Renesas Synergy™ Platform

External IRQ Framework Module Guide

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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 an efficient starting point. References to more detailed API descriptions and suggestions of other application projects that illustrate more advanced uses of the module are included in this document and should be valuable resources for creating more complex designs.

The External IRQ Framework is a generic API for applications using the external pin interrupts with the ThreadX RTOS. The Framework is implemented on sf_external_irq and supports the external IRQ pins on the Synergy microcontroller.

Contents

1. External IRQ Framework Module Features

- Responds to external interrupt inputs
- RTOS aware implementation using an internal semaphore for thread synchronization
    - Can signal internal threads
    - Can trigger transfers via the Event Link Controller (ELC)
- Uses the port pins available on Synergy MCUs
    - Pins may differ between MCUs so refer to MCU User’s Manuals for specifics
- Supports several hardware features such as
    - Channel selection
    - Trigger conditions
    - Digital filtering
    - Auto-start

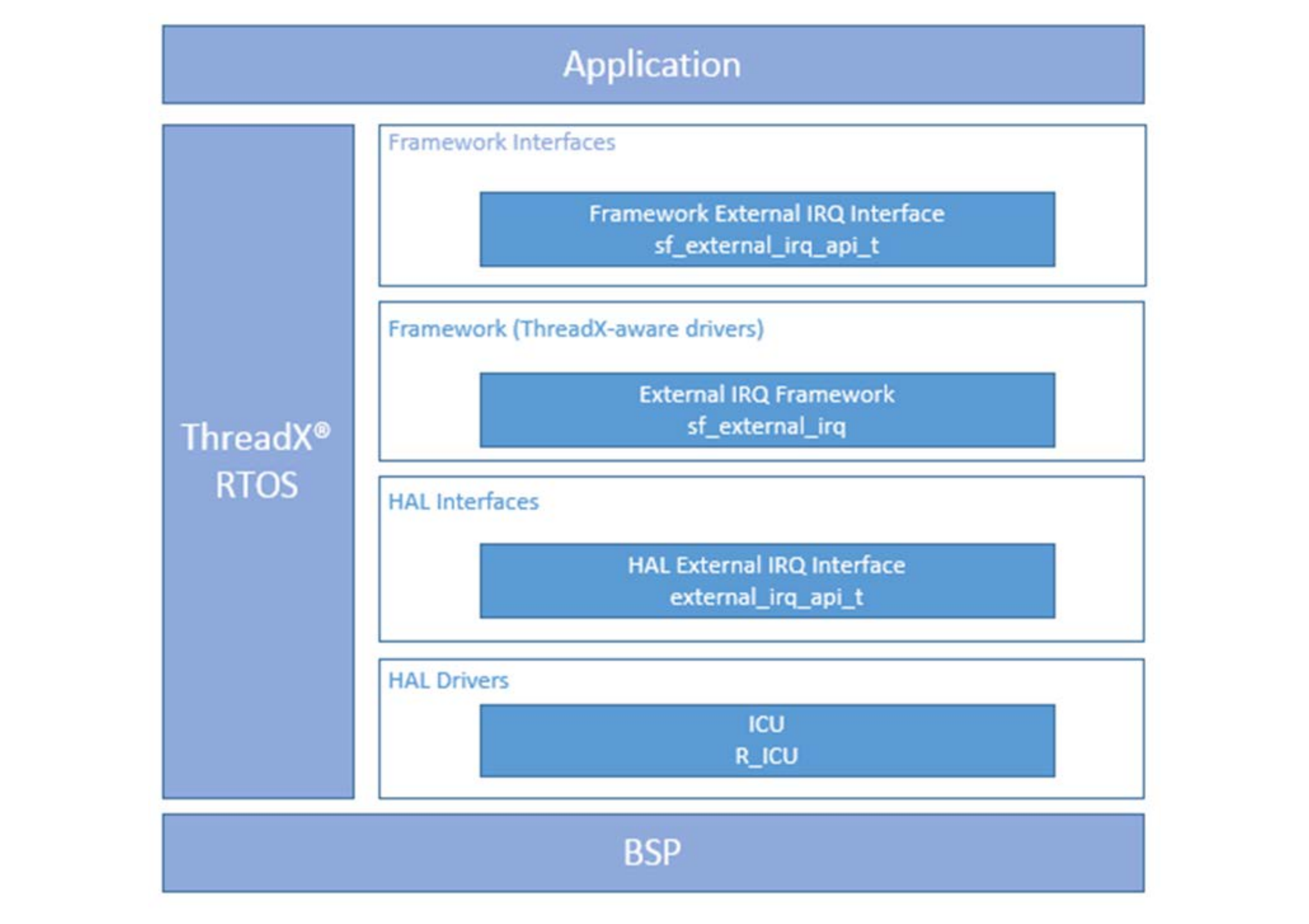

Figure 1 External IRQ Framework Module Block Diagram

2. External IRQ Framework Module APIs Overview

The External IRQ Framework module defines APIs for opening, waiting, or closing the module. 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 status return values follows the API summary table.

Table 1 External IRQ Framework Module API Summary

Function Name	Example API Call and Description
.open	`g_sf_external_irq.p_api->open(g_sf_external_irq.p_ctrl, g_sf_external_irq.p_cfg);` Acquire mutex, then handle driver initialization at the HAL layer.
.wait	`g_sf_external_irq.p_api->wait(g_sf_external_irq.p_ctrl, TX_WAIT_FOREVER);` Wait for the next external interrupt expiration, then return.
.versionGet	`g_sf_external_irq.p_api->versionGet(&version);` Retrieve the API version and store it in the version pointer.
.close	`g_sf_external_irq.p_api->close(g_sf_external_irq.p_ctrl);` Release channel mutex and close channel at HAL layer.

Note: For more complete descriptions of 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	Function successful
SSP_ERR_ASSERTION	Assertion error
SSP_ERR_IN_USE	Device in use
SSP_ERR_NOT_OPEN	Device unopened
SSP_ERR_TIMEOUT	Timeout error
SSP_ERR_WAIT_ABORTED	Suspension aborted
SSP_ERR_UNSUPPORTED	Function unsupported by the HAL driver

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. External IRQ Framework Module Operational Overview

