RX Family

M3S-DFL-Tiny: Digital Filter Software

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Introduction

This document explains the usage of the digital filter software library along with a sample program.

Target device

RX family

Contents

1. Abstract

This document explains Renesas Digital Filter Software.
A set of Digital Filter Software consists of following elements.

Digital Filter Library
The Digital Filter Library is designed to be run on RX600 series.
It consists of the filter function main body as object file and some header files in C language.
And a sample program performed with the Digital Filter Library is provided in a form of High-Performance Embedded Workshop work space.

Sample program
Sample program for Digital Filter Library is provided in the form of High-Performance Embedded Workshop work space.
It is executable on RSK without any changes. Therefore, it is recommended to try the sample software at first and confirm the characteristics. It could be helpful for further usage of Digital Filter Library.

Digital Filter PC Tool
The Tool works on PC and generates filter coefficients file for Digital Filter Library.
Corresponding to the parameters to be set its window, it generates filter coefficients file as in C header style.
The generated file and the library function are to be embedded in the customer's software, it could totally work as a digital filter system.

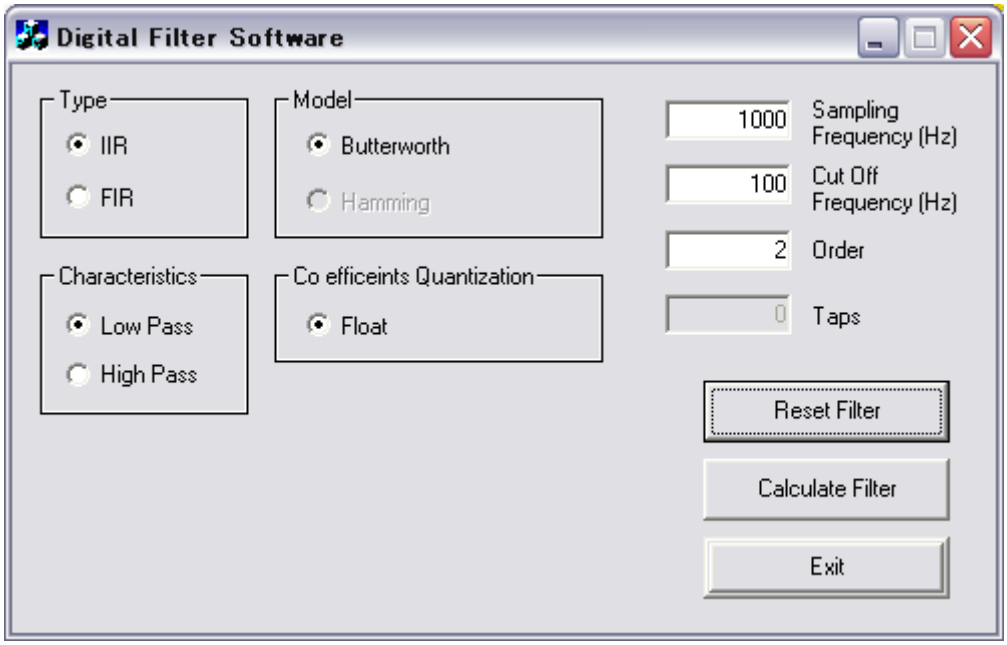


Figure 1: PC Tool to generate filter coefficients (informative)

2. Specifications

Following are the main specifications of the Digital Filter Software:

Filter Type:
FIR, IIR

Filter Characteristics:
Low Pass Filter, High Pass Filter

Coefficients of Quantization:
Float

Maximum Sampling Frequency:
200 kHz

Order for IIR Filter:
From 1 to 4

Number of Taps for FIR Filter:
From 1 to 255

Filter Model:
For FIR Filter
Hamming
For IIR Filter
Butterworth

* The expected characteristic might not appear by combining the parameter.

3. Software type definitions

This section gives details about the type definitions used in the library.
With the definitions listed below the Digital Filter Library could be worked.
Those definitions are contained in the file “CommonDefs.h".

Data type	Typedef
signed char	int8_t
unsigned char	uint8_t
signed short	int16_t
unsigned short	uint16_t
signed long	int32_t
unsigned long	uint32_t

4. Library functions

4.1 R_dfl_float_init

Prototype

```
void R_dfl_float_init( uint8_t filterId, uint8_t filterType, uint8_t taps, uint8_t order,
                       float* ffCoefPtr, float* fbCoefPtr, float* inDataPtr );
```

Explanation

This function initializes the configuration of filter function and could be used for both FIR and IIR filter functions.

