Example of RE01 1500KB Group DSP Library FIR Usage (Polling)  
RE01 1500KB Group CMSIS Driver Package FIR Filter Processing Sample Code

Introduction

This application note describes sample code that uses the RE01 1500KB Group CMSIS Driver Package. For the sample code, refer to the projects included.

The summary of this sample code is shown below.

Table  Overview of Sample Code

<table>
<thead>
<tr>
<th>Overview of Sample Code Operation</th>
<th>Peripheral Functions</th>
<th>Drivers Used in Sample Code</th>
</tr>
</thead>
</table>
| Execute FIR filter processing and FFT processing using DSP library function.  
As input signal, it can select analog input signal and test signal on flash memory. | AGT0  
ELC  
S14AD  
DMAC0 | R_SYSTEM  
R_LPM  
R_ADC  
R_DMAC |

Target Device

RE01 1500KB Group

Caution

If you apply this application note to another device, it is necessary to modify the software according to the specification of the MCU you use and evaluate it adequately.
Example of RE01 1500KB Group DSP Library FIR Usage (Polling)
RE01 1500KB Group CMSIS Driver Package FIR Filter Processing Sample Code

Contents

1. Specification ............................................................................................................................ 3
  1.1 Project Description ............................................................................................................. 3
  1.2 List of Used Pin ................................................................................................................... 3
  1.3 File Configuration .............................................................................................................. 4
  1.4 Option-Setting Memory .................................................................................................... 4

2. Operation Confirmation Conditions ........................................................................................ 5

3. Software Description ............................................................................................................. 6
  3.1 DSP Arithmetic ..................................................................................................................... 7
    3.1.1 Filter Coefficient .......................................................................................................... 8
  3.2 Input Signal ......................................................................................................................... 10
    3.2.1 External Input Signal from Analog Input Pin ............................................................... 10
    3.2.2 Test Signal .................................................................................................................... 11
  3.3 List of Functions ................................................................................................................ 13
  3.4 List of Constants ................................................................................................................ 14
  3.5 Data and Buffer Control .................................................................................................. 14
  3.6 Flowchart ........................................................................................................................... 15

4. DSP Library Specification ..................................................................................................... 16
  4.1 External Specification (Doxygen) ...................................................................................... 16
  4.2 DSP Library Import (GCC) ............................................................................................ 17
  4.3 DSP Library Import (IAR) ............................................................................................... 20

5. References ............................................................................................................................ 22

Revision History ....................................................................................................................... 23
1. Specification

1.1 Project Description
This application note includes sample code project as shown below.

an4718_re_example_dsp_fir.zip : Execute FIR filter processing and FFT processing.

This sample code project is confirmed to operate on the Evaluation Kit RE01 1500KB (RTK70E015DxxxxBE). The project settings are adjusted to R7F0E015D2CFB which is mounted on the Evaluation Kit RE01 1500KB. For other devices, modify devices in project settings before using.

1.2 List of Used Pin
The pin used in sample code is shown in Table 1-1.

Table 1-1 Pin Used in Sample Code

<table>
<thead>
<tr>
<th>Used Pin</th>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>AN000(P000)</td>
<td>Analog input pin for AD converter</td>
</tr>
</tbody>
</table>
1.3 File Configuration

Added or modified files in the sample code are shown in Table 1-2.

### Table 1-2 Added or Modified Files in Sample Code

<table>
<thead>
<tr>
<th>File Name</th>
<th>Processing/Settings Outline</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>main.c</td>
<td>Main processing</td>
<td></td>
</tr>
<tr>
<td>main.h</td>
<td>Declare structure type</td>
<td>Added file</td>
</tr>
<tr>
<td>main_cfg.h</td>
<td>Constants used in sample code</td>
<td>Added file</td>
</tr>
<tr>
<td>adc_signal.c</td>
<td>Analog input signal settings (AGT0, ELC, S14AD, DMAC0 control)</td>
<td>Added file</td>
</tr>
<tr>
<td>adc_signal.h</td>
<td>Definition of analog input signal function</td>
<td>Added file</td>
</tr>
<tr>
<td>coef.c</td>
<td>Filter coefficient used in DSP arithmetic</td>
<td>Added file</td>
</tr>
<tr>
<td>coef.h</td>
<td>Definition of DSP filter coefficient</td>
<td>Added file</td>
</tr>
<tr>
<td>wave_sample.c</td>
<td>Test signal used for input signal</td>
<td>Added file</td>
</tr>
<tr>
<td>wave_sample.h</td>
<td>Definition of test signal</td>
<td>Added file</td>
</tr>
<tr>
<td>nop.c</td>
<td>NOP processing</td>
<td>Added file</td>
</tr>
<tr>
<td>nop.h</td>
<td>Definition of NOP processing function</td>
<td>Added file</td>
</tr>
<tr>
<td>pin.c note 1</td>
<td>Modify pin settings used in S14AD</td>
<td>Modified file</td>
</tr>
<tr>
<td>r_core_cfg.h</td>
<td>Modify clock settings</td>
<td>Modified file</td>
</tr>
<tr>
<td>r_system_cfg.h</td>
<td>Modify interrupt settings</td>
<td>Modified file</td>
</tr>
</tbody>
</table>

