Radio Driver

# Support Functions for Regional Radio Regulations

## Introduction

This application note provides the information necessary to use the radio drivers described in the Radio Driver Reference Guide (See [1]) in compliance with the regional radio regulations.

## Disclaimer

Renesas Electronics does not warrant or guarantee that the functions provided by Renesas Electronics complies with the radio laws and regulations. The functions are intended to make it easier for you to design for compliance with the radio laws and regulations.
You shall be responsible for using the functions in compliance with the applicable laws and regulations.

## Target Devices

- RA2E1 (R7FA2E1A9xxFM) + RF (Semtech SX1261/SX1262)
- RA2L1 (R7FA2L1ABxxFP) + RF (Semtech SX1261/SX1262)
- RA0E1 (R7FA0E1073CFJ) + RF (Semtech SX1261/SX1262)
- RA0E2 (R7FA0E2094CFM) + RF (Semtech SX1261/SX1262)
- RL78/G23 (R7F100GLG, R7F100GSN) + RF (Semtech SX1261/SX1262)
- RL78/G22 (R7F102GGE) + RF (Semtech SX1261/SX1262)
- RL78/L23 (R7F100LPL) + RF (Semtech SX1261/SX1262)
- RL78/G14 (R5F104ML) + RF (Semtech SX1261/SX1262)

## Contents

# 1. Overview

## 1.1 Overview of Radio Configurations Validation Function

The radio drivers described in [1] can be operated in compliance with the regional radio regulations by enabling the radio configurations validation function described in this chapter.

The radio configurations validation function is enabled if the compiling macro `RP_USE_RADIO_CFG_CHECK` is specified when building the radio driver and the PIB `PIB_RADIO_CFG_CHECK_ENABLE` is set to true. For details on PIB and how to use it, please refer to [1]. Hereinafter, the term "with the radio configurations validation function enabled" refers to the state in which the PIB is enabled.

If the radio configurations validation function is unnecessary, this function can be excluded from the build target to reduce the object size by setting the macro `RP_USE_RADIO_CFG_CHECK` to be undefined.

## 1.2 Basic Usage

When using the radio driver with the radio configurations validation function enabled, the following procedure is required.

- After initializing the radio driver with `RadioInit()`, the PIB `PIB_RADIO_CFG_CHECK_ENABLE` is set to true (enabled) with `RadioSetPib()`.
- All other radio driver APIs must be issued in keeping with the PIB `PIB_RADIO_CFG_CHECK_ENABLE` set to true (enabled).

## 1.3 Directories (informative)

Table 1 shows a basic concept of the type of codes that each directory includes. The radio configurations validation function is located in the sub directory of the radio driver.

**Table 1. Directories**

| Directories | Description |
|---|---|
| `src/apps` | Application code. |
| `src/boards` | Board specific codes. |
| `src/boards/mcu` | MCU drivers (except RL78/G23, RL78/G22 and RL78/L23). |
| `src/radio` | Radio driver. |
| `src/radio/region` | Radio configurations validation function. |
| `src/system` | Utility APIs and so forth. |
| `src/peripherals` | Peripheral drivers. |
| `<ProjectDir>/src/smc_gen` | MCU drivers for RL78/G23, RL78/G22 and RL78/L23 generated by RL78 Smart Configurator.<br>* <ProjectDir> is a folder for e2studio/CS+ project. |

## 1.4 Resource Usage

Please refer to [2] for RL78 and [3] for RA2 and RA0 in the following folder as for the resource usage such as memory and peripherals.

