Renesas RA Family

Getting Started with Low Power Applications for RA6 and RA4 Groups

Introduction

This Application Note describes how you can reduce the adequate power consumption of the RA Microcontroller using Low Power Modes (LPMs). Two accompanying application projects show typical use cases of entering Low Power Modes and configuring the various peripherals to exit the entered mode. Upon completing this guide, you can add an LPM module to your design, configure it correctly for the target application, and write code using the included application project as a reference and efficient starting point.

- This application note describes LPM module usage in different modes and supported peripherals.
- Application overview for the different use cases.
- FSP configuration steps for LPM.
- Application design highlights.
- Importing, loading, and running the application project.
- Project migration steps to other RA Kits.

Required Resources

- e^2 studio IDE v2024-01.1
- Flexible Software Package (FSP) v5.2.0
- J-Link RTT viewer V7.94g

Primary Target Devices

- EK-RA6M3 kit
- FPB-RA6E1 board
- FPB-RA4E1 board

Table 1. RA Kits Tested with LPM Application

Kit	Operable Long Timer in LPM	LPM Transition and Clock Changing at Run-Time
EK-RA6M3	Yes	Yes
FPB-RA6E1	Yes	Yes
FPB-RA4E1	Yes	Yes
EK-RA6M2	Yes	Yes
EK-RA6M1	Yes	Yes
EK-RA4M1	Yes	Yes
EK-RA2A1	Yes	Yes
EK-RA2L1	Yes	Yes

Contents

1. Application Overview

Application projects accompanying this document serve as references to operate the microcontroller (MCU) in various Low Power Modes demonstrating different levels of power consumption often required to maximize battery life.

For ease of understanding the LPM, these application projects cover the different Low Power Modes with varying settings of clock to showcase each mode, operation of different peripherals in an LPM, required pin configurations, trigger/end source configuration, and a user interface to initiate transition to different LPM states and switch back to Normal mode. The configuration for each mode is maintained as an independent instance. Users can use these example configurations and change settings to trigger/end operation as desired.

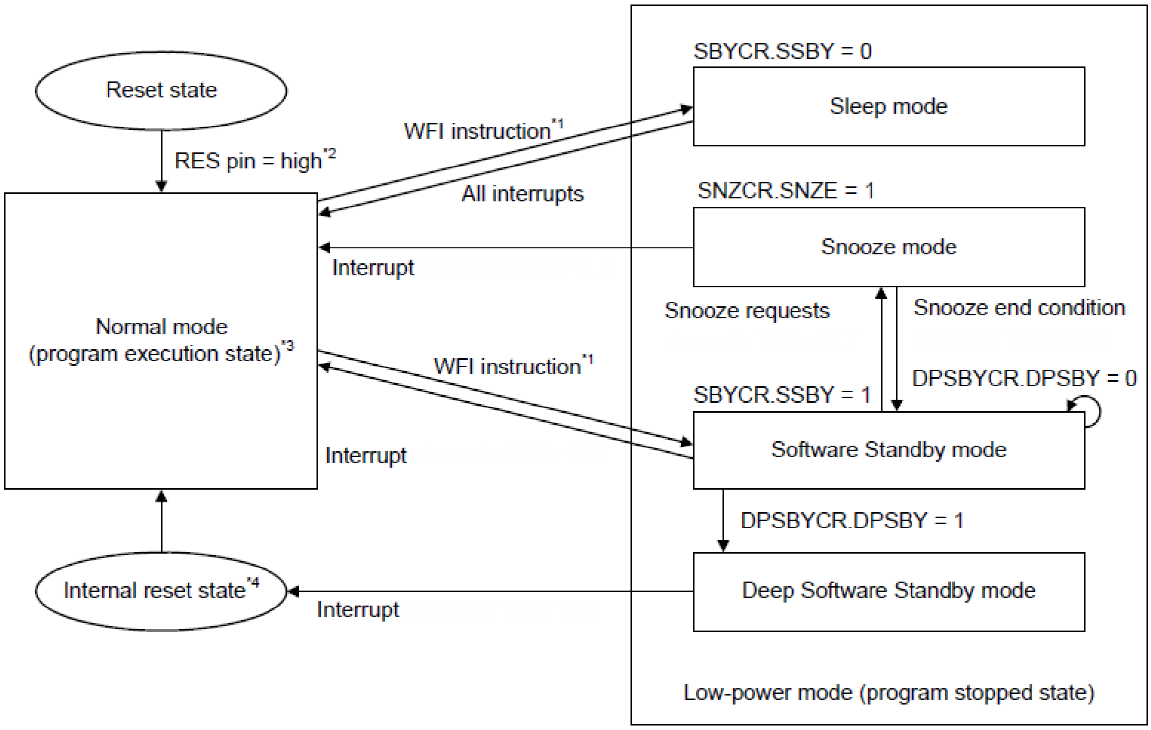
In addition to the LPM, the application also supports changing the source clock of the MCU dynamically and running LPM for these clocks.

1.1 Low Power Modes

RA MCUs support four different types of LPM depending on the MCU family. These are:

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

Low power mode transition and triggering sources for RA MCUs are illustrated in Figure 1. See the User's Manual for the specific MCU for more details on these transitions.



Note 1. When an interrupt that acts as a trigger for cancel is received during a transition to the program stopped state after the execution of a WFI instruction, the MCU executes interrupt exception handling instead of transitioning to low power mode.
Note 2. The MOCO clock is the source of the operating clock following a transition from the reset state to Normal mode.
Note 3. The transition to Normal mode is made because of an interrupt from Sleep, Snooze, or Software Standby mode. The clock source is the same as before entering the low power mode.
Note 4. When an available interrupt request is generated, an internal reset (Deep Software Standby reset) is generated over a fixed period. Canceling of Deep Software Standby mode accompanies release from the internal reset state, and then the MCU transitions to Normal mode and execute a reset exception processing with the MOCO clock as the source of the operating clock.

Figure 1. LPM Transition Diagram for RA6M3

In LPM, the CPU stops, but on-chip peripherals and oscillator states may be operational depending on the LPM selected. Therefore, their effects on MCU power consumption are very different. The typical current consumption when the MCU is in a Low Power Mode is found in the MCU Hardware User's Manual section on Operating and Standby Current. Figure 2 shows the typical power consumption when the MCU is in a Low Power Mode vs throughput.

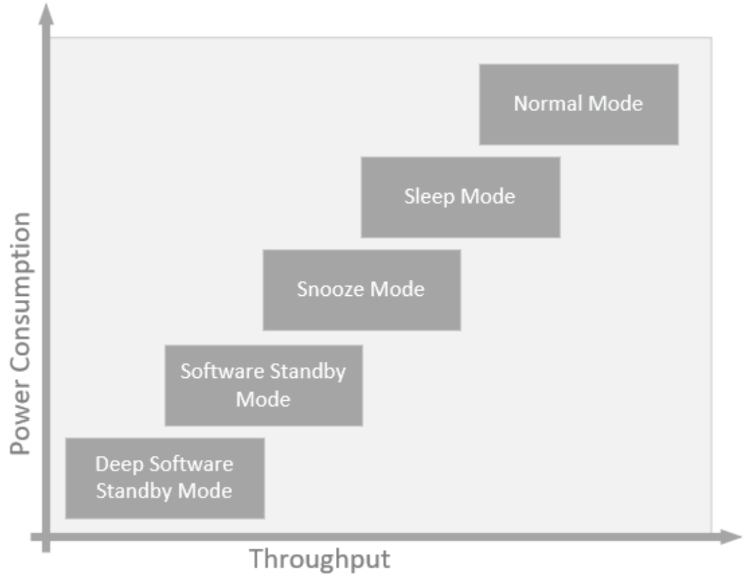


Figure 2. Power Consumption and Throughput of the LPM

In order for the MCU to enter or exit the LPM, associated special function registers need to be configured. This application note does not focus on the bit-level configuration details since the bits can be configured using the API provided by the FSP. The API provided by the FSP is documented in the FSP User's Manual. To explore the LPM and its supported list of peripherals and interrupts, refer to the Low Power Modes section in the RA MCU Datasheet. Low Power Modes commonly available with RA MCUs are described next.

1.1.1 Sleep Mode

An operational CPU is typically the primary cause of power consumption. In Sleep mode, the CPU stops operating, but the contents of its internal registers are retained. Other peripheral functions in the MCU do not stop. Available resets or interrupts in Sleep mode can cause the MCU to cancel Sleep mode. All interrupt sources are available in this mode to cancel the Sleep mode. When using an interrupt to cancel Sleep mode successfully, you must set the associated IELSRn register before executing a WFI instruction.

1.1.2 Software Standby Mode

In Software Standby mode, the CPU, most of the on-chip peripheral functions, and the oscillators stop operation. However, the contents of the CPU internal registers and the SRAM data, the states of the on-chip peripheral functions, and the I/O port states are retained. Software Standby mode significantly reduces power consumption since most of the oscillators stop in this mode.

1.1.3 Snooze Mode

The Snooze feature provides operational flexibility to reduce current consumption dramatically. Snooze is an extension to the Software Standby mode, where limited peripheral modules can operate without waking up the CPU. The Snooze mode can be entered through the Software Standby mode via configured interrupt sources, and similarly, it is woken up from Snooze mode by interrupts supported in the Snooze mode.

1.1.4 Deep Software Standby Mode

In Deep Software Standby mode, the CPU and on-chip peripheral functions are stopped except for some internal modules. Current consumption is reduced since the internal power supply to these modules is stopped before entering Deep Software Standby mode. The contents of all the CPU registers and internal peripheral modules, except for the RTC alarm, RTC interval, and USB suspend/resume detecting unit, become undefined.

1.2 Activation and Cancel Sources

Low power modes are canceled by various interrupt sources such as RES pin reset, power-on reset, voltage monitor reset, and peripheral interrupts. Refer to the Low Power Modes section in Renesas RA MCU User's Manual for a list of interrupt sources for different LPMs.

For Deep Software Standby mode, the reset cause can be identified via the DPSRSTF flag bit in the Reset Status Register0 (RSTSR0).

Only Snooze mode is triggered by a Snooze request to enter Snooze mode from Software Standby mode. The transitions to other LPMs are done by executing a WFI instruction with appropriate settings in the Standby Control register (SBYCR).

1.3 Peripheral Operation in LPM

Not all the MCU peripherals are available in different LPMs. MCU peripherals also have different setting retention capabilities during the different LPMs. For example, the contents of the internal registers may be retained in some LPMs, but the contents may be undefined in other modes. Depending upon the application, users must choose the peripherals and LPM settings for maximum power savings. Users must also turn off/disable oscillators and on-chip peripherals that are not clock-gated or powered off to maximize power savings. Refer to the Low Power Modes section in each RA MCU User's Manual: Hardware to understand different oscillators and peripherals available in a specific LPM.

The following sections will discuss the use case scenarios for the different LPMs with different clock settings and peripherals.

1.4 Use Case: Changing Clocks at Run-Time

This application use case describes how to dynamically change the RA MCU clock and set it to different clock settings supported by the RA MCU using the FSP CGC HAL driver APIs. While the user can configure the Clock Generation Circuits (CGC) within the MCU using the RA FSP Clock Configurator, in many applications where a battery eventually powers the MCU, there is an inherent requirement to change the clock configuration settings as the MCU is running. Based on the desired set of clock sources, the MCU changes to a different clock source and operates normally without rebooting.

Changing the system clock affects the peripherals, which use derivatives of the system clock as a source and other clocks in the system. Users are advised to select the dividers that apply to the system. When changing the clock, make sure that stabilization with the proper settling time is in place. This stabilization time is designed for the CGC HAL Driver.

This application uses the user switch input to change the MCU clock mode from the previously running clock to the desired clock. The new clock settings are applied and displayed via the RTT interface for the user notification.

Table 2 shows the available user-selectable clock settings in the application.

Table 2. User Selectable Clock

Clock Source	Description
MOSC	Main Oscillator Clock
HOCO	High speed on-chip Oscillator
MOCO	Medium Speed on-chip Oscillator
LOCO	Low Speed on-chip Oscillator
SOSC	Sub Oscillator Clock

Note: By default, MOSC and SOSC are not supported on FPB-RA6E1 and FPB-RA4E1.

The sequence of the clocks being configured is MOSC→HOCO→MOCO→LOCO→SOSC→MOSC. The objective of this use case is to show the different clock sources that can be changed during run time without halting the MCU. Changing the clock dynamically is accomplished using the RA CGC HAL driver API `R_CGC_ClocksCfg`. For more details on CGC HAL driver API, refer to the FSP User's Manual.

1.5 Use Case: LPM Transition at Run-Time

This use case shows the different LPMs supported by the MCU for the other clock settings.

The application requires the user to push the button switch input to change the LPM available for the MCU and perform transitions as programmed. The supported LPM and its transitions to the different LPMs are displayed using the RTT interface for notifying the user. The application also showcases the use of a few peripherals, like the AGT timer and RTC operating in different LPMs, and regularly displays the RTC time information when MCU transitions to the normal mode from the LPM. The AGT1 Timer is used in the Snooze mode to alternate between Software Standby and Snooze modes. RTC Alarm interrupt is used to cancel the Software Standby mode and enter normal mode. IRQn (User Switch Interrupt) cancels the Sleep and Deep Software Standby modes.

The visual indication of the LPM transition can also be seen with the User LED on the board. When the LED blinks approximately every 1 second, it runs in Normal mode. If the LED is turned OFF, it is in an LPM.

Note: More details on the application are explained in the architecture section 4.1 .The peripherals used in the application are just a few available for the MCU. For the complete list of peripherals supported in the LPM, refer to the LPM section of the MCU datasheet.

Different clock sources and LPMs supported for the RA MCUs are shown in Table 3.

Table 3. Clock Sources and Supported LPM for RA MCUs

Clock Source Supported	LPM Supported	LPM Supported
	MCU	
	RA6M3, RA6M2, RA6E1, RA4E1	**RA2A1**
MOSC	SLEEP, SW_STNDBY, SNOOZE, DEEP_SW_STANDBY	SLEEP, SW_STNDBY, SNOOZE
HOCO	SLEEP, SW_STNDBY, SNOOZE, DEEP_SW_STANDBY	SLEEP, SW_STNDBY, SNOOZE
MOCO	SLEEP, SW_STNDBY, SNOOZE, DEEP_SW_STANDBY	SLEEP, SW_STNDBY, SNOOZE
LOCO	SLEEP, SW_STNDBY, SNOOZE, DEEP_SW_STANDBY	SLEEP, SW_STNDBY, SNOOZE
SOSC	SLEEP, SW_STNDBY, SNOOZE, DEEP_SW_STANDBY	SLEEP, SW_STNDBY, SNOOZE

Note: By default, MOSC and SOSC are not supported on FPB-RA6E1 and FPB-RA4E1.

Transitioning to the different LPMs is accomplished by using the RA LPM HAL driver API `R_LPM_LowPowerModeEnter`. More details of this API can be found in the FSP User's Manual.

1.6 Use Case: Operable Long Timer in Software Standby and Deep Software Standby Modes

The Operable Long Timer in Software Standby and Deep Software Standby modes require a timer that can operate in a Low Power mode. The count source of the timer is another element that should be considered carefully. In Renesas RA MCUs, the 16-bit Asynchronous General-Purpose Timer channel 0 (AGT0) and 16-bit channel 1 (AGT1) can be used in cascade mode to create a 32-bit timer. In cascade mode, AGT0 Underflow Interrupt will trigger the counter of AGT1. The AGT0 count source can be the sub-clock oscillator or LOCO clock, available in both Software Standby and Deep Software Standby modes. The AGT1 Underflow Interrupt is used to wake the MCU up from LPM.

The maximum period of the 16-bit AGT timer channel 0 with the sub-clock count source running at 32.768 kHz is approximately 2.0 seconds. The Operable Long Timer with two AGT timer channels in cascade mode will have a maximum period of approximately 2184.5 hours with a timer resolution of 30.517 µs.

Note: If a longer wakeup time is required, the RTC can be used via the RTC alarm, but here, the resolution of the timer is limited to 1 second.

2. LPM HAL Module

The LPM HAL module in FSP provides a method to include the LPM driver into the application and to configure them for different modes. It also configures different trigger/cancel signals required for LPM activation/cancellation. FSP also provides essential APIs to configure and place the MCU in Low Power modes. It supports the following Low Power modes:

- Deep Software Standby mode (on supported MCUs)
- Software Standby mode
- Sleep mode
- Snooze mode

It also supports reducing power consumption in Deep Software Standby mode through internal power supply control and resetting the states of I/O ports.

3. FSP Configuration

When developing an FSP application in e[2] studio, first configure the FSP using the RA Configurator. To properly configure the FSP, you must have detailed knowledge of both the software design you will be implementing and the specific hardware it will be running on. This includes the peripherals used on the hardware and the pins they are mapped to, internal or external to the MCU. From the software perspective, you need to add the HAL modules for the peripherals you use and decide how many threads will be used and what additional software objects like semaphores, queues, and so on each thread will require. Once you have this information, you will be ready to successfully configure the FSP for your specific application needs.

In an application using FSP, the FSP configuration is stored in a file named `configuration.xml`. Double-clicking on this file opens the **RA Configuration** tab for the project.

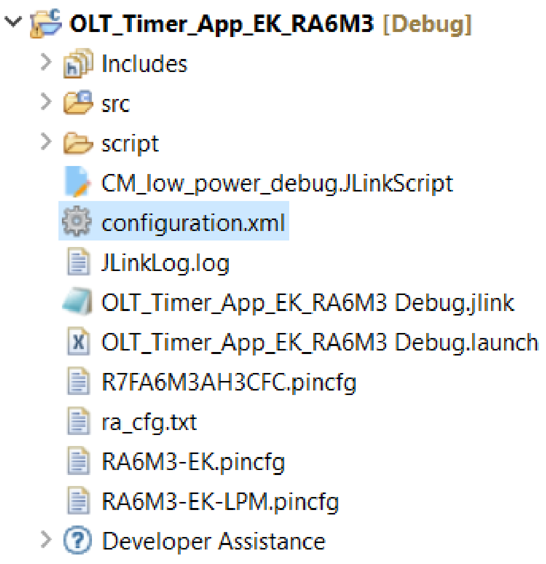


Figure 3. configuration.xml on the Project Plane

When a project is built from scratch, this configuration tab is where you will perform the initial configuration of the FSP. As shown in Figure 4The RA Configuration pane contains a Summary screen highlighting the items you may configure, along with a scrolling window listing all the software components currently selected for this project. Below this scrolling window are tabs that allow you to tailor the FSP to the needs of your specific application. The FSP user's manual provides more details on using the FSP configurator.

