Radiocrafts
Embedded Wireless Solutions

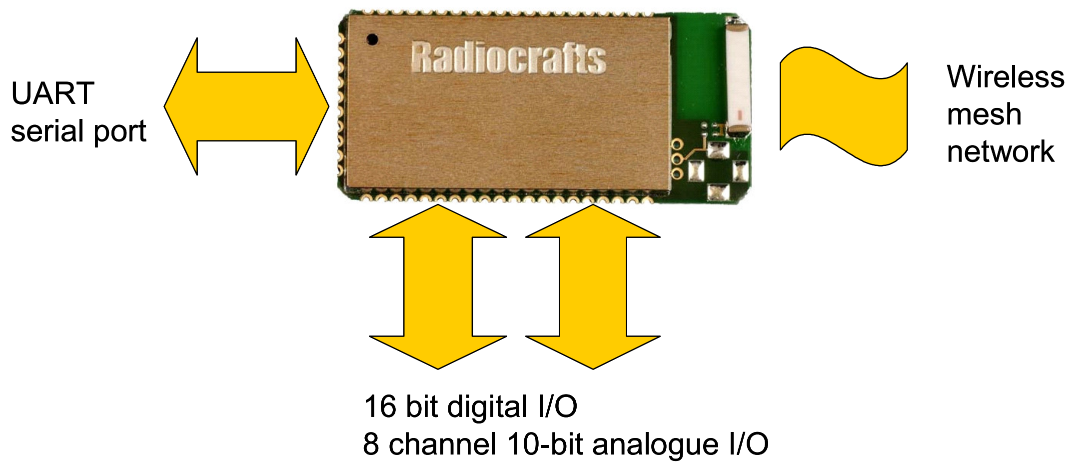
RC2200AT-SPPIO

ZigBee™- based RF Transceiver Module with SPPIO™ profile (Serial Port Profile and I/O mapping)

Product Description

The RC2200AT-SPPIO is a complete off-the-shelf Zigbee-based module with embedded Serial Port Profile and I/O mapping (SPPIO™) application with underlying mesh networking protocol stack. The module acts like a serial port modem with UART interface. In addition it offers up to 16 digital I/Os (of which up to 8 analogue) that can be mapped to any one other module within the mesh network. All configuration of the module is done through an easy-to-use AT-command interface using the serial port.

The device is using the ZigBee™ standard protocol stack for wireless mesh networks based on IEEE 802.15.4 compliant PHY and MAC layers providing 16 channels in the 2.45 GHz world-wide license-free ISM band. The shielded module is only 16.5 x 35.6 x 3.5 mm including the integrated antenna. It is surface mounted and tape & reel delivery enables low cost pick & place manufacturing.



Applications

- RS232 / RS485 / RS422 serial cable replacement
- Sensor / actuator systems
- Home control, building and industrial automation
- Fleet and inventory management

Features

- ZigBee-based mesh networking / IEEE 802.15.4 compliant PHY and MAC
- Serial port profile with UART interface
- I/O mapping with up to 16 digital I/Os, of which up to 8 analogue I/Os (10-bit ADC / PWM)
- Configurable via AT-commands
- Transmission on interrupt, event or timer
- Ultra low power modes
- High performance direct sequence spread spectrum (DSSS) RF transceiver
- 16 channels in the 2.45 GHz ISM band
- Integrated antenna
- 2.7 – 3.6 V supply voltage
- 16.5 x 35.6 x 3.5 mm compact shielded module for SMD mounting
- Conforms with EN 300 440 (Europe), FCC CFR 47 part 15 (US), ARIB STD-T66 (Japan)

Quick Reference Data

Parameter	Value	Unit
Frequency band	2.400-2.4835	GHz
Number of channels	16	
Data rate (on air)	250	kbit/s
Max output power	0	dBm
2nd harmonic	-37	dBm
3rd harmonic	-51	dBm
Sensitivity (PER 1%)	-94	dBm
Adjacent Channel Rejection	39	dB
Alternate Channel Rejection	55	dB
UART data rate	1.2 – 115.2	kBd
Supply voltage	2.7 – 3.6	Volt
Current consumption, RX	30	mA
Current consumption, TX	27	mA
Current consumption, PD	13	uA
Current consumption, SLEEP	20-50	uA
Operating Temperature	-30 to +85	°C

Quick Product Introduction

The RC2200AT-SPPIO is a module pre-programmed with embedded protocol and application firmware. Using a pre-qualified module with the SPPIO profile application is the fastest way to make a ZigBee-based product and achieve the shortest time to market. Because it contains all the RF HW and firmware needed in a 100% RF tested and pre-qualified module it shortens the qualification and approval process. No RF design or expertise is required to add powerful wireless networking to a product.

