RX64M, RX71M Group

Using the Trusted Memory Function

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Introduction

This application note explains how to use the trusted memory function of RX64M and RX71M Group microcontrollers.

The trusted memory (TM) function prevents unauthorized reading of programs stored in blocks 8 and 9 of the code flash memory or programming of additional data to those blocks.

Target Devices

RX64M Group

- RX64M Group 177- and 176-pin versions, ROM capacity: 2 MB to 4 MB
- RX64M Group 145- and 144-pin versions, ROM capacity: 2 MB to 4 MB
- RX64M Group 100-pin version, ROM capacity: 2 MB to 4 MB

RX71M Group

- RX71M Group 177- and 176-pin versions, ROM capacity: 2 MB to 4 MB
- RX71M Group 145- and 144-pin versions, ROM capacity: 2 MB to 4 MB
- RX71M Group 100-pin version, ROM capacity: 2 MB to 4 MB

When using this application note with other Renesas MCUs, careful evaluation is recommended after making modifications to comply with the alternate MCU.

Contents

1. Specifications

The description in this application note assumes a 1st user, who enables the TM function, and a 2nd user who uses the device with the TM function enabled. The 1st user writes a program to the area protected by TM, and then the 2nd user executes writes to areas other than the area protected by TM.

Renesas Flash Programmer (RFP), a tool for programming flash memory, is used to write program data and to enable or disable the TM function.

Running the sample code executes processing that turns LEDs on and off.

Table 1.1 lists the peripheral functions used and their applications, and figure 1.1 is an overview diagram.

Table 1.1 Peripheral Functions Used and Their Applications

Peripheral Function	Application
Trusted memory function	Prevents unauthorized reading of programs stored in blocks 8 and 9 of the code flash memory or programming of additional data to those blocks.

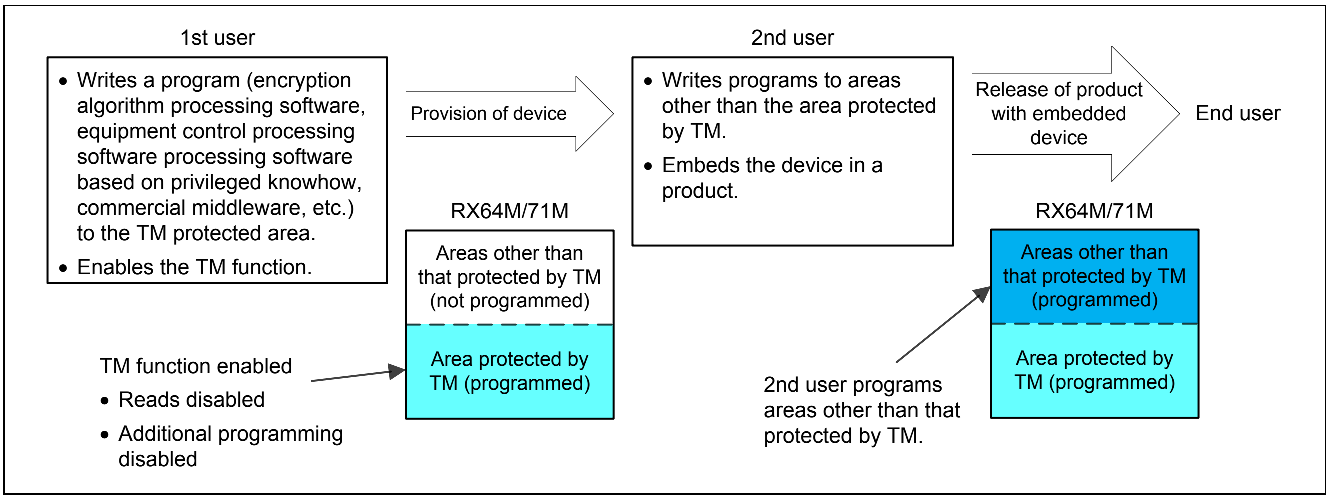

1st user
• Writes a program (encryption algorithm processing software, equipment control processing software processing software based on privileged knowhow, commercial middleware, etc.) to the TM protected area.
• Enables the TM function.
Provision of device
RX64M/71M
Areas other than that protected by TM (not programmed)
Area protected by TM (programmed)
TM function enabled
• Reads disabled
• Additional programming disabled
2nd user
• Writes programs to areas other than the area protected by TM.
• Embeds the device in a product.
Release of product with embedded device
End user
RX64M/71M
Areas other than that protected by TM (programmed)
Area protected by TM (programmed)
2nd user programs areas other than that protected by TM.

Figure 1.1 Overview Diagram

2. Operation Confirmation Conditions

The sample code accompanying this application note has been run and confirmed under the conditions below.

Table 2.1 Operation Confirmation Conditions

Item	Contents
MCU used	R5F571MLCDFC (RX71M Group)
RAM capacity	512 Kbytes
Code flash memory capacity	4 MB
Operating frequency	Main clock: 24 MHz PLL: 240 MHz (main clock divided by 1 and multiplied by 10) System clock (ICLK): 120 MHz (PLL divided by 2) Peripheral module clock A (PCLKA): 120 MHz (PLL divided by 2) Peripheral module clock B (PCLKB): 60 MHz (PLL divided by 4) Flash interface clock (FCLK): 60 MHz (PLL divided by 4)
Operating voltage	3.3 V
Integrated development environment	Renesas Electronics e^2 studio Version: 4.0.0.26
C compiler	Renesas Electronics C/C++ Compiler Package for RX Family V.2.03.00
	Compiler options The integrated development environment default settings are used.
iodefine.h version	V1.00
Endian	Little endian
Operating mode	Single-chip mode
Processor mode	Supervisor mode
Sample code version	Version 1.00
Board used	Renesas Starter Kit+ for RX71M (product type: R0K50571MSxxxBE)
Tools used	Renesas Flash Programmer V2.05

3. Reference Application Note

For additional information associated with this document, refer to the following application notes.

- RX71M Group Initial Settings Rev.1.00 (R01AN2459EJ)

The initial settings function of the above application note is used in the sample code of this application note. The revision number is that which was current at the time of the preparation of this application note.

If a newer version is available, replace the version included with this application note with the newer version. The latest version can be checked and downloaded from the Renesas Electronics website.

4. TM Function Operation Example

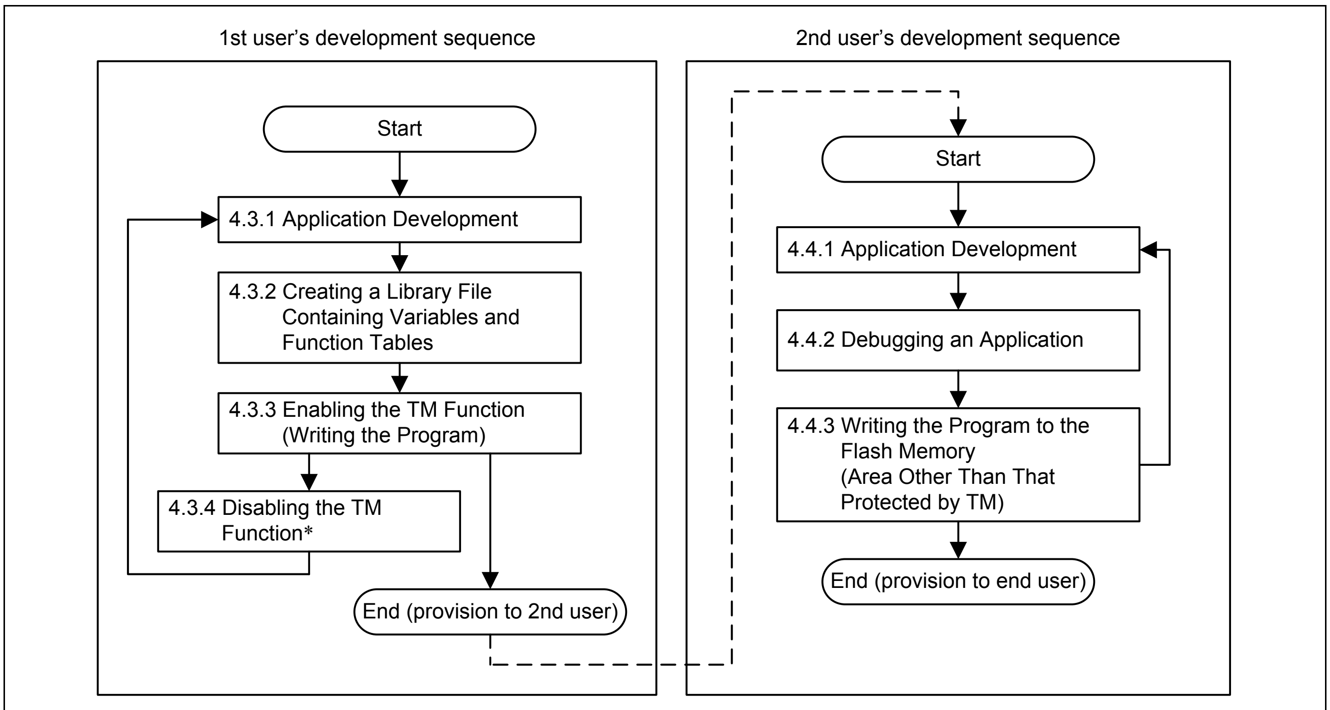
The 1st user (who supplies the program in the area protected by TM) develops an application and creates a library file (.lib) containing the variables and function tables used by the program in the area protected by TM. After developing the application, the 1st user uses RFP to write the program to the area protected by TM and enables the TM function.

The 1st user should provide the 2nd user with the specifications of the program in the area protected by TM, sample code section information, and the library file (.lib) created as described above.

The 2nd user (application developer) uses the provided program specifications, section information, and library file (.lib) to develop an application. After developing the application, the 2nd user uses e^2 studio to debug the application and uses RFP to write the program to an area other than that protected by TM.