【Note】

1. For peripheral function pin settings, refer to "Peripheral Function Pin Settings (pin.c File)" in RE01 1500KB CMSIS Package Startup Guide.
2. For "r_system_cfg.h" interrupt settings, refer to "Interrupt (NVIC) Settings" in RE01 1500KB CMSIS Package Startup Guide.

1.4 Option-Setting Memory

The status of the option-setting memory used in the sample code is shown in Table 1-3. If necessary, set the optimal value for your system.

### Table 1-3 Option-Setting Memory Used in Sample Code

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Address</th>
<th>Setting Value</th>
<th>Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>AWS</td>
<td>0100A164h - 0100A167h</td>
<td>FFFF FFFFh</td>
<td>No access window settings</td>
</tr>
<tr>
<td>OSIS</td>
<td>0100A150h - 0100A15Fh</td>
<td>FFFF FFFFh</td>
<td>No ID code protection (ALL FFh)</td>
</tr>
<tr>
<td>SECMPUxxx</td>
<td>00000408h - 0000043Bh</td>
<td>FFFF FFFFh</td>
<td>Security MPU disabled</td>
</tr>
<tr>
<td>OFS1</td>
<td>00000404h - 00000407h</td>
<td>FFFF FFFFh</td>
<td>LVD0 reset invalid after reset release. HOCO oscillation stop after reset release.</td>
</tr>
<tr>
<td>OFS0</td>
<td>00000400h - 00000403h</td>
<td>FFFF FFFFh</td>
<td>IWDT stop after reset release. WDT stop after reset release.</td>
</tr>
</tbody>
</table>
## 2. Operation Confirmation Conditions

The sample code is confirmed to operate under the conditions shown in Table 2-1.

### Table 2-1 Operation Confirmation Conditions

<table>
<thead>
<tr>
<th>Item</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCU</td>
<td>R7F0E015D2CFB 144pin</td>
</tr>
<tr>
<td>Operating Frequency</td>
<td></td>
</tr>
<tr>
<td>Select MOSC</td>
<td></td>
</tr>
<tr>
<td>System Clock</td>
<td></td>
</tr>
<tr>
<td>• Main clock oscillator (MOSC) : 32MHz</td>
<td></td>
</tr>
<tr>
<td>• System clock (ICLK)       : 32MHz (MOSC*1/1)</td>
<td></td>
</tr>
<tr>
<td>• Peripheral module clock A (PCLKA) : 32MHz (MOSC*1/1)</td>
<td></td>
</tr>
<tr>
<td>• Peripheral module clock B (PCLKB) : 32MHz (MOSC*1/1)</td>
<td></td>
</tr>
<tr>
<td>Power Control</td>
<td>NORMAL: High-Speed mode</td>
</tr>
<tr>
<td>Operating Voltage</td>
<td>3.3V</td>
</tr>
<tr>
<td>Target Board</td>
<td>Evaluation Kit RE01 1500KB (RTK70E015DSxxxxBE)</td>
</tr>
<tr>
<td>GCC</td>
<td>Development environment</td>
</tr>
<tr>
<td>C compiler</td>
<td>GCC Arm® Embedded Version 6.3.1.20170620</td>
</tr>
<tr>
<td></td>
<td>GNU 6-2017-q2-update</td>
</tr>
<tr>
<td>IAR</td>
<td>Development environment</td>
</tr>
<tr>
<td>C compiler</td>
<td>IAR Embedded Workbench for Arm® Version 8.32</td>
</tr>
<tr>
<td>Debugger</td>
<td>Segger J-Link OB</td>
</tr>
<tr>
<td>I/O header version</td>
<td>Rev1.00</td>
</tr>
<tr>
<td>CMSIS Driver Package Version</td>
<td>Rev1.00</td>
</tr>
<tr>
<td>DSP Library</td>
<td>CMSIS-DSP V1.5.2</td>
</tr>
<tr>
<td></td>
<td>Arm®-provided DSP for Cortex® -M0+ is used^note1</td>
</tr>
</tbody>
</table>

**Note** 1. Because the code size of some of the functions are too large, the DSP library included in CMSIS package from Arm® cannot be compiled with the evaluation version of EWARM (code size limitation). Refer to Chapter 4.3 for DSP library import.
3. Software Description

The sample code executes FIR filter processing and FFT processing on an input signal.

