RN2483 LoRa® Technology Module Command Reference User's Guide

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Preface

NOTICE TO CUSTOMERS

All documentation becomes dated, and this manual is no exception. Microchip tools and documentation are constantly evolving to meet customer needs, so some actual dialogs and/or tool descriptions may differ from those in this document. Please refer to our website (www.microchip.com) to obtain the latest documentation available.

Documents are identified with a "DS" number. This number is located on the bottom of each page, in front of the page number. The numbering convention for the DS number is "DSXXXXXA", where "XXXXX" is the document number and "A" is the revision level of the document.

For the most up-to-date information on development tools, see the MPLAB® IDE online help. Select the Help menu, and then Topics to open a list of available online help files.

INTRODUCTION

This chapter contains general information that will be useful to know before using the RN2483 module. Topics discussed in this chapter include:

- Document Layout
- Conventions Used in this Guide
- Recommended Reading
- The Microchip Website
- Development Systems Customer Change Notification Service
- Customer Support
- Revision History

DOCUMENT LAYOUT

This command reference user's guide provides information for configuring the RN2483 low-power long-range LoRa® technology transceiver module, including a description of communication and command references. The document is organized as follows:

- **Chapter 1. "Introduction"** – This chapter introduces the RN2483 module and provides a brief overview of its features.
- **Chapter 2. "Command Reference"** – This chapter provides information on the commands used to configure the RN2483 module with examples.
- **Chapter 3. "Bootloader Usage"** - This chapter gives further information on the bootloader usage and protocol commands.
- **Appendix A. "Current Firmware Features and Fixes "** – This chapter provides information on the release notes for each revision of the firmware.

CONVENTIONS USED IN THIS GUIDE

This manual uses the following documentation conventions:

DOCUMENTATION CONVENTIONS

Description	Represents	Examples
Arial font:		
Italic characters	Referenced books	*MPLAB® IDE User's Guide*
	Emphasized text	...is the *only* compiler...
Initial caps	A window	the Output window
	A dialog	the Settings dialog
	A menu selection	select Enable Programmer
Quotes	A field name in a window or dialog	"Save project before build"
Underlined, italic text with right angle bracket	A menu path	*File>Save*
Bold characters	A dialog button	Click **OK**
	A tab	Click the **Power** tab
N'Rnnnn	A number in verilog format, where N is the total number of digits, R is the radix and n is a digit.	4'b0010, 2'hF1
Text in angle brackets < >	A key on the keyboard	Press <Enter>, <F1>
Courier New font:		
Plain Courier New	Sample source code	`#define START`
	Filenames	`autoexec.bat`
	File paths	`c:\mcc18\h`
	Keywords	`_asm, _endasm, static`
	Command-line options	`-Opa+, -Opa-`
	Bit values	`0, 1`
	Constants	`0xFF, 'A'`
Italic Courier New	A variable argument	*`file`*`.o`, where *`file`* can be any valid filename
Square brackets [ ]	Optional arguments	`mcc18 [options]` *`file`* `[options]`
Curly brackets and pipe character: { | }	Choice of mutually exclusive arguments; an OR selection	`errorlevel {0|1}`
Ellipses...	Replaces repeated text	`var_name [, var_name...]`
	Represents code supplied by user	`void main (void) { ... }`

RECOMMENDED READING

This command reference user's guide describes how to configure the RN2483 module. The module-specific data sheet contains current information on the module specifications. Other useful documents are listed below. The following documents are available and recommended as supplemental reference resources:

RN2483 Low-Power Long-Range LoRa® Technology Transceiver Module Data Sheet (DS50002346)

This data sheet provides detailed specifications for the RN2483 module.

LoRa® Alliance: LoRaWAN™ Specification

This document describes the LoRaWAN Class A protocol, which is optimized for battery-powered end devices. This specification is available from the LoRa Alliance at http://www.lora-alliance.org.

To obtain any of Microchip's documents, visit the Microchip website at www.microchip.com.

THE MICROCHIP WEBSITE

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- **Product Support** – Data sheets and errata, application notes and sample programs, design resources, user's guides and hardware support documents, latest software releases and archived software
- **General Technical Support** – Frequently Asked Questions (FAQs), technical support requests, online discussion groups, Microchip consultant program member listing
- **Business of Microchip** – Product selector and ordering guides, latest Microchip press releases, listing of seminars and events, listings of Microchip sales offices, distributors and factory representatives

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- **Compilers** – The latest information on Microchip C compilers, assemblers, linkers and other language tools. These include all MPLAB C compilers; all MPLAB assemblers (including MPASM™ assembler); all MPLAB linkers (including MPLINK™ object linker); and all MPLAB librarians (including MPLIB™ object librarian).
- **Emulators** – The latest information on Microchip in-circuit emulators.This includes the MPLAB REAL ICE™ and MPLAB ICE 2000 in-circuit emulators.
- **In-Circuit Debuggers** – The latest information on the Microchip in-circuit debuggers. This includes MPLAB ICD 3 in-circuit debuggers and PICkit™ 3 debug express.
- **MPLAB® IDE** – The latest information on Microchip MPLAB IDE, the Windows® Integrated Development Environment for development systems tools. This list is focused on the MPLAB IDE, MPLAB IDE Project Manager, MPLAB Editor and MPLAB SIM simulator, as well as general editing and debugging features.
- **Programmers** – The latest information on Microchip programmers. These include production programmers such as MPLAB REAL ICE in-circuit emulator, MPLAB ICD 3 in-circuit debugger and MPLAB PM3 device programmers. Also included are non-production development programmers such as PICSTART® Plus and PICkit 2 and 3.

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- Distributor or Representative
- Local Sales Office
- Field Application Engineer (FAE)
- Technical Support

Customers should contact their distributor, representative or field application engineer (FAE) for support. Local sales offices are also available to help customers. A listing of sales offices and locations is included in the back of this document.

Technical support is available through the website at:

http://www.microchip.com/support.

REVISION HISTORY

Revision A (March 2015)

Initial release of the document.

Revision B (March 2015)

Update to Section 1.4.

Revision C (November 2015)

Added 2.3.6.5, 2.3.6.6, 2.3.6.7, 2.4.8.16, 2.4.8.17 sections; Updated 2-4, 2-6, 2-8 and 2-14 Tables, Updated 2.3.5.2, 2.4.4, 2.4.9.7, 2.4.9.18, and 2.5.5.17 sections; Other minor corrections.

Revision D (February 2016)

Added a new Note box in section 2.4.9.2, updated section 2.4.9.16 and Figure 2-1, added A.3 section; Other minor corrections.

Revision E (February 2016)

Removed Version 1.0.2 in section A.4; Other minor corrections.

Revision F (March 2017)

Added Chapter 3 (Bootloader Usage); Other minor corrections.

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Chapter 1. Introduction

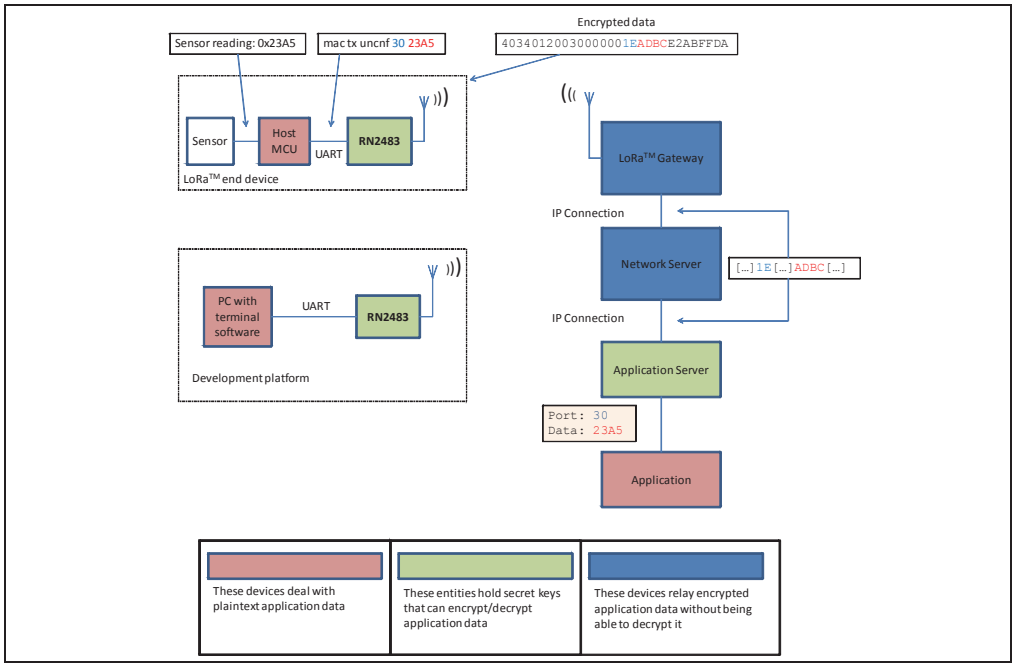
1.1 OVERVIEW

The Microchip RN2483 module provides LoRaWAN™ protocol connectivity using a simple UART interface. This module handles the LoRaWAN Class A protocol and provides an optimized text command/response interface to the host system. This document is intended to describe an implementation of the LoRaWAN Class A protocol. LoRaWAN protocol terms are described in more detail in the *LoRaWAN Specification* available from the LoRa Alliance (http://www.lora-alliance.org). Thus, it is recommended to review the *LoRaWAN Specification* before using the RN2483 module.

The required configuration for accessing a LoRa technology network is minimal and can be stored in the module's EEPROM, allowing for factory configuration of these parameters, lowering the requirements for the host system while also increasing system security. The module also features GPIO pins that can be configured through the UART interface.

A simple use case is described in Figure 1-1 where an end device, containing a host MCU which reads a sensor, commands the RN2483 to transmit the sensor reading over the LoRa network. Data are encrypted by the RN2483 and the radio packet is received by one or multiple gateways which forward it to the network server. The network server sends the data to the application server which has the key to decrypt the application data. Similarly, a development platform may consist of an RN2483 directly connected over UART to a PC which becomes the host system in this case. Users can then type commands into the module using a terminal program.

FIGURE 1-1: SIMPLE LoRa® TECHNOLOGY NETWORK DIAGRAM



The flow of data can be followed as it gets generated by an end device and transported on the network.

1.2 FEATURES

- LoRaWAN Class A protocol compliance
- Integrated FSK, GFSK and LoRa technology transceiver allowing the user to transmit custom packets using these protocols
- Globally unique 64-bit identifier (EUI-64™)
- Configurable GPIOs
- Intelligent Low-Power mode with programmable/on-demand wake-up
- Bootloader for firmware upgrade
- All configuration and control done over UART using simple ASCII commands

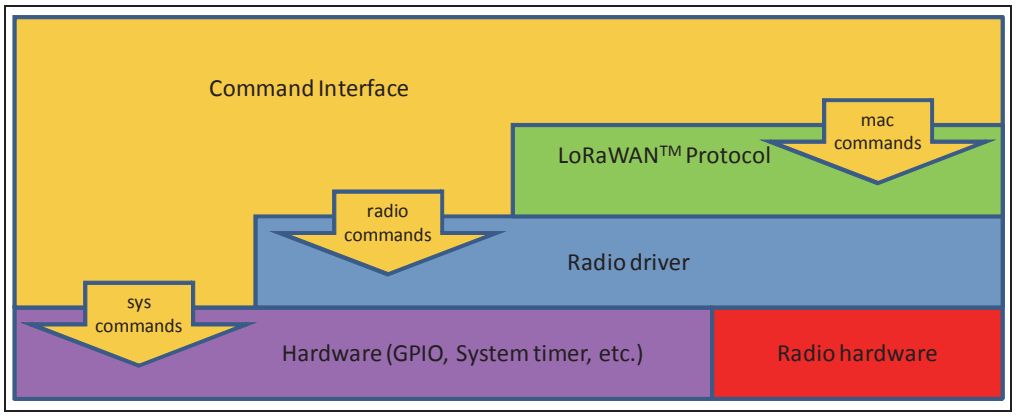
Refer to the *RN2483, Low-Power Long-Range LoRa® Technology Transceiver Module Data Sheet* (DS50002346) for details on the hardware specifications of the module.

