Renesas RA Family

RA4 Quick Design Guide

Introduction

This document answers common questions and points out subtleties of the MCU that might be missed unless the hardware manual was extensively reviewed. The document is not intended to be a replacement for the hardware manual; it is intended to supplement the manual by highlighting some key items most engineers will need to start their own design. It also discusses some design decisions from an application point of view.

Target Device

RA4 MCU Series

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1. Power Supplies

The RA family has digital power supplies and analog power supplies. The power supplies use the following pins.

**Table 1. Digital Power Supplies**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>VCC</td>
<td>Power supply</td>
<td>Power supply pin. Connect to the system power supply. Connect this pin to VSS via a 0.1-µF capacitor placed close to the VCC pin.</td>
</tr>
<tr>
<td>VSS</td>
<td>Ground</td>
<td>Ground.</td>
</tr>
<tr>
<td>VCL</td>
<td>Power supply</td>
<td>Connect this pin to VSS via a capacitor close to the VCL pin. The value depends upon the specific MCU Group.</td>
</tr>
<tr>
<td>VCL0</td>
<td>Power supply</td>
<td>Connect this pin to VSS via a 0.1-µF capacitor close to the VCL0 pin.</td>
</tr>
<tr>
<td>VBATT</td>
<td>Backup power</td>
<td>Backup power pin. Supplies power to RTC and sub-clock oscillator in the absence of VCC. When VBATT pin is not used, connect to VCC or VSS.</td>
</tr>
<tr>
<td>VCC_USB</td>
<td>USB FS power supply</td>
<td>USB Full-speed power supply pin. Connect this pin to VCC. Connect this pin to VSS_USB via a 0.1-µF capacitor placed close to the VCC_USB pin.</td>
</tr>
<tr>
<td>VSS_USB</td>
<td>USB FS ground</td>
<td>USB Full-speed ground pin. Connect this pin to VSS.</td>
</tr>
</tbody>
</table>

Note 1: For RA4M1, VCC_USB can be either input or output. As input, it is the supply voltage for the USB transceiver. As output it is the voltage out from the USB LDO Regulator, and needs an external capacitor. When the USB LDO Regulator is not used, connect to VCC. When the regulator is used, connect to VSS through a 1.0-µF capacitor.

**Table 2. Analog Power Supplies**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVCC0</td>
<td>Analog power supply</td>
<td>Analog voltage supply pin for the respective modules. Connect this pin to the same voltage as the VCC pin.</td>
</tr>
<tr>
<td>AVSS0</td>
<td>Analog ground</td>
<td>Analog ground for the respective modules. Connect this pin to the same voltage as the VSS pin.</td>
</tr>
<tr>
<td>VREFH01</td>
<td>12-bit ADC high reference voltage</td>
<td>Reference voltage input pin for the 12-bit A/D. Connect this pin to AVCC0 if the 12-bit A/D converter is not used.</td>
</tr>
<tr>
<td>VREFL01</td>
<td>12-bit ADC low reference voltage</td>
<td>Analog reference ground pin for the 12-bit A/D converter. Connect this pin to VSS if the 12-bit A/D converter is not used.</td>
</tr>
<tr>
<td>VREFH</td>
<td>12-bit ADC and DAC analog supply</td>
<td>Reference voltage input pin for the 12-bit A/D converter, unit 1 (if present) and the D/A converter. Connect this pin to AVCC0 if these features are not used.</td>
</tr>
<tr>
<td>VREFL</td>
<td>12-bit ADC and DAC analog ground</td>
<td>Reference ground pin for the 12-bit A/D converter, unit 1 (if present) and the D/A converter. Connect this pin to VSS if these features are not used.</td>
</tr>
</tbody>
</table>

Note 1. For RA4M1, this applies to the 14-bit ADC.

1.1 References

Further information regarding the power supply for the RA MCU Group can be found in the following documents:

- R01UH0887 RA4M1 Group, RA4M1 Group User's Manual: Hardware
- R01UH0892 RA4M2 Group, RA4M2 Group User's Manual: Hardware
- R01UH0893 RA4M3 Group, RA4M3 Group User's Manual: Hardware

Chapter numbers may vary between Arm® Cortex®-M4 and Arm® Cortex®-M33 devices.

Chapter 1, “Overview”, lists power pins in each package with recommended bypass capacitors.
Chapter 5, “Resets”, discusses the Power-On Reset and how to differentiate this from other reset sources.

Chapter 7, “Low Voltage Detection”, provides details on the Low-Voltage Detection Circuit that can be used to monitor the power supply. Chapter 6, “Option-Setting Memory”, additionally describes how to enable Low-Voltage Detection 0 Circuit automatically at startup.

Chapter 11, “Battery Backup Function”, shows how to provide battery backup to the RTC and sub-clock oscillator.

If you plan to use the on-chip Analog to Digital Converters (ADC) or the Digital to Analog Converter (DAC), see 12-Bit A/D Converter (ADC12) or 14-Bit A/D Converter (ADC14) and 12-Bit D/A Converter (DAC12) for details on how to provide filtered power supplies for these peripherals.

Table 3. RA4 MCU Groups, User’s Manual: Hardware

<table>
<thead>
<tr>
<th>Chapter Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overview</td>
<td>Lists power pins in each package with notes on termination and bypassing.</td>
</tr>
<tr>
<td>Resets</td>
<td>Discusses the Power-on Reset and how to differentiate this from other reset sources.</td>
</tr>
<tr>
<td>Voltage Detection Circuit</td>
<td>Provides details on the Low-Voltage Detection Circuit that can be used to monitor the power supply.</td>
</tr>
<tr>
<td>Low Power Modes</td>
<td>Using low power modes may allow you to reduce the voltage of the power supply. See this chapter for details on how operating modes affect power supply requirements.</td>
</tr>
<tr>
<td>Battery Backup Function</td>
<td>Shows how to provide battery backup to the RTC and sub-clock oscillator.</td>
</tr>
<tr>
<td>12-Bit A/D Converter</td>
<td>If you plan to use the on-chip A/D or D/A converters, these chapters give details on how to provide filtered power supplies for these peripherals.</td>
</tr>
<tr>
<td>14-Bit A/D Converter</td>
<td></td>
</tr>
<tr>
<td>12-bit D/A Converter</td>
<td></td>
</tr>
<tr>
<td>Clock Generation Circuit</td>
<td>Provides detailed descriptions on how to configure and use the available clocks, including PCB design recommendations.</td>
</tr>
</tbody>
</table>

2. Emulator Support

RA MCU devices have an emulator interface that supports both debugging using SWD or JTAG communication, and serial programming using SCI communication. This emulator makes it easy to switch between debugging and serial programming.

The SWD or JTAG emulator interface should be connected to an Arm®-standard 10-pin or 20-pin socket. MD, TXD, and RXD pins are added for serial programming using SCI communication.

The serial programming interface must be used to program the Arm® TrustZone® IDAU boundary register settings. For devices that support TrustZone, it is recommended to connect P300/SWCLK/TCK and P201/MD pins using a wired-OR circuit on the board to use both debugging and serial programming.

Emulator support is useful for product development and prototyping, but may not be needed once a design moves to production. If emulator support is no longer needed for a design, make sure to configure the ports according to the “Handling of Unused Pins” section of the related MCU Hardware User’s Manual. See also section 10.5 in this document.
2.1 SWD Interface

The following diagram shows the typical connectivity of the debug interface when using Serial Wire Debug (SWD).

![SWD Interface Diagram]

**Figure 1. SWD Interface Connections**

Note:
1. The output of the reset circuit of the user system must be open collector.
2. Arm Cortex-M4 devices, such as RA4M1, do not support the TRACECLK or TRACEDATA[n] pins.
2.2 JTAG Interface

The following diagram shows the typical connectivity of the debug interface when using an ARM-standard JTAG debug interface.

![JTAG Interface Connections Diagram]

Note: 1. The output of the reset circuit of the user system must be open collector.
2. Use 4.7-kΩ to 10-kΩ pull-ups on TMS, TCK, and TDI.
3. Arm Cortex-M4 devices, such as RA4M1, do not support the TRACECLK or TRACEDATA[n] pins.
2.3 Serial Programming Interface using SCI

The following diagram shows the typical connectivity of the serial programming interface using SCI.

![Serial Programming Interface using SCI Connections](image)

Figure 3. Serial Programming Interface using SCI Connections

Note:
1. The output of the reset circuit of the user system must be open collector.
2. The MD pin is not part of the Serial Programming Interface using SCI. However the MD pin must be set to low to enable serial programming mode.
2.4 Serial Programming Interface using SCI: Devices with Arm® TrustZone® Support

The following diagram shows the typical connectivity of the serial programming interface using SCI for devices that include TrustZone support. Note the additional connection of P201/MD, which enables the programming of the Arm TrustZone IDAU boundary register settings.

Figure 4. Serial Programming Interface using SCI: Devices with TrustZone Support Connections

Notes: 1. The output of the reset circuit of the user system must be open collector.
2. P201/MD must be connected to the Arm-standard JTAG connector pin 4 to support programing the Arm TrustZone IDAU boundary register settings.
2.5 Multiple Emulator Interface

The following diagram shows the typical connectivity of the debug interface to support multiple emulator types, including SWD, JTAG, SCI Serial Programming, and TrustZone support.

![Diagram of Multiple Emulator Interface Connections](image)

Figure 5. Multiple Emulator Interface Connections

Notes:
1. Reset circuitry on the target must be open-collector. Pull up the nRESET signal. Do not put a capacitor on this signal as it may affect the operation of the power-on reset circuit.
2. Use 4.7-kΩ to 10-kΩ pull-ups on TMS, TCK, and TDI.
3. To use both debugging and serial programming on devices with TrustZone support, connect P201/MD to P300/SWCLK/TCK using a wired OR circuit.
4. Arm Cortex-M4 devices, such as RA4M1, do not support the TRACECLK or TRACEDATA[n] pins.
2.6 Software Setups for Emulator Connections

2.6.1 SWD and JTAG Interfaces
SWD and JTAG pins are in default state after reset. Table 4 shows the associated pins and their default settings after reset.

<table>
<thead>
<tr>
<th>Pin</th>
<th>P108</th>
<th>P109</th>
<th>P110</th>
<th>P300</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function</td>
<td>TMS/SWDIO</td>
<td>TDO/SWO</td>
<td>TDI</td>
<td>TCK/SWCLK</td>
</tr>
</tbody>
</table>

2.6.2 Trace Port
A 4-bit Trace Port Interface Unit (TPIU) and Serial Wire Output (SWO) provide trace output in RA4 devices. Trace ports and clock need to be enabled before they can be used by the debugger script. When using the Trace Port functionality, avoid using the trace pins for other functions.

Table 5 lists the Trace Port pins and their associated functions.

