Renesas Synergy™ Platform

DTC HAL Module Guide

Introduction

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

The Data Transfer Controller (DTC) HAL module is a high-level API for data-transfer applications and is implemented on r_dtc. The DTC HAL module uses the DTC peripheral on the Synergy MCU. A user-defined callback can be created to inform the CPU when transfer events occur.

Contents

1. DTC HAL Module Features

The Data Transfer Controller (DTC) HAL module moves data from a user-specified source to a user-specified destination when an interrupt or event occurs.

The DTC HAL module has the following features:

- Supports the DTC module on a Synergy MCU
- Supports interrupts, if desired
- Supports multiple transfer modes
  - Single transfer
  - Repeat transfer
  - Block transfer
  - Address increment or fixed modes
  - Chain transfers
- Supports multiple channels (depending on selected implementation)
  - Number of channels is limited only by the size of the RAM-based vector table.

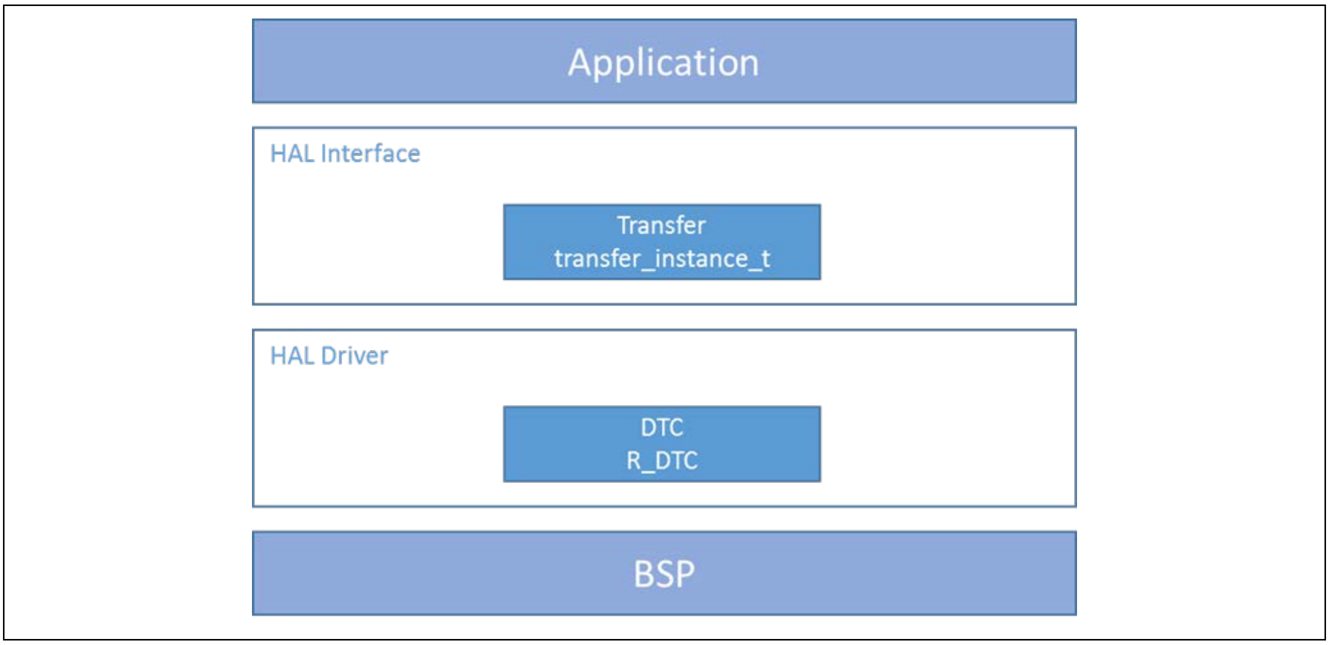


Figure 1. DTC HAL Module Block Diagram

2. DTC HAL Module APIs Overview

The DTC HAL module defines APIs for opening, closing, reset, enabling, disabling, starting, and stopping. The DTC and the DMAC use the same transfer interface to make it easier to change between DTC and DMA implementations. The API calls are the same, independent of the lower-level implementations. A complete list of the available APIs, an example API call, and a short description of each can be found in the table below. A table of status return values follows the API summary table.