This function has to be executed only once before filtering of successive input data.

The arguments apart from the feedback and feedforward coefficients are to be set by the user depending upon the required filter configuration. The feedback and the feedforward coefficients corresponding to the float configuration are generated by the Digital Filter PC Tool in form of arrays. The base addresses of these two arrays are also to be passed as arguments.

Arguments

Argument	Type	Explanation
filterId	uint8_t	ID of the filter to be executed, 0, 1, 2,or 3 could be set, Same ID should be chosen for initialization and filter functions working together.
filterTypeId	uint8_t	Set the filter type to be executed, FIR_FLT or IIR_FLT could be set, They are defined as macros in the file “DigitalFilter.h”.
taps	uint8_t	Number of Taps for the FIR filter, 1, 2 .. 255 could be set (Should be set to zero in case of IIR)
order	uint8_t	Order of the filter, 1, 2, 3,or 4 could be set (Should be set to zero in case of FIR)
ffCoefPtr	float*	Pointer to the feedforward coefficients array generated by the Digital Filter PC Tool.
fbCoefPtr	float*	Pointer to the feedback coefficients array generated by the Digital Filter PC Tool. Should be set to null in case of FIR filter.
inDataPtr	float*	Pointer to the input signal to be filtered.

Return value

None

4.2 R_dfl_float_FIR

Prototype

float R_dfl_float_FIR (uint8_t filterId)

Explanation

This function executes the FIR filter for float coefficients.

The filter configuration is set by the initialization function and the filter is performed corresponding to the configuration. Therefore before a filter is performed, it should be called once. The filter ID is passed as argument to this function. The function returns the filtered output value in the float format.

This function returns one sample of data corresponding to function calling.

Arguments

Argument	Type	Explanation
filterId	uint8_t	ID of the filter to be executed, 0, 1, 2,or 3 could be set, Same ID should be chosen for initialization and filter functions working together.

Return value

Type	Explanation
float	Filtered output value

4.3 R_dfl_float_IIR

Prototype

float R_dfl_float_IIR (uint8_t filterId)

Explanation

This function executes the IIR filter for float coefficients.

The filter configuration is set by the initialization function and the filter is performed corresponding to the configuration. Therefore before a filter is performed, it should be called once. The filter ID is passed as argument to this function. The function returns the filtered output value in the float format.

This function returns one sample of data corresponding to function calling.

Arguments

Argument	Type	Explanation
filterId	uint8_t	ID of the filter to be executed, 0, 1, 2,or 3 could be set, Same ID should be chosen for initialization and filter functions working together.

Return value

Type	Explanation
float	Filtered output value

5. Sample Program

This section explains the sample program for Digital Filter library. The sample program is in the form of a High-Performance Embedded Workshop workspace. Change the initialization of the microcomputer and its peripherals according to the system in use.

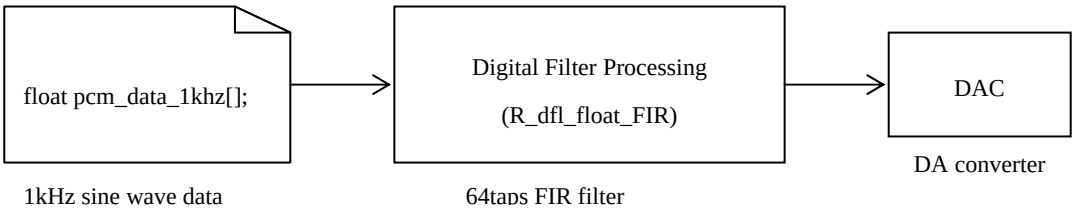
5.1 Outline

The sample program includes Digital Filter Library is provided in a form of High-Performance Embedded Workshop work space. Without any changes, Digital filter is performed on RSK with audible sounds output to on-chip DAC.

A 1kHz sine wave of pcm data table (sampling frequency 16kHz) is contained in it, therefore filter behavior could be confirmed only with this sample program alone.

The table is described in the header file R_dfl_sample_software.h. Although the table is limited length, the sine wave could be fed to a filter function while running the sample program continuously, because of circular addressing.

PCM data processed by filter function is given to on-chip DAC to make audible sound.



Note) Arrows in the chart above show signal direction.

Figure 2 Signal flow Model

The filter specification of sample program is shown as follows.