Folder: `(package top)\documents\`

## 1.5 Related Documentation

| | Document No. | Title | Author | Language |
|---|---|---|---|---|
| [1] | R11AN0227 | Radio Driver Reference Guide | Renesas Electronics | English |
| [2] | R11AN0595 | RL78/G23, RL78/G22, RL78/L23, RL78/G14 LoRa®-based Wireless Software Package | Renesas Electronics | English |
| [3] | R11AN0596 | RA2E1, RA2L1, RA0E1, RA0E2 LoRa®-based Wireless Software Package | Renesas Electronics | English |
| [4] | R11AN0937 | Smart Configurator Usage for RL78 LoRa®-based Wireless Software Reference Guide | Renesas Electronics | English |

## 2. Radio Configurations Validation Function Operation

The radio configurations validation function checks and restricts the radio settings according to the flow shown in Figure 1 when sending and receiving packets. In this function, the Duty Cycle limitation function calculates when the next packet can be transmitted based on the last transmission completion time and the transmission duration calculated by the function `RadioTimeOnAir()` of the radio driver.

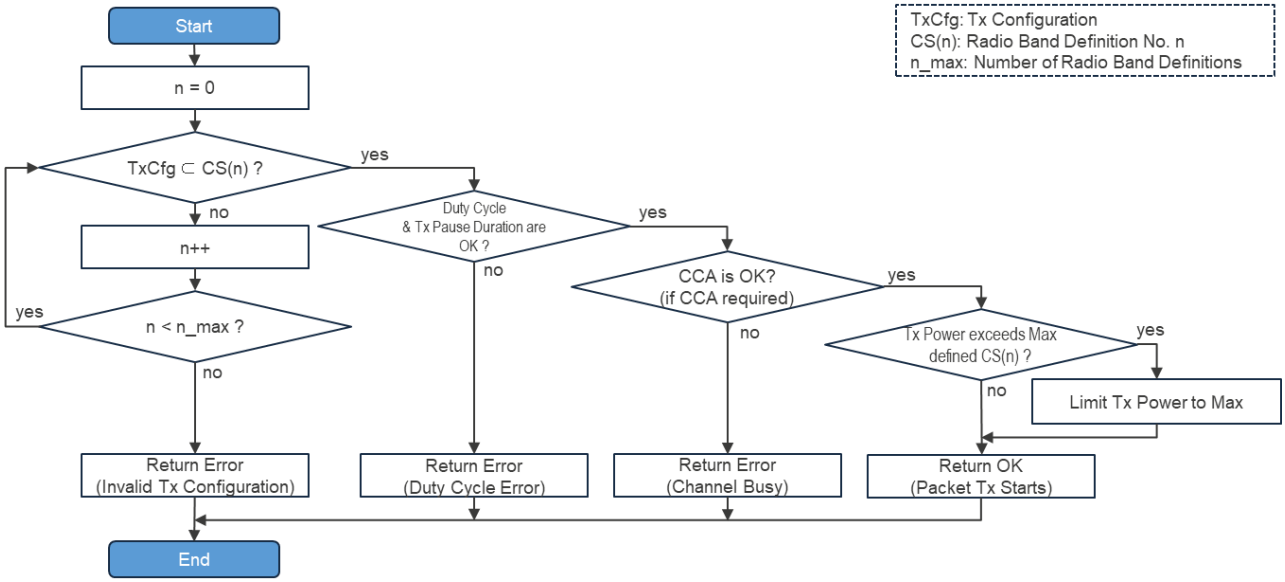


Figure 1 Operation flow of the radio setting restriction function (when `RadioSend()` is called)