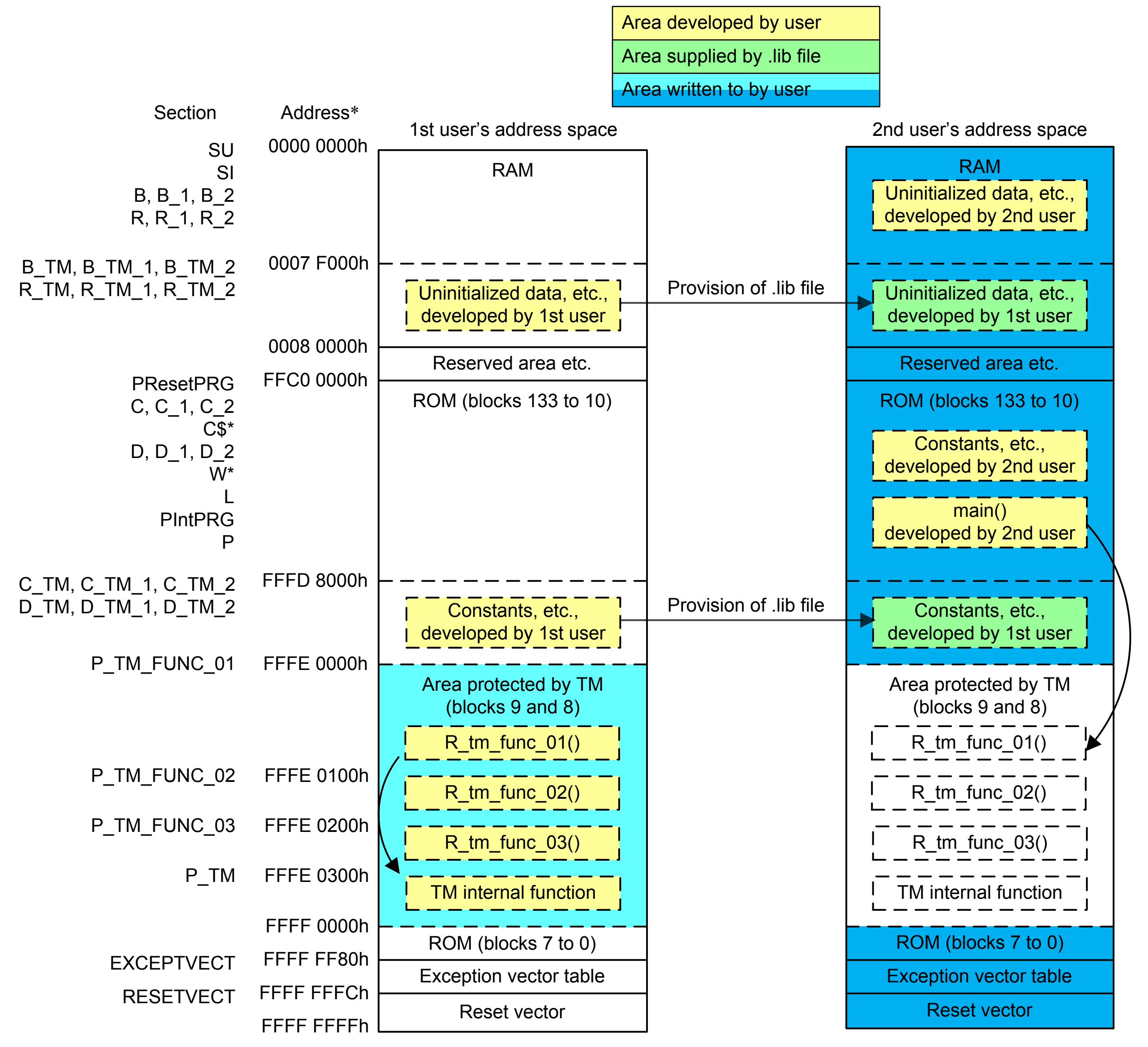
The 2nd user then embeds the device to which the program was written in the finished product and supplies it to the end user.

Figure 4.1 shows the development sequence, and figure 4.2 is a block diagram.


1st user's development sequence
Start
4.3.1 Application Development
4.3.2 Creating a Library File Containing Variables and Function Tables
4.3.3 Enabling the TM Function (Writing the Program)
4.3.4 Disabling the TM Function*
End (provision to 2nd user)
2nd user's development sequence
Start
4.4.1 Application Development
4.4.2 Debugging an Application
4.4.3 Writing the Program to the Flash Memory (Area Other Than That Protected by TM)
End (provision to end user)

Note: * To disable the TM function after it has been enabled, follow the instructions in 4.3.4, Disabling the TM Function.

Figure 4.1 Development Sequence



Note: * The code flash memory capacity of the device used in this application note is 4 MB.
Note that the actual code flash memory capacity differs depending on the product version.

Figure 4.2 Block Diagram

4.1 Creating a New Project in RFP

Renesas Flash Programmer (RFP) is a software application for programming flash memory. In this application note it is used to write a program to the area protected by TM and to enable and disable the TM function.

The procedure for creating a new project in RFP is as follows:

1. Launch RFP.
2. In the **Welcome!** dialog box, select **Create new workspace** and **Basic mode**.
3. In the **Using Target Microcontroller:** list box, select **RX** as the group.
4. Enter appropriate values for **Workspace Name:**, **Project Name:**, and **Folder:**, then click the **Next** button.
5. Select **E1** in the **Tool:** list box, then click the **Next** button.
6. Check the box next to **Power target from the emulator**, select **3.3 V**, then click the **Next** button.
7. Next to **Pin Outputs**, check the boxes for **io3** and **io2** to specify the mode pins at connection, then click the **OK** button.
8. Select the emulator, then click the **OK** button.
9. Select **Little Endian** as the endian mode.
10. Enter settings in the **Clock supply** area, then click the **OK** button.
11. Select **2000000** bps in the **Communication Speed (Recommended):** list box.
12. Click the **Finish** button.

RFP is available on the Renesas Electronics website.

For detailed information on RFP, refer to Renesas Flash Programmer Flash memory programming software User's Manual: Common and Renesas Flash Programmer Flash memory programming software User's Manual: RH850, RX700 (Include RX64x).

4.2 Creating a New Project in e^2 studio

Both the 1st user and the 2nd user use e^2 studio to make section settings, specify ROM options, and initialize sections.

4.2.1 Section Settings

In order to clarify the areas of memory used for development by the 1st user and 2nd user, separate sections should be specified for use by the 1st user's program in the area protected by TM and for application development by the 2nd user.

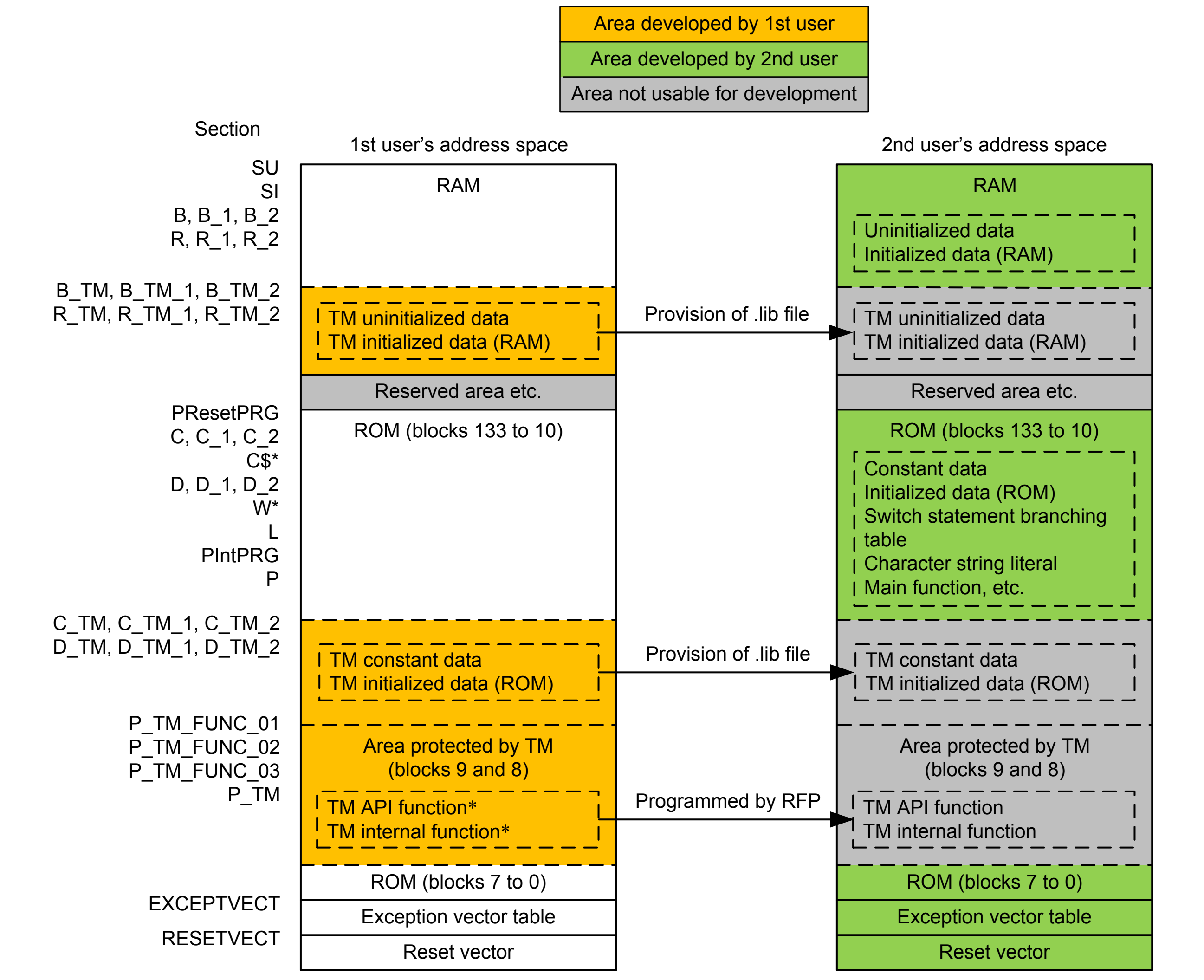
Note that sections L and W are not used because they are #pragma sections that cannot be renamed. If switch statements are used, it is necessary to not specify **table** format (allocation to switch branching table area) but rather **if_then** format (allocation to program area).

This setting causes switch statements to be allocated to the program area and written to the device.

The switch statement code expansion setting is made by the 1st user only. The 1st user should provide the 2nd user with information on the sections used.

The 2nd user should then make settings for the sections used by the 1st user, based on the information provided. It is important that the addresses be accurate when making section settings. It is also important that the sections used by the 2nd user be specified such that they do not overlap the areas used by the 1st user.

For the section configuration used in this application note, see 6.3, Section Configuration. Figure 4.3 is a section diagram.

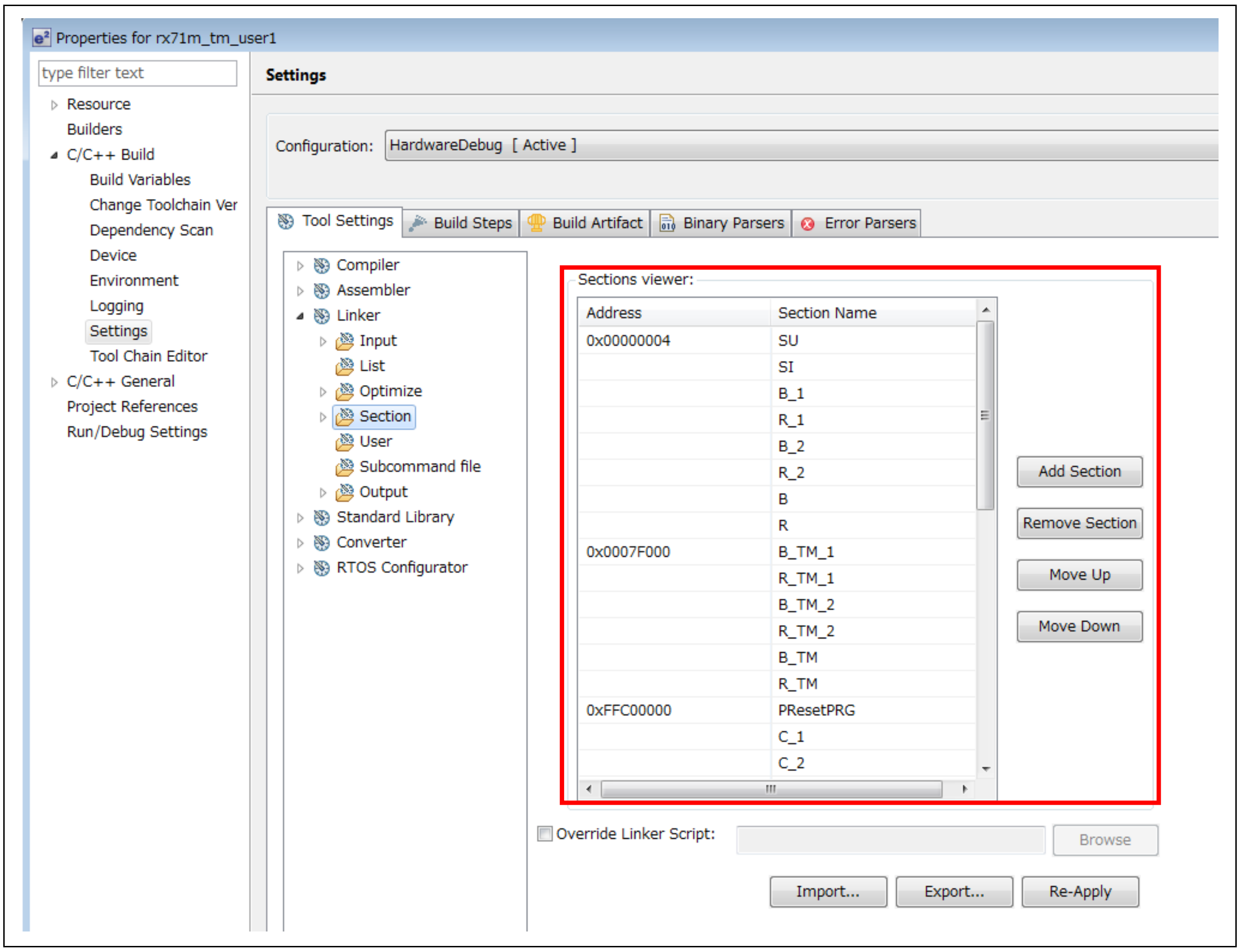


Note: * Switch statements are expanded in **if_then** format, so they are allocated to sections in the area protected by TM (API function section P_TM_FUNC_xx and internal function section P_TM).

