

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 on 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 Audio Playback Framework handles synchronization to play mono 16-bit pulse-code modulation (PCM) samples. For hardware access it uses the digital-to-analog converter (DAC) Audio Playback Framework or I²S Audio Playback Framework hardware port. This module guide focuses on the DAC Audio Playback Framework hardware port. The DAC Audio Playback Framework module is a high-level API for audio playback applications and is implemented on `sf_audio_playback_hw_dac`. The module handles the synchronization needed to play 16-bit pulse-code modulation (PCM) samples. The Audio Playback Framework uses the DAC, the Asynchronous General Purpose Timer (AGT) or General Purpose Timer (GPT), and the DMA or DTC data-transfer peripherals on a Synergy MCU. A user-defined callback can be created to respond additional data needs.

Contents

1. Audio Playback Hardware DAC Framework Module Features	2
2. Audio Playback Framework Module APIs Overview	2
3. Audio Playback Hardware DAC Framework Module Operational Overview	3
3.1 Audio Playback Hardware DAC Framework Module Important Operational Notes and Limitations	5
3.1.1 Audio Playback Hardware DAC Framework Module Operational Notes	5
3.1.2 Audio Playback Hardware DAC Framework Module Limitations	6
4. Including the Audio Playback Hardware DAC Framework Module in an Application	6
5. Configuring the Audio Playback Hardware DAC Framework Module	7
5.1 Configuration Settings for the Audio Playback Framework Low-Level Modules	8
5.2 Audio Playback Hardware DAC Framework Module Clock Configuration.....	13
5.3 Audio Playback Hardware DAC Framework Module Pin Configuration.....	13
6. Using the Audio Playback Hardware DAC Framework Module in an Application	14
7. The Audio Playback Hardware DAC Framework Module Application Project.....	15
8. Customizing the Audio Playback Hardware DAC Framework Module for a Target Application	18
9. Running the Audio Playback Hardware DAC Framework Module Application Project.....	18
10. Audio Playback Hardware DAC Framework Module Conclusion	19
11. Audio Playback Hardware DAC Framework Module Next Steps	19
12. Audio Playback Hardware DAC Framework Module Reference Information	19
Revision History	21

1. Audio Playback Hardware DAC Framework Module Features

The Audio Playback Hardware DAC Framework module supports the following features:

- Plays long buffers by splitting the data into manageable chunks.
- Repeats playback until a ThreadX® timeout (for repeated audio like sine wave tones or looped background music).
- Requests next data using callback after last buffer playback begins.
- Software volume control.
- Pauses and resumes functions.
- Scaling to move signed 16-bit PCM data into range of the unsigned 12-bit DAC.
- Basic mixing for multiple streams.

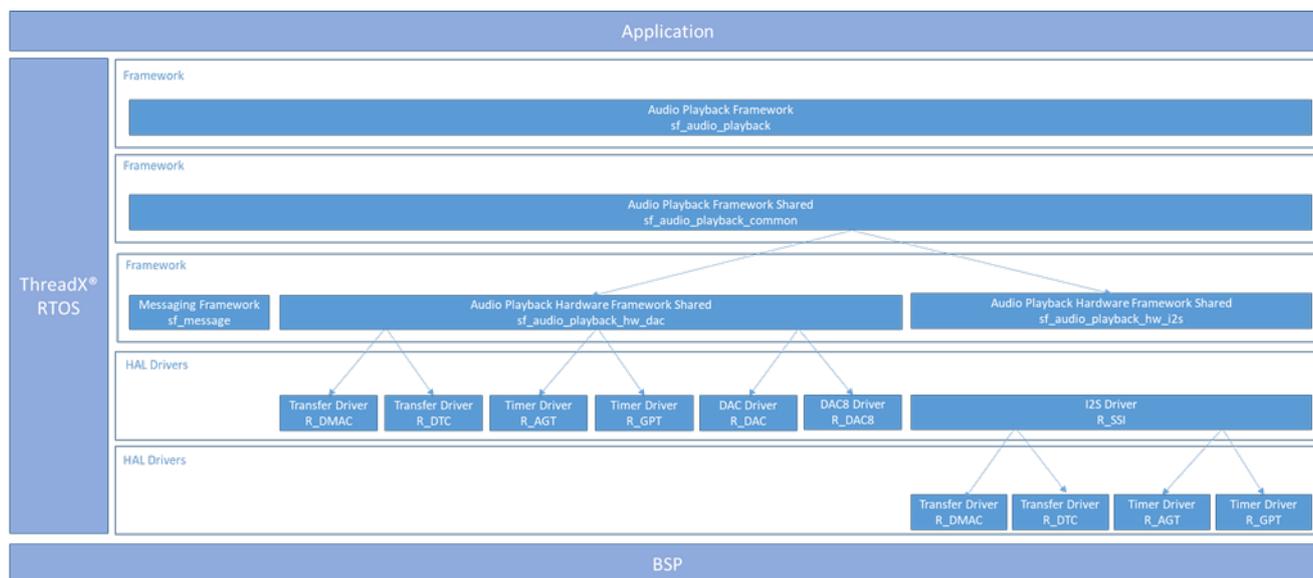


Figure 1 Audio Playback Hardware DAC Framework Module

2. Audio Playback Framework Module APIs Overview

The Audio Playback Framework defines APIs for such operations as opening, starting, playing and stopping. 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 Audio Playback Framework Module API Summary

Function Name	Example API Call and Description
.open	<pre>g_sf_audio_playback0.p_api->open(g_sf_audio_playback0.p_ctrl, g_sf_audio_playback0.p_cfg);</pre> <p>Configure the audio framework by creating a thread for audio playback and configuring HAL layer drivers used.</p>
.start	<pre>g_sf_audio_playback0.p_api->start(g_sf_audio_playback0.p_ctrl, &p_data, 100);</pre> <p>Play audio</p>
.stop	<pre>g_sf_audio_playback0.p_api->stop(g_sf_audio_playback0.p_ctrl);</pre> <p>Stop audio playback.</p>

Function Name	Example API Call and Description
.pause	<pre>g_sf_audio_playback0.p_api- >pause(g_sf_audio_playback0.p_ctrl);</pre> Pause audio playback.
.resume	<pre>g_sf_audio_playback0.p_api- >resume(g_sf_audio_playback0.p_ctrl);</pre> Resume audio playback.
.volumeSet	<pre>g_sf_audio_playback0.p_api- >volumeSet(g_sf_audio_playback0.p_ctrl, 255);</pre> Sets software volume control. Software volume control is applied globally to all streams on the hardware.
.close	<pre>g_sf_audio_playback0.p_api- >close(g_sf_audio_playback0.p_ctrl);</pre> The close API handles the cleanup of internal driver data.
.versionGet	<pre>g_sf_audio_playback0.p_api->versionGet(&version);</pre> Return the version of the driver.