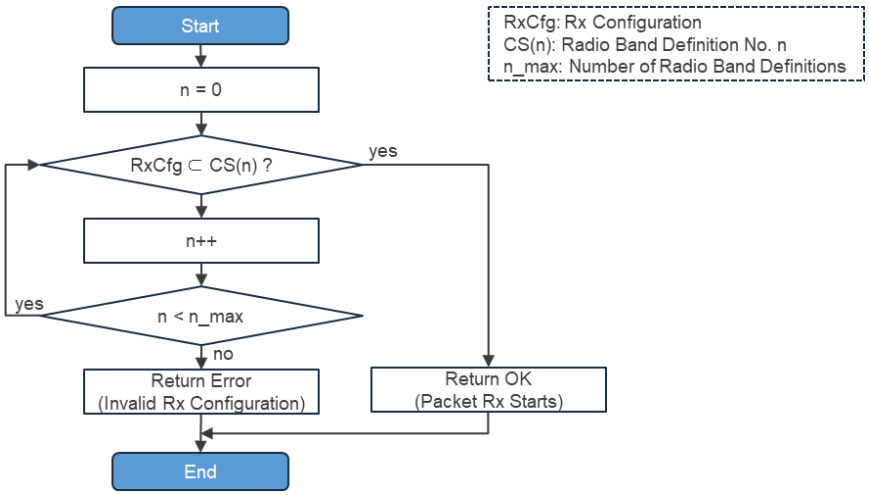


Figure 2 Operation flow of the wireless setting restriction function (when `RadioRx()` is called)

# 3. Details of Radio Configurations Validation Function

## 3.1 Radio Band Definitions

This software includes the example of the radio band definition table (`RpRegionBandDef[]`) to define the major radio configurations for the regional radio regulations. When sending and receiving packets, the operation is restricted according to the table. For example, some of the definitions for Japan (without low duty cycle method) are shown in Table 1.

The tables are examples and need to be added or modified according to the regional radio regulations if necessary. Please refer to 3.5 for the instructions how to change the definitions.

**Table 2 Radio Band Definition for Japan (without low duty cycle method)**

| Band number | Center Frequency (Lower Limit) [MHz] | Center Frequency (Upper Limit) [MHz] | Channel bandwidth [kHz] | Maximum transmit power (aerial line power) [dBm] | Minimum transmit pause time [msec] | Maximum transmission time per shipment [msec] | Maximum Transmit Duty Cycle [%] | Minimum Career Sense Time [msec] | Career Sense Threshold [dBm] | Available Modulation Settings |
|---|---|---|---|---|---|---|---|---|---|---|
| **0** | 920.6 | 923.4 | 200 | +13 | 50 | 4000 | 100 | 5 | -80 | LoRa(BW:125 kHz, SF:7 - 12)<br>FSK (fdev: 25 kHz, data rate: 50 kbps) |
| **1** | 923.6 | 928.0 | 200 | +13 | 2 | 400 | 10 | 5 | -80 | LoRa(BW:125 kHz, SF:7 - 12)<br>FSK (fdev: 25 kHz, data rate: 50 kbps) |
| **2** | 920.7 | 921.9 | 400 | +13 | 50 | 4000 | 100 | 5 | -80 | LoRa(BW: 250 kHz, SF: 7) |
| **3** | 922.7 | 927.9 | 400 | +13 | 2 | 200 | 10 | 5 | -80 | LoRa(BW: 250 kHz, SF: 7) |
| **4** | 920.9 | 923.3 | 400 | +13 | 50 | 4000 | 100 | 5 | -80 | LoRa(BW: 250 kHz, SF: 7) |
| **5** | 923.7 | 927.7 | 400 | +13 | 2 | 200 | 10 | 5 | -80 | LoRa(BW: 250 kHz, SF: 7) |

## 3.2 Details of Radio Band Definition

The following is an overview of the restrictions on the radio operation by the definitions of each item in the radio band definitions.

- **Center Frequency, Channel Bandwidth**

  The center frequency for transmission and reception specified by the function `RadioSetChannel()` shall be within the center frequency of the lower limit and the center frequency of the upper limit defined in the radio band table. And it shall also be aligned with the following equation if the channel space is other than one.

  (Center Frequency of Lower Limit) + (Channel Space * N) *N = 0, 1, ...

  If the specified frequency does not match the criteria, the transmission and reception operation by the function `RadioRx()` or `RadioSend()` are restricted and aborted.

  The frequency specified as the argument of the function `RadioCheckRfFrequency()` is verified whether the frequency is within the range. The function returns false if the frequency is out of range.