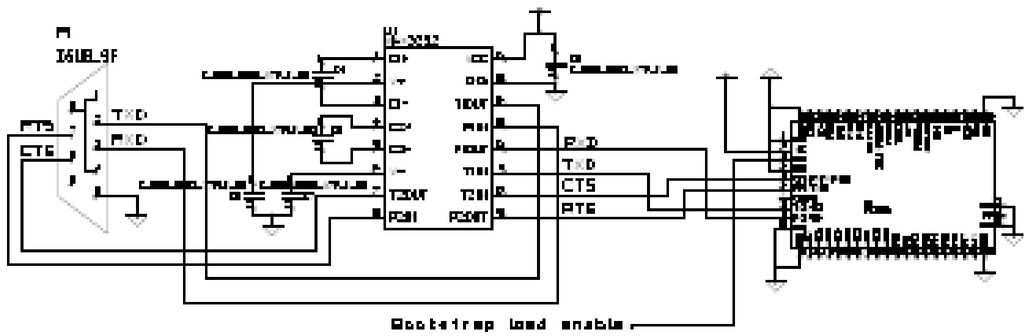
The SPPIO™ application profile offers the following features:

- Buffered UART data packet transmission
- Variable packet length, end character or timeout
- I/O mapping between paired devices of up to 16 digital signals
- I/O mapping between paired devices of up to 8 analogue signals
- Transmission of I/O data trigged by event, interrupt or timer
- Addressing of packets to a unique node
- In-circuit configuration of the radio modem by AT-commands
- Ultra low power consumption using Power Down mode or SLEEP mode
- SLEEP mode with automatic interval transmission feature (End Device only)

Radiocrafts also offers the RC220x family of ZigBee-based modules which are intended for customer specific application development. More information on these products is available at Radiocrafts' website.

Typical Application Circuit

Below is shown a Serial Port application circuit.



Full resolution schematic is found in RC2200_Application_Circuit_SPPIO_1_0.pdf

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. The multi-hop and ad-hoc routing properties is ideal for non-static networks covering a house or building.

What is SPPIO?
SPPIO is an application profile that offers the user a set of standard interfaces and networking features. The interfaces are a serial port (UART) and 16 digital I/O, of which up to 8 analogue I/O. A wide range of sensors and actuators can therefore be directly interfaced to the module. Using the SPPIO means that no further firmware development is required and the module can be used as a plug-and-play network device.

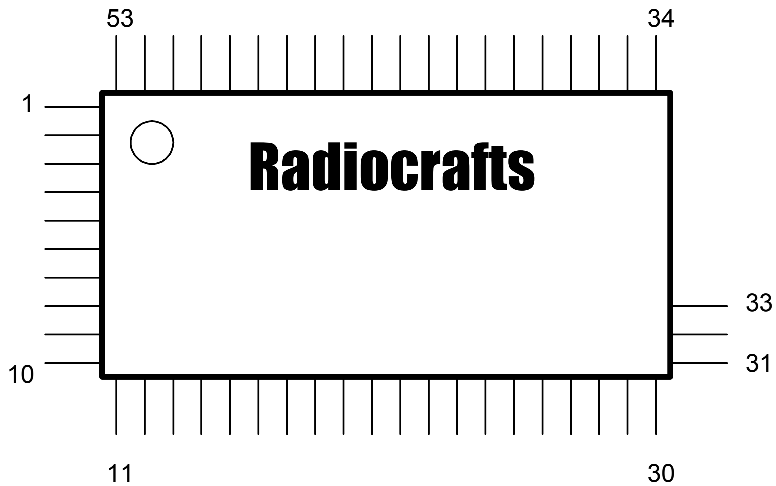
How do I set up an SPPIO mesh network?
All configurations are done by AT-commands at the UART interface. The basic steps are:

- Configure one module as the PAN Coordinator
- Configure all other modules as Routers or End Devices
- Bind or pair devices by mapping one's unique address as the other's destination address
- Select the UART data transmission scheme (on full buffer, end character or timeout)
- Configure the I/O pins to either analogue or digital
- Configure the I/O port direction (input or output)
- Select the I/O data transmission scheme (on events, interrupts or timers)

The Routers and End Devices will automatically associate to the network coordinator as soon as they are switched on. And all the devices will organize themselves in a mesh network with automatic routing. UART data and I/O data will then be exchanged or mapped between devices that are paired. See page 14 for details.