Note: For details on the 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	A pointer is NULL or a parameter is invalid.
SSP_ERR_OUT_OF_MEMORY	The number of streams open at once is limited to SF_AUDIO_PLAYBACK_CFG_MAX_STREAMS. If this number is exceeded, an out of memory error occurs.
SSP_ERR_TIMEOUT	Timeout occurred before playback finished.
SSP_ERR_NOT_OPEN	The stream control block p_ctrl is not initialized.

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

3. Audio Playback Hardware DAC Framework Module Operational Overview

The Audio Playback Framework module creates a thread internally to support audio playback. The following figure shows a flowchart of the audio playback framework thread and its interactions with the public Audio Playback Framework APIs.

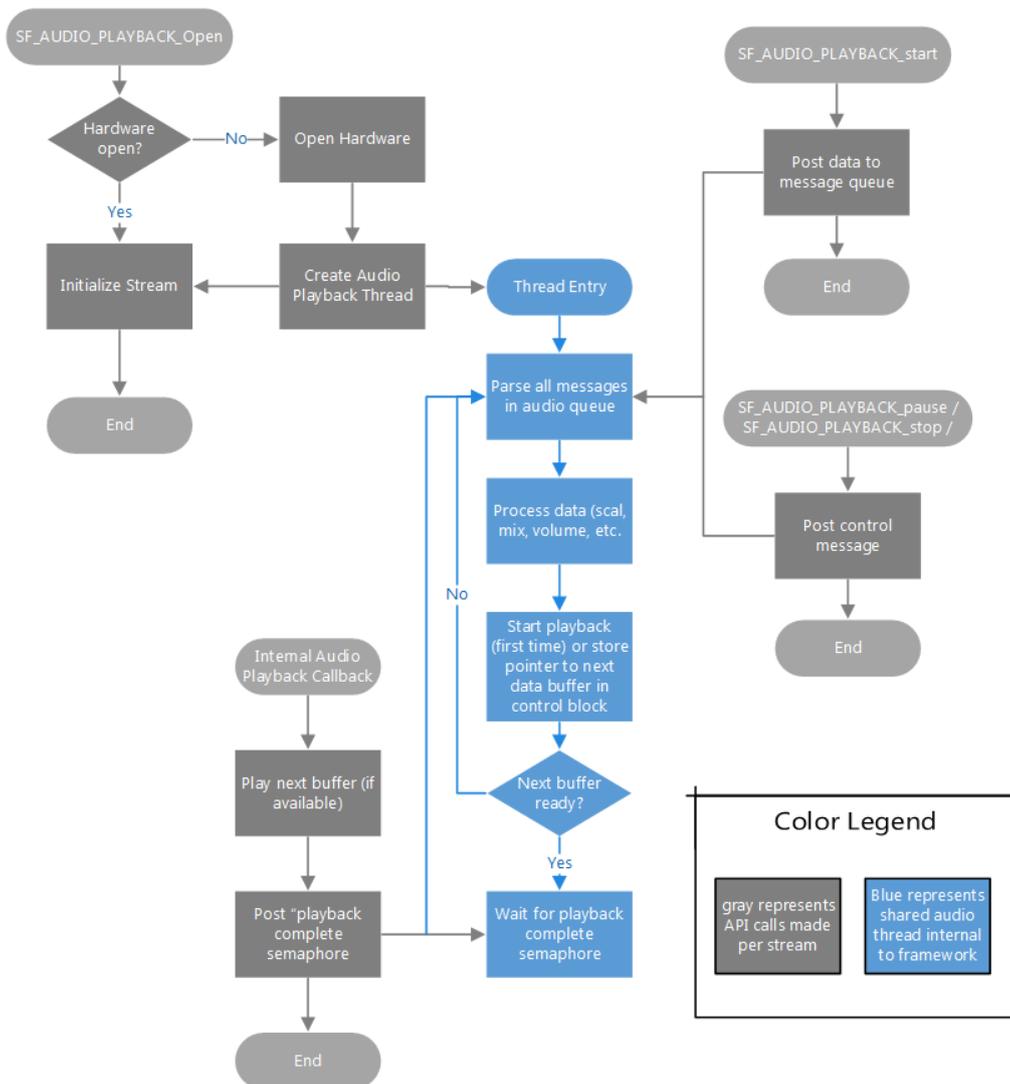


Figure 2: Audio Playback Framework Flowchart

Suggested use of the audio playback framework:

- Create a semaphore (for example, `g_sf_audio_playback_semaphore`). You can create it on the Threads Tab. Set the initial value to 2 (the audio playback framework can store up to two data messages per stream).
- Create a callback function (for example, `sf_audio_playback_callback`). Enter the name of your callback function in the Audio Playback Framework instance. The callback function will be called when the audio playback framework is done with the data. In the callback, put the semaphore created above.
- In your main loop, get the semaphore before playing data. To play data, first acquire a buffer from the messaging framework, then create your audio playback data structure inside the buffer.

The Audio Playback Framework supports multiple audio streams on a single hardware port. The following figure shows the modules required if two streams are used.

