

Low-Power Long Range LoRa® Technology Transceiver Module

General Features

- On-Board LoRaWAN™ Protocol Stack
- · ASCII Command Interface over UART
- Compact Form Factor: 17.8 x 26.7 x 3.34 mm
- Castellated SMT Pads for Easy and Reliable PCB Mounting
- · Environmentally Friendly, RoHS Compliant
- · European RED Certified Radio Module
- Device Firmware Upgrade (DFU) over UART, see "RN2483 LoRa® Technology Module Command Reference User's Guide" (DS40001784)

Operational

- Single Operating Voltage: 2.1V to 3.6V (3.3V typical)
- Temperature Range: -40°C to +85°C
- Low-Power Consumption
- Programmable RF Communication Bit Rate up to 300 kbps with FSK Modulation, 10937 bps with LoRa Technology Modulation
- Integrated MCU, Crystal, EUI-64 Node Identity Serial EEPROM, Radio Transceiver with Analog Front End, Matching Circuitry
- 14 GPIOs for Control and Status, Shared with 13 Analog Inputs

RF/Analog Features

- Low-Power Long Range Transceiver Operating in the 433 MHz and 868 MHz Frequency Bands
- · High Receiver Sensitivity: Down to -146 dBm
- TX Power: Adjustable up to +14 dBm high Efficiency PA
- · FSK, GFSK and LoRa Technology Modulation
- IIP3 = -11 dBm
- Up to 15 km Coverage at Suburban and up to 5 km Coverage at Urban Area



Description

Microchip's RN2483 Low-Power Long Range LoRa Technology Transceiver module provides an easy-to-use, low-power solution for long range wireless data transmission. The advanced command interface offers rapid time to market.

The RN2483 module complies with the LoRaWAN Class A protocol specifications. It integrates RF, a baseband controller, command Application Programming Interface (API) processor, making it a complete long range solution.

The RN2483 module is suitable for simple long range sensor applications with external host MCU.

Applications

- · Automated Meter Reading
- Home and Building Automation
- · Wireless Alarm and Security Systems
- · Industrial Monitoring and Control
- · Machine to Machine (M2M)
- Internet of Things (IoT)

Table of Contents

1.0	Device Overview	3
2.0	General Specifications	6
3.0	Typical Hardware Connections	9
	Physical Dimensions	
	Application Information	
6.0	Regulatory Approval	. 13
	ndix A: Revision History	
The N	/licrochip WebSite	. 19
	omer Change Notification Service	
	omer Support	
	uct Identification System	

TO OUR VALUED CUSTOMERS

It is our intention to provide our valued customers with the best documentation possible to ensure successful use of your Microchip products. To this end, we will continue to improve our publications to better suit your needs. Our publications will be refined and enhanced as new volumes and updates are introduced.

If you have any questions or comments regarding this publication, please contact the Marketing Communications Department via E-mail at docerrors@microchip.com. We welcome your feedback.

Most Current Data Sheet

To obtain the most up-to-date version of this data sheet, please register at our Worldwide Web site at:

http://www.microchip.com

You can determine the version of a data sheet by examining its literature number found on the bottom outside corner of any page. The last character of the literature number is the version number, (e.g., DS30000000A is version A of document DS30000000).

Errata

An errata sheet, describing minor operational differences from the data sheet and recommended workarounds, may exist for current devices. As device/documentation issues become known to us, we will publish an errata sheet. The errata will specify the revision of silicon and revision of document to which it applies.

To determine if an errata sheet exists for a particular device, please check with one of the following:

- Microchip's Worldwide Web site; http://www.microchip.com
- · Your local Microchip sales office (see last page)

When contacting a sales office, please specify which device, revision of silicon and data sheet (include literature number) you are using.

Customer Notification System

Register on our web site at www.microchip.com to receive the most current information on all of our products.

1.0 DEVICE OVERVIEW

The RN2483 transceiver module features LoRa Technology RF modulation, which provides long range spread spectrum communication with high interference immunity.

Using LoRa Technology modulation technique, RN2483 can achieve a receiver sensitivity of -146 dBm. The high sensitivity combined with the integrated +14 dBm power amplifier yields industry leading link budget, which makes it optimal for applications requiring extended range and robustness.

FIGURE 1-1: RN2483 TOP VIEW



LoRa Technology modulation also provides significant advantages in both blocking and selectivity compared to the conventional modulation techniques, solving the traditional design compromise between extended range, interference immunity and low-power consumption.

The RN2483 module delivers exceptional phase noise, selectivity, receiver linearity and IIP3 for significantly lower power consumption. Figure 1-1, Figure 1-2 and Figure 1-3 show the top view, the pinout and the block diagram of the module.

