

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.

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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)

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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</projectdir>	MCU drivers for RL78/G23, RL78/G22 and RL78/L23 generated by
_	RL78 Smart Configurator.
	* <projectdir> is a folder for e2studio/CS+ project.</projectdir>

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.

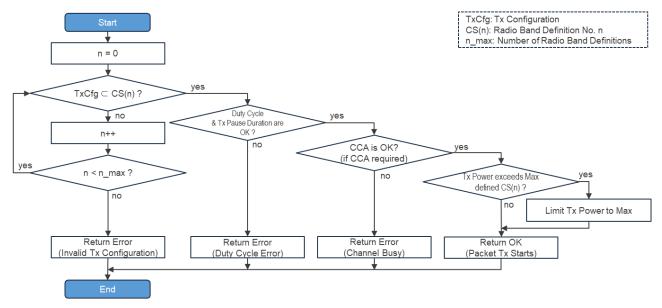


Figure 1 Operation flow of the radio setting restriction function (when RadioSend() is called)

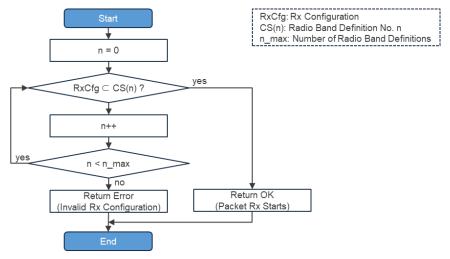


Figure 2 Operation flow of the wireless setting restriction function (when RadioRx() is called)

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.

Center Channel Maximum Minimum Maximum Maximum Minimum **Available Modulation Settings** Center Career Sense bandwidth transmission Frequency Frequency transmit transmit Transmit number Duty Cycle (Upper Limit) Threshold pause time per [kHz] time Limit) (aerial Time [dBm] line [MHz] [MHz] [msec] [msec] [%) [msec] power) [dBm] 0 920.6 923.4 200 +13 50 4000 100 5 -80 LoRa(BW:125 kHz, SF:7 - 12) 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) 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) LoRa(BW: 250 kHz, 4 920.9 923.3 400 +13 50 4000 100 5 -80 SF: 7) 5 923.7 927.7 400 +13 2 200 10 5 -80 LoRa(BW: 250 kHz, SF: 7)

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

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 <code>RadioSetChannel()</code> 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 transmission 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 <code>RadioSend()</code>, 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 <code>RadioSend()</code> 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()	RadioRx()	RadioCheckRfFrequency()
	Return Values (Error Codes)	Return Values (Error Codes)	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	RADIO_CHECK_FAIL	RADIO_CHECK_	-
Settings	_TX_CFG	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.

```
If necessary, RpRegionModemCfgDevN[] (N=0, 1, ...) that defines the radio
     configurations such as the modulation schemes, data rates and bandwidth needs
     to be added or modified according to the regional radio regulation to comply with.
//! Valid modem configuration No.4
const_RpRegionModemCfgDef_t_RpRegionModemCfgDef4[]
   = {
      // modem.
                 sfDr, bwFdev
      {MODEM_LORA, 7, 125000}, {MODEM_FSK, 50000, 25000}
                .....
//! Valid modem configuration management
 const RpRegionModemCfg_t RpRegionModemCfg[]
   = {
                                                                pModemCfg
      {sizeof(RpRegionModemCfgDef0)/sizeof(RpRegionModemCfgDef t), &RpRegionModemCfgDef0[0]},
      {sizeof(RpRegionModemCfgDef1)/sizeof(RpRegionModemCfgDef t), &RpRegionModemCfgDef1[0]},
      {sizeof(RpRegionModemCfgDef2)/sizeof(RpRegionModemCfgDef t), &RpRegionModemCfgDef2[0]},
{sizeof(RpRegionModemCfgDef3)/sizeof(RpRegionModemCfgDef_t), &RpRegionModemCfgDef3[0]}, 
{sizeof(RpRegionModemCfgDef4)/sizeof(RpRegionModemCfgDef_t), &RpRegionModemCfgDef4[0]},
       If additionally defined RpRegionModemCfgDevN[], its related information
       needs be added to RpRegionModemCfg[].
```

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 1millisecond (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 RSSI OFFSET of the radio driver. For PIB RSSI OFFSET, refer to [1].



Revision History

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

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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.).
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(Rev.5.0-1 October 2020)

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TOYOSU FORESIA, 3-2-24 Toyosu, Koto-ku, Tokyo 135-0061, Japan www.renesas.com

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