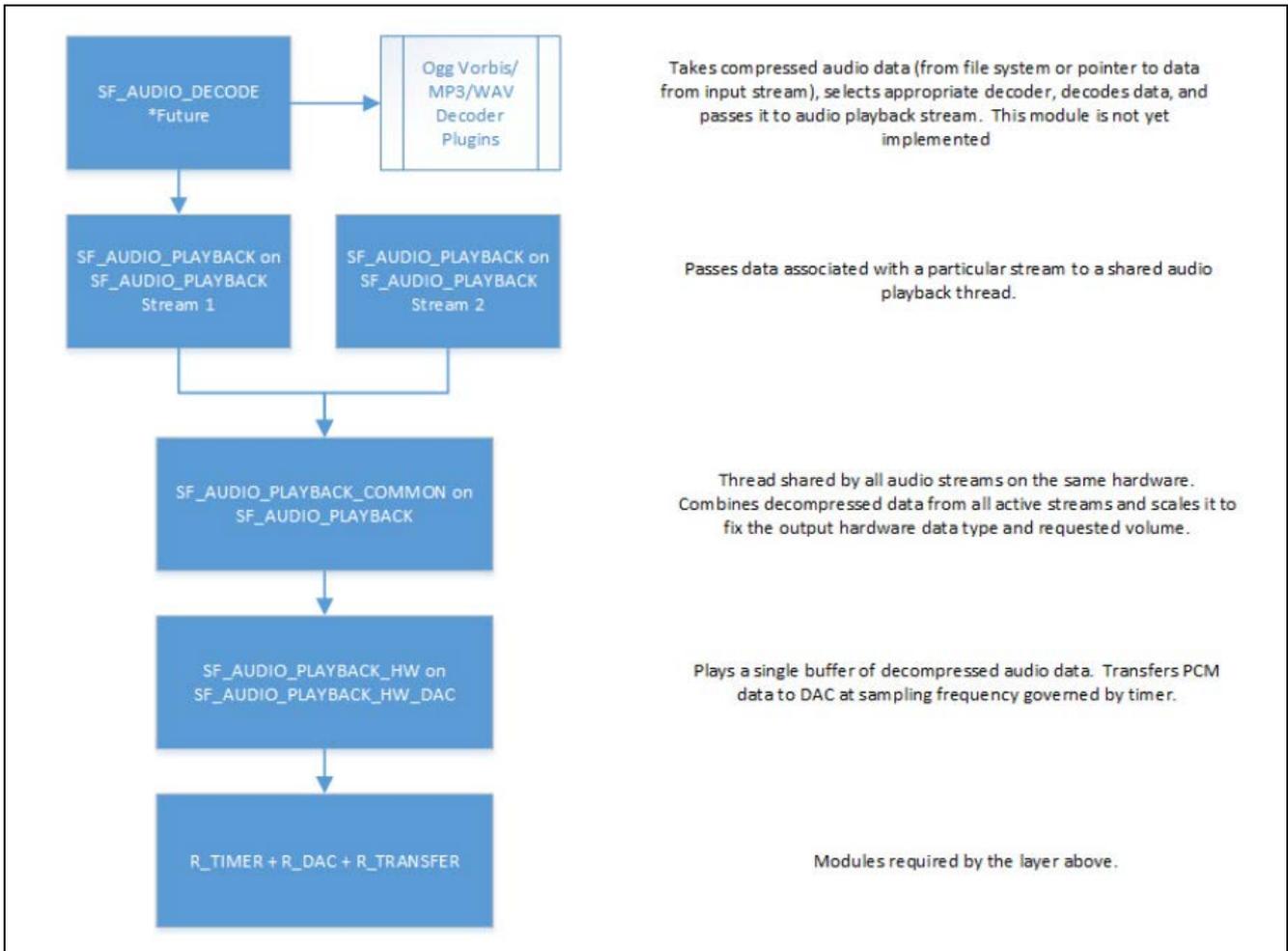


Figure 3 Implementing Multiple Audio Streams

3.1 Audio Playback Hardware DAC Framework Module Important Operational Notes and Limitations

3.1.1 Audio Playback Hardware DAC Framework Module Operational Notes

Configuring Messages

Use the Messaging Framework configurator on the Messaging tab to configure the messaging framework.

1. Highlight the Audio Playback event class.
2. Add a new subscriber.
3. Select the following configurations.
 - Make sure the **Message Class Instance** property is between the Start and End instance. This property is set in the **Properties** tab of the Audio Playback Framework on the `sf_audio_playback` module.
 - Thread: Any thread in the application.
 - Start: First audio instance used in application.
 - End: Last audio instance used in application.
4. Highlight the new Subscriber in the Audio Playback Subscribers. Record the Symbol name.
5. Go back to the **Threads** tab.
6. Highlight the Audio Playback Framework Shared module in HAL/Common.
7. Set the Audio Message Queue Name to the Symbol name from the Audio Playback Subscriber.

Using the I²S Implementation

The audio framework I²S hardware port has dependencies on the I²S Driver module. The I²S driver module can be accelerated with DTC (recommended).

Set the ISDE properties for the I²S driver module.

- Set the Audio Clock Frequency (Hertz) to the frequency of the input audio clock used.
- Set the Sampling Frequency (Hertz) to the sampling frequency of your audio data.
- Set the Data Bits and Word Length to 16 bits (audio framework accepts 16-bit samples only).
- Enable the SSIn TXI and SSIn INT interrupts.

Recommended: The transfer module on `r_dtc` is added automatically.

Using the DAC Implementation

- The Queue used must match the name specified in Properties for Audio Playback Framework Shared on `sf_audio_playback` (default is `g_sf_audio_playback_queue`).
- The audio framework DAC hardware port has dependencies on the Timer, DAC, and Transfer API modules.
- Timer module.
 - Set the Frequency in Hz to the sampling frequency of your audio data.
 - Enable the interrupt if using DTC as the transfer module (recommended).
- Transfer module on `r_dtc`.
 - Set the Destination pointer to `&R_DAC->DADRn[0]` if using DAC channel 0 or `&R_DAC->DADRn[1]`, if using DAC channel 1.
 - Set the Activation source to the timer interrupt chosen above.
- The Audio Playback Framework is designed to support the following MCU families with no changes to the API:
 - S7G2
 - S3A7
 - S124

Other Operational Notes

The buffer used for the playback should not be more than 2048 bytes

3.1.2 Audio Playback Hardware DAC Framework Module Limitations

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

4. Including the Audio Playback Hardware DAC Framework Module in an Application

To include the Audio Playback Hardware Framework module in an application using the SSP configurator, use the following instructions.

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, see the *SSP User's Manual* to learn how to manage each of these important steps in creating SSP-based applications.

To add the Audio Playback Framework to your application, simply add it to a project thread using the stacks selection sequence given in the following table. (The default name for the Audio Playback Hardware Framework is `g_sf_audio_playback`. The default name can be changed in the associated Properties window.)

Table 3 Audio Playback Framework Module Selection Sequence

Resource	ISDE Tab	Stacks Selection Sequence
<code>g_sf_audio_playback</code> Audio Playback Framework on <code>g_sf_audio_playback</code>	Threads	New Stack> Framework> Audio> Audio Playback Framework on <code>g_sf_audio_playback</code>
<code>g_sf_audio_playback_hw</code> Audio Playback Hardware Framework Shared on <code>sf_audio_playback_hw_dac</code>	Threads	Add Audio Playback Hardware > Audio Playback Hardware Framework Shared on <code>sf_audio_playback_hw_dac</code>

The following figures show when the Audio Playback Hardware Framework module on `sf_audio_playback` is added to the thread stack, the configurator automatically adds any needed lower-level drivers. Any drivers needing configuration information are highlighted in **red**. Modules with a **gray** band are individual, standalone modules. Modules with a **blue** band are shared or common, and need to be added only once to be used by multiple stacks. Modules with a **pink** band can require selecting of lower-level drivers; these drivers are either optional or recommended (indicated by text in the block). If additional lower-level drivers are required, the module description includes “Add” in the text. Clicking any **pink**-banded modules brings up the “New” icon and displays possible choices.