The External IRQ Framework is a set of ThreadX-aware framework APIs. The External IRQ Framework external inputs such as switches can signal, via an internal semaphore, threads or trigger transfers via the Event Link Controller (ELC). Both the External IRQ Framework module and the External IRQ HAL module need to be configured for proper operation. The HAL configuration settings allow control over hardware options such as triggering level and digital filtering settings.

3.1 External IRQ Framework Module Important Operational Notes and Limitations

3.1.1 External IRQ Framework Module Operational Notes

- Refer to the datasheet for the Synergy device to be programmed to find the port pins which support the external interrupt functions and to obtain the external IRQ number for a given port pin.
- The external IRQ number corresponds to the channel setting in the ISDE **Properties** window for the external IRQ driver.

3.1.2 External IRQ Framework Module Limitations

- Refer to the most recent *SSP Release Notes* for any additional operational limitations for this module.

4. Including the External IRQ Framework Module in an Application

This section describes how to include the External IRQ Framework module in an application using the SSP configurator.

Note: This section assumes 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 chapters of the *SSP User's Manual* to learn how to manage each of these important steps in creating SSP-based applications.

To add the External IRQ Framework module to an application, simply add it to a thread using the stacks selection sequence given in the following table. (The default name for the External IRQ Framework module is `g_sf_external_irq0`. This name can be changed in the associated Properties window.)

Table 3 External IRQ Framework Selection Sequence

Resource	ISDE Tab	Stacks Selection Sequence
g_sf_external_irq0 External IRQ Framework on sf_external_irq	Threads	New Stack> Framework> Input> External IRQ Framework on sf_external_irq

When the External IRQ Framework module on `sf_external_irq` is added to the thread stack as shown in the following figure, the configurator automatically adds the needed lower-level drivers. Any drivers that need additional configuration information will be highlighted in Red. The specific settings required can be viewed by hovering the cursor over the highlighted text or suggested in the highlighted stack frame. For this stack, the reported requirements for the External IRQ Framework module are to enable the decompression-interrupt priority and the data-transfer interrupt-priority interrupts.