FIGURE 1-2: RN2483 PIN DIAGRAM

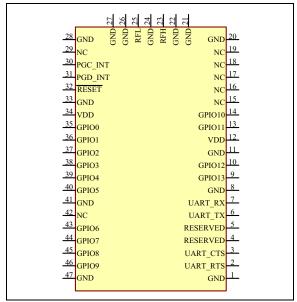
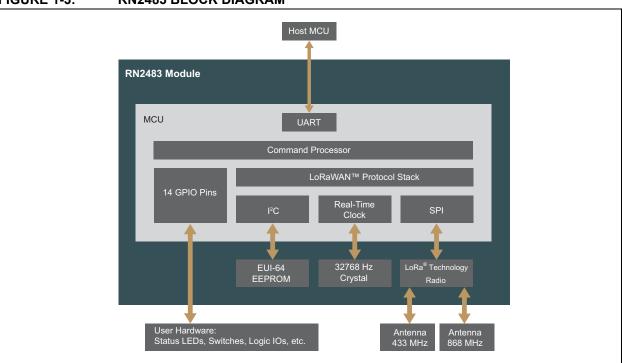


FIGURE 1-3: RN2483 BLOCK DIAGRAM



RN2483

Table 1-1 describes the RN2483 pins.

TABLE 1-1: PIN DESCRIPTION

Pin	Name	Туре	Description
1	GND	Power	Ground supply terminal
2	UART_RTS	Output	Communication UART RTS signal ⁽¹⁾ , or GPIO
3	UART_CTS	Input	Communication UART CTS signal ⁽¹⁾ , or GPIO
4	RESERVED	_	Do not connect
5	RESERVED	_	Do not connect
6	UART_TX	Output	Communication UART Transmit (TX)
7	UART_RX	Input	Communication UART Receive (RX)
8	GND	Power	Ground supply terminal
9	GPIO13	Input/Output	General purpose I/O pin or analog input
10	GPIO12	Input/Output	General purpose I/O pin or analog input
11	GND	Power	Ground supply terminal
12	VDD	Power	Positive supply terminal
13	GPIO11	Input/Output	General purpose I/O pin or analog input
14	GPIO10	Input/Output	General purpose I/O pin or analog input
15	NC	_	Not connected
16	NC	_	Not connected
17	NC	_	Not connected
18	NC	_	Not connected
19	NC	_	Not connected
20	GND	Power	Ground supply terminal
21	GND	Power	Ground supply terminal
22	GND	Power	Ground supply terminal
23	RFH	RF analog	RF signal pin for high band
24	GND	Power	Ground supply terminal
25	RFL	RF analog	RF signal pin for low band
26	GND	Power	Ground supply terminal
27	GND	Power	Ground supply terminal
28	GND	Power	Ground supply terminal
29	NC	_	Not connected
30	PGC_INT	Input/Output	Internal MCU ICSP program clock or general purpose I/O pin ⁽²⁾
31	PGD_INT	Input/Output	Internal MCU ICSP program data or general purpose I/O pin ⁽²⁾
32	RESET	Input	Active-low device Reset input
33	GND	Power	Ground supply terminal
34	VDD	Power	Positive supply terminal
35	GPIO0	Input/Output	General purpose I/O pin or analog input
36	GPIO1	Input/Output	General purpose I/O pin or analog input
37	GPIO2	Input/Output	General purpose I/O pin or analog input
38	GPIO3	Input/Output	General purpose I/O pin or analog input
39	GPIO4	Input/Output	General purpose I/O pin
40	GPIO5	Input/Output	General purpose I/O pin or analog input
41	GND	Power	Ground supply terminal
42	NC		Not connected

TABLE 1-1: PIN DESCRIPTION (CONTINUED)

Pin	Name	Туре	Description
43	GPIO6	Input/Output	General purpose I/O pin or analog input
44	GPIO7	Input/Output	General purpose I/O pin or analog input
45	GPIO8	Input/Output	General purpose I/O pin or analog input
46	GPIO9	Input/Output	General purpose I/O pin or analog input
47	GND	Power	Ground supply terminal

Note 1: Optional handshake lines are supported in future firmware releases.

^{2:} The "RN2483 LoRa® Technology Module Command Reference User's Guide" (DS40001784) uses the pin name TEST0 for PGC_INT and TEST1 for PGD_INT.

2.0 GENERAL SPECIFICATIONS

Table 2-1 provides the general specifications for the module. Table 2-2, Table 2-3 and Table 2-4 provide the electrical characteristics, current consumption and

dimensions of the module, respectively. Table 2-5 shows the RF output power calibration data. Table 2-6 shows the RF output power at different supply voltages and temperatures.

TABLE 2-1: GENERAL SPECIFICATIONS

Specification	Description
Frequency Band	863.000 MHz to 870.000 MHz; 433.050 MHz to 434.790 MHz
Modulation Method	FSK, GFSK and LoRa Technology modulation
Maximum Over-the-Air Data Rate	300 kbps with FSK modulation; 10937 bps with LoRa Technology modulation
RF Connection	Board edge connection
Interface	UART
Operation Range	Up to 15 km coverage at suburban; up to 5 km coverage at urban area
Sensitivity at 1% PER	-146 dBm ⁽¹⁾
RF TX Power	Adjustable up to max. 10 dBm on 433 MHz band (limited to meet regulations); max. 14 dBm on the 868 MHz band ⁽²⁾
Temperature (operating)	-40°C to +85°C
Temperature (storage)	-40°C to +115°C
Humidity	10% ~ 90% non-condensing

Note 1: Dependent on modulation settings, Receiver Bandwidth (RBW) and Spreading Factor (SF).