<table>
<thead>
<tr>
<th>Pin</th>
<th>P208</th>
<th>P209</th>
<th>P210</th>
<th>P211</th>
<th>P214</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function</td>
<td>TDATA3</td>
<td>TDATA2</td>
<td>TDATA1</td>
<td>TDATA0</td>
<td>TCLK</td>
</tr>
</tbody>
</table>

Arm Cortex-M4 devices, such as RA4M1, do not support the TRACECLK or TRACEDATA[n] pins. For these devices, trace data is available through the SWO pin.

For an example of using the Trace Port on Arm Cortex-M33 core devices with SEGGER J-Trace Pro, refer to the following link:

https://wiki.segger.com/RA6M4

For an example of using the Trace Port on Arm Cortex-M4 core devices with SEGGER J-Trace Pro, refer to the following link:

https://wiki.segger.com/J-Link_Renesas_RA6M3

Trace ports can also be enabled at runtime by using the Pin Configurator in Renesas FSP, but some trace data may be lost in this case.

![Figure 6. Enabling Trace Ports at Runtime Using FSP Configurator](image-url)
3. MCU Operating Modes

The RA4 MCU series can enter one of two modes after reset: Single-chip mode or SCI/USB boot mode. The boot mode is selected by the MD pin:

Table 6. Operating Modes Available at Reset

<table>
<thead>
<tr>
<th>Operating Mode</th>
<th>MD</th>
<th>On-Chip Flash Memory</th>
<th>External Bus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-chip mode</td>
<td>1</td>
<td>Enable</td>
<td>Disable</td>
</tr>
<tr>
<td>SCI/USB boot mode</td>
<td>0</td>
<td>Enable</td>
<td>Disable</td>
</tr>
</tbody>
</table>

Figure 7 shows operating mode transitions as determined by the Mode-Setting (MD) pin.

![Mode Setting Pin level and Operating Mode](image)

Figure 7. Mode Setting Pin level and Operating Mode

A typical MCU boot mode circuit includes a jumper and a couple of resistors to allow selections to connect the MD pin to VCC or Ground.

![Typical Circuit for MCU Boot Mode Selection](image)

Figure 8. Typical Circuit for MCU Boot Mode Selection

4. Option Setting Memory

The option-setting memory determines the state of the MCU after a reset. It is allocated to the configuration setting area and the program flash area of the flash memory. Option setting memory may be different in size and layout for Arm Cortex-M33 based devices.
The registers are detailed in the “Option Setting Memory” chapter in the Hardware User’s Manual.

The flash option registers occupy space in the code flash memory map. Although the registers are located in a portion of the flash memory that was reserved on the RA MCUs, it is possible that some customers may store data in these locations inadvertently. The user must check to ensure that no unwanted data is written to these locations or else unexpected behavior of the chip may result. For instance, settings in the flash option registers can enable the Independent Watchdog Timer (IWDT) immediately after reset. If data stored in program ROM inadvertently overlaps the Option Setting Memory register, it is possible to turn on the IWDT without realizing it. This will cause the debugger to have communications problems with the board.

The figure below shows the option setting memory, which consists of the option function select registers on RA4M3, which is an Arm Cortex-M33 device. The Option Setting Memory may be different for each device. Please consult MCU User’s Manual for the specific device details.
Figure 9. Option Function Select Registers for RA4M3
4.1 Option Setting Memory Registers

Following is a summary of the Option Setting Memory registers. Make sure that they are configured properly before startup.

- **OFS0 register**
  - Independent Watchdog Timer (IWDT) auto start
  - IWDT timeout, frequency, windowing, interrupt type, and low power mode behavior
  - Watchdog Timer (WDT) auto start
  - WDT timeout, frequency, windowing, and interrupt type

- **OFS1 register**
  - LVD0 enable after reset
  - HOCO startup after reset

Renesas FSP Configurator supports setting of option memory in BSP settings, as shown in the following figure for RA4M3 MCU. The settings made through the FSP configurator are reflected in the binary file compiled to operate on the MCU.

<table>
<thead>
<tr>
<th>Settings</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>part_number</td>
<td>RA4M1AF3CFB</td>
</tr>
<tr>
<td>rem_size_bytes</td>
<td>1048576</td>
</tr>
<tr>
<td>ann_size_bytes</td>
<td>131072</td>
</tr>
<tr>
<td>data_flex_size_bytes</td>
<td>8192</td>
</tr>
<tr>
<td>package_style</td>
<td>LOCP</td>
</tr>
<tr>
<td>package_pins</td>
<td>144</td>
</tr>
</tbody>
</table>

![Figure 10. Option Memory Settings in FSP Configuration for RA4M3 MCU](image)

5. Clock Circuits

The RA4 MCUs have six primary oscillators. Five of these may be used as the source for the main system clock. The remaining oscillator is dedicated to the Independent Watchdog Timer. In a typical system, the main clock is driven with an external crystal or clock. This input is directed to the PLL where it is multiplied up to the PLL clock, then post-divided down into the main system clock (ICLK), flash clock, peripheral module clocks, external bus clock, trace clock, and USB clock. The ICLK is further used for the CPU clock, DMAC clock, internal flash clock and SDRAM clock. Refer to the Hardware User’s Manual “Clock Generation Circuit” chapter for the block diagram of the clock generation circuit.

Each clock has specific tolerances and timing values. Refer to the Hardware User’s Manual “AC Characteristics” section in the “Electrical Characteristics” chapter for the Frequency and Clock Timing specifications. Refer to the Hardware User’s Manual “Clock Generation Circuit” chapter for the relationship between the various clock frequencies.
Table 7. RA4 Oscillators

<table>
<thead>
<tr>
<th>Oscillator</th>
<th>Input Source</th>
<th>Frequency</th>
<th>Primary Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main clock</td>
<td>External crystal/resonator -or- External clock</td>
<td>8 MHz to 24 MHz&lt;sup&gt;3&lt;/sup&gt;</td>
<td>PLL input, PLL2 input&lt;sup&gt;1&lt;/sup&gt;, main system clock, CLKOUT, CAN clock, CAC clock, LCD clock&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
<tr>
<td>Sub-clock (SOSC)</td>
<td>External crystal/resonator</td>
<td>32.768 kHz</td>
<td>Real-time clock, main system clock in low power modes, CLKOUT, AGT clock, CAC clock, Real-time clock, LCD clock&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
<tr>
<td>High-speed on-chip (HOCO)</td>
<td>On-chip oscillator</td>
<td>16/18/20 MHz&lt;sup&gt;4&lt;/sup&gt;</td>
<td>PLL input&lt;sup&gt;1&lt;/sup&gt;, main system clock, CLKOUT, CAC clock, LCD clock&lt;sup&gt;2&lt;/sup&gt;, USB clock&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
<tr>
<td>Middle-speed on-chip (MOCO)</td>
<td>On-chip oscillator</td>
<td>8 MHz</td>
<td>Main system clock at startup, CLKOUT, CAC clock</td>
</tr>
<tr>
<td>Low-speed on-chip (LOCO)</td>
<td>On-chip oscillator</td>
<td>32.768 kHz</td>
<td>Main system clock in low power modes &amp; during main oscillator stop detection, Systick timer&lt;sup&gt;1&lt;/sup&gt;, AGT clock, CLKOUT, CAC clock, Real-time clock</td>
</tr>
<tr>
<td>Independent Watchdog (IWDT)</td>
<td>On-chip oscillator</td>
<td>15 kHz</td>
<td>Independent watchdog timer clock, CAC clock</td>
</tr>
</tbody>
</table>

Note 1. On Arm Cortex-M33 devices
2. On Arm Cortex-M4 devices
3. On Arm Cortex-M4 devices, the main clock input frequency range using an external crystal resonator or external clock source is 1 MHz to 20 MHz. The maximum input frequency for an external clock or external crystal resonator may be limited to 8 MHz, 4 MHz, or 1 MHz, depending on the supply voltage to the MCU.
4. On Arm Cortex-M4 devices, the HOCO frequency options are 24/32/48/64 MHz.

5.1 Reset Conditions
After reset, RA4 MCUs begin running with the middle-speed on-chip oscillator (MOCO) as the main clock source. At reset, the main oscillator and the PLL are off by default. The HOCO and IWDT may be on or off depending on the settings in the option setting memory (see section 4).

5.2 Clock Frequency Requirements
Minimum and maximum clock oscillation frequencies are shown in the tables below. Details can be found in the “Overview” section of the “Clock Generation Circuit” chapter in the MCU Hardware User’s Manual, including external and internal clock source specifications. Additional details can be found in the “AC Characteristics” section of the “Electrical Characteristics” chapter in the MCU Hardware User’s Manual.

Table 8. Frequency Range for Arm Cortex-M4 MCU Internal Clocks

<table>
<thead>
<tr>
<th></th>
<th>ICLK</th>
<th>PCLKA</th>
<th>PCLKB</th>
<th>PCLKC</th>
<th>PCLKD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Frequency [MHz]</td>
<td>48</td>
<td>48</td>
<td>32</td>
<td>64</td>
<td>64</td>
</tr>
<tr>
<td>Minimum Frequency [MHz]</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FCLK&lt;sup&gt;1&lt;/sup&gt;</th>
<th>UCLK</th>
<th>CANCLK</th>
<th>SLCDC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Frequency [MHz]</td>
<td>32</td>
<td>48</td>
<td>20</td>
</tr>
<tr>
<td>Minimum Frequency [MHz]</td>
<td>1</td>
<td>48</td>
<td>1</td>
</tr>
</tbody>
</table>

Note 1. The FCLK must run at a frequency of at least 4 MHz when writing or erasing ROM or data flash.
Table 9. Frequency Range for Arm Cortex-M33 MCU Internal Clocks

<table>
<thead>
<tr>
<th></th>
<th>ICLK</th>
<th>PCLKA</th>
<th>PCLKB</th>
<th>PCLKC</th>
<th>PCLKD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Frequency [MHz]</td>
<td>100</td>
<td>100</td>
<td>50</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>Minimum Frequency [MHz]</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>FCLK</th>
<th>USBCLK</th>
<th>CANCLK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Frequency [MHz]</td>
<td>50</td>
<td>48</td>
<td>24</td>
</tr>
<tr>
<td>Minimum Frequency [MHz]</td>
<td>4</td>
<td>48</td>
<td>8</td>
</tr>
</tbody>
</table>

Note 1. The FCLK must run at a frequency of at least 4 MHz when writing or erasing ROM or data flash.

5.2.1 Requirements for USB Communications

The USB 2.0 Full-Speed Module (USBFS) requires a 48-MHz USB clock signal (UCLK or USBCLK).

When USB is used on Arm Cortex-M33 devices and the HOCO is selected as the clock source for the PLL, the Frequency Locked Loop (FLL) function must be enabled. Arm Cortex-M4 devices do not have the FLL function.

When the USB peripheral is used, the main clock oscillator frequency is limited to specific choices. This is due to the specific division ratios available in the clock generation circuit and the 48-MHz clock required by the USB modules. The limitations are dependent on the multiplication and division settings in the associated registers.