For the purposes of this application note, we will highlight a few of the details of the FSP properties, such as the r_lpm driver, r_rtc driver, and r_agt driver modules, as they are key components operated in the use cases provided in the application.

When you have configured the project appropriately, click Generate **Project Content**, the green arrow button above the summary screen, to build all the auto-generated files necessary to implement the components you defined.

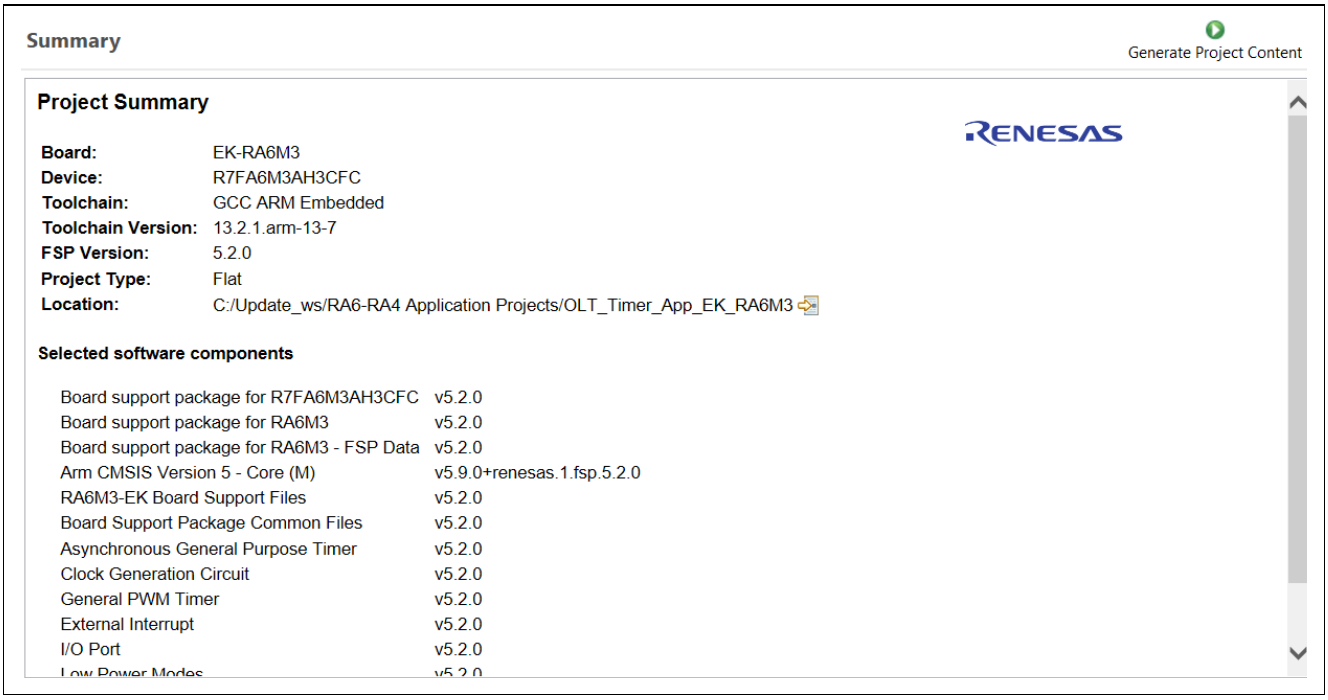


Figure 4. Summary of the Operable Long Timer Configuration

3.1 BSP Tab

For the Operable Long Timer Application, as you can see in Figure 5, the **RA Configuration** pane contains a **Summary** screen highlighting the items you may configure in the BSP tab, **Properties > RA Common > Subclock Populated** should be selected as **Not Populated**.

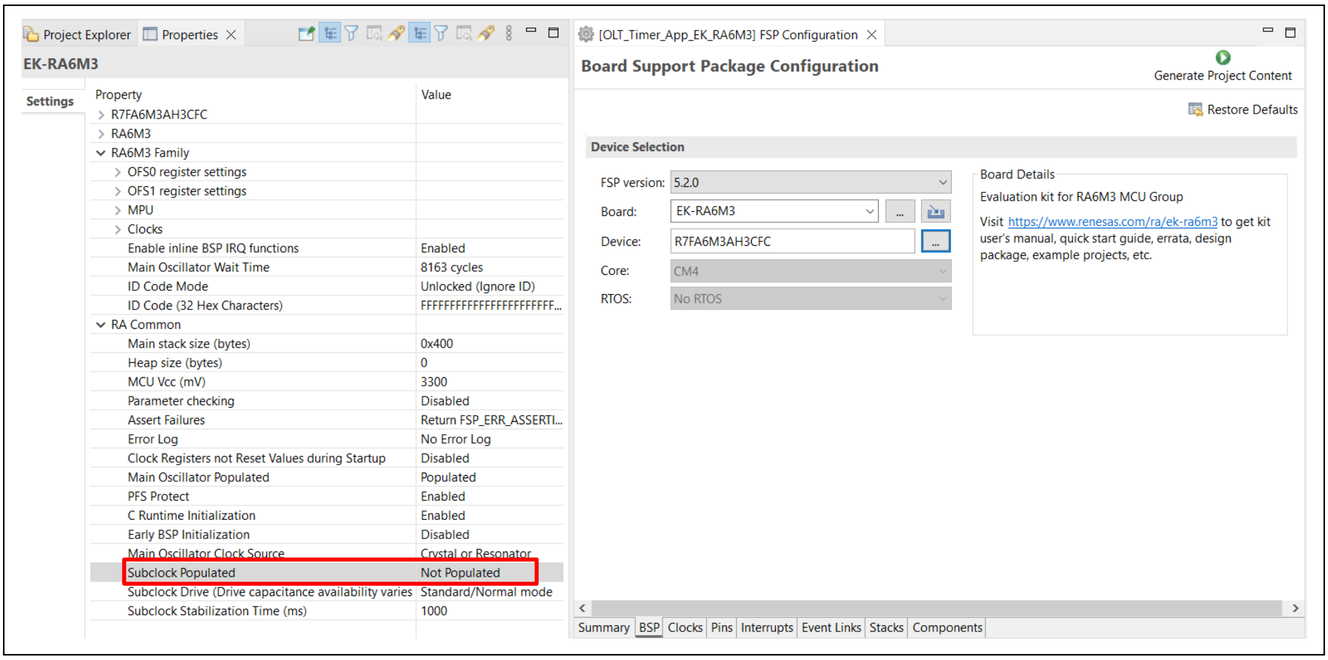


Figure 5. BSP Settings of the Operable Long Timer

Note: This setting is required only for the Operable Long Timer Application.

3.2 Components Tab

Even though the **Components** tab is the last tab showing, it is important to visit and verify that the configured components are checked against the desired FSP version. Components are automatically selected when the modules are added in the **Stack** tab specific to the application. As the final step to verify the chosen components, it is a good practice to confirm these selections are checked in the **Components** tab. One of the advantages of the FSP is that it will only compile the components you choose, thereby reducing the size of your overall application. As shown in Figure 6, components are broken down into seven categories.

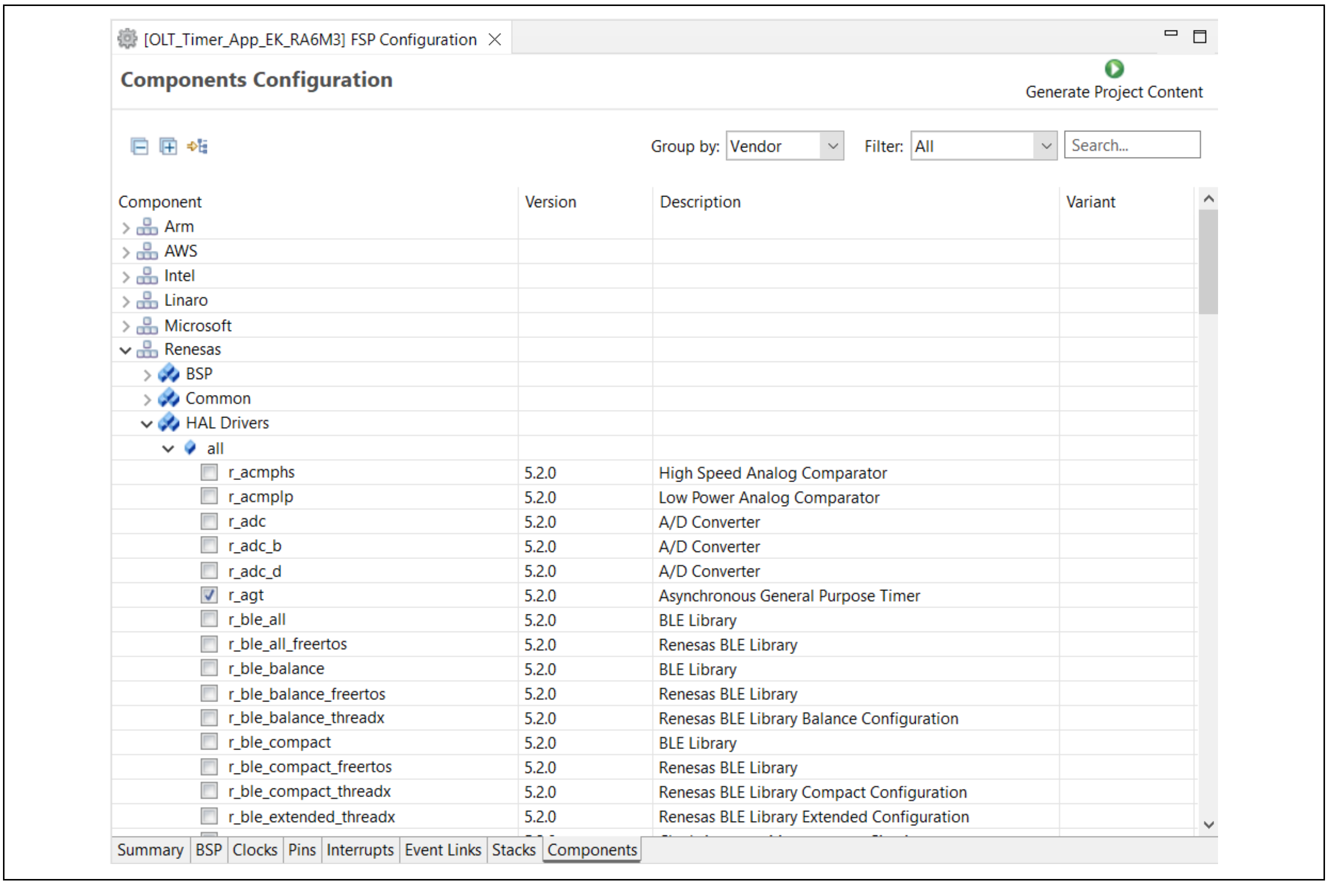


Figure 6. Components Tab Categories

You may expand any categories by clicking the arrow to the left of the category name. The following table highlights the selections used for the LPM applications.

Table 4. Components Used in the LPM Applications

Category	Component	Version	Description
BSP	`ra6m3_ek`	5.2.0	RA6M3-EK Board Support Package Files
CMSIS	`CoreM`	5.9.0+renesas.1.fsp.5.2.0	Arm CMSIS Version5 - Core (M)
Common	`fsp_common`	5.2.0	Board Support Package Common Files
HAL Drivers	`r_cgc`	5.2.0	Clock Generation Circuit
	`r_ioport`	5.2.0	I/O Port
	`r_lpm`	5.2.0	Low Power Modes
	`r_icu`	5.2.0	External Interrupt
	`r_gpt`	5.2.0	General PWM Timer
	`r_agt`	5.2.0	Asynchronous General-Purpose Timer
	`r_rtc`	5.2.0	Real Time Clock

3.3 Stacks Tab

The **Stacks** tab allows you to add and configure the threads that the FSP automatically creates for your application. You define a new thread by clicking the button and then entering a unique name for your new thread. Once you add a new thread, you must define the modules that the thread will use along with any thread objects used by your application thread.

As an example, if you click the **Stacks** tab and then single-click on the **HAL/Common** thread, you should see something like the screen capture shown in Figure 7. This shows that the application requires multiple drivers. For example, the r_lpm driver is the driver for Low Power Modes of a Renesas RA MCU. The LPM applications do not use RTOS, hence there is only one HAL/Common thread is available in this type of application.

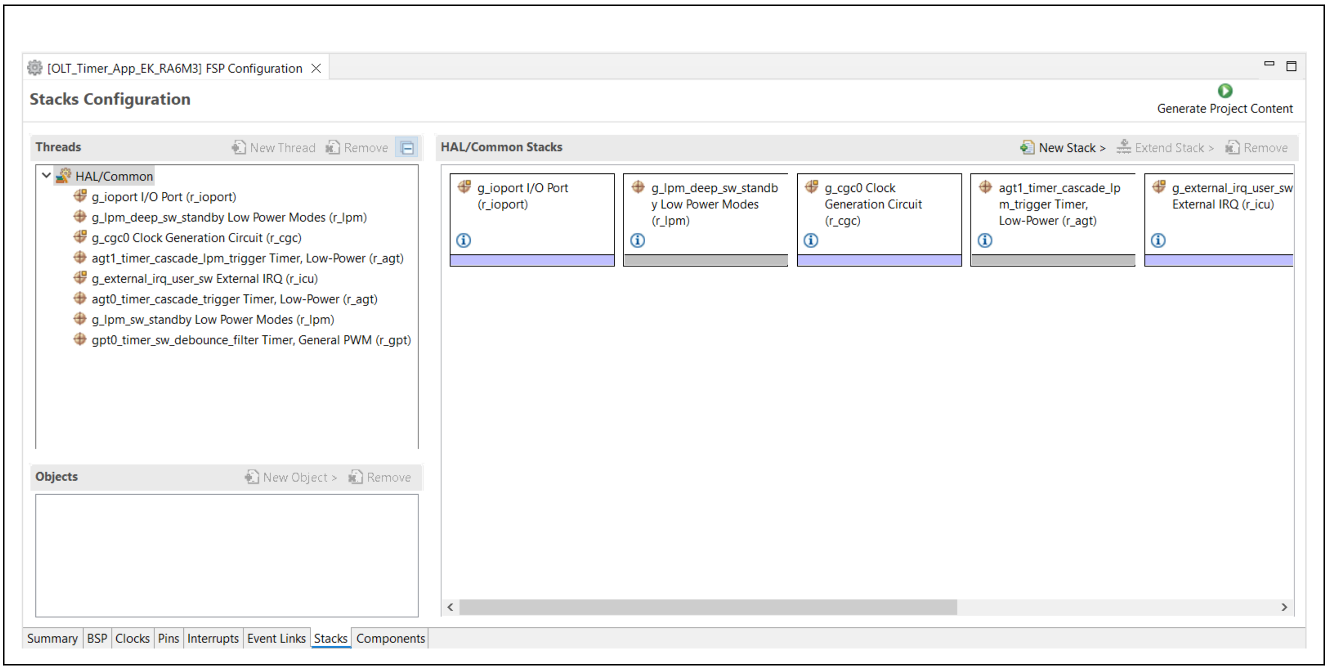


Figure 7. Drivers Usage in LPM Application

You can add additional modules to a thread by clicking the  button. As an example, Figure 8This shows you how to add an AGT timer. You add the timer by choosing **(+) New Stack** > **Timers** > **Timer, Low-Power (r_agt)**.

If you pick a module you have not preselected, the appropriate component for the module will be automatically selected by FSP for you. If the configurator tool detects errors due to incorrect settings with the module addition, it presents the module with a mistake. You may examine the errors by hovering over the module name.

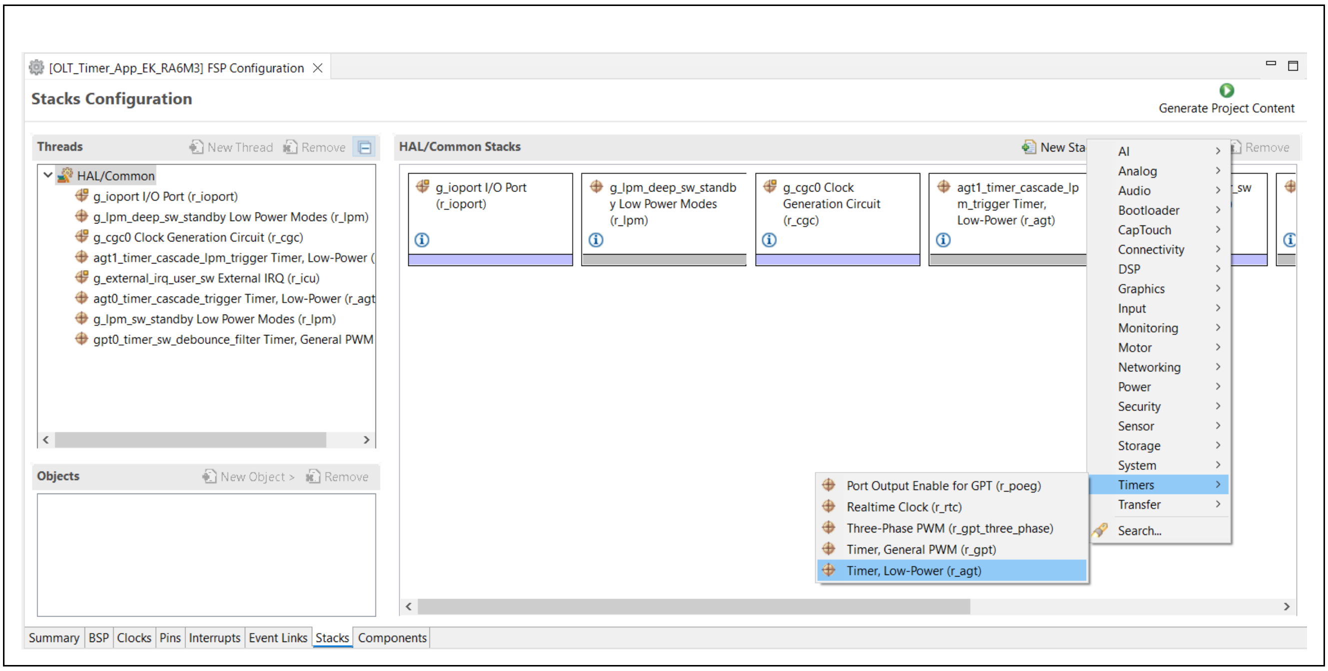


Figure 8. Adding r_agt Driver to HAL/Common Thread

3.4 Module Configuration

Once you have added a module to your project, you must configure its properties. The properties are dependent on the module(s) that you have added. Use the **Properties** tab to configure them.