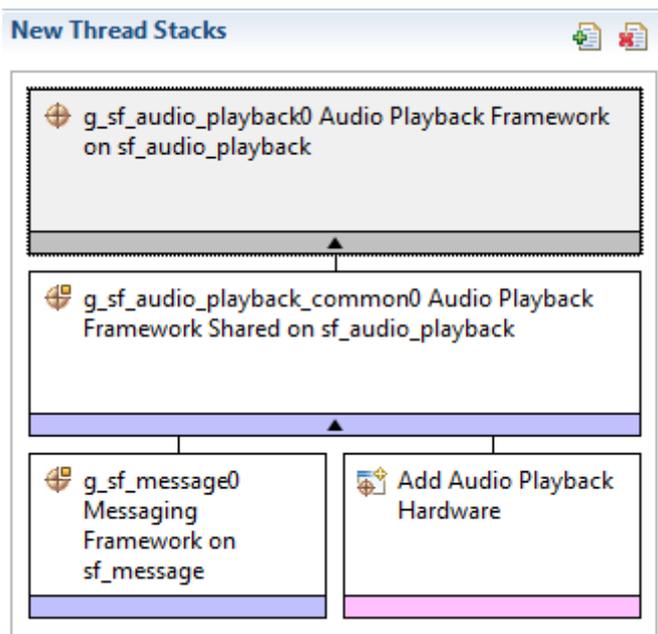


Figure 4 Audio Playback Framework Module Stack

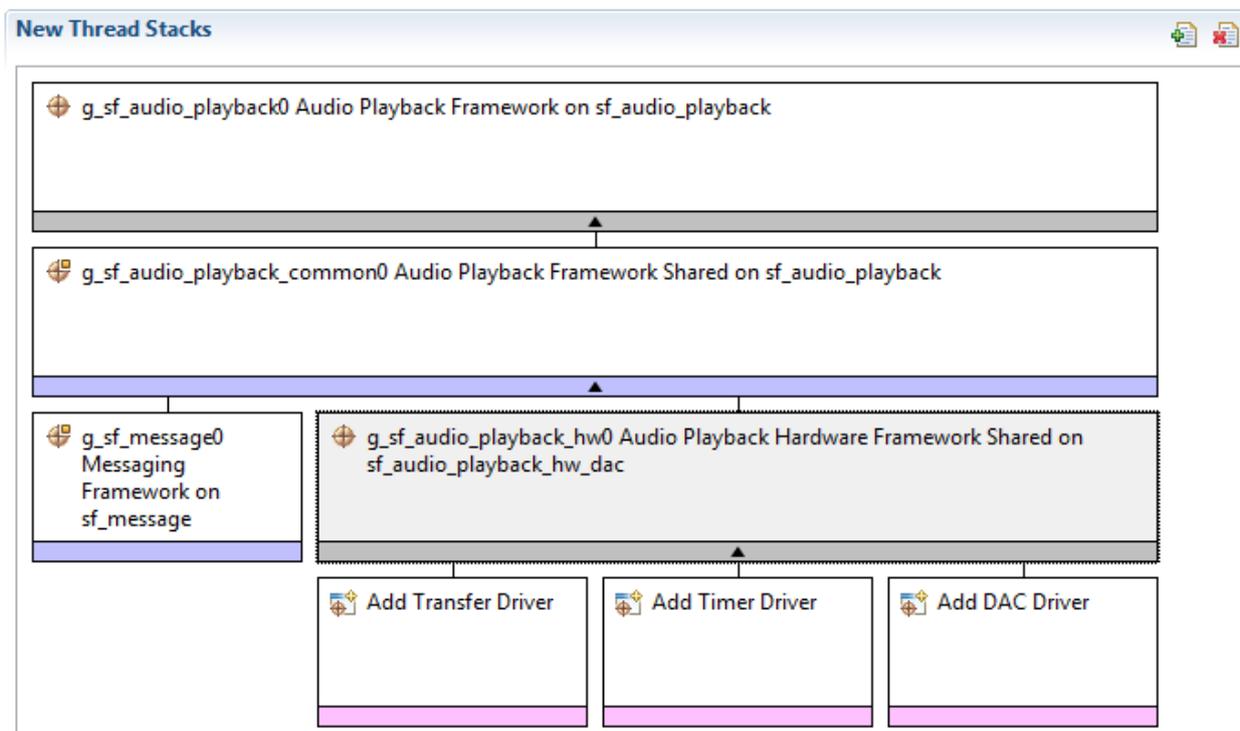


Figure 5 Audio Playback Hardware DAC Framework Module Stack

5. Configuring the Audio Playback Hardware DAC Framework Module

You configure the Audio Playback Hardware DAC Framework module to the desired operation. The SSP configuration window automatically identifies (by highlighting the block in red) any required configuration for lower-level modules, such as interrupts or operating modes, needed for successful operation. Only properties that can be changed without causing conflicts are available. Other properties are unavailable for modification and ‘locked’ with a lock icon in the ISDE Properties window to indicate the ‘locked’ property. This approach simplifies the configuration process and makes it much less error-prone than previous ‘manual’ approaches. The available configuration settings and the defaults for all the user-accessible properties are displayed in the Properties tab within the SSP configurator, and are also listed in the following tables for easy reference.

One of the properties that often needs changing is the interrupt priority; this configuration setting is available within the Properties window of the associated module. Simply select the module and view the Properties window; the interrupt settings are usually near the bottom of the properties list, so scroll down until they become available. Notice that the interrupt priorities listed in the ISDE Properties window indicates the validity of the setting based on the MCU targeted (CM4 or CM0+). This level of detail is not 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 reviewing the following configuration table settings. This helps to 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 Audio Playback Framework Module on sf_audio_playback

ISDE Property	Value	Description
Parameter Checking	BSP, Enabled, Disabled Default: BSP	Enables or disables the parameter checking.
Buffer Size Bytes	512	Buffer size bytes selection.
Maximum Number of Streams	1	Maximum number of streams selection.
Thread Stack Size	512	Thread stack size selection.
Name	g_sf_audio_playback0	Module name.
Message Class Instance	0	Message class instance selection.
Callback	NULL	Callback selection.
Name of generated initialization function	sf_audio_playback_init0	Name of generated initialization function selection
Auto Initialization	Enable, Disable Default: Enable	Auto initialization selection

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

In some cases, settings other than the defaults for lower-level modules can be desirable. For example, it might be useful to select the DAC Channel based on the target hardware implementation. For completeness, and as a reference, configurable properties for lower-level stack modules are provided in the following subsections.

Note: Most property settings for lower-level modules are intuitive and usually can be determined by inspection of the associated properties window from the SSP configurator.

5.1 Configuration Settings for the Audio Playback Framework Low-Level Modules

Typically, only a small number of settings are modified from the default for lower-level drivers, as the red text in the thread stack block indicates. Notice that some configuration properties must be set to a certain value for proper framework operation and are locked to prevent user modification. The following table identifies all the settings within the properties section for the module.