For Arm® Cortex-M4 devices, the divider used depends on the setting of the control bits in the PLLCCR2 register (PLL Clock Control Register 2).

For Arm® Cortex-M33 devices, the divider used depends on the setting of the USBCKDIV bits in the USBCKDIVCR register. The USBCLK is also dependent on the PLL settings in the PLLCCR and PLL2CCR registers.

For details of the relevant division and multiplication ratios, see the Clock Generation Circuit chapter of the specific MCU Hardware User’s Manual.

5.2.2 Requirements for Programming and Erasing ROM or Data Flash

The FCLK must be at least 4 MHz to perform programming and erasing on internal ROM and data flash.

5.3 Lowering Clock Generation Circuit (CGC) Power Consumption

To aid in saving power, set the dividers for any unused clocks to the highest possible value whenever possible. Also, when not using a clock then make sure that it has been stopped by adjusting settings in the appropriate register(s). The registers for controlling each clock source are shown in the table below.

Table 10. Clock Source Configuration Registers

<table>
<thead>
<tr>
<th>Oscillator</th>
<th>Register</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main clock</td>
<td>MOSCCR</td>
<td>Starts/stops main clock oscillator</td>
</tr>
<tr>
<td>Sub-clock</td>
<td>SOSCCR</td>
<td>Starts/stops sub-clock oscillator</td>
</tr>
<tr>
<td>High-speed on-chip (HOCO)</td>
<td>HOCOCR</td>
<td>Starts/stops HOCO</td>
</tr>
<tr>
<td>Middle-speed on-chip (MOCO)</td>
<td>MOCOCR</td>
<td>Starts/stops MOCO</td>
</tr>
<tr>
<td>Low-speed on-chip (LOCO)</td>
<td>LOCOCR</td>
<td>Starts/stops LOCO</td>
</tr>
</tbody>
</table>

5.4 Writing the System Clock Control Registers

Care should be taken when writing to the individual bit fields in the System Clock Division Control Register (SCKDIVCR) and System Clock Source Control Register (SCKSCR).

When the clock source of the peripheral module clock is switched, the duration of the peripheral module clock cycle becomes longer during the clock source transition period. See Figure 11. As a result, a delay in instruction processing must be added to allow the clocks to stabilize whenever the source is switched.
To ensure correct processing after the clock frequency changes, first write to the relevant Clock Control register to change the frequency, then read the value from the register, and finally perform the subsequent processing.

**Figure 11. Timing of Clock Source Switching**

### 5.5 Clock Setup Example

Renesas FSP provides a simple, visual clock configuration tool for RA4M3 MCU shown as follows.
5.6 HOCO Accuracy

The internal high-speed on-chip oscillator (HOCO) runs at 16 MHz, 18 MHz, or 20 MHz for Arm Cortex-M33 core devices, and 24 MHz, 32 MHz, 48 MHz, or 64 MHz for Arm Cortex-M4 devices, with a typical accuracy of +/-2% or better. HOCO accuracy specifications are characterized for various ambient operating temperature (Ta) ranges.

For Arm Cortex-M33 devices, the accuracy of the HOCO may be improved by enabling the Frequency Locked Loop (FLL) function, which results in a clock accuracy of +/-0.25% or better. Refer to the Electrical Specifications in the hardware manual for details.

The HOCO may be used as an input to the PLL circuit. When the HOCO is used this way, no external oscillator is required. This may be an advantage when space constraints, cost, or other limitations require a reduced component count in a PCB design. However, there are performance tradeoffs and limitations due to the clock accuracy which should be evaluated for your application.

5.7 Flash Interface Clock

The Flash interface Clock (FCLK) is used as the operating clock when programming and erasing internal flash (ROM and DF) and for reading from the data flash. Therefore, the frequency setting of the FCLK will have a direct impact on the amount of time it takes to read from the data flash. If the user’s program is reading from the data flash, or performing programming or erasures on internal flash, then using the maximum FCLK frequency is recommended.

The FCLK must run at a frequency of at least 4 MHz when writing or erasing code flash (ROM) or data flash. Please note that the FCLK frequency does not have any impact upon reading from ROM or reading and writing to RAM.

5.8 Board Design

Refer to the “Usage Notes” section of the Clock Generation Circuit (CGC) chapter in the Hardware User’s Manual for more information on using the CGC and for board design recommendations.
When a crystal resonator is used, place the resonator and its load capacitors as close to the MCU clock pins (XTAL/EXTAL, XCIN/XCOUT) as possible. Avoid routing any other signals between the crystal resonator and the MCU. Minimize the number of connecting vias used on each trace.

5.9 External Crystal Resonator selection

An external crystal resonator may be used as the main clock source. The external crystal resonator is connected across the EXTAL and XTAL pins of the MCU. The frequency of the external crystal resonator must be in the frequency range of the main clock oscillator.

Selection of a crystal resonator will be largely dependent on each unique board design. Due to the large selection of crystal resonators available that may be suitable for use with RA4 MCU devices, carefully evaluate the electrical characteristics of the selected crystal resonator to determine the specific implementation requirements.

The following diagram shows a typical example of a crystal resonator connection.

![Figure 13. Example of Crystal Resonator Connection](image)

Careful evaluation must be used when selecting the crystal resonator and the associated capacitors. The external feedback resistor (R_f) and damping resistor (R_d) should be added if recommended by the crystal resonator manufacturer.

![Figure 14. Equivalent Circuit of the Crystal Resonator](image)

Selection of the capacitor values for CL1 and CL2 will affect the accuracy of the internal clock. To understand the impact of the values for CL1 and CL2, the circuit should be simulated using the equivalent circuit of the crystal resonator in the figure above. For more accurate results, also take into account the stray capacitance associated with the routing between the crystal resonator components.

5.10 External Clock Input

A digital clock input may be used as the main clock source. Figure 15 shows an example of connecting an external clock input. To operate the oscillator with an external clock signal, set the MOMCR.MOSEL bit to 1. The XTAL pin becomes high impedance.
Figure 15. Equivalent Circuit for External Clock

Note: The frequency of the external clock input can only be changed when the main clock oscillator is stopped. Do not change the frequency of the external clock input when the setting of the Main Clock Oscillator Stop bit (MOSCCR.MOSTP) is 0.

6. Reset Requirements and the Reset Circuit

There are fourteen types of resets for Arm® Cortex-M4 devices.

Table 11. Arm Cortex-M4 Device Resets

<table>
<thead>
<tr>
<th>Reset Name</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pin reset</td>
<td>RES# is driven low</td>
</tr>
<tr>
<td>Power-on reset</td>
<td>VCC rises (voltage detection: VPOR)</td>
</tr>
<tr>
<td>VBATT-selected voltage power-on reset</td>
<td>VCC falls (voltage detection: VDETBATT)</td>
</tr>
<tr>
<td>Independent watchdog timer reset</td>
<td>The independent watchdog timer underflows, or a refresh does not occur</td>
</tr>
<tr>
<td>Watchdog timer reset</td>
<td>The watchdog timer underflows, or a refresh does not occur</td>
</tr>
<tr>
<td>Voltage monitor 0 reset</td>
<td>VCC falls (voltage detection: Vdet0)</td>
</tr>
<tr>
<td>Voltage monitor 1 reset</td>
<td>VCC falls (voltage detection: Vdet1)</td>
</tr>
<tr>
<td>Voltage monitor 2 reset</td>
<td>VCC falls (voltage detection: Vdet2)</td>
</tr>
<tr>
<td>SRAM parity error reset</td>
<td>SRAM parity error detection</td>
</tr>
<tr>
<td>SRAM ECC error reset</td>
<td>SRAM ECC error detection</td>
</tr>
<tr>
<td>Bus master MPU error reset</td>
<td>Bus master MPU error detection</td>
</tr>
<tr>
<td>Bus slave MPU error reset</td>
<td>Bus slave MPU error detection</td>
</tr>
<tr>
<td>Stack pointer error reset</td>
<td>Stack pointer error detection</td>
</tr>
<tr>
<td>Software reset</td>
<td>Register setting</td>
</tr>
</tbody>
</table>
There are thirteen or fourteen types of resets for Arm® Cortex-M33 devices, depending on the specific device.

### Table 12. Arm® Cortex-M33 Device Resets

<table>
<thead>
<tr>
<th>Reset Name</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pin reset</td>
<td>RES# is driven low</td>
</tr>
<tr>
<td>Power-on reset</td>
<td>VCC rises (voltage detection: VPOR)</td>
</tr>
<tr>
<td>Independent watchdog timer reset</td>
<td>The independent watchdog timer underflows, or a refresh does not occur</td>
</tr>
<tr>
<td>Watchdog timer reset</td>
<td>The watchdog timer underflows, or a refresh does not occur</td>
</tr>
<tr>
<td>Voltage monitor 0 reset</td>
<td>VCC falls (voltage detection Vdet0)</td>
</tr>
<tr>
<td>Voltage monitor 1 reset</td>
<td>VCC falls (voltage detection Vdet1)</td>
</tr>
<tr>
<td>Voltage monitor 2 reset</td>
<td>VCC falls (voltage detection Vdet2)</td>
</tr>
<tr>
<td>SRAM parity error reset</td>
<td>SRAM parity error detection</td>
</tr>
<tr>
<td>SRAM ECC error reset</td>
<td>SRAM ECC error detection</td>
</tr>
<tr>
<td>Bus master MPU error reset</td>
<td>Bus Master MPU error detection</td>
</tr>
<tr>
<td>TrustZone error reset</td>
<td>TrustZone error detection</td>
</tr>
<tr>
<td>Cache Parity error reset</td>
<td>Cache Parity error detection</td>
</tr>
<tr>
<td>Deep software standby reset</td>
<td>Deep software standby mode is canceled by an interrupt</td>
</tr>
<tr>
<td>Software reset</td>
<td>Register setting</td>
</tr>
</tbody>
</table>

Note 1. RA4M3 devices only.

### 6.1 Pin Reset

When the RES# pin is driven low, all processing is aborted and the MCU enters a reset state. To reset the MCU while it is running, RES# should be held low for the specified reset pulse width. Refer to the “Reset Timing” section of the “Electrical Characteristics” chapter of the Hardware User’s Manual for more detailed timing requirements. Also refer to section 2 of this document, “Emulator Support” for details on reset circuitry in relation to debug support.

There is no need to use an external capacitor on the RES# line because the POR circuit holds it low internally for a good reset and a minimum reset pulse is required to initiate this process.

### 6.2 Power-On Reset

There are two conditions that will generate a power-on reset (POR):

1. If the RES# pin is in a high-level state when power is supplied.
2. If the RES# pin is in a high-level state when VCC is below $V_{POR}$.