3.4.1 LPM Configuration

The LPM applications add the r_lpm driver module as the main component to configure the Renesas RA MCUs in Low Power Modes, for Sleep, Software Standby, Snooze, and Deep Software Standby. The main settings of Low Power Modes configures the trigger/cancel sources, and internal power supply conditions for Deep Software Standby mode.

3.4.1.1 Activation and Cancelation Sources

The cancelation source of an LPM will wake up the MCU from the specific LPM. The request for Snooze mode puts the MCU into Snooze mode from Software Standby mode. These sources are interrupt sources. Refer to the Low Power Modes section in Renesas RA MCU Hardware User's Manual for more details on what interruptions are available in the LPM.

Table 5 shows the activation and cancelation sources used in the LPM applications.

Table 5. Activation and Cancelation Source Configuration

Category	Interrupt Source	Application	Description
Request Source	`AGT1_AGTI`	Clock Changing and LPM Transition	AGT Channel 1 Underflow Interrupt
End Source	`AGT1_AGTI`	Clock Changing and LPM Transition	AGT Channel 1 Underflow Interrupt
Wake/Cancel Source	`AGT1_AGTI`	Operable Long Timer	AGT Channel 1 Underflow Interrupt
	`PORT_IRQ13-DS`	Clock Changing and LPM Transition	External Interrupt 13-DS
	`PORT_IRQ1-DS`	Clock Changing and LPM Transition	External Interrupt 1-DS
	`RTC_ALM`	Clock Changing and LPM Transition	RTC Alarm Interrupt

3.4.1.2 Sleep Mode Configuration

Since Sleep mode is canceled by any interrupts, there is no need to set up a cancel source for this mode in driver r_lpm configuration, as long as there is at least one source of interrupt active in the system. If the LPM application uses RTOS, the Systick timer must be stopped before entering the Sleep mode because the Systick interrupt will wake up the MCU. When you are using the RTOS, if the Systick timer is stopped, it must be restarted after waking up for the proper RTOS kernel operation.

3.4.1.3 Software Standby Mode Configuration

Figure 9 shows how the LPM may be configured to exit Software Standby mode with AGT1 underflow interrupt as the wake source.

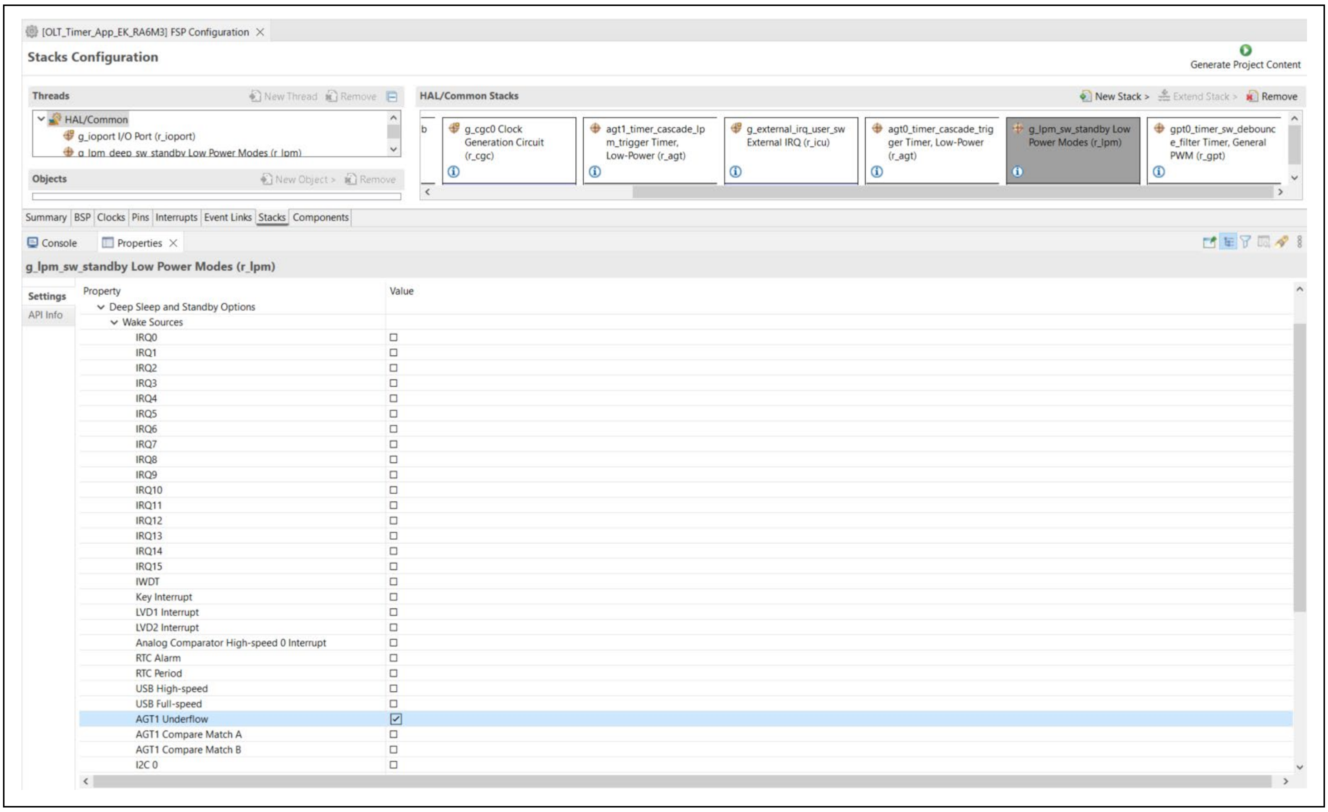


Figure 9. Software Standby Properties Configuration using the Properties Tab

3.4.1.4 Snooze Mode Configuration

The Snooze Request source triggers a transition from Software Standby mode to Snooze mode. The Snooze End source cancels Snooze Mode and transitions the MCU back to Software Standby mode.

The wake source of Software Standby mode will wake up the MCU from both Software Standby and Snooze modes.

Figure 10 shows how to configure Snooze mode with AGT1 Underflow as both Snooze Request and End sources for Clock change and LPM application.

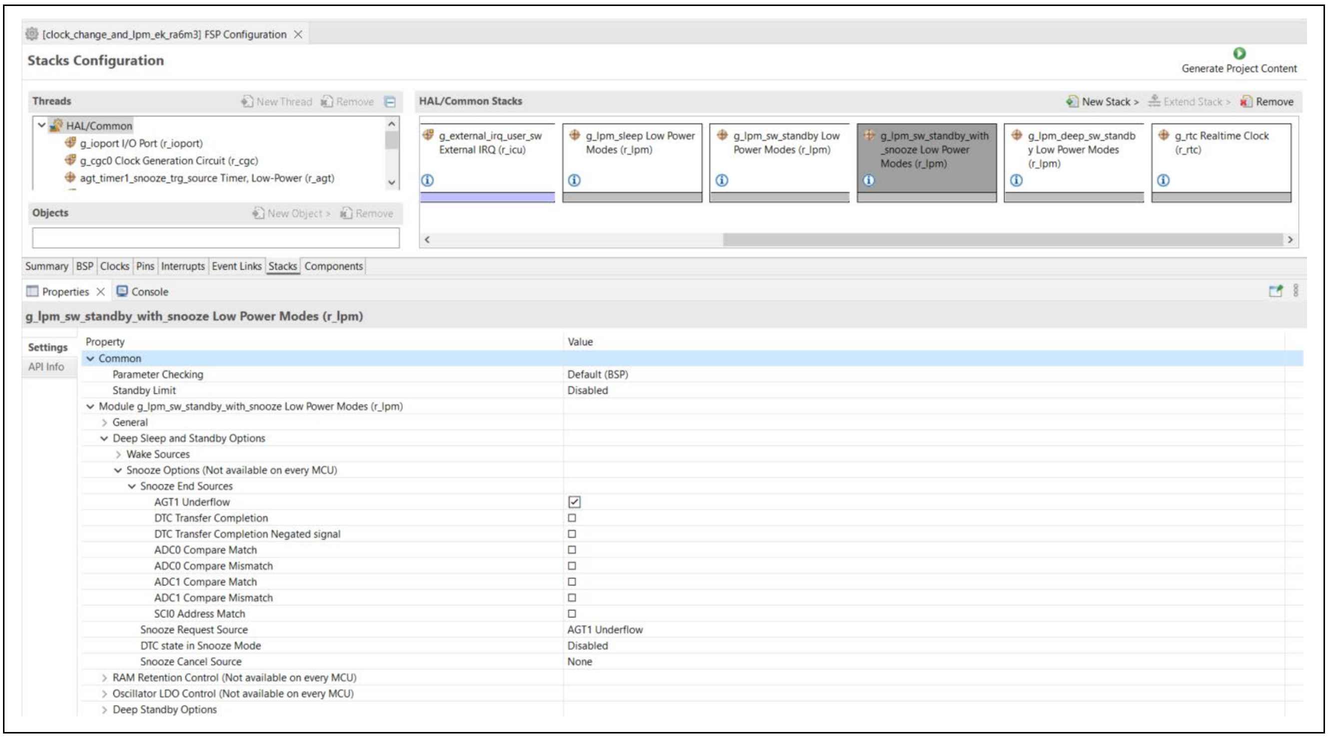


Figure 10. Snooze Properties Configuration using the Properties Tab

3.4.1.5 Deep Software Standby Configuration

Figure 11 shows Deep Software Standby Mode with AGT1 underflow interrupt as cancel source.

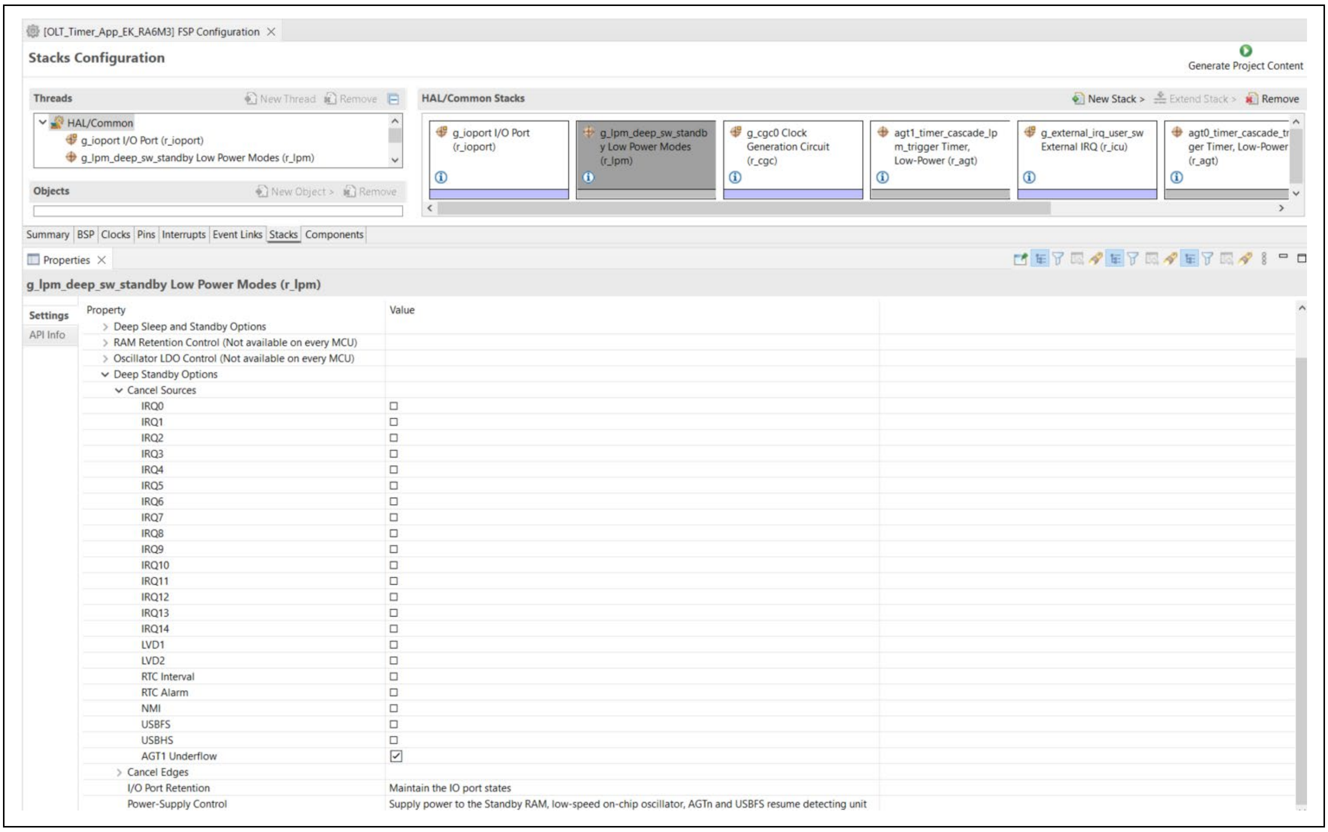


Figure 11. Deep Software Standby Properties Configuration using the Properties Tab

If IRQ is used to cancel the Deep Software Standby mode, you must use the IRQn-DS interrupts.

In Deep Software Standby mode, the **Power-Supply Control** provides an option to maintain the internal power supply to the peripherals or cut down the internal power supply to most of the internal peripherals. For example, **Supply power to the Standby RAM, low-speed on-chip oscillator, AGTn, and USBFS resume detecting unit** is needed to keep the AGT timer running in the Operable Long Timer application, as shown in Figure 12.

This is the option used in this application example. For other available options, refer to the FSP User's manual and MCU Hardware User's manual.

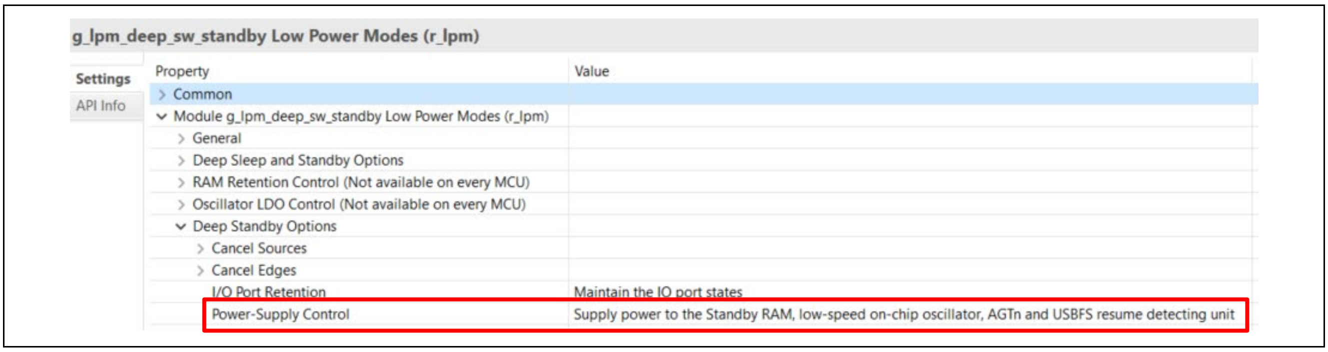


Figure 12. Power Supply Selection in Deep Software Standby Mode

3.4.2 Timer Configuration

3.4.2.1 RTC Configuration

The Real-Time Clock (RTC) is one of the peripherals that can operate in all the Low Power Modes. It is primarily used for timekeeping, updating the time independent of the MCU in LPM. In this application, the RTC is used to keep track of the time in the Clock Changing and LPM Transition application and to wake up from Software Standby mode via the RTC alarm interrupt. The RTC uses the LOCO as the clock source in the application.

The application displays the RTC time when the MCU transitions from LPM to Normal mode. This gives an indication of how long the MCU was in LPM and provides the latest time information.

The following Figure 13 shows the configurations of RTC for Time and Alarm. Alarm is used as trigger in the LPM. The clock source of RTC is LOCO, which is available in Low Power Modes.

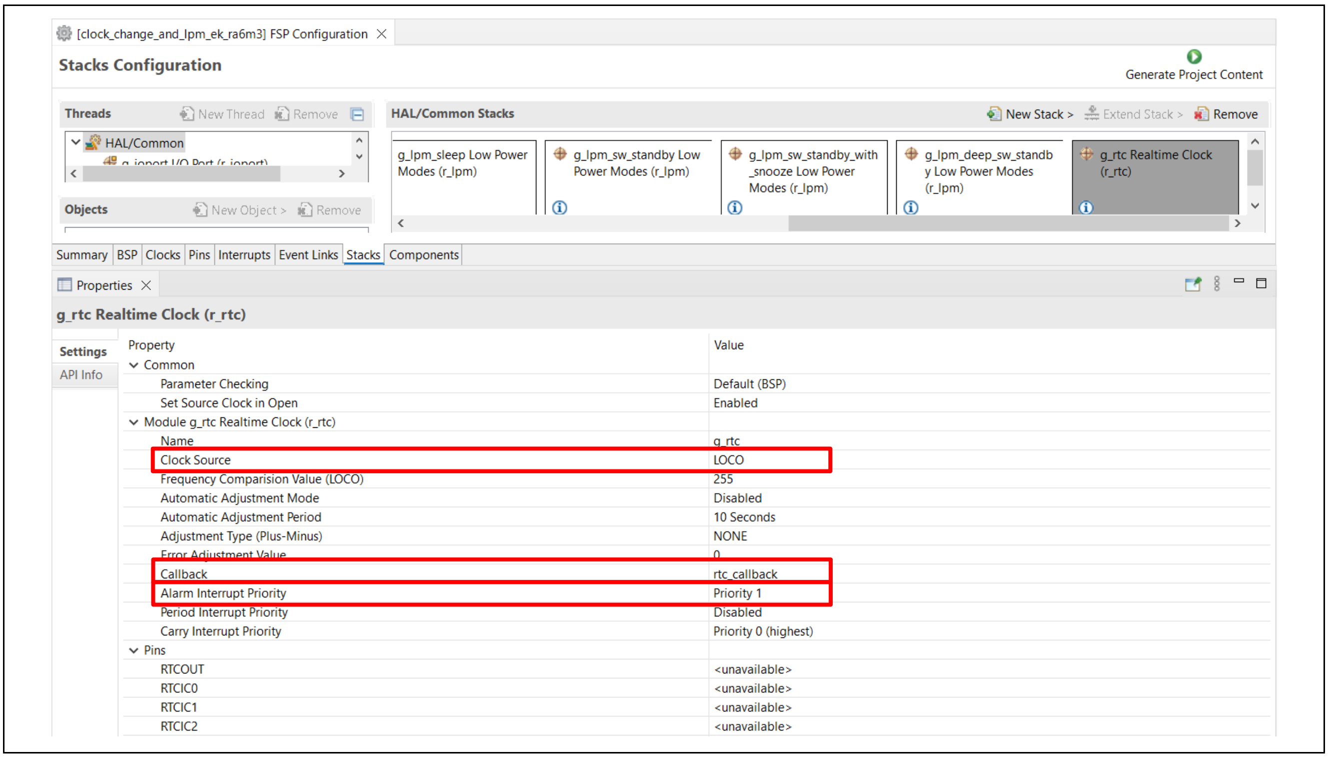


Figure 13. RTC Properties Configuration using the Properties Tab

3.4.2.2 AGT Timer Configuration

As mentioned earlier, the Operable Long Timer application in LPM uses AGT timer channel 0 (AGT0) and AGT timer channel 1 (AGT1) in cascade mode to create a 10-second operable long timer. In this mode, the AGT0 Underflow Interrupt will trigger the AGT1 counter.