Table 5 Configuration Settings for the Audio Playback Framework Shared on sf_audio_playback_common

ISDE Property	Value	Description
Name	g_sf_audio_playback_common0	Module name
Thread Priority	3	Priority for the thread (do not edit)
Audio Message Queue Name	g_sf_audio_playback_queue	Message Queue name

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

Table 6 Configuration Settings for the Messaging Framework on sf_message

ISDE Property	Value	Description
Parameter Checking	BSP, Enabled, Disabled Default: BSP	Enables or disables the parameter checking.
Message Queue Depth (Total number of messages to be enqueued in a Message Queue)	16	Specify the size of Thread X Message Queue in bytes for Message Subscribers. This value is applied to all the Message Queues.
Name	g_sf_message0	The name of Messaging Framework module control block instance.
Work memory size in bytes	2048	Specify the work memory size in bytes. Choosing a small number results a small number of buffers which can be allocated at the same time (You can confirm the total buffer number on: sf_message_ctrl_t::number_of_buffers). If the value is smaller than the peak number of messages to be posted at the same time, the Framework occurs a buffer allocation failure affecting system performance.
Pointer to subscriber list array	p_subscriber_lists	Specify the name of pointer to the Subscriber List array.
name of the block pool internally used in the messaging framework	sf_msg_blk_pool	The name of memory block memory the Framework creates in the control block. This parameter might be useful for debugging purpose but NULL can be specified for saving memory.

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 7 Configuration Settings for the Audio Playback Hardware Framework Shared on sf_audio_playback_hw_dac

ISDE Property	Value	Description
Parameter Checking	BSP, Enabled, Disabled Default: BSP	Enables or disables the parameter checking.
DMAC Support	Disabled, Enabled Default: Disabled	DMAC support selection.
Name	g_sf_audio_playback_hw0	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 8 Configuration Settings for the DMAC HAL Module on r_dmac Software Activation

ISDE Property	Value	Description
Parameter Checking	BSP, Enabled, Disabled Default: BSP	Selects if code for parameter checking is to be included in the build
Name	g_transfer0	Module name
Channel	0	Channel selection
Mode	Normal	Mode selection
Transfer Size	2 Bytes	Transfer size selection
Destination Address Mode	Fixed	Destination address mode selection
Source Address Mode	Incremented	Source address mode selection
Repeat Area (Unused in Normal Mode)	Source	Repeat area selection
Destination Pointer	NULL	Destination pointer selection
Source Pointer	NULL	Source pointer selection

ISDE Property	Value	Description
Number of Transfers	0	Number of transfers selection
Number of Blocks (Valid only in Block Mode)	0	Number of blocks selection
Activation Source	Software Activation, Peripheral Events Default: Software Activation	Activation source selection
Auto Enable	False	Auto enable selection
Callback	NULL	Callback selection
Interrupt Priority	Priority 0 (highest), Priority 1:2, Priority 3 (CM4: valid, CM0+: lowest-not valid if using ThreadX), Priority 4:14 (CM4: valid, CM0+: invalid), Priority 15 (CM4 lowest - not valid if using ThreadX, CM0+: invalid) Default: Disabled	Interrupt priority selection

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

Table 9 Configuration Settings for the DTC HAL Module on r_dtc Software Activation 1

ISDE Property	Value	Description
Parameter Checking	BSP, Enabled, Disabled Default: BSP	Selects whether code for parameter checking is to be included in the build
Software Start	Enabled, Disabled Default: Disabled	Software start selection
Linker section to keep DTC vector table	.ssp_dtc_vector_table	Linker section selection
Name	g_transfer0	Module name
Mode	Normal	Mode selection
Transfer Size	2 Bytes	Transfer size selection
Destination Address Mode	Fixed	Destination address mode selection
Source Address Mode	Incremented	Source address mode selection
Repeat Area (Unused in Normal Mode)	Source	Repeat area selection
Interrupt Frequency	After all transfers have completed	Interrupt frequency selection
Destination Pointer	NULL	Destination pointer selection
Source Pointer	NULL	Source pointer selection
Number of Transfers	0	Number of transfers selection
Number of Blocks (Valid only in Block Mode)	0	Number of blocks selection
Activation Source (Must enable IRQ)	Software Activation 1, Software Activation 2, Peripheral Events Default: Software Activation 1	Activation source selection
Auto Enable	False	Auto enable selection
Callback (Only valid with Software start)	NULL	Callback selection
ELC Software Event Interrupt Priority	Priority 0 (highest), Priority 1:2, Priority 3 (CM4: valid, CM0+: lowest-not valid if using ThreadX), Priority 4:14 (CM4: valid, CM0+: invalid), Priority 15 (CM4 lowest - not valid if using ThreadX, CM0+: invalid) Default: Disabled	ELC Software Event interrupt priority 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.

Table 10 Configuration Settings for the AGT HAL Module on r_agt

ISDE Property	Value	Description
Parameter Checking	BSP, Enabled, Disabled Default: BSP	Enables or disables parameter checking.
Name	g_timer0	Module name.
Channel	0	Physical hardware channel.
Mode	Periodic	Warning: One Shot functionality is not available in the GPT hardware; it is implemented in software by stopping the timer in the interrupt service routine (ISR) called when the period expires. For this reason, any ISRs must be enabled for one-shot mode even if the callback is unused.
Period Value	10	See Timer Period Calculation.
Period Unit	Hertz	See Timer Period Calculation.
Auto Start	FALSE	Set to true to start the timer after configuring, or false to leave the timer stopped until timer_api_t::start is called.
Count Source	PCLKB, PCLKB/8, PCLKB/2, LOCO, AGT0 Underflow, AGT0 fSub Default: PCLKB	The clock source for the AGT counter.
AGTO Output Enabled	True, False Default: False	Set to true to output the timer signal on a port pin configured for AGT (AGTO pin). Set to false for no output of the timer signal.
AGTIO Output Enabled	True, False Default: False	Set to true to output the timer signal on a port pin configured for AGT (AGTIO pin). Set to false for no output of the timer signal.
Output Inverted	True, False Default: False	Set to false to start the output signal low. Set to true to start the output signal high.
Callback	NULL	A user callback function can be registered in timer_api_t::open. If this callback function is provided, it is called from the ISR each time the timer period elapses. Warning: Since the callback is called from an ISR, care should be taken not to use blocking calls or lengthy processing. Spending excessive time in an ISR can affect the responsiveness of the system.
Interrupt Priority	Priority 0 (highest), Priority 1:2, Priority 3 (CM4: valid, CM0+: lowest-not valid if using ThreadX), Priority 4:14 (CM4: valid, CM0+: invalid), Priority 15 (CM4 lowest - not valid if using ThreadX, CM0+: invalid) Default: Disabled	Timer interrupt priority. 0 is the highest priority.