The DSP library function is used for FIR filter processing and FFT processing. The coefficients used in FIR filter processing can be modified by modifying “coef.c” file contents.

The input signal can be selected from either an external input signal using an analog input pin or a test signal stored in flash memory by modifying “main_cfg.h” file settings. The test signal placed on flash memory can be modified by changing the contents of the file “wave_sample.c”.

In this sample code, when test signal is set as the input signal, the effect of FIR filter processing and the result of FFT conversion can be obtained as shown in Figure 3-1. Refer to Figure 3-10 in Chapter 3.5 for the relationship between the original data (buffer) of output waveform in Figure 3-1 and dataflow between each buffer.

![Figure 3-1 Input Signal Waveform and Output Waveform Image](image1)

The waveform of buffer can be displayed in debug screen with e² studio. The waveform image is shown in Figure 3-2.

![Figure 3-2 Input Signal Waveform and Output Waveform Display Image by e² studio](image2)
3.1 DSP Arithmetic

The DSP arithmetic operation overview is shown in Table 3-1.

Table 3-1 DSP Arithmetic Operation Overview

<table>
<thead>
<tr>
<th>Item</th>
<th>Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIR processing</td>
<td><strong>Input Signal</strong> Follow &quot;MAIN_CFG_INPUT_SIGNAL&quot; settings in &quot;main_cfg.h&quot; file.</td>
</tr>
<tr>
<td></td>
<td>Initial value : 1 (Execute FIR filter processing with test signal as input signal)</td>
</tr>
<tr>
<td>Filter Coefficient</td>
<td>Filter coefficient of &quot;coef.c&quot; file is used. 31 taps coefficient is used for this sample code.</td>
</tr>
<tr>
<td>Sample Number</td>
<td>Execute filter processing on 1024 samples by processing 64 samples at a time and executing FIR function 16 times.</td>
</tr>
<tr>
<td>FFT Processing Input Signal</td>
<td>Execute FFT on FIR filter processed result</td>
</tr>
</tbody>
</table>
3.1.1 Filter Coefficient

Filter coefficients in the “coef.c” file are used for FIR filter processing.

The filter coefficient file comes in the form of one file per filter and includes coefficient body and coefficient information in the file. The file structure when project name is "RE01_1500KB_prototype" is shown in Figure 3-3.

![Figure 3-3 Filter Coefficient Location](image)

31 taps coefficient is used as sample code. By modifying “coef.c” file contents, filter coefficients used in FIR filter processing can be modified to any desired coefficients.
Example of RE01 1500KB Group DSP Library FIR Usage (Polling)
RE01 1500KB Group CMSIS Driver Package FIR Filter Processing Sample Code

Figure 3-4 Filter Coefficient Configuration

The filter coefficient information consists of the start address of the filter coefficient body and the type of coefficient (not used in the sample code), and configuration type is declared in "coef.h" file.

Figure 3-5 Configuration Type of Filter Coefficient Information
3.2 Input Signal

This sample code allows to use either an external input signal using analog input pin (analog input signal) or a test signal stored in flash memory as the test input signal.

The operation overview of each input signal is shown in Table 3-2.

### Table 3-2 Operation Overview of Each Input Signal

<table>
<thead>
<tr>
<th>Item</th>
<th>Analog Input Signal</th>
<th>Test Signal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Signal</td>
<td>Use AD conversion of analog input signal from AN000 pin.</td>
<td>Use test signal in “wave_sample.c” file.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Following mixed frequencies are used as a test signal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>in sample code:7.8125Hz, 120Hz, 400Hz.</td>
</tr>
<tr>
<td>Operation Module</td>
<td>AGT0, ELC, S14AD, DMAC0</td>
<td>None</td>
</tr>
<tr>
<td>Module Stop Status</td>
<td>Stop release AGT0, ELC, S14AD, DMAC/DTC</td>
<td>All module stop status</td>
</tr>
<tr>
<td>Power Supply Open</td>
<td>AVCC0 (Used in S14AD)</td>
<td>All power supply off</td>
</tr>
</tbody>
</table>

#### 3.2.1 External Input Signal from Analog Input Pin

When external signal from the analog input pin is selected as input signal, the analog input signal from AN000 pin can be used as the FIR filter processing input signal through multiple peripheral modules.