Figure 4.3 Section Diagram

The procedure for making section settings is described below:

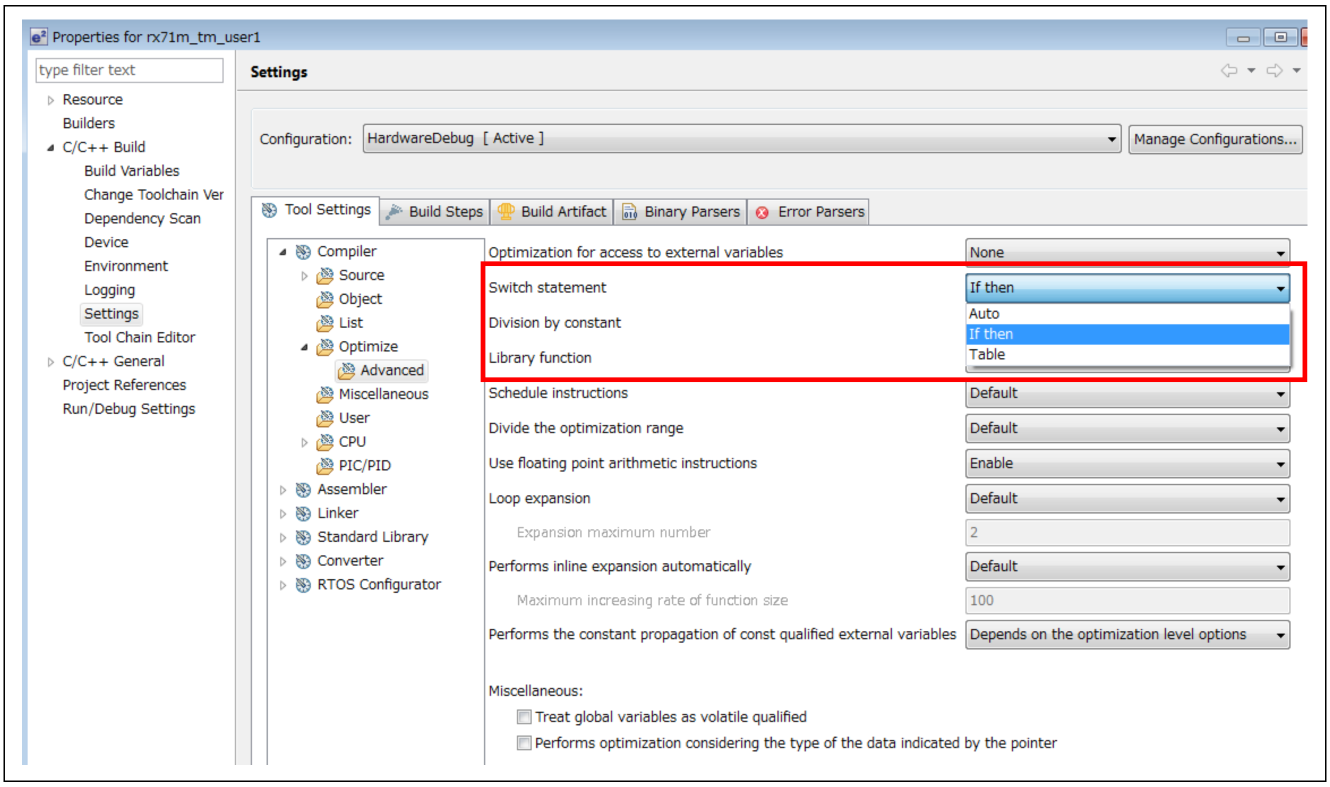
1. In e^2 studio, right-click the target project and select **Properties**.
2. Under **C/C++ Build** select **Settings**. Switch to the **Tool Settings** tab and select **Section** under **Linker**.
3. Enter settings for each section.
4. Click the **Apply** button.



Address	Section Name
0x00000004	SU
	SI
	B_1
	R_1
	B_2
	R_2
	B
	R
0x0007F000	B_TM_1
	R_TM_1
	B_TM_2
	R_TM_2
	B_TM
	R_TM
0xFFC00000	PResetPRG
	C_1
	C_2

The procedure for setting the code expansion format for switch statements is described below:

1. In e^2 studio, right-click the target project and select **Properties**.
2. Under **C/C++ Build** select **Settings**. Switch to the **Tool Settings** tab and select **Advanced** under **Optimize**.
3. In the **Switch statement:** list box, select **if then**.
4. Click the **Apply** button.


Properties for rx71m_tm_user1

Settings

Configuration: HardwareDebug [Active]

Optimization for access to external variables	None
Switch statement	If then (Auto / If then / Table)
Division by constant	
Library function	
Schedule instructions	Default
Divide the optimization range	Default
Use floating point arithmetic instructions	Enable
Loop expansion	Default
Expansion maximum number	2
Performs inline expansion automatically	Default
Maximum increasing rate of function size	100
Performs the constant propagation of const qualified external variables	Depends on the optimization level options

Miscellaneous:
- [ ] Treat global variables as volatile qualified
- [ ] Performs optimization considering the type of the data indicated by the pointer

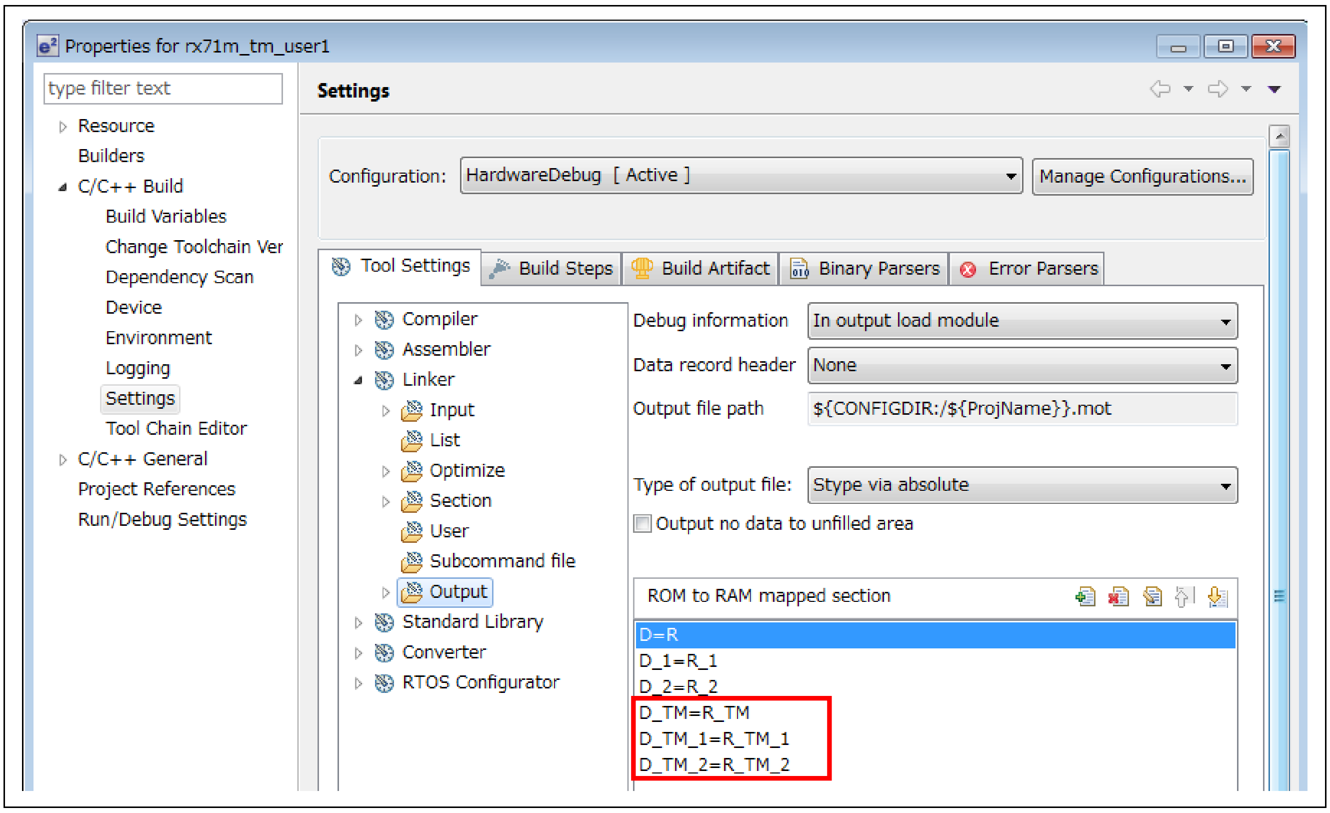
4.2.2 ROM Option Settings

ROM options are used to secure areas in ROM and RAM for the initialized data area and to relocate symbols defined in ROM sections to addresses in RAM sections.

ROM option settings are specified by default for sections D and R only. When creating a new project, it is necessary to enter ROM option settings for the initialized data areas (D_TM and R_TM) used by the 1st user.

The procedure for setting ROM options is described below:

1. In e^2 studio, right-click the target project and select **Properties**.
2. Under **C/C++ Build** select **Settings**. Switch to the **Tool Settings** tab and select **Output** under **Linker**.
3. Add the sections to be mapped from ROM to RAM.
   (In this application note the additions are D_TM = R_TM, D_TM_1 = R_TM_1, and D_TM_2 = R_TM_2.)
4. Click the **Apply** button.