1.3 CONFIGURATION

The RN2483 module's architecture is described in Figure 1-2 from the command interface point of view. There are three types of commands that can be used, and each allows access to different module functions:

- LoRaWAN Class A configuration and control, using the `mac` group of commands
- Radio configuration and control, using the `radio` group of commands
- Other module functions, using the `sys` group of commands

FIGURE 1-2: RN2483 COMMAND INTERFACE (YELLOW) AND ITS RELATIONSHIP TO THE MODULE'S INTERNAL COMPONENTS



The available commands can be used to configure and control the LoRaWAN protocol layer, the radio driver and some system peripherals.

In order to communicate with a LoRa network, a specific number of parameters need to be configured. Since two distinctive methods are offered for a device to become part of the network, each of these requires different parameters:

- Over-the-Air Activation (OTAA), where a device negotiates network encryption keys at the time it joins the network. For this, the device EUI, application EUI and application key need to be configured and then the OTAA procedure can start.
- Activation by Personalization (ABP) where the device already contains the network keys and can directly start communication with the network. Configuring the device address, network session key and application session key is sufficient for this type of initialization.

For increased security, these parameters can be configured and stored in the module's EEPROM during manufacturing of devices requiring LoRaWAN connectivity. Thus, the keys do not need to be sent over the UART interface by the host system every time the device powers up.

1.4 UART INTERFACE

All of the RN2483 module's settings and commands are transmitted over UART using the ASCII interface.

All commands need to be terminated with <CR><LF> and any replies they generate will also be terminated by the same sequence.

The default settings for the UART interface are 57600 bps, 8 bits, no parity, 1 Stop bit, no flow control. The baud rate can be changed by triggering the auto-baud detection sequence of the module. To do this, the host system needs to transmit to the module a break condition followed by a 0x55 character at the new baud rate. The auto-baud detection mechanism can also be triggered during Sleep to wake the module up before the predetermined time has expired.

Note: A break condition is signaled to the module by keeping the UART_RX pin low for longer than the time to transmit a complete character. For example, at the default baud rate of 57600 bps keeping the UART_RX pin low for 938 μs is a valid break condition, whereas at 9600 bps this would be interpreted as a 0x00 character. Thus, the break condition needs to be long enough to still be interpreted as such at the baud rate that is currently in use.

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Chapter 2. Command Reference

The RN2483 LoRa technology module supports a variety of commands for configuration. This section describes these commands in detail and provides examples.

2.1 COMMAND SYNTAX

To issue commands to the RN2483 module, the user sends keywords followed by optional parameters. Commands (keywords) are case sensitive, and spaces must not be used in parameters. Hex input data can be uppercase or lowercase. String text data, such as `OTAA` used for the join procedure, is case-insensitive.

The use of shorthand for parameters is *NOT* supported.

Depending on the command, the parameter may expect values in either decimal or hexadecimal form; refer to the command description for the expected form. For example, when configuring the frequency, the command expects a decimal value in Hertz such as `868100000` (868.1 MHz). Alternatively, when configuring the LoRaWAN device address, the hex value is entered into the parameter as `aabbccdd`. To enter a number in hex form, use the value directly. For example, the hex value `0xFF` would be entered as `FF`.

2.2 COMMAND ORGANIZATION

There are three general command categories, as shown in Table 2-1.

TABLE 2-1: COMMAND TYPES

Command Type	Keyword	Description
System	`<sys>`	Issues system level behavior actions, gathers status information on the firmware and hardware version, or accesses the module user EEPROM memory.
LoRaWAN™ Class A Protocol	`<mac>`	Issues LoRaWAN Class A protocol network communication behaviors, actions and configurations commands.
Transceiver commands	`<radio>`	Issues radio specific configurations, directly accessing and updating the transceiver setup.

Once the LoRaWAN Class A protocol configuration is complete, the user must save the settings to store the configuration data, otherwise it will not take effect upon reboot or Reset.

Note: Upon successful reception of commands, the module will respond with one of the following:

- `ok`
- `invalid_param`
- Requested Information
- Descriptive Error Message

Note: To facilitate the sharing of the radio between user custom applications and the LoRaWAN MAC, please refer to the `mac pause` and `mac resume` commands. Since no sharing exists between `sys` and other types of commands, there is no need for additional `pause` commands.

2.3 SYSTEM COMMANDS

System commands begin with the system keyword `<sys>` and include the categories shown in Table 2-2, Table 2-3 and Table 2-4.

TABLE 2-2: SYSTEM COMMANDS

Parameter	Description
`sleep`	Puts the system in Sleep for a finite number of milliseconds.
`reset`	Resets and restarts the RN2483 module.
`eraseFW`	Deletes the current RN2483 module application firmware and prepares it for firmware upgrade. The RN2483 module bootloader is ready to receive new firmware.
`factoryRESET`	Resets the RN2483 module's configuration data and user EEPROM to factory default values and restarts the RN2483 module.
`set`(1)	Sets specified system parameter values.
`get`(1)	Gets specified system parameter values.

Note 1: Refer to Table 2-3 for system `<set>` and Table 2-4 for system `<get>` command summaries.

2.3.1 sys sleep <length>

`<length>`: decimal number representing the number of milliseconds the system is put to Sleep, from 100 to 4294967296.

Response: `ok` after the system gets back from Sleep mode

`invalid_param` if the length is not valid

This command puts the system to Sleep for the specified number of milliseconds. The module can be forced to exit from Sleep by sending a break condition followed by a `0x55` character at the new baud rate. Note that the break condition needs to be long enough not to be interpreted as a valid character at the current baud rate.

Example: **`sys sleep 120`** // Puts the system to Sleep for 120 ms.

2.3.2 sys reset

Response: `RN2483 X.Y.Z MMM DD YYYY HH:MM:SS`, where X.Y.Z is firmware version, MMM is month, DD is day, HH:MM:SS is hour, minutes, seconds (format: [HW] [FW] [Date] [Time]). [Date] and [Time] refer to the release of the firmware.

This command resets and restarts the RN2483 module; stored internal configurations will be loaded automatically upon reboot.

Example: **`sys reset`** // Resets and restarts the RN2483 module.

2.3.3 sys eraseFW

Response: no response

This command deletes the current RN2483 module application firmware and prepares it for firmware upgrade. The RN2483 module bootloader is ready to receive new firmware.

Example: **`sys eraseFW`** // Deletes the current RN2483 module application firmware.

2.3.4 sys factoryRESET

Response: RN2483 X.Y.Z MMM DD YYYY HH:MM:SS, where X.Y.Z is firmware version, MMM is month, DD is day, HH:MM:SS is hour, minutes, seconds (format: [HW] [FW] [Date] [Time]). [Date] and [Time] refer to the release of the firmware.

This command resets the module's configuration data and user EEPROM to factory default values and restarts the module. After factoryRESET, the RN2483 module will automatically reset and all configuration parameters are restored to factory default values.

Example: **sys factoryRESET** // Restores factory default values.

2.3.5 System Set Commands

TABLE 2-3: SYSTEM SET COMMANDS

Parameter	Description
nvm	Stores <data> to a location <address> of user EEPROM.
pindig	Allows user to set and clear available digital pins.
pinmode	Allows user to set the functionality of a pin to either digital input, digital output or analog input (if available).

2.3.5.1 sys set nvm <address> <data>

<address>: hexadecimal number representing user EEPROM address, from 300 to 3FF

<data>: hexadecimal number representing data, from 00 to FF

Response: ok if the parameters (address and data) are valid

invalid_param if the parameters (address and data) are not valid

This command allows the user to modify the user EEPROM at <address> with the value supplied by <data>. Both <address> and <data> must be entered as hex values. The user EEPROM memory is located inside the MCU on the module.

Example: **sys set nvm 300 A5** // Stores the value 0xA5 at user EEPROM address 0x300.

2.3.5.2 sys set pinmode <pinname> <pinFunc>

<pinname>: string representing the pin. Parameters can be: GPIO0 - GPIO13, UART_CTS, UART_RTS, TEST0, TEST1

<pinFunc>: string representing the function of the pin. Parameters can be: digout, digin or ana.

Response: ok if the parameters are valid

invalid_param if the parameters are not valid

This command allows the user to configure the function on a pin. A pin can be configured as digital output by using the digout parameter. A pin can be configured as digital input by using the digin parameter. A pin can be configured as analog input by using the ana parameter.

Note: Not all pins have analog input functionality.

Example: `sys set pinmode GPIO0 ana` //Configures GPIO0 as analog input

Note: This command must be called prior to reading or setting the value of a pin in order to have correct behavior.

2.3.5.3 `sys set pindig <pinname> <pinstate>`

`<pinname>`: string representing the pin. Parameter values can be: `GPIO0 - GPIO13`, `UART_CTS`, `UART_RTS`, `TEST0`, `TEST1`

`<pinstate>`: decimal number representing the state. Parameter values can be: 0 or 1.

Response: `ok` if the parameters (`<pinname>`, `<pinstate>`) are valid

`invalid_param` if the parameters (`<pinname>`, `<pinstate>`) are not valid

This command allows the user to modify the unused pins available for use by the module. The selected `<pinname>` is driven high or low depending on the desired `<pinstate>`.

Default: `GPIO0-GPIO13`, `UART_CTS`, `UART_RTS`, `TEST0` and `TEST1` are driven low (value 0).

Example: **`sys set pindig GPIO5 1`** // Drives GPIO5 high 1, VDD.

Note: In order for the pin to be driven to a value, make sure you have first configured the pin to be a digital output using the command `sys set pinmode <pinname> digout`.

2.3.6 System Get Commands

TABLE 2-4: SYSTEM GET COMMANDS

Parameter	Description
`ver`	Returns the information on hardware platform, firmware version, release date.
`nvm`	Returns data from the requested user EEPROM `<address>`.
`vdd`	Returns measured voltage in mV.
`hweui`	Returns the preprogrammed EUI node address.
`pindig`	Returns the state of a digital input.
`pinana`	Returns the state of an analog input.

2.3.6.1 `sys get ver`

Response: `RN2483 X.Y.Z MMM DD YYYY HH:MM:SS`, where X.Y.Z is firmware version, MMM is month, DD is day, HH:MM:SS is hour, minutes, seconds (format: [HW] [FW] [Date] [Time]). [Date] and [Time] refer to the release of the firmware.

This command returns the information related to the hardware platform, firmware version, release date and time stamp on firmware creation.

Example: **`sys get ver`** // Returns version-related information.

2.3.6.2 `sys get nvm <address>`

`<address>`: hexadecimal number representing user EEPROM address, from 300 to 3FF

Response: 00 – FF (hexadecimal value from 00 to FF) if the address is valid

`invalid_param` if the address is not valid

This command returns the data stored in the user EEPROM of the RN2483 module at the requested `<address>` location.

Example: **`sys get nvm 300`** // Returns the 8-bit hex value stored at 300.