The following figures show the configurations of AGT0 and AGT1. The count source of AGT0 is the Sub-Clock, which is available in Low Power modes, and the count source for AGT1 is the AGT0 Underflow Interrupt.

Figure 14 shows AGT0 configured in a periodic mode that generates an underflow interrupt every second.

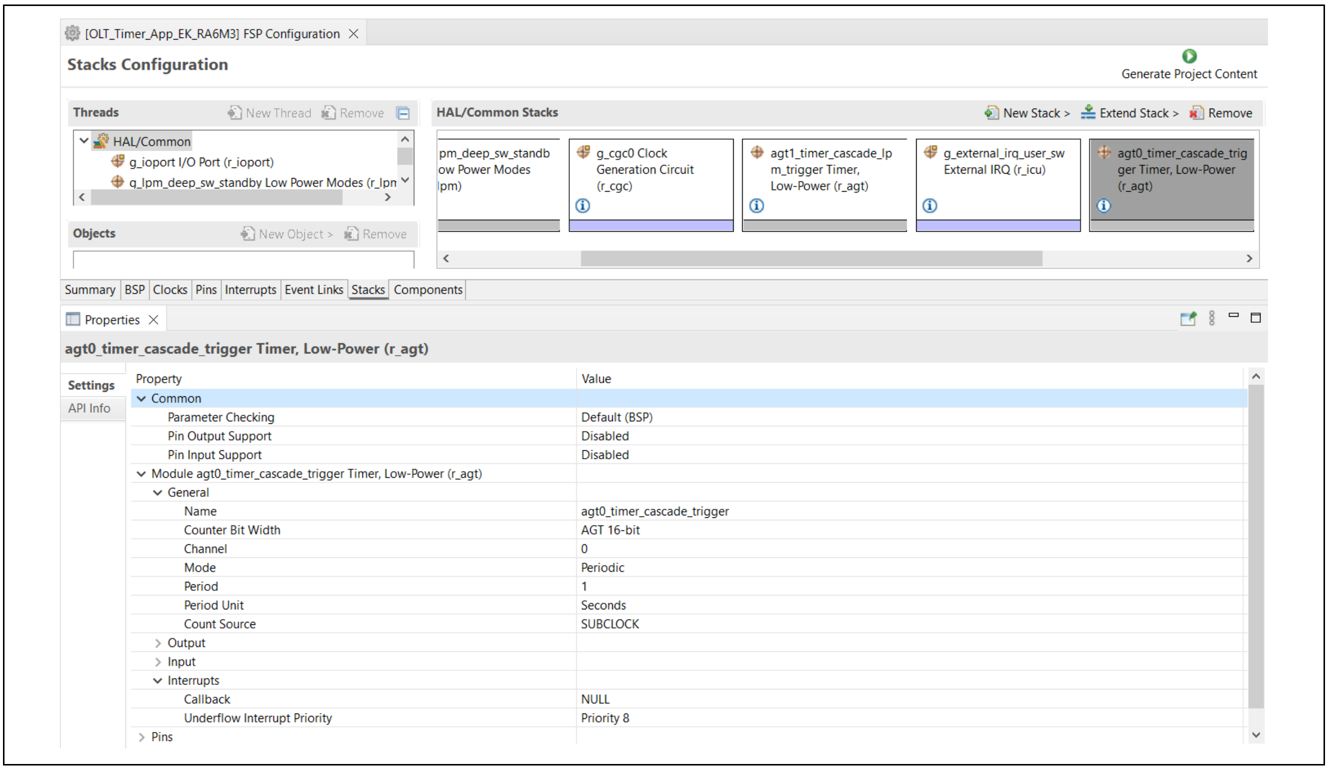


Figure 14. AGT0 Properties Configuration using the Properties Tab

AGT1 is also configured in a periodic mode with raw count as the period unit shown in Figure 15.

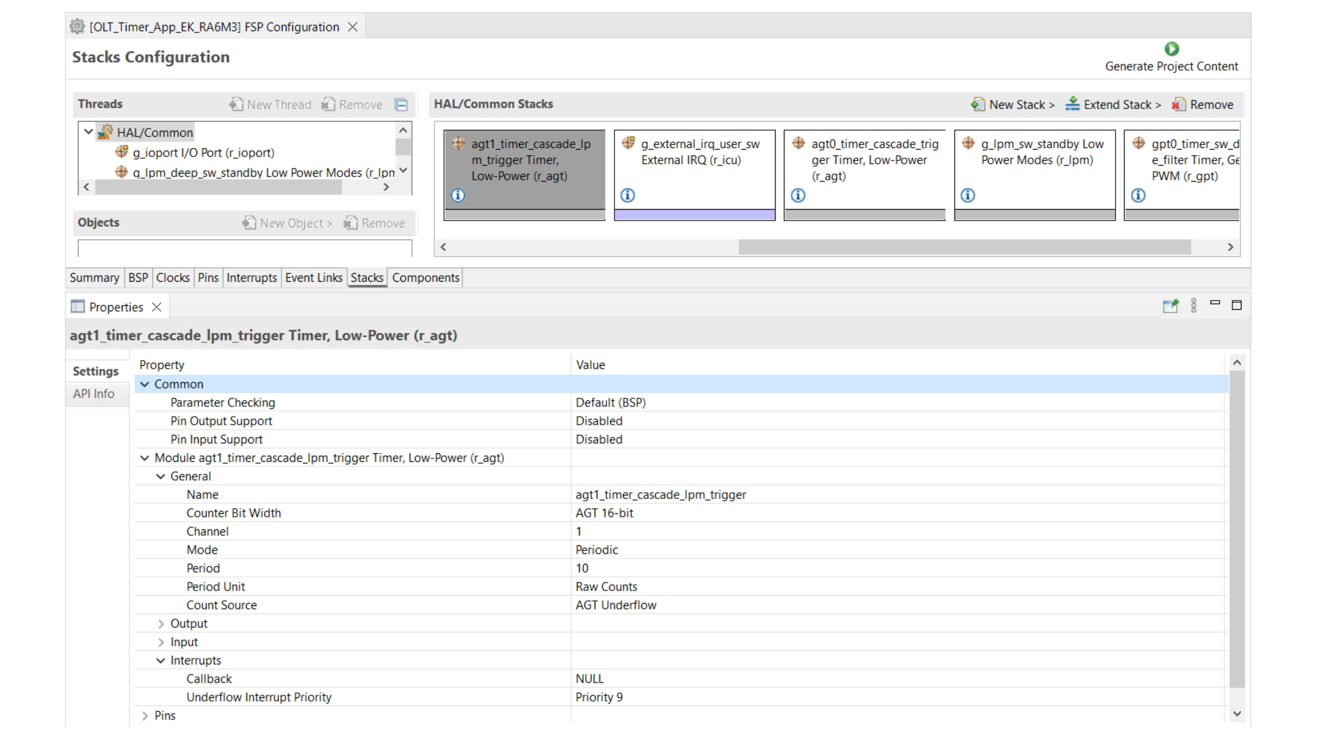


Figure 15. AGT1 Properties Configuration using the Properties Tab

3.5 Pin Configuration

The FSP application can support multiple pin configurations. In this application, we use two different pin configurations, one for an active mode of operation and the other for the power-saving mode of operation. For instructions on configuring the FSP pin configuration, refer to the Renesas Flexible Software Package (FSP) User's Manual.

3.5.1 Pin Configuration in Normal Mode

The pin configuration in normal mode refers to the MCU pin functions that you want to use in normal operating conditions. Figure 16 shows the pin configuration of the EK-RA6M3 kit used in normal mode.

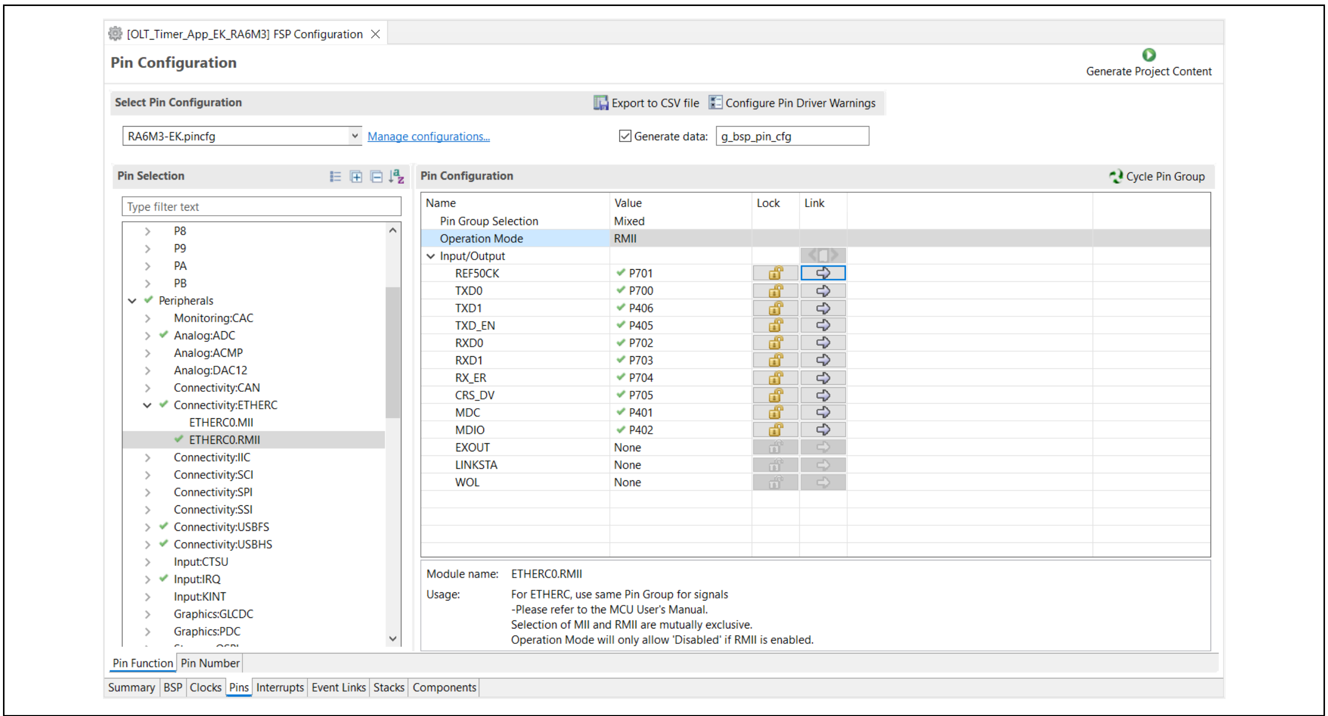


Figure 16. Pin Configuration of EK-RA6M3 Kit in Normal Mode

3.5.2 Pin Configuration in LPM

Use the pin configuration in Low Power Modes to reduce power consumption by disabling unused pins, which puts them in the input mode. Refer to the “Handling of Unused Pins” section of the MCU Hardware User’s manual for more details.

Figure 17 shows the pin configuration of the EK-RA6M3 kit in LPM named `RA6M3-EK-LPM.pincfg` with unused pins disabled. You may observe that most pins are disabled, except for the IRQ pins, and CGC pins, which are used to wake up the MCU and provide clock input through the XTAL and EXTAL pins.

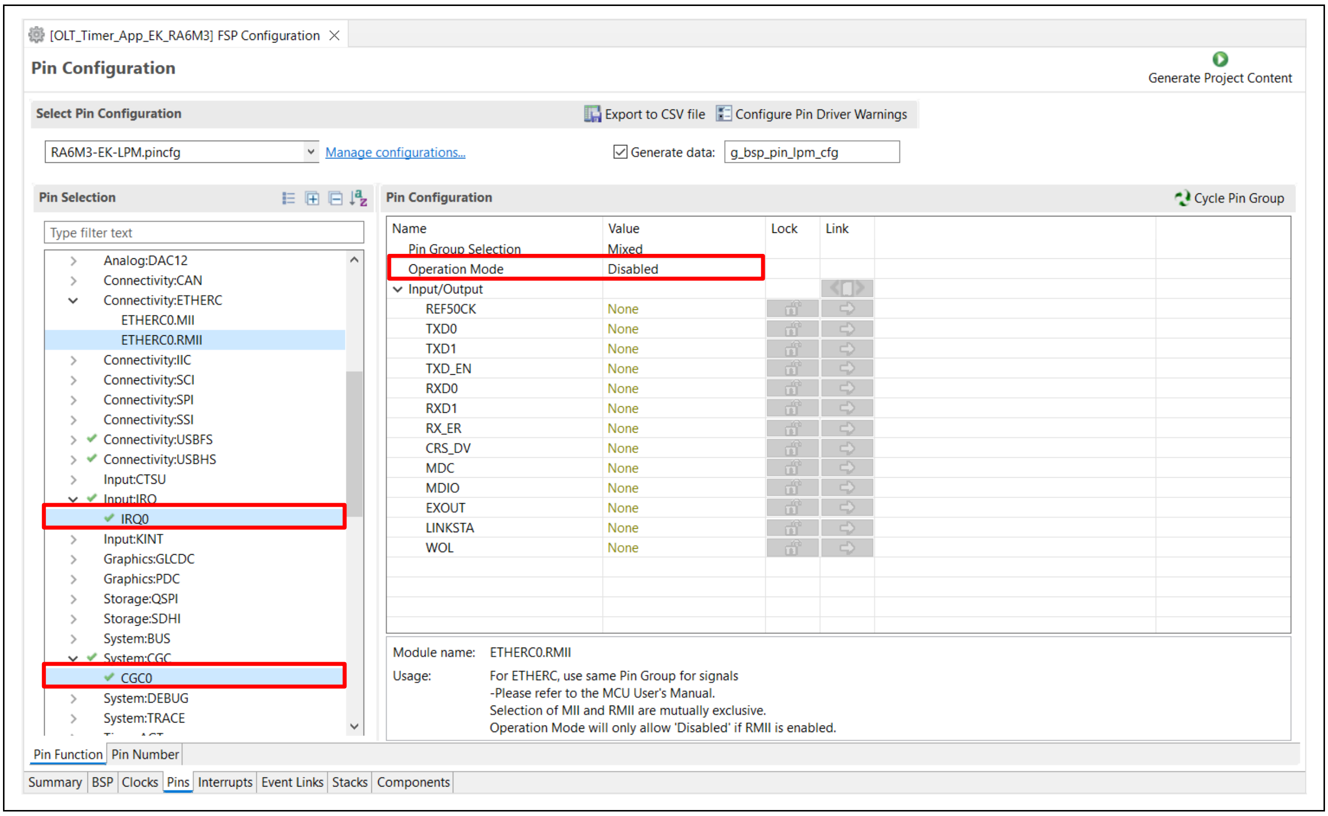


Figure 17. Pin Configuration of EK-RA6M3 Kit, operating in LPM

4. Application Architectures

Figure 18 shows the transitions between LPM and Normal mode in LPM applications. The WFI instructions activate LPM, and the configured interrupt, such as AGT1 underflow interrupt or external interrupt IRQ13-DS, cancels LPM and wakes up the MCU.

Note: The transition from the Normal Mode to the Deep Software Standby mode is handled internally by the LPM driver via the Software Standby mode with the DPSBYCR. The DPSBY bit is set to 1.