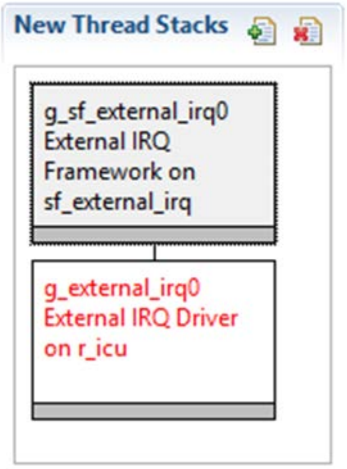
New Thread Stacks
g_sf_external_irq0 External IRQ Framework on sf_external_irq
g_external_irq0 External IRQ Driver on r_icu

Figure 2 External IRQ Framework Module Stack

5. Configuring the External IRQ Framework Module

The External IRQ Framework module must be configured for the desired operation. The SSP configuration window will automatically identify (by highlighting the block in red) any required configuration selections, such as interrupts or operating modes, that must be configured for lower-level modules for successful operation. Furthermore, only those properties that can be changed without causing conflicts are available for modification. Other properties are locked and 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.

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

Table 4 Configuration for the JPEG HAL Module on sf_external_irq

ISDE Property	Value	Description
Parameter Checking	BSP, Enabled, Disabled (Default: BSP)	Parameter selection.
Name	g_sf_external_irq0	Framework name.
Event	Semaphore Put, None (Default: Semaphore Put)	Event selection.

5.1 Configuration Settings for the External IRQ Framework Module Low-Level Drivers

Typically, only a small number of settings must be modified from the default for lower level modules. (These are indicated with red text in the thread stack block.) Notice that some of the configuration properties must be set to a certain value for proper framework operation and will be locked to prevent user modification. The following tables identify all the settings within the properties section for the module.

Table 5 Configuration Settings for the External IRQ Driver on r_icu

ISDE Property	Setting	Description
Parameter Checking	BSP, Enabled, Disabled (Default: BSP)	Parameter selection
ICU IRQ0	Priority 0 (highest), 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15 (lowest, not valid if using ThreadX), Disabled (Default: Disabled)	ICU selection
Name	g_external_irq0	Driver name.
Channel	0	Specifies the hardware IRQ channel used
Trigger	Falling, Rising, Both Edges, Low Level (Default: Rising)	Trigger selection
Digital Filtering	Enabled, Disabled (Default: Disabled)	Digital filter enable/disable
Digital Filtering Sample Clock (only valid when digital filtering is enabled)	PCLK/1, PLCK/8, PLCK/32, PCLK/64 (Default: PCKL/64)	Sets noise filter sampling period
Interrupt enabled after initialization	True, False (Default: True)	Interrupt enable selection
Callback	NULL	Callback 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.

6. Using the External IRQ Framework Module in an Application

The typical steps in using the External IRQ Framework module in an application are:

1. Open the External IRQ Framework module with the `open` API
2. Wait for an interrupt using the `wait` API
3. Process External IRQ event
4. Close the module using the `close` API