2.3.6.3 `sys get vdd`

Response: 0–3600 (decimal value from 0 to 3600)

This command informs the RN2483 module to do an ADC conversion on the VDD. The measurement is converted and returned as a voltage (mV).

Example: **`sys get vdd`** // Returns mV measured on the VDD module.

2.3.6.4 `sys get hweui`

Response: hexadecimal number representing the preprogrammed EUI node address

This command reads the preprogrammed EUI node address from the RN2483 module. The value returned by this command is a globally unique number provided by Microchip.

Example: **`sys get hweui`** // Reads the preprogrammed EUI node address.

Note: The preprogrammed EUI node address is a read-only value and cannot be changed or erased. This value can be used to configure the device EUI using the `mac set deveui` command (see Section 2.4.8.2).

2.3.6.5 `sys get pindig <pinname>`

`<pinname>`: string representing the pin. Parameters can be: `GPIO0 – GPIO13`, `UART_CTS`, `UART_RTS`, `TEST0`, `TEST1`

Response: decimal number representing the state (either 0 or 1).

This command allows the user to read the state of a digital input. To be used as a digital input, a pin needs to be configured using the `sys set pinmode` command.

Example: `sys get pindig GPIO0` //Reads the state of the GPIO0 digital input

Note: The `sys set pinmode <pinname> digin` command must be called to configure the function of the pin prior to reading its digital input value.

2.3.6.6 `sys get pinana <pinname>`

`<pinname>`: string representing the pin. Parameters can be: `GPIO0` - `GPIO3`, `GPIO5` - `GPIO13`

Response: decimal number representing the result of the conversion, from 0 to 1023, where 0 represents 0V and 1023 is VDD, the supply voltage of the module.

This command allows the user to read the state of an analog input. To be used as an analog input, a pin needs to be configured using the `sys set pinmode` command.

Example: `sys get pinana GPIO0` //Reads the state of the GPIO0 analog input

Note: The `sys set pinmode <pinname> ana` command must be called to configure the function of the pin prior to reading its analog input value.

2.4 MAC COMMANDS

LoRaWAN Class A protocol commands begin with the system keyword `mac` and include the categories shown in Table 2-5 through Table 2-9.

TABLE 2-5: MAC COMMANDS

Parameter	Description
`reset`	Resets the RN2483 module to a specific frequency band.
`tx`	Sends the data string on a specified port number and sets default values for most of the LoRaWAN™ parameters.
`join`	Informs the RN2483 module to join the configured network.
`save`	Saves LoRaWAN Class A configuration parameters to the user EEPROM.
`forceENABLE`	Enables the RN2483 module after the LoRaWAN network server commanded the end device to become silent immediately.
`pause`	Pauses LoRaWAN stack functionality to allow transceiver (radio) configuration.
`resume`	Restores the LoRaWAN stack functionality.
`set`	Accesses and modifies specific MAC related parameters.
`get`	Reads back current MAC related parameters from the module.

2.4.1 `mac reset <band>`

`<band>`: decimal number representing the frequency band, either 868 or 433

Response: `ok` if band is valid

`invalid_param` if band is not valid

This command will automatically reset the software LoRaWAN stack and initialize it with the parameters for the selected band.

Example: **`mac reset 868`** // Sets the default values and selects the 868 default band.

Note: This command will set default values for most of the LoRaWAN™ parameters. Everything set prior to this command will lose its set value.

2.4.2 mac tx <type> <portno> <data>

<type>: string representing the uplink payload type, either cnf or uncnf (cnf – confirmed, uncnf – unconfirmed)

<portno>: decimal number representing the port number, from 1 to 223

<data>: hexadecimal value. The length of <data> bytes capable of being transmitted are dependent upon the set data rate (please refer to the *LoRaWAN™ Specification* for further details).

Response: this command may reply with two responses. The first response will be received immediately after entering the command. In case the command is valid (ok reply received), a second reply will be received after the end of the uplink transmission. Please refer to the *LoRaWAN™ Specification* for further details.

Response after entering the command:

- ok – if parameters and configurations are valid and the packet was forwarded to the radio transceiver for transmission
- invalid_param – if parameters (<type> <portno> <data>) are not valid
- not_joined – if the network is not joined
- no_free_ch – if all channels are busy
- silent – if the module is in a Silent Immediately state
- frame_counter_err_rejoin_needed – if the frame counter rolled over
- busy – if MAC state is not in an Idle state
- mac_paused – if MAC was paused and not resumed back
- invalid_data_len if application payload length is greater than the maximum application payload length corresponding to the current data rate

Response after the uplink transmission:

- mac_tx_ok if uplink transmission was successful and no downlink data was received back from the server;
- mac_rx <portno> <data> if transmission was successful, <portno>: port number, from 1 to 223; <data>: hexadecimal value that was received from the server;
- mac_err if transmission was unsuccessful, ACK not received back from the server
- invalid_data_len if application payload length is greater than the maximum application payload length corresponding to the current data rate

A confirmed message will expect an acknowledgment from the server; otherwise, the message will be retransmitted by the number indicated by the command mac set retx <value>, whereas an unconfirmed message will not expect any acknowledgment back from the server. Please refer to the *LoRaWAN™ Specification* for further details.

If the automatic reply feature is enabled and the server sets the Frame Pending bit or initiates downlink confirmed transmissions, multiple responses will be displayed after each downlink packet is received by the module. A typical scenario for this case would be (prerequisites: free LoRaWAN channels available and automatic reply enabled):

- The module sends a packet on port 4 with application payload `0xAB`
- Radio transmission is successful and the module will display the first response: `ok`
- The server needs to send two separate downlink confirmed packets back on port 1 with the following data: `0xAC`, then `0xAF`. First it will transmit the first one (`0xAC`) and will set the Frame Pending bit. The module will display the second response `mac_rx 1 AC`
- The module will initiate an automatic uplink unconfirmed transmission with no application payload on the first free channel because the Frame Pending bit was set in the downlink transmission
- The server will send back the second confirmed packet (`0xAF`). The module will display a third response `mac_rx 1 AF`
- The module will initiate an automatic unconfirmed transmission with no application payload on the first free channel because the last downlink transmission was confirmed, so the server needs an ACK
- If no reply is received back from the server, the module will display the fourth response after the end of the second Receive window: `mac_tx_ok`
- After this scenario, the user is allowed to send packets when at least one enabled channel is free

Based on this scenario, the following responses will be displayed by the module:

- `mac tx cnf 4 AB`
- `ok`
- `mac_rx 1 AC`
- `mac_rx 1 AF`
- `mac_tx_ok`

Example: **`mac tx cnf 4 5A5B5B`** // Sends a confirmed frame on port 4 with application payload 5A5B5B.

2.4.3 mac join <mode>

<mode>: string representing the join procedure type (case-insensitive), either otaa or abp (otaa – over-the-air activation, abp – activation by personalization).

Response: this command may reply with two responses. The first response will be received immediately after entering the command. In case the command is valid (ok reply received) a second reply will be received after the end of the join procedure. Please refer to the *LoRaWAN™ Specification* for further details.

Response after entering the command:

- ok – if parameters and configurations are valid and the join request packet was forwarded to the radio transceiver for transmission
- invalid_param – if <mode> is not valid
- keys_not_init – if the keys corresponding to the Join mode (otaa or abp) were not configured
- no_free_ch – if all channels are busy
- silent – if the device is in a Silent Immediately state
- busy – if MAC state is not in an Idle state
- mac_paused – if MAC was paused and not resumed back

Response after the join procedure:

- denied if the join procedure was unsuccessful (the module attempted to join the network, but was rejected);
- accepted if the join procedure was successful;

This command informs the RN2483 module it should attempt to join the configured network. Module activation type is selected with <mode>. Parameter values can be otaa (over-the-air activation) or abp (activation by personalization). The <mode> parameter is not case sensitive. Before joining the network, the specific parameters for each activation type should be configured (for over the air activation: device EUI, application EUI, application key; for activation by personalization: device address, network session key, application session key).

Example: **mac join otaa** // Attempts to join the network using over-the-air activation.

2.4.4 mac save

Response: `ok`

The `mac save` command must be issued after configuration parameters have been appropriately entered from the `mac set <cmd>` commands. This command will save LoRaWAN Class A protocol configuration parameters to the user EEPROM. When the next `sys reset` command is issued, the LoRaWAN Class A protocol configuration will be initialized with the last saved parameters.

The LoRaWAN Class A protocol configuration savable parameters are:

- `band`: Band
- `fcntup`: Uplink Frame Counter
- `fcntdown`: Downlink Frame Counter
- `dr`: Data Rate
- `rx2dr`: Data Rate parameter for the second receive window
- `rx2freq`: Frequency parameter for the second receive window
- `adr`: Adaptive Data Rate state
- `deveui`: End-Device Identifier
- `appeui`: Application Identifier
- `appkey`: Application Key
- `nwkskey`: Network Session Key
- `appskey`: Application Session Key
- `devaddr`: End Device Address
- `ch`: All Channel Parameter
  - `freq`: Frequency
  - `dcycle`: Duty Cycle
  - `drrange`: Data Rate Range
  - `status`: Status

Example: **`mac save`** // Saves the LoRaWAN Class A protocol configuration parameters to the user EEPROM.

2.4.5 mac forceENABLE

Response: `ok`

The network can issue a certain command (Duty Cycle Request frame with parameter 255) that would require the RN2483 module to go silent immediately. This mechanism disables any further communication of the module, effectively isolating it from the network. Using `mac forceENABLE`, after this network command has been received, restores the module's connectivity by allowing it to send data.

Example: **`mac forceENABLE`** // Disables the Silent Immediately state.

2.4.6 mac pause

Response: 0 – 4294967295 (decimal number representing the number of milliseconds the mac can be paused)

This command pauses the LoRaWAN stack functionality to allow transceiver (radio) configuration. Through the use of `mac pause`, radio commands can be generated between a LoRaWAN Class A protocol uplink application (`mac tx` command), and the LoRaWAN Class A protocol Receive windows (second response for the `mac tx` command). This command will reply with the time interval in milliseconds that the transceiver can be used without affecting the LoRaWAN functionality. The maximum value (4294967295) is returned whenever the LoRaWAN stack functionality is in Idle state and the transceiver can be used without restrictions. '`0`' is returned when the LoRaWAN stack functionality cannot be paused. After the radio configuration is complete, the `mac resume` command should be used to return to LoRaWAN Class A protocol commands.

Example: **`mac pause`** // Pauses the LoRaWAN stack functionality if the response is different from 0.

Note:	If already joined to a network, this command *MUST* be called *BEFORE* configuring the radio parameters, initiating radio reception, or transmission.

2.4.7 mac resume

Response: `ok`

This command resumes LoRaWAN stack functionality, in order to continue normal functionality after being paused.

Example: **`mac resume`** // Resumes the LoRaWAN stack functionality.

Note:	This command *MUST* be called *AFTER* all radio commands have been issued and all the corresponding asynchronous messages have been replied.