The overview of module operation related to analog input signal is shown in Table 3-3, and connection status of each module is shown in Figure 3-6.

### Table 3-3 Overview of Module Operation Related to Analog Input Signal

<table>
<thead>
<tr>
<th>Module</th>
<th>Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGT0</td>
<td>In order to generate underflow event signal (AGT0_AGTI) at AD startup cycle, set a value in AGT counter and execute down-count.</td>
</tr>
<tr>
<td>Operation Mode</td>
<td>Timer mode</td>
</tr>
<tr>
<td>ELC</td>
<td>Event signal (AGT_AGTI) from AGT0 is output to S14AD as trigger signal (ELC_S14AD).</td>
</tr>
<tr>
<td>S14AD</td>
<td>A/D conversion starts by trigger signal (ELC_S14AD) from ELC, and A/D conversion end interrupt (ADC140_ADI) is generated at one conversion end.</td>
</tr>
<tr>
<td>Operation Mode</td>
<td>Single scan mode</td>
</tr>
<tr>
<td>Resolution</td>
<td>14-bit</td>
</tr>
<tr>
<td>DMAC0</td>
<td>DMA transfer starts by interruption (ADC140_ADI) from S14AD, and interruption (DMAC0_INT) is generated at the end of 1024 transfers.</td>
</tr>
<tr>
<td>Transfer mode</td>
<td>Normal transfer mode</td>
</tr>
<tr>
<td>Transfer source</td>
<td>Fix AD conversion result storage register (ADDR0)</td>
</tr>
<tr>
<td>Transfer destination</td>
<td>Increment buffer for analog input signal storage</td>
</tr>
<tr>
<td>Transfer count</td>
<td>1024 times</td>
</tr>
</tbody>
</table>
3.2.2 Test Signal

The "wave_sample.c" file signal can be used as FIR filter processing input signal.

The test signal comprises of one file (for one signal), and the file includes the test signal itself and its related information. Fig. 3-7 shows the file configuration for a project named "RE01_1500KB_prototype".

In the sample code, mixed frequency signal (7.8125Hz, 120Hz, 400Hz) are used as the test signal.

By modifying the contents of the file "wave_sample.c", the test signal that is subject to FIR filtering processing can be modified to any desired waveform.
Figure 3-8 Test Signal configuration

The test signal information consists of the start address of the test signal body and the type of test signal (not used in the sample code), and configuration type is declared in "wave_sample.h" file.

Figure 3-9 Configuration Type of Test Signal Information
3.3 List of Functions

Main functions of sample code are explained below.

<table>
<thead>
<tr>
<th>Function</th>
<th>Outline</th>
<th>Header</th>
<th>Declaration</th>
<th>Description</th>
<th>Argument</th>
<th>Return Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>main</td>
<td>Main processing</td>
<td>None</td>
<td>int main (void)</td>
<td>Stop unused functions after reset.</td>
<td>None</td>
<td>Fix to 0</td>
</tr>
<tr>
<td>adc_signal_setup</td>
<td>Set module related to analog signal input.</td>
<td>None</td>
<td>void adc_signal_setup (uint32_t fs)</td>
<td>Set up AGT0, ELC, S14AD and DMAC0 to capture the analog input signal.</td>
<td>fs</td>
<td>None</td>
</tr>
<tr>
<td>adc_signal_start</td>
<td>Start analog signal input</td>
<td>None</td>
<td>void adc_signal_start (void)</td>
<td>Start periodic analog signal input.</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>normalize_16to32</td>
<td>Normalize analog input signal data</td>
<td>None</td>
<td>static void normalize_16to32 (int16_t *in_buf, int32_t *out_buf)</td>
<td>Convert 16-bit data with 14-bit resolution captured by the S14AD into 32-bit data.</td>
<td>in_buf</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>out_buf</td>
<td>Address of buffer storing 32-bit output data</td>
<td>out_buf</td>
<td>None</td>
</tr>
<tr>
<td>BoardInit</td>
<td>Pin settings on used board</td>
<td>None</td>
<td>void BoardInit (void)</td>
<td>This function is called from SystemInit() function of R_SYSTEM driver after reset.</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>
3.4 List of Constants

Among constants used in sample code, the user-modifiable constants which is defined in "main_cfg.h" file are shown in Table 3-4.