Configuration: HardwareDebug [Active]

Debug information: In output load module
Data record header: None
Output file path: ${CONFIGDIR:/${ProjName}}.mot
Type of output file: Stype via absolute
Output no data to unfilled area

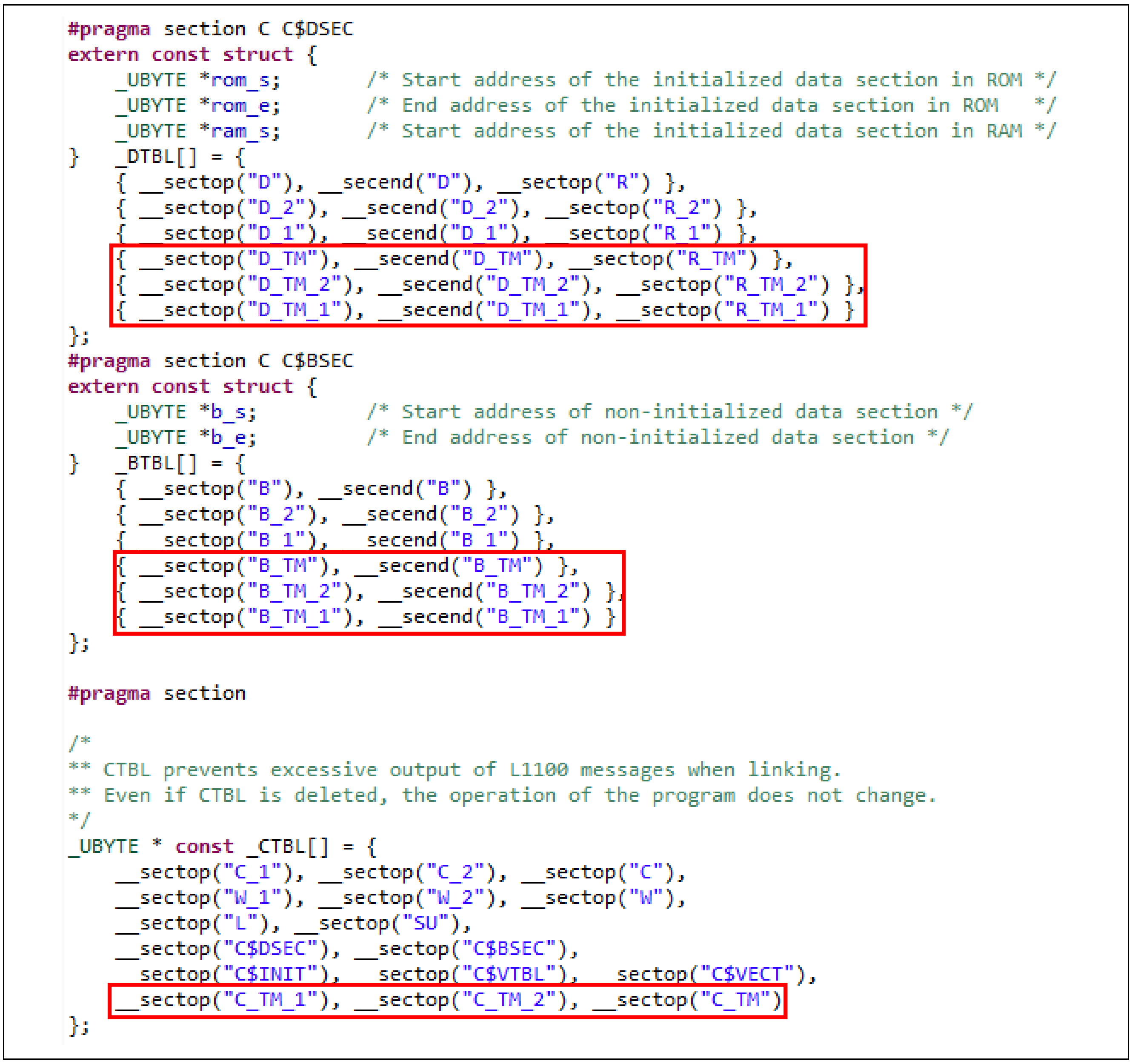
ROM to RAM mapped section
D=R
D_1=R_1
D_2=R_2
D_TM=R_TM
D_TM_1=R_TM_1
D_TM_2=R_TM_2

For detailed information about ROM options, see CC-RX V2.03.00 RX Family C/C++ Compiler: User’s Manual.

4.2.3 Section Initialization

When the _INITSCT function in **reset_program.c**, a file generated automatically by e^2 studio, is called, uninitialized data sections are zero-initialized and initialized data sections are copied from the ROM area to the RAM area.

The user must declare the sections to be initialized in section initialization tables (DTBL and BTBL). Add the lines indicated below to the section initialization tables in the file **dbsct.c**, which is generated automatically by e^2 studio.



```
#pragma section C C$DSEC
extern const struct {
    _UBYTE *rom_s;       /* Start address of the initialized data section in ROM */
    _UBYTE *rom_e;       /* End address of the initialized data section in ROM   */
    _UBYTE *ram_s;       /* Start address of the initialized data section in RAM */
}   _DTBL[] = {
    { __sectop("D"), __secend("D"), __sectop("R") },
    { __sectop("D_2"), __secend("D_2"), __sectop("R_2") },
    { __sectop("D_1"), __secend("D_1"), __sectop("R_1") },
    { __sectop("D_TM"), __secend("D_TM"), __sectop("R_TM") },
    { __sectop("D_TM_2"), __secend("D_TM_2"), __sectop("R_TM_2") },
    { __sectop("D_TM_1"), __secend("D_TM_1"), __sectop("R_TM_1") }
};
#pragma section C C$BSEC
extern const struct {
    _UBYTE *b_s;         /* Start address of non-initialized data section */
    _UBYTE *b_e;         /* End address of non-initialized data section */
}   _BTBL[] = {
    { __sectop("B"), __secend("B") },
    { __sectop("B_2"), __secend("B_2") },
    { __sectop("B_1"), __secend("B_1") },
    { __sectop("B_TM"), __secend("B_TM") },
    { __sectop("B_TM_2"), __secend("B_TM_2") },
    { __sectop("B_TM_1"), __secend("B_TM_1") }
};

#pragma section

/*
** CTBL prevents excessive output of L1100 messages when linking.
** Even if CTBL is deleted, the operation of the program does not change.
*/
_UBYTE * const _CTBL[] = {
    __sectop("C_1"), __sectop("C_2"), __sectop("C"),
    __sectop("W_1"), __sectop("W_2"), __sectop("W"),
    __sectop("L"), __sectop("SU"),
    __sectop("C$DSEC"), __sectop("C$BSEC"),
    __sectop("C$INIT"), __sectop("C$VTBL"), __sectop("C$VECT"),
    __sectop("C_TM_1"), __sectop("C_TM_2"), __sectop("C_TM")
};
```

For detailed information about section initialization, see CC-RX V2.03.00 RX Family C/C++ Compiler: User’s Manual.

4.3 Development Procedure for 1st User

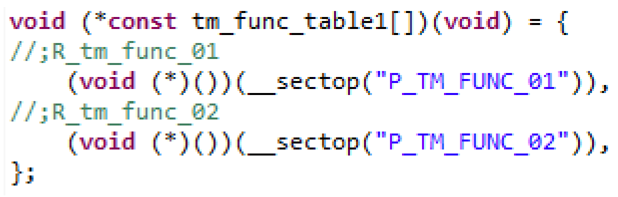
4.3.1 Application Development

Generally speaking, symbols are used to call functions, but the 2nd user cannot use this method to access functions in the area protected by TM because the 2nd user is not provided with symbol information for these functions. In order to access functions in the area protected by TM, the 2nd user requires address information for these functions.

The 1st user must therefore prepare function tables containing function address information for the area protected by TM. The function tables are allocated to the constant area, so they are provided to the 2nd user in the library file (.lib). This enables the 2nd user to call functions located in the area protected by TM by utilizing the function tables.

API functions in the area protected by TM are assigned sections and addresses individually. The first user should store the section start address of each API function in the function table. Information other than variables and function tables is omitted when the library file is created, so it is not possible to use function symbols in function tables.

An example of a function table is shown below:



```
void (*const tm_func_table1[])(void) = {
//;R_tm_func_01
    (void (*)())(__sectop("P_TM_FUNC_01")),
//;R_tm_func_02
    (void (*)())(__sectop("P_TM_FUNC_02")),
};
```

When the TM function is enabled, performing data access to the area protected by TM causes zeros to be read, so only section P should be allocated to the area protected by TM. All areas to which data access will be performed (section C, etc.) should be assigned to areas other than the area protected by TM.

This application note includes confirmation of data access operation when accessing the area protected by TM while the TM function is enabled. For information on data access operation when the TM function is enabled, see 6.1.1, Data Access.

4.3.2 Creating a Library File Containing Variables and Function Tables

To access functions in the area protected by TM, the 2nd user requires address information for these functions. The 1st user must therefore prepare and supply to the 2nd user a library file (.lib) containing variables and function tables for the area protected by TM.

The library file is created with the sample code **rx71m_tm_user1_lib** by building the file **tm_api.c**, with information other than global variables, const variables, and function tables for the area protected by TM removed.

The procedure for creating a new library file project is described below:

1. From the e^2 studio **File** menu, select **New** > **C Project**.
2. In the **Project type:** list box, select **Static Library (Renesas)** > **Sample Project**.
3. In the **Toolchains:** list box, select **Renesas RXC Toolchain**.
4. Enter a name for the project, then click the **Next** button.
5. For ISA type, select **RXv2 architecture**.
6. Click the **Finish** button.

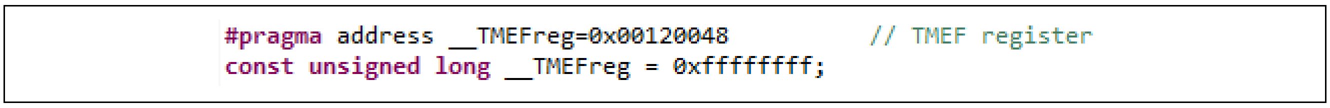
4.3.3 Enabling the TM Function

RFP is used to enable the TM function. Enabling of the TM and program writing to the area protected by TM take place at the same time.*1*2

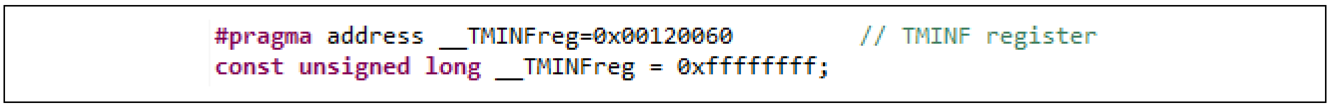
The 1st user creates mot files from which all code except that related to the TM enable flag register (TMEF register), TM identification data register (TMINF register), and area protected by TM has been removed, and writes them to the target device.

The TM function is enabled by setting the TMEF bits in the TMEF register to 000b.*3 The TMINF register stores the code used to identify programs in the area protected by TM.

To make settings to the TMEF register and TMINF register, make the modifications shown below to the file **vector_table.c**, which is generated automatically by e^2 studio.



```
#pragma address __TMEFreg=0x00120048          // TMEF register
const unsigned long __TMEFreg = 0xffffffff;
```



```
#pragma address __TMINFreg=0x00120060         // TMINF register
const unsigned long __TMINFreg = 0xffffffff;
```

The procedure for writing the mot files to the target device with REP is described below:

1. Launch RFP.
2. From the RFP **Microcontroller** menu, select **All Erase**.
3. Click the **Start** button.
4. From the RFP **Microcontroller** menu, select **Program**.
5. Click **Browse** next to **User/Data area:** and select the previously created mot files.
6. Click the **Start** button.

For details on enabling the TM function, see “How to Enable the TM Function” in the “Flash Memory” section in RX64M Group User’s Manual: Hardware or RX71M Group User’s Manual: Hardware.