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

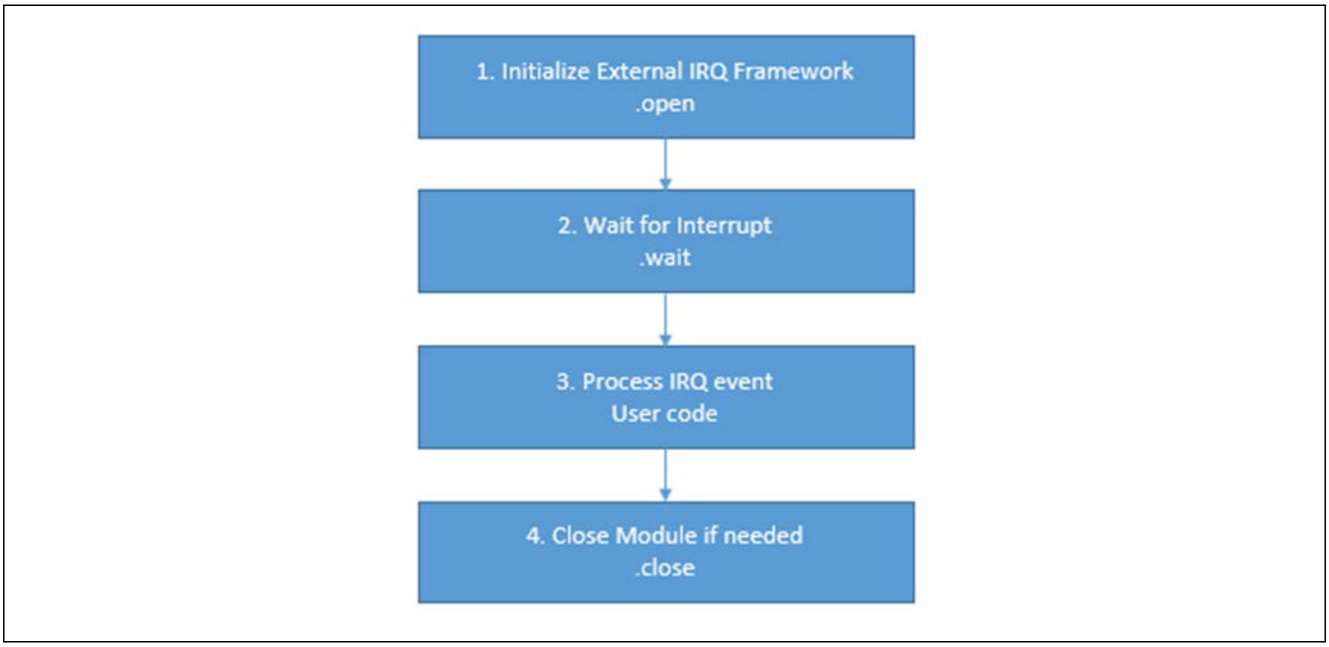

Figure 3 Flow Diagram of a Typical JPEG HAL/Framework Module Application

7. The External IRQ Framework Module Application Project

The application project associated with this module guide demonstrates the aforementioned steps in a full design. The project can be found using the link provided in the References section at the end of this document. You may want to import and open the application project in the ISDE and view the configuration settings for the External IRQ Framework module. You can also read over the code in `external_irq_fw_led_blinking.c`, which illustrate the External IRQ Framework APIs in a complete design.

The application project demonstrates the typical use of the External IRQ Framework module APIs. External IRQ Framework module handles the interrupts triggered by the SK-S7G2 user buttons: S4 and S5. Pushing the user button S4 increases the LEDs blinking frequency, whereas pushing the user button S5 decreases this frequency. The debug output is available through the Renesas Debug Virtual Console in e^2 studio in case of any error occurs during the program run. The following table identifies the target versions for the associated software and hardware used by the application project:

Table 6 Software and Hardware Resources Used by the Application Project

Resource	Revision	Description
e^2 studio	5.3.1 or later	Integrated Solution Development Environment
SSP	1.2.0 or later	Synergy Software Platform
IAR EW for Synergy	7.71.2 or later	IAR Embedded Workbench® for Renesas Synergy™
SSC	5.3.1 or later	Synergy Standalone Configurator
SK-S7G2	v3.0 to v3.1	Starter Kit

A simple flow diagram of the application project is given in the following figure:

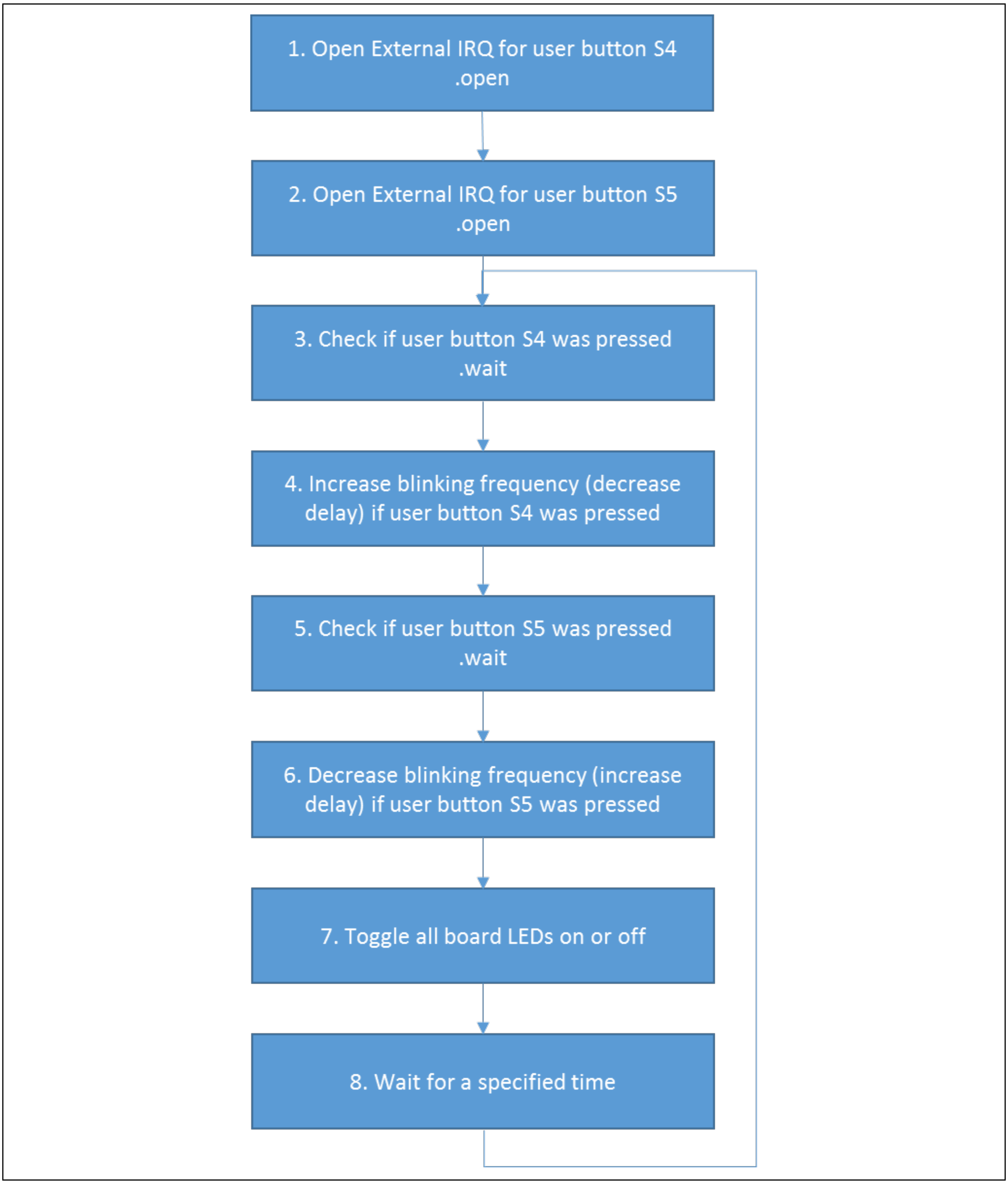
1. Open External IRQ for user button S4
.open
2. Open External IRQ for user button S5
.open
3. Check if user button S4 was pressed
.wait
4. Increase blinking frequency (decrease delay) if user button S4 was pressed
5. Check if user button S5 was pressed
.wait
6. Decrease blinking frequency (increase delay) if user button S5 was pressed
7. Toggle all board LEDs on or off
8. Wait for a specified time

Figure 4 External IRQ Framework Module Application Project Flow Diagram

The complete application project can be found using the link provided in the References section at the end of this document. The `external_irq_fw_led_blinking.c` files are located in the project once it has been imported into the ISDE. You can open these files within the ISDE and follow along with the description provided to help identify key uses of APIs. Descriptions of what each of the files contain is provided as well.

The first section of `external_irq_fw_led_blinking.c` provide references to header files which contain auxiliary constants and a code section which allows semihosting to display debug output using `printf()` function. There is also a declaration of the `external_irq_fw_led_blinking()` function in the included header file.

Second section of the `external_irq_fw_led_blinking.c` file contain a definition of the `external_irq_fw_led_blinking()` function. At the beginning of the function body there is a block of code which initializes the debug output. After declaring few variables the `R_BSP_LedsGet()` function is called to acquire LED information. If there are no LEDs on the board, the appropriate notification will be sent to the Renesas Debug Virtual Console and the program will be trapped using the `tx_thread_sleep()` function. Otherwise the program continues. The `.open()` function of the External IRQ Framework is called twice to open the external IRQ for two user buttons: S4 and S5. If any of these calls results with an error, the appropriate notification will be sent to the Renesas Debug Virtual Console and the program will be trapped using the `tx_thread_sleep()` function. Otherwise the program continues. The main `while` loop body begins with the `.wait()` function which allows it to check if the user button S4 was pressed. If so, the LEDs blinking frequency is increased. Likewise, it checks if the user button S5 was pressed. The blinking frequency is decreased in this case. Then the board LEDs are toggled on or off according to their state in the previous loop execution. At the end of the main while loop body a delay is performed using the `tx_thread_sleep()` function. Changing the LEDs blinking frequency is achieved by changing this delay.