TABLE 2-2: ELECTRICAL CHARACTERISTICS

Parameter	Min.	Тур.	Max.	Units
Supply Voltage	2.1	_	3.6	V
Voltage on any pin with respect to VSS (except VDD) and RESET	-0.3	_	VDD + 0.3	V
Voltage on VDD with respect to VSS	-0.3	_	3.9	V
Voltage on RESET with respect to VSS	0	_	+11	V
Input Clamp Current (IIK) (VI < 0 or VI > VDD)	_	_	+/-20	mA
Output Clamp Current (IOK) (VO < 0 or VO > VDD)	_	_	+/-20	mA
GPIO sink/source current each	_	_	25/25	mA
Total GPIO sink/source current	_	_	200/185	mA
RAM Data Retention Voltage (in Sleep mode or Reset state)	1.5	_	_	V
VDD Start Voltage to ensure internal Power-on Reset signal	_	_	0.7	V
VDD Rise Rate to ensure internal Power-on Reset signal	0.05	_	_	V/ms
Brown-out Reset Voltage	1.75	1.9	2.05	V
Logic Input Low Voltage	_	_	0.15 x VDD	V
Logic Input High Voltage	0.8 x VDD	_	_	V
Input Leakage at <25°C (VSS <vpin<vdd, at="" high-impedance)<="" pin="" td=""><td>_</td><td>0.1</td><td>50</td><td>nA</td></vpin<vdd,>	_	0.1	50	nA
Input Leakage at +60°C (VSS <vpin<vdd, at="" high-impedance)<="" pin="" td=""><td>_</td><td>0.7</td><td>100</td><td>nA</td></vpin<vdd,>	_	0.7	100	nA
Input Leakage at +85°C (VSS <vpin<vdd, at="" high-impedance)<="" pin="" td=""><td></td><td>4</td><td>200</td><td>nA</td></vpin<vdd,>		4	200	nA
RF Input Level	_	_	+10	dBm

^{2:} TX power is adjustable. For more information, refer to the "RN2483 LoRa® Technology Module Command Reference User's Guide" (DS40001784).

TABLE 2-3: CURRENT CONSUMPTION

Mode	Temperature (°C)	Typical Current (mA)		
Wiode		VDD = 2.1V	VDD = 3.3V	VDD = 3.6V
Idle	-40 to +85	1.7	2.8	3.1
Transmit	25	28.6	38.9	44.5
	-40	0.0011	0.0013	0.0014
Sleep	25	0.0015	0.0016	0.0016
	85	0.002	0.0026	0.0026
Receive	-40 to +85	12.96	14.22	14.69

TABLE 2-4: MODULE DIMENSIONS

Parameter	Value	
Dimensions	17.8 x 26.7 x 3.34 mm	
Weight	2.05g	

TABLE 2-5: OUTPUT POWER OF TX POWER SETTING

Band	TX Power Setting	Output Power (dBm)	Typical Supply Current at 3.3V (mA)
	-3	-4.0	17.3
	-2	-2.9	18.0
	-1	-1.9	18.7
	0	-1.7	20.2
	1	-0.6	21.2
	2	0.4	22.3
	3	1.4	23.5
	4	2.5	24.7
	5	3.6	26.1
868 MHz	6	4.7	27.5
	7	5.8	28.8
	8	6.9	30.0
	9	8.1	31.2
	10	9.3	32.4
	11	10.4	33.7
	12	11.6	35.1
	13	12.5	36.5
	14	13.5	38.0
	15	14.1	38.9

TABLE 2-5: OUTPUT POWER OF TX POWER SETTING (CONTINUED)

Band	TX Power Setting	Output Power (dBm)	Typical Supply Current at 3.3V (mA)
	-3	-3.5	14.7
	-2	-2.3	15.1
	-1	-1.3	15.6
	0	-2.3	15.8
	1	-1.2	16.4
	2	-0.1	17.0
	3	1.0	17.7
	4	2.1	18.5
	5	3.2	19.4
433 MHz	6	4.3	20.3
	7	5.4	21.4
	8	6.5	22.3
	9	7.6	23.3
	10	8.8	24.5
	11	9.9	25.8
	12	10.9	27.3
	13	11.9	28.8
	14	12.9	30.7
	15	13.6	32.9

TABLE 2-6: OUTPUT POWER OF SUPPLY VOLTAGE AND TEMPERATURE

Temperature	Typical Output Power at 868 MHz (dBm)		
(°C)	VDD = 2.1V	VDD = 3.3V	VDD = 3.6V
-40	10.5	13.8	13.7
25	10.0	14.1	14.6
85	9.1	13.4	13.7

