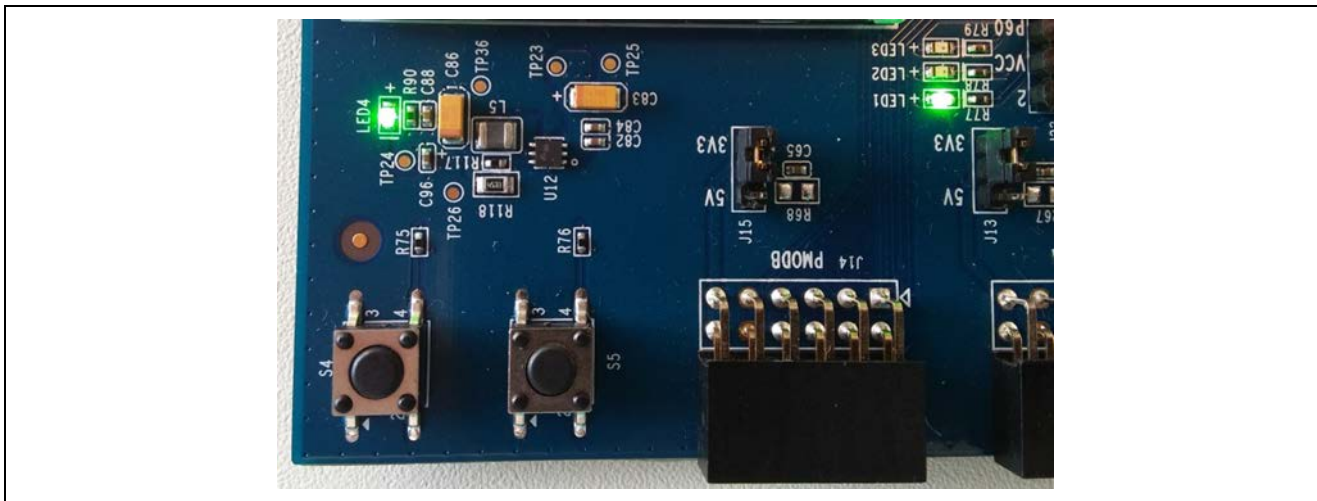


Figure 8. Example Output from the Low Power Modes V2 Module Application Project

10. Low Power Modes V2 HAL Module Conclusion

This module guide has provided all the background information needed to select, add, configure and use the module in an example project. Many of these steps were time consuming and error-prone activities in previous generations of embedded systems. The Renesas Synergy Platform makes these steps much less time consuming and removes the common errors, like conflicting configuration settings or the incorrect selection of lower-level drivers. The use of high-level APIs (as demonstrated in the application project) illustrates additional development time savings by allowing work to begin at a high level and avoiding the time required in older development environments to use or, in some cases, create, lower-level drivers.

11. Low Power Modes V2 HAL Module Next Steps

After you have mastered a simple Low Power Modes V2 HAL module project, you may want to review a more complex example. You may find that disabling the clocks is necessary; the CGC HAL module is able to reconfigure or switch the clocks on and off. The module guide for the CGC HAL module is available to download, simply follow the instructions in the References section at the end of this document.

12. Low Power Modes V2 HAL Module Reference Information

SSP User Manual: Available in HTML format at www.renesas.com/us/en/products/synergy/software/ssp.html as a SSP distribution package, and also as a pdf from the Synergy Gallery.

Links to all the most up-to-date r_lpm2 module reference materials and resources are available on the Synergy Knowledge Base: <https://en-support.renesas.com/knowledgeBase/16977494>

Website and Support

Visit the following vanity URLs to learn about key elements of the Synergy Platform, download components and related documentation, and get support.

Synergy Software	www.renesas.com/synergy/software
Synergy Software Package	www.renesas.com/synergy/ssp
Software add-ons	www.renesas.com/synergy/addons
Software glossary	www.renesas.com/synergy/softwareglossary
Development tools	www.renesas.com/synergy/tools
Synergy Hardware	www.renesas.com/synergy/hardware
Microcontrollers	www.renesas.com/synergy/mcus
MCU glossary	www.renesas.com/synergy/mcuglossary
Parametric search	www.renesas.com/synergy/parametric
Kits	www.renesas.com/synergy/kits
Synergy Solutions Gallery	www.renesas.com/synergy/solutionsgallery
Partner projects	www.renesas.com/synergy/partnerprojects
Application projects	www.renesas.com/synergy/applicationprojects
Self-service support resources:	
Documentation	www.renesas.com/synergy/docs
Knowledgebase	www.renesas.com/synergy/knowledgebase
Forums	www.renesas.com/synergy/forum
Training	www.renesas.com/synergy/training
Videos	www.renesas.com/synergy/videos
Chat and web ticket	www.renesas.com/synergy/resourcelibrary

Revision History

Rev.	Date	Description	
		Page	Summary
1.00	Jun.08.17		Initial version
1.01	Aug.23.17		Update to Hardware and Software Resources Table
1.02	Feb.08.19		Updated to SSP v1.5.0

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