Table 3-4 Constants Used in Sample Code (User-modifiable)

<table>
<thead>
<tr>
<th>Constants Name</th>
<th>Initial Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAIN_CFG_INPUT_SIGNAL</td>
<td>1</td>
<td>0 : Analog input signal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 : Test signal</td>
</tr>
<tr>
<td>MAIN_CFG_SAMPLING_FS_VALUE</td>
<td>1000</td>
<td>Set AD startup cycle (unit: Hz)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Used for AD startup cycle generation and arithmetic of frequency.</td>
</tr>
</tbody>
</table>

3.5 Data and Buffer Control

The relationship between dataflow of FIR filter/FFT processing and buffer is shown in Figure 3-10. [1] – [4] in Figure 3-10 correspond to the processes with the same number in the flowchart in Figure 3-11.
3.6 Flowchart

The flowchart of FIR filter processing and main processing of FFT processing using DSP library function is shown in Figure 3-11. [1] – [4] in flowchart correspond to the processes with the same number in Figure 3-10.
4. DSP Library Specification

The driver specification of DSP library included in the CMSIS Driver Package is published in Doxygen data. Refer to following folder in the project for specification and precautions of each driver.

4.1 External Specification (Doxygen)

The Doxygen data that describes external specification of DSP library are included.

Data can be viewed by double-clicking "index.html" in the "Documentation" folder under CMSIS folder. The file configuration when project name is "RE01_1500KB_prototype" is shown in Figure 4-1.

![Figure 4-1 Doxygen Data (DSP Library External Specification) Location](image)

In addition, external specification of DSP library is described in the DSP section.

![Figure 4-2 Location of DSP Library External Specification Description](image)
4.2 DSP Library Import (GCC)

This sample code uses the DSP library included in the CMSIS package provided by Arm®.

The procedure of importing DSP library included in CMSIS package into sample code is shown below. Refer to Figure 4-3 for locations of each file. In Figure 4-3, left side shows CMSIS package provided by Arm®, and right side shows project name of this sample code as "RE01_1500KB_prototype".

1. Import DSP header files “arm_common_tables.h”, “arm_const_structs.h”, “arm_math.h” in CMSIS package provided by Arm® and DSP library “libarm_cortexM0l_math.a” into sample code.

2. Execute settings as following in the sample code project property. Refer to Figure 4-4 to Figure 4-6 for e² studio property settings.

   Add folder path containing DSP header file to included path
   Add “ARM_MATH_CM0” to preprocessor
   Add DSP file name and folder path containing DSP library file to library

Figure 4-3 DSP Library Import (GCC)
Example of RE01 1500KB Group DSP Library FIR Usage (Polling)
RE01 1500KB Group CMSIS Driver Package FIR Filter Processing Sample Code

Figure 4-4 e² studio Include Path Settings

Figure 4-5 e² studio Preprocessor Settings
Example of RE01 1500KB Group DSP Library FIR Usage (Polling)
RE01 1500KB Group CMSIS Driver Package FIR Filter Processing Sample Code

Figure 4-6 e² studio Library Settings
4.3 DSP Library Import (IAR)

The DSP library included in CMSIS package cannot be compiled when using the free evaluation version of EWARM (code size limited version) as the code size of some of the DSP functions are too large.

This sample code uses library generated by compiling DSP source code in CMSIS package so that it can be used with free evaluation version of EWARM (code size limited version).

The procedure of generating a library from DSP source code in the CMSIS package provided by Arm® and import into sample code is shown below. Refer to Figure 4-7 for locations of each file. In Figure 4-7, left side shows CMSIS package provided by Arm®, and right side shows project name of this sample code as “RE01_1500KB_prototype”.

1. Start project by double-clicking "arm_cortex M_math.eww" in CMSIS package provided by Arm®.
2. Ensure "Cortex-M0" is selected as processor in project options, and execute compilation. The DSP library "iar_cortex M0_math.a" is generated.
3. Import DSP header file “arm_common_tables.h”, “arm_const_structs.h”, “arm_math.h”, and generated DSP library “iar_cortexM0_math.a” into sample code.
4. Add DSP library as corresponding build file to sample code project.
5. Execute settings as following in the sample code project option. Refer to Figure 4-8 for EWARM option settings.
   Add folder path containing DSP header file to the include path
   Add “ARM_MATH_CM0” to preprocessor

---

**Figure 4-7 DSP Library Import (IAR)**
Figure 4-8 Include Path and Preprocessor Settings in EWARM
5. References

User's Manual: Hardware

RE01 1500KB User's Manual Hardware R01UH0796

Technical Update/Technical News

(The latest information can be downloaded from the Renesas Electronics website.)


(The latest version can be downloaded from the Renesas Electronics website.)