After VCC has exceeded the power-on reset voltage ($V_{POR}$) and the power-on reset time ($t_{POR}$) has elapsed, the chip is released from the power-on reset state. The power-on reset time is a period that allows for stabilization of the external power supply and the MCU. Refer to the “POR and LVD Characteristics” section of the “Electrical Characteristics” chapter of the Hardware User’s Manual for voltage level and timing details.

Because the POR circuit relies on having RES# high concurrently with VCC, don’t place a capacitor on the reset pin. This will slow the rise time of RES# in relation to VCC, preventing the POR circuit from properly recognizing the power-on condition.

If the RES# pin is high when the power supply (VCC) falls to or below $V_{POR}$, a power-on reset is generated. The chip is released from the power-on state after VCC has risen above $V_{POR}$ and the $t_{POR}$ has elapsed.

After a power-on reset, the PORF bit in RSTSR0 is set to 1. Following a pin reset PORF is cleared to 0.

### 6.3 VBATT-Selected Voltage Power-On Reset

When the voltage at the VCC pin drops, power can be supplied to the RTC, LOCO and sub-clock oscillator from the VBATT pin. When a power supply drop from the VCC pin is detected, connection to power is switched from the VCC pin to the VBATT pin.

For Arm Cortex-M4 devices, when this occurs a reset can be generated to flag the switch from VCC to VBATT. Details of this reset and the related VBATT configuration can be found in the Battery Backup Function chapter of the MCU Hardware User’s Manual.
6.4 Independent Watchdog Timer Reset
This is an internal reset generated by the Independent Watchdog Timer (IWDT).

When the IWDT underflows, an independent watchdog timer reset is optionally generated (NMI can be generated instead) and the IWDT RF bit in RSTSR1 is set to a 1. After a short delay the IWDT reset is canceled. Refer to MCU User’s Manual for the specific timing.

6.5 Watchdog Timer Reset
This is an internal reset generated by the Watchdog Timer (WDT).

When the WDT overflows, a watchdog timer reset is optionally generated (NMI can be generated instead), and the WDTRF bit in RSTSR1 is set to a 1. After a short delay the WDT reset is canceled. Refer to MCU User’s Manual for the specific timing.

6.6 Voltage-Monitoring Resets
The RA4 MCU family includes circuitry that allows the MCU to protect against unsafe operation during brownouts. On-board comparators check the supply voltage against three reference voltages, \text{V}_{\text{det}0}, \text{V}_{\text{det}1}, \text{and} \text{V}_{\text{det}2}. As the supply dips below each reference voltage, an interrupt or a reset can be generated. The detection voltages \text{V}_{\text{det}0}, \text{V}_{\text{det}1}, \text{and} \text{V}_{\text{det}2} are each selectable from 3 different levels.

When \text{V}_{\text{cc}} subsequently rises above \text{V}_{\text{det}0}, \text{V}_{\text{det}1}, \text{or} \text{V}_{\text{det}2}, release from the voltage-monitoring reset proceeds after a stabilization time has elapsed.

Low Voltage Detection is disabled after a power-on reset. Voltage monitoring can be enabled by using the Option Function register OFS1. For more details, see the chapter “Low Voltage Detection (LVD)” in the Hardware User’s Manual.

After an LVD Reset, the \text{LVDnRF} (n = 0, 1, 2) bit in RSTSR0 is set to 1.

6.7 Deep Software Standby Reset
Deep Software Standby Reset is an internal reset generated when deep software standby mode is canceled by an interrupt.

When deep software standby mode is canceled, a deep software standby reset is generated, and clock oscillation starts. On receiving the interrupt, after the Deep Standby Cancellation Wait Time (tDSBYWT 34-35 clock cycles) has elapsed, reset is canceled, and normal processing starts. For details of the deep software standby mode refer to the “Low Power Modes” chapter in the Hardware User’s Manual.

After a Deep Software Standby Reset, the \text{DPSRSTF} bit in RSTSR0 is set to 1.

6.8 Software Reset
The software reset is an internal reset generated by a software setting of the SYSRESETREQ bit in the AIRCR register in the Arm core. When the SYSRESETREQ bit is set to 1, a software reset is generated.

When the internal reset time \text{tRESW2} elapses after the software reset is generated, the internal reset is canceled and the CPU starts the reset exception handling. Refer to MCU User’s Manual for the specific timing.

For details on the SYSRESETREQ bit, see the ARM® Cortex®-M33 and Cortex®-M4 Technical Reference Manuals.

6.9 Other Resets
Most peripheral functions within the MCU can generate a reset under specific fault conditions. No hardware configuration is required to enable these resets. Refer to the relevant chapters in the Hardware User’s Manual for details of the conditions that will generate a reset for each peripheral function.

6.10 Determination of Cold/Warm Start
The RA4 MCUs allow the user to determine the cause of the reset processing. The CWSF flag in RSTSR2 indicates whether a power-on reset caused the reset processing (cold start) or a reset signal input during operation caused the reset processing (warm start).

The flag is set to 0 when a power-on reset occurs. Otherwise, the flag is not set to 0. The flag is set to 1 when 1 is written to it through software. It is not set to 0 even on writing 0 to it.
6.11 Determining the Reset Source

The RA4 MCUs allow the user to determine the reset signal generation source. Read RSTSR0 and RSTSR1 to determine which reset was the source of the reset. Refer to the Hardware User's Manual section “Determination of Reset Generation Source” for the flow diagram.

The following sample code shows how to determine if a reset is caused by Software Reset, Deep Software Standby or Power-On Reset using CMSIS based register structure in Renesas FSP.

```c
/* Deep Software Standby Reset */
if (1 == R_SYSTEM->RSTSR0_b.DPSRSTF)
{
    /* Do something */
}

/* Power-on Reset */
if (1 == R_SYSTEM->RSTSR0_b.PORF)
{
    /* Do something */
}

/* Software Reset */
if (1 == R_SYSTEM->RSTSR1_b.SWRF)
{
    /* Do something */
}
```

7. TrustZone Support

7.1 Implementation of Arm TrustZone Technology

Some RA4 MCUs, such as RA4M2 and RA4M3, include Arm TrustZone (TZ) security features. For full details of TZ implementation, please refer to Arm documentation (https://developer.arm.com/ip-products/security-ip/trustzone) or the appropriate Hardware User’s Manual.

Arm TZ technology can create separations in the memory map within the MCU and therefore separate the application into Secure and Non-Secure partitions. Secure applications can access both Secure and Non-Secure memory and resources. Non-Secure code can access Non-Secure memory and resources as well as Secure resources through a set of so-called veneers located in the Non-Secure Callable (NSC) region. This ensures a single access point for Secure code when called from the Non-Secure partition.

The FSP configures the MCU to start the secure application upon reset. The security state of the CPU can be either Secure or Non-Secure. The MCU code flash, data flash, and SRAM are divided into Secure (S) and Non-Secure (NS) regions. Code flash and SRAM include a further region known as Non-Secure Callable (NSC). These memory security attributes are set into the non-volatile memory via SCI or USB boot mode commands when the device lifecycle is Secure Software Debug (SSD) state. The memory security attributes are loaded into the Implementation Defined Attribution Unit (IDAU) peripheral and the memory controller before application execution and cannot be updated by application code.
Figure 16. Secure and Non-Secure Regions

Note: All external memory accesses are considered to be Non-Secure.

Code Flash and SRAM can be divided into Secure, Non-Secure, and Non-Secure Callable. All secure memory accesses from the Non-Secure region MUST go through the Non-Secure Callable gateway and target a specific Secure Gateway (SG) assembler instruction. This forces access to Secure APIs at a fixed location and prevents calls to sub-functions and so on. Failing to target an SG instruction will generate a TZ exception. TZ enabled compilers will manage generation of the NSC veneer automatically using CMSE extensions. These Secure, Non-Secure, and Non-Secure Callable memory regions are easily configured and managed using FSP.

Figure 17. Using the RA Project Generator to Set Up New TZ Enabled Projects
Reference documents:

- RA Arm TrustZone Tooling Primer
- Securing Data at Rest Using the Arm TrustZone
- Security Design with Arm TrustZone - IP Protection
- Establishing and Protecting Device Identity using SCE9 and Arm TrustZone
- Device Lifecycle Management Key Installation
- Arm TrustZone Security section in the relevant MCU Hardware User’s Manual.

### 7.2 Emulator Support for TrustZone

Renesas provides an emulator which supports both debugging using SWD or JTAG communication and serial programming using SCI communication. This emulator makes it easy to switch between debugging and serial programming. The following table shows the pinout of a 10-pin or 20-pin socket when using this emulator. The pinout of SWD and JTAG is Arm® standard, and MD, TXD, and RXD pins are added for the serial programming using SCI communication.

The serial programming interface must be used to program the TrustZone IDAU boundary register settings. It is recommended to connect P300/SWCLK/TCK and P201/MD pins using wired OR circuit on the board to use both debugging and serial programming.
Table 13. Pin Assignments for Emulator

<table>
<thead>
<tr>
<th>Pin No.</th>
<th>SWD</th>
<th>JTAG</th>
<th>Serial Programming Using SCI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>VCC</td>
<td>VCC</td>
<td>VCC</td>
</tr>
<tr>
<td>2</td>
<td>P108/SWDIO</td>
<td>P108/SWDIO</td>
<td>NC</td>
</tr>
<tr>
<td>4</td>
<td>P300/SWCLK</td>
<td>P300/TCK</td>
<td>P201/MD</td>
</tr>
<tr>
<td></td>
<td>Wired OR with P201/MD</td>
<td>Wired OR with P201/MD</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>P109/SWO/TXD9</td>
<td>P109/TDO/TXD9</td>
<td>P109/TDO/TXD9</td>
</tr>
<tr>
<td>8</td>
<td>P110/SWO/RXD9</td>
<td>P110/TDI/RXD9</td>
<td>P110/TDI/RXD9</td>
</tr>
<tr>
<td>9</td>
<td>GNDdetect</td>
<td>GNDdetect</td>
<td>GNDdetect</td>
</tr>
<tr>
<td>10</td>
<td>nRESET</td>
<td>nRESET</td>
<td>nRESET</td>
</tr>
<tr>
<td>12</td>
<td>P214/TCLK</td>
<td>P214/TCLK</td>
<td>NC</td>
</tr>
<tr>
<td>14</td>
<td>P211/TDATA[0]</td>
<td>P211/TDATA[0]</td>
<td>NC</td>
</tr>
<tr>
<td>3,5,15,17,19</td>
<td>GND</td>
<td>GND</td>
<td>GND</td>
</tr>
<tr>
<td>7</td>
<td>NC</td>
<td>NC</td>
<td>NC</td>
</tr>
<tr>
<td>11,13</td>
<td>NC</td>
<td>NC</td>
<td>NC</td>
</tr>
</tbody>
</table>
7.2.1 Device Lifecycle Management

RA4 MCUs with Arm Cortex-M33 cores are equipped with Device Lifecycle Management (DLM), which is the management of the process by which a product goes from inception to development to production and then eventually end-of-life. The RA Family MCU debug capability and serial programming capability are defined by the device lifecycle states.