2.4.8 MAC Set Commands

TABLE 2-6: MAC SET COMMANDS

Parameter	Description
devaddr	Sets the unique network device address for the RN2483 module.
deveui	Sets the globally unique identifier for the RN2483 module.
appeui	Sets the application identifier for the RN2483 module.
nwkskey	Sets the network session key for the RN2483 module.
appskey	Sets the application session key for the RN2483 module.
appkey	Sets the application key for the RN2483 module.
pwridx	Sets the output power to be used on the next transmissions.
dr	Sets the data rate to be used for the next transmissions.
adr	Sets if the adaptive data rate is to be enabled, or disabled.
bat	Sets the battery level needed for Device Status Answer frame command response.
retx	Sets the number of retransmissions to be used for an uplink confirmed packet.
linkchk	Sets the time interval for the link check process to be triggered.
rxdelay1	Sets the value used for the first Receive window delay.
ar	Sets the state of the automatic reply.
rx2	Sets the data rate and frequency used for the second Receive window.
sync	Sets the synchronization word for the LoRaWAN™ communication.
upctr	Sets the value of the uplink frame counter that will be used for the next uplink transmission.
dnctr	Sets the value of the downlink frame counter that will be used for the next downlink reception.
ch	Allows modification of channel related parameters.

2.4.8.1 mac set devaddr <address>

<address>: 4-byte hexadecimal number representing the device address, from 00000000 – FFFFFFFF

Response: ok if address is valid

invalid_param if address is not valid

This command configures the module with a 4-byte unique network device address <address>. The <address> *MUST* be *UNIQUE* to the current network. This must be directly set solely for activation by personalization devices. This parameter must not be set before attempting to join using over-the-air activation because it will be overwritten once the join process is over.

Example: **mac set devaddr ABCDEF01**

Note: If this parameter had previously been saved to user EEPROM by issuing the mac save command, after modifying its value, the mac save command should be called again.

2.4.8.2 mac set deveui <devEUI>

<devEUI>: 8-byte hexadecimal number representing the device EUI

Response: ok if address is valid

invalid_param if address is not valid

This command sets the globally unique device identifier for the module. The identifier must be set by the host MCU. The module contains a pre-programmed unique EUI and can be retrieved using the sys get hweui command (see Section 2.3.6.4) or user provided EUI can be configured using the mac set deveui command.

Example: **mac set deveui 0004A30B001A55ED**

> **Note:** If this parameter was previously saved to user EEPROM by issuing the mac save command, after modifying its value, the mac save command should be called again.

2.4.8.3 mac set appeui <appEUI>

<appEUI>: 8-byte hexadecimal number representing the application EUI

Response: ok if EUI is valid

invalid_param if EUI is not valid

This command sets the application identifier for the module. The application identifier should be used to identify device types (sensor device, lighting device, etc.) within the network.

Example: **mac set appeui FEDCBA9876543210**

> **Note:** If this parameter was previously saved to user EEPROM by issuing the mac save command, after modifying its value, the mac save command should be called again.

2.4.8.4 mac set nwkskey <nwksesskey>

<nwkSessKey>: 16-byte hexadecimal number representing the network session key

Response: ok if key is valid

invalid_param if key is not valid

This command sets the network session key for the module. This key is 16 bytes in length, and provides security for communication between the module and network server.

Example: **mac set nwkskey 1029384756AFBECD5647382910DACFEB**

> **Note:** If this parameter was previously saved to user EEPROM by issuing the mac save command, after modifying its value, the mac save command should be called again.

2.4.8.5 `mac set appskey <appSesskey>`

`<appSessKey>`: 16-byte hexadecimal number representing the application session key

Response: `ok` if key is valid

`invalid_param` if key is not valid

This command sets the application session key for the module. This key provides security for communication between module and application server.

Example: **`mac set appskey AFBECD56473829100192837465FAEBDC`**

> **Note:** If this parameter was previously saved to user EEPROM by issuing the `mac save` command, after modifying its value, the `mac save` command should be called again.

2.4.8.6 `mac set appkey <appKey>`

`<appKey>`: 16-byte hexadecimal number representing the application key

Response: `ok` if key is valid

`invalid_param` if key is not valid

This command sets the application key for the module. The application key is used to derive the security credentials for communication during over-the-air activation.

Example: **`mac set appkey 00112233445566778899AABBCCDDEEFF`**

> **Note:** If this parameter was previously saved to user EEPROM by issuing the `mac save` command, after modifying its value, the `mac save` command should be called again.

2.4.8.7 `mac set pwridx <pwrIndex>`

`<pwrIndex>`: decimal number representing the index value for the output power, from 0 to 5 for 433 MHz frequency band and from 1 to 5 for 868 MHz frequency band.

Response: `ok` if power index is valid

`invalid_param` if power index is not valid

This command sets the output power to be used on the next transmissions. Refer to the *LoRaWAN™ Specification* for the output power corresponding to the `<pwrIndex>` and also to the *RN2483 Low-Power Long-Range LoRa® Technology Transceiver Module Data Sheet* (DS50002346) for the actual radio power capabilities.

Example: **`mac set pwridx 1`** // Sets the TX output power to 14 dBm on the next transmission for a 868 MHz EU module.

2.4.8.8 `mac set dr <dataRate>`

`<dataRate>`: decimal number representing the data rate, from 0 and 7, but within the limits of the data rate range for the defined channels.

Response: `ok` if data rate is valid

`invalid_param` if data rate is not valid

This command sets the data rate to be used for the next transmission. Please refer to the *LoRaWAN™ Specification* for the description of data rates and the corresponding spreading factors.

Example: **`mac set dr 5`** // On EU863-870; SF7/125 kHz.

> **Note:** If this parameter had previously been saved to user EEPROM by issuing the `mac save` command, after modifying its value, the `mac save` command should be called again.

2.4.8.9 `mac set adr <state>`

`<state>`: string value representing the state, either `on` or `off`.

Response: `ok` if state is valid

`invalid_param` if state is not valid

This command sets if the adaptive data rate (ADR) is to be enabled, or disabled. The server is informed about the status of the module's ADR in every uplink frame it receives from the ADR field in uplink data packet. If ADR is enabled, the server will optimize the data rate and the transmission power of the module based on the information collected from the network.

Example: **`mac set adr on`** // This will enable the ADR mechanism.

> **Note:** If this parameter had previously been saved to user EEPROM by issuing the `mac save` command, after modifying its value, the `mac save` command should be called again.

2.4.8.10 `mac set bat <level>`

`<level>`: decimal number representing the level of the battery, from 0 to 255. '`0`' means external power, '`1`' means low level, 254 means high level, 255 means the end device was not able to measure the battery level.

Response: `ok` if the battery level is valid

`invalid_param` if the battery level is not valid

This command sets the battery level required for Device Status Answer frame in use with the LoRaWAN Class A protocol.

Example: **`mac set bat 127`** // Battery is set to ~50%.

2.4.8.11 `mac set retx <reTxNb>`

`<reTxNb>`: decimal number representing the number of retransmissions for an uplink confirmed packet, from 0 to 255.

Response: `ok` if `<retx>` is valid

`invalid_param` if `<retx>` is not valid

This command sets the number of retransmissions to be used for an uplink confirmed packet, if no downlink acknowledgment is received from the server.

Example: **`mac set retx 5`** // The number of retransmissions made for an uplink confirmed packet is set to 5.

2.4.8.12 `mac set linkchk <linkCheck>`

`<linkCheck>`: decimal number that sets the time interval in seconds for the link check process, from 0 to 65535

Response: `ok` if the time interval is valid

`invalid_param` if the time interval is not valid

This command sets the time interval for the link check process to be triggered periodically. A `<value>` of '0' will disable the link check process. When the time interval expires, the next application packet that will be sent to the server will include also a link check MAC command. Please refer to the *LoRaWAN™ Specification* for more information on the Link Check MAC command.

Example: **`mac set linkchk 600`** // The module will attempt a link check process at 600-second intervals.

Note: If the command `mac reset` is issued, the link check process will be set as disabled.

2.4.8.13 `mac set rxdelay1 <rxDelay>`

`<rxDelay>`: decimal number representing the delay between the transmission and the first Reception window in milliseconds, from 0 to 65535.

Response: `ok` if `<rxDelay>` is valid

`invalid_param` if `<rxDelay>` is not valid

This command will set the delay between the transmission and the first Reception window to the `<rxDelay>` in milliseconds. The delay between the transmission and the second Reception window is calculated in software as the delay between the transmission and the first Reception window + 1000 (ms).

Example: **`mac set rxdelay1 1000`** // Set the delay between the transmission and the first Receive window to 1000 ms.

2.4.8.14 `mac set ar <state>`

`<state>`: string value representing the state, either `on` or `off`.

Response: `ok` if state is valid

`invalid_param` if state is not valid

This command sets the state of the automatic reply. By enabling the automatic reply, the module will transmit a packet without a payload immediately after a confirmed downlink is received, or when the Frame Pending bit has been set by the server. If set to OFF, no automatic reply will be transmitted.

Example: **`mac set ar on`** // Enables the automatic reply process inside the module.

Note: The RN2483 module implementation will initiate automatic transmissions with no application payload if the automatic reply feature is enabled and the server sets the Frame Pending bit or initiates a confirmed downlink transmission. In this case, if all enabled channels are busy due to duty cycle limitations, the stack will wait for the first channel that will become free to transmit. The user will not be able to initiate uplink transmissions until the automatic transmissions are done.

2.4.8.15 `mac set rx2 <dataRate> <frequency>`

`<dataRate>`: decimal number representing the data rate, from 0 to 7.

`<frequency>`: decimal number representing the frequency, from 863000000 to 870000000 or from 433050000 to 434790000, in Hz.

Response: `ok` if parameters are valid

`invalid_param` if parameters are not valid

This command sets the data rate and frequency used for the second Receive window. The configuration of the Receive window parameters should be in concordance with the server configuration.

Example: **`mac set rx2 3 865000000`** // Receive window 2 is configured with SF9/125 kHz data rate with a center frequency of 865 MHz.

> **Note:** If this parameter had previously been saved to user EEPROM by issuing the `mac save` command, after modifying its value, the `mac save` command should be called again.

2.4.8.16 `mac set sync <synchWord>`

`<synchWord>`: one byte long hexadecimal number representing the synchronization word for the LoRaWAN communication

Response: `ok` if parameters are valid

`invalid_param` if parameter is not valid

This command sets the synchronization word for the LoRaWAN communication. The configuration of the synchronization word should be in concordance with the Gateway configuration.

Example: `mac set sync 34` //Synchronization word is configured to use the 0x34 value

2.4.8.17 `mac set upctr <fCntUp>`

`<fCntUp>`: decimal number representing the value of the uplink frame counter that will be used for the next uplink transmission, from 0 to 4294967295.

Response: `ok` if parameter is valid

`invalid_param` if parameter is not valid

This command sets the value of the uplink frame counter that will be used for the next uplink transmission.

Example: `mac set upctr 10`

> **Note:** If this parameter had previously been saved to user EEPROM by issuing the `mac save` command, after modifying its value, the `mac save` command should be called again.

2.4.8.18 mac set dnctr <fCntDown>

<fCntDown>: decimal number representing the value of the downlink frame counter that will be used for the next downlink reception, from 0 to 4294967295.

Response: ok if parameter is valid

invalid_param if parameter is not valid

This command sets the value of the downlink frame counter that will be used for the next downlink reception.

Example: mac set dnctr 30

> **Note:** If this parameter had previously been saved to user EEPROM by issuing the mac save command, after modifying its value, the mac save command should be called again.

2.4.8.19 MAC SET CHANNEL COMMANDS

TABLE 2-7: MAC SET CHANNEL COMMANDS

Parameter	Description
freq	Sets the module operation frequency on a given channel ID.
dcycle	Sets the module operation duty cycle on a given channel ID.
drrange	Sets the module allowed data rate range (min.- max.) allowed on a given channel ID.
status	Sets the use of the specified channel ID.

2.4.8.19.1 mac set ch freq <channelID> <frequency>

<channelId>: decimal number representing the channel number, from 3 to 15.