Filter Specification

Filter Characteristics : Low pass filter

Filter Model : Hamming

Cut-off frequency: 1 kHz

Sampling frequency : 16kHz

Filter Type : FIR

Taps : 64

Therefore, the arguments (for float type initialize function) to be set on to initialized function are as shown follows;

```
R_dfl_float_init( 0, FLT_TYPE, FLT_TAPS, FLT_ORDER, f_feedforwardCoeffs, f_f_feedbackCoeffs, &input );
```

Note) The sample program is designed to be performed on RSK under the condition of the 16kHz sampling frequency.

5.2 Flow of Sample Program

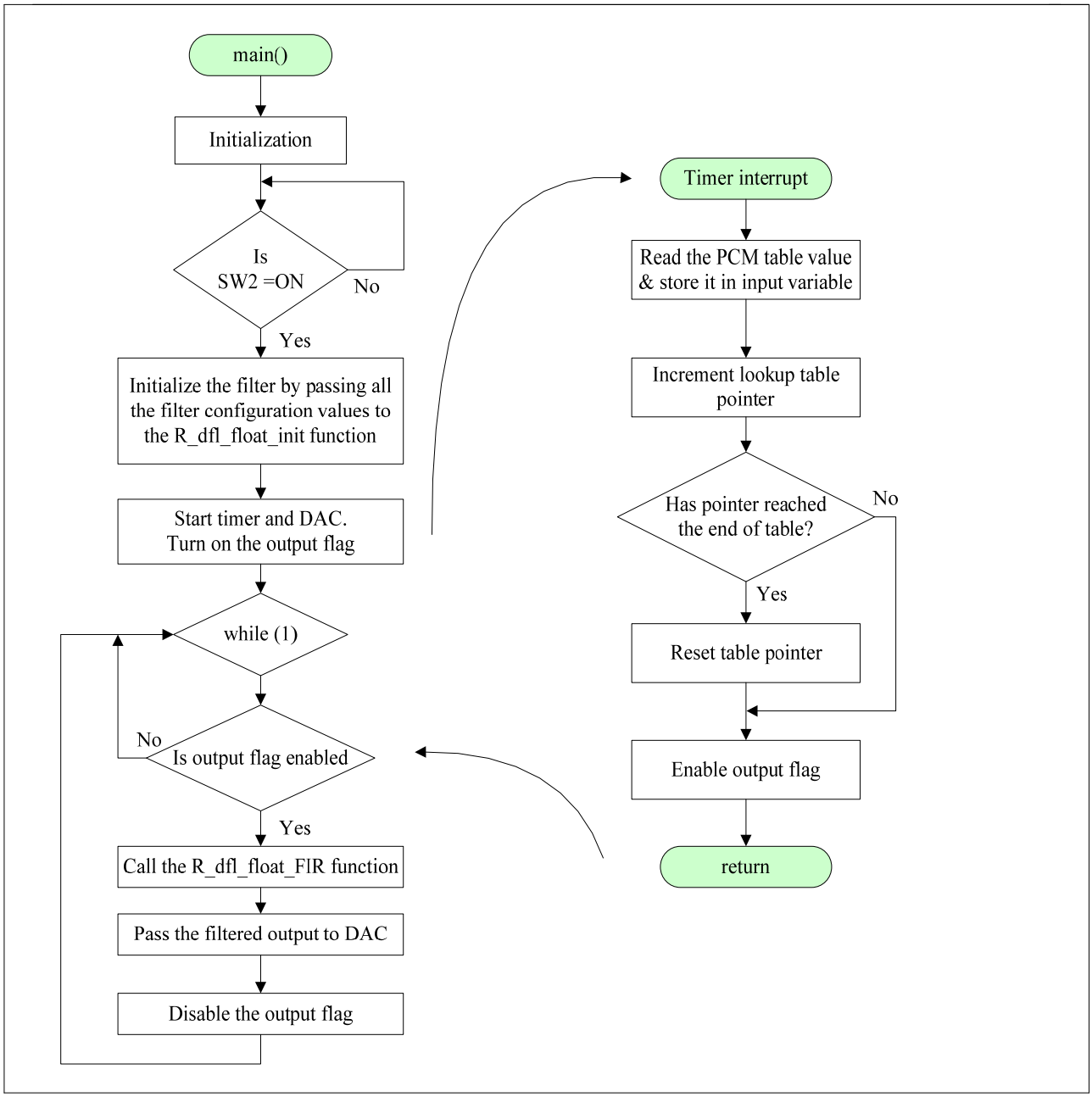


Figure 3: Flow of sample program

5.3 Function list

This following table gives a list of functions present in the sample program.