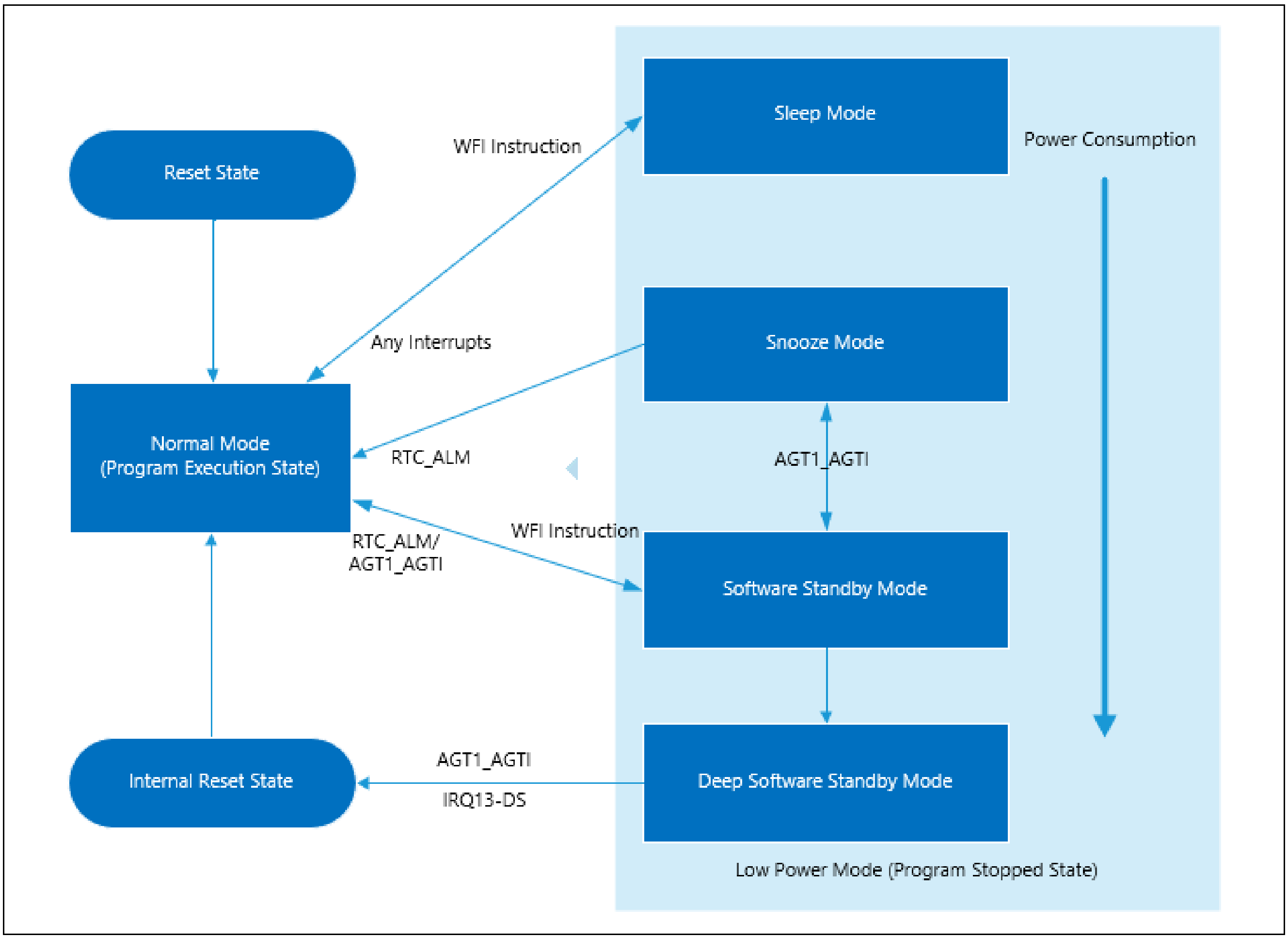


Figure 18. Transition Between LPM and Normal Mode

4.1 Clock Changing and LPM Transition

This application demonstrates the use case where the clock source to the CPU is changed at runtime. It also demonstrates entering and exiting the different LPM using the API provided by the FSP. Without the availability of the APIs, a developer would need to manually configure the registers related to LPM and CGC, thereby adding to the development timeline.

The following Figure 19 This shows the different clock sources and the associated LPM used in the application and different transition states. The application is implemented using an event-driven mechanism. In this event-driven system, events can be user-driven or system-generated and are used as input to the finite state machine. Two separate state transition tables are used here in the application.

- Clock transition table (`clock_transition_table`)
- LPM Transition table (`lpm_transition_table`).

The transition table has a list of actions to be performed based on the events received. For instance, when user event "Button Press—Long" is received upon power-on reset, the finite state machine will start running and change the clock to HOCO. If user event "Button Press—Short" is received, the finite state machine will switch to the LPM state machine and start the LPM operation.

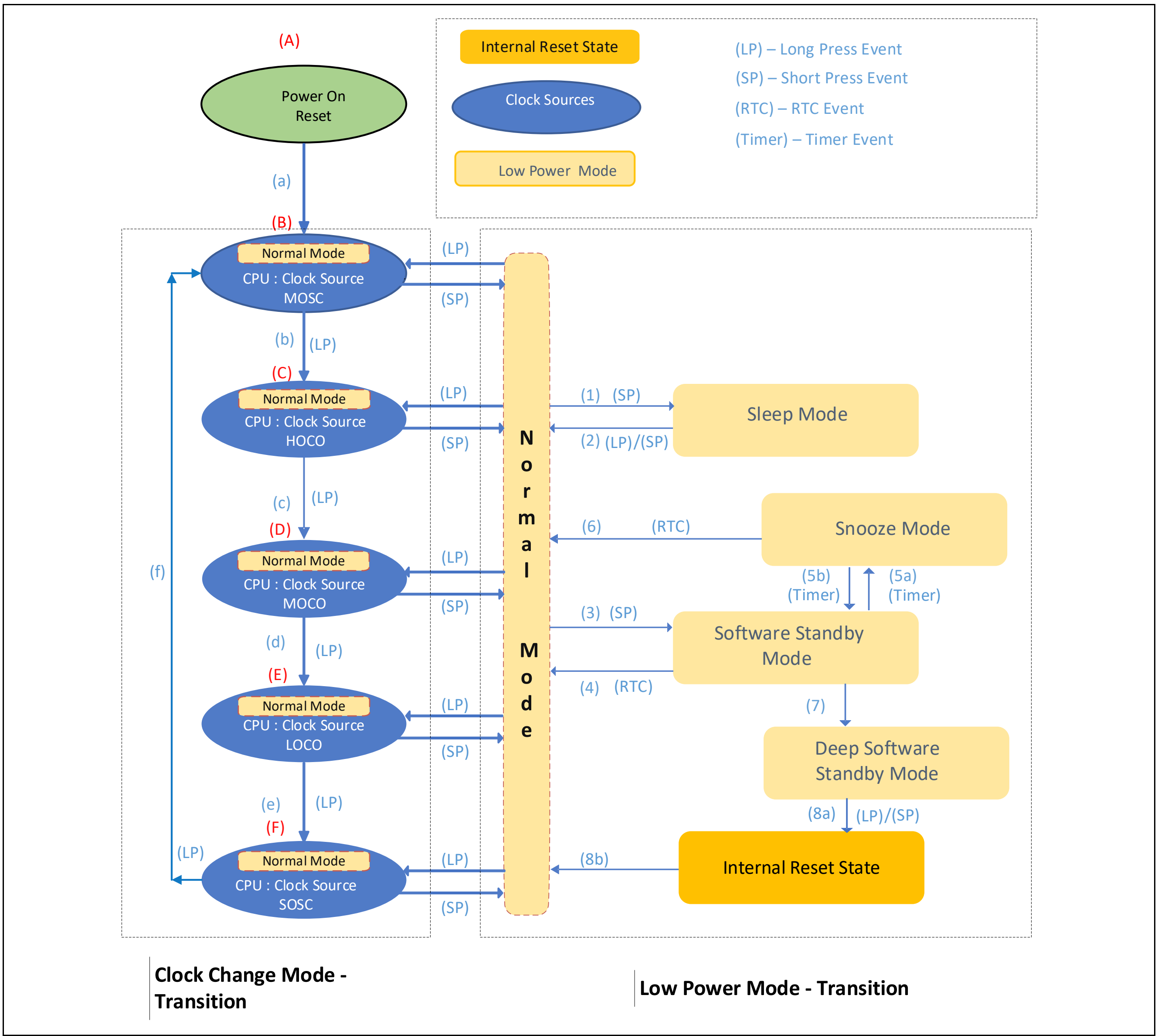


Figure 19. Clock Changing and LPM Transition

In Figure 19The blue oval-shaped blocks (B) through (F) represent the different clock states used in the application, and the labeled arrows (b) through (f) indicate the different transition paths it takes when changing the clock.

The yellow blocks are the different LPM states as applicable to the MCU, and the (1) through (8) numbered arrows represent the transition path at the different Low Power Modes.

Note: The dotted block represents the Clock Change Mode transition on the left and the LPM Transition on the right as shown in Figure 19.

Note: The Deep Software Standby Mode and Snooze Mode are entered via Software Standby mode. For Snooze and Deep Software Standby mode from the application perspective, the MCU and LPM drivers handle the Software Standby mode internally, while it is configured for the Snooze or Deep Software Standby Mode.

Note: The clock can only be changed in Normal Mode. Changing clock in the LPM mode is not allowed.

Note: For FPB-RA6E1 and FPB-RA4E1 boards.

Events used in this application are as listed in the Table 6.

Table 6. Events used for the Clock and LPM transitions

List of Event	Description
EV_PB_SHORT_PR	User push button event – “Short Press” – held for 1-2 seconds
EV_PB_LONG_PR	User push button event – “Long Press”– held for 4-6 seconds
EV_PERIODIC_TIMER	AGT1 timer event generated by timer overflow
EV_RTC_ALARM	RTC Alarm Interrupt generated based on the configured time.
EV_POWER_ON_RESET	Power on Reset event
EV_POWER_ON_RESET_DSSBY	Reset from Deep Software Standby mode

4.2 RTC Timer Operation in LPM

An additional clock-changing and LPM transition application feature showcases the running RTC peripheral during the LPM. Even when the CPU and most components in the MCU enter Low Power Modes and cease operation, the RTC clock and its timer operate independently. Updated RTC time information is displayed on the RTT when transitioning back to the Normal mode.

RTC Periodic/Alarm Interrupts can be used as signals to transition to different LPMs. In this LPM application project, the RTC Alarm interrupt cancels Snooze/Software Standby mode and reverts to Normal mode.

Note: The RTC Periodic interrupt can also be used for this event. The RTC Periodic interrupt has a maximum period of 2 seconds. For demo purposes, we avoid this to showcase the step-by-step transition and not be limited to 2 seconds. However, the RTC alarm can be configured to the desired seconds.

4.3 Operable Long Timer in Software Standby and Deep Software Standby Modes

The Operable Long Timer Application uses LPM configurations in Software Standby and Deep Software Standby modes. It disables unused clock and IO ports before entering LPM with the WFI instruction, then places IO ports back to normal operating condition after waking up as shown in Figure 20.

LPM is canceled by the Operable Long Timer underflow interrupt, which is created by using AGT0 and AGT1 in cascade mode.

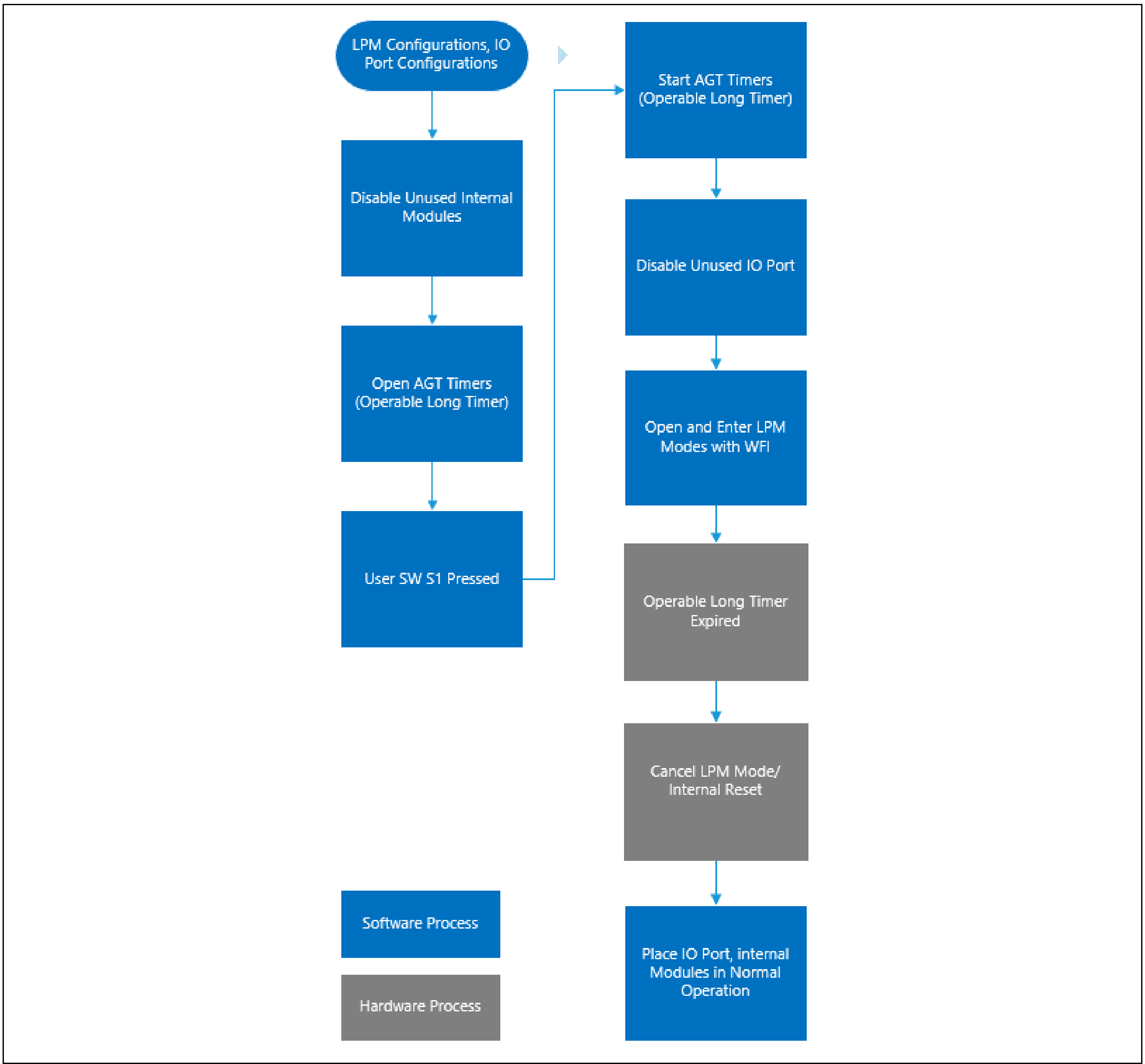


Figure 20. Operable Long Timer Process

5. Application Code Highlights

5.1 Clock Source Setup

5.1.1 Handle On-Chip Modules in LPM to Reduce Power Consumption

Oscillators and on-chip modules may be started automatically after the MCU reset and still be running in LPM modes. Therefore, you should disable these modules before entering LPM to reduce MCU power consumption.

Unused IO ports in LPM other than in Deep Software Standby mode should be put into input mode before entering the LPM by using the `g_bsp_pin_lpm_cfg`, which is generated from the `RA6M3-EK-LPM.pincfg`.

The following code fragments highlight the steps in the application to reduce MCU power consumption before placing the MCU in LPM and restoring the IO port settings after waking it up.

```
/* Disable IO port if it's not in Deep SW Standby mode */
if(APP_LPM_DEEP_SW_STANDBY_STATE != g_lpm_transition_sequence[g_lpm_transition_pos])
{
    /* Disable IO port before going to LPM mode*/
    err = R_IOPORT_PinsCfg(&g_ioport_ctrl, &g_bsp_pin_lpm_cfg);
    /* Handle error */
    if(FSP_SUCCESS != err)
    {
        APP_ERR_TRAP(err);
    }
}
```

Figure 21. Put Unused IO ports in Input Mode

Open and configure the LPM.

```
/* Open LPM instance*/
err = R_LPM_Open(&g_lpm_ctrl_instance_ctrls[g_lpm_transition_pos], &g_lpm_ctrl_instance_cfgs[g_lpm_transition_pos]);
/* Handle error */
if (FSP_SUCCESS != err)
{
    APP_ERR_TRAP(err);
}
```

Figure 22. Open and Configure the LPM

Place the MCU in the LPM.

```
/* Enter LPM mode */
err = lpm_mode_enter(g_lpm_transition_sequence[g_lpm_transition_pos]);
/* Handle error */
if (FSP_SUCCESS != err)
{
    /* Turn on user LED to indicate error occurred*/
    R_IOPORT_PinWrite(&g_ioport_ctrl, leds.p_leds[LED_NO_0], BSP_IO_LEVEL_HIGH);
    APP_ERR_TRAP(err);
}
```

Figure 23. Place the MCU in the LPM

Put IO port in normal mode by configuring them using the `g_bsp_pin_cfg` generated from the `RA6M3-EK.pincfg` after exiting from LPM.

```
/* Put IO port configuration back to user's selections */
err = R_IOPORT_PinsCfg(&g_ioport_ctrl, &g_bsp_pin_cfg);
/* Handle error */
if(FSP_SUCCESS != err)
{
    APP_ERR_TRAP(err);
}
```

Figure 24. Place IO Ports in Normal Mode

In this application example, for the Deep Software Standby mode, the IO port must be released from the IOKEEP state after the MCU reset.

```
/* Release IO from IOKEEP state if reset from Deep SW Standby mode */
if(1 == R_SYSTEM->RSTSR0_b.DPSRSTF)
{
    /* Input parameter is unused */
    R_LPM_IoKeepClear(NULL);

    /* Restart LPM sequence */
    g_lpm_transition_pos = 0;

    /* Clear DPSRSTF flag */
    R_SYSTEM->RSTSR0_b.DPSRSTF          = 0;
}
```

Figure 25. Release IO from IOKEEP State MCU Reset

The following code stops the LOCO clock when it is not used as count source for AGT0 as shown in Figure 26.

```
/* Stop LOCO clock if it's unused (not use as AGT1 count source)*/
if(AGT_CLOCK_LOCO != p_agt0_extend->count_source)
{
    err = R_CGC_ClockStop(&g_cgc0_ctrl, CGC_CLOCK_LOCO);
}
```

Figure 26. Stop LOCO Clock when It is Unused

5.1.2 Change System Clock at Run-Time

When the MCU powers up, the default clock will be the configured clock as part of the BSP. Selecting the clock for the application is done through the FSP configurator using the clock tree, which is available in the **Clocks** tab.

In the changing clock use case application, the current running system clock is read via the `R_CGC_SystemClockGet` API and a new system clock source is configured. The following code is used for reading the currently running system clock shown in Figure 27.

```
err = R_CGC_SystemClockGet(&g_cgc0_ctrl, &sys_clock_source, &sys_divider_cf);
if (FSP_SUCCESS != err)
{
    APP_ERR_TRAP(err);
}
```

Figure 27. Read the running System Clock

In order to configure the new source for the system clock, proper divisors are required so that the peripherals get the permitted range of frequencies. Users need to calculate this based on the peripherals used in the application. The new system clock is configured via the API `R_CGC_ClocksCfg`.

Also, the clock sources need to be started if they are not already running. This is done using the API `R_CGC_ClockStart` as shown in the Figure 28.

```
if (CGC_CLOCK_SUBCLOCK == sys_clock_source)
{
    new_clk.source_clock = CGC_CLOCK_SUBCLOCK;
    err = R_CGC_ClockStart(&g_cgc0_ctrl, CGC_CLOCK_SUBCLOCK, &new_clk);
    if (FSP_SUCCESS != err)
    {
        APP_ERR_TRAP(err);
    }
}
```

Figure 28. Starting the Clock Source

6. Importing and Building the Project

To bring the applications into the e^2 studio IDE, follow these steps:

1. Launch e^2 studio IDE.
2. In the workspace launcher, browse to the workspace location of your choice.
3. Close the **Welcome** window.
4. In the IDE go to **File** > **Import.**
5. In the Import dialog box pick **Existing Projects into Workspace.**
6. Select the Root directory of your workspace (where you placed the project).
7. Select the project you wish to import and click **Finish**.
8. Click on **Generate Project Content** on the FSP configurator window.
9. Now build the project.

