Radiocrafts

Embedded Wireless Solutions

RC2300-ZNM

ZigBee® Network Module

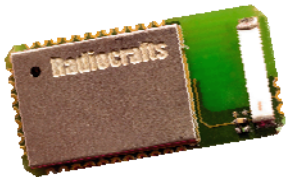
Product Description

The RC2300-ZNM ZigBee Network Module is a compact surface mounted module with a complete embedded ZigBee® network protocol stack supporting wireless star and mesh topologies based on IEEE 802.15.4 compliant PHY and MAC layers. The network module features an easy-to-use serial interface and API for configuration of the module and for sending and receiving ZigBee packets.

The module operates in 16 channels in the 2.45 GHz world-wide license-free ISM band. The complete shielded module is only 12.7 x 25.4 x 2.5 mm with integrated antenna (RC2300AT-ZNM) or pins for external antenna (RC2300-ZNM).

The API gives access to 2 digital and 4 analogue I/Os, 4 channels 12 bit ADC and timers. Using the ZigBee Network Module drastically reduces development time and gives a fast-track to a ZigBee compliant product. The ZigBee application can be implemented on any small external MCU (typically 4k Flash) or embedded controller with tools and compilers the developer is already familiar with.

Applications



- Wireless sensor networks
- Home automation / Building automation
- Smart metering / AMI / AMR
- Asset tracking
- OEM equipment
- Fleet and inventory management

Features

- Compact API command set for ZigBee network configuration and data communication
- API available via UART or SPI serial interface
- Complete shielded module with integrated antenna
- 12.7 x 25.4 x 2.5 mm compact module for SMD mounting
- IEEE 802.15.4 compliant PHY
- Supports all device types (Coordinator, Router and End Devices)
- I/O expansion with 2 digital and 4 analogue I/O pins
- On-board 32.768 kHz real time clock (RTC) oscillator, 4 timers available through the serial interface
- High performance direct sequence spread spectrum (DSSS) RF transceiver
- 16 channels in the 2.45 GHz ISM band
- 2.0 – 3.6 V supply voltage, ultra low power modes (only available using SPI)
- Conforms with EN 300 440 and EN 300 328 (Europe), FCC CFR 47 part 15 (US), ARIB STD-T66 (Japan)

Quick Reference Data

Parameter	RC2300-ZNM	Unit
Frequency band	2.405-2.480	GHz
Number of channels	16	
Data rate	250	kbit/s
Max output power	0	dBm
Sensitivity (PER 1%)	-92	dBm
Adjacent Channel Rejection	29	dB
Alternate Channel Rejection	53	dB
Supply voltage	2.0 – 3.6	Volt
Current consumption, RX/TX	27	mA
Current consumption, PD	0.6	uA
Operating Temperature	-30 to +85	°C

Typical application circuit

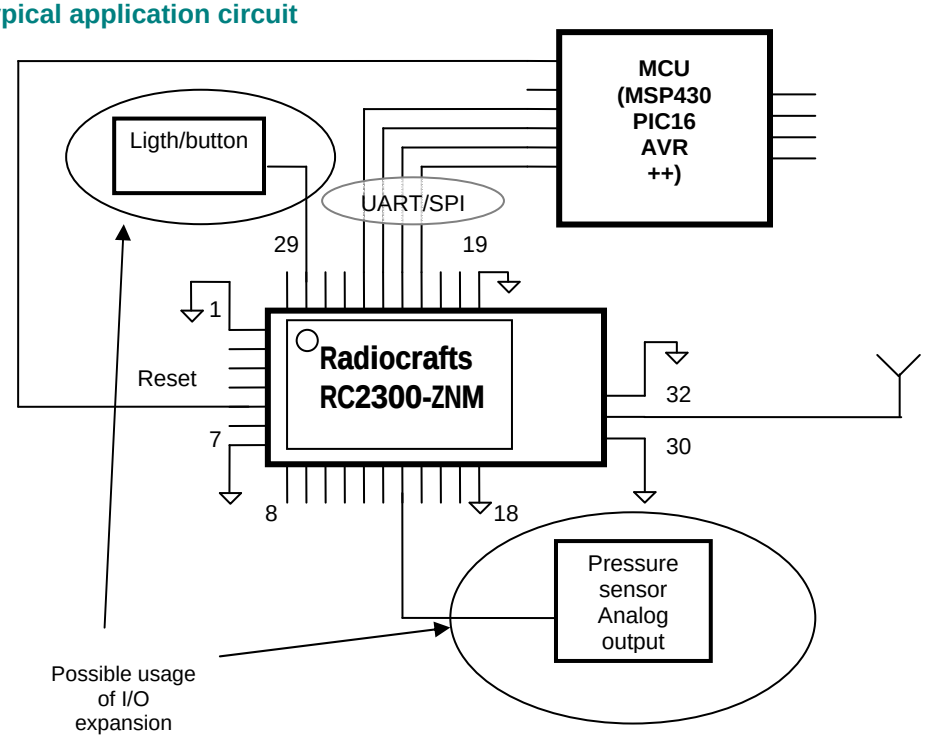


Figure 1. Example application circuit

For more details on I/O possibilities, see page 4 and page 6 regarding pin description and I/O resources.