Table 1. DTC HAL Module API Summary

Function Name	Example API Call and Description
.open	`g_transfer0.api->open(g_transfer0.p_ctrl, g_transfer0.p_cfg)` Initial configuration. Enables the transfer if auto_enable is true and p_src, p_dest, and length are valid. Transfers can also be enabled using enable or reset.
.close	`g_transfer0.api->close(g_transfer0.p_ctrl)` Close device channel. Turns off hardware if last channel open.

Function Name	Example API Call and Description
.reset	`g_transfer0.api->reset(g_transfer0.p_ctrl, &source, &destination, number_of_transfers)` Reset source address pointer, destination address pointer, and/or length, keeping all other settings the same. Enable the transfer if p_src, p_dest, and length are valid.
.start	`g_transfer0.api->start(g_transfer0.p_ctrl, mode)` Start transfer in software.
.stop	`g_transfer0.api->stop(g_transfer0.p_ctrl)` Stop transfer in software. The transfer stops after completion of the current transfer.
.enable	`g_transfer0.api->enable(g_transfer0.p_ctrl)` Enable transfer. Transfers occur after the activation source event (or when start is called if ELC_EVENT_ELC_SOFTWARE_EVENT_0 or ELC_EVENT_ELC_SOFTWARE_EVENT_0 is chosen as activation source).
.disable	`g_transfer0.api->disable(g_transfer0.p_ctrl)` Disable transfer. Transfers do not occur after the transfer_info_t::activation source event (or when start is called if ELC_EVENT_ELC_SOFTWARE_EVENT_0 or ELC_EVENT_ELC_SOFTWARE_EVENT_0 is chosen as transfer_info_t::activation_source).
.versionGet	`g_transfer0.api->versionGet(&version)` Gets version and stores it in provided pointer version.
.infoGet	`g_transfer0.api->infoGet(g_transfer0.p_ctrl, &info)` Provides information about this transfer.
.blockReset	`g_transfer0.api->blockReset(g_transfer0.p_ctrl, &source, &destination, length, size, number_of_transfers)` Reset source address pointer, destination address pointer, and/or length, for block transfer keeping all other settings the same. Enable the transfer if p_src, p_dest, and length are valid.

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

Table 2. Status Return Values

Name	Description
SSP_SUCCESS	API Call Successful.
SSP_ERR_ASSERTION	Parameter has invalid value.
SSP_ERR_NOT_OPEN	The channel is not opened.
SSP_ERR_UNSUPPORTED	Operation not configured correctly.
SSP_ERR_IN_USE	The channel specified has already been opened. No configurations were changed. Call the associated Close function or use associated Control commands to reconfigure the channel.
SSP_ERR_HW_LOCKED	The DTC hardware resource is locked.
SSP_ERR_IRQ_BSP_DISABLED	IRQ not enabled in BSP.
SSP_ERR_NOT_ENABLED	Operation failed.
SSP_ERR_NOT_OPEN	The channel is not opened.

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. DTC HAL Module Operational Overview

The Direct Memory Access Controller (DMAC) and the Data Transfer Controller (DTC) can be used to move data within the Synergy MCU. There are some considerations when selecting between these implementations. This section includes information on each to help you determine which implementation is best for your application. The DTC module is recommended for most generic transfer applications, but either module can be used for basic transfer functionality. The following use-cases for each transfer module are given.

Selecting the DTC HAL Module

The DTC HAL module uses a RAM-based vector table with slots for every interrupt in the system. When the DTC transfer completes, the activation source interrupt is called. To use the DTC, the activation source interrupt must be enabled. Generally, the activation source interrupt is muted by the DTC until the transfer completes unless TRANSFER_IRQ_EACH is specified in the configuration. For example, if a normal-mode transfer with a length of 16 is triggered by a timer, the timer interrupt does not fire the first 15 times while the transfer is in effect. After the 16th transfer, the timer interrupt fires. DTC can also allow chained transfers, meaning more than one transfer can occur after a single activation-source interrupt. This feature is supported by the driver but must be configured outside the ISDE.