- **Maximum Transmission Power**

If the transmission output power specified by the function `RadioSetTxConfig()` exceeds the maximum value defined in the radio band definitions table, the specified transmission power is limited to the maximum value before sending the packet by `RadioSend()` and continue the transmmission operation.

- **Minimum Transmission Pause Time**

  If the elapsed time since the last packet transmission completion does not exceed the minimum transmission time defined in the radio band definition table, the transmission operation by `RadioSend()` is restricted and aborted.

- **Maximum Transmission Time**

  If the expected transmission time of a packet calculated by `RadioTimeOnAir()` exceeds the maximum transmission time defined in the radio band table, the transmission operation by `RadioSend()` is restricted and aborted.

- **Maximum Duty Cycle of Transmission**

  If the elapsed time since the last packet transmission completion does not exceed the maximum duty cycle of transmission defined in the radio band table, the transmission operation by `RadioSend()` is restricted and aborted.

- **Minimum Career Sense Time**

  Before sending a packet by `RadioSend()`, the carrier sense is performed for more than the time specified by the minimum carrier sense time defined in the radio band definitions table and a carrier is detected, the transmission operation by `RadioSend()` is restricted and aborted. If zero is specified, the carrier sense is not performed and transmission operation not restricted.

- **Carrier Sense Threshold**

  When the carrier sense is performed before the packet transmission and the RSSI value exceeds the carrier sense threshold value added by the offset value (`RP_REGION_CCA_RSSI_OFFSET`) during the carrier sense, the transmission operation by `RadioSend()` is restricted and aborted.

- **Available Modulation Settings**

  If the transmission and reception settings do not match the available modulation settings, the transmission and reception operations by `RadioSend()` and `RadioRx()` are restricted and aborted.

If any of the above ratio operations is restricted and aborted, the radio driver API will return an error code. The following table shows the types of restrictions and their corresponding radio driver error codes.

**Table 3 Wireless Operation Limits and Radio driver API Returns**

| Restriction Name | RadioSend()<br>Return Values (Error Codes) | RadioRx()<br>Return Values (Error Codes) | RadioCheckRfFrequency()<br>Return Values (Error Codes) |
|---|---|---|---|
| Center Frequency, Channel Bandwidth | RADIO_CHECK_FAIL_TX_CFG | RADIO_CHECK_FAIL_RX_CFG | false |
| Maximum Transmit Power | - (*1) | - | - |
| Minimum Transmit Pause Time | RADIO_CHECK_FAIL_TX_DUTY_CYCLE | - | - |
| Maximum Transmit Duration Time | RADIO_CHECK_FAIL_TX_CFG | - | - |
| Maximum Transmit Duty Cycle | RADIO_CHECK_FAIL_TX_DUTY_CYCLE | - | - |
| Career Sense Threshold | RADIO_CHECK_FAIL_TX_CHANNEL_BUSY | - | - |

| | | | |
|---|---|---|---|
| (+ Minimum Carrier Sense Time) | | | |
| Available Modulation Settings | RADIO_CHECK_FAIL _TX_CFG | RADIO_CHECK_ FAIL_RX_CFG | - |

*1) The specified Tx power is limited to the maximum power before sending the packet without returnning an error code.

## 3.3 Other Operation Restrictions

The following radio driver API functions are always restricted and returns an error code (`RADIO_FAIL`) when the radio configurations validation function is enabled.

- `RadioSetTxInfinitePreamble()`: Continuous modulated signal transmission function
- `RadioSetTxContinuousWave()`: Continuous unmodulated signal transmission function

## 3.4 Radio Driver API RadioGetTimeToNextTx()

The radio driver provides `RadioGetTimeToNextTx()` as an API related to the transmission time limit of the radio configurations validation function. The purpose of this function is to calculate the estimated time period until the next packet can be transmitted considering the duty cycle or pause time limitation for the transmission.

## 3.5 How to Change Contents of Radio Band Definitions

This section describes how users can add or modify the radio band definitions described in the previous section.