Frequently Asked Questions

What is IEEE 802.15.4?
It is a standard for low data rate wireless Personal Area Networks (PAN) focusing on low power, low cost and robustness. It defines a Physical layer (PHY) and a Medium Access Control layer (MAC) and is the basis for the open ZigBee protocol or proprietary protocols.

What is ZigBee?
ZigBee is an open global standard aimed for wireless network communication between devices in home control, industrial and building automation applications. It provides star, cluster tree and mesh topologies (see illustration). The multi-hop and ad-hoc routing properties is ideal for non-static networks covering a house or building.

How do I implement my application?
Your application can be implemented in any external microcontroller. Chose a MCU and development tools that are already

What about the ZigBee stack?
The ZigBee 2006 compliant *Z-Stack* from Texas Instruments is implemented and embedded in module.

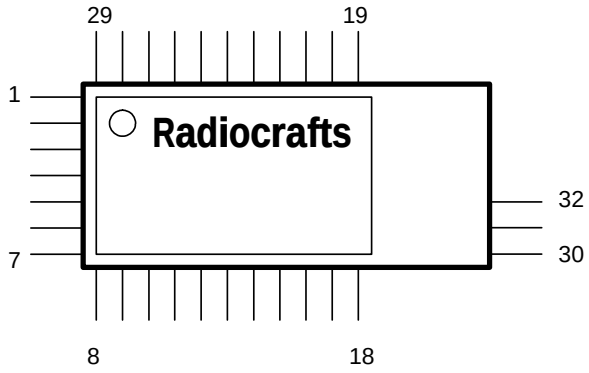
What microcontroller could be used for application?
In principle any microcontroller could be used but we recommend a minimum set of

- 4 kB Flash
- HW UART or SPI HW support

Embedded resources

PHY/MAC: Texas Instruments SoC
ZigBee stack: ZNM implementation based on Z-stack from Texas Instruments