Selecting the DMAC HAL Module

The DMAC HAL module moves data from a user-specified source to a user-specified destination when an interrupt or event occurs. The DMAC HAL module uses the DMAC peripheral registers, so the number of transfers in the system is limited to the number of DMAC channels on the device. The activation source does not have to be enabled to use the DMAC. When the DMAC transfer completes, a DMAC interrupt is called. If the activation source interrupt is enabled, it fires at the same time the transfer is triggered. If the DMAC interrupt is enabled, it fires after all transfers are complete. For example, if a normal-mode transfer with a length of 16 is triggered by a timer, the timer interrupt fires at the same time each transfer occurs and the DMAC interrupt fires after the 16th transfer completes. The DMAC HAL module does not support chained transfers.

3.1 DTC HAL Module Operational Notes

Normal Mode

In normal mode, a single transfer is triggered each time an activation-source event occurs. A single transfer is 1 byte, 2 bytes, or 4 bytes, depending on the setting selected in the size parameter. Each time a transfer occurs, the transfer length is decremented by 1. When the transfer length reaches 0, the transfer is complete.

Repeat Mode

In repeat mode, a single transfer is triggered each time an activation-source event occurs. A single transfer is 1 byte, 2 bytes, or 4 bytes, depending on the setting selected in the size parameter. Each time a transfer occurs, the transfer length is decremented by 1. When the transfer length reaches 0, the transfer length is reloaded with its initial value and the transfer restarts. If the repeat area is set to source, the source register is also reloaded with its initial value when the transfer restarts. Alternatively, if the repeat area is set to destination, the destination register is reloaded with its initial value when the transfer restarts.

Block Mode

In the block mode, the entire transfer length is transferred each time an activation-source event occurs. For example, if a transfer is configured in block mode with the timer as the activation source, a 2-byte size, and a 12-byte length, 24 bytes are transferred each time the activation source event occurs. Each time a transfer occurs, the transfer length is decremented by 1. When the transfer length reaches 0, the transfer length is reloaded with its initial value and the transfer restarts. If the repeat area is set to source, the source register is also reloaded with its initial value when the transfer restarts. Alternatively, if the repeat area is set to destination, the destination register is reloaded with its initial value when the transfer restarts.

Address Mode

After each transfer of size (1 byte, 2 bytes, or 4 bytes), the source pointer and destination pointer are adjusted by `src_addr_mode` and `dest_addr_mode`, respectively. For example, if `src_addr_mode` is set to TRANSFER_ADDR_MODE_INCREMENTED and size is set to TRANSFER_SIZE_4_BYTES, the `p_dest` pointer is incremented by 4 (the transfer size) after each transfer. The pointer does not change if set to TRANSFER_ADDR_MODE_FIXED.

Chained Transfers

Chained transfers are only supported by the DTC. To use a chained transfer, create an array of `transfer_info_t` structures. Set `chain_mode` to TRANSFER_CHAIN_MODE_ENABLED for all transfers except the last transfer. Set `p_info` to the base of the first structure in the array for `transfer_info_t` structures.

3.2 DTC HAL Module Limitations

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

4. Including the DTC HAL Module in an Application

This section describes how to include the DTC HAL module in an application using the SSP configurator.

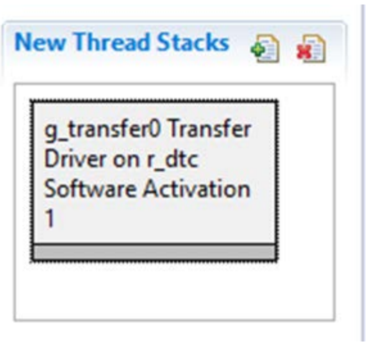
Note: This section assumes that you are familiar with creating a project, adding threads, adding a stack to a thread, and configuring a block within the stack. If you are unfamiliar with any of these items, refer to the first few chapters of the *SSP User's Manual* to learn how to manage each of these important steps in creating SSP-based applications.