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 11 Configuration Settings for the GPT HAL Module on r_gpt

ISDE Property	Value	Description
Parameter Checking	BSP, Enabled, Disabled Default: BSP	Enables or disables the parameter checking.
Name	g_timer0	Module name.
Channel	0	Channel selection.
Mode	Periodic	Warning: One-shot functionality is not available in the GPT hardware; it is implemented in software by stopping the timer in the ISR called when the period expires. For this reason, ISR's must be enabled for one-shot mode even if the callback is unused.
Period Value	10	See Timer Period Calculation
Period Unit	Hertz	See Timer Period Calculation
Duty Cycle Value	50	Duty cycle value selection
Duty Cycle Unit	Unit Raw Counts, Unit Percent, Unit Percent x 1000 Default: Unit Raw Counts	Duty cycle unit selection
Auto Start	FALSE	Set to true to start the timer after configuring or false to leave the timer stopped until timer_api_t::start is called.
GTIOCA Output Enabled	True, False Default: False	Set to true to output the timer signal on a port pin configured for GPT. Set to false for no output of the timer signal.
GTIOCA Stop Level	Pin Level Low, Pin Level High, Pin Level Retained Default: Pin Level Low	Controls output pin level when the timer is stopped.
GTIOCB Output Enabled	True, False Default: False	Set to true to output the timer signal on a port pin configured for GPT. Set to false for no output of the timer signal.
GTIOCB Stop Level	Pin Level Low, Pin Level High, Pin Level Retained Default: Pin Level Low	Controls output pin level when the timer is stopped.
Callback	NULL	A user callback function can be registered in timer_api_t::open. If this callback function is provided, it will be called from the ISR each time the timer period elapses. Warning: Since the callback is called from an ISR, care should be taken not to use blocking calls or lengthy processing. Spending excessive time in an ISR can affect the responsiveness of the system.
Interrupt Priority	Priority 0 (highest), Priority 1:2, Priority 3 (CM4: valid, CM0+: lowest- not valid if using ThreadX), Priority 4:14 (CM4: valid, CM0+: invalid), Priority 15 (CM4 lowest - not valid if using ThreadX, CM0+: invalid) Default: Disabled	Interrupt priority 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.

Table 12 Configuration Settings for the DAC HAL Module on r_dac

ISDE Property	Value	Description
Parameter Checking	BSP, Enabled, Disabled Default: BSP	Enable or disable the parameter error checking.
Name	g_dac0	Module name.
Channel	0	Set to 0 for output DA0 or 1 for output DA1.
Synchronize with ADC	Enabled, Disabled Default: Disabled	Set to true for anti-interference synchronization with the Analog-to-Digital Converter (ADC) Module. Set to false if power supply interference between the analog modules is not a problem, or if asynchronous conversion by the DAC Module is desired.
Data Format	Right Justified	Set to zero, if 12-bit data values are loaded in bits 11 through 0, or right justified. Set to one, if 12-bit data values are loaded in bits 15 through 4, or left justified.
Output Amplifier	Enable, Disable Default: Disable	Set to true, if output amplifier hardware function is desired. Set to false to bypass output amplifier hardware function.

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 13 Configuration Settings for the DAC8 HAL Module on r_dac8

ISDE Property	Value	Description
Parameter Checking	BSP, Enabled, Disabled Default: BSP	Enable or disable the parameter error checking.
Name	g_dac8_0	Module name
Channel	0	Channel selection
Synchronize with ADC	Enabled, Disabled Default: Disabled	Choose whether to sync with the ADC module
Data Format	Right Justified, Left Justified Default: Right Justified	Data format selection
DAC Mode	Normal Mode, Real-time (Event Link) Mode Default: Normal Mode	DAC mode selection
Charge Pump Enabled (Requires MOCO active)	Enabled, Disabled Default: Enabled	Enable or disable the charge pump

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.

5.2 Audio Playback Hardware DAC Framework Module Clock Configuration

The Audio Playback Framework hardware modules (DAC) use the peripheral clocks available in the Clocks configuration window.

5.3 Audio Playback Hardware DAC Framework Module Pin Configuration

The DAC or SSI peripheral module uses pins on the MCU to communicate to external devices. Select and configure these I/O pins as required by the external device. The following table lists how to select the pins within the SSP configuration window and the subsequent table has an example selection for associated pins.

Note: For some peripherals, the operational mode selected determines the peripheral signals available and the MCU pins required.

Table 14 Pin Selection for DAC

Resource	ISDE Tab	Pin selection Sequence
ADC	Pins	Select Peripherals > Analog:ADC > ADC0/ADC1

Note: The selection sequence assumes the desired hardware target for the driver is:
 ADC0 or ADC1
 SSI0 or SSI1

Table 15 Pin Configuration Settings for the DAC HAL Module on r_dac

Pin Configuration	Value	Description
Operation Mode	Enabled, Disabled	Operation selection
DA	None, P014 (Default: P014)	DAC pin selection

Note: The example values are for a project using the Synergy S7G2 MCU and the SK-S7G2 Kit. Other Synergy MCUs and other Synergy Kits may have different available pin configuration settings.

6. Using the Audio Playback Hardware DAC Framework Module in an Application

The following steps are typical when using the Audio Playback Hardware DAC Framework module in an application:

- Initialize the Audio Framework using the `open` API
- Use the callback function to post the semaphore while the main thread is waiting on the same semaphore.
- Acquire the buffer from the Messaging Framework.
- Create the Audio Framework Data Structure inside the buffer
- Start the Audio Playback Framework using the `start` API.

A semaphore needs to be created before it is used. To create a semaphore, open up the Synergy Configurator and select the Threads tab. You select the thread on which you added the Audio Playback Framework and use the sequence in the following table. The semaphore name can be changed according to the user's requirements.

Table 16 Audio Playback Framework Module Selection Sequence

Resource	ISDE Tab	Stacks Selection Sequence
g_new_semaphore0 Semaphore	Threads	New Object> Semaphore

The following figure shows these common steps in a typical operational flow.