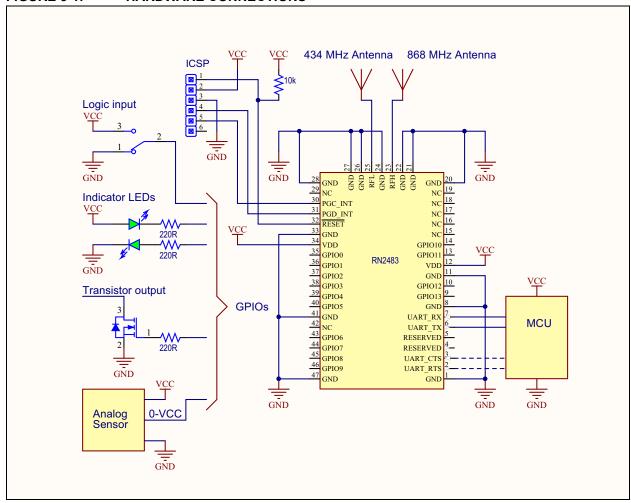
TABLE 2-7: OUTPUT POWER OF SUPPLY VOLTAGE AND TEMPERATURE

Temperature (°C)	Typical Output Power at 434 MHz (dBm)			
	VDD = 2.1V	VDD = 3.3V	VDD = 3.6V	
-40	10.1	13.2	13.2	
25	9.7	13.6	14.2	
85	9.3	13.0	13.4	

3.0 TYPICAL HARDWARE CONNECTIONS

Figure 3-1 shows the typical hardware connections.

FIGURE 3-1: HARDWARE CONNECTIONS



3.1 Interface to Host MCU

The RN2483 module has a dedicated UART interface to communicate with a host controller. Optional handshake lines are supported in future firmware releases. The "RN2483 LoRa® Technology Module Command Reference User's Guide" (DS40001784) provides a detailed UART command description. Table 3-1 shows the default settings for the UART communication.

TABLE 3-1: DEFAULT UART SETTINGS

Specification	Description
Baud Rate	57600 bps
Packet Length	8 bit
Parity Bit	No
Stop Bits	1 bit
Hardware Flow Control	No

3.2 GPIO Pins (GPIO0-GPIO13)

The module has 14 GPIO pins. These lines can be connected to switches, LEDs and relay outputs. The pins can be either logic inputs or outputs, and some pins (see Table 1-1) have analog input capability that can be accessed via the module firmware. These pins have limited sink and source capabilities. Electrical characteristics are described in Table 2-2. For more information, see "RN2483 LoRa® Technology Module Command Reference User's Guide" (DS40001784).

3.3 RF Connections (RFL, RFH)

RFL is the RF analog port for the lower frequency band (433 MHz) while RFH is for the higher frequency band (868 MHz). When routing RF paths, use proper strip lines with an impedance of 50 Ohm.

3.4 RESET Pin

The RESET pin of the module is an active-low logic input. An internal weak pull-up resistor is enabled when the pin is configured as the MCLR input.

3.5 Power Pins

It is recommended to connect power pins (Pin 12 and 34) to a stable supply voltage with sufficient source current. Table 2-3 shows the current consumption.

Additional filtering capacitors are not required but used to ensure stable supply voltage in a noisy environment.

3.6 Internal Program Pins

PGC_INT (Pin 30) and PGD_INT (Pin 31) are internal program pins used during manufacturing. For normal operation, these pins can be left unconnected.

The normal firmware upgrade method is through the internal bootloader of the module via the UART. The method is documented in the "RN2483 LoRa® Technology Module Command Reference User's Guide" (DS40001784).

However, for backup firmware update purposes the user can place a 6-pin ICSP header on their host PCB with PGC_INT (Pin 30), PGD_INT (Pin 31), RESET (Pin 32), power and ground.

During High Voltage In-Circuit Serial Programming mode, the RESET pin is driven with high-voltage (9V), therefore protection may be necessary for sensitive devices.

4.0 PHYSICAL DIMENSIONS

Figure 4-1 and Figure 4-2 illustrate the physical dimensions and the recommended PCB layout for the RN2483 module.

FIGURE 4-1: RN2483 PHYSICAL DIMENSIONS

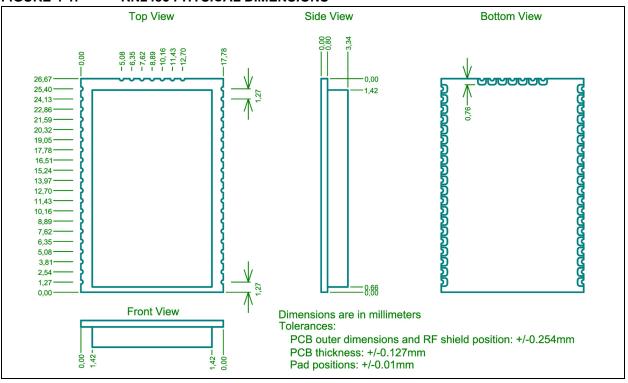
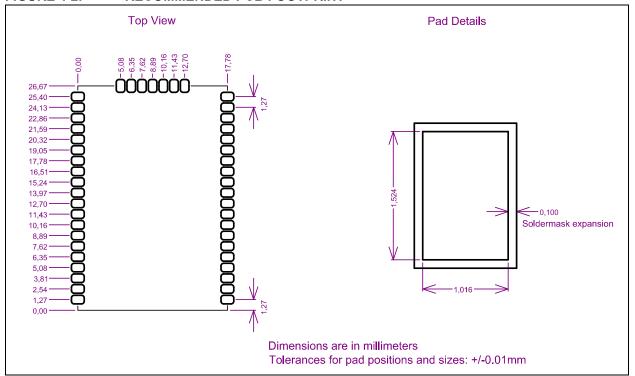