7. Running Applications

To connect and run the code, follow the steps in the following sections.

7.1 Board Setups

The EK-RA6M3 kit contains a few switch settings that must be configured prior to running the application associated with this application note. In addition to these switch settings, it has a USB debug port and connectors to access the J-Link® programming interface.

Table 7. Switch settings for EK-RA6M3

Switch	Setting
J8	Jumper on pins 1-2
J9	Open

Figure 29. EK-RA6M3 Kit

There is no jumper setting needed for FPB-RA6E1 and FPB-RA4E1.

7.2 Downloading the Executables

The executable file may be programmed into the target MCU through any one of three means.

7.2.1 Using a debugging interface with e² studio

Instructions to program the executable binary are found in the latest RA FSP User's Manual. See Section *Starting Development > e² studio ISDE User Guide > Tutorial: Your First RA MCU Project > Debug the Blinky Project.*

This is the preferred method for programming as it allows for additional debugging functionality available through the on-chip debugger.

7.2.2 Using J-Link tools

SEGGER J-Link Tools such as J-Flash, J-Flash Lite, and J-Link Commander can be used to program the executable binary into the target MCU. For more information, refer to User Manuals UM08001 and UM08003 on www.segger.com.

7.2.3 Using Renesas Flash Programmer

The Renesas Flash Programmer provides usable and functional support for programming the on-chip flash memory of Renesas microcontrollers in each development and mass production phase. The software supports all RA MCUs. The software user's manual is available on renesas.com.

7.3 User Interface

The user interface to interact with the application is shown below. The Operable Long Timer application uses the LED and user push button switch. Whereas the Clock Changing and LPM Transition application uses the RTT interface in addition to the LED and push button switch.

7.3.1 LED Indication

7.3.1.1 Clock Changing and LPM Transition

The Clock Changing and LPM Transition application uses LED1 to indicate the board initialization status, error condition, and normal mode operation. In the Sleep, Software Standby, Snooze, and Deep Software Standby modes, LED1 will be turned off. In the Normal mode, this LED1 will blink every second. If any error condition occurs, LED1 will be turned ON.

7.3.1.2 Operable Long Timer

The Operable Long Timer application uses LED1 to indicate the normal mode. In the normal mode, this LED1 will blink. In the Software Standby and Deep Software Standby modes, LED1 will be turned off.

7.3.2 User Push Button Input

7.3.2.1 Clock Changing and LPM Transition

Push button switch S1 input is mainly used for transition to different MCU clocks and transition to different LPM. For the Clock Changing and LPM Transition application, the same switch has dual functions. If the switch is held under 1-2 seconds, it is considered a short press. It is considered a long press if the switch is held for 3–6 seconds. A long press event is used to change the clock source dynamically, and a short press event is used to transition the LPM mode.

Note: A long press event during the LPM will not change the system clock source to a different clock, but instead has a different role: to exit the LPM and go back to the normal mode.

7.3.2.2 Operable Long Timer

In the application, pressing the push button switch S1 will set the Software Standby and Deep Software Standby modes. The AGT1 Underflow Interrupt will cancel the LPM in 10 seconds.

7.3.3 RTT Console

The RTT console is handy for viewing the application messages while running/debugging the application. While you are using the RTT console, the debugger script for the LPM must be selected as shown in Figure 30.

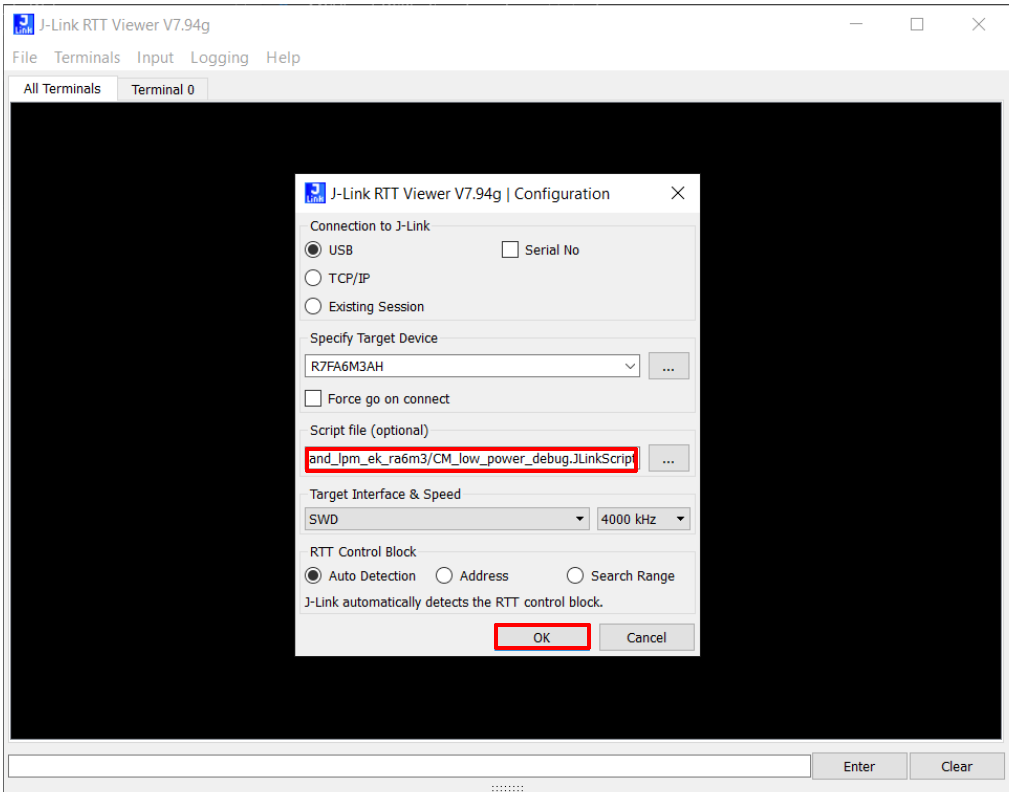


Figure 30. RTT Console for User Print Messages

Note: While invoking the RTT console for FPB-RA6E1 and FPB-RA4E1 kits, the target device, RTT control block needs to be selected along with the debugger script for the LPM as shown in Figure 31.

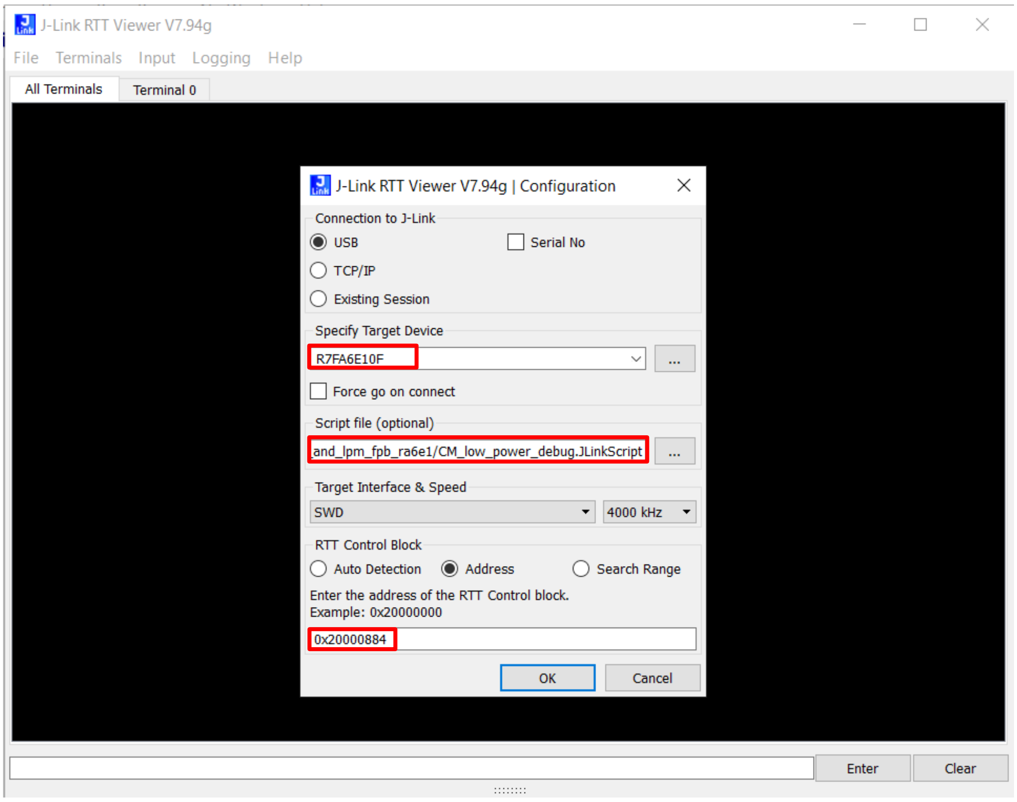


Figure 31. RTT Console for (Cortex M33 Devices) User Print Messages

7.4 Debugging Low Power Modes

By default, it is not possible to debug the low power modes of an RA device. If an application tries to enter Sleep mode, pending a peripheral interrupt to wake it, this will not happen as it will be woken almost immediately by a debug interrupt.

If the application tries to enter Software or Deep Software Standby modes, then the connection between the CPU and the IDE will be lost, closing the debug session within the IDE.

However, if the supplied debug script is specified then it will be possible to debug the low power modes.

For demonstrating the LPM, these scripts are used. Note that even though this will allow you to develop your application, it will not allow you to measure accurate Icc figures, as you will be measuring the Icc of the on-chip debug circuit. Once you have created your low power application, accurate Icc figures can be measured with the OCD disabled.

The low power script also allows for the RTT application to be used. While debugging the application, configure the debugger as shown in Figure 32. With these modifications one can use the RTT without getting disconnected during the LPM.

Note: The script is attached as part of this project and the debugger is pointing to the same location.

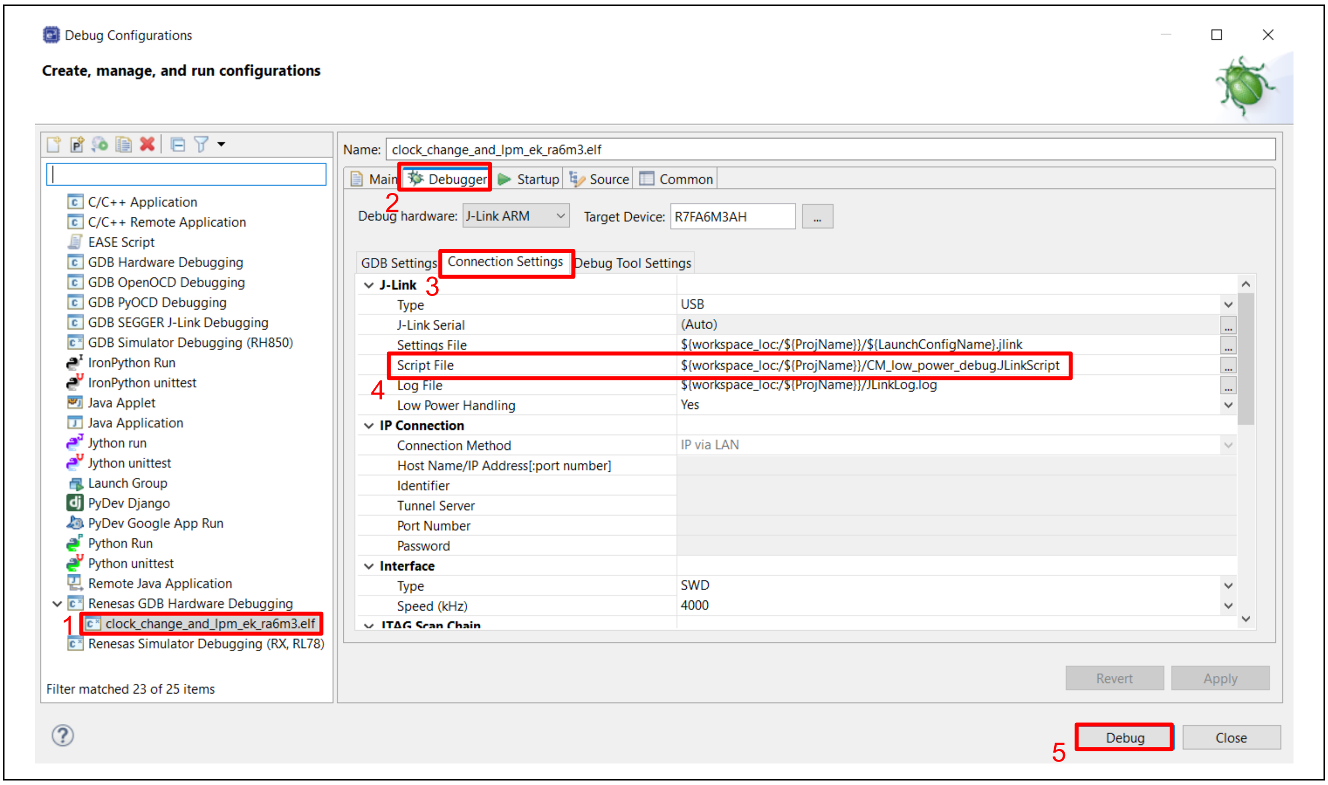


Figure 32. Debugger Settings for LPM Application Debugging

7.5 Steps to Run the Application

The following table shows the steps to run the Clock-Changing and LPM Transition application. On power up, when the board is connected to RTT, it will display the welcome message. To change the clock/LPM and run through the different use cases in this application, use the following tables as a reference. These tables have the list of events, current mode, the new transition states, and the expected outcome.

7.5.1 Clock Changing

The user button has two functions, based on how long you press and hold it. In the clock changing mode, the user button pressed and held for 3-6 seconds selects the different system clocks for the MCU. Whereas the user button pressed and held for 1-2 seconds exits the clock changing mode and enters LPM for the configured clock. The details are as shown in Table 8.

Table 8. Clock Mode Transition Table

	Events	
System Clock	**User Button – Long Press**	**User Button – Short Press**
MOSC (Main Oscillator)	Changes the System Clock to HOCO	Exits the Clock State Machine and enters the LPM State Machine for the configured clock MOSC.
HOCO (High speed on-chip oscillator)	Changes the System Clock to MOCO	Exits the Clock State Machine and enters the LPM State Machine for the configured clock HOCO.
MOCO (Medium speed on-chip oscillator)	Changes the System Clock to LOCO	Exits the Clock State Machine and enters the LPM State Machine for the configured clock MOCO.
LOCO (Low speed on-chip oscillator)	Changes the System Clock to SOSC	Exits the Clock State Machine and enters the LPM State Machine for the configured clock LOCO.
SOSC (Sub Oscillator)	Changes the System Clock to MOSC	Exits the Clock State Machine and enters the LPM State Machine for the configured clock SOSC.

Note: By default, MOSC and SOSC are not supported on FPB-RA6E1 and FPB-RA4E1.

7.5.2 LPM Transition

In the LPM application, the user switch has two functions based on how long you press, hold, and release it. If the MCU is in the LPM modes (Sleep or Deep Software Standby) and the user button is pressed, held, and released, the MCU exits the LPM mode and enters the Normal mode, whether it is a short or long press. The behavior is different when the MCU is in Normal mode.

When the MCU is in Normal mode, if the user button is pressed, held, and released for 1-2 seconds, the MCU exits Normal mode and enters Sleep, Software Standby, Snooze, or Deep Software Standby modes, depending on the previous transition states.

If the switch is pressed, held, and released for 3-6 seconds, the MCU exits the LPM transition setting mode and enters the Clock setting mode. The user switch has no effect during the LPM modes (Software Standby or Snooze).

Timer events cancel the Software Standby and Snooze modes and return the MCU to Normal mode.

The details of the switch events and timer events are shown in Table 9.

Table 9. LPM Transition Table

	Events		
Low Power Modes	**User Button – Long Press**	**User Button – Short Press**	**Timer Event**
Normal	Exits the LPM transition State Machine and enters the Clock Mode State Machine	Enters the Sleep mode	Not Applicable
Sleep	Exits the Sleep mode and enters the Normal mode	Exits the Sleep mode and enters the Normal mode	Not Applicable
Normal (From Sleep)	Exits the LPM transition State Machine and enters the Clock Mode State Machine	Exits the Normal mode and enters the Software Standby mode	Not Applicable
Software Standby	Not Applicable	Not Applicable	Exits the Software Standby mode and Enters the Normal mode
Normal (From Software Standby)	Exits the LPM transition State Machine and enters the Clock Mode State Machine	Exits the Normal mode and enters the Snooze with Software Standby mode	Not Applicable
Snooze with Software Standby	Not Applicable	Not Applicable	Exits the Snooze with Software Standby mode and Enters the Normal mode
Normal (From Snooze)	Exits the LPM transition State Machine and enters the Clock Mode State Machine	Exits the Normal mode and enters the Deep Software Standby mode	Not Applicable
Deep Software Standby	Exits the Deep Software Standby mode and resets the MCU	Exits the Deep Software Standby mode and resets the MCU	Not Applicable

7.5.3 Operable Long Timer

In the Operable Long Timer application, the user button enters Software Standby and Deep Software Standby modes from normal mode. AGT1 underflow interrupt is used to exit the LPM modes.

Table 10 shows the transition sequence and associated events used in the Operable Long Timer application.

Table 10. LPM Transition Table in Operable Long Timer Application

	Events	
Low Power Modes	**User Button – Press**	**Timer Event – AGT1_AGTI**
Normal	Enters Software Standby Mode	Not Applicable
Software Standby	Not Applicable	Exits the Software Standby mode and enters the Normal Mode
Normal (From Software Standby)	Enters Deep Software Standby Mode	Not Applicable
Deep Software Standby	Not Applicable	Exits the Deep Software Standby Mode and resets the MCU

7.6 Measure MCU Current

The following steps are required to measure MCU current on EK-RA6M3, which is supported by the LPM applications:

- Remove the R2 (resistor).
- Measure the voltage drops across R3 and calculate MCU current (Icc); replace R3 with a bigger resistor if needed.

To measure the MCU current (Icc) directly, connect a multimeter between the +3V3 and +3V3_MCU pins on the kit connectors after removing the R3 resistor.

To measure MCU current (Icc) on FPB-RA6E1 and FPB-RA4E1, replace R3 with a bigger resistor, measure the voltage drops across R3, and calculate MCU current (Icc).