RE01 1500KB CMSIS Package Startup Guide

RE01 1500KB Group Startup Guide to Development Using CMSIS Package R01AN4660
### Revision History

<table>
<thead>
<tr>
<th>Rev.</th>
<th>Date</th>
<th>Description</th>
<th>Page</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.10</td>
<td>2019.05.28</td>
<td>First edition issued</td>
<td>—</td>
<td>First edition issued</td>
</tr>
<tr>
<td>0.72</td>
<td>2019.06.26</td>
<td>Change the revision number of this sample program from 1.10 to 0.72 according to the CMSIS package version</td>
<td>8, 11, 16, 17, 20</td>
<td>Align folder configuration to CMSIS package Rev0.72 and update folder configuration diagram Figure 3-3, Figure 3-7, Figure 4-1, Figure 4-3, Figure 4-7</td>
</tr>
</tbody>
</table>
| 1.00 | 2019.10.15 | Changed device name and CMSIS package name because group name was changed.  
  Device name: R7F0E01xxxxx -> RE01 1500KB Group  
  CMSIS package name :SOTB CMSIS software package -> RE01 1500KB Group CMSIS software package | 1     | Changed device name and CMSIS package name because group name was changed.  
  Device name: R7F0E01xxxxx -> RE01 1500KB Group  
  CMSIS package name :SOTB CMSIS software package -> RE01 1500KB Group CMSIS software package |
|      |            |                                                                                               | 3     | Changed Sample Code Project                                                                                                           |
|      |            |                                                                                               |       | Changed Sample Code Project                                                                                                           |
|      |            |                                                                                               |       | Changed Target board.  
  Renesas E015 SDK Evaluation Board (RTK70E015DC02001BJ) -> Evaluation Kit RE01 1500KB (RTK70E015DSxxxxBE) | 4     | Changed Target board.  
  Renesas E015 SDK Evaluation Board (RTK70E015DC02001BJ) -> Evaluation Kit RE01 1500KB (RTK70E015DSxxxxBE) |
|      |            |                                                                                               |       | Table 1-2 Changed storage folder of pin.c, r_core_cfg.h, r_system_cfg.h according to the CMSIS package Rev1.00.  
  Table 1-2 Note1,2, 5.  
  Changed reference document name.                                                                                                       |
|      |            |                                                                                               | 5     | Table 2-1 Changed confirmed operating conditions.  
  MCU : SOTB E015 Group -> 144pin  
  IAR Version : Version 8.32.3 -> Version 8.32  
  e² studio Version : Version 7.4.0 (Alpha4) -> Version 7  
  Debugger : Integrated Segger J-Link OB  
  Target board : RTK70E015DC02001BJ  
  =>RTK70E015DSxxxxBE  
  Driver Version : Rev0.72 -> Rev1.00  
  I/O header code Version : Rev 0.72 -> Rev 1.00  
  18,21 Figure4-4, Figure4-8  
  Changed include path to CMSIS package Rev1.00 configuration.                                                                                   |
General Precautions in the Handling of Microprocessing Unit and Microcontroller
Unit Products

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

1. Precaution against Electrostatic Discharge (ESD)
   A strong electrical field, when exposed to a CMOS device, can cause destruction of the gate oxide and ultimately degrade the device operation. Steps must be taken to stop the generation of static electricity as much as possible, and quickly dissipate it when it occurs. Environmental control must be adequate. When it is dry, a humidifier should be used. This is recommended to avoid using insulators that can easily build up static electricity.
   Semiconductor devices must be stored and transported in an anti-static container, static shielding bag or conductive material. All test and measurement tools including work benches and floors must be grounded. The operator must also be grounded using a wrist strap. Semiconductor devices must not be touched with bare hands. Similar precautions must be taken for printed circuit boards with mounted semiconductor devices.

2. Processing at power-on
   The state of the product is undefined at the time when power is supplied. The states of internal circuits in the LSI are indeterminate and the states of register settings and pins are undefined at the time when power is supplied. In a finished product where the reset signal is applied to the external reset pin, the states of pins are not guaranteed from the time when power is supplied until the reset process is completed. In a similar way, the states of pins in a product that is reset by an on-chip power-on reset function are not guaranteed from the time when power is supplied until the power reaches the level at which resetting is specified.

3. Input of signal during power-off state
   Do not input signals or an I/O pull-up power supply while the device is powered off. The current injection that results from input of such a signal or I/O pull-up power supply may cause malfunction and the abnormal current that passes in the device at this time may cause degradation of internal elements.
   Follow the guideline for input signal during power-off state as described in your product documentation.