FIGURE 4-2: RECOMMENDED PCB FOOTPRINT



5.0 APPLICATION INFORMATION

5.1 RF Trace Layout Design

The RN2483 modular transmitter is certified with a PCB edge SMA connector and micro-strip trace layout as shown in Figure 5-1 and Figure 5-2. The two RF paths

are axisymmetric with the same linear dimensions. Gerber files are available on the RN2483 product web page at www.microchip.com/RN2483.

FIGURE 5-1: RF TRACE ROUTING (TOP LAYER)

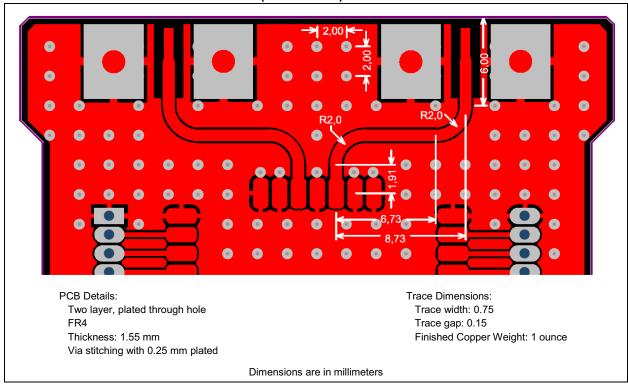
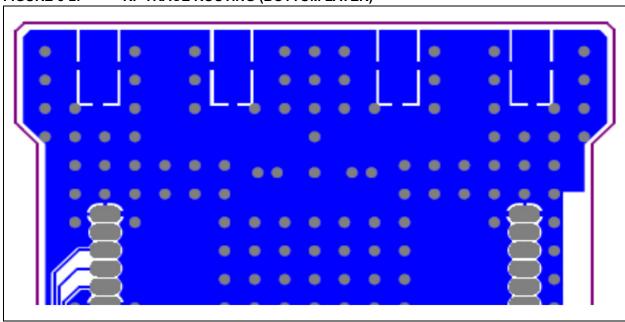


FIGURE 5-2: RF TRACE ROUTING (BOTTOM LAYER)



6.0 REGULATORY APPROVAL

This section outlines the regulatory information for the RN2483 module for Europe.

6.1 Europe

The RN2483 module is Radio Equipment Directive (RED) assessed, CE marked, and have been manufactured and tested with the intention of being integrated into a final product.

The RN2483 module has been tested to RED 2014/53/ EU Essential Requirements mentioned in the following European Compliance table.

TABLE 6-1: EUROPEAN COMPLIANCE TESTING

Certification	Standards	Article			
Safety	EN 62368	3.1a			
Health	EN 62479				
Electro Magnetic	EN 301 489-1	3.1b			
Compatibility (EMC)	EN 301 489-3				
Radio	EN 300 220-1	3.2			
	EN 300 220-2				

The ETSI provides guidance on modular devices in "Guide to the application of harmonised standards covering Article 3.1(b) and Article 3.2 of the Directive 2014/53/EU RED to multi-radio and combined radio and nonradio equipment" document available at http://www.etsi.org/deliver/etsi_eg/203300_203399/20 3367/01.01.01 60/eg 203367v010101p.pdf.

Note: To maintain conformance to the testing listed in Table 6-1, the module shall be installed in accordance with the installation instructions in this data sheet and shall not be modified. When integrating a radio module into a completed product the integrator becomes the manufacturer of the final product and is therefore responsible for demonstrating compliance of the final product with the essential requirements against the RED.

6.1.1 LABELING AND USER INFORMATION REQUIREMENTS

The label on the final product which contains the RN2483 module must follow CE marking requirements.

6.1.2 CONFORMITY ASSESSMENT

From ETSI Guidance Note EG 203367, section 6.1 Non-radio products are combined with a radio product:

If the manufacturer of the combined equipment installs the radio product in a host non-radio product in equivalent assessment conditions (i.e. host equivalent to the one used for the assessment of the radio product) and according to the installation instructions for the radio product, then no additional assessment of the combined equipment against article 3.2 of the RED is required.

The European Compliance Testing listed in Table 6-1 was performed using the Integral PCB antenna listed in Table 6-2.

6.1.2.1 SIMPLIFIED EU DECLARATION OF CONFORMITY

Hereby, Microchip Technology Inc. declares that the radio equipment type RN2483 is in compliance with Directive 2014/53/EU.

The full text of the EU declaration of conformity, for this product, is available at: https://www.microchip.com/wwwproducts/en/RN2483.