To add the DTC Driver to an application, simply add it to a thread using the stacks selection sequence provided in the following table. (The default name for the Transfer Driver is `g_transfer0`. This name can be changed in the associated Properties window.)

Table 3. DTC Driver Selection Sequence

Resource	ISDE Tab	Stacks Selection Sequence
g_ transfer0 DTC Driver on r_dtc	Threads > HAL/Common	New Stack > Driver > Transfer > Transfer Driver on r_dtc

When the DTC HAL module on `r_dtc` is added to the thread stack as shown in the following figure, the configurator automatically adds any needed lower-level modules. Any drivers that need additional configuration information will be box text highlighted in Red. Modules with a Gray band are individual modules that stand alone.



g_transfer0 Transfer Driver on r_dtc Software Activation 1

Figure 2. DTC HAL Module Stack

5. Configuring the DTC HAL Module

The DTC HAL module must be configured by the user 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, which 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 are unavailable to change, and these are identified with a lock icon for the 'locked' property in the ISDE Properties window. This approach simplifies the configuration process and making it 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 in the SSP configurator and are shown in the following tables for easy reference.

One of the properties most often identified as requiring a change is the interrupt priority; this configuration setting is available within the Properties window of the associated module. Simply select the indicated module and then view the Properties window; the interrupt settings are often toward the bottom of the properties list, so scroll down until they become available. Also, note that the interrupt priorities listed in the Properties window in the ISDE will include an indication as to the validity of the setting based on the targeted

MCU (CM4 or CM0+). This level of detail is not included in the following configuration properties tables, but it is easily visible with the ISDE when configuring interrupt-priority levels.

Note: You may want to open your ISDE, create the module and explore the property settings in parallel with looking over the configuration table settings given below. 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 Settings for the DTC HAL Module on r_dtc

ISDE Property	Value	Description
Parameter Checking	BSP, Enabled, Disabled (Default: BSP)	Selects if code for parameter checking is to be included in the build.
Software Start	Disabled, Enabled (Default: Disabled)	Selects if Software Start to be enabled
Linker section to keep DTC vector table	.ssp_dtc_vector_table	Section to place dtc vector table in
Name	g_transfer0	Module name.
Mode	Normal	Mode selection.
Transfer Size	1 Byte, 2 Bytes, 4 Bytes (Default: 2 Bytes)	Transfer size selection.
Destination Address Mode	Fixed, Incremented, Decremented (Default: Fixed)	Destination address mode selection.
Source Address Mode	Fixed, Incremented, Decremented (Default: Fixed)	Source address mode selection.
Repeat Area (Unused in Normal Mode)	Source, Destination (Default: Source)	Repeat area selection.
Interrupt Frequency	After all transfers have completed, After each transfer (Default: After all transfers have completed)	Defines when an interrupt occurs.
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)	The full list of interrupt activation sources can be found in Table 14.4 of the MCU user manual. (Default: Software Activation 1)	Activation source selection.
Auto Enable	True, False (Default: True)	Auto enable selection.
Callback (Only valid with Software start)	NULL	Callback selection.
ELC Software Event Interrupt Priority	Priority 0 (highest), 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15 (lowest, not valid if using Thread X), Disabled (Default: Disabled)	Interrupt priority.

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

DTC HAL Module Clock Configuration

The DTC peripheral module uses ICLK as the clock source. The ICLK frequency is set by using the SSP configurator Clocks tab prior to a build, or by using the CGC Interface at run-time.

DTC HAL Module Pin Configuration

The DTC is not associated with any pins.

6. Using the DTC HAL Module in an Application

The typical steps in using the DTC HAL module in an application are:

1. Initialize the DTC using the open API.
2. Enable the DTC using the enable API (if not auto enabled).
3. Manage transfers using other APIs as needed.
4. Close the DTC when needed using the close API.