No.	Function name	Outline
1.0	main	Filters the 1 kHz input sine wave signal
1.1	R_init_clock	The clock of the microcomputer and other clock related registers are initialized.
1.2	R_init_dac	Initializes the DAC for generating the sine wave output
1.3	R_init_timer	Initializes the timer with 16 kHz operating frequency. This setting should be matched with the sampling frequency.
1.4	R_dfl_float_init	Initializes the filter configuration – Library function
1.5	R_dfl_float_FIR	Filters the input signal – Library Function
2.0	R_int_timer_TGI1A	Refreshes the filter input data

5.4 Function chart

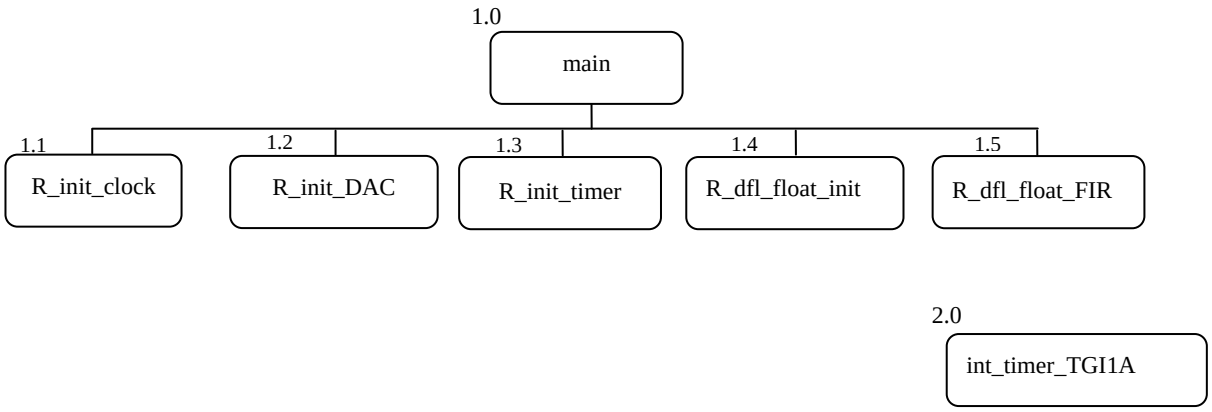


Figure 4: Function chart

5.5 Folder composition in workspace

dfl_sample_RX600	Workspace directory
|	
|	
|-- R5F56108	Project directory
|	
|-- Debug	Configuration directory
|	
|-- Debug_RX600_E1_E20_SYSTEM	Configuration directory
|	
|-- lib	Digital Filter library storage directory
|	
|-- Release	Configuration directory
|	
|-- src	Sample source storage directory.
|	
|-- hew_files	High-Performance Embedded Workshop auto-generated files storage directory.

6. Sample software usage

This section explains the details related to sample software execution.

6.1 Sample software execution

- Build the sample software workspace and download the .abs file to the RSK*.
- After the “Reset Go” button is clicked, program starts running.
- The library function for filter initialization initializes the filter with the given configuration.
- The timer interrupt service routine reads the data from the PCM data look up table and stores it in the input variable to be passed to the filter function.
- The library function for filter execution returns the filtered output value. This return value is then suitably modified before passing it to the DAC.
- The current state of the program is indicated by the LEDs on board the RSK.
- Following table gives the LED indications corresponding to program execution.

LED0	Significance
ON	Program running

6.2 Filter Output Signal

The sample software outputs the filtered signal via the Digital to Analog Converter (DAC). The DAC output is available on one of the pins of the JA1 Application Header of the RSK (*). The mapping of the pins is as follows:

JA1 Pin	JA1 Header Pin Name	RSK Signal Name	Microcontroller Pin
13	DA0	DA0	4

(*)RSK refers to Renesas Starter Kit for RX610

6.3 Filter output data conversion

The return value from the filter function is to be passed to the DAC (or PWM, if applicable) for conversion into analog signal. But this return value i.e. filtered output signal needs to be modified suitably before passing it to the DAC. The return value needs to be divided or multiplied by a suitable factor so as to bring it within the dynamic range of the DAC. Depending upon the return value, the user should decide the necessary factor by which to multiply or divide the return value.

6.4 Filter customization

The header file DigitalFilter.h concludes macro definitions (ie. type, taps) to configure a filter characteristics. The definitions should be changed when filter characteristics to be changed.

The header file DigitalFilter.h is generated by PC Tool and macro definitions are changed automatically according to the setting on the PC Tool window.