For detailed information on RFP, refer to Renesas Flash Programmer Flash memory programming software User’s Manual: Common and Renesas Flash Programmer Flash memory programming software User’s Manual: RH850, RX700 (Include RX64x).

Notes: 1. It is also possible to enable the TM function after writing a program to the area protected by TM. To accomplish this, create a mot file containing the TMEF register code only and proceed from step 4 to write it to the microcontroller.
2. It is also possible to enable the TM function internally by means of self-programming.
3. It is not possible to enable the TM function by using the e^2 studio environment (download). RFP must be used to write to the microcontroller.

4.3.4 Disabling the TM Function

The TM function can be disabled by first erasing the data flash memory, user boot area, and the areas other than that protected by TM (blocks 8 and 9), and then issuing the clear configuration command.

When the clear configuration command is issued, the configuration settings area, including the TMEF and TMINF registers, and the code flash memory, which is the area protected by TM, are erased.

The procedure for disabling the TM function is described below:

1. Launch RFP.
2. From the RFP **Microcontroller** menu, select **Set Project**.
3. Select the **Other Settings** tab.
4. Under **Command Options**, set **Clear Configuration After All Erase** to **True**.
5. Click the **OK** button.
6. From the **Microcontroller** menu, select **All Erase**.
7. Click the **Start** button.

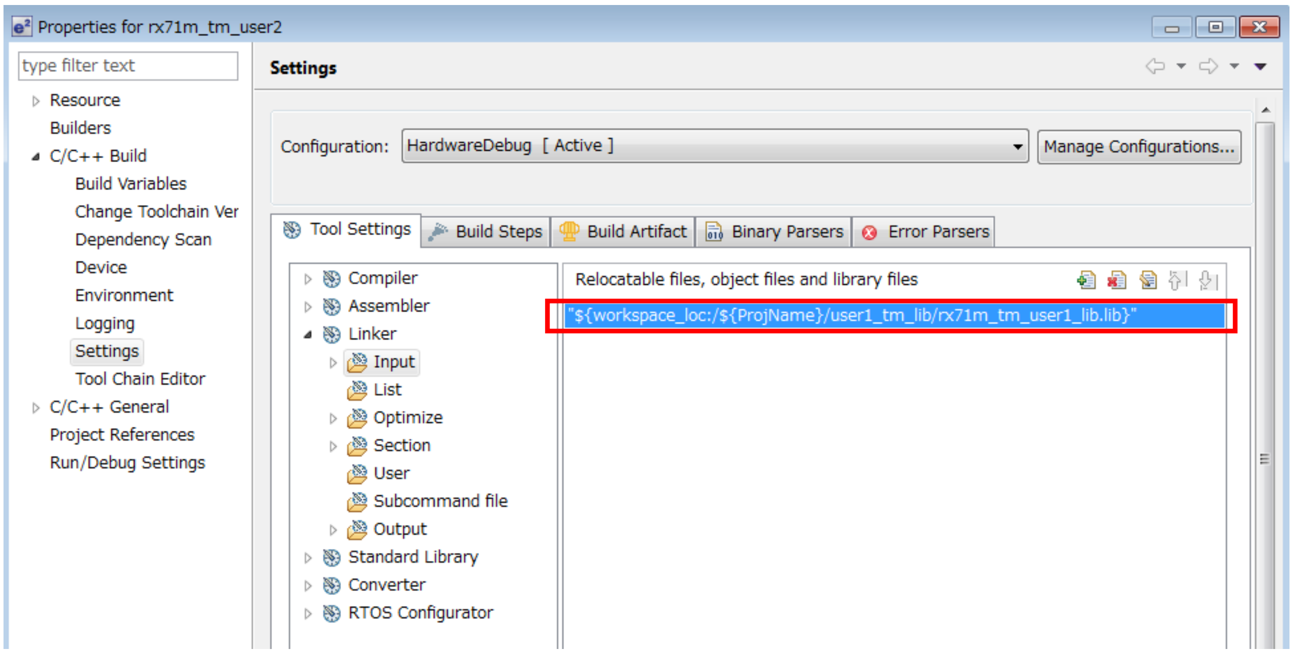
4.4 Development Procedure for 2nd User

4.4.1 Application Development

Using the provided library file (.lib) containing variables and function tables, the 2nd user can develop an application.*

The procedure for linking the library file (.lib) is described below:

1. In e^2 studio, right-click the target project and select **Properties**.
2. Under **C/C++ Build** select **Settings**. Switch to the **Tool Settings** tab and select **Input** under **Linker**.
3. Add the provided .lib file.
4. Click the **Apply** button.


Properties for rx71m_tm_user2

Settings

Configuration: HardwareDebug [Active]

Relocatable files, object files and library files

"${workspace_loc:/${ProjName}/user1_tm_lib/rx71m_tm_user1_lib.lib}"

The 2nd user should use the function tables in the provided library file (.lib) to call API functions in the area protected by TM.

An example of calling API functions using function tables is shown below.

```
/* ==== Initialize LED ports ==== */
tm_func_table1[R_TM_PORT_INIT]();

/* ==== LEDs ON ==== */
tm_func_table2[R_TM_SET_LED](*table);

/* ==== LEDs OFF ==== */
tm_func_table1[R_TM_LED_OFF]();
```

Note: * The 2nd user must not allocate programs to the area protected by TM when developing applications. This will result in errors during programming because the TM function is enabled.

4.4.2 Debugging an Application after Development

The e^2 studio integrated development environment can be used to download programs to areas other than that protected by TM for application debugging.

The e^2 studio integrated development environment offers the options when downloading programs to "overwrite without erasing" or to "erase and then overwrite." The default setting is "erase and then overwrite," but when the TM function is enabled it is not possible to erase programs in the area protected by TM.

To erase the area protected by TM, issue the clear configuration command. When the clear configuration command is issued, the configuration settings area, including the TMEF and TMINF registers, and blocks 8 and 9 of the code flash memory, which is the area protected by TM, are erased.

4.4.3 Writing the Program to the Flash Memory (Area Other Than That Protected by TM)

Following application development, RFP is used to write the mot files to the microcontroller.

The procedure for writing the file is described below:

1. Launch RFP.
2. From the RFP **Microcontroller** menu, select **Erase**.
3. Click the **Start** button.
4. Check the boxes for the blocks in areas other than that protected by TM.
5. Click the **Erase** button.
6. From the RFP **Microcontroller** menu, select **Program**.
7. Click **Browse** next to **User/Data area:** and select the previously created mot files.
8. Click the **Start** button.

5. Hardware

5.1 Pin Used

Table 5.1 lists the pins used and their functions, and figure 5.1 is a connection diagram.

Table 5.1 Pins Used and Their Functions

Pin Name	I/O	Function
P03	Output	LED0 output
P05	Output	LED1 output
P26	Output	LED2 output
P27	Output	LED3 output

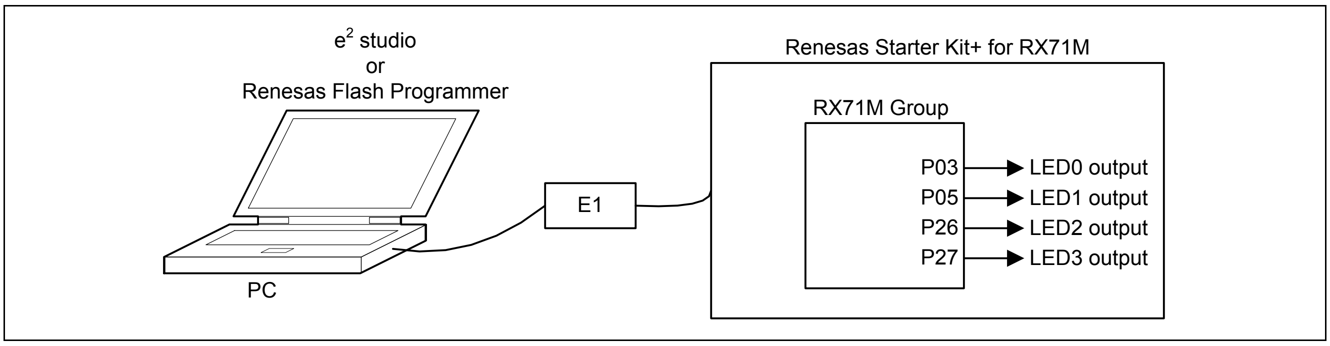


Figure 5.1 Connection Diagram

6. Software

6.1 Operation Overview

Operation when rx71m_tm_user1.mot and rx71m_tm_user2.mot have been written to the target device is described below.

After initial settings are made by the main function, the LEDs turn on in predetermined patterns. The tables below show the LED patterns associated with the area protected by TM and with the areas not protected by TM. Figure 6.1 shows the LED tables.

After the display of the patterns, all the LEDs turn off.

	Area Protected by TM – LED Table					Area Not Protected by TM – LED Table				
	Programmed Value	LED				Programmed Value	LED			
		Bit 3	Bit 2	Bit 1	Bit 0		Bit 3	Bit 2	Bit 1	Bit 0
Pattern 1	0x09	🟡	⚫	⚫	🟡	0x01	⚫	⚫	⚫	🟡
Pattern 2	0x06	⚫	🟡	🟡	⚫	0x02	⚫	⚫	🟡	⚫
Pattern 3	0x09	🟡	⚫	⚫	🟡	0x04	⚫	🟡	⚫	⚫
Pattern 4	0x06	⚫	🟡	🟡	⚫	0x08	🟡	⚫	⚫	⚫

🟡 : LED on ⚫ : LED off

Figure 6.1 LED Table

6.1.1 Data Access

The LED patterns in the table for the area protected by TM differ when the TM function is enabled and when it is disabled. When the TM function is enabled, performing data access to the area protected by TM results in all zeros being read, rather than the programmed value. The program associated with this application note turns all LEDs on when the pattern value 0x00 is read.

Figure 6.2 shows the different LED patterns when the TM function is enabled and when it is disabled.

	Area Protected by TM – LED Table											
	TM Function Disabled						TM Function Enabled					
	Programmed Value	Read Value	LED				Programmed Value	Read Value	LED			
			Bit 3	Bit 2	Bit 1	Bit 0			Bit 3	Bit 2	Bit	Bit 0
Pattern 1	0x09	0x09	🟡	⚫	⚫	🟡	0x09	0x00	🟡	🟡	🟡	🟡
Pattern 2	0x06	0x06	⚫	🟡	🟡	⚫	0x06	0x00	🟡	🟡	🟡	🟡
Pattern 3	0x09	0x09	🟡	⚫	⚫	🟡	0x09	0x00	🟡	🟡	🟡	🟡
Pattern 4	0x06	0x06	⚫	🟡	🟡	⚫	0x06	0x00	🟡	🟡	🟡	🟡

🟡 : LED on ⚫ : LED off

Figure 6.2 Difference in LED Patterns when TM Function Is Enabled and Disabled

6.2 Sample Code Configuration

Table 6.1 lists the sample code supplied with this application note.

Table 6.1 Sample Code Supplied with Application Note

File Name	Outline	Remarks
rx71m_tm_user1	Project developed by 1st user	
rx71m_tm_user1_lib	.lib file generation project provided to 2nd user	
rx71m_tm_user2	Project developed by 2nd user	

6.3 Section Configuration

Table 6.2 lists section information for the sample code.

For information on how to add, modify, or erase sections, see the latest version of the RX Family C/C++ Compiler: User's Manual.