<frequency>: decimal number representing the frequency, from 863000000 to 870000000 or from 433050000 to 434790000, in Hz.

Response: ok if parameters are valid

invalid_param if parameters are not valid

This command sets the operational frequency on the given channel ID. The default channels (0-2) cannot be modified in terms of frequency.

Example: **mac set ch freq 13 864000000** // Define frequency for channel 13 to be 864 MHz.

> **Note:** If this parameter was previously saved to user EEPROM by issuing the mac save command, after modifying its value, the mac save command should be called again.

2.4.8.19.2 `mac set ch dcycle <channelID> <dutyCycle>`

`<channelId>`: decimal number representing the channel number, from 0 to 15.

`<dutyCycle>`: decimal number representing the duty cycle, from 0 to 65535.

Response: `ok` if parameters are valid

`invalid_param` if parameters are not valid

This command sets the duty cycle used on the given channel ID on the module. The `<dutyCycle>` value that needs to be configured can be obtained from the actual duty cycle X (in percentage) using the following formula: `<dutyCycle>` = (100/X) – 1. The default settings consider only the three default channels (0-2), and their default duty cycle is 0.33%. If a new channel is created either by the server or by the user, all the channels (including the default ones) must be updated by the user in terms of duty cycle to comply with the ETSI regulations.

Example: **`mac set ch dcycle 13 9`** // Defines duty cycle for channel 13 to be 10%. Since (100/10) – 1 = 9, the parameter that gets configured is 9.

Note: If this parameter was previously saved to user EEPROM by issuing the `mac save` command, after modifying its value, the `mac save` command should be called again.

2.4.8.19.3 `mac set ch drrange <channelID> <minRange> <maxRange>`

`<channelId>`: decimal number representing the channel number, from 0 to 15

`<minRange>`: decimal number representing the minimum data rate, from 0 to 7

`<maxRange>`: decimal number representing the maximum data rate, from 0 to 7

Response: `ok` if parameters are valid

`invalid_param` if parameters are not valid

This command sets the operating data rate range, min. to max., for the given `<channelId>`. By doing this the module can vary data rates between the `<minRange>` and `<maxRange>` on the specified `<channelId>`. Please refer to the *LoRaWAN™ Specification* for the actual values of the data rates and the corresponding spreading factors (SF).

Example: **`mac set ch drrange 13 0 2`** // Using EU863-870 band: on channel 13 the data rate can range from 0 (SF12/125 kHz) to 2 (SF10/125 kHz) as required.

Note: If this parameter was previously saved to user EEPROM by issuing the `mac save` command, after modifying its value, the `mac save` command should be called again.

2.4.8.19.4 `mac set ch status <channel ID> <status>`

`<channelId>`: decimal number representing the channel number, from 0 to 15.

`<status>`: string value representing the state, either `on` or `off`.

Response: `ok` if parameters are valid

`invalid_param` if parameters are not valid

This command sets the operation of the given `<channelId>`.

Example: **`mac set ch status 4 off`** // Channel ID 4 is disabled from use.

WARNING

`<ChannelId>` parameters (frequency, data range, duty cycle) must be issued prior to enabling the status of that channel.

Note: If this parameter was previously saved to user EEPROM by issuing the `mac save` command, after modifying its value, the `mac save` command should be called again.

2.4.9 MAC Get Commands

TABLE 2-8: MAC GET COMMANDS

Parameter	Description
devaddr	Gets the current stored unique network device address for that specific end device.
deveui	Gets the current stored globally unique identifier for that specific end device.
appeui	Gets the application identifier for the end device.
dr	Gets the data rate to be used for the next transmission.
band	Gets the current frequency band in operation.
pwridx	Gets the output power index value.
adr	Gets the state of adaptive data rate for the device.
retx	Gets the number of retransmissions to be used for an uplink confirmed packet.
rxdelay1	Gets the interval value stored for rxdelay1.
rxdelay2	Gets the interval value stored for rxdelay2.
ar	Gets the state of the automatic reply.
rx2	Gets the data rate and frequency used for the second Receive window.
dcycleps	Gets the duty cycle prescaler which can only be configured by the server.
mrgn	Gets the demodulation margin as received in the last Link Check Answer frame.
gwnb	Gets the number of gateways that successfully received the last Link Check Request frame.
status	Gets the current status of the RN2483 module.
sync	Gets the synchronization word for the LoRaWAN communication.
upctr	Gets the value of the uplink frame counter that will be used for the next uplink transmission.
dnctr	Gets the value of the downlink frame counter that will be used for the next downlink reception.
ch	Gets parameters related information which pertains to channel operation and behaviors.

2.4.9.1 mac get devaddr

Response: 4-byte hexadecimal number representing the device address, from 00000000 to FFFFFFFF.

This command will return the current end-device address of the module.

Default: 00000000

Example: **mac get devaddr**

2.4.9.2 mac get deveui

Response: 8-byte hexadecimal number representing the device EUI.

This command returns the globally unique end-device identifier, as set in the module.

Default: pre-programmed EUI node address

Example: **mac get deveui**

> **Note:** After the `mac reset <band>` command is explicitly called, the device EUI value will be set to all zeros. Make certain that a valid value is given to the device EUI.

2.4.9.3 mac get appeui

Response: 8-byte hexadecimal number representing the application EUI.

This command will return the application identifier for the module. The application identifier is a value given to the device by the network.

Default: 0000000000000000

Example: **mac get appeui**

2.4.9.4 mac get dr

Response: decimal number representing the current data rate.

This command will return the current data rate.

Default: 5

Example: **mac get dr**

2.4.9.5 mac get band

Response: decimal number representing the frequency band, either 868 or 433.

This command returns the current frequency band of operation. The band reflects the module's operation types.

Default: 868

Example: **mac get band**

2.4.9.6 mac get pwridx

Response: decimal number representing the current output power index value, from 0 to 5.

This command returns the current output power index value.

Default: 1

Example: **mac get pwridx**

2.4.9.7 mac get adr

Response: string representing the state of the adaptive data rate mechanism, either `on` or `off`.

This command will return the state of the adaptive data rate mechanism. It will reflect if the ADR is `on` or `off` on the requested device.

Default: `off`

Example: **`mac get adr`**

2.4.9.8 mac get retx

Response: decimal number representing the number of retransmissions, from 0 to 255.

This command will return the currently configured number of retransmissions which are attempted for a confirmed uplink communication when no downlink response has been received.

Default: 7

Example: **`mac get retx`**

2.4.9.9 mac get rxdelay1

Response: decimal number representing the interval, in milliseconds, for `rxdelay1`, from 0 to 65535.

This command will return the interval, in milliseconds, for `rxdelay1`.

Default: 1000

Example: **`mac get rxdelay1`**

2.4.9.10 mac get rxdelay2

Response: decimal number representing the interval, in milliseconds, for `rxdelay2`, from 0 to 65535.

This command will return the interval, in milliseconds, for `rxdelay2`.

Default: 2000

Example: **`mac get rxdelay2`**

2.4.9.11 mac get ar

Response: string representing the state of the automatic reply, either `on` or `off`.

This command will return the current state for the automatic reply (AR) parameter. The response will indicate if the AR is on or off.

Default: `off`

Example: **`mac get ar`**

2.4.9.12 mac get rx2 <freqBand>

<freqBand>: decimal number representing the frequency band, either 868 or 433.

Response: decimal number representing the data rate configured for the second Receive window, from 0 to 7 and a decimal number for the frequency configured for the second Receive window, from 863000000 to 870000000 or from 433050000 to 434790000, in Hz.

This command will return the current data rate and frequency configured to be used during the second Receive window.

Default: 0 869525000 // for 868 band

0 434665000 // for 433 band

Example: **mac get rx2 868**

2.4.9.13 mac get dcycleps

Response: decimal number representing the prescaler value, from 0 to 65535.

This command returns the duty cycle prescaler. The value of the prescaler can be configured *ONLY* by the *SERVER* through use of the Duty Cycle Request frame. Upon reception of this command from the server, the duty cycle prescaler is changed for all enabled channels.

Default: 1

Example: **mac get dcycleps**

2.4.9.14 mac get mrgn

Response: decimal number representing the demodulation margin, from 0 to 255.

This command will return the demodulation margin as received in the last Link Check Answer frame. Please refer to the *LoRaWAN™ Specification* for the description of the values.

Default: 255

Example: **mac get mrgn**

2.4.9.15 mac get gwnb

Response: decimal number representing the number of gateways, from 0 to 255.

This command will return the number of gateways that successfully received the last Link Check Request frame command, as received in the last Link Check Answer.

Default: 0

Example: **mac get gwnb**

2.4.9.16 `mac get status`

Response: 4-byte hexadecimal number representing the current status of the module.

This command will return the current status of the module. The value returned is a bit mask represented in hexadecimal form. Please refer to Figure 2-1 for the significance of the bit mask.

Default: 00000000

Example: **`mac get status`**

2.4.9.17 `mac get sync`

Response: one byte long hexadecimal number representing the synchronization word for the LoRaWAN communication.

This command will return the synchronization word for the LoRaWAN communication.

Default: 34

Example: `mac get sync`

2.4.9.18 `mac get upctr`

Response: decimal number representing the value of the uplink frame counter that will be used for the next uplink transmission, from 0 to 4294967295.

This command will return the value of the uplink frame counter that will be used for the next uplink transmission.

Default: 0

Example: `mac get upctr`

2.4.9.19 `mac get dnctr`

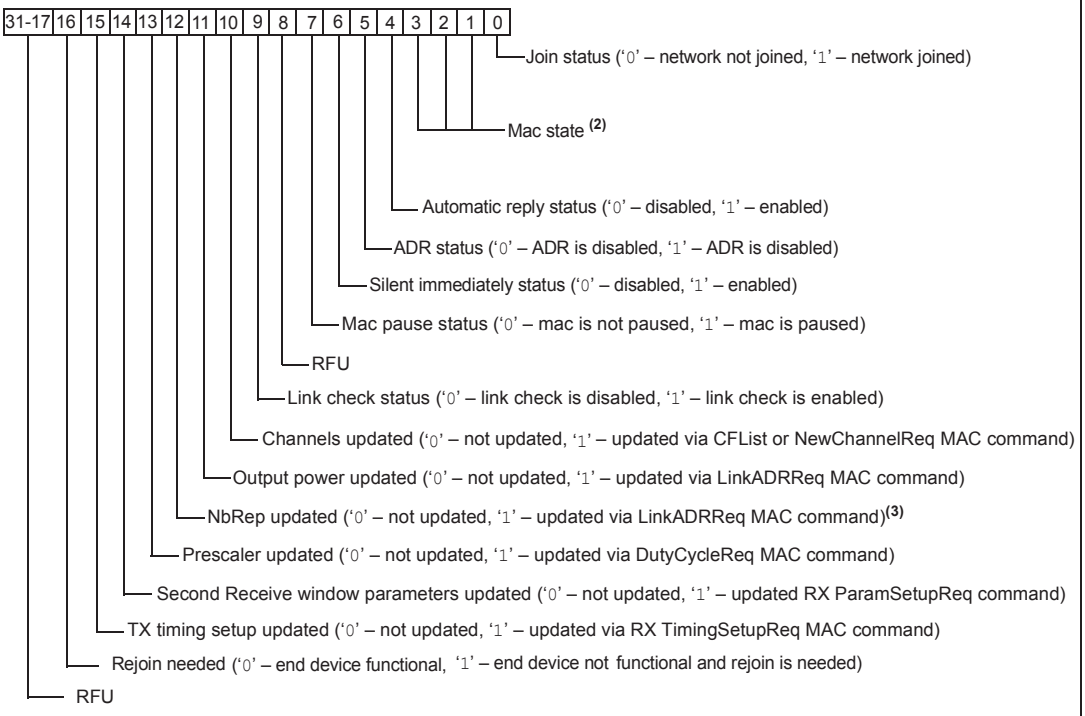
Response: decimal number representing the value of the downlink frame counter that will be used for the next downlink reception, from 0 to 4294967295.