6.1.3 APPROVED ANTENNAS

For RN2483, the approval is received using the antennas listed in Table 6-2.

TABLE 6-2: APPROVED ANTENNAS

Sino	P/N	Vendor	Antenna Gain @ 824 ~ 960MHz band	Antenna type
1	AL-A80355-UB701	Alead Technology	2 dBi	Dipole
2	RFA-ZW-C55-B70-D034	Alead Technology	2 dBi	Dipole

6.1.4 HELPFUL WEBSITES

A document that can be used as a starting point in understanding the use of Short Range Devices (SRD) in Europe is the European Radio Communications

Committee (ERC) Recommendation 70-03 E, which can be downloaded from the European Communications Committee (ECC) at: http://www.ecodocdb.dk/

Additional helpful web sites are:

Radio Equipment Directive (2014/53/EU): https://

RN2483

ec.europa.eu/growth/single-market/european-standards/harmonised-standards/red_en

- European Conference of Postal and Telecommunications Administrations (CEPT): http://www.cept.org
- European Telecommunications Standards Institute (ETSI): http://www.etsi.org
- The Radio Equipment Directive Compliance Association (REDCA): http://www.redca.eu/



APPENDIX A: REVISION HISTORY

Revision A (March 2015)

This is the initial release of this document.

Revision B (December 2015)

This revision includes the following updates:

- Updated Deep Sleep value in Table 2-3
- Updated Dimensions value in Table 2-4
- Updated Figure 4-1
- Updated Figure 4-2
- Added Figure 5-2
- Updated information for Section 5.1 "RF Trace Layout Design".

Revision C (April 2017)

This revision includes the following updates:

- Updated Figure 1-2 and Figure 3-1
- Updated Table 1-1, Table 2-2 and Table 2-3
- Added Table 2-6 and Table 2-7
- Updated Section 3.4 "RESET Pin"
- Added Section 3.6 "Internal Program Pins"
- · Deleted Section "5.2 Application Schematic".

Revision D (March 2019)

This revision includes the following update:

- Updated Section 6.1, Europe.
- Updates to Trademarks and Worldwide Sales and Service pages.

Revision E (June 2020)

- Updated Table 2-3
- Updated Table 6-1 and Table 6-2

Revision F (May 2021)

• Updated Section 6.1, Europe

R	N	2	4	8	3
			_	v	v

THE MICROCHIP WEBSITE

Microchip provides online support via our WWW site at www.microchip.com. This website is used as a means to make files and information easily available to customers. Accessible by using your favorite Internet browser, the website contains the following information:

- 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 (FAQ), 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

CUSTOMER CHANGE NOTIFICATION SERVICE

Microchip's customer notification service helps keep customers current on Microchip products. Subscribers will receive e-mail notification whenever there are changes, updates, revisions or errata related to a specified product family or development tool of interest.

To register, access the Microchip website at www.microchip.com. Under "Support", click on "Customer Change Notification" and follow the registration instructions.

CUSTOMER SUPPORT

Users of Microchip products can receive assistance through several channels:

- · 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://microchip.com/support

R	N	2	4	8	3
			т	u	v

PRODUCT IDENTIFICATION SYSTEM

 $\begin{tabular}{ll} \textbf{To order or obtain information, e.g., on pricing or delivery, refer to the factory or the listed sales office.} \end{tabular}$

PART NO.	ł	<u>RM</u>	xxx	Examples:
Device	Temperature Range	Package	Firmware Revision Number	RN2483A-I/RM: Industrial temperature
Device:		Low-Power Long Range Transceiver module	LoRa Technology	
Temperature Range:	1 =	-40°C to +85°C (Industria	al)	
Package:	RM =	Radio Module		

R	N	2	4	8	3
			т	u	v

Note the following details of the code protection feature on Microchip devices:

- Microchip products meet the specifications contained in their particular Microchip Data Sheet.
- · Microchip believes that its family of products is secure when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods being used in attempts to breach the code protection features of the Microchip devices. We believe that these methods require using the Microchip products in a manner outside the operating specifications contained in Microchip's Data Sheets. Attempts to breach these code protection features, most likely, cannot be accomplished without violating Microchip's intellectual property rights.
- Microchip is willing to work with any customer who is concerned about the integrity of its code.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of its code. Code protection does not
 mean that we are guaranteeing the product is "unbreakable." Code protection is constantly evolving. We at Microchip are
 committed to continuously improving the code protection features of our products. Attempts to break Microchip's code protection
 feature may be a violation of the Digital Millennium Copyright Act. If such acts allow unauthorized access to your software or
 other copyrighted work, you may have a right to sue for relief under that Act.

Information contained in this publication is provided for the sole purpose of designing with and using Microchip products. Information regarding device applications and the like is provided only for your convenience and may be superseded by updates. It is your responsibility to ensure that your application meets with your specifications.