Table 6.2 Sample Code Section Information

Section Name	Address	1st User	2nd User	Description
SU	0000 0004	—	—	User stack area
SI		—	—	Interrupt stack area
B_1		—	—	Uninitialized data area Initialized data area (RAM)
R_1		—	—	
B_2		—	—	
R_2		—	—	
B		—	—	
R		—	—	
B_TM_1	0007 F000	Addition	Addition	Used by area protected by TM • Uninitialized data area • Initialized data area (RAM)
R_TM_1		Addition	Addition	
B_TM_2		Addition	Addition	
R_TM_2		Addition	Addition	
B_TM		Addition	Addition	
R_TM		Addition	Addition	
PResetPRG	FFC0 0000	—	—	Power-on reset PC
C_1		—	—	Constant area
C_2		—	—	
C		—	—	
C$*		—	—	
D_1		Addition	Addition	Initialized data area (ROM) Changed from default (D* → D)
D_2		Addition	Addition	
D		Change	Change	
W*		—	—	Switch statement branching table area
L		—	—	Literal area
PIntPRG		—	—	Interrupt vector table
P		—	—	Program area
C_TM_1	FFFD F000	Addition	Addition	Used by area protected by TM • Constant area
C_TM_2		Addition	Addition	
C_TM		Addition	Addition	
D_TM_1		Addition	Addition	Used by area protected by TM • Initialized data area (ROM)
D_TM_2		Addition	Addition	
D_TM		Addition	Addition	
P_TM_FUNC_01	FFFE 0000	Addition	Addition	API function 01 in area protected by TM
P_TM_FUNC_02	FFFE 0100	Addition	Addition	API function 02 in area protected by TM
P_TM_FUNC_03	FFFE 0200	Addition	Addition	API function 03 in area protected by TM
P_TM	FFFE 0300	Addition	Not needed	Internal function in area protected by TM
(C_TM_TEST*)Note 1	(FFFE 0400)	(Addition)	(Addition)	(Area protected by TM – constant area)
EXCEPTVECT	FFFF FF80	—	—	Exception vector table
RESETVECT	FFFF FFFC	—	—	Reset vector

—: Default

Note: 1. Section C_TM_TEST* is provided with this application note to confirm the behavior of data access operations targeting the area protected by TM when the TM function is enabled. When the TM function is enabled, performing data access to the area protected by TM causes zeros to be read, so only section P should be allocated to the area protected by TM.

6.4 1st User

6.4.1 File Composition

Tables 6.3 and 6.4 list the files used in the sample code. Files generated by the integrated development environment are not included in this table.

Table 6.3 Files Used in the Sample Code (rx71m_tm_user1)

File Name	Outline	Remarks
r_tm_api.c	Program in area protected by TM	
r_tm_api.h	Header file of r_tm_api.c	

Table 6.4 Files Used in the Sample Code (rx71m_tm_user1_lib)

File Name	Outline	Remarks
r_tm_api.c	Program in area protected by TM	All information other than variables and function tables deleted

6.4.2 Option-Setting Memory

Table 6.5 lists the option-setting memory configured in the sample code. When necessary, set a value suited to the user system.

Table 6.5 Option-Setting Memory Configured in the Sample Code

Symbol	Address	Setting Value	Contents
OFS1	0012 006Fh to 0012 006Ch	FFFF FFFFh	Voltage monitor 0 reset disabled after a reset HOCO oscillation disabled after a reset
OFS0	0012 006Bh to 0012 0068h	FFFF FFFFh	IWDT stopped after a reset WDT stopped after a reset
MDE	0012 0067h to 0012 0064h	FFFF FFFFh	Little endian
TMINF*[1]	0012 0063h to 0012 0060h	544D 3031h	ASCII code: TM01
TMEF*[1]*[2]	0012 004Bh to 0012 0048h	F8FF FFFFh	FFFF FFFFh: TM function disabled F8FF FFFFh: TM function enabled

Notes: 1. See 4.3.3, Enabling the TM Function, and 4.3.4, Disabling the TM Function, for information on making settings to the TMEF and TMINF registers.

2. It is not possible to make settings to the TMEF register by using the e^2 studio environment (download). RFP must be used to make settings to the TMEF register.

6.4.3 Constants

Table 6.6 lists the constants used in the sample code.

Table 6.6 Constants Used in the Sample Code

Constant Name	Setting Value	Description
LED_ON	0	LED output data: On
LED_OFF	1	LED output data: Off
LED0_REG_PODR	PORT0.PODR.BIT.B3	LED0 output data storage bit
LED1_REG_PODR	PORT0.PODR.BIT.B5	LED1 output data storage bit
LED2_REG_PODR	PORT2.PODR.BIT.B6	LED2 output data storage bit
LED3_REG_PODR	PORT2.PODR.BIT.B7	LED3 output data storage bit
LED0_REG_PDR	PORT0.PDR.BIT.B3	LED0 direction control bit
LED1_REG_PDR	PORT0.PDR.BIT.B5	LED1 direction control bit
LED2_REG_PDR	PORT2.PDR.BIT.B6	LED2 direction control bit
LED3_REG_PDR	PORT2.PDR.BIT.B7	LED3 direction control bit
LED0_REG_PMR	PORT0.PMR.BIT.B3	LED0 pin mode control bit
LED1_REG_PMR	PORT0.PMR.BIT.B5	LED1 pin mode control bit
LED2_REG_PMR	PORT2.PMR.BIT.B6	LED2 pin mode control bit
LED3_REG_PMR	PORT2.PMR.BIT.B7	LED3 pin mode control bit

6.4.4 Variables

Table 6.7 lists the const variables.

Table 6.7 const Variables

Type	Variable Name	Description	Function Used
const uint8_t	g_test_tm_led_table[]	LED table of area protected by TM	main
const uint8_t	g_tm_led_table[]	LED table of area not protected by TM	main
const uint8_t	g_led_pattern_num	Number of LED patterns	main

6.4.5 Functions

Table 6.8 lists the functions used in the sample code.

Table 6.8 Functions Used in the Sample Code

Function	Outline
R_TM_PortInit	Initial port settings (API function in area protected by TM)
R_TM_SetLedPattern	Display LED pattern (API function in area protected by TM)
R_TM_LedOff	Turn off all LEDs (API function in area protected by TM)
tm_led_on	Turn on all LEDs (internal function in TM function area)

6.4.6 Function Tables

Table 6.9 lists the function tables.

Table 6.9 Function Tables

Type	Function Pointer Name	Argument	Storage Address
void	tm_func_table1[]	void	__sectop("P_TM_FUNC_01"), __sectop("P_TM_FUNC_03")
void	tm_func_table2[]	uint8_t argument	__sectop("P_TM_FUNC_02")

6.4.7 Function Specifications

The following tables lists the sample code function specifications.

R_TM_PortInit	
Outline	Initial port settings (API function in area protected by TM)
Header	r_tm_api.h
Declaration	void R_TM_PortInit (void)
Description	Performs initial LED port settings.
Arguments	None
Return Value	None

R_TM_SetLedPattern		
Outline	Display LED pattern (API function in area protected by TM)	
Header	r_tm_api.h	
Declaration	void R_TM_SetLedPattern (uint8_t pattern)	
Description	Outputs an LED pattern. All LEDs turn on when the LED pattern is 0x00.	
Arguments	uint8_t pattern	LED pattern
Return Value	None	

R_TM_LedOff	
Outline	Turn off all LEDs (API function in area protected by TM)
Header	r_tm_api.h
Declaration	void R_TM_LedOff (void)
Description	Turns off all LEDs.
Arguments	None
Return Value	None

tm_led_off	
Outline	Turn on all LEDs (internal function in TM function area)
Header	r_tm_api.h
Declaration	void tm_led_on (void)
Description	Turns on all LEDs.
Arguments	None
Return Value	None

6.4.8 Flowcharts

(1) Initial Port Settings (API Function in Area Protected by TM)

Figure 6.3 is a flowchart of the initial port settings.

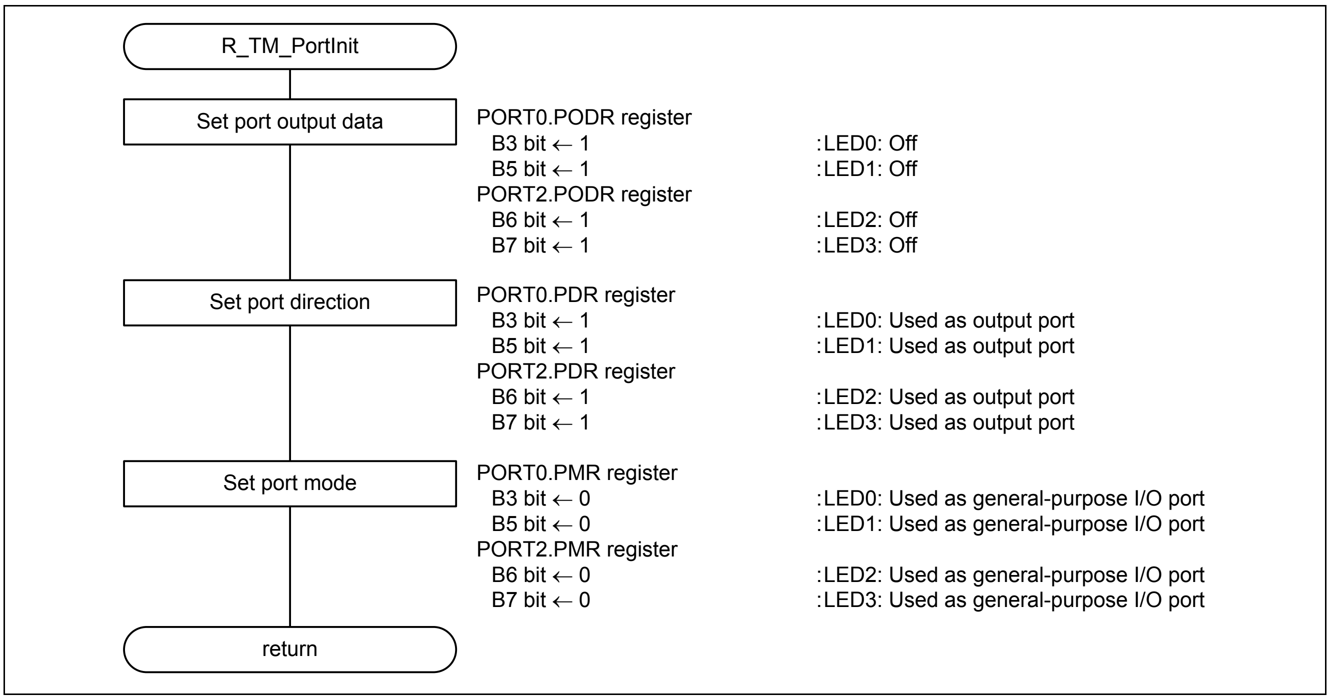

R_TM_PortInit
Set port output data
PORT0.PODR register
B3 bit ← 1 :LED0: Off
B5 bit ← 1 :LED1: Off
PORT2.PODR register
B6 bit ← 1 :LED2: Off
B7 bit ← 1 :LED3: Off
Set port direction
PORT0.PDR register
B3 bit ← 1 :LED0: Used as output port
B5 bit ← 1 :LED1: Used as output port
PORT2.PDR register
B6 bit ← 1 :LED2: Used as output port
B7 bit ← 1 :LED3: Used as output port
Set port mode
PORT0.PMR register
B3 bit ← 0 :LED0: Used as general-purpose I/O port
B5 bit ← 0 :LED1: Used as general-purpose I/O port
PORT2.PMR register
B6 bit ← 0 :LED2: Used as general-purpose I/O port
B7 bit ← 0 :LED3: Used as general-purpose I/O port
return

Figure 6.3 Initial Port Settings

(2) Display LED Pattern (API Function in Area Protected by TM)

Figure 6.4 is a flowchart of the processing to display LED patterns.