The following flow diagram illustrates common steps to using the DTC HAL module are illustrated:

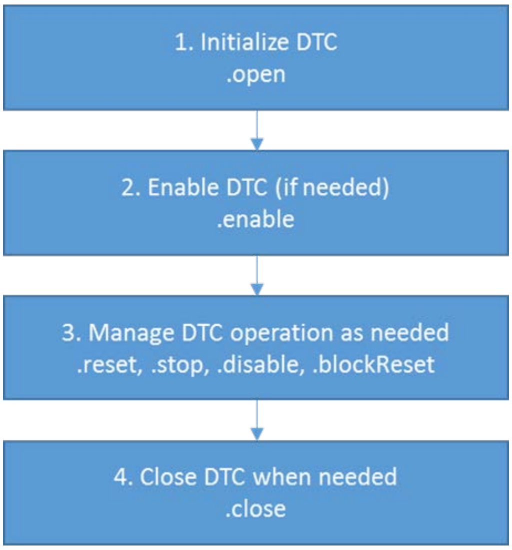

1. Initialize DTC
.open
2. Enable DTC (if needed)
.enable
3. Manage DTC operation as needed
.reset, .stop, .disable, .blockReset
4. Close DTC when needed
.close

Figure 3. Flow Diagram of a Typical DTC HAL Module Application

7. The DTC HAL Module Application Project

The application project associated with this module guide demonstrates the given 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 within the ISDE and view the configuration settings for the DTC HAL module. You can also read over the code (`DTC_HAL_MG_AP.c`) used to illustrate the DTC HAL module APIs in a complete design. The following table shows the software and hardware resources required for the application project.

Table 5. Software and Hardware Resources Used by the Application Project

Resource	Revision	Description
e^2 studio	v6.2.0 or later	Integrated Solution Development Environment
SSP	v1.4.0 or later	Synergy Software™ Platform
IAR EW for Synergy	v8.21.1 or later	IAR Embedded Workbench® for Renesas Synergy™
SSC	v6.2.0 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.