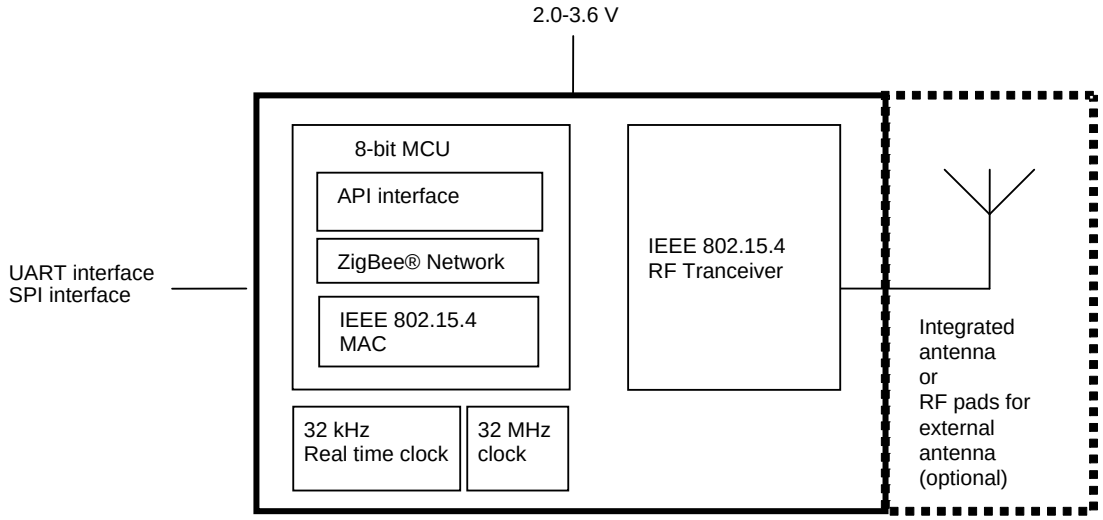
Pin Assignment



Pin Description

Pin no	Pin name	Description and internal MCU connection
1	GND	System ground
2	VCC	Supply voltage input
3	NC	Not connected
4	NC	Not connected
5	NC	Not connected
6	RESET_N	Reset. Active low with internal pull-up.
7	GND	System ground
8	CFG0	Configuration pin 0 (1 = use internal 32kHz crystal, default)
9	CFG1	Configuration pin 1 (1= SPI, 0 = UART)
10	NC	Not connected
11	NC	Not connected
12	A3	Analogue input, A3
13	A4	Analogue input, A4
14	A1	Analogue input, A1
15	A2	Analogue input, A2
16	NC	Not connected
17	NC	Not connected
18	GND	System ground
19	GND	System ground
20	NC	Not connected
21	NC	Not connected
22	RXD/SO	UART/SPI
23	TXD/SI	UART/SPI
24	RTS/CS	UART/SPI
25	CTS/SS	UART/SPI
26	SRDY	Slave ready, for SPI flow control and power management
27	MRDY	Master ready, for SPI flow control and power management
28	GPIO_1	Digital I/O, 20 mA sink/source capability
29	GPIO_0	Digital I/O, 20 mA sink/source capability
30	GND	System ground
31	RF	RF I/O connection to antenna, 50 Ohm. Do not connect for integrated antenna variant (AT).
32	GND	System ground

Block Diagram



Circuit Description

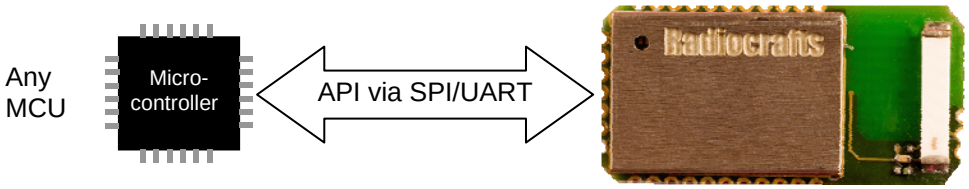
The module contains an IEEE 802.15.4 compliant SoC RF transceiver, high speed oscillator and an RTC 32 kHz oscillator. The module is running the ZigBee network protocol.

The MCU provides several low power modes whitch can be used to reduce the current consumption in battery operated applications. An internal 32 kHz crystal oscillator can be used for real-time clock and timer applications.

The module has an internal POR circuit and a brown out detector, but it is still **highly recommended to add an external power supervisory circuit** to ensure a proper reset when a power fault has occurred.

Serial Communication

Through a serial interface, either SPI or UART, the module/network can be configured and data can be sent and received.



SPI Interface

The SPI interface consists of these signals:

- SO - Slave output
- SI - Slave input
- CS - SPI clock
- SS - SPI Slave select
- MRDY - Master ready
- SRDY - Slave ready

The four upper signals are used for standard SPI operation with RC2300-ZNM as the slave. The MRDY and SRDY are used for power control/flow control. MRDY -> low indicates that the master has data to send and can be used to wake up the ZNM module from sleep. The module will reply with SRDY --> low when it is ready to receive data.

The SPI interface has the following characteristics:

- RC2300-ZNM is SPI slave
- Max clock speed = 4 MHz
- Clock polarity on RC2300-ZNM = 0
- Clock phase on RC2300-ZNM = 0
- Bit order MSB first

UART Interface

The UART interface is implemented as DTE and consists of these signals

- RX - RXD - data to module
- TX - TXD - data from module
- CTS - Input to module
- RTS - Output from module

The setting for the UART is as follows:

UART Configuration	
Baud rate	115.2 kBaud
Data bits	8
Parity	Even
Stop bit	1
Flow control	RTS/CTS (implemented as DTE)

The frame format for the UART is as follows:

Start Of Frame(SOF)	Commands	Frame Check Sum- FCS (1 byte)
0xFE	General frame format	XOR of all bytes in General Data Format

General frame format

The general frame format for sending commands is as follow:

Length of data 1 byte	Command ID 2 bytes	Data 0-253 bytes
0xNN	0xNN NN	0xNN NN ...

API command set

The set of API commands that can be sent via the UART/SPI interface can be divided into four categories:

- System commands
- Simple API (SAPI) commands
- AF commands
- ZDO commands

System commands are for controlling the HW device and include commands for resetting the module and utilizing resources within the module.

Simple API commands consist of only 10 commands which is the easiest way to build a complete application that does network creation and sending/receiving of data.