4. Handling of unused pins
   Handle unused pins in accordance with the directions given under handling of unused pins in the manual. The input pins of CMOS products are generally in the high-impedance state. In operation with an unused pin in the open-circuit state, extra electromagnetic noise is induced in the vicinity of the LSI, an associated shoot-through current flows internally, and malfunctions occur due to the false recognition of the pin state as an input signal become possible.

5. Clock signals
   After applying a reset, only release the reset line after the operating clock signal becomes stable. When switching the clock signal during program execution, wait until the target clock signal is stabilized. When the clock signal is generated with an external resonator or from an external oscillator during a reset, ensure that the reset line is only released after full stabilization of the clock signal. Additionally, when switching to a clock signal produced with an external resonator or by an external oscillator while program execution is in progress, wait until the target clock signal is stable.

6. Voltage application waveform at input pin
   Waveform distortion due to input noise or a reflected wave may cause malfunction. If the input of the CMOS device stays in the area between $V_{IL}$ (Max.) and $V_{IH}$ (Min.) due to noise, for example, the device may malfunction. Take care to prevent chattering noise from entering the device when the input level is fixed, and also in the transition period when the input level passes through the area between $V_{IL}$ (Max.) and $V_{IH}$ (Min.).

7. Prohibition of access to reserved addresses
   Access to reserved addresses is prohibited. The reserved addresses are provided for possible future expansion of functions. Do not access these addresses as the correct operation of the LSI is not guaranteed.

8. Differences between products
   Before changing from one product to another, for example to a product with a different part number, confirm that the change will not lead to problems. The characteristics of a microprocessing unit or microcontroller unit products in the same group but having a different part number might differ in terms of internal memory capacity, layout pattern, and other factors, which can affect the ranges of electrical characteristics, such as characteristic values, operating margins, immunity to noise, and amount of radiated noise. When changing to a product with a different part number, implement a system-evaluation test for the given product.
Notice

1. Descriptions of circuits, software and other related information in this document are provided only to illustrate the operation of semiconductor products and application examples. You are fully responsible for the incorporation or any other use of the circuit, software, and information in the design of your product or system. Renesas Electronics disclaims any and all liability for any losses and damages incurred by you or third parties arising from the use of these circuits, software, or information.

2. Renesas Electronics hereby expressly disclaims any warranties against infringement or any other claims involving patents, copyrights, or other intellectual property rights of third parties, by or arising from the use of Renesas Electronics products or technical information described in this document, including but not limited to, the product data, drawings, charts, programs, algorithms, and application examples.

3. No license, express, implied or otherwise, is granted hereby under any patents, copyrights or other intellectual property rights of Renesas Electronics or others.

4. You shall not alter, modify, copy, or reverse engineer any Renesas Electronics product, whether in whole or in part. Renesas Electronics disclaims any and all liability for any losses or damages incurred by you or third parties arising from such alteration, modification, copying or reverse engineering.

5. Renesas Electronics products are classified according to the following two quality grades: “Standard” and “High Quality.” The intended applications for each Renesas Electronics product depends on the product’s quality grade, as indicated below.

   - “Standard”: Computers, office equipment, communications equipment, test and measurement equipment, audio and visual equipment, home electronic appliances, machine tools, personal electronic equipment, industrial robots, etc.
   - “High Quality”: Transportation equipment (automobiles, trains, etc.); traffic control (traffic lights); large-scale communication equipment; key financial terminal systems; safety control equipment; etc.

   Unless expressly designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not intended or authorized for use in products or systems that may pose a direct threat to human life or bodily injury (critical life support devices or systems; surgical implantations, etc.) or may cause serious property damage (space system; undersea repeaters; nuclear power control systems; aircraft control systems; key plant systems; military equipment; etc.). Renesas Electronics disclaims any and all liability for any damages or losses incurred by you or any third parties arising from the use of any Renesas Electronics product that is inconsistent with any Renesas Electronics product data sheet, user’s manual or other Renesas Electronics document.

When using Renesas Electronics products, refer to the latest product information (data sheets, user’s manuals, application notes, “General Notes for Handling and Using Semiconductor Devices” in the reliability handbook, etc.), and ensure that usage conditions are within the ranges specified by Renesas Electronics with respect to maximum ratings, operating power supply voltage range, heat dissipation characteristics, installation, etc. Renesas Electronics disclaims any and all liability for any malfunctions, failures or accident arising out of the use of Renesas Electronics products outside of such specified ranges.