Refer to the *Device Lifecycle Management Key Installation* application note for more details.
8. Memory

The RA4 MCUs support a 4-GB linear address space ranging from 0000 0000h to FFFF FFFFh that can contain program, data, and external memory bus. Program and data memory share the address space; separate buses are used to access each, increasing performance and allowing same-cycle access of program and data. Contained within the memory map are regions for on-chip RAM, peripheral I/O registers, program code flash, and data flash.

---

**Figure 20. RA4M3 Memory Map**
8.1 SRAM

The RA4 MCUs provide on-chip high-speed SRAM modules with either parity-bit checking or ECC (Error Correction Code). The first 32 KB of SRAM0 is subject to ECC. Parity check is performed on other areas. The following table lists the SRAM specifications. The number of SRAM modules and capacity vary by device. Consult the Hardware User’s Manual for specifics.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Without ECC</th>
<th>With ECC</th>
</tr>
</thead>
<tbody>
<tr>
<td>SRAM capacity</td>
<td>SRAM0: 64 KB</td>
<td>SRAM0: 64 KB</td>
</tr>
<tr>
<td>SRAM address</td>
<td>SRAM0: 0x2000_0000 to 0x2001_FFFF</td>
<td>SRAM0: 0x2000_0000 to 0x2001_FFFF</td>
</tr>
<tr>
<td>Access</td>
<td>Can access with no wait. One wait access is set at initial state. For details, see section 42.3.9. Access Cycle</td>
<td></td>
</tr>
<tr>
<td>Data retention function</td>
<td>Not available in deep standby mode</td>
<td></td>
</tr>
<tr>
<td>Module-stop function</td>
<td>Module-stop state can be set to reduce power consumption</td>
<td></td>
</tr>
<tr>
<td>Parity</td>
<td>Even parity with 8-bit data and 1-bit parity</td>
<td>No parity</td>
</tr>
<tr>
<td>Error checking</td>
<td>even-parity (Data: 8 bit, parity: 1 bit)</td>
<td>SEC-DED (Single-Error Correction and Double-Error Detection Code)</td>
</tr>
<tr>
<td>Security</td>
<td>TrustZone Filter is integrated for memory access and SFR access. Access to the memory space is controlled by setting the memory Security Attribute (SA). And, access to I/O space (SFR) space is controlled by setting the register SA. See section 42.3.6. TrustZone Filter function.</td>
<td></td>
</tr>
</tbody>
</table>

Figure 21. RA4M3 SRAM Specification

8.2 Standby SRAM

The RA4 MCUs provide an on-chip SRAM to retain data in Deep Software Standby mode. The table below lists the Standby SRAM specifications.

The power supply to the Standby SRAM in Deep Software Standby mode is enabled by the DPSBYCR.DEEPCUT[1:0] bits. If the DPSBYCR.DEEPCUT[1:0] bits are set to 00b, data in the Standby SRAM is retained in Deep Software Standby mode. See section 11, Low Power Modes, for details on the DPSBYCR.DEEPCUT[1:0] bits.

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SRAM capacity</td>
<td>1 KB</td>
</tr>
<tr>
<td>SRAM address</td>
<td>0x2800_0000 to 0x2800_03FF</td>
</tr>
<tr>
<td>Access</td>
<td>Standby SRAM clock is the same clock as the PCLKB. See section 43.3.5. Access Cycle for details.</td>
</tr>
<tr>
<td>Data retention function</td>
<td>Data can be retained in deep standby mode. See section 43.3.1. Data Retention for details.</td>
</tr>
<tr>
<td>Parity</td>
<td>Even parity (data: 8 bits, parity: 1 bit)</td>
</tr>
<tr>
<td>Module-stop function</td>
<td>Module-stop state can be set to reduce power consumption. See section 43.3.2. Setting for the Module-stop Function for details.</td>
</tr>
<tr>
<td>Security</td>
<td>Permits the read and write operations to Standby RAM following TrustZone Filter function. See section 43.3.4. TrustZone Filter function for details.</td>
</tr>
</tbody>
</table>

Figure 22. RA4M3 Standby SRAM Specification

The LPM (Low Power Mode) driver in Renesas FSP provides an option to cut or keep power to Standby SRAM as shown in the following figure. The LPM driver’s APIs still need to be invoked to write the selected settings to the MCU registers.
8.3 Peripheral I/O Registers

Blocks of peripheral I/O registers appear at various locations in the memory map depending on the device and the current operating mode. The majority of peripheral I/O registers occupy a region from address 4000 0000h to 400F FFFFh. However, this may vary in location and size by device. Consult the Hardware User’s Manual for specifics. Details can be found in the “I/O Registers” appendix, and also in the register descriptions for each peripheral function. This region contains registers that are available at all times in all modes of operation. Flash I/O registers to control access flash memory occupy two regions, 407E 0000h to 407F FFFFh and 407F C000h to 407F FFFFh.

The Renesas FSP provides C header files in CMSIS data structure that map all of the peripheral I/O registers for a specific device to easily accessible I/O data structures.

8.4 On-Chip Flash Memory

The RA4 MCUs feature two flash memory sections, code flash and data flash, which vary in size and programmable cycle capacity by device. The Flash Control Unit (FCU) controls programming and erasure of the flash memory. The Flash Application Command Interface (FACI) controls the FCU in accordance with the specified FACI commands.

The code flash is designed to store user application code and constant data. The data flash is designed to store information that may be updated from time to time such as configuration parameters, user settings, or logged data. The units of programming and erasure in the data flash area are much smaller than that of the code flash (4/8/16 bytes for data flash versus 128 bytes for code flash).

Both the data flash and code flash areas can be programmed or erased by application code. This enables field firmware updates without having to connect an external programming tool.

Renesas FSP provides HAL layer drivers for both code flash memory and data flash memory.

The following figure shows example specifications of code flash memory and data flash memory.
Figure 24. Specifications of Code Flash Memory and Data Flash Memory on RA4M3 MCU

Note: Erase state of code flash is FFh but erase state of data flash is undefined.

8.4.1 Background Operation

RA4 MCUs support background operations for code flash and data flash. This means that when a program or erase is started, the user can keep executing and accessing memory from memory areas other than the one being operated on. For example, the CPU can execute application code from code flash while the data flash memory is being erased or programmed. Also, the CPU can execute application code from SRAM while the code flash memory is being erased or programmed.

8.4.2 ID Code Protection

RA4 MCUs with Arm Cortex-M4 core have a 128-bit memory in the option setting memory area that is used as an ID code. If this ID code is left blank (0xFF’s) then no protection is enabled and access to the MCU is allowed through boot mode or using the on-chip debugger. If the ID code is set then the user can control access to these modes. The user can choose to always disallow connections or can choose to allow connections when a matching ID code is input. Refer to the “OCD/Serial Programmer ID Setting Register (OSIS)” and “ID Code Protection” and sections of RA4 MCU Hardware User’s Manual for more information.

The Renesas FSP configurator provides options to set up ID code protection for RA4 MCUs with the Arm Cortex-M4 core.
8.4.3 Flash Block Protection

RA4 MCUs with Arm Cortex-M33 core have a Flash Block Protection feature that protects secure or non-secure flash region from being erased or reprogrammed by secure or non-secure software. It is worth noting that the protection is for both Secure and Non-secure software accesses.

Refer to section “Configuring the Flash Block Protection” in Securing Data at Rest Using the Arm® TrustZone® application note for more details.

8.4.4 Memory Protection Unit

RA4 MCUs have a Memory Protection Unit (MPU). They have the ability to protect various MCU memory regions from illegal access. The choices include allowing both reading and writing, prohibiting writing, and prohibiting writing and reading. Select one of these options by setting the corresponding constant value at the specific memory address. See ‘Memory Protection Unit’ in the MCU Hardware User’s Manual for more details.
8.5 Restriction on Endianness

Memory space containing instruction codes must be little-endian to execute code on the Arm Cortex-M core.

9. Register Write Protection

The register write protection function protects important registers from being overwritten because of software errors. The registers to be protected are set with the Protect Register (PRCR). Table 14 lists the association between the PRCR bits and the registers to be protected.

<table>
<thead>
<tr>
<th>b15</th>
<th>b14</th>
<th>b13</th>
<th>b12</th>
<th>b11</th>
<th>b10</th>
<th>b9</th>
<th>b8</th>
<th>b7</th>
<th>b6</th>
<th>b5</th>
<th>b4</th>
<th>b3</th>
<th>b2</th>
<th>b1</th>
<th>b0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRKEY[7:0]</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>PRC4'1</td>
<td>PRC3</td>
<td>---</td>
<td>PRC1</td>
<td>PRC0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note 1. Not present on Arm Cortex-M4 devices.
Table 14. PRCR Protection Bits

<table>
<thead>
<tr>
<th>PRCR bit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRC0</td>
<td>• Registers related to the Clock Generation Circuit: SCKDIVCR, SCKSCR, PLLCR, PLLCR, BCKCR, MOSCCR, HOCOCR, MOCOCR, CKOCR, TRCKCR, OSTDCR, OSTDSR, EBKOCR, SDCOCR, MOCOUTCR, HOCOUTCR, MOSCWCRR, MOCMR, SOSCCR, SOMCR, LOCCCR, LOCOUTCR, HOCOWCRR, FLLCR1, FLLCR2</td>
</tr>
<tr>
<td>PRC1</td>
<td>• Registers related to the low power modes: SBYCR, SNZCR, SNZEDCR, SNZREQCR, OPCCR, SOPCCR, DPSBYCR, DPSIER0-3, DPSIFR0-3, DPSIEGR0-2, SYOCDCR, STCONR</td>
</tr>
<tr>
<td></td>
<td>• Registers related to the battery backup function: VBTBKRN ((n = 0 \text{ to } 511)), VBTICTLR</td>
</tr>
<tr>
<td>PRC3</td>
<td>• Registers related to the LVD: LVD1CR1, LVD1SR, LVD2CR1, LVD2SR, LVCMPCR, LVDLVLR, LVD1CR0, LVD2CR0</td>
</tr>
<tr>
<td>PRC4(^{1})</td>
<td>• Registers related to the security function: CGFSAR, RSTSAR, LPMSAR, LVDSAR, BBFSAR, DPFSAR, CSAR, SRAMSAR, STBRAMSAR, DTCSAR, DMACSAR, ICUSRx, BUSSARx, MMPUSARx, TZFSA, CPUDSAR, FSAR, PSARx, MSSAR, PmSAR, ELCSARx</td>
</tr>
<tr>
<td>PRKEY[7:0]</td>
<td>These bits control write access to the PRCR register. To modify the PRCR register, write A5h to the eight higher-order bits and the wanted value to the eight lower-order bits as a 16-bit unit.</td>
</tr>
</tbody>
</table>

Note 1. Not present on Arm Cortex-M4 devices.