This command will return the value of the downlink frame counter that will be used for the next downlink reception.

Default: 0

Example: `mac get dnctr`

FIGURE 2-1: MAC STATUS BIT-MAPPED REGISTER (1)



Note 1: Bits 10 (Channels updated), 11 (Output power updated), 12 (NbRep updated), 13 (Prescaler updated), 14 (Second Receive window parameters updated) and 15 (TX timing setup updated) are cleared after issuing a "`mac get status`" command.

2: Mac state:

0 – Idle (transmissions are possible)

1 – Transmission occurring

2 – Before the opening of Receive window 1

3 – Receive window 1 is open

4 – Between Receive window 1 and Receive window 2

5 – Receive window 2 is open

6 – Ack_timeout (Ack_timeout is described in more detail in the *LoRaWAN™ specification*)

3: NbRep is the number of repetitions for unconfirmed packets (please refer to the *LoRaWAN™ Specification* for more details).

2.4.9.20 MAC GET CHANNEL COMMANDS

TABLE 2-9: MAC GET CHANNEL COMMANDS

Parameter	Description
`freq`	Gets the module operation frequency for the specified channel ID.
`dcycle`	Gets the module duty cycle used for transmission on the specified channel ID.
`drrange`	Gets the valid data rate range (min. to max.) allowed for the module on the specified channel ID
`status`	Gets the status for the specified channel ID to indicate if it is enabled for use.

TABLE 2-10: DEFAULT PARAMETERS FOR CHANNELS

Channel Number	Parameters	Frequency band	
		868	433
Channel 0	Frequency (Hz)	868100000	433175000
	Duty cycle (1)	302	302
	Data rate range	0-5	0-5
	Status	On	On
Channel 1	Frequency (Hz)	868300000	433375000
	Duty cycle(1)	302	302
	Data rate range	0-5	0-5
	Status	On	On
Channel 2	Frequency (Hz)	868500000	433575000
	Duty cycle(1)	302	302
	Data rate range	0-5	0-5
	Status	On	On
Channels 3-15	Frequency (Hz)	0	0
	Duty cycle(1)	65535	65535
	Data rate range	15 15	15 15
	Status	Off	Off

Note 1: The default settings consider only the three default channels (0-2), and their default duty cycle is 0.33%. If a new channel is created either by the server or by the user, all the channels (including the default ones) must be updated by the user in terms of duty cycle to comply with the ETSI regulations.

2.4.9.20.1 `mac get ch freq <ChannelId>`

`<channelId>`: decimal number representing the channel number, from 0 to 15.

Response: decimal number representing the frequency of the channel, from 863000000 to 870000000 or from 433050000 to 434790000, in Hz, depending on the frequency band selected.

This command returns the frequency on the requested `<channelId>`, entered in decimal form.

Default: see Table 2-10

Example: **`mac get ch freq 0`**

2.4.9.20.2 `mac get ch dcycle <channelId>`

`<channelId>`: decimal number representing the channel number, from 0 to 15.

Response: decimal number representing the duty cycle of the channel, from 0 to 65535.

This command returns the duty cycle on the requested `<channelId>`. The duty cycle is returned in decimal value. The actual duty cycle (in percentage) can be obtained using the returned value V as: percent = 100/(V + 1).

Default: see Table 2-10

Example: **`mac get ch dcycle 0`** // Reads back duty cycle setting on Channel ID 0. If the value reported back is 99, the actual duty cycle on the channel (in percentage) is 100/(99 + 1) = 1.

2.4.9.20.3 `mac get ch drrange <channelId>`

`<channelId>`: decimal number representing the channel number, from 0 to 15.

Response: decimal number representing the minimum data rate of the channel, from 0 to 7 and a decimal number representing the maximum data rate of the channel, from 0 to 7

This command returns the allowed data rate index range on the requested `<channelId>`, entered in decimal form. The `<minRate>` and `<maxRate>` index values are returned in decimal form and reflect index values. Please refer to the *LoRaWAN™ Specification* for the description of data rates and the corresponding spreading factors.

Default: see Table 2-10

Example: **`mac get ch drrange 0`**

2.4.9.20.4 `mac get ch status <channelId>`

`<channelId>`: decimal number representing the channel number, from 0 to 15.

Response: string representing the state of the channel, either `on` or `off`.

This command returns if `<channelId>` is currently enabled for use. `<channelId>` is entered in decimal form and the response will be `on` or `off` reflecting the channel is enabled or disabled appropriately.

Default: see Table 2-10

Example: **`mac get ch status 2`**

Note: `<ChannelId>` parameters must be issued prior to enabling the status of that channel. If a channel is disabled through the `<status>`, all channel parameters must be reconfigured prior to enabling.

2.5 RADIO COMMANDS

TABLE 2-11: RADIO COMMANDS(1)

Parameter	Description
rx	This command configures the radio to receive simple radio packets according to prior configuration settings.
tx	This command configures a simple radio packet transmission according to prior configuration settings.
cw	This command will put the module into a Continuous Wave (cw) Transmission for system tuning or certification use.
set	This command allows modification to the radio setting directly. This command allows for the user to change the method of radio operation within module type band limits.
get	This command grants the ability to read out radio settings as they are currently configured.

Note 1: The `mac pause` command must be called before any radio transmission or reception, even if no MAC operations have been initiated before.

TABLE 2-12: RADIO PARAMETERS AVAILABILITY FOR DIFFERENT OPERATIONS

Command	`radio get`	`radio set`	Availability for LoRa® Modulation	Availability for FSK Modulation
bt	√	√	—	√
mod	√	√	√	√
freq	√	√	√	√
pwr	√	√	√	√
sf	√	√	√	—
afcbw	√	√	—	√
rxbw	√	√	—	√
bitrate	√	√	—	√
fdev	√	√	—	√
prlen	√	√	—	√
crc	√	√	√	√
iqi	√	√	√	—
cr	√	√	√	—
wdt	√	√	√	√
sync	√	√	√	√
bw	√	√	√	—
snr	√	—	√	—

2.5.1 radio rx <rxWindowSize>

<rxWindowSize>: decimal number representing the number of symbols (for LoRa modulation) or time-out (in milliseconds, for FSK modulation) that the receiver will be opened, from 0 to 65535. Set <rxWindowSize> to '0' in order to enable the Continuous Reception mode. Continuous Reception mode will be exited once a valid packet is received.

Response: this command may reply with two responses. The first response will be received immediately after entering the command. If the command is valid (ok reply received), a second reply will be received after the reception of a packet or after the time-out occurred.

Response after entering the command:

- ok – if parameter is valid and the transceiver is configured in Receive mode
- invalid_param – if parameter is not valid
- busy – if the transceiver is currently busy

Response after the receive process:

- radio_rx <data> – if reception was successful, <data>: hexadecimal value that was received;
- radio_err – if reception was not successful, reception time-out occurred

Example: **radio rx 0** // Puts the radio into continuous Receive mode.

Ensure the radio Watchdog Timer time-out is higher than the Receive window size.

Note: The mac pause command must be called before any radio transmission or reception, even if no MAC operations have been initiated before.

Note: When transmitting FSK packets, the payload and the 2-byte CRC is whitened by being XORed with a pseudorandom sequence generated by an LFSR with the polynomial $X^9 + X^5 + 1$. This process is automatically reverted on reception so that it is transparent to the user.

2.5.2 radio tx <data>

<data>: hexadecimal value representing the data to be transmitted, from 0 to 255 bytes for LoRa modulation and from 0 to 64 bytes for FSK modulation.

Response: this command may reply with two responses. The first response will be received immediately after entering the command. If the command is valid (ok reply received), a second reply will be received after the effective transmission.

Response after entering the command:

- ok – if parameter is valid and the transceiver is configured in Transmit mode
- invalid_param – if parameter is not valid
- busy – if the transceiver is currently busy

Response after the effective transmission:

- radio_tx_ok – if transmission was successful
- radio_err – if transmission was unsuccessful (interrupted by radio Watchdog Timer time-out)

This command transmits the <data> passed.

Example: **radio tx 48656c6C6F** // Transmits a packet of [0x48][0x65][0x6c][0x6C][0x6F]; Hello.

Note:	In order to meet ETSI regulations in the given frequency bands, the radio has to use either Listen Before Talk (LBT) + Adaptive Frequency Agility (AFA) or duty cycle limitations. By issuing the radio tx <data> command the module does not perform LBT before transmission, thus the user has to make sure that duty cycle limits are not violated. For more information on duty cycle limits please check the EN 300 220-2 v2.4.1 standard.

Note:	The mac pause command must be called before any radio transmission or reception, even if no MAC operations have been initiated before.

Note:	When transmitting FSK packets, the payload and the 2-byte CRC is whitened by being XORed with a pseudorandom sequence generated by an LFSR with the polynomial $X^9 + X^5 + 1$. This process is automatically reverted on reception so that it is transparent to the user.

2.5.3 radio cw <state>

<state>: string representing the state of the Continuous Wave (CW) mode, either on or off.

Response: ok if state is valid

invalid_param if state is not valid

This command will enable or disable the CW mode on the module. CW mode allows the user to put the transceiver into Transmission mode to observe the generated signal. By altering the settings for the radio the user can observe the changes in transmissions levels.

Example: **radio cw on**

Note:	Please note that using radio cw off resets the module, this command being semantically identical to sys reset.

2.5.4 Radio Set Commands

TABLE 2-13: RADIO SET COMMANDS

Parameter	Description
bt	Set the data shaping for frequency shift keying (FSK) modulation type.
mod	Set the module Modulation mode.
freq	Set the current operation frequency for the radio.
pwr	Set the output power level used by the radio during transmission.
sf	Set the requested spreading factor (SF) to be used during transmission.
afcbw	Set the value used by the automatic frequency correction bandwidth.
rxbw	Set the operational receive bandwidth.
bitrate	Set the frequency shift keying (FSK) bit rate.
fdev	Set the frequency deviation allowed by the end device.
prlen	Set the preamble length used during transmissions.
crc	Set if a CRC header is to be used.
iqi	Set if IQ inversion is used.
cr	Set the coding rate used by the radio.
wdt	Set the time-out limit for the radio Watchdog Timer.
sync	Set the sync word used.
bw	Set the value used for the radio bandwidth.

2.5.4.1 radio set bt <gfBT>

<gfBT>: string representing the Gaussian baseband data shaping, enabling GFSK modulation. Parameter values can be: none, 1.0, 0.5, 0.3.

Response: ok if the data shaping is valid

invalid_param if the data shaping is not valid

This command modifies the data shaping applied to FSK transmissions. Entering any <gfBT> other than none will result in a Gaussian Filter BT being applied to transmissions in FSK mode.

Example: **radio set bt none** // Data shaping in FSK mode is disabled or null.

2.5.4.2 radio set mod <mode>

<mode>: string representing the modulation method, either lora or fsk.

Response: ok if the modulation is valid

invalid_param if the modulation is not valid

This command changes the modulation method being used by the module. Altering the mode of operation does not affect previously set parameters, variables or registers. FSK mode also allows GFSK transmissions when data shaping is enabled.