What development tools do I need?
Radiocrafts offer a demo kit, RC2200DK-SPPIO, with two demo boards. The demo boards contain the SPPIO module as well as a voltage regulator, RS232 driver circuit, temperature sensor, potentiometer, LEDs and push buttons. By using the kit, the module can be tested and prototypes of the end application can be built on the boards which gives easy access to all I/Os. The kit comes with one board configured as a Coordinator and the other as a Router (which easily can be re-configured as End Device). No further configuration is required for instant operation, and the kit works out-of-the-box.

Pin Assignment



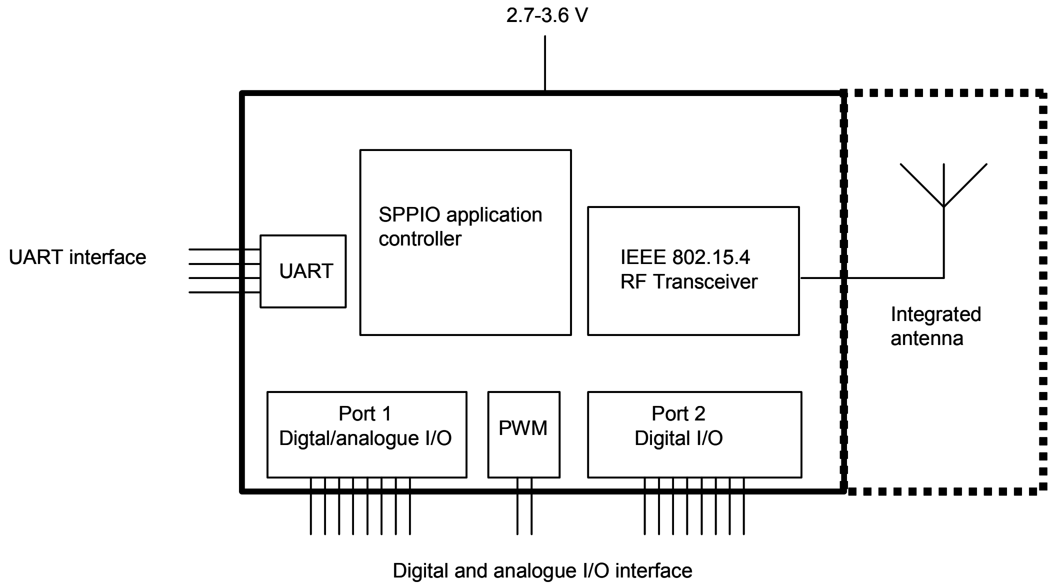
Pin Description

Pin no	Pin name	Description
1	GND	System ground
2	VCC	Supply voltage input
3	PG0	BSL Enable. Connect to ground for using Bootstrap loader for firmware upgrades. Leave open for normal operation.
4	GND	System ground
5	CTS1	UART CTS1
6	RTS1	UART RTS1
7	RXTX	UART RXTX (for control of RS485 driver)
8	TXD1	UART TXD1
9	RXD1	UART RXD1
10	GND	System ground
11	GND	System ground
12	ADC7	Digital or analogue I/O, Port 1, bit 7 (May be used for JTAG TDI)
13	ADC6	Digital or analogue I/O, Port 1, bit 6 (May be used for JTAG TDO)
14	ADC5	Digital or analogue I/O, Port 1, bit 5 (May be used for JTAG TMS)
15	ADC4	Digital or analogue I/O, Port 1, bit 4 (May be used for JTAG TCK)
16	ADC3	Digital or analogue I/O, Port 1, bit 3
17	ADC2	Digital or analogue I/O, Port 1, bit 2
18	ADC1	Digital or analogue I/O, Port 1, bit 1
19	ADC0	Digital or analogue I/O, Port 1, bit 0
20	AREF	Analogue reference voltage pin for the internal A/D Converter. Internally decoupled with 22nF. Do not connect.
21	PE0	Digital I/O, Port 2, bit 0 (May be used for ISP PDI)
22	PE1	Digital I/O, Port 2, bit 1 (May be used for ISP PDO)
23	PE2	Digital I/O, Port 2, bit 2
24	PE3	Digital I/O, Port 2, bit 3
25	PE4	Digital I/O, Port 2, bit 4 (Interrupt capability)
26	PE5	Digital I/O, Port 2, bit 5 (Interrupt capability)
27	PE6	Digital I/O, Port 2, bit 6 (Interrupt capability)
28	PE7	Digital I/O, Port 2, bit 7 (Interrupt capability)
29	1.8V	Internally regulated voltage. Do not connect.
30	GND	System ground