The Renesas FSP provides two APIs (R_BSP_RegisterProtectEnable and R_BSP_RegisterProtectDisable) to enable and disable Register Write Protection respectively.

10. I/O Port Configuration

The “I/O Ports” section of the Hardware User’s Manual describes exact pin configurations based on peripheral selection and other register settings. Some general information is listed as follows.

It is important to note that after a reset, each pin will be in the default state for that pin. Most pins are not configured until the application code starts to execute. There may be a small period where some pins may be in an undesirable state. This will be true regardless of what configuration method is used. The user should consider the impact this may have for each application, including the effect this may have on other system features.

The IO Port Configuration may be set using either direct write to registers or using FSP Pin Configuration.

10.1 Multifunction Pin Selection Design Strategies

Most pins on the RA4 Series of MCUs can be configured from a selection of multiple peripheral functions. Tools, such as the pin configurator in FSP, are available from Renesas to assist with assigning pins for each peripheral function. When several peripheral functions are needed, use the following design strategies to help with pin selection.

- Assign peripheral functions with only one pin option first. For example, there is only one pin option for each Trace Data signal in the debug function. When this function is needed, assign these pins first.
- Assign peripheral functions with limited pin options next. For example, devices that support the QSPI peripheral typically only have two pin options for each QSPI signal.
- Assign peripheral functions with multiple pin options last. One example would be the Serial Communications Interface (SCI) which typically has many available pin options.
- Some peripheral function pin options are interchangeable, while others must be assigned in logical groups. For example, the IIC peripheral has some pins with the suffix “_A” while others have the suffix “_B” in the signal name. Pins should be selected to have the same suffix for the peripheral function. Other peripheral functions do not have this type of suffix, and pins may be assigned interchangeably, such as the USB_VBUSEN signal for the USBFS peripheral function. Also see Section 15.3 in this document.
10.2 Setting Up and Using a Pin as GPIO

There are two methods for setting up and using a pin as GPIO, either using the Port Control Register (PCNTR1), or the PmnPFS registers.

Method 1: Port Control Register (PCNTR1)

- Select a pin as an output by writing a “1” to the Port Direction bit (PDRn) in Port Control Register 1 (PCNTR1).
- The Port Direction bits (PDRn) are read/write. Setting the value to a “1” selects the pin as an output. Default state for I/O Ports is “0” (input). The port direction registers can be read on the RA4 MCUs.
- The Port Output Data bits (PODRn) in the corresponding Port Control Register (PCNTR1) are read/write. When the PODR is read the state of the output data latch (not the pin level) is read.
- The Port Input bits (PIDRn) in Port Control Register 2 (PCNTR2) are read only. Read the PIDRn bit in the PCNTR2 register to read the pin state.

Method 2: Port mn Pin Function Select (PmnPFS) registers

- The Port Mode Register (PMR) is read/write and is used to specify whether individual pins function as GPIO or as peripheral pins. Just after reset, all PMR registers are set to 0, which sets all pins to work as GPIO. If a PMR register is set to 1 then that corresponding pin will be used for peripheral functions. The peripheral function is defined by that pin’s MPC setting.
- When setting a pin as an output, it is recommended that the desired output value of the port be written to the data latch first, then the direction register is set to an output. Though not important in all systems, this prevents an unintended output glitch on the port being set up.

In general, using PCNTR1 to configure a port will provide faster access but will have fewer configuration features available. Using the PmnPFS registers will have more configuration features available but will have slower access.

The Renesas FSP provides a Pin Configurator to configure GPIO pins after reset as shown below. After the GPIO is configured, it can be controlled using HAL layer APIs in FSP.

![Figure 28. Configuring P302 as Output and Low using FSP Configurator](image-url)
10.2.1 Internal Pull-Ups

- Most pins on ports 0 through 9 have the option of enabling a pull-up resistor. The pull-up is controlled by the Pull-Up Control (PCR) bit in each Port mn Pin Function Select (PmnPFS) Register. The PCR bit in each PmnPFS register controls the corresponding pin on the port.
- The pin must first be set as an input with the associated bit in the PmnPFS register. Set the PCR bit to “1” to enable the pull-up and to “0” to disable it.
- After reset, all PCR registers are cleared to “0”, so all pull-up resistors are disabled.
- The pull-up is automatically turned off whenever a pin is designated as an external bus pin, a GPIO output, or a peripheral function output pin.

10.2.2 Open-Drain Output

- Pins configured as outputs normally operate as CMOS outputs.
- Most pins on ports 0 through 9 have the option of being configured as an NMOS open-drain output.
- The N-channel open-drain control (NCODR) bit in each Port mn Pin Function Select (PmnPFS) Register controls which pins operate in open-drain mode. Setting the applicable bit in each register to a “1” makes the output open-drain. Setting the applicable bit in each register to a “0” sets the port to CMOS output.

10.2.3 Drive Capacity

Most pins on ports 1 through 9 have the option of enabling an output drive capacity. For Arm Cortex-M4 devices, the drive capacity can be set to low- or middle-drive capacity. For Arm Cortex-M33 devices, the drive capacity can be set to low-, middle- or high-drive capacity.

- The drive capacity switching is controlled by the Drive Capacity Control Register (DSCR) bits in each Port mn Pin Function Select (PmnPFS) register.
- After reset all DSCR registers are cleared to 0 therefore all pins are set to low drive output. Setting a value other than “00” will change the drive capacity of the output for the selected pin.
- The maximum total output of all pins summed together is 60 mA for Arm Cortex-M4 devices or 80 mA for Arm Cortex-M33 devices.
- The typical differences the drive levels are shown below. Actual output current levels vary by device and pin type. See the specific MCU User Manual for details.

<table>
<thead>
<tr>
<th>Typical output pins</th>
<th>DSCR[1:0]</th>
<th>Drive Capacity</th>
<th>Max (mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permissible output current per pin</td>
<td>0 0</td>
<td>Low Drive</td>
<td>4.0</td>
</tr>
<tr>
<td>Permissible output current per pin</td>
<td>0 1</td>
<td>Middle Drive</td>
<td>8.0</td>
</tr>
<tr>
<td>Invalid setting; do not use</td>
<td>1 0</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Permissible output current per pin</td>
<td>1 1</td>
<td>High Drive</td>
<td>32</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>High drive output pins</th>
<th>DSCR[1:0]</th>
<th>Drive Capacity</th>
<th>Max (mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permissible output current per pin</td>
<td>0 0</td>
<td>Low Drive</td>
<td>4.0</td>
</tr>
<tr>
<td>Permissible output current per pin</td>
<td>0 1</td>
<td>Middle Drive</td>
<td>8.0</td>
</tr>
<tr>
<td>Invalid setting; do not use</td>
<td>1 0</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Permissible output current per pin</td>
<td>1 1</td>
<td>High Drive</td>
<td>40</td>
</tr>
</tbody>
</table>

Output drive capacity can have a significant impact on overall performance of a board design. The following points should be considered when selecting the drive capacity for each output.

- It is recommended to start with all pins set to low-drive capacity (default) and evaluate the performance.
- Depending on the board layout, pins set to middle- or high-drive capacity may result in higher EMI radiation.
- Long traces may require higher drive capacity for signals to propagate correctly to the receiver.
10.3 Setting Up and Using Port Peripheral Functions

The Port mn Pin Function Select Registers (PmnPFS) are used to configure the characteristics of each port. The PSEL bits select the peripheral function selected for each port.

- Since most pins have multiple functions, the RA4 MCUs have Pin Function Control Registers (PmnPFS) that allow you to change the function assigned to a pin.
- Each pin has its own PmnPFS register.
- Each PmnPFS register allows a pin to be used for peripheral function (PSEL bits), as an IRQ input pin (ISEL bit), or as an analog input pin (ASEL bit). If the ASEL bit is set to “1” (use pin as analog input pin) then the pin’s PMR bit should be set for GPIO use and the pin’s PDR bit should be set for input.
- Refer to the “Peripheral Select Settings for each Product” section in the “I/O Ports” chapter of the Hardware User’s Manual.
- In order to ensure that no unexpected edges are input or output on peripheral pins, make sure to clear the Port Mode Control (PMR) bit for the targeted pin before modifying the pin’s PmnPFS register.
- All PmnPFS registers are write protected after reset. In order to write to these registers, the Write-Protect Register (PWPR) must first be used to enable writing.
- Care should be taken when setting PmnPFS registers such that a single function is not assigned to multiple pins. The user should not do this but the MCU will allow it. If this occurs the function on the pins will be undefined.
- If you are using the external bus, the Ethernet controller, or USB, there are additional registers in the MPC that must be configured before using these peripherals.
- The figure below shows an example of enabling QSPI pins using FSP Pin configuration.

![Figure 29. Enabling QSPI pins Using Pin Configurator in Renesas FSP](image)
10.4 Setting Up and Using IRQ Pins

- Certain port pins can be used as hardware interrupt lines (IRQ). See the “Peripheral Select Settings for each Product” section in the “I/O Ports” chapter of the Hardware User’s Manual for information on which pins are available for your MCU.

- Some IRQ pins have a “-DS” suffix (e.g. IRQ1-DS). The “-DS” designates that this pin can be used to wake the MCU out of deep software standby mode.

- Note: It is not possible to use IRQn and IRQn-DS at the same time. Same number interrupts with the -DS and without the -DS suffix connect to the same interrupt internally, even though they use different external pin connections.

- To set a port pin to be used as an IRQ pin, the Interrupt Input Function Select bit (ISEL) in the pin’s PFS register must be set to “1”.

- Pins can be used for both IRQ and peripheral functions simultaneously. To enable this the user should set both the ISEL and PSEL bits in the pin’s PFS register.

- IRQ functions of the same number must only be enabled on one pin.

- IRQ pins can trigger interrupts on detection of:
  - Low level
  - Falling edge
  - Rising edge
  - Rising and falling edges

  Which trigger is selected is chosen using the IRQ Control Registers (IRQCRi).

- Digital filtering is available for IRQ pins. The filters are based on repetitive sampling of the signal at one of four selectable clock rates (PCLK, PCLK/8, PCLK/32, PCLK/64). They filter out short pulses: any high or low pulse less than 3 samples at the filter rate. The filters are useful for filtering out ringing and noise in these lines but are much too quick for filtering out long events like mechanical switch bounce. Enabling filtering adds a short bit of latency (the filter time) to the hardware IRQ lines.

- Digital filtering can be enabled for each IRQ pin independently. This is done by setting the IRQ Pin Digital Filter Enable (FLTEN) bit in the IRQCRi register for each IRQ.

- The clock rate for digital filtering is configurable for each IRQ pin independently. This is done by setting the IRQ Pin Digital Filter Setting (FCLKSEL[1:0]) bits in the IRQCRi register for each IRQ.

- Figure 30 and Figure 31 show examples of enabling and configuring IRQ pins using Renesas FSP.