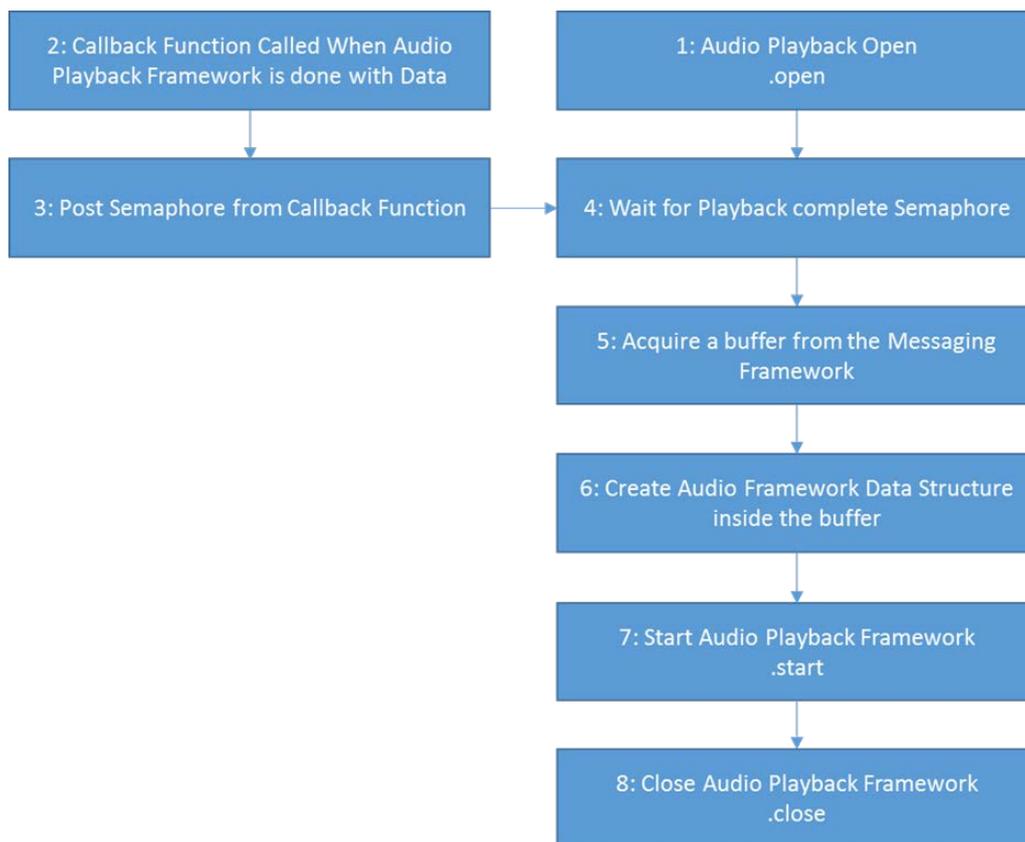


Figure 6 Typical Audio Playback Hardware DAC Framework module application flow

7. The Audio Playback Hardware DAC Framework Module Application Project

The application project associated with this module guide demonstrates these 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 Audio Playback Hardware DAC Framework module. The project can be found using the link provided in the References section at the end of this document. You can also read over the code in `audio_playback_thread_entry.c` that is used to demonstrate the Audio Playback APIs in a complete design.

This application project shows the typical use of the Audio Playback APIs. The main thread entry initializes the Audio Playback Framework and plays the RAW PCM file on flash memory. The playback framework gets information from the Messaging Framework and stores this data in the audio buffer. Stream-related information is in the `audio.c` file. The following table lists target versions for the associated software and hardware used by the application project:

Table 17 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	8.21.1 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 figure shows a simple flow of the application project.

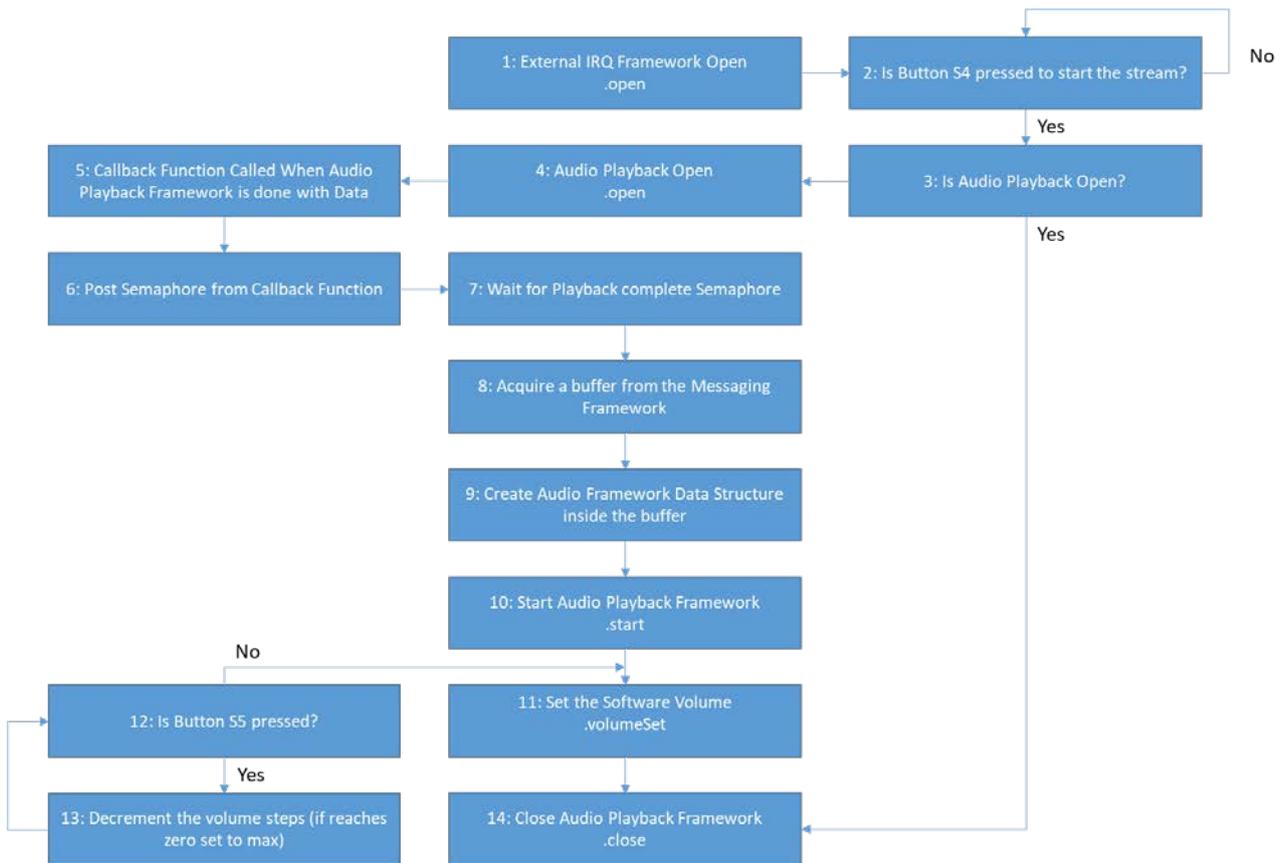


Figure 7 Audio Playback Hardware DAC Framework Module Application Project Flow

The complete application project can be found using the link in the References section at the end of this document.

The `audio_playback_hw_dac_control.c` file is in the application project once it has been imported into the ISDE. The project also includes the `application_define.h` and `audio_data.c` files. You can open these files from the ISDE and follow along to help learn key uses of the APIs.

The first section of `audio_playback_hw_dac_control.c` has the header files referencing the audio playback framework instance structure and structure for basic information about the PCM stream and payload for `sf_audio_playback`. An audio callback function next executes a post of the previously created semaphore (`g_sf_audio_playback_sem`). The callback function executes when the audio playback framework is done with the data.

The next `audio_playback_thread_entry.c` file section is the entry function for the main program control section. The application uses the on-board push buttons S4 and S5 to control the audio playback. The application pends for a user input – external IRQ – generated by pressing the on-board push button S4 – before playing the audio data. After successfully receiving the external IRQ event, a local variable is updated with the stream-related information. The GPT’s `periodSet` API is called to set the period of the timer to the sample period of the audio stream. Thereafter, it acquires the semaphore `g_sf_audio_playback_sem` before starting to play data. After acquiring this semaphore, the main program control acquires a buffer from the messaging framework, and copies the audio playback data into the buffer. Playback is started by calling the `.start` API.