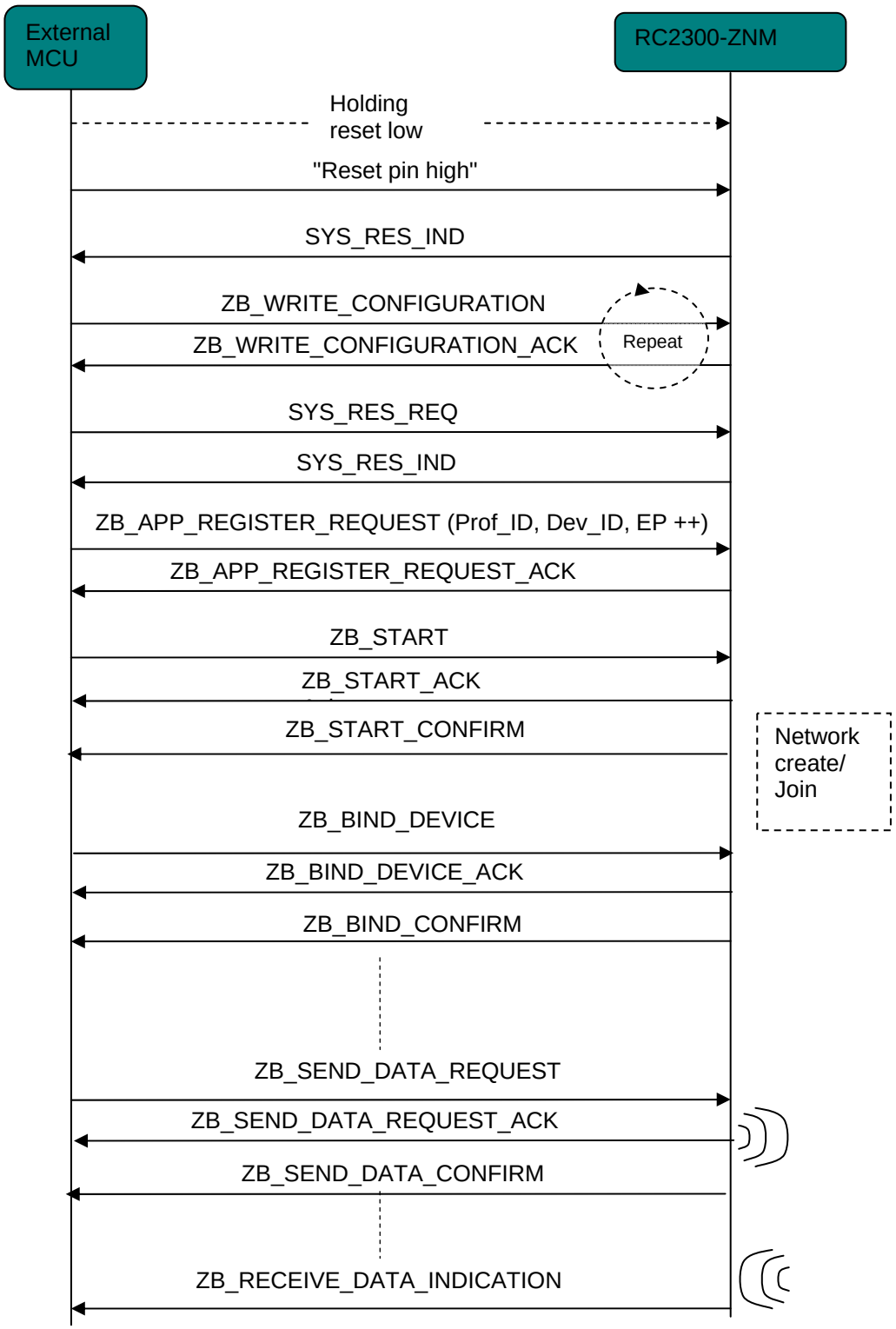
AF commands are commands for registering application and sending data with complete flexibility.

ZDO commands are commands for detailed control of ZigBee device operation regarding ZigBee Device Object. This includes binding devices, finding and matching descriptors.

The complete set of commands **to** the module is shown below:

System commands	Simple API commands	AF commands	ZDO commands
SYS_RESET_REQ	ZB_READ_CONFIGURATION	AF_REGISTER	ZDO_NWK_ADDR_REQ
SYS_VERSION	ZB_WRITE_CONFIGURATION	AF_DATA_REQUEST	ZDO_IEEE_ADDR_REQ
SYS_OSAL_NV_WRITE	ZB_APP_REGISTER_REQUEST		ZDO_NODE_DESC_REQ
SYS_OSAL_NV_READ	ZB_START_REQUEST		ZDO_SIMPLE_DESC_REQ
SYS_OSAL_START_TIMER	ZB_PERMIT_JOINING		ZDO_ACTIVE_EP_REQ
SYS_OSAL_STOP_TIMER	ZB_BIND_DEVICE		ZDO_MATCH_DESC_REQ
SYS_RANDOM	ZB_ALLOW_BIND		ZDO_USER_DESC_REQ
SYS_ADC_READ	ZB_SEND_DATA_RQUEST		ZDO_USER_DESC_SET
SYS_GPIO	ZB_GET_DEVICE_INFO		ZDO_END_DEVICE_ANNCE
	ZB_FIND_DEVICE_REQUEST		ZDO_END_DEVICE_BIND_REQ
			ZDO_BIND_REQ
			ZDO_UNBIND_REQ
			ZDO_MGMT_LQI_REQ
			ZDO_MGMT_LEAVE_REQ
			ZDO_MGMT_PERMIT_JOIN_REQ

For a complete overview of the command interface see *CC2480 Interface Specification* from Texas Instruments. (http://www.ti.com/litv/pdf/swra175a). The RC2300-ZNM is compliant to that interface.