31	GND	System ground
32	RF	RF I/O connection to antenna, 50 Ohm. Do not connect for integrated antenna or connector variant.
33	GND	System ground
34	GND	System ground
35	Reserved	Do not connect
36	Reserved	Do not connect (May be used for ISP SCK)
37	Reserved	Do not connect
38	Reserved	Do not connect
39	Reserved	Analogue PWM output, channel 0. High frequency PWM.
40	Reserved	Do not connect
41	Reserved	Do not connect
42	Reserved	Analogue PWM output, channel 1. High frequency PWM.
43	TOSC2	Internal 32.768 kHz oscillator
44	RESET	Internal MCU reset. Active low with internal pull-up.
45	Reserved	Do not connect
46	Reserved	Do not connect
47	RXD1	Same as pin 9
48	TXD1	Same as pin 8
49	Reserved	Do not connect
50	RTS1	Same as pin 6
51	Reserved	Do not connect
52	CTS1	Same as pin 5
53	GND	System ground

Note 1: UART interface: Pin 8 TXD1, pin 9 RXD1, pin 5 CTS1, pin 6 RTS1
Note 2: ISP (In-System Programming) interface: Pin 36 SCK, pin 21 PDI, pin 22 PDO, pin 44 RESET. See page 27 for more information.
Note 3: JTAG interface: Pin 12 TDI, pin 13 TDO, pin 14 TMS, pin 15 TCK, pin 44 RESET. See page 27 for more information.

Block Diagram



Embedded resources

The module has embedded the Radiocrafts SPPIO application profile based on the Airbee-ZNS. Future upgrades of the firmware will support the Airbee-ZNMS Network Management System.

Circuit Description

The module contains a micro controller unit (MCU) and an IEEE 802.15.4 compliant RF transceiver. The MCU is running the ZigBee-based network protocol with the SPPIO application profile.

The MCU controls the RF transceiver through an SPI interface and hardware handshake signals. The antenna is an integrated chip antenna.

The supply voltage is connected to the VCC pin. The module contains an internal low noise voltage regulator for the RF transceiver, and can therefore operate over a wide supply voltage range. The regulated voltage is available at the 1.8V pin (pin 29), but should not be used to supply external circuits.

The module provides one UART with handshaking possibilities and two 8-bit I/O ports. Port 1 can be configured as either analogue or digital I/O pins. The analogue inputs are connected to an internal 10-bit A/D converter. The port 1 analogue outputs are driven by low frequency software PWMs. Two of the analogue outputs are also available driven by high frequency hardware PWMs. Port 2 provide only digital I/O pins. The configuration of the I/O is done by setting the S-registers using AT-commands.

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

The RC2200AT-SPPIO module is using the ZigBee-based protocol based on the stack implementation by Airbee Wireless.

ZigBee Device Types

ZigBee and the SPPIO™ application profile provide three different device types:

- Coordinator
- Router
- End Device

The Coordinator and Router are referred to as Full Function Devices (FFD), while the End Device is a Reduced Functionality Device (RFD). The SPPIO has implemented both the FFD and the RFD in one build. Hence any SPPIO module can be easily reconfigured as any device type.

The device type can be configured as Coordinator, Router or End Device by setting the NETWORK_DEVICE parameter to 1, 2 or 3 respectively.

SPPIO™ Embedded Application Profile

The SPPIO™ offers the following features:

- Buffered UART data packet transmission
- Configurable packet length, end character or timeout
- I/O mapping between paired devices of up to 16 digital signals
- I/O mapping between paired devices of up to 8 analogue signals
- Transmission of I/O data trigged by event, interrupt or timer
- Addressing of packets to a unique node
- In-circuit configuration of the radio modem by AT-commands

The UART data packet transmission is compatible with RS232, RS422 and RS485 serial busses. Data is transferred to / from the module using a UART interface, the same as used for RS232, RS422 and RS485, except that it use logic level signals (3 — 5V logic).

The I/O mapping feature send the status of digital and analogue input pins on one module, setting corresponding output pins on the module to which it is paired. The pairing, or binding of units, is done by configuring their destination addresses.

The condition for when UART data or I/O data is to be transmitted can be configured. UART data is buffered in the module and transmitted when the buffer is full, when an end character is received, or at a timeout. The I/O data is transmitted together with the UART data, at interrupt or pin change, or at a timeout.

A set of simple, but powerful AT-commands makes it possible to alter the configuration of the module. The configuration is stored permanently in the module's internal EEPROM.