Example: **radio set mod lora**

2.5.4.3 radio set freq <frequency>

<frequency>: decimal representing the frequency, from 433050000 to 434790000 or from 863000000 to 870000000, in Hz.

Response: ok if the frequency is valid

invalid_param if the frequency is not valid

This command changes the communication frequency of the radio transceiver.

Example: **radio set freq 868000000**

2.5.4.4 `radio set pwr <pwrout>`

`<pwrOut>`: signed decimal number representing the transceiver output power, from -3 to 15.

Response: `ok` if the output power is valid

`invalid_param` if the output power is not valid

This command changes the transceiver output power. However, note that the transceiver is designed to transmit a maximum of +14 dBm. It is possible to set the output power above the regulatory limits. This power setting allows some compensation on the cable or transmission line loss. For more details on output power please check the *RN2483 Low-Power Long-Range LoRa® Technology Transceiver Module Data Sheet*.

Example: **`radio set pwr 14`**

2.5.4.5 `radio set sf <spreadingfactor>`

`<spreadingFactor>`: string representing the spreading factor. Parameter values can be: `sf7`, `sf8`, `sf9`, `sf10`, `sf11` or `sf12`.

Response: `ok` if the spreading factor is valid

`invalid_param` if the spreading factor is not valid

This command sets the spreading factor used during transmission.

Example: **`radio set sf sf7`**

2.5.4.6 `radio set afcbw <autoFreqBand>`

`<autoFreqBand>`: float representing the automatic frequency correction, in kHz. Parameter values can be: 250, 125, 62.5, 31.3, 15.6, 7.8, 3.9, 200, 100, 50, 25, 12.5, 6.3, 3.1, 166.7, 83.3, 41.7, 20.8, 10.4, 5.2, 2.6.

Response: `ok` if the automatic frequency correction is valid

`invalid_param` if the automatic frequency correction is not valid

This command modifies the automatic frequency correction bandwidth for receiving/transmitting.

Example: **`radio set afcbw 125`**

2.5.4.7 `radio set rxbw <rxbandwidth>`

`<rxBandwidth>`: float representing the signal bandwidth, in kHz. Parameter values can be: 250, 125, 62.5, 31.3, 15.6, 7.8, 3.9, 200, 100, 50, 25, 12.5, 6.3, 3.1, 166.7, 83.3, 41.7, 20.8, 10.4, 5.2, 2.6.

Response: `ok` if the signal bandwidth is valid

`invalid_param` if signal bandwidth is not valid

This command sets the signal bandwidth when receiving.

Example: **`radio set rxbw 250`** // Signal bandwidth for receiving is 250 kHz.

2.5.4.8 `radio set bitrate <fskBitRate>`

`<fskBitRate>`: decimal number representing the FSK bit rate value, from 1 to 300000.

Response: `ok` if the bit rate value is valid

`invalid_param` if the bit rate value is not valid

This command sets the FSK bit rate value.

Example: **radio set bitrate 5000** // FSK bit rate is set to 5 kb/s.

2.5.4.9 radio set fdev <freqdev>

<freqDev>: decimal number representing the frequency deviation, from 0 to 200000.

Response: ok if the frequency deviation is valid

invalid_param if frequency deviation is not valid

This command sets the frequency deviation during operation.

Example: **radio set fdev 5000** // Frequency deviation is 5 kHz.

2.5.4.10 radio set prlen <preamble>

<preamble>: decimal number representing the preamble length, from 0 to 65535.

Response: ok if the preamble length is valid

invalid_param if the preamble length is not valid

This command sets the preamble length for transmit/receive.

Example: **radio set prlen 8** // Preamble length is 8.

2.5.4.11 radio set crc < crcHeader >

<crcHeader>: string representing the state of the CRC header, either on or off.

Response: ok if the state is valid

invalid_param if the state is not valid

This command enables or disables the CRC header for communications.

Example: **radio set crc on** // Enables the CRC header.

2.5.4.12 radio set iqi <iqInvert>

<iqInvert>: string representing the state of the invert IQ, either on or off.

Response: ok if the state is valid

invalid_param if the state is not valid

This command enables or disables the Invert IQ for communications.

Example: **radio set iqi on** // Invert IQ is enabled.

2.5.4.13 radio set cr <codingRate>

<codingRate>: string representing the coding rate. Parameter values can be: 4/5, 4/6, 4/7, 4/8.

Response: ok if the coding rate is valid

invalid_param if the coding rate is not valid

This command modifies the coding rate currently being used by the radio.

Example: radio set cr 4/7 // The coding rate is set to 4/7.

2.5.4.14 radio set wdt <watchDog>

<watchDog>: decimal number representing the time-out length for the Watchdog Timer, from 0 to 4294967295. Set to '0' to disable this functionality.

Response: ok if the watchdog time-out is valid

invalid_param if the watchdog time-out is not valid

This command updates the time-out length, in milliseconds, applied to the radio Watchdog Timer. If this functionality is enabled, then the Watchdog Timer is started for every transceiver reception or transmission. The Watchdog Timer is stopped when the operation in progress in finished.

Example: **radio set wdt 2000** // The Watchdog Timer is configured for 2000 ms.

> **Note:** Ensure the value configured for the Watchdog Timer matches the radio configurations. For example, set the <watchDog> value to '0' in order to disable this functionality during the radio continuous reception.

2.5.4.15 radio set sync <syncWord>

<syncWord>: hexadecimal value representing the Sync word used during communication. For LoRa modulation one byte is used, for FSK up to eight bytes can be entered.

Response: ok if the sync word is valid

invalid_param if the sync word is not valid

This command configures the sync word used during communication.

Example: **radio set sync 12** // Set the sync word to a single byte with the value 0x12.

2.5.4.16 radio set bw <bandWidth>

<bandWidth>: decimal representing the operating radio bandwidth, in kHz. Parameter values can be: 125, 250, 500.

Response: ok if the bandwidth is valid

invalid_param if the bandwidth is not valid

This command sets the operating radio bandwidth for LoRa operation.

Example: **radio set bw 250** // The operating bandwidth is 250 kHz.

2.5.5 Radio Get Commands

TABLE 2-14: RADIO GET COMMANDS

Parameter	Description
bt	Get the data shaping for frequency shift keying (FSK) modulation type.
mod	Get the module Modulation mode.
freq	Get the current operation frequency for the radio.
pwr	Get the output power level used by the radio during transmission.
sf	Get the requested spreading factor (SF) to be used during transmission.
afcbw	Get the value used by the automatic frequency correction bandwidth.
rxbw	Get the operational receive bandwidth.
bitrate	Get the frequency shift keying (FSK) bit rate.
fdev	Get the frequency deviation allowed by the end device.
prlen	Get the preamble length used during transmissions.
crc	Get if a CRC header is to be used.
iqi	Get if IQ inversion is used.
cr	Get the coding rate used by the radio.
wdt	Get the time-out limit for the Watchdog Timer.
bw	Get the value used for the radio bandwidth.
snr	Get the signal noise ratio (SNR) of the last received packet.
sync	Get the synchronization word used for communication.

2.5.5.1 radio get bt

Response: string representing the configuration for data shaping. Parameter values can be: `none`, `1.0`, `0.5`, `0.3`.

This command reads back the current configuration for data shaping applied to FSK transmissions.

Default: `0.5`

Example: **`radio get bt`** // Reads the current data shaping FSK configuration.

2.5.5.2 radio get mod

Response: string representing the current mode of operation of the module, either `lora` or `fsk`.

This command reads back the current mode of operation of the module.

Default: `lora`

Example: **`radio get mod`** // Reads if module is modulating in LoRa or FSK.

2.5.5.3 radio get freq

Response: decimal number representing the frequency, from 433050000 to 434790000 or from 863000000 to 870000000, in Hz.

This command reads back the current operation frequency of the module.

Default: 868100000

Example: **radio get freq** // Reads back the current frequency the transceiver communicates on.

2.5.5.4 radio get pwr

Response: signed decimal representing the current power level, from -3 to 15.

This command reads back the current power level settings used in operation.

Default: 1

Example: **radio get pwr** // Reads back the current transmit output power.

2.5.5.5 radio get sf

Response: string representing the current spreading factor.

This command reads back the current spreading factor being used by the transceiver. Parameter values can be: sf7, sf8, sf9, sf10, sf11, sf12"

Default: sf12

Example: **radio get sf** // Reads back the current spreading factor settings.

2.5.5.6 radio get afcbw

Response: float representing the automatic frequency correction band, in kHz. Parameter values can be: 250, 125, 62.5, 31.3, 15.6, 7.8, 3.9, 200, 100, 50, 25, 12.5, 6.3, 3.1, 166.7, 83.3, 41.7, 20.8, 10.4, 5.2, 2.6.

This command reads back the status of the Automatic Frequency Correction Bandwidth.

Default: 41.7

Example: **radio get afcbw** // Reads back the current automatic frequency correction bandwidth.

2.5.5.7 radio get rxbw

Response: float representing the signal bandwidth, in kHz. Parameter values can be: 250, 125, 62.5, 31.3, 15.6, 7.8, 3.9, 200, 100, 50, 25, 12.5, 6.3, 3.1, 166.7, 83.3, 41.7, 20.8, 10.4, 5.2, 2.6.

This command reads back the signal bandwidth used for receiving.

Default: 25

Example: **radio get rxbw** // Reads back the receive signal bandwidth.

2.5.5.8 radio get bitrate

Response: signed decimal representing the configured bit rate, from 1 to 300000.

This command reads back the configured bit rate for FSK communications.

Default: 50000

Example: **radio get bitrate** // Reads back the current FSK bit rate setting.

2.5.5.9 radio get fdev

Response: signed decimal representing the frequency deviation setting, from 0 to 200000.

This command reads frequency deviation setting on the transceiver.

Default: 25000

Example: **radio get fdev** // Reads back current configured frequency deviation setting.

2.5.5.10 radio get prlen

Response: signed decimal representing the preamble length, from 0 to 65535.

This command reads the current preamble length used for communication.

Default: 8

Example: **radio get prlen** // Reads back the preamble length used by the transceiver.

2.5.5.11 radio get crc

Response: string representing the status of the CRC header, either `on` or `off`

This command reads back the status of the CRC header, to determine if it is to be included during operation.

Default: `on`

Example: **radio get crc** // Reads back if the CRC header is enabled for use.

2.5.5.12 radio get iqi

Response: string representing the status of the Invert IQ functionality, either `on` or `off`.

This command reads back the status of the Invert IQ functionality.

Default: `off`

Example: **radio get iqi** // Reads back the status of the Invert IQ functionality.

2.5.5.13 radio get cr

Response: string representing the current value settings used for the coding rate. Parameter values can be: `4/5`, `4/6`, `4/7`, `4/8`.

This command reads back the current value settings used for the coding rate during communication.

Default: `4/5`

Example: **radio get cr** // Reads back the current coding rate transceiver settings.

2.5.5.14 radio get wdt

Response: decimal number representing the length used for the watchdog time-out, from 0 to 4294967295.

This command reads back, in milliseconds, the length used for the watchdog time-out.

Default: 15000

Example: **radio get wdt** // Reads back the current time-out value applied to the Watchdog Timer

2.5.5.15 radio get bw

Response: decimal representing the current operating radio bandwidth, in kHz. Parameter values can be: 125, 250 or 500.

This command reads back the current operating radio bandwidth used by the transceiver.

Default: 125

Example: **radio get bw** // Reads back the current operational bandwidth applied to transmissions.

2.5.5.16 radio get snr

Response: signed decimal number representing the signal to noise ratio (SNR), from -128 to 127.