External MCU
RC2300-ZNM
Holding reset low
"Reset pin high"
SYS_RES_IND
ZB_WRITE_CONFIGURATION
ZB_WRITE_CONFIGURATION_ACK
Repeat
SYS_RES_REQ
SYS_RES_IND
ZB_APP_REGISTER_REQUEST (Prof_ID, Dev_ID, EP ++)
ZB_APP_REGISTER_REQUEST_ACK
ZB_START
ZB_START_ACK
ZB_START_CONFIRM
Network create/ Join
ZB_BIND_DEVICE
ZB_BIND_DEVICE_ACK
ZB_BIND_CONFIRM
ZB_SEND_DATA_REQUEST
ZB_SEND_DATA_REQUEST_ACK
ZB_SEND_DATA_CONFIRM
ZB_RECEIVE_DATA_INDICATION

IEEE 802.15.4

The IEEE 802.15.4 standard, approved in May 2003, provides a worldwide standard for Personal Area Networks or short distance wireless networks for low data rate solutions with long battery life and very low complexity. It defines a Physical layer (PHY) and a Medium Access Control layer (MAC) and is the basis for the open ZigBee protocol or proprietary protocols. The typical applications are home and building automation, industrial control and monitoring systems, wireless sensor networks, remote controls and consumer electronics.

The module complies with the IEEE 802.15.4 standard operating in the 2.45 GHz band. It uses direct sequence spread spectrum (DSSS) with 2 Mc/s chip rate giving a raw data rate of 250 kbit/s 16 channels are available in the 2.45 GHz band, channel 11 – 26 (channels 0-10 are reserved for use in the 868 and 915 MHz bands).

For more information on the standard, please consult www.ieee802.org/15/pub/TG4.html

Reference:
IEEE std 802.15.4 -2003: Wireless Medium Access Control (MAC) and Physical layer (PHY) specifications for Low Rate Wireless Personal Area Networks (LR-WPANs)
http://standards.ieee.org/getieee802/download/802.15.4-2003.pdf

The ZigBee Protocol

The ZigBee Alliance is an association of companies working together to enable reliable, cost-effective, low-power, wirelessly networked, monitoring and control products based on an open global standard. The ZigBee Alliance is a rapidly growing, non-profit industry consortium of leading semiconductor manufacturers, technology providers, OEMs and end-users worldwide. Membership is open to all. The ZigBee Alliance, in collaboration with the IEEE, is defining the network, security, and application layers above the IEEE 802.15.4 PHY and MAC layers. This cooperation has resulted in an easy-to-use, standards-based wireless network platform optimised for wireless monitoring and control applications. For more information about the ZigBee Alliance and the ZigBee standard, please consult www.zigbee.org

Power Management

The ZigBee protocol allows End Devices to be powered down, while Routers must be powered all the time in order to handle packet routing. Battery operated devices should be End Devices in order to reduce the power consumption to a minimum.

RF Frequency, Output Power Levels and Data Rates

The following table shows the RF channels as defined by the IEEE 802.15.4 standard.

RF channel	Frequency
11	2405 MHz
12	2410 MHz
13	2415 MHz
14	2420 MHz
15	2425 MHz
16	2430 MHz
17	2435 MHz
18	2440 MHz
19	2445 MHz
20	2450 MHz
21	2455 MHz
22	2460 MHz
23	2465 MHz
24	2470 MHz
25	2475 MHz
26	2480 MHz

The RF transceiver uses direct sequence spread spectrum (DSSS) with 2 Mchip/s chip rate, giving a raw data rate of 250 kbit/s. The modulation format is Offset – Quadrature Phase Shift Keying (O-QPSK). The DSSS makes the communication link robust in noisy environments when sharing the same frequency band with other applications.

The use of RF frequencies and maximum allowed RF power is limited by national regulations. The RC2300 series is complying with the applicable regulations for the world wide 2.45 GHz ISM band.

Specifically it complies with the European Union R&TTE directive meeting EN 300 328 and EN300 440 class 2. It also meets the FCC CFR47 Part15 regulations for use in the US and the ARIB T-66 for use in Japan.

Antenna and Range Considerations

As an option the module is delivered with an integrated antenna (RC2300-ZNM-AT). This is highly recommended for most applications, as this gives a very compact solution containing all the critical RF parts within the module. However, a somewhat better range can be achieved using an external antenna.

Range testing using the integrated antenna shows these typical distances:

- 105 meter outdoor line-of-sight (LOS)
- 10-30 meters indoors depending on building material and construction
- 10-15 meters when passing through floors
- 25-30 meters in the same floor

The variation between different orientations of the antenna measured outdoors line-of-sight is typically within +/- 20%.