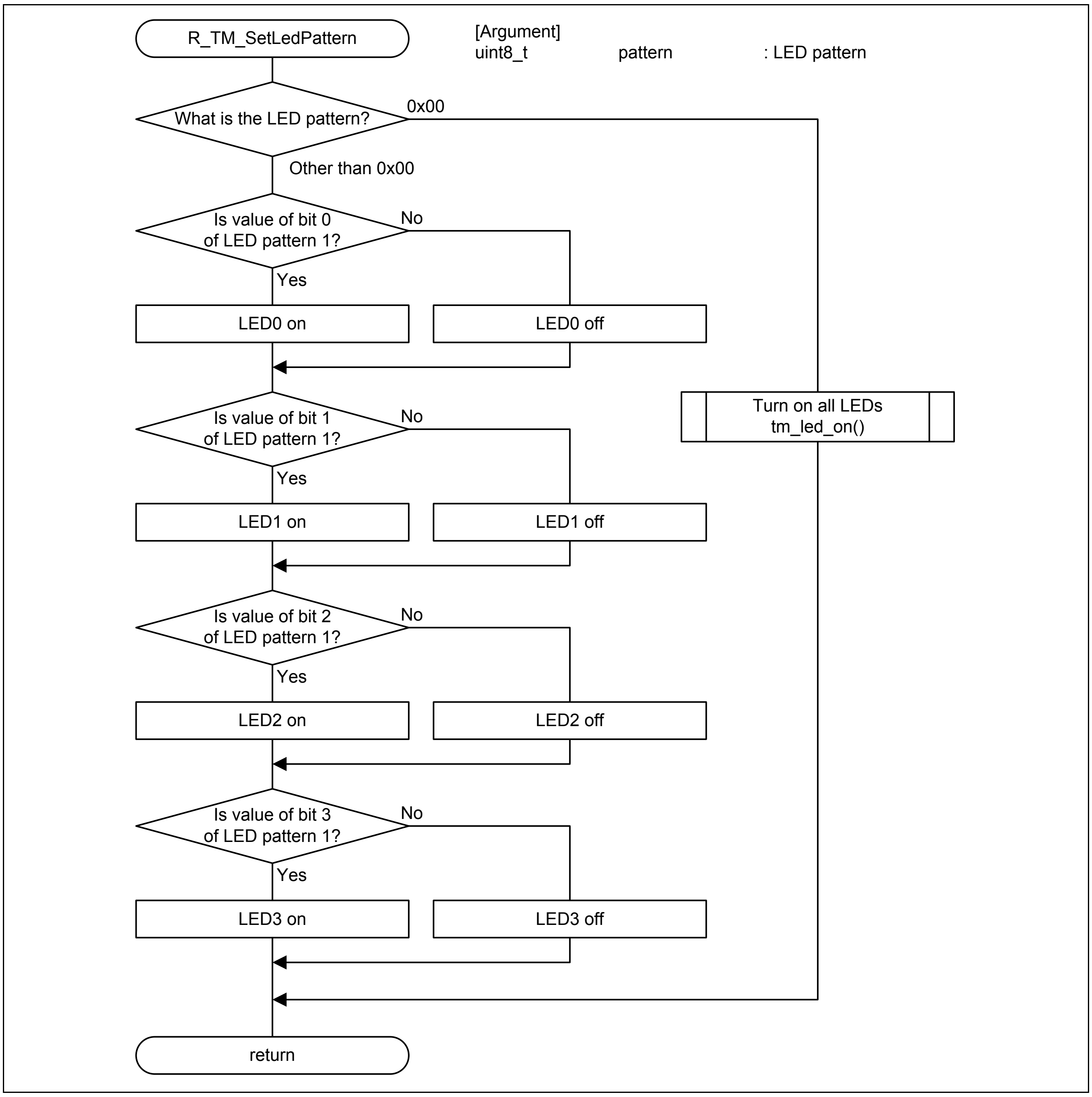

R_TM_SetLedPattern
[Argument]
uint8_t pattern : LED pattern
What is the LED pattern?
0x00
Other than 0x00
Is value of bit 0 of LED pattern 1?
No
Yes
LED0 on
LED0 off
Turn on all LEDs tm_led_on()
Is value of bit 1 of LED pattern 1?
No
Yes
LED1 on
LED1 off
Is value of bit 2 of LED pattern 1?
No
Yes
LED2 on
LED2 off
Is value of bit 3 of LED pattern 1?
No
Yes
LED3 on
LED3 off
return

Figure 6.4 Display LED Pattern

(3) Turn Off All LEDs (API Function in Area Protected by TM)

Figure 6.5 is a flowchart of the processing to turn off all LEDs.

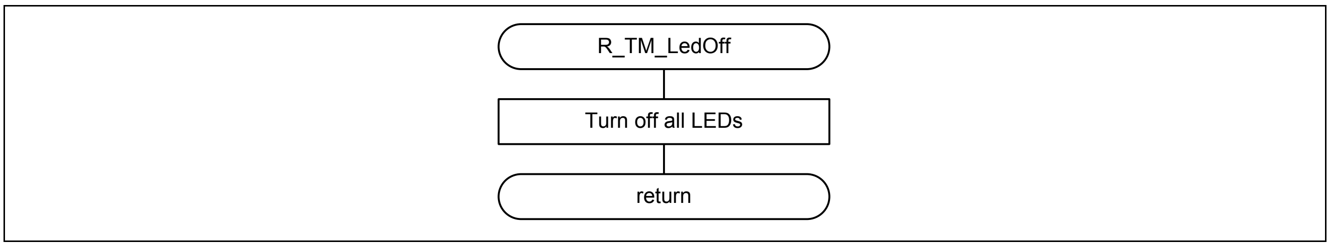


Figure 6.5 Turn Off All LEDs

(4) Turn On All LEDs (Internal Function in TM Function Area)

Figure 6.6 is a flowchart of the processing to turn on all LEDs.

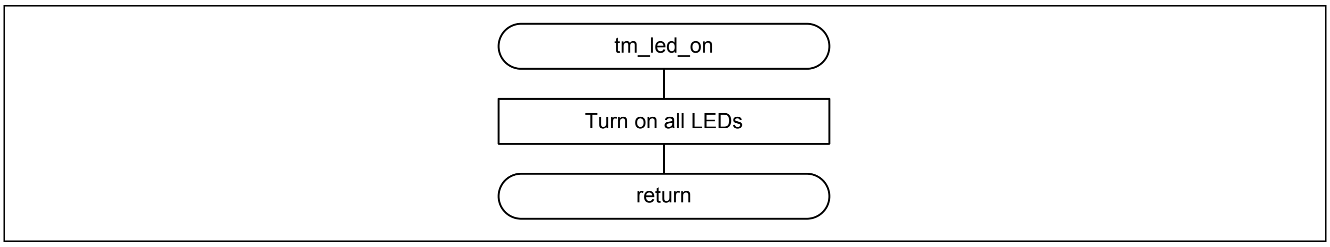


Figure 6.6 Turn On All LEDs

6.5 2nd User

6.5.1 File Composition

Tables 6.10 and 6.11 list the files used in the sample code. Files generated by the integrated development environment are not included in this table.

Table 6.10 Files Used in the Sample Code (c File and h File)

File Name	Outline	Remarks
main.c	Main processing routine	
r_init_stop_module.c	Stop peripheral functions still running after reset	
r_init_stop_module.h	Header file of r_init_stop_module.c	
r_init_non_existent_port.c	Initial settings of nonexistent ports	
r_init_non_existent_port.h	Header file of r_init_non_existent_port.c	
r_init_clock.c	Initial clock settings	
r_init_clock.h	Header file of r_init_clock.c	

Table 6.11 Files Used in the Sample Code (use File)

File Name	Outline	Remarks
rx71m_tm_user1_lib.lib	Library file provided by 1st user	

6.5.2 Option-Setting Memory

Table 6.12 lists the option-setting memory configured in the sample code. When necessary, set a value suited to the user system.

Table 6.12 Option-Setting Memory Configured in the Sample Code

Symbol	Address	Setting Value	Description
OFS1	0012 006Fh to 0012 006Ch	FFFF FFFFh	Voltage monitor 0 reset disabled after a reset HOCO oscillation disabled after a reset
OFS0	0012 006Bh to 0012 0068h	FFFF FFFFh	IWDT stopped after a reset WDT stopped after a reset
MDE	0012 0067h to 0012 0064h	FFFF FFFFh	Little endian
TMINF*[1]*[2]	0012 0063h to 0012 0060h	FFFF FFFFh	TM identification data
TMEF*[1]*[2]	0012 004Bh to 0012 0048h	FFFF FFFFh	FFFF FFFFh: TM function disabled F8FF FFFFh: TM function enabled

Notes: 1. When the TM function is enabled, values set by the 1st user are stored.
2. See 4.3.3, Enabling the TM Function, and 4.3.4, Disabling the TM Function, for information on making settings to the TMEF and TMINF registers.

6.5.3 Constants

Table 6.13 lists the constants used in the sample code.

Table 6.13 Constants Used in the Sample Code

Constant Name	Setting Value	Description
R_TM_PORT_INIT	0	Function table 1 element
R_TM_LED_OFF	1	Function table 1 element
R_TM_SET_LED_PATTERN	0	Function table 2 element

6.5.4 Functions

Table 6.14 lists the functions used in the sample code.

Table 6.14 Functions Used in the Sample Code

Function	Outline
main	Main processing routine
R_INIT_StopModule	Stop peripheral functions still running after reset
R_INIT_NonExistentPort	Initial settings of nonexistent ports
R_INIT_Clock	Initial clock settings
led_control	LED control

6.5.5 Function Specifications

The following tables lists the sample code function specifications.

main	
Outline	Main processing routine
Header	None
Declaration	void main(void)
Description	After making initial settings, accesses the area protected by TM (LED display processing).
Arguments	None
Return Value	None

R_INIT_StopModule	
Outline	Stop peripheral functions still running after reset
Header	r_init_stop_module.h
Declaration	void R_INIT_StopModule(void)
Description	Makes settings to transition to the module-stop state.
Arguments	None
Return Value	None
Outline	The sample code does not perform the transition to the module-stop state. For detailed information about this function, see the application note RX71M Group Initial Settings Example, Rev. 1.00.

R_INIT_NonExistentPort	
Outline	Initial settings of nonexistent ports
Header	r_init_non_existent_port.h
Declaration	void R_INIT_NonExistentPort(void)
Description	Makes initial settings to port direction registers corresponding to pins of ports that do not exist.
Arguments	None
Return Value	None
Notes	The settings in the sample code are for 176-pin microcontrollers (PIN_SIZE=176). After calling this function, when writing in byte units to PDR or PODR registers containing nonexistent ports, set the direction control bits and port output data storage bits corresponding to the nonexistent ports to 1 and 0, respectively. For detailed information about this function, see the application note RX71M Group Initial Settings Example, Rev. 1.00.