6.5 Sample Data for Filter Input

The PCM sample data array is stored in the header file r_dfl_sample_software.h. It is a source of input data for filter functions. The data array consists of elements equivalent to one sine wave of 1kHz. When output with a frequency of 16 kHz, these PCM data elements generate a sine wave of 1 kHz. A data pointer is incremented every 62.5µs (16 kHz) and the new data element is passed as input to the filter.

6.6 Perform two or more filters

Although the sample program performs just one filter, two or more filters (up to four) could also be performed by ID configuration at once. The initialization and two of filter functions have ID as argument “filterId”. Giving 1, 2, or 3 to areguments filterId for functions of additional filter, two or more filters could be performed.

Mind that, the name of filter coefficients array in the header file DigitalFilter.h is not changed automatically. Therefore the name of array for additional filter should also be changed manually.

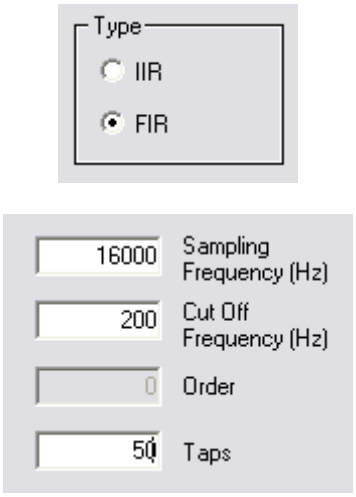
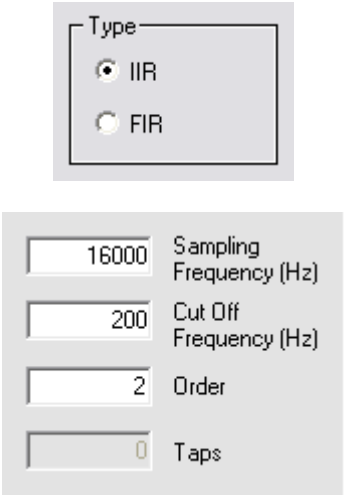
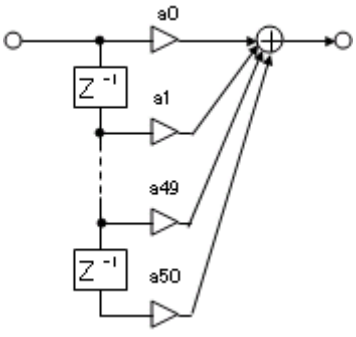
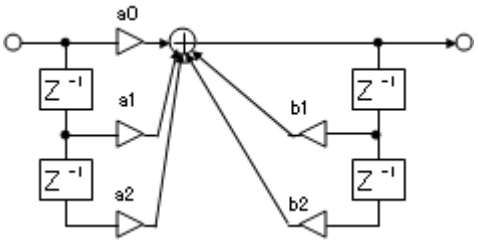
7. PC Tool

7.1 Header file generation

PC Tool is helpful when filter characteristics to be modified, because it generates not only filter coefficients but also updates macro definitions to configure filter functions automatically.

The coefficients and the macros are both included in the header file DigitalFilter.h which is generated by PC Tool.

As shown in following table of one example, according to PC Tool setting a set of macro definitions are given.

item	FIR filter	IIR filter
PC Tool setting		
SAMPLE_FREQ	16000	16000
FLT_TYPE	FIR	IIR
FLT_TAPS	50	0
FLT_ORDER	0	2
Filter structure		

8. Library Characteristics

This section explains the memory consumption and processing speed of the library functions.

8.1 Occupied memory size

ROM	RAM
446	4320

Unit: Byte

8.2 Occupied stack size

Function	Size
R_dfl_float_init	20
R_dfl_float_FIR	28
R_dfl_float_IIR	20

Unit:Byte

8.3 Processing speed

Function: R_dfl_float_FIR

Taps	Processing time (µsec)
255	54.9
128	27.8
64	14.0

Function: R_dfl_float_IIR

Order	Processing time (µsec)
4	2.5
2	1.5

The above values are reference values at an operating frequency of 100 MHz for the given microcomputers.

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Revision Record

Rev.	Date	Description	
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The following usage notes are applicable to all MPU/MCU products from Renesas. For detailed usage notes on the products covered by this manual, refer to the relevant sections of the manual. If the descriptions under General Precautions in the Handling of MPU/MCU Products and in the body of the manual differ from each other, the description in the body of the manual takes precedence.

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 one with a different type number, confirm that the change will not lead to problems.
   — The characteristics of MPU/MCU in the same group but having different type numbers may differ because of the differences in internal memory capacity and layout pattern. When changing to products of different type numbers, implement a system-evaluation test for each of the products.

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