With more efficient antennas the range can be extended. LOS distances can typically be:

- 250 meters with ¼ wave monopole antenna on ground plane
- 350 meters with 5/8 wave dipole antenna

The integrated antenna is a compact ceramic antenna working as a quarter-wave resonant antenna. Due to the dielectric ceramic material the antenna is shorter than a normal quarter wave antenna (in air), still providing high radiation efficiency (typical 1 dBi). The antenna is matched for use in the 2.45 GHz band. The radiating part of the antenna is the white ceramic component located outside the shield can. The radiation pattern from the antenna is similar to the donut-shaped radiation from a quarter wave antenna. That is, the maximum radiation is in the plane normal to the length axis of the antenna. For best possible omni-directional radiation the module should be oriented so that the antenna is vertical. To achieve the very best range the transmitting and receiving antenna should be oriented the same way, ensuring the same polarity at both devices. However, indoors reflections of the radio waves in metallic structures tend to spread the polarisation, so even if same orientation is not possible, communication will still take place, but the range is somewhat shorter, typically by 20%.

The antenna should be kept away (> 10mm) from metallic or other conductive and dielectric materials, and should never be used inside a metallic enclosure.

Compared to lower frequencies, operation at 2.45 GHz is more limited to LOS. Reflections from walls and other objects may give multi-path fading resulting in dead-zones. The ZigBee mesh network topology is used to overcome this fading as it allows for alternative routing paths. The mesh network is therefore highly recommended for increased reliability and extended coverage throughout buildings.

In applications where the module must be placed in a metallic enclosure, an external antenna must be used. The RF available at a module pin must be fed to external antenna. The RF input/output is matched to 50 Ohm. If the antenna or antenna connector is placed away from the module at the motherboard, the track between the RF pin and the connector should be a 50 Ohm transmission line.

Using an external antenna, the VSWR of the antenna should be less than 2:1. The VSWR is normally specified in the antenna datasheet and most commercial available antennas fulfil this requirement. If you design a PCB antenna this is an important input requirement for such a design. Using a VSWR higher than 2:1, will result in much reflected power into the module and reducing both the module performance and radiated power. This will in turn reduce the range. Using a VSWR higher than 4:1 is not recommended.

On a two layer board made of FR4 the width of a microstrip transmission line should be 1.8 times the thickness of the board, assuming a dielectric constant of 4.8. The line should be run at the top of the board, and the bottom side should be a ground plane.

Example: For a 1.6 mm thick FR4 board, the width of the trace on the top side should be 1.8 x 1.6 mm = 2.88 mm.

The simplest antenna to use is the quarter wave whip antenna. A quarter wave whip antenna above a ground plane yields 37 Ohm impedance and a matching circuit for 50 Ohm are usually not required.

A PCB antenna can be made as a copper track where the ground plane is removed on the back side. The rest of the PCB board should have a ground plane as large as possible, preferably as large (in one dimension) as the antenna itself, to make it act as a counterweight to the antenna. A quarter wavelength antenna on a PCB must be shorter than the wire antenna due to the influence of the dielectric material of the PCB. The length reduction depends on the PCB thickness and material, as well as how close to the edge of the board the antenna is placed. Typical reduction is to 75-90 % but must be found empirically.

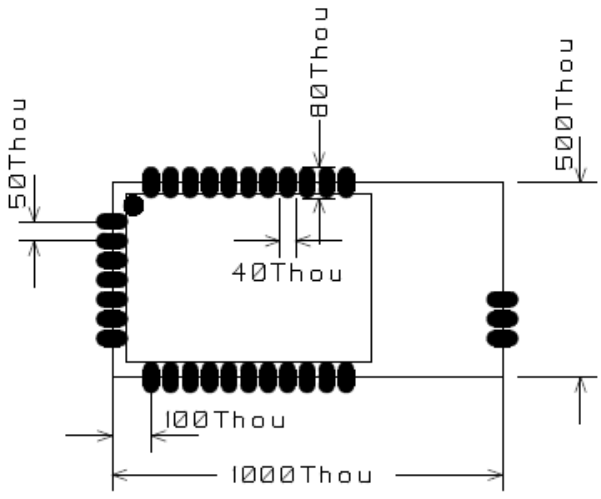
The length of a quarter-wave antenna is given in the table below.

Frequency [MHz]	Length of whip antenna [cm]	Length of PCB track [cm]
2450	2.9	2.25 – 2.7

If, for space reasons, the track is made even shorter than the resonating quarter of a wavelength, the antenna should be matched to 50 ohms using a series inductor and a shunt capacitor.

PCB Layout Recommendations

The recommended layout pads for the module are shown in the figure below. All dimensions are in thousands of an inch (mil). The circle in upper left corner is an orientation mark only, and should not be a part of the copper pattern.