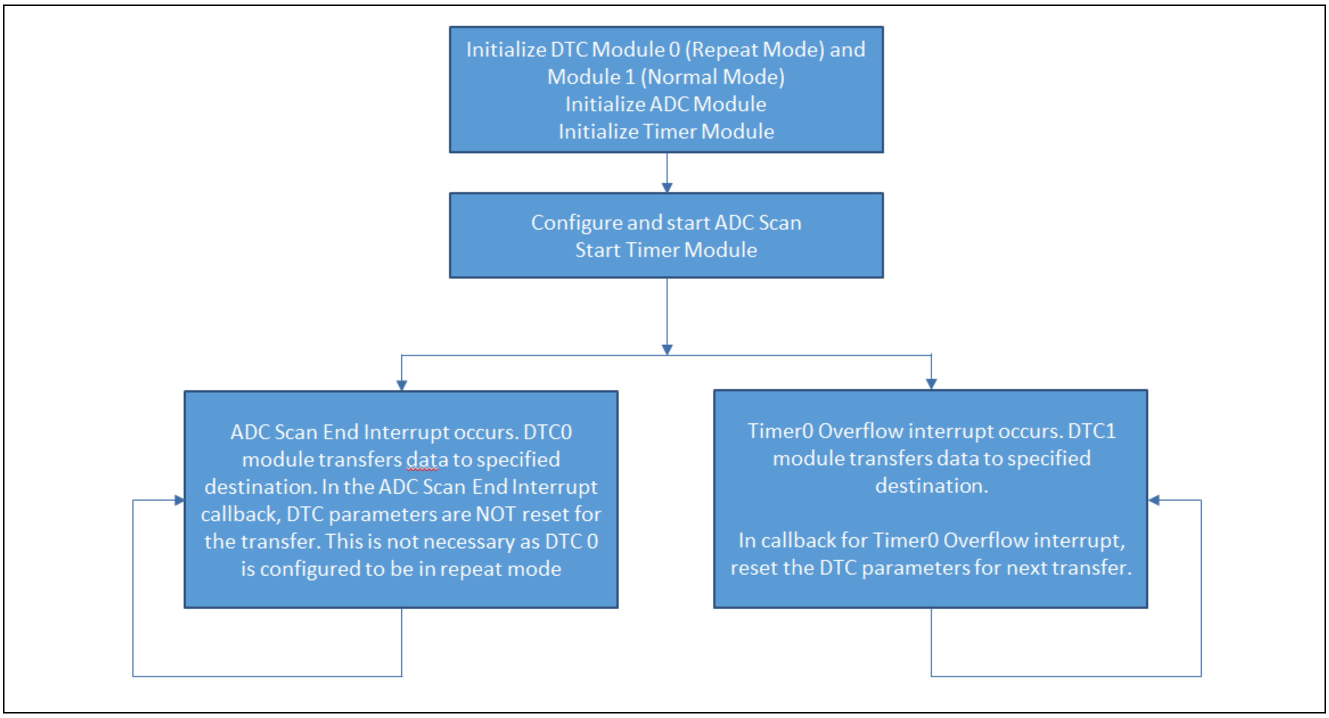

Initialize DTC Module 0 (Repeat Mode) and Module 1 (Normal Mode)
Initialize ADC Module
Initialize Timer Module
Configure and start ADC Scan
Start Timer Module
ADC Scan End Interrupt occurs. DTC0 module transfers data to specified destination. In the ADC Scan End Interrupt callback, DTC parameters are NOT reset for the transfer. This is not necessary as DTC 0 is configured to be in repeat mode
Timer0 Overflow interrupt occurs. DTC1 module transfers data to specified destination.
In callback for Timer0 Overflow interrupt, reset the DTC parameters for next transfer.

Figure 4. DTC HAL Module Application Project Flow Diagram

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

Two DTC instances will be used in this project:

`g_transfer0` will be set up as a DTC HAL module in repeat mode

`g_transfer1` will be set up as a DTC HAL module in normal mode

The first section of the file initializes two DTC HAL modules, an ADC HAL module, and a timer module. The timer module is set up to be a periodic 1s timer, and the ADC is set up to read the temperature sensor. The DTC modules do not have to be enabled, as the Auto Enable option in the Synergy Configurator for DTC has been enabled.

The DTC0 instance shows how to use the transfer module in repeat mode. The source address of the transfer is set to the address of the ADTSDR (register for storing the A/D conversion result of the temperature sensor), and the destination address is set to the address of a destination variable, `destination_TemperatureVal`. The file starts the ADC conversion. When the interrupt for ADC0 Scan End occurs, the transfer is activated. The transfer occurs without CPU intervention. At the end of each interrupt, a transfer will occur. The Reset API does not have to be used to restart the transfer as DTC0 was configured to be in the repeat mode.

The DTC1 instance shows how to use the transfer module in normal mode. The transfer is reset in the Timer0 Overflow interrupt callback, timer_cb. The source address is set to the address of local variable source_TimerVal. This holds the value of the number of timer interrupts. The destination address is set to the address of a global destination_TimerVal variable. When the interrupt for Timer0 overflow occurs, a transfer from the callback local variable to the global destination occurs without CPU intervention. A reset of the transfer is done each time the interrupt occurs.

The last section of the application code is the user callback function for the ADC scan and timer overflow.

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

Table 6. DTC0 Configuration Settings for the Application Project

ISDE Property	Value Set
Mode	Repeat
Transfer Size	2 Bytes
Activation Source	Event ADC0 Scan End
Interrupt Frequency	After each transfer

Table 7. DTC1 Configuration Settings for the Application Project

ISDE Property	Value Set
Mode	Normal
Transfer Size	1 Byte
Activation Source	Event GPT0 COUNTER OVERFLOW
Interrupt Frequency	After each transfer

8. Customizing the DTC HAL Module for a Target Application

Some configuration settings will normally be changed by the developer from those shown in the application project. The user can easily change the configuration settings for the DTC HAL module on r_dtc in the Properties window. The user can select between the 3 available modes: normal, repeat, and block mode. The user can also select the preferred transfer size according to the application: 1, 2, or 4 bytes. The Activation Source can also be selected.