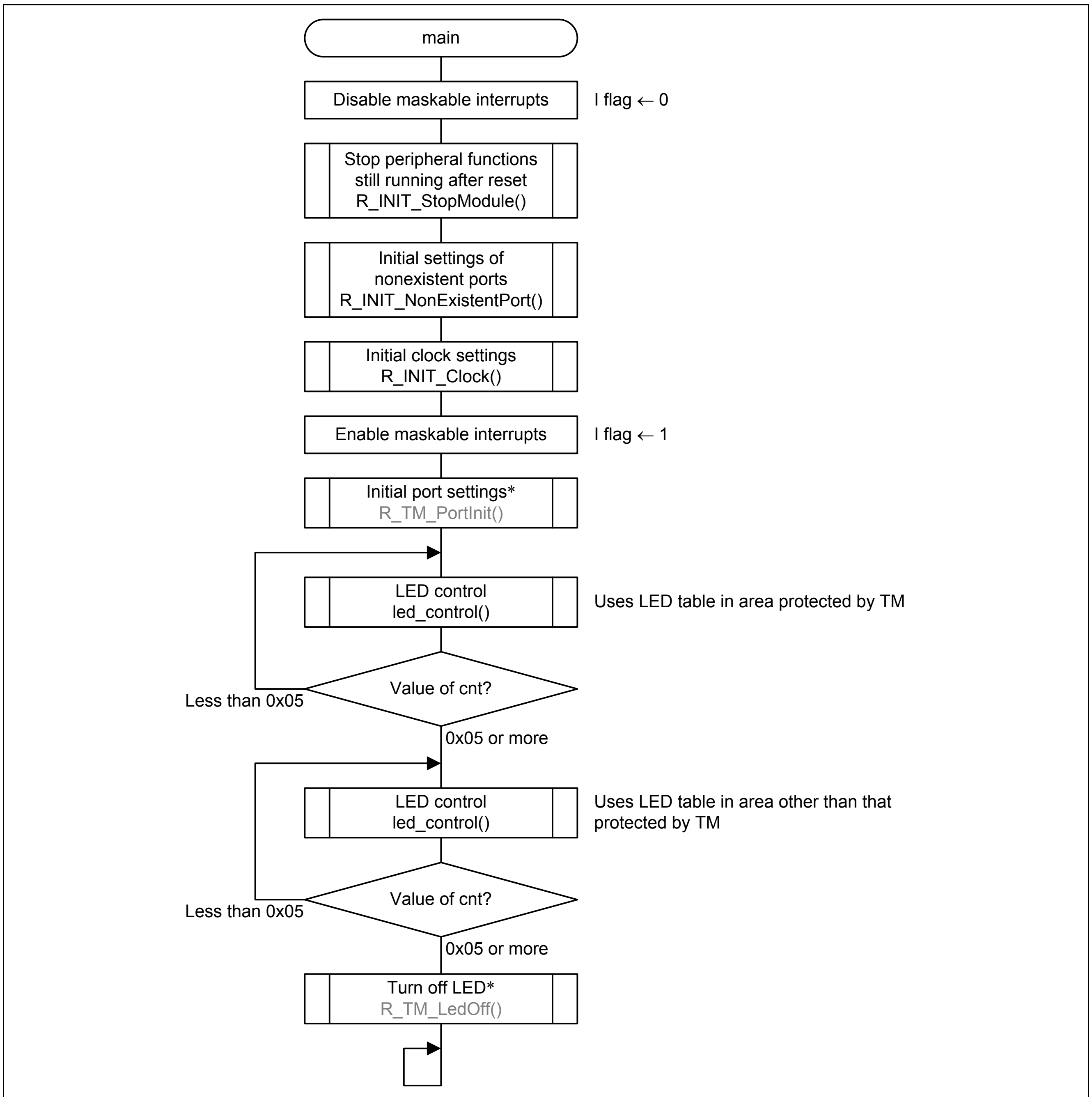
R_INIT_Clock	
Outline	Initial clock settings
Header	r_init_clock.h
Declaration	void R_INIT_Clock(void)
Description	Makes initial clock settings.
Arguments	None
Return Value	None
Notes	In the sample code PLL is set as the system clock and no subclock is used. For detailed information about this function, see the application note RX71M Group Initial Settings Example, Rev. 1.00.

led_control		
Outline	LED control (API function in area protected by TM)	
Header	None	
Declaration	static void tm_control (const uint8_t *table, const uint8_t pattern_num)	
Description	Outputs LED patterns from the LED table in sequence.	
Arguments	const uint8_t *table	LED table
	const uint8_t pattern_num	Number of LED patterns
Return Value	None	

6.5.6 Flowcharts

(1) Main Processing Routine

Figure 6.7 is a flowchart of the main processing routine.

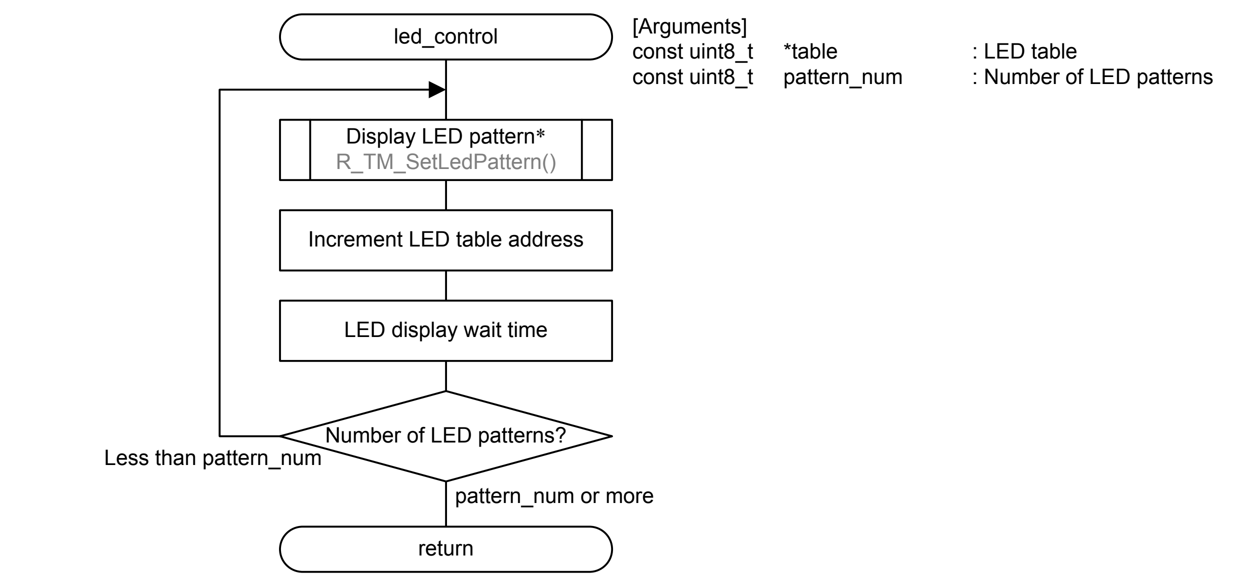


Note: * The 2nd user uses function tables to call API functions in the area protected by TM.

Figure 6.7 Main Processing Routine

(2) LED Control

Figure 6.8 is a flowchart of the LED control processing.



Note: * The 2nd user uses function tables to call API functions in the area protected by TM.

Figure 6.8 LED Control

7. Cautions

7.1 Initial Settings Example

The sample code referenced in this application note includes partial modifications to the sample code provided in the application note RX71M Group Initial Settings Example. When upgrading to the latest version of the initial settings sample code, make sure to make the modifications listed below.

Table 7.1 lists the modifications to the initial settings sample code.

Table 7.1 Initial Settings Constants (r_init_clock.h) Modified in Sample Code

Constant Name	Value Before Change	Value After Change	Description
REG_SCKCR	20C2 1222h (PLL selected)	21C2 1222h (PLL selected)	Internal clock division ratio (SCKCR register setting value) Before change: ICLK = 240 MHz After change: ICLK = 120 MHz
REG_MEMWAIT	MEMWAIT_1WAIT	MEMWAIT_0WAIT	Memory wait cycles Before change: 1 wait cycle After change: 0 wait cycles

7.2 Other

The 1st user can also provide the 2nd user with a section information file (.esi) containing section information.

To do this, the 1st user should export a section information file (.esi) from e^2 studio. The procedure for creating a section information file (.esi) is described below:

1. In e^2 studio, right-click the target project and select **Properties**.
2. Under **C/C++ Build** select **Settings**. Switch to the **Tool Settings** tab and select **Section** under **Linker**.
3. Click **Export**.
4. Select a destination to save the file.

The 2nd user can then use e^2 studio to import the section information file (.esi).* The procedure for importing a section information file (.esi) is described below:

1. In e^2 studio, right-click the target project and select **Properties**.
2. Under **C/C++ Build** select **Settings**. Switch to the **Tool Settings** tab and select **Section** under **Linker**.
3. Click **Import**.
4. Open the provided section information file (.esi).

Note: * Care should be exercised, because importing a section information file (.esi) causes all existing section settings to be erased and overwritten with the new ones.

8. Sample Code

Sample code can be downloaded from the Renesas Electronics website.

9. Reference Documents

User's Manual: Hardware

RX64M Group User's Manual: Hardware (R01UH0377EJ)
RX71M Group User's Manual: Hardware (R01UH0493EJ)
(The latest version can be downloaded from the Renesas Electronics website.)

User's Manual: Flash Memory

RX64M Group, RX71M Group Flash Memory User's Manual: Hardware Interface (R01UH0435EJ)
(The latest version can be downloaded from the Renesas Electronics website.)

User's Manual: Renesas Flash Programmer

Renesas Flash Programmer V2.05 Flash memory programming software User's Manual: Common (R20UT2906EJ)
Renesas Flash Programmer V2.05 Flash memory programming software User's Manual: RH850, RX700 (Include RX64M) (R20UT2909EJ)
(The latest version can be downloaded from the Renesas Electronics website.)

Technical Update/Technical News

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

User's Manual: Development Tools

CC-RX V2.03.00 RX Family C/C++ Compiler User's Manual (R20UT3248EJ)
(The latest version can be downloaded from the Renesas Electronics website.)

Website and Support

Renesas Electronics Website

http://www.renesas.com/

Inquiries

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Revision History

		Description	
Rev.	**Date**	**Page**	**Summary**
1.00	Apr 01, 2015	—	First edition issued
1.01	Jun 18, 2015	3	Integrated development environment changed in table 2.1 Operation Confirmation Conditions
		17	4.4.2 Debugging an Application after Development changed
		—	Information on debugging removed from 7.2

General Precautions in the Handling of MPU/MCU Products

The following usage notes are applicable to all MPU/MCU 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. Handling of Unused Pins
   Handle unused pins in accord 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 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. Unused pins should be handled as described under Handling of Unused Pins in the manual.
2. Processing at Power-on
   The state of the product is undefined at the moment 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 moment 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 moment 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 moment when power is supplied until the power reaches the level at which resetting has been specified.
3. Prohibition of Access to Reserved Addresses
   Access to reserved addresses is prohibited.
   — The reserved addresses are provided for the possible future expansion of functions. Do not access these addresses; the correct operation of LSI is not guaranteed if they are accessed.
4. Clock Signals
   After applying a reset, only release the reset line after the operating clock signal has become stable. When switching the clock signal during program execution, wait until the target clock signal has 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. Moreover, 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.
5. Differences between Products
   Before changing from one product to another, i.e. to a product with a different type number, confirm that the change will not lead to problems.
   — The characteristics of an MPU or MCU in the same group but having a different part number may differ in terms of the 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.

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