The area underneath the module should be covered with solder resist in order to prevent short circuiting the test pads on the back side of the module. A solid ground plane is

preferred. Unconnected pins should be soldered to the pads, and the pads should be left floating. For the module version with integrated antenna, the RF pad can be soldered, but the pad should not be connected further. The two ground pads (pin 30 and 32 should be grounded for all variants.

When using the onboard chip antenna ("AT" version), careful attention is required to the layout of the PCB where the module is mounted. In Figure 2 the area were no ground plane or other conductive parts must be present, is shown as shaded. This means that there should be no metal on any layer in this region. If possible, the area should stretch infinitely along the two axes. The rest of the PCB should have a solid ground plane.

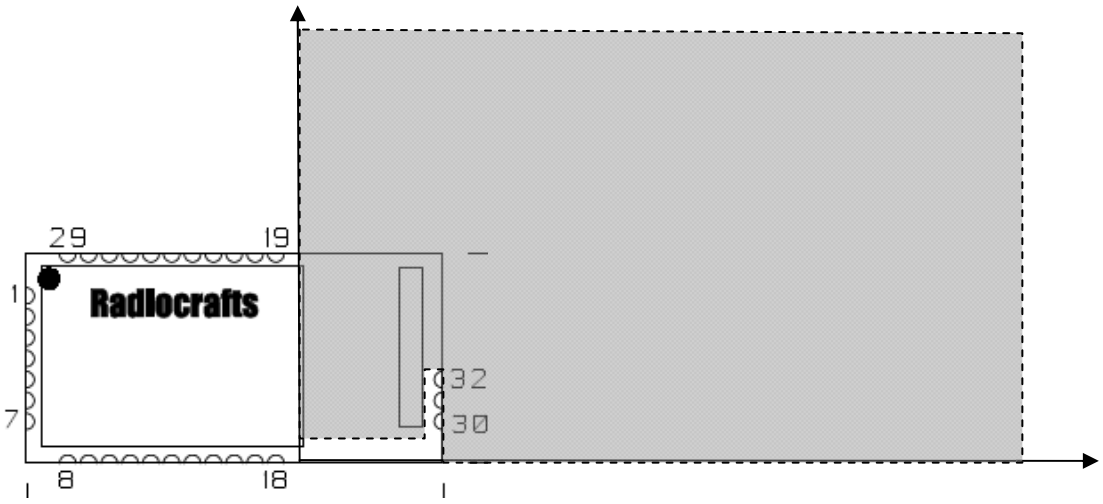


Figure 2. Area without ground plane

In Figure 3, a motherboard is shown with a recommended placement of the module. The recommended PCB type is FR4 with 1.6 mm thickness.

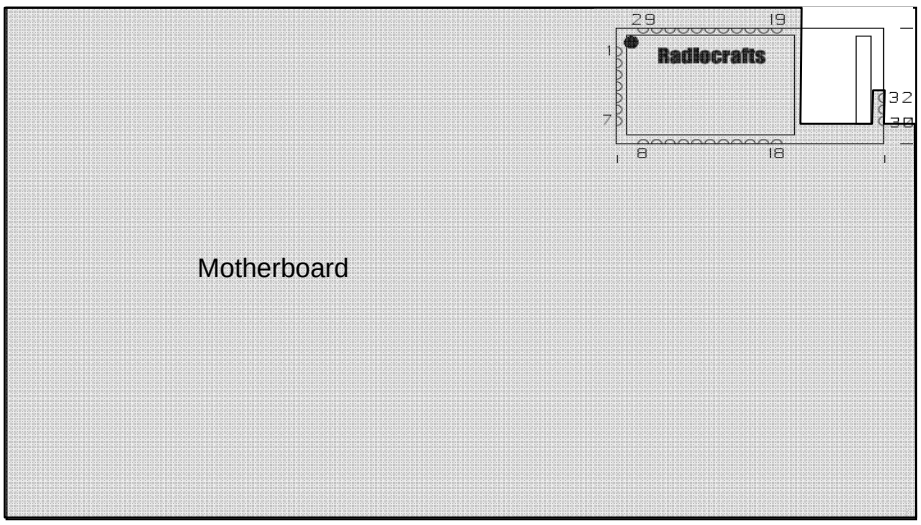
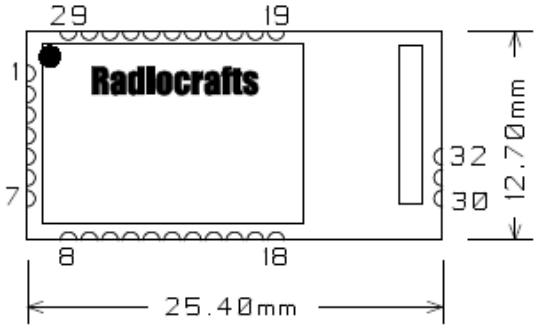


Figure 3. Recommended placement of the module on a motherboard (shaded area is ground plane on the motherboard)

Mechanical Drawing



Mechanical Dimensions

The module size is 0.5” x 1.0” x 0.1” (12.7 x 25.4 x 2.5 mm).