The on-board pushbutton S4 is used to start and stop playback. The `.stop` API is used to stop the playback. Pushbutton S5 is used to change the volume of the playback. Volume is changed by using the `volumeSet` API. Each press of S5 decreases the volume by 50. If the volume is currently 0, the volume is set to 255, the maximum value.

Note: It is assumed you are familiar with using External IRQ Framework. If you are unfamiliar with this framework, see the SSP User's Manual. The external IRQ Framework has been used to implement S4 and S5 button press event notification and wait to execute other API functionalities. Currently on this application project, SK-S7G2 button S4 starts and stops the playback stream, while during playback button S5 presses decreases the playback volume because normal playback starts with full volume.

Remember to add the subscriber thread for the Audio event in the Messaging Tab. Highlight the new **Subscriber** in the Audio Playback Subscribers. Record the **Symbol** name. Highlight the **Audio Playback Framework Shared** module in the HAL/Common in thread tab and set the **Audio Message Queue** name to the Symbol name from the Audio Playback Subscriber.

A few key properties are configured in this Application Project support the required operations and the physical properties of the target board and MCU. The following tables show properties that are listed with the values set for this specific project. You can also open the Application Project and view these settings in the property window as a hands-on exercise.

Table 18 Audio Playback Framework Module Configuration Settings

ISDE Property	Value Set
Buffer Size Bytes	2048
Maximum Number of Streams	1
Thread Stack Size	512
Name	sf_audio_playback
Message Class Instance	0
Callback	sf_audio_playback_callback

Table 19 Audio Playback Framework Shared Module Configuration Settings

ISDE Property	Value Set
Name	g_sf_audio_playback_common
Thread Priority	3
Audio Message Queue Name	audio_playback_thread_message_queue

Table 20 Audio Playback Hardware Framework Shared Module Configuration Settings

ISDE Property	Value Set
Name	g_sf_audio_playback_hw
DMAC Support	Disabled

Table 21 Transfer Driver Module Configuration Settings

ISDE Property	Value Set
Name	g_audio_transfer
Destination Pointer	&R_DAC->DADRn [0]
Activation Source (Must Enable IRQ)	Event GPT0 COUNTER OVERFLOW

Table 22 Timer Driver Module Configuration Settings

ISDE Property	Value Set
Name	g_audio_timer
Channel	0
Period Value	11025
Duty Cycle Value	50
Duty Cycle Unit	Unit Percent
Overflow Interrupt Priority	Priority 5

Table 23 DAC Driver Module Configuration Settings

ISDE Property	Value Set
Name	g_audio_dac
Channel	0

Table 24 Semaphore Configuration Settings

ISDE Property	Value Set
Name	Audio Playback Framework Semaphore
Symbol	g_sf_audio_playback_sem
Channel	2

The Messaging Framework also has to be configured. Use the Messaging Framework configurator on the Messaging tab to configure the framework.

8. Customizing the Audio Playback Hardware DAC Framework Module for a Target Application

Some configuration settings are normally changed by the developer from those in the Application Project. For example, you can change the sampling frequency and transfer driver through timer module and transfer driver, respectively. For the transfer driver, you have a choice between the DTC and DMAC.

In the case of the DMAC driver, you should enable the driver interrupt and set its priority to be of a higher value than that of the Audio Playback Hardware Framework module.

This particular Audio Playback HW DAC Framework Application Project uses the on-board S4 and S5 push buttons for user control. The user control can be customized by the user.

9. Running the Audio Playback Hardware DAC Framework Module Application Project

To run the application project for the Audio Playback Hardware DAC Framework module and watch it execute on a target kit, you can simply import it into your ISDE, compile, and run debug. In the package, refer to the *Renesas Synergy Project Import Guide* (r11an0023eu0121-synergy-ssp-import-guide.pdf) for instructions on importing the project into e² studio, or IAR EW for Synergy, and then building and running the application.

To implement the Audio Playback Hardware DAC Framework module application in a new project, use the following steps to define, configure, auto-generate files, add code, compile and debug the target kit. Following these steps is a hands-on approach that can help make the development process with SSP more practical.

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* to learn how to accomplish these steps.

1. Create a new Renesas Synergy project for the SK-S7G2 called **Audio_framework_with_HW_DAC_MG**
2. Select the **Threads** tab.
3. Add a new thread called **audio_playback_thread** and add the Audio Playback Framework on **sf_audio_playback** using the framework>Audio selection path.
4. Add DTC, timer and HW DAC drivers in the given stack.
5. Click the **Generate Project Content** button.
6. Add the code from the supplied project file **audio_playback_thread_entry.c**, or copy over the generated **audio_playback_thread_entry.c** file.
7. Add the application_define.h, audio_playback_hw_dac_control.c, audio_playback_hw_dac_control.h, audio_data.c and audio_playback_thread_entry.c files from the supplied project files.
8. Build the application code and connect the board to flash the executable binary.
9. Execute the application program.
10. The output can be heard on a speaker or a headphone, whichever is connected to the 3.5 mm audio jack on the SK-S7G2 board. Playback is started when the on-board pushbutton S4 is pressed for the first time. Volume can be set by pressing pushbutton S5 in decrement steps of 50 units.
11. Press S4 again to stop the playback. To restart the playback, press S4 once more.

10. Audio Playback Hardware DAC Framework 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 less time consuming and removes common errors, like conflicting configuration settings or incorrect selection of low-level drivers. The use of high-level APIs (as demonstrated in the application project) showcases the development time savings in allowing work to begin at a high level, avoiding the time required in older development environments to use or, in some cases, create lower-level drivers.

11. Audio Playback Hardware DAC Framework Module Next Steps

After you have mastered a simple Audio Playback Framework with DAC driver project, you may want to review a more complex example. You may find that the Audio Playback Framework is a better fit for your target application. The Audio Playback Framework with DAC driver Module Guide demonstrates the use of the Audio Framework within a ThreadX-based implementation on the DAC driver. This guide is available at the link shown in the References section at the end of this document.

12. Audio Playback Hardware DAC 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 Audio Playback Hardware DAC Framework module reference materials and resources are available on the Synergy Knowledge Base: . https://en-support.renesas.com/search/sf_audio_playback_hw_dac%20module%20Guide%20Resources

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
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Videos	www.renesas.com/synergy/videos
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Revision History

Rev.	Date	Description	
		Page	Summary
1.00	Jun 14, 2017	-	Version 1.0
1.01	Jan 8, 2018	-	Update to Hardware and Software Resources Table
1.02	Dec 13, 2018	-	Updated for SSP v1.5.0

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