9. Running the DTC HAL Module Application Project

To run the DTC HAL module application project and to see it executed on a target kit, you can simply import it into your ISDE, compile, and run debug.

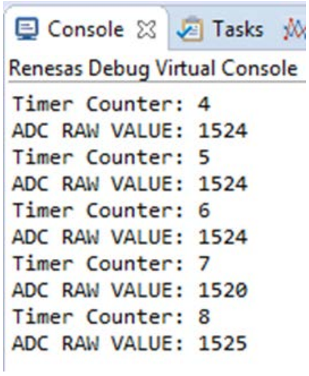
To implement the DTC HAL module application in a new project, follow the steps below for defining, configuring, auto-generating files, adding code, compiling and debugging on the target kit. Following these steps is a hands-on approach that can help make the development process with SSP more practical, while simply reading over this guide tends to be more theoretical.

To simply run the DTC HAL module application project, use the following steps:

1. Refer to the *Renesas Synergy Project Import Guide* (r11an0023eu0121-synergy-ssp-import-guide.pdf) for instructions on importing the project into e^2 studio or IAR EW for Synergy, and building/running the application.
2. Connect to the host PC through a micro USB cable to J19 on SK-S7G2.
3. Start to debug the application
4. The output can be viewed in the Expression window.

To create and run the DTC HAL module application project, use the following steps:

1. Create a new Renesas Synergy project for the SK-S7G2 kit called **DTC_HAL_MG_AP**.
2. Add to HAL/Common, the DTC HAL modules, the ADC HAL module, and the timer module. Refer the example projects configuration enclosed in the package for details.
3. Click the **Generate Project** content button.
4. Add the code from the supplied project files **hal_entry.c, DTC_HAL_MG_AP.c**, and **DTC_HAL_MG_AP.h**.
5. Build the project.
6. Connect to the host PC via a micro USB cable to J19 on the SK-S7G2 board.
7. Start to debug the application.
8. The output can be viewed on the Renesas Virtual Debug Console (see Figure 5), or by adding variable expressions to the watch view.



```
Timer Counter: 4
ADC RAW VALUE: 1524
Timer Counter: 5
ADC RAW VALUE: 1524
Timer Counter: 6
ADC RAW VALUE: 1524
Timer Counter: 7
ADC RAW VALUE: 1520
Timer Counter: 8
ADC RAW VALUE: 1525
```

Figure 5. Example Output from the DTC HAL Module Application Project

10. DTC HAL Module Conclusion

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

11. DTC HAL Module Next Steps

After you have mastered a simple DTC HAL module project, you may want to review a more complex example. The touch slider application project for DK-S124 v3.0 with SSP 1.2.0 shows how to use the DTC in a complete application. You can find this application project as described in the References section of this document.

12. DTC HAL Module Reference Information

SSP User Manual: Available in HTML format in the SSP distribution package and as a pdf at the Synergy Gallery (www.renesas.com/synergy/software).

Links to all the most up-to-date r_dtc module reference materials and resources are available on the Synergy Knowledge Base: https://en-support.renesas.com/search/r_dtc%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
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Partner projects	www.renesas.com/synergy/partnerprojects
Application projects	www.renesas.com/synergy/applicationprojects
Self-service support resources:	
Documentation	www.renesas.com/synergy/docs
Knowledgebase	www.renesas.com/synergy/knowledgebase
Forums	www.renesas.com/synergy/forum
Training	www.renesas.com/synergy/training
Videos	www.renesas.com/synergy/videos
Chat and web ticket	www.renesas.com/synergy/resourcelibrary

Revision History

Rev.	Date	Description	
		Page	Summary
1.00	Sep.01.17	–	Initial release
1.01	Jan.07.19	7	Updated Table 5 for SSP v1.5.0

Notice

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