This command reads back the Signal Noise Ratio (SNR) for the last received packet.

Default: -128

Example: **radio get snr** // Reads back the measured SNR for the previously packet reception.

2.5.5.17 radio get sync

Response: hexadecimal number representing the synchronization word used for radio communication.

This command reads back the configured synchronization word used for radio communication. One byte long synchronization word is used for the LoRa modulation while up to eight bytes can be entered for FSK.

Default: 34

Example: radio get sync

Chapter 3. Bootloader Usage

Introduction

This chapter describes the operation of the bootloader that exists on Microchip RN2483 LoRa modules and the process to upgrade the firmware using this bootloader. This paper assumes that there is a microcontroller or other similar device attached to the UART lines of the RN2483 module, and that this microcontroller has enough storage to hold the image that is to be programmed into the module.

The bootloader on the RN2483 module is based on the standard 8-bit UART bootloader which can be found on Microchip's website at http://www.microchip.com/bootloader.

In the Protocol section of the bootloader generator user's guide, there is a table of supported commands. The RN2483 bootloader supports each of these commands; however, there are some subtle nuances that need to be followed for successful operation.

TABLE 3-1: SUPPORTED COMMANDS

Command	Description
0x00	Get Version and other info
0x01	Read Flash
0x02	Write Flash
0x03	Erase Flash
0x04	Read EE Data
0x05	Write EE Data
0x06	Read Configuration Words
0x07	Write Configuration Words
0x08	Calculate and return Flash checksum
0x09	Reset Device

3.1 PROTOCOL

The standard 8-bit UART bootloader has a common command protocol for all commands.

TABLE 3-2: COMMAND PROTOCOL

Byte:	0	1	2	3	4	5	6	7	8
Fields:	CMD	Length(LSB··MSB)		Key 1	Key 2	Address (LSB··MSB)			

<Command><LenLSB><LenMSB><Key1><Key2><address(4 bytes)LSB··MSB>

Byte Order

There are two multi-byte fields common to all commands. These are the Length field, and the Address field. These values are sent in little-endian format. This means that the low-order byte (Least Significant Byte) is sent first, and the high-order byte (Most Significant Byte) is sent last.

Write Operations

When an Erase or Write command is issued, the two key fields must be supplied with correct values. For read operations, they key fields are not used. The values of the keys are always:

- Key1 = 0x55
- Key2 = 0xaa

General Differences from 8-Bit Bootloader

- Module bootloader only uses the first-length byte and ignores the second-length byte in all commands. The protocol still requires that the second length-byte be sent, but the bootloader ignores this value.
- Each command is preceded by 0x55 (ASCII 'U'); this is used for auto-baud detection.

3.2 RN MODULE BOOTLOADER COMMANDS

Because of the differences between the normal Microchip 8-bit bootloader and the bootloader in the RN2483 module, the command format has an initial byte of 0x55, and the second byte of the length field (MSB) is always 0x00.

TABLE 3-3: RN MODULE BOOTLOADER COMMANDS

Byte:	0	1	2	3	4	5	6	7	8	9
Fields:	0x55	CMD	Len	0x00	Key1	Key2	Address (LSB··MSB)			

<0x55><Command><Len><0x00><Key1><Key2><address(4 bytes)LSB··MSB>

3.3 COMMAND DETAILS

TABLE 3-4: GET VERSION INFO

Byte:	0	1	2	3	4	5	6	7	8	9
Values:	0x55	0x00	0x00	0x00	0x00	0x00	0x00	0x00	0x00	0x00

This command returns bootloader version and memory information.

Response:

<0x55><0x01><Len><0x00><0x00><0x00><address(4 bytes)LSB··MSB>

TABLE 3-5:

Byte	Value
0	Bootloader version – low byte
1	Bootloader version – high byte
2	Max. packet size – low byte (not used)
3	Max. packet size – high byte (not used)
4	ACK packet size – low byte (not used)
5	ACK packet size – high byte (not used)
6	Device ID – low byte
7	Device ID – high byte
8	(not used)
9	(not used)
10	Erase Row size
11	Write Latch size
12	User ID 1
13	User ID 2
14	User ID 3
15	User ID 4

Len bytes of information follow the address field.

TABLE 3-6: READ FLASH

Byte:	0	1	2	3	4	5	6	7	8	9
Values:	0x55	0x01	Len	0x00	0x00	0x00	Address			

This command returns data read from the Flash memory. The length field can range from 0 to 255. This determines the number of bytes read from Flash and returned by the bootloader in the response.

Response:

<0x55><0x01><Len><0x00><0x00><0x00><address(4 bytes)LSB··MSB><byte0><byte1>···<byteN>

Len bytes are returned after the address field.

TABLE 3-7: WRITE FLASH

Byte:	0	1	2	3	4	5	6	7	8	9
Values:	0x55	0x02	Len	0x00	Key1	Key2	Address			

Byte:	Len Number of bytes (9 through 8+Len)
Values:	Data[0]-Data[Len-1]

This command writes data into the Flash memory. The length field can range from 0 to 255. This determines the number of bytes written to Flash. The Write Flash command does not erase any Flash memory before writing data; therefore, this command should be preceded by an Erase Flash command for proper operation.

Response:

<0x55><0x02><Len><0x00><Key1><Key2><address(4 bytes)LSB··MSB><Status>

Status is either a '0' indicating that the command failed, or a '1' indicating the command was successful

.

TABLE 3-8: ERASE FLASH

Byte:	0	1	2	3	4	5	6	7	8	9
Values:	0x55	0x03	Blocks	0x00	Key1	Key2	Address			

This command erases one or more blocks of Flash memory, starting at address *Address*. The Blocks field can range from 0 to 255. The 1-255 value of the Blocks field represents the number of blocks to erase. If the Blocks field is '0', the bootloader will erase 256 blocks.

Response:

<0x55><0x03><Blocks><0x00><Key1><Key2><address(4 bytes)LSB··MSB><Status>

Status is either a '0' indicating that the command failed, or a '1' indicating the command was successful.

TABLE 3-9: READ EE

Byte:	0	1	2	3	4	5	6	7	8	9
Values:	0x55	0x04	Len	0x00	0x00	0x00	Address			

This command reads data from the EEPROM memory located on the embedded PIC® device in the module beginning at address *Address*. Len can range from 0 to 255.

Response:

<0x55><0x04><Len><0x00><0x00><0x00><address(4 bytes)LSB··MSB><byte0><byte1>···<byteN>

Len bytes are returned after the Address field.

TABLE 3-10: WRITE EE

Byte:	0	1	2	3	4	5	6	7	8	9
Values:	0x55	0x05	Len	0x00	Key1	Key2	Address			

Byte:	Len Number of bytes (9 through 8+Len)
Values:	Data[0]-Data[Len-1]

This command writes data into the EEPROM memory of the embedded PIC device. The Len field can range from 0 to 255. This determines the number of bytes written to EEPROM. The Write EE command does not require any form of Erase command to be issued prior to writing data into the EEPROM.

Response:

<0x55><0x05><Len><0x00><Key1><Key2><address(4 bytes)LSB··MSB><Status>

Status is either a '0' indicating that the command failed, or a '1' indicating the command was successful.

TABLE 3-11: READ CONFIGURATION WORDS

Byte:	0	1	2	3	4	5	6	7	8	9
Values:	0x55	0x06	Len	0x00	0x00	0x00	Address			

This command reads data from the Configuration memory located on the embedded microcontroller in the module beginning at address *Address*. The Len field can range from 0 to 255. There are only 14 Configuration Words, and data repeats if the Len(gth) is greater than the number of Configuration Words.

Response:

<0x55><0x06><Len><0x00><0x00><0x00><address(4 bytes)LSB··MSB><byte0><byte1>···<byteN>

Len bytes are returned after the Address field.

TABLE 3-12: WRITE CONFIGURATION WORDS

Byte:	0	1	2	3	4	5	6	7	8	9
Values:	0x55	0x07	Len	0x00	Key1	Key2	Address			

Byte:	*Len* Number of bytes (9 through 8+Len)
Values:	Data[0]-Data[Len-1]

This command writes data into the Configuration memory. The Length field can range from 0 to 255. This determines the number of bytes written to the Configuration memory. The Write Configuration Words command does not erase any Flash memory before writing data; therefore, this command should be preceded by an Erase Flash command for proper operation.

Response:

<0x55><0x07><Len><0x00><Key1><Key2><address(4 bytes)LSB··MSB><Status>

Status is either a '0' indicating that the command failed, or a '1' indicating the command was successful.

TABLE 3-13: CALCULATE AND RETURN CHECKSUM

Byte:	0	1	2	3	4	5	6	7	8	9
Values:	0x55	0x08	Len	0x00	0x00	0x00	Address			

This command returns the checksum calculated over the Flash memory range beginning at Address for a length of Len bytes. If Len is odd, 1 is added to make Len even.

The checksum algorithm treats the Flash memory as an array of 16-bit values during the calculation, which is not performed byte by byte. In MPLAB® X, this is known as Checksum Algorithm 2.

Response:

<0x55><0x08><Len><0x00><Key1><Key2><address(4 bytes)LSB··MSB><CSumLSB><CSumMSB>

Status is either a '0' indicating that the command failed, or a '1' indicating the command was successful.

TABLE 3-14: RESET DEVICE

Byte:	0	1	2	3	4	5	6	7	8	9
Values:	0x55	0x09	0x00	0x00	0x00	0x00	0x00000000			

This command does not generate a response and immediately performs a software reset of the module.

Appendix A. Current Firmware Features and Fixes

Please check the product web page for the current RN2483 firmware version at www.microchip.com/lora.

A.1. Version 0.9.5

Initial release of the firmware.

A.2. Version 1.0.0

Release for LoRaWAN™ specification V1.0

- Added support for additional RN2483 commands:

  `mac set sync`

  `mac get sync`

  `mac set upctr`

  `mac get upctr`

  `mac set dnctr`

  `mac get dnctr`

  `sys set pinmode`

  `sys get pindig`

  `sys get pinana`

  `radio get sync`

- Added new parameters to be saved in nonvolatile memory whenever a `mac save` command is triggered

  LoRaWAN current data rate

  LoRaWAN RX2 window parameters (data rate and frequency)

  Adaptive Data Rate status

  LoRaWAN uplink frame counter

  LoRaWAN downlink frame counter

- Changed the default value for the LoRaWAN End-Device Identifier (deveui)
- Changed the valid range for the `radio set fdev` parameter to [0.. 200000]
- Changed the valid range for the `radio set bitrate` parameter to [1.. 300000]
- Changed `sys sleep` command behavior to not influence the GPIO configuration
- Changed the 433 MHz radio frequency band to [433050000 .. 434790000]
- Fixed an issue that may have caused the RN2483 module to mishandle data on LoRaWAN port 0
- Fixed an issue that may have caused the module to fail joining
- Fixed `radio get snr` command to display correct value

A.3. Version 1.0.1

Release containing modifications needed to successfully pass the LoRaWAN Certification Program testing in 868 MHz band**.**

- Added support for usage of the reserved ports, from 224 to 255 for transmitting and receiving Application Data
- Increased the size of the value returned by the `mac get status` command from 2 bytes to 4 bytes
- Updated the size of the LoRaWAN receive windows and the moment in time at which these are opened
- Fixed an issue that may have caused the RN2483 module to mishandle packets received with DR = 7
- Fixed an issue that may have caused the RN2483 module to mishandle the LoRaWAN RXParamSetupReq command
- Fixed an issue that may have caused the RN2483 module to mishandle the usage of LoraWAN ADRACKReq in packets

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