8. Migrating LPM Applications to Different MCU/Kit

Even though the LPM applications are created for the EK-RA6M3 kit, they are designed to easily migrate to other Renesas RA Kits. Refer to Table 1 of this document for more details about the supported Renesas RA kits. The following steps are the basic procedures to port the project to support Renesas RA kits.

Rename and import the projects to e^2 studio, for example, changing **OLT_Timer_App_EK_RA6M3** to **OLT_Timer_App_EK_RA6M2**.

Choose **File** > **Import** > **General** > **Rename and Import and Existing C/C++ Project into the workspace** then a pop-up appears, indicate the Project name and select archive file as shows in Figure 33.

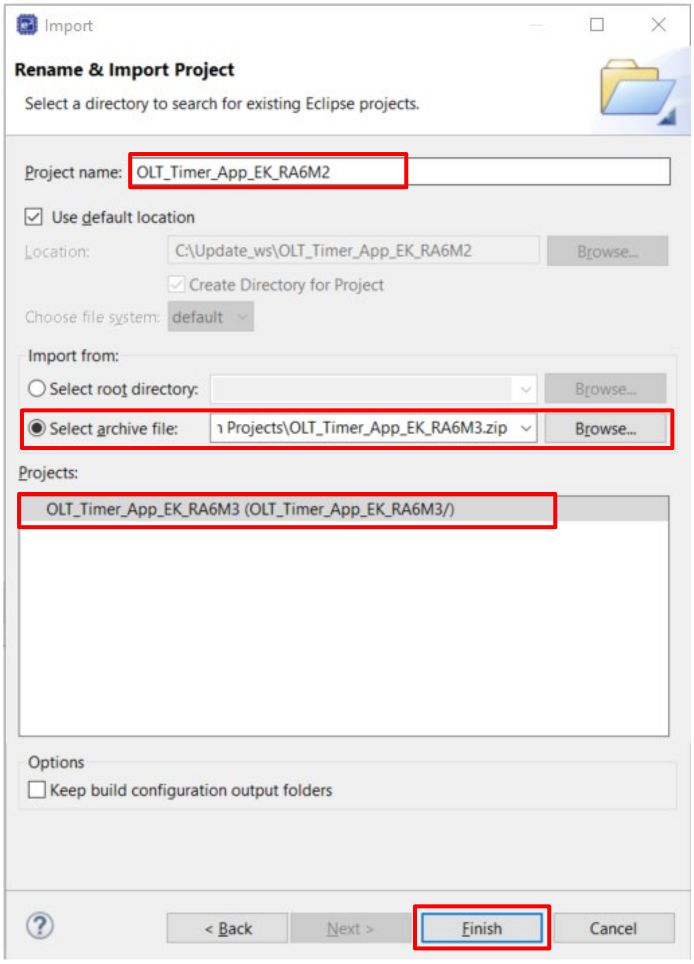


Figure 33. Rename and Import Project into e^2 studio

Open the project configuration and change the board BSP from **EK-RA6M3** to **EK-RA6M2** in the **BSP** tab.

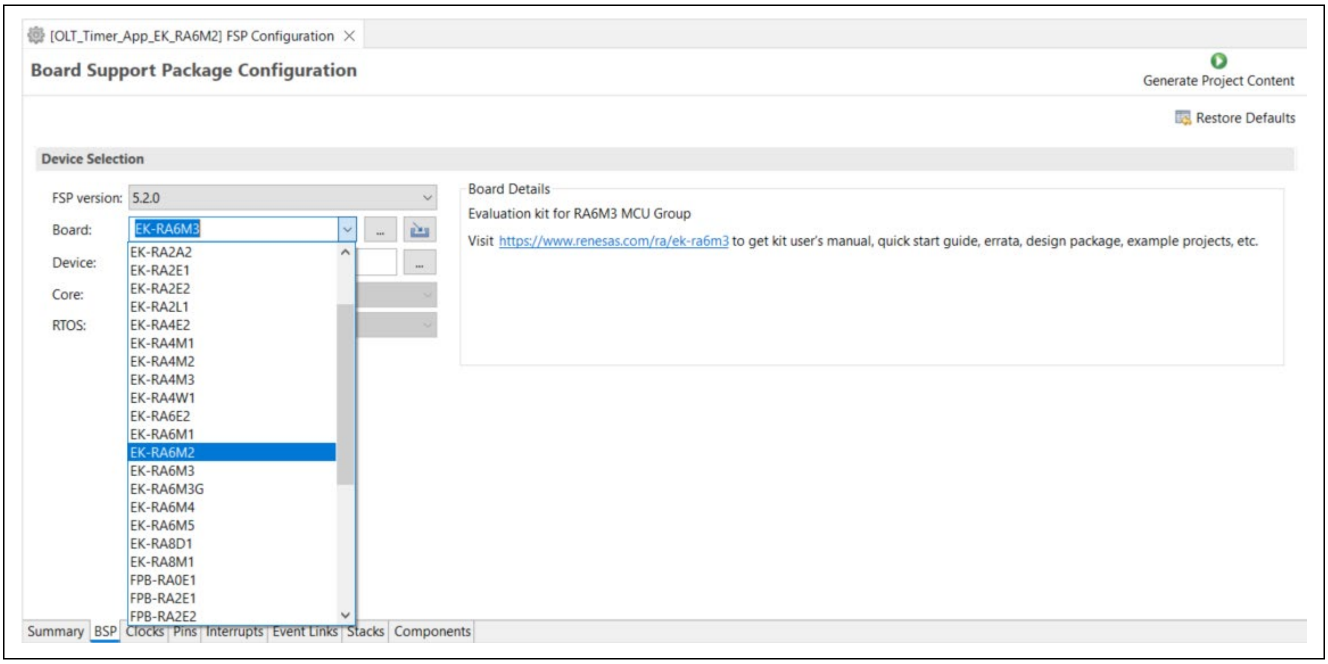


Figure 34. Change Board BSP

Click the **Pins** tab, uncheck **Generate data** for `RA6M3-EK.pincfg`. Select `RA6M2-EK.pincfg`, check **Generate data** and then **Generate Project Content**.

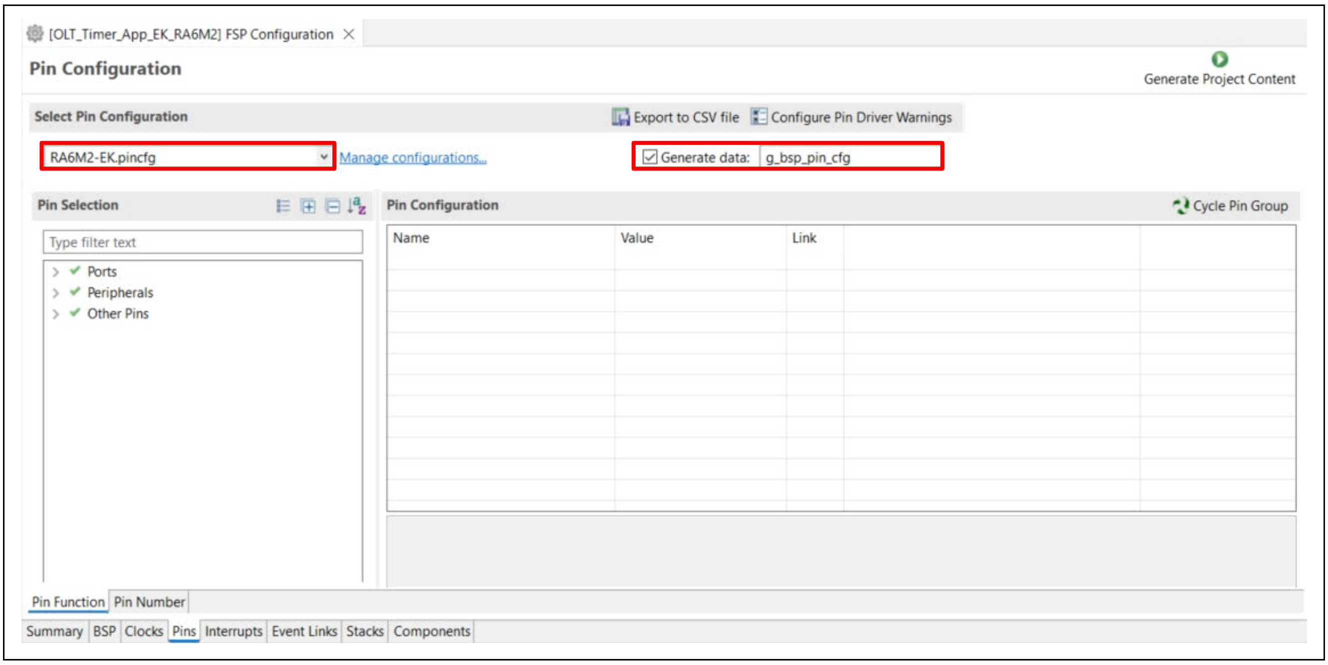


Figure 35. Select Default Pin Configuration

Create a new pin configuration file named `RA6M2-EK-LPM.pincfg` in the same project folder by using **Manage configuration**, duplicating `RA6M2-EK.pincfg`, and renaming it to `RA6M2-EK-LPM.pincfg`.

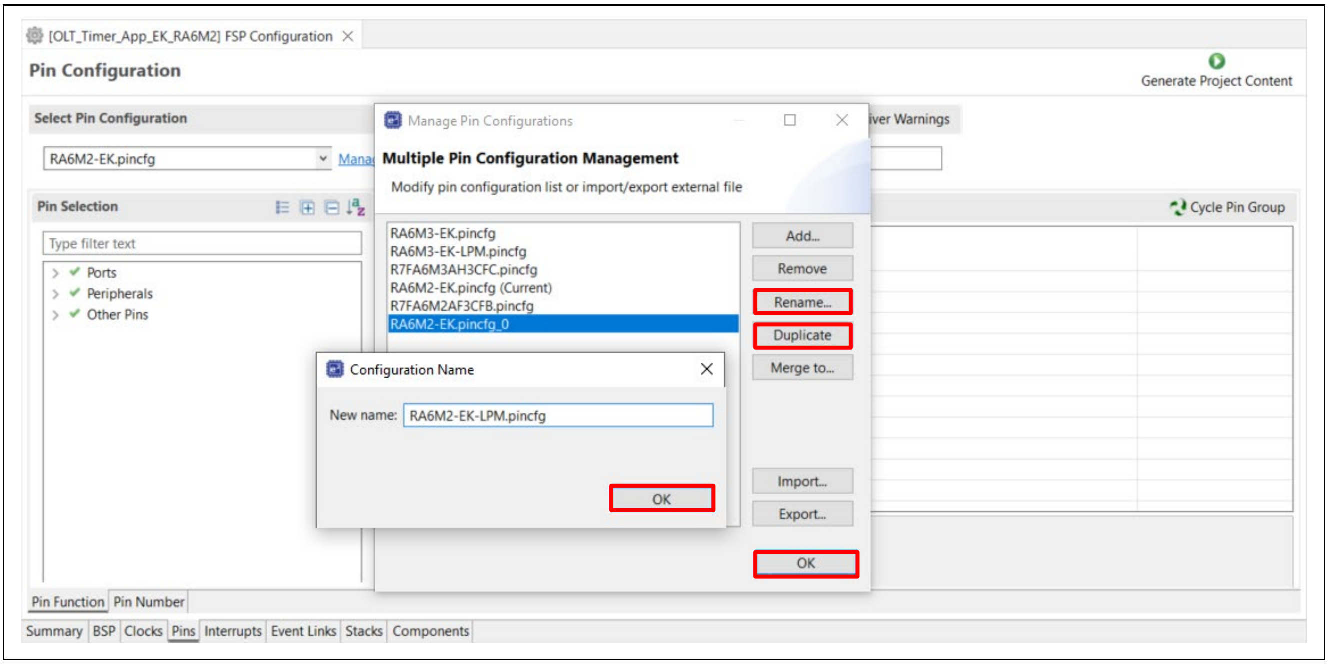


Figure 36. Create a New Pin Configuration

Select the RA6M3-EK-LPM.pincfg and uncheck the **Generate Data** box to deselect the old pin configuration.

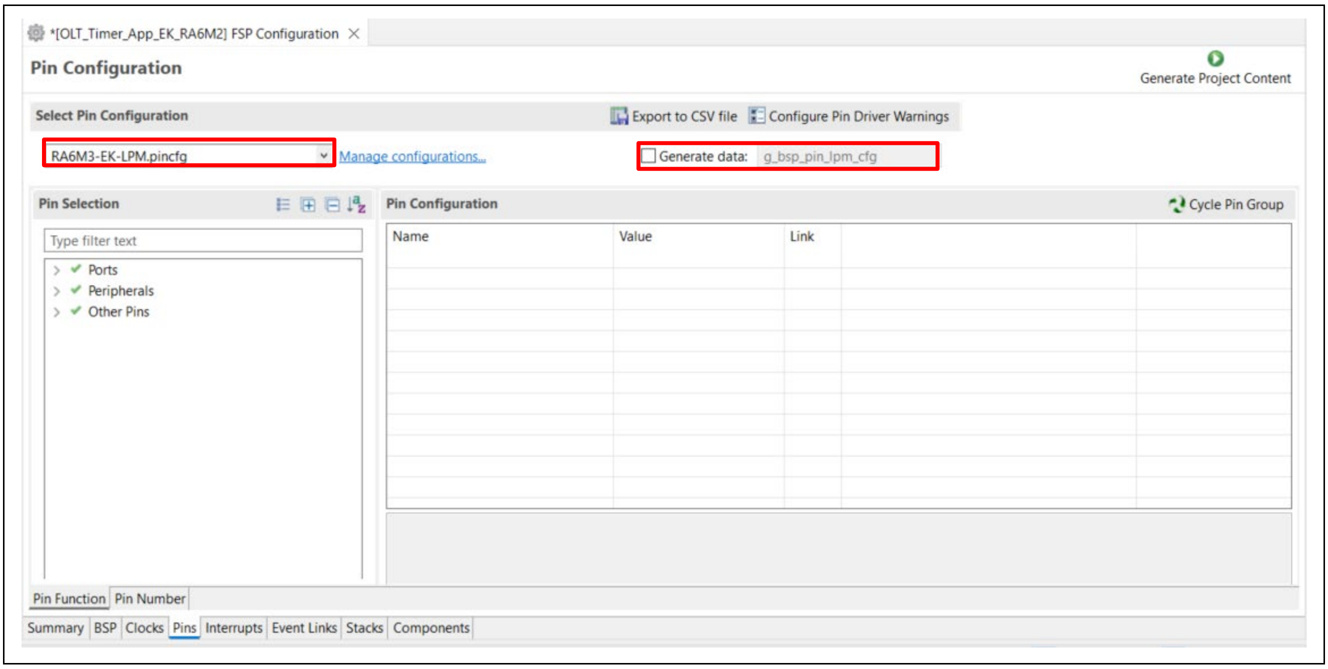


Figure 37. Deselect the Old LPM Pin Configuration

Select the newly created `RA6M2-EK-LPM.pincfg`, check the Generate Data box, and rename it to "g_bsp_pin_lpm_cfg". You can disable unused pins and peripherals and generate the pin configuration for LPM, for example, disabling SCI7 as shown in Figure 38.

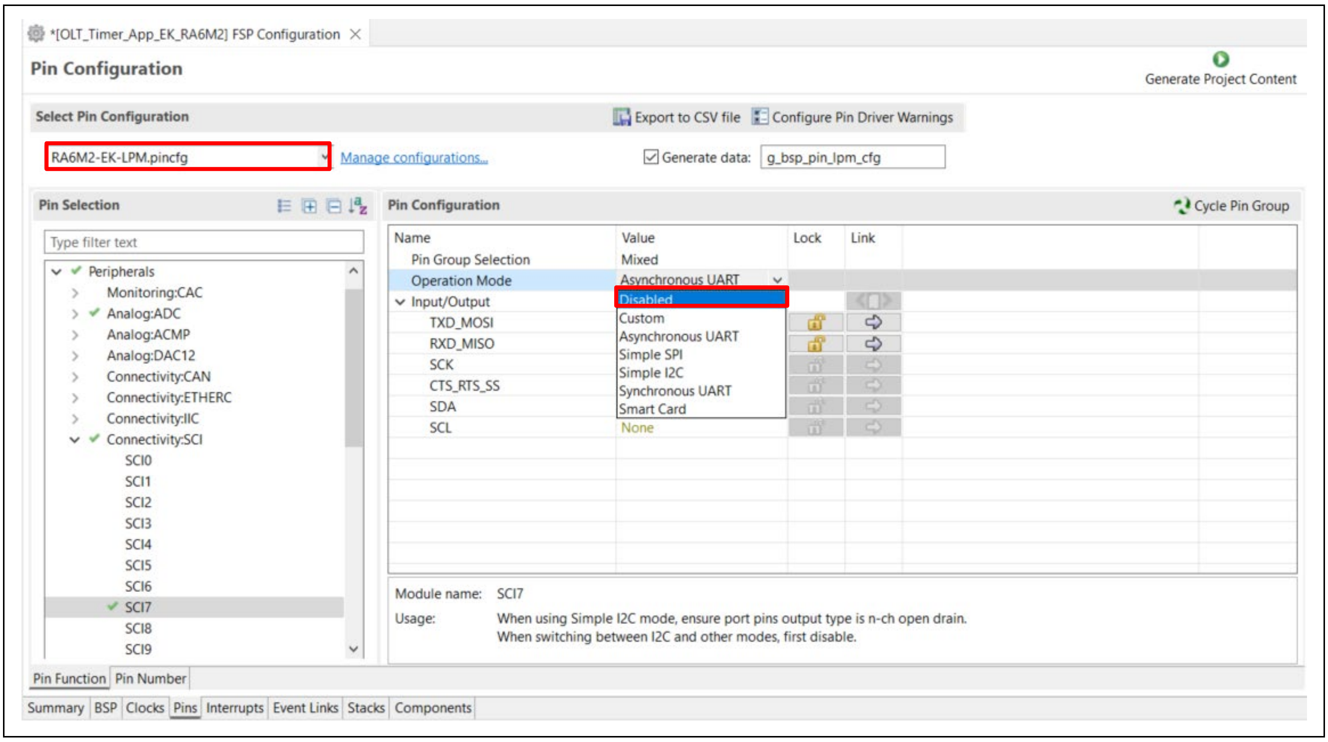


Figure 38. Select the New Pin Configuration and Disable Unused Peripherals

Figure 39 shows an example of placing P106 into input mode.