THIS INFORMATION IS PROVIDED BY MICROCHIP "AS IS". MICROCHIP MAKES NO REPRESENTATIONS OR WARRANTIES OF ANY KIND WHETHER EXPRESS OR IMPLIED, WRITTEN OR ORAL, STATUTORY OR OTHERWISE, RELATED TO THE INFORMATION INCLUDING BUT NOT LIMITED TO ANY IMPLIED WARRANTIES OF NON-INFRINGEMENT, MERCHANTABILITY, AND FITNESS FOR A PARTICULAR PURPOSE OR WARRANTIES RELATED TO ITS CONDITION, QUALITY, OR PERFORMANCE.

IN NO EVENT WILL MICROCHIP BE LIABLE FOR ANY INDI-RECT, SPECIAL, PUNITIVE, INCIDENTAL OR CONSEQUEN-TIAL LOSS, DAMAGE, COST OR EXPENSE OF ANY KIND WHATSOEVER RELATED TO THE INFORMATION OR ITS USE, HOWEVER CAUSED, EVEN IF MICROCHIP HAS BEEN ADVISED OF THE POSSIBILITY OR THE DAMAGES ARE FORESEEABLE. TO THE FULLEST EXTENT ALLOWED BY LAW, MICROCHIP'S TOTAL LIABILITY ON ALL CLAIMS IN ANY WAY RELATED TO THE INFORMATION OR ITS USE WILL NOT EXCEED THE AMOUNT OF FEES, IF ANY, THAT YOU HAVE PAID DIRECTLY TO MICROCHIP FOR THE INFORMATION. Use of Microchip devices in life support and/or safety applications is entirely at the buyer's risk, and the buyer agrees to defend, indemnify and hold harmless Microchip from any and all damages, claims, suits, or expenses resulting from such use. No licenses are conveyed, implicitly or otherwise, under any Microchip intellectual property rights unless otherwise stated.

For information regarding Microchip's Quality Management Systems, please visit www.microchip.com/quality.

Trademarks

The Microchip name and logo, the Microchip logo, Adaptec, AnyRate, AVR, AVR logo, AVR Freaks, BesTime, BitCloud, chipKIT, chipKIT logo, CryptoMemory, CryptoRF, dsPIC, FlashFlex, flexPWR, HELDO, IGLOO, JukeBlox, KeeLoq, Kleer, LANCheck, LinkMD, maXStylus, maXTouch, MediaLB, megaAVR, Microsemi, Microsemi logo, MOST, MOST logo, MPLAB, OptoLyzer, PackeTime, PIC, picoPower, PICSTART, PIC32 logo, PolarFire, Prochip Designer, QTouch, SAM-BA, SenGenuity, SpyNIC, SST, SST Logo, SuperFlash, Symmetricom, SyncServer, Tachyon, TimeSource, tinyAVR, UNI/O, Vectron, and XMEGA are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

AgileSwitch, APT, ClockWorks, The Embedded Control Solutions Company, EtherSynch, FlashTec, Hyper Speed Control, HyperLight Load, IntelliMOS, Libero, motorBench, mTouch, Powermite 3, Precision Edge, ProASIC, ProASIC Plus, ProASIC Plus logo, Quiet-Wire, SmartFusion, SyncWorld, Temux, TimeCesium, TimeHub, TimePictra, TimeProvider, WinPath, and ZL are registered trademarks of Microchip Technology Incorporated in the U.S.A.

Adjacent Key Suppression, AKS, Analog-for-the-Digital Age, Any Capacitor, AnyIn, AnyOut, Augmented Switching, BlueSky, BodyCom, CodeGuard, CryptoAuthentication, CryptoAutomotive, CryptoCompanion, CryptoController, dsPICDEM, dsPICDEM.net, Dynamic Average Matching, DAM, ECAN, Espresso T1S, EtherGREEN, IdealBridge, In-Circuit Serial Programming, ICSP, INICnet, Intelligent Paralleling, Inter-Chip Connectivity, JitterBlocker, maxCrypto, maxView, memBrain, Mindi, MiWi, MPASM, MPF, MPLAB Certified logo, MPLIB, MPLINK, MultiTRAK, NetDetach, Omniscient Code Generation, PICDEM, PICDEM.net, PICkit, PICtail, PowerSmart, PureSilicon, QMatrix, REAL ICE, Ripple Blocker, RTAX, RTG4, SAM-ICE, Serial Quad I/O, simpleMAP, SimpliPHY, SmartBuffer, SMART-I.S., storClad, SQI, SuperSwitcher, SuperSwitcher II, Switchtec, SynchroPHY, Total Endurance, TSHARC, USBCheck, VariSense, VectorBlox, VeriPHY, ViewSpan, WiperLock, XpressConnect, and ZENA are trademarks of Microchip Technology Incorporated in the U.S.A. and other

 $\ensuremath{\mathsf{SQTP}}$ is a service mark of Microchip Technology Incorporated in the U.S.A.

The Adaptec logo, Frequency on Demand, Silicon Storage Technology, and Symmcom are registered trademarks of Microchip Technology Inc. in other countries.

GestIC is a registered trademark of Microchip Technology Germany II GmbH & Co. KG, a subsidiary of Microchip Technology Inc., in other countries.