7. Although Renesas Electronics endeavors to improve the quality and reliability of Renesas Electronics products, semiconductor products have specific characteristics, such as the occurrence of failure at a certain rate and certain conditions under certain conditions. Unless designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not subject to radiation resistance design. You are responsible for implementing safety measures to guard against the possibility of bodily injury, injury or damage caused by fire, or any other to the public in the event of a failure or malfunction of Renesas Electronics products, such as safety design for hardware and software, including but not limited to redundancy, fire control and malfunction prevention, appropriate treatment for aging degradation or any other appropriate measures. Because the evaluation of microcomputer software alone is very difficult and impractical, you are responsible for evaluating the safety of the final products or systems manufactured by you.

8. Please contact a Renesas Electronics sales office for details as to environmental matters such as the environmental compatibility of each Renesas Electronics product. You are responsible for carefully and sufficiently investigating applicable laws and regulations that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive, and using Renesas Electronics products in compliance with all these applicable laws and regulations. Renesas Electronics disclaims any and all liability for damages or losses occurring as a result of your noncompliance with applicable laws and regulations.

9. Renesas Electronics products and technologies shall not be used or incorporated into any products or systems whose manufacture, use, or sale is prohibited under any applicable domestic or foreign laws or regulations. You shall comply with any applicable export control laws and regulations promulgated and administered by the governments of any countries asserting jurisdiction over the parties or transactions.

10. It is the responsibility of the buyer or distributor of Renesas Electronics products, or any other party who distributes, disposes of, or otherwise sells or transfers the product to a third party, to notify such third party in advance of the contents and conditions set forth in this document.

11. This document shall not be reprinted, reproduced or duplicated in any form, in whole or in part, without prior written consent of Renesas Electronics.

12. Please contact a Renesas Electronics sales office if you have any questions regarding the information contained in this document or Renesas Electronics products.

(Rev. 4.0.1 November 2017)

SALES OFFICES

Renesas Electronics Corporation

Refer to “http://www.renesas.com” for the latest and detailed information.

Renesas Electronics Corporation
FOTOFO FOREIA, 3-2-4A Toyosu, Koto-ku, Tokyo 135-0061, Japan

Renesas Electronics America Inc.
1001 Murphy Ranch Road, Milpitas, CA 95035, U.S.A.
Tel: +1-408-432-9999, Fax: +1-408-434-5351

Renesas Electronics Canada Limited
9281 Yonge Street, Suite 609 Richmond Hill, Ontario Canada L4C 9T3
Tel: +1-905-237-2001

Renesas Electronics Europe GmbH
Amstelhoekstraat 10, 4047Z Dusseldorf, Germany
Tel: +49-211-66030, Fax: +49-211-6603-1327

Renesas Electronics (China) Co., Ltd.
Room 101-103, Building 7, Yard No. 7, 8th Street, Shangdi, Haidian District, Beijing 100085, China
Tel: +86-10-8236-1156, Fax: +86-10-8236-1679

Renesas Electronics (Shanghai) Co., Ltd.
Unit 301, Tower A, Central Towers, 555 Longao Road, Putuo District, Shanghai 200333, China
Tel: +86-21-2206-9898, Fax: +86-21-2206-9999

Renesas Electronics Hong Kong Limited
Unit 1005, 16/F, Tower 2, Grand Century Place, 103 Praya Edward Road West, Mongkok, Kowloon, Hong Kong
Tel: +852-2266-6688, Fax: +852-2886-0022

Renesas Electronics Taiwan Co., Ltd.
13F., No. 362, Xie Sheng North Road, Taipei 10543, Taiwan
Tel: +886-2-8176-9600, Fax: +886-2-8176-9670

Renesas Electronics Singapore Pvt. Ltd.
80 Boon Tiek Road, Unit #6-02, Mulan Innovation Centre, Singapore 339545
Tel: +65-6213-0202, Fax: +65-6213-0300

Renesas Electronics Malaysia Sdn.Bhd.
Unit No 34-1, Level 3A Tower B UOA Business Park, No 1 Jalan Pengaturan U151A, Sektor U1, 40150 Shah Alam, Selangor, Malaysia
Tel: +60-3-5522-1289, Fax: +60-3-5522-1289

Renesas Electronics India Pvt. Ltd.
No. 777, 100 Fast Road, HAL 2nd Stage, Indiranagar, Bangalore 560 036, India
Tel: +91-80-67200700

Renesas Electronics Korea Co., Ltd.
1F., KAMCO Yangjae Tower, J2-9, Gangnam-dong, Gangnam-gu, Seoul, 06265 Korea
Tel: +82-2-558-3371, Fax: +82-2-558-5338

© 2019 Renesas Electronics Corporation. All rights reserved

Colophon 8.6