Note: This description assumes you are familiar with using `printf()`with the Debug Console in the Synergy Software Package. If you are unfamiliar with this, refer to the How do I Use Printf() with the Debug Console in the Synergy Software Package Knowledge Base article, available as described in the References section at the end of this document. Alternatively, the user can see results via the watch variables in the debug mode.

A few key properties are configured in this application project to support the required operations and the physical properties of the target board and MCU. The following table lists the properties with the 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 7 External IRQ Framework Module Configuration Settings for the Application Project

ISDE Property	Value Set
Parameter Checking	Default (BSP)
Name	g_sf_external_irq_button_S4
Event	Semaphore Put

Table 8 External IRQ Driver Module Configuration Settings for the Application Project

ISDE Property	Value Set
Parameter Checking	Default (BSP)
Name	g_external_irq_button_S4
Channel	11
Trigger	Rising
Digital Filtering	Enabled
Digital Filtering Sample Clock (Only valid when Digital Filtering is Enabled)	PCLK/64
Interrupt enabled after initialization	True
Callback	NULL
Interrupt Priority	Priority 8 (CM4: valid, CM0+: invalid)

Table 9 External IRQ Framework Module Configuration Settings for the Application Project

ISDE Property	Value Set
Parameter Checking	Default (BSP)
Name	g_sf_external_irq_button_S5
Event	Semaphore Put

Table 10 External IRQ Driver Module Configuration Settings for the Application Project

ISDE Property	Value Set
Parameter Checking	Default (BSP)
Name	g_external_irq_button_S5
Channel	10
Trigger	Rising
Digital Filtering	Enabled
Digital Filtering Sample Clock (Only valid when Digital Filtering is Enabled)	PCLK/64
Interrupt enabled after initialization	True
Callback	NULL
Interrupt Priority	Priority 8 (CM4: valid, CM0+: invalid)

8. Customizing the External IRQ Framework Module for a Target Application

Some configuration settings will normally be changed by the developer from those shown in the application project. For example, you can easily change the interrupt trigger edge, disable digital filtering, or change the digital filtering sample clock. User buttons S4 and S5 use interrupt channels 11 and 10 respectively. Other interrupt channels can be used instead which makes it possible to handle other events. Changes can be made in the **Threads** tab by modifying the parameters of the External IRQ HAL module.

9. Running the External IRQ Framework Module Application Project

To run the External IRQ Framework 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* (11an0023eu0116-synergy-ssp-import-guide.pdf, included in this package) for instructions on importing the project into ISDE or IAR EW for Synergy and building/running the application.

Note: The following steps are described 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 External IRQ Framework module application project, simply follow these steps:

1. Create a new Renesas Synergy project for the SK-S7G2 called **External_IRQ_FW_MG_AP**.
2. In Synergy Configuration window select the **Threads** tab.
3. Create a new thread and set its parameters as follows:
   - Symbol: external_irq_fw_thread
   - Name: External IRQ FW Thread
4. While External IRQ FW Thread is selected, add two new stacks by selecting two times:
   New Stack > Framework > Input > External IRQ Framework on sf_external_irq
5. Set parameters for the two created stacks according to tables: Table 7, Table 8, Table 9, and Table 10.
6. Click on the **Generate Project Content** button.
7. Add the code from the supplied project files: `external_irq_fw_thread_entry.c`, `external_irq_fw_led_blinking.c`, and `external_irq_fw_led_blinking.h`, or simply copy these files into the `src` subdirectory overwriting the existing `external_irq_fw_thread_entry.c` file.
8. Build the project.
9. Connect to the host PC via a micro USB cable to J19 on SK-S7G2.
10. Start to debug the application.
11. The board LEDs will start blinking. The blinking frequency can be changed by pushing the user buttons S4 and S5.