![Figure 30](image)

**Figure 30.** Enable P202, P000 as IRQ03, IRQ06 Inputs Respectively Using Pin Configurator in Renesas FSP
10.5 Unused Pins

Note: Some pins require specific termination: See the “Handling of Unused Pins” section of the Hardware User’s Manual for specific recommendations.

Unused pins that are left floating can consume extra power and leave the system more susceptible to noise problems. Terminate unused pins with one of the methods detailed here:

1. The first option is to set the pin to an input (the default state after reset) and connect the pin to Vcc or Vss using a resistor. There is no difference to the MCU between one connection or another. However, there may be an advantage from a system noise perspective. Vss is probably the most typical choice. Avoid connecting a pin directly to Vcc or Vss since an accidental write to the port’s direction register that sets the pin to an output could create a shorted output.

2. A second method is to set the pin to an output. The pin level may be set high or low. However, setting the pin as an output and making the output low connects the pin internally to the ground plane. This may help with overall system noise concerns.

A disadvantage of setting unused pins to outputs is that the configuration of the port must be done via software control. While the MCU is held in reset and until the direction register is set for output, the pin will be a floating input and may draw extra current. If the extra current can be tolerated during this time, this method eliminates the external resistors required in the first method.

3. A variation on leaving the pins as inputs and terminating them with external resistors uses the internal pull-ups available on many ports of the MCU. This has the same limitation as setting the pins to outputs (requires the program to set up the port) but it does limit the effect of accidental pin shorts to ground, adjacent pins or Vcc since the device will not be driving the pin.
10.6 Nonexistent Pins
Each RA4 MCU group is available in multiple package sizes, with different total pin counts. For any package smaller than the largest package for that MCU group (typically 100 pins or 144 pins), set the corresponding bits of nonexistent ports in the PDR register to “1” (output) and in the PODR register to “0”. The user can see which ports are available on each MCU package by reviewing the “Specifications of I/O Ports” table in the I/O Ports section of the Hardware User’s Manual. For example, pins 0 and 1 on port 1 are only available on 176 pin packages. Note that no additional handling of nonexistent pins is required.

10.7 Electrical Characteristics
Normal GPIO ports typically require CMOS level inputs (High ≥ 0.8 * Vcc, Low ≤ 0.2 * Vcc). Some GPIO ports have Schmitt Trigger inputs, which have slightly different input requirements. See the Hardware User’s Manual section “Electrical Characteristics” for more information.

11. Module Stop Function
To maximize power efficiency, the RA4 series of MCUs allow on-chip peripherals to be stopped individually by writing to the Module Stop Control Registers (MSTPCRi, i=A, B, C, D, E). Once a module stops, access to the module registers is not possible.

After a reset, most of the modules are placed in module-stop state, except for DMAC, DTC, and SRAM. See Hardware User’s Manual for details.

Before accessing any of the registers for a peripheral, it must be enabled by taking it out of stop mode by writing a ‘0’ to the corresponding bit in the MSTPCRi register.

Peripherals may be stopped by writing a ‘1’ to the proper bit in the MSTPCRi register.

HAL drivers in Renesas FSP handle module start/stop function automatically.

12. Interrupt Control Unit
The Interrupt Controller Unit (ICU) controls which event signals are linked to the NVIC, DTC, and DMAC modules. The ICU also controls non-maskable interrupts. Figure 32 shows an example of the ICU specifications, and Figure 33 shows an example of the ability to raise the IRQi event from the I/O pins. Refer to the Hardware User’s Manual for details for each RA4 MCU Group.
The following figure is an example of using Renesas FSP configurator to enable and configure an interrupt using Renesas FSP. The ICU and interrupts are configured as part of the HAL driver configuration through FSP.
13. Low Power Consumption

The RA4 devices have several functions for reducing power consumption. These include setting clock dividers, stopping modules, selecting power control mode in Normal mode, and transitions to low power modes. Refer to the chapter “Low Power Modes” in the Hardware User’s Manual for more details.

RA4 MCUs support four different types of LPM depending on the MCU Group. These are:

- Sleep mode
- Software Standby mode
- Snooze mode
- Deep Software Standby mode.

The following table is an overview of the functions available for reducing power consumption.
Table 16. Specifications of the lower power mode functions

<table>
<thead>
<tr>
<th>Item</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reducing power consumption by modifying clock signals</td>
<td>The frequency division ratio can be selected independently for the system clock (ICLK), peripheral module clock (PCLKA, PCLKB, PCLKC, PCLKD), and flash interface clock (FCLK).*1</td>
</tr>
<tr>
<td>Module stop</td>
<td>Functions can be stopped independently for each peripheral module.</td>
</tr>
<tr>
<td>Low-power modes</td>
<td>• Sleep mode</td>
</tr>
<tr>
<td></td>
<td>• Software Standby mode</td>
</tr>
<tr>
<td></td>
<td>• Snooze mode</td>
</tr>
<tr>
<td></td>
<td>• Deep Software Standby mode</td>
</tr>
<tr>
<td>Power control modes</td>
<td>Three operating power control modes:</td>
</tr>
<tr>
<td></td>
<td>• High-speed mode</td>
</tr>
<tr>
<td></td>
<td>• Low-speed mode</td>
</tr>
<tr>
<td></td>
<td>• Subosc-speed mode</td>
</tr>
<tr>
<td>TrustZone Filter*2</td>
<td>Security attributes can be set for each register</td>
</tr>
</tbody>
</table>

Notes: 1. For details, see the chapter “Clock Generation Circuit” in the Hardware User’s Manual.
2. For devices that support TrustZone security features.

The following table lists the conditions to transition to low power modes, the states of the CPU and the peripheral modules, and the method for cancelling each mode.

Table 17. Low Power Consumption Modes

<table>
<thead>
<tr>
<th>State of operation*1</th>
<th>Sleep Mode</th>
<th>All-Module Clock Stop Mode</th>
<th>Software Standby Mode</th>
<th>Deep Software Standby Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transition condition</td>
<td>WFI instruction while SBYCR.SSBY=0</td>
<td>WFI instruction while SBYCR.SSBY=1 and DPSBYCR.DPSBY=0</td>
<td>Snooze request trigger in Software Standby mode. SNZCR.SNZE=1</td>
<td>WFI instruction while SBYCR.SSBY=1 and DPSBYCR.DPSBY=1</td>
</tr>
<tr>
<td>Canceling method</td>
<td>All interrupts. Any reset available in the mode.</td>
<td>Interrupts defined for this mode. Any reset available in the mode.</td>
<td>Interrupts defined for this mode. Any reset available in the mode.</td>
<td>Interrupts defined for this mode. Any reset available in the mode.</td>
</tr>
<tr>
<td>State after cancellation by an interrupt</td>
<td>Program execution state (interrupt processing)</td>
<td>Program execution state (interrupt processing)</td>
<td>Program execution state (interrupt processing)</td>
<td>Reset state</td>
</tr>
<tr>
<td>State after cancellation by a reset</td>
<td>Reset state</td>
<td>Reset state</td>
<td>Reset state</td>
<td>Reset state</td>
</tr>
</tbody>
</table>

Notes: 1. Refer to the table “Operating Conditions of Each Low Power Mode” in the Hardware User’s Manual for additional details.

RA4 devices include register settings that allow the MCU to operate with lower power consumption in Normal mode and Sleep mode. These modes are referred to as the Operating Power Control Modes and are controlled by the OPCCCR register.

The following is a summary of the Operating Power Consumption Control modes and the maximum permissible clocking and voltage levels under each mode.
Table 18. Available Oscillators in Each Operating Power Consumption Control Mode

<table>
<thead>
<tr>
<th>Mode</th>
<th>Oscillator</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PLL, PLL2</td>
</tr>
<tr>
<td>High-speed</td>
<td>High-speed on-chip oscillator</td>
</tr>
<tr>
<td></td>
<td>Middle-speed on-chip oscillator</td>
</tr>
<tr>
<td></td>
<td>Low-speed on-chip oscillator</td>
</tr>
<tr>
<td></td>
<td>Main clock oscillator</td>
</tr>
<tr>
<td></td>
<td>Sub-clock oscillator</td>
</tr>
<tr>
<td></td>
<td>IWDT-dedicated on-chip oscillator</td>
</tr>
<tr>
<td>Low-speed</td>
<td>Available</td>
</tr>
<tr>
<td></td>
<td>Available</td>
</tr>
<tr>
<td></td>
<td>Available</td>
</tr>
<tr>
<td>Subosc-speed</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Available</td>
</tr>
<tr>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Available</td>
</tr>
</tbody>
</table>

Note: While it may be possible to set the value in the OPCCR register to any of the low power operating modes, clocking and voltage levels must also be set to meet the requirements of the desired mode. Otherwise, the settings in the OPCCR register will not have any effect in lowering power consumption.

In order to achieve the lowest power consumption, use the maximum possible frequency division ratios in the clock generation circuits.

Low power modes are canceled by various interrupt sources such as RES pin reset, power-on reset, voltage monitor reset, and peripheral interrupts. Refer to the Low Power Modes section in the Hardware User’s Manual for a list of interrupt sources for different LPMs.

Only Snooze mode is triggered by a Snooze request to enter snooze mode from Software Standby mode. The transitions to other LPMs are done by executing a WFI instruction with appropriate settings in the Standby Control register (SBYCR).

Renesas FSP provides a low power mode (LPM) driver and driver configurator to set up low power mode, wake source/cancel source, and so forth.

Figure 35. Set up Low Power Mode Using Renesas FSP Configurator

After a specific LPM mode is set up by FSP Configurator, the LPM driver's API can be used to initialize LPM driver and place MCU in configured LPM mode, as shown in the following example:
/* Open LPM driver and initialize LPM mode */
err = R_LPM_Open(&g_lpm_deep_sw_standby_ctrl, &g_lpm_deep_sw_standby_cfg);
/* Handle error */
if (FSP_SUCCESS != err)
{
    return (err);
}
/* Transition to configured LPM mode: Deep Software Standby Mode */
err = R_LPM_LowPowerModeEnter(&g_lpm_deep_sw_standby_ctrl);
/* Handle error */
if (FSP_SUCCESS != err)
{
    return (err);
}

Refer to the Application Notes "Getting Started with Low Power Applications" for RA devices for examples of how to use FSP configurator and driver APIs for LPM.

14. Buses

The buses in Arm Cortex-M33 MCU consist of a 32-bit AHB (Advanced High-performance Bus) bus matrix. Figure 36 lists the bus masters and bus slaves and Figure 37 shows the bus configuration.

Note: Memory space is accessed in little-endian format when executing Arm Cortex instruction code.