### 3.5.1 Modifying Radio Band Definitions

If necessary, please change the radio band definitions specified in `r_radio_region.c` with reference to the information in this section. The file is in the folder, `samples/project/src/radio/region`.

Please carefully check the changes and confirm the behavior if changed.

#### 3.5.1.1 Changing or Adding Modulation Settings

A modulation setting table `RpRegionModemCfg[]` is defined in `r_radio_region.c` and the entries of the table are referred by the index of the talbe from the radio band definitions table. The modulation setting table is used to check whether the spefified Tx/Rx modulation settings are allowed for the regional radio regulations when transmitting and receiving.

By default, the modulation setting table consists of the following four types of tables.

(1) `RpRegionModemCfgDef0[]`: LoRa/SF7 - 12/BW 125 kHz, FSK/50 kbps/fdev 25 kHz

(2) `RpRegionModemCfgDef1[]`: LoRa/SF7/BW 250 kHz

(3) `RpRegionModemCfgDef2[]`: LoRa/SF7 - 12/BW 125 kHz

(4) `RpRegionModemCfgDef3[]`: LoRa/SF7 - 12/BW 500 kHz

If the modulation settings table needs to be added or changed, please change the tables with reference to the information shown in Figure 3.

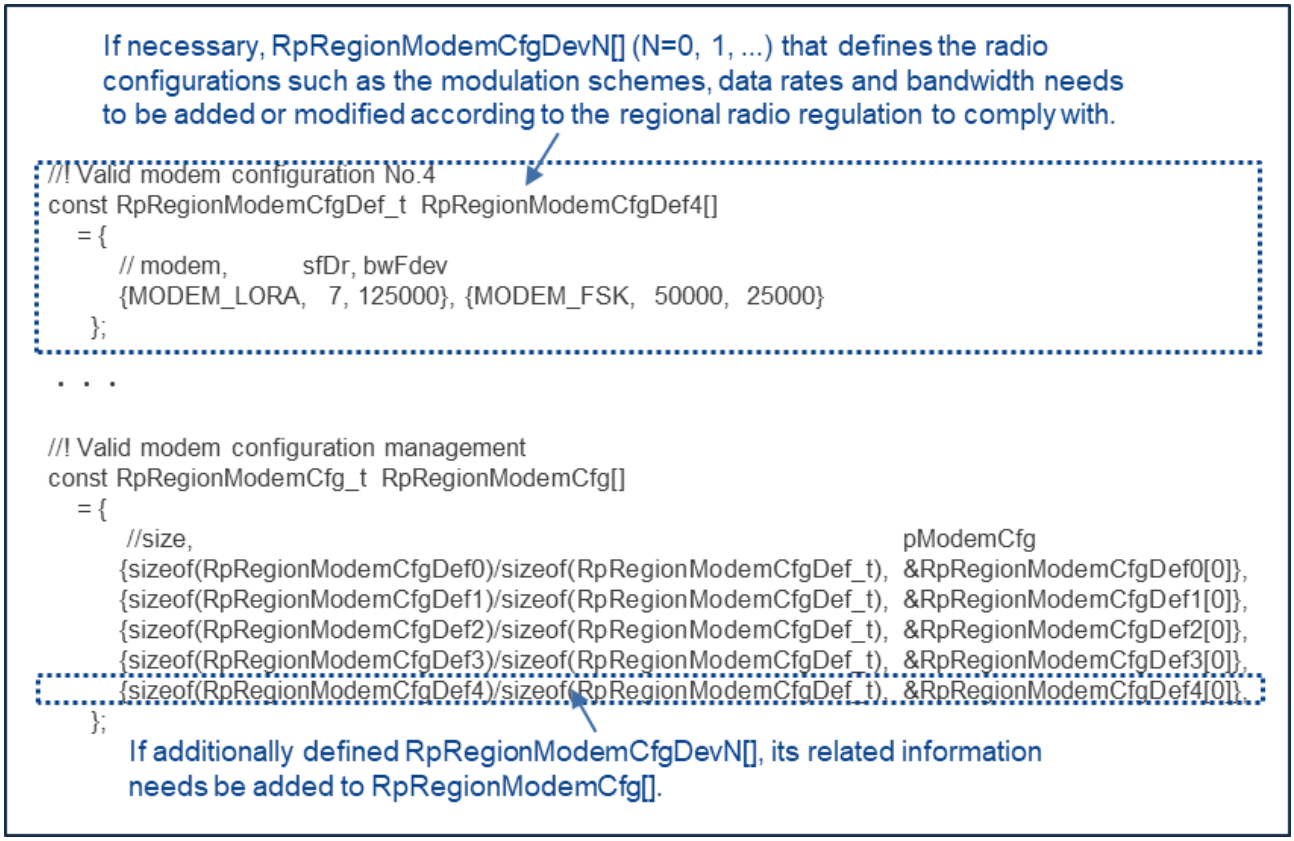


**Figure 3 How to Change or Add Modulation Setting Table**

#### 3.5.1.2 Changing or Adding Radio Band Definitions Settings

The radio bands permitted for the regional radio regulation are defined in the adio band definitions table `RpRegionBandDef[]`.

If necessary, please add or change the elements of the existing radio band definitions table according to the existing definition. The maximum number of the radio band definitions for each region/country is 16.

The following are points to be aware of when adding or changing definitions.

- The lower and upper frequencies (freqStart, freqEnd) need to be set as the values of the center frequency.
- The radio bands need to be defined in descending order of the bandwidth and transmission priority.
- The unit of carrier sense time (ccaTime) is microseconds, and the value of the time needs to be set by the unit of 1milisecond (1000, 2000, ...). Please refrain from setting fractions such as 0.1 milliseconds or 1.1 milliseconds. If the carrier sense before sending is not required, specify 0.