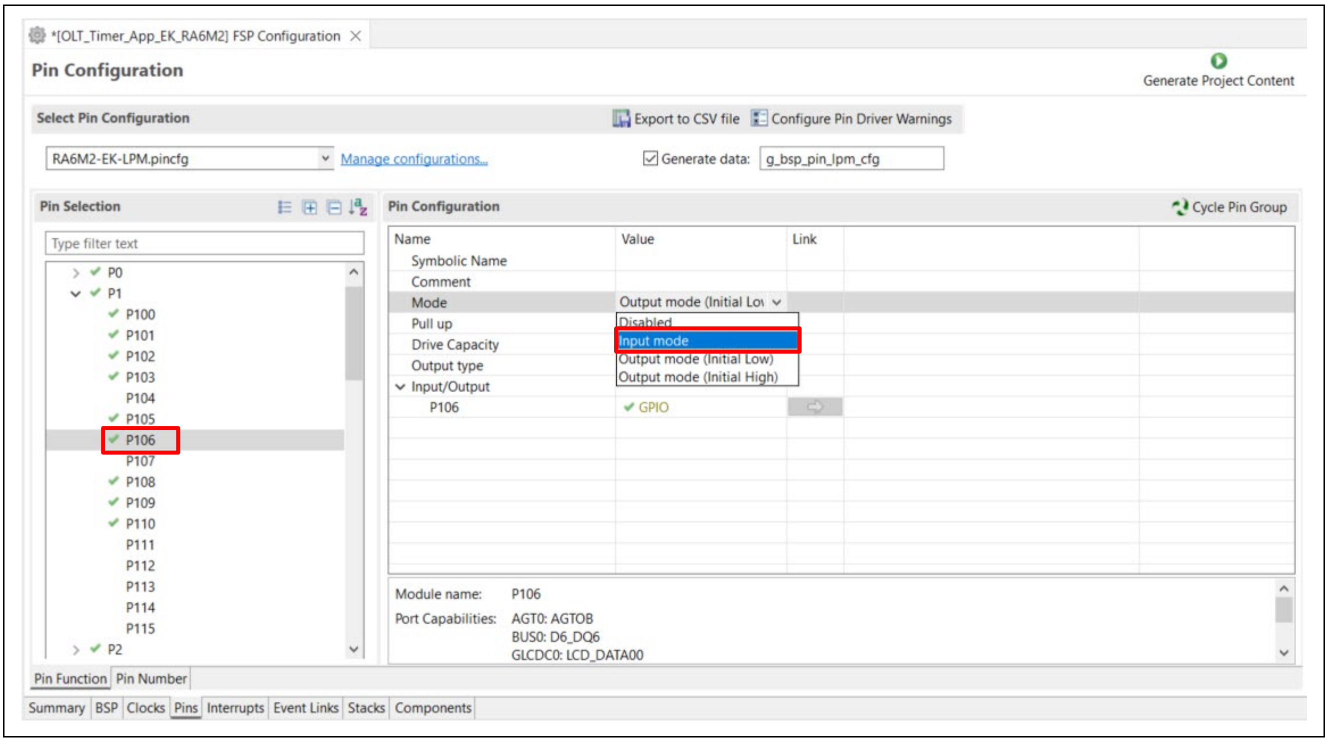


Figure 39. Place Unused in Input Mode

Change the r_icu driver configuration and other peripheral configurations if needed. This is necessary since the user push-button S1 used in the applications may be different from board to board. Check the Board Schematic documentation for more details.

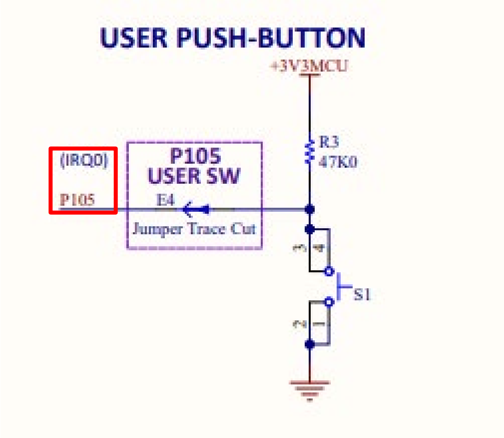


Figure 40. EK-RA6M2 USER PUSH-BUTTON Schematic

EK-RA6M2 user push-button connects to P105 channel 0. In this case, P105 is already in use as input mode, so it needs to be disabled before being used as an IRQ.

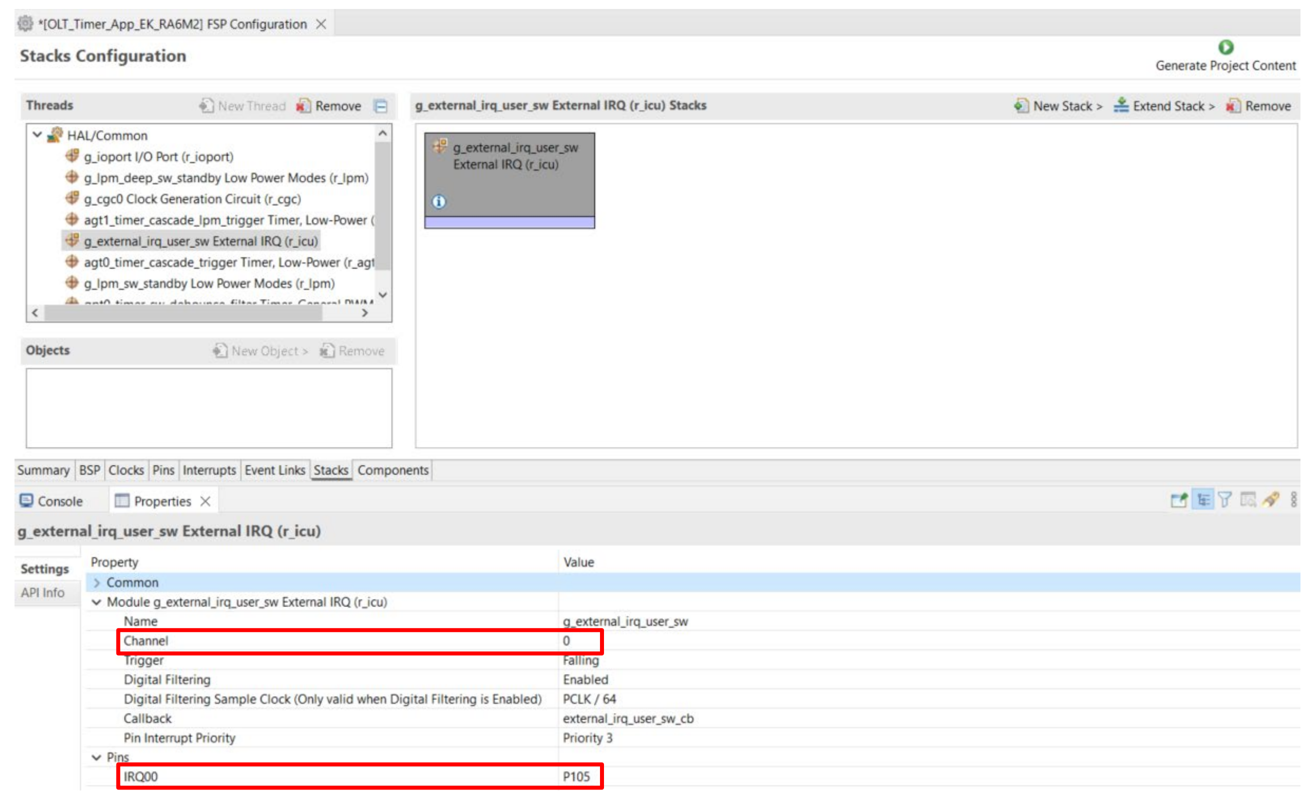


Figure 41. Change Peripheral Configuration

When migrating the projects to a new board that is not listed in Table 1, you must modify the code to add a board definition for the new board type. Similarly, add the new board type in other application parts as required. The sample code fragment of the board type being used in the application is shown below in Figure 42.

```c
/***********************************************************************************************************************
 * File Name    : lpm_app_transition_sequence_config.h
 * Description  : Contains declarations of data structures and functions used in hal_entry.c.
 **********************************************************************************************************************/
 * DISCLAIMER

#ifndef LPM_APP_TRANSITION_SEQUENCE_CONFIG_H_
#define LPM_APP_TRANSITION_SEQUENCE_CONFIG_H_

/*******************************************************************
 * @brief Pre-defined LPM Transition Sequence
 * There are 2 kinds of sequence, one supports RA6Mx device and the other supports other RA devices
 *******************************************************************/
#if defined (BOARD_RA6M3_EK) || defined (BOARD_RA6M3G_EK) || defined (BOARD_RA6M2_EK) || defined (BOARD_RA6M1_EK) || defined (BOARD_RA6E1_FPB) || defined (BOARD_RA4E1_FPB)
app_lpm_states_t g_lpm_transition_sequence[] = {
    APP_LPM_SW_STANDBY_STATE,          ///< SW Standby mode
    APP_LPM_DEEP_SW_STANDBY_STATE,     ///< Deep SW Standby mode
    APP_LPM_NORMAL_STATE               ///< Normal mode
};
#elif defined (BOARD_RA4M1_EK) || defined (BOARD_RA2A1_EK)
app_lpm_states_t g_lpm_transition_sequence[] = {
    APP_LPM_SW_STANDBY_STATE,          ///< SW Standby mode
    APP_LPM_NORMAL_STATE               ///< Normal mode
};
#endif

#endif /* LPM_APP_TRANSITION_SEQUENCE_CONFIG_H_ */
```

Figure 42. Board Types Used in the LPM Application

Change Debug Configuration Target Device as shown in Figure 43.

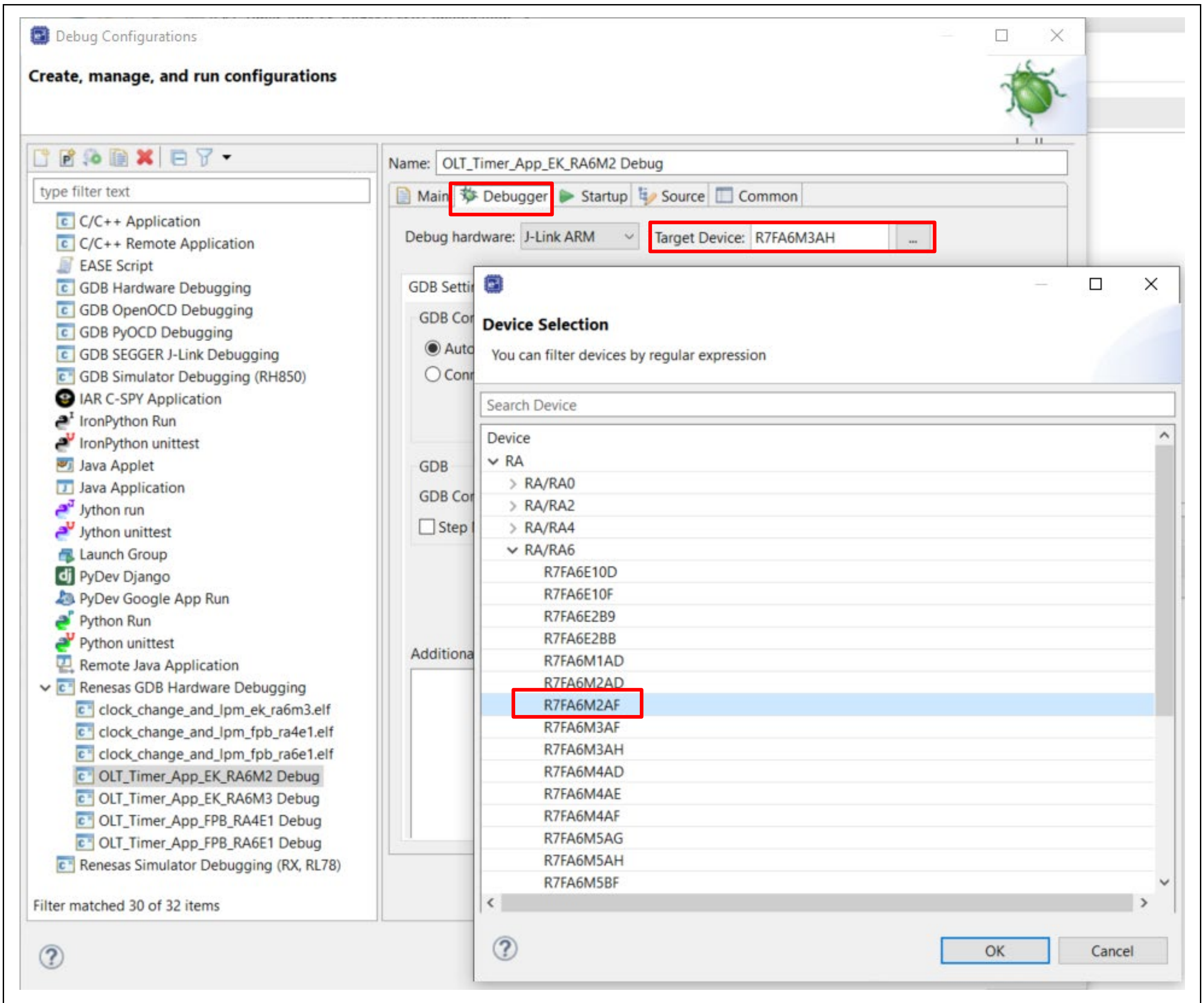


Figure 43. Change Debug Configuration Target Device

Build, run, and clean up the migrated project.

9. References

- Renesas FSP User's Manual: https://renesas.github.io/fsp
- Renesas RA MCU Datasheets, User's Manuals: See http://renesas.com/ra and select the relevant MCU.
- LPM Example Projects on Renesas RA GitHub: https://github.com/renesas/ra-fsp-examples

Website and Support

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

RA Product Information	www.renesas.com/ra
RA Product Support Forum	www.renesas.com/ra/forum
RA Flexible Software Package	www.renesas.com/FSP
Renesas Support	www.renesas.com/support

Revision History

Rev.	Date	Description	
		Page	Summary
1.00	Sep.29.20	-	Initial version
1.01	Dec.02.20	-	Updated for RA6M3
1.02	Jan.26.21	-	General updates
1.03	Sep.24.21	-	Changed document name, updated for RA6E1, RA4E1
1.04	Oct.01.21	-	Changed document name to reflect RA6E1
1.05	Jun.29.23	-	Document updated as per FSP v4.4.0
1.06	Jul.21.24	-	Document updated as per FSP v5.2.0

General Precautions in the Handling of Microprocessing Unit and Microcontroller Unit Products

The following usage notes are applicable to all Microprocessing unit and Microcontroller unit products from Renesas. For detailed usage notes on the products covered by this document, refer to the relevant sections of the document as well as any technical updates that have been issued for the products.

1. Precaution against Electrostatic Discharge (ESD)
   A strong electrical field, when exposed to a CMOS device, can cause destruction of the gate oxide and ultimately degrade the device operation. Steps must be taken to stop the generation of static electricity as much as possible, and quickly dissipate it when it occurs. Environmental control must be adequate. When it is dry, a humidifier should be used. This is recommended to avoid using insulators that can easily build up static electricity. Semiconductor devices must be stored and transported in an anti-static container, static shielding bag or conductive material. All test and measurement tools including work benches and floors must be grounded. The operator must also be grounded using a wrist strap. Semiconductor devices must not be touched with bare hands. Similar precautions must be taken for printed circuit boards with mounted semiconductor devices.
2. Processing at power-on
   The state of the product is undefined at the time when power is supplied. The states of internal circuits in the LSI are indeterminate and the states of register settings and pins are undefined at the time when power is supplied. In a finished product where the reset signal is applied to the external reset pin, the states of pins are not guaranteed from the time when power is supplied until the reset process is completed. In a similar way, the states of pins in a product that is reset by an on-chip power-on reset function are not guaranteed from the time when power is supplied until the power reaches the level at which resetting is specified.
3. Input of signal during power-off state
   Do not input signals or an I/O pull-up power supply while the device is powered off. The current injection that results from input of such a signal or I/O pull-up power supply may cause malfunction and the abnormal current that passes in the device at this time may cause degradation of internal elements. Follow the guideline for input signal during power-off state as described in your product documentation.
4. Handling of unused pins
   Handle unused pins in accordance with the directions given under handling of unused pins in the manual. The input pins of CMOS products are generally in the high-impedance state. In operation with an unused pin in the open-circuit state, extra electromagnetic noise is induced in the vicinity of the LSI, an associated shoot-through current flows internally, and malfunctions occur due to the false recognition of the pin state as an input signal become possible.
5. Clock signals
   After applying a reset, only release the reset line after the operating clock signal becomes stable. When switching the clock signal during program execution, wait until the target clock signal is stabilized. When the clock signal is generated with an external resonator or from an external oscillator during a reset, ensure that the reset line is only released after full stabilization of the clock signal. Additionally, when switching to a clock signal produced with an external resonator or by an external oscillator while program execution is in progress, wait until the target clock signal is stable.
6. Voltage application waveform at input pin
   Waveform distortion due to input noise or a reflected wave may cause malfunction. If the input of the CMOS device stays in the area between V_{IL} (Max.) and V_{IH} (Min.) due to noise, for example, the device may malfunction. Take care to prevent chattering noise from entering the device when the input level is fixed, and also in the transition period when the input level passes through the area between V_{IL} (Max.) and V_{IH} (Min.).
7. Prohibition of access to reserved addresses
   Access to reserved addresses is prohibited. The reserved addresses are provided for possible future expansion of functions. Do not access these addresses as the correct operation of the LSI is not guaranteed.
8. Differences between products
   Before changing from one product to another, for example to a product with a different part number, confirm that the change will not lead to problems. The characteristics of a microprocessing unit or microcontroller unit products in the same group but having a different part number might differ in terms of internal memory capacity, layout pattern, and other factors, which can affect the ranges of electrical characteristics, such as characteristic values, operating margins, immunity to noise, and amount of radiated noise. When changing to a product with a different part number, implement a system-evaluation test for the given product.

Corporate Headquarters

TOYOSU FORESIA, 3-2-24 Toyosu,
Koto-ku, Tokyo 135-0061, Japan
www.renesas.com

Contact information

For further information on a product, technology, the most up-to-date version of a document, or your nearest sales office, please visit: www.renesas.com/contact/.