<table>
<thead>
<tr>
<th>Classification</th>
<th>Bus Master/Slave name</th>
<th>Bus IF Max Freq</th>
<th>Sync Clock</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bus Masters</td>
<td>Code bus (Cortex-M33)</td>
<td>100 MHz</td>
<td>ICLK</td>
<td>Connected to the CPU Instruction Cache for Instructions and operands</td>
</tr>
<tr>
<td></td>
<td>System bus (Cortex-M33)</td>
<td>100 MHz</td>
<td>ICLK</td>
<td>Connected to the CPU Data Cache for system</td>
</tr>
<tr>
<td></td>
<td>DMAC / DTC</td>
<td>100 MHz</td>
<td>ICLK</td>
<td>Connected to the DMAC/DTC</td>
</tr>
<tr>
<td>Bus Slaves</td>
<td>FHBIU</td>
<td>100 MHz</td>
<td>ICLK</td>
<td>Connected to Code Flash memory and Configuration area</td>
</tr>
<tr>
<td></td>
<td>FLBIU</td>
<td>50 MHz</td>
<td>FCLK</td>
<td>Connected to Data Flash memory, FACI</td>
</tr>
<tr>
<td></td>
<td>S0BIU</td>
<td>100 MHz</td>
<td>ICLK</td>
<td>Connected to SRAM0 (Standby RAM)</td>
</tr>
<tr>
<td></td>
<td>PSBIU</td>
<td>100 MHz</td>
<td>ICLK</td>
<td>Connected to peripheral system modules (OTC, DMAC, ICU, Flash, MPU, SRAM, Debug/Trace module, System controller and Bus controller)</td>
</tr>
<tr>
<td></td>
<td>PLBIU</td>
<td>50 MHz</td>
<td>PCLKB</td>
<td>Connected to peripheral modules (CAC, ELC, IO ports, PCEG, RTC, WDT, IWD, AST, IIC, CAN, USBFS, SDHI, ISSIE, TSN, and CTSU)</td>
</tr>
<tr>
<td></td>
<td>PhBIU</td>
<td>100 MHz</td>
<td>PCLKA</td>
<td>Connected to peripheral modules (GPT, SCI, SPI, CRC, DOC, ADC12, DAC12 and SCEO)</td>
</tr>
<tr>
<td></td>
<td>EGBIU (QSPI area)</td>
<td>100 MHz</td>
<td>PCLKA</td>
<td>Connected to the QSPI (External Memory Interface)</td>
</tr>
</tbody>
</table>

Note: FHBIU: Flash High speed Bus Interface Unit.
FLBIU: Flash Low speed Bus Interface Unit.
S0BIU: SRAM0 Bus Interface Unit.
PSBIU: Peripheral System Bus Interface Unit.
PLBIU: Peripheral Low speed Bus Interface Unit.
PhBIU: Peripheral High speed Bus Interface Unit.
EGBIU: External memory interface Qspi Bus Interface Unit.
14.1 Bus Error Monitoring

The bus error monitoring system monitors each individual area. When an error is detected, an error is returned to the requesting master IP using the AHB-Lite error response protocol.

14.1.1 Bus Error Types

The following types of errors can occur on each bus:

- Illegal address access.
- Bus master MPU error.
- TrustZone Filter error (MCUs that support Trustzone only).
- Bus error transmitted from each slave IP.

14.1.2 Operations When a Bus Error Occurs

When a bus error occurs, operation is not guaranteed, and the error is returned to the requesting master IP. The bus errors that occur for each master are stored in the BUSnERRADD and BUSnERRSTAT registers. These registers must only be cleared by a reset. For more information, see section “Bus Error Address Register (BUSnERRADD)” and “Bus Error Status Register (BUSnERRSTAT)” in the Hardware User’s Manual.

Note: The DMAC and DTC do not receive bus errors, so their operation is not affected by bus errors.
15. General Layout Practices

15.1 Digital Domain vs. Analog Domain

Renesas RA4 Microcontroller devices have three primary types of pin functions: Power, Digital, and Analog.

Generally, power pins are dedicated for voltage and reference input and do not have multiple functions. Power pins are typically dedicated to specific portions, or domains, within the MCU. For example, the main supply voltage for the MCU will provide power to the digital core, many of the digital peripheral functions and many of the digital I/O pins. The digital domain can be defined as the digital circuitry, digital I/O pins, and the related power pins. Power pins which are designated for analog functions (such as AVCC0 and the associated AVSS0) supply specific analog circuitry within the MCU, which is separate from the digital domain circuitry. The analog domain can be defined as the analog circuitry, analog I/O pins, and the related power pins.

Digital signals are typically repetitive, switched patterns that are associated with periodic clocks. The transitions on digital signals tend to be relatively sharp edges, with stable levels of high or low between the transitions. Each signal must be stable at an acceptable voltage level, referred to as a logic state, within a specified timeframe. The state of the signal is typically sampled at predetermined clock intervals, using the edge transition of a clock to evaluate the associated data signals. Small variations in the voltage level of digital signals are typically acceptable, as long as the level remains within a specified range. However, large external influences on digital signals can have an acute influence on a digital signal, which can result in an incorrect logic state at the moment when the data is sampled.

Analog signals are usually quite different. Analog signals may be periodic, but the evaluation of an analog signal is a measurement of voltage over a range instead of logic state. The voltage level of an analog signal is sampled based on a specific trigger event, and the resulting measurement is processed using the analog circuitry in the MCU. The accuracy of an analog measurement is directly related to the accuracy of the sampled voltage level. Any unwanted external influence which may change the voltage level of an analog input signal, even slightly, can influence the accuracy of the measurement.

Due to the highly multiplexed nature of the I/O pins on Renesas RA4 MCU devices, many I/O pins can be used for either Analog or Digital functions. This can result in situations where digital and analog functions may overlap and result in data errors.

To minimize potential problems between digital and analog signal domains, consider the following guidelines.

- When assigning I/O pin functions, select pin functions such that analog pins and digital pins are physically separated as much as possible.
- Each analog signal should be separated from all other signals as much as possible.
- PCB routing should isolate each analog signal as much as possible. Avoid routing any other signals, either analog or digital, in the same area.
- Ensure that analog supply voltages and analog reference voltages include appropriate AC filters. This may be in the form of recommended capacitors located near the MCU voltage pin, or appropriate inductive filters. The goal is to provide voltage supply and reference voltage with little or no voltage ripple.
- When using dedicated power layers in a PCB design, avoid routing digital signals in the areas of analog voltages, and avoid routing analog signals in the areas of digital voltages.

For highly sensitive applications, it is highly recommended to evaluate the specific design using simulation tools to understand the effect that circuit design has on the performance. For example, this may include applications such as precision sensor designs, or very high-speed digital bus interfaces. Refer to the “Electrical Characteristics” chapter in the Hardware User’s Manual for the specific requirements for each peripheral function.

15.2 High Speed Signal Design Considerations

As clock speeds for digital signals increase, the influence of external stimuli on those signals can become more significant. Some peripheral functions can be classified as "High Speed" digital signals. Additional design considerations should be made for high-speed digital signals.

Crosstalk is a condition where transitions on one signal have an inductive influence on another nearby signal. When this crosstalk effect is strong enough, the first signal may cause errors on the second signal. To reduce the effects of crosstalk, use the following general PCB routing guidelines.
• Provide sufficient space between routed signals on the same routing layer. Generally, keep a minimum of one trace width space between signals of the same digital group, and a minimum of 3-5 trace widths space between signals of different digital groups.
• Provide extra space between clock signals and data signals on the same routing layer. Generally, keep a minimum of 3-5 trace widths space between clocks and any other digital signals.
• Avoid parallel routing of digital signals on any adjacent routing layers. If signals must be routed on adjacent signals layers, try to use only orthogonal crossings wherever possible.

If possible, separate PCB signal layers using power or ground layers between signal layers. The solid copper of the power or ground layer can act as a "shield" for the digital signals.

Each standardized interface will have specific requirements. To ensure that the PCB is designed to avoid signal crosstalk problems, it is strongly suggested to refer to the relevant standards for each interface in the design.

15.3 Signal Group Selections
Some pin names have an added _A, _B, or _C suffix to indicate signal groups. When assigning certain peripheral functions, such as IIC, SPI, SSIE, ETHERC, and SDHI, select the functional pins having the same suffix. In some cases, the AC timing characteristics shown in the "Electrical Characteristics" chapter of the Hardware User's Manual are measured for each signal group. If the signal groups are mixed, the peripheral is not guaranteed to function and the stated AC timing characteristics may not apply.

If the pin names for a peripheral function to not have a signal group suffix, it is safe to select the most convenient pin assignment for each function signal.

Refer to the sections "Peripheral Select Settings for each Product" and "Notes on the PmnPFS Register Setting" in the "I/O Ports" chapter of the Hardware User's Manual.

16. References
The following documents were used in creating this Quick Design Guide. Visit the Renesas website for the latest version of each of these documents.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Document Number</th>
<th>Description</th>
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<tbody>
<tr>
<td>1</td>
<td>R01UH0887</td>
<td>Renesas RA4M1 Group, User's Manual: Hardware</td>
</tr>
<tr>
<td>2</td>
<td>R01UH0892</td>
<td>Renesas RA4M2 Group, User's Manual: Hardware</td>
</tr>
<tr>
<td>3</td>
<td>R01UH0893</td>
<td>Renesas RA4M3 Group, User's Manual: Hardware</td>
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<tr>
<td>4</td>
<td>R20AN0577</td>
<td>RA Arm® TrustZone® Tooling Primer</td>
</tr>
<tr>
<td>5</td>
<td>R11AN0467</td>
<td>Security Design with Arm® TrustZone® - IP Protection</td>
</tr>
<tr>
<td>6</td>
<td>R11AN0468</td>
<td>Securing Data at Rest Using the Arm® TrustZone®</td>
</tr>
<tr>
<td>7</td>
<td>R11AN0475</td>
<td>Establishing and Protecting Device Identity using SCE9 and Arm® TrustZone®</td>
</tr>
<tr>
<td>8</td>
<td>R11AN0469</td>
<td>Device Lifecycle Management Key Installation</td>
</tr>
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</table>
Website and Support

Visit the following vanity URLs to learn about key elements of the RA family, download components and related documentation, and get support.

1. RA Product Information  www.renesas.com/ra
2. RA Product Support Forum  www.renesas.com/ra/forum
3. RA Flexible Software Package  www.renesas.com/FSP
4. Renesas Support  www.renesas.com/support
## Revision History

<table>
<thead>
<tr>
<th>Rev.</th>
<th>Date</th>
<th>Page</th>
<th>Description</th>
<th>Summary</th>
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<tr>
<td>1.00</td>
<td>Jul.21</td>
<td>—</td>
<td>—</td>
<td>Initial release</td>
</tr>
<tr>
<td>1.01</td>
<td>Dec.10.21</td>
<td>21, 22</td>
<td>Clarifies conditions for watchdog timer and independent watchdog time reset.</td>
<td>Registers RSTSR0 and RSTSR1 show the reset source.</td>
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<td></td>
<td></td>
<td>23</td>
<td>—</td>
<td>Units of programming and erasure are 4/8/16 bytes for data flash, not 2 bytes.</td>
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