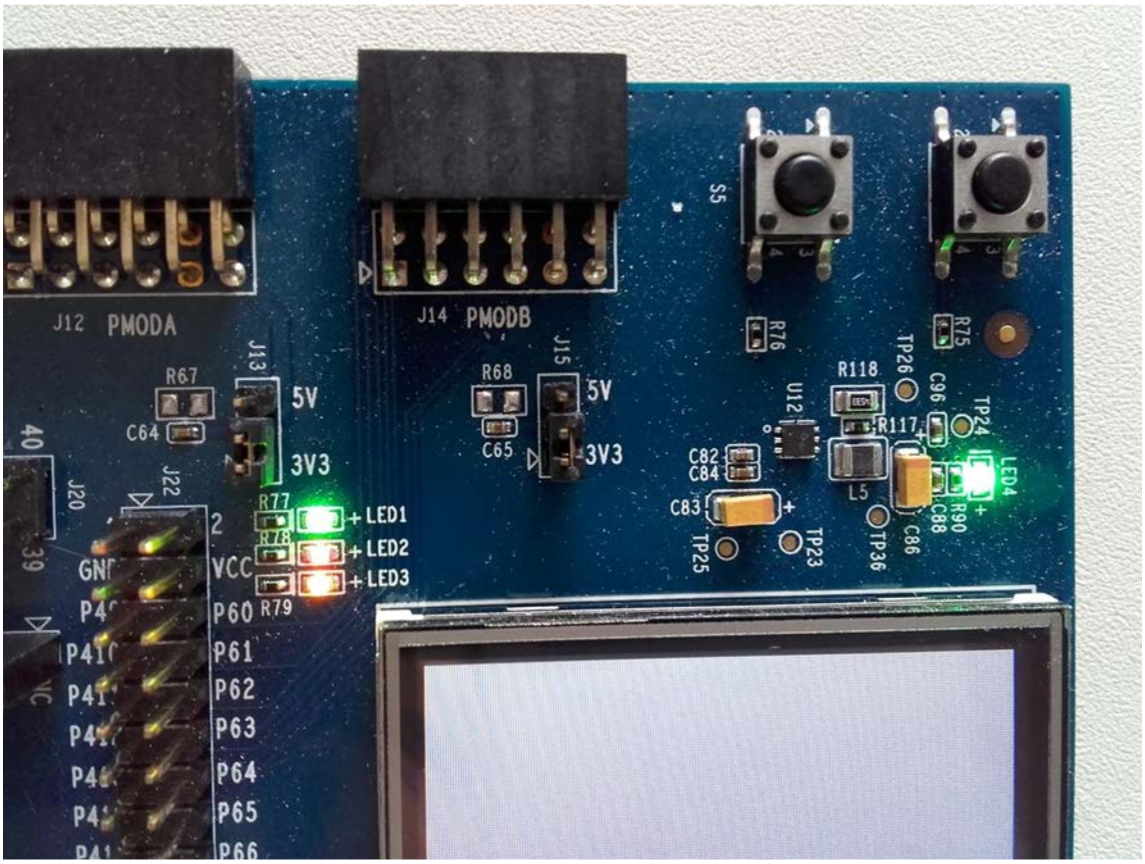

Figure 7 SK-S7G2 board view while running the External IRQ Framework Module Application Project

10. External IRQ Framework Module Conclusion

This module guide has provided all the background information needed to select, add, configure, and use the External IRQ Framework 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, such as 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. External IRQ Framework Module Next Steps

After you have mastered a simple External IRQ Framework module project, you may want to review a more complex example. Other application projects and application notes that demonstrate External IRQ Framework use can be found as described in the References section at the end of this document.

If you would like to further investigate the external interrupt functionality, you may be interested in familiarizing yourself with the External IRQ HAL module, which makes it possible to use your own callback function. If so, there is a module guide available: External IRQ HAL Module Guide. This guide is available as described in the References section at the end of this document.

12. External IRQ Framework Module Reference Information

SSP User Manual: Available in html format in the SSP distribution package and as a pdf from the Synergy Gallery.

Links to all the most up-to-date sf_external_irpq module reference materials and resources are available on the Synergy Knowledge Base: https://en-us.knowledgebase.renesas.com/English_Content/Renesas_Synergy%E2%84%A2_Platform/Renesas_Synergy_Knowledge_Base/SF_External_IRQ_Module_Guide_Resources.

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Revision History

Rev.	Date	Description Page	Summary
1.00	Jun 15, 2017	-	Initial Release
1.01	Sep 12, 2017	6	Update to Hardware and Software Resources Table

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Colophon 6.0