Carrier Tape and Reel Specification

Carrier tape and reel is in accordance with EIA Specification 481.

Tape width	Component pitch	Hole pitch	Reel diameter	Units per reel
44 mm	16 mm	4 mm	13”	Max 800

Absolute Maximum Ratings

Parameter	Min	Max	Unit
Supply voltage, VCC	-0.3	3.6	V
Voltage on any pin	-0.3	VCC+0.5	V
Input RF level		10	dBm
Storage temperature	-50	150	°C
Operating temperature	-30	85	°C

Caution ! *ESD sensitive device. Precaution should be used when handling the device in order to prevent permanent damage.*

Under no circumstances the absolute maximum ratings given above should be violated. Stress exceeding one or more of the limiting values may cause permanent damage to the device.

Electrical Specifications

T=25°C, VCC = 3.0V if nothing else stated.

Parameter	Min	Typ.	Max	Unit	Condition / Note
Operating frequency	2400		2483	MHz	Programmable in 1 MHz steps, 5 MHz steps for IEEE 802.15.4 compliance
Number of channels		16			For IEEE 802.15.4 compliance
Channel spacing		5		MHz	For IEEE 802.15.4 compliance
Input/output impedance		50		Ohm	
Data rate		250		kbit/s	
DSSS chip rate		2		Mc/s	
Frequency stability			+/-40	ppm	
Transmit power	-25		0	dBm	Programmable from firmware
Harmonics 2nd harmonic 3rd harmonic		 -55 -57			
Spurious emission, TX 30 – 1000 MHz 1-12.75 GHz 1.8-1.9 GHz 5.15-5.3 GHz			 -58 -48 -58 -56	dBm	Complies with EN 300 328, EN 300 440, FCC CRF47 Part 15 and ARIB STD-T66
Sensitivity		-92		dBm	PER = 1%
Adjacent channel rejection +/- 5 MHz		41/29		dB	At -82 dBm, PER = 1%. 0 dB for IEEE 802.15.4 compliance
Alternate channel selectivity +/- 10 MHz		54/53		dB	At -82 dBm, PER = 1%. 30 dB for IEEE 802.15.4 compliance
Blocking / Interferer rejection / desensitization +/- 5 MHz +/- 10 MHz +/- 20 MHz +/- 50 MHz		 -29 -25 -19 -17		dBm	Wanted signal 3 dB above sensitivity level, CW interferer, PER = 1%. Minimum numbers corresponds to class 2 receiver requirements in EN 300 440.
Saturation	0	10		dBm	
Spurious emission, RX 30 -1000 MHz 1-12.75 GHz			 -57 -47	dBm	Complies with EN 300 328, EN 300 440, FCC CRF47 Part 15 and ARIB STD-T66

Parameter	Min	Typ.	Max	Unit	Condition / Note
Supply voltage	2.0		3.6	V	
Current consumption, RX		27		mA	MCU in Idle mode using the 32 MHz oscillator.
Current consumption, TX		27		mA	At 0 dBm output power. MCU in Idle mode using the 32 MHz oscillator.
Current consumption, Sleep mode, End Devices		0.6		µA	
MCU clock frequency		32		MHz	
MCU low frequency crystal		32.768		kHz	
Antenna VSWR		<2:1	4:1		

Ordering Information

Ordering Part Number	Description
RC2300-ZNM	ZigBee Network Module, RF available on pin for external antenna
RC2300AT-ZNM	ZigBee Network Module, integrated antenna

Document Revision History

Document Revision	Changes
1.0	First release
1.01	Removed reference to RC2300-ZNM-HP

Product Status and Definitions

Current Status	Data Sheet Identification	Product Status	Definition
	Advance Information	Planned or under development	This data sheet contains the design specifications for product development. Specifications may change in any manner without notice.
X	**Preliminary**	**Engineering Samples and First Production**	**This data sheet contains preliminary data, and supplementary data will be published at a later date. Radiocrafts reserves the right to make changes at any time without notice in order to improve design and supply the best possible product.**
	No Identification Noted	Full Production	This data sheet contains final specifications. Radiocrafts reserves the right to make changes at any time without notice in order to improve design and supply the best possible product.
	Obsolete	Not in Production	This data sheet contains specifications on a product that has been discontinued by Radiocrafts. The data sheet is printed for reference information only.

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This Radiocrafts product is not designed for use in life support appliances, devices, or other systems where malfunction can reasonably be expected to result in significant personal injury to the user, or as a critical component in any life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness. Radiocrafts AS customers using or selling these products for use in such applications do so at their own risk and agree to fully indemnify Radiocrafts AS for any damages resulting from any improper use or sale.

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