All other trademarks mentioned herein are property of their respective companies.

© 2015-2021, Microchip Technology Incorporated, All Rights Reserved.

ISBN: 978-1-5224-8111-9



Worldwide Sales and Service

AMERICAS

Corporate Office 2355 West Chandler Blvd. Chandler, AZ 85224-6199 Tel: 480-792-7200

Fax: 480-792-7200 Fax: 480-792-7277 Technical Support:

http://www.microchip.com/ support

Web Address:

www.microchip.com
Atlanta

Duluth, GA Tel: 678-957-9614 Fax: 678-957-1455

Austin, TX Tel: 512-257-3370

Boston

Westborough, MA Tel: 774-760-0087 Fax: 774-760-0088

Chicago Itasca, IL

Tel: 630-285-0071 Fax: 630-285-0075

Dallas Addison, TX Tel: 972-818-7423

Fax: 972-818-2924 **Detroit** Novi, MI

Tel: 248-848-4000

Houston, TX Tel: 281-894-5983

Indianapolis Noblesville, IN

Tel: 317-773-8323 Fax: 317-773-5453 Tel: 317-536-2380

Los Angeles Mission Viejo, CA Tel: 949-462-9523

Fax: 949-462-9608 Tel: 951-273-7800

Raleigh, NC Tel: 919-844-7510

New York, NY Tel: 631-435-6000

San Jose, CA Tel: 408-735-9110 Tel: 408-436-4270

Canada - Toronto Tel: 905-695-1980 Fax: 905-695-2078

ASIA/PACIFIC

Australia - Sydney Tel: 61-2-9868-6733

China - Beijing Tel: 86-10-8569-7000

China - Chengdu Tel: 86-28-8665-5511

China - Chongqing Tel: 86-23-8980-9588

China - Dongguan Tel: 86-769-8702-9880

China - Guangzhou Tel: 86-20-8755-8029

China - Hangzhou Tel: 86-571-8792-8115

China - Hong Kong SAR Tel: 852-2943-5100

China - Nanjing Tel: 86-25-8473-2460

China - Qingdao Tel: 86-532-8502-7355

China - Shanghai Tel: 86-21-3326-8000

China - Shenyang Tel: 86-24-2334-2829

China - Shenzhen Tel: 86-755-8864-2200

China - Suzhou Tel: 86-186-6233-1526

China - Wuhan Tel: 86-27-5980-5300

China - Xian Tel: 86-29-8833-7252

China - Xiamen

Tel: 86-592-2388138

China - Zhuhai Tel: 86-756-3210040

ASIA/PACIFIC

India - Bangalore Tel: 91-80-3090-4444

India - New Delhi Tel: 91-11-4160-8631

India - Pune Tel: 91-20-4121-0141

Japan - Osaka

Tel: 81-6-6152-7160

Japan - Tokyo

Tel: 81-3-6880- 3770

Korea - Daegu Tel: 82-53-744-4301

Korea - Seoul Tel: 82-2-554-7200

Malaysia - Kuala Lumpur Tel: 60-3-7651-7906

Malaysia - Penang Tel: 60-4-227-8870

Philippines - Manila Tel: 63-2-634-9065

Singapore Tel: 65-6334-8870

Taiwan - Hsin Chu Tel: 886-3-577-8366

Taiwan - Kaohsiung Tel: 886-7-213-7830

Taiwan - Taipei Tel: 886-2-2508-8600

Thailand - Bangkok Tel: 66-2-694-1351

Vietnam - Ho Chi Minh Tel: 84-28-5448-2100

EUROPE

Austria - Wels Tel: 43-7242-2244-39 Fax: 43-7242-2244-393

Denmark - Copenhagen Tel: 45-4485-5910 Fax: 45-4485-2829

Finland - Espoo Tel: 358-9-4520-820

France - Paris
Tel: 33-1-69-53-63-20
Fax: 33-1-69-30-90-79

Germany - Garching Tel: 49-8931-9700

Germany - Haan Tel: 49-2129-3766400

Germany - Heilbronn Tel: 49-7131-72400

Germany - Karlsruhe Tel: 49-721-625370

Germany - Munich Tel: 49-89-627-144-0 Fax: 49-89-627-144-44

Germany - Rosenheim Tel: 49-8031-354-560

Israel - Ra'anana Tel: 972-9-744-7705

Italy - Milan Tel: 39-0331-742611 Fax: 39-0331-466781

Italy - Padova Tel: 39-049-7625286

Netherlands - Drunen Tel: 31-416-690399 Fax: 31-416-690340

Norway - Trondheim Tel: 47-7288-4388

Poland - Warsaw Tel: 48-22-3325737

Romania - Bucharest Tel: 40-21-407-87-50

Spain - Madrid Tel: 34-91-708-08-90 Fax: 34-91-708-08-91

Sweden - Gothenberg Tel: 46-31-704-60-40

Sweden - Stockholm Tel: 46-8-5090-4654

UK - Wokingham Tel: 44-118-921-5800 Fax: 44-118-921-5820