- Carrier sense bandwidth (ccaBw) defines the bandwidth (unit: Hz) at which carrier sense is to be performed. The specified bandwidth should be selected from the values that can be set to `PIB_CCA_BANDWIDTH` of the radio driver. For more information on `PIB_CCA_BANDWIDTH`, please refer to [1].
- The duty cycle (dutyCycle) for the trasmission defines the maximum duty cycle in basis point [bp].

  For example, 1 [%] = 100 [bp], 10 [%] = 1000 [bp], and the maximum of 100 [%] = 10000 [bp].
- The modulation setting (modemCfgNo) is set to the index number of `RpRegionModemCfg[]` to be used.

### 3.5.2 Others

#### 3.5.2.1 RSSI Offset for Carrier Sense

In the radio driver, the carrier sense detection is determined whether the received signal level exceeds the carrier sense threshold specified in the radio band definitions table adding the RSSI offset

This RSSI offset for carrier sense is macro defined as a `RP_REGION_CCA_RSSI_OFFSET` in r_radio_region.c. If necessary, please specify an appropriate RSSI offset value (unit: dB) to the `RP_REGION_CCA_RSSI_OFFSET`.

In addition, the limit of the setting value limit of `RP_REGION_CCA_RSSI_OFFSET` is the same as the one of the PIB `PIB_RSSI_OFFSET` of the radio driver. For `PIB_RSSI_OFFSET`, refer to [1].

## Revision History

| Rev. | Date | Description | |
|---|---|---|---|
| | | Page | Summary |
| 4.40 | Dec.22.23 | --- | First official version. |
| 4.50 | May.24.24 | 1, 3<br>1 | Support RA0E1.<br>Fixed a typo. |
| 4.60 | Sep.27.24 | 3<br>4 | Updated directories.<br>Added related document [4]. |
| 4.70 | Apr.18.25 | --- | Support RA0E2 |
| 4.80 | Aug.21.25 | --- | Support RL78/L23 |
| 4.90 | Nov.28.25 | --- | Changed document revision. |

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1. Precaution against Electrostatic Discharge (ESD)

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

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

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

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

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

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

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