UART Interface

A UART serial bus is used as the interface between the module and the host system for data transmission and for configuration of the module. The UART default setting is 19.2 kBaud, 8 data bits, 1 stop bit and no parity bit. The UART data rate is configurable, see the Configuration memory section. Normally no flow control (handshake) is used. Any microcontroller with hardware or software UART with these settings can be used to communicate with the module. Alternatively, any RS232/422/485 port can be connected via a simple standard level-shifter IC.

The UART baud rate etc is set in the UART_BAUD_RATE, UART_NUMBER_OF_BITS, UART_PARITY, UART_STOP_BITS and UART_FLOW_CTRL in the non-volatile configuration memory (S-registers).

Optionally the CTS, RTS or RXTX can be used for hardware flow control:

CTS pin – Clear to send: The low-asserted CTS pin provides flow control for the module. When CTS is asserted (low), serial data can be sent to the module for RF transmission. If the module is busy, like during RF data transmission or reception, the CTS pin will be de-asserted (high) to stop any data transfer to the module.

RTS pin – Ready to send: When RTS is asserted (low) the host allow data to be sent from the module to the host. The host can stop the module from sending data by de-asserting (high) the RTS signal. Note that if the module has data waiting in the receive buffer, it will not be able to receive or transmit further data until the RTS has been asserted and the data in the buffer is transferred to the host.

RXTX pin – RS485 driver control: RXTX is low when the module can receive data on RXD. RXTX is high when the module is transmitting data on TXD. The RXTX pin is normally connected to the /RE and DE pins on the RS485 driver circuit.

The configuration of the flow control for the UART interface is done by changing UART_FLOW_CTRL in the non-volatile configuration memory (S-registers).

Note: The module CTS is set up during the first stop bit sent from the module when the buffer is full, and the host should then halt further character transmissions to prevent character loss. If the host can not detect the CTS quickly enough during hardware handshake, it should be configured for two stop bits.

Data mode and Command mode

The UART interface is used for sending/receiving data or for AT-commands depending on the module's operating mode. These two modes are referred to as *Data mode* and *Command mode*.

The module will be in the Data mode after power-on or reset. In order to enter Command mode, the command sequence '+++' must be sent to the module. In Command mode the module can receive and interpret AT-commands. *The module cannot receive data over-the-air while in Command mode.* To set the module into Data mode the 'AT0' command must be sent to the module.

UART data transmission

When the module is in the Data mode, all data received at the UART will be buffered and transmitted as a radio packet. The module can handle dynamic packet lengths, only limited by the maximum buffer size. The module will start to transmit the data stored in the buffer when:

- The buffer is full (buffer size is set by PACKET_LENGTH)
- The "End character" is received (character set by PACKET_END_CHARACTER)
- Reaching a timeout after the last character is received on the UART (timeout set by PACKET_TIMEOUT)

The buffer size, end character and the time-out pause can be configured using the AT-commands by changing PACKET_LENGTH, PACKET_TIMEOUT or PACKET_END_CHARACTER parameters in the Configuration memory (S-registers). The data is sent on the air once one of these criteria is met, and the buffer is then cleared.

If more than 60 bytes (which is the maximum packet length) are to be sent as for data file transfer, special precautions must be taken. The data must be split and sent in more than one packet. Do not send an excessive number of bytes to the module, as this may cause overflow in the input buffer. ZigBee or SPPIO does not support fragmentation, so each data packet is sent separately. Any packet loss will therefore mean lost characters, and this must be handled by the end application. The most effective way to do file transfer is to set maximum packet length (PACKET_LENGTH = 60), enable CTS handshake (UART_FLOW_CTRL = 1) and turn off local echo (AT_ECHO_CHARACTER=0). See also Application Note 006 for further details.

I/O mapping

There are two 8-pin ports that are used for I/O mapping. Port 1 can be configured as analogue or digital I/O. Port 2 is digital I/O only.

The direction (input or output) of each pin for the ports are configured by IO_MASK1 and IO_MASK2 respectively. If the bit is set (=1) in this mask, the corresponding pin is used as an input. Clearing the bit (=0) sets an output.

The selection of analogue or digital I/O for port 1 is configured by AD_MASK. If the bit is set (=1) in this mask, the corresponding pin is analogue. Clearing the bit (=0) sets it as a digital I/O.

The combination of IO_MASK1 and AD_MASK sets the direction and pin type for port 1. Analogue inputs are sampled by a 10-bit A/D converter. Analogue outputs are driven as Pulse Width Modulation (PWM) outputs. The PWM outputs at port 1 are driven by software PWMs with limited pulse rate (typ 4 Hz). Analogue channels 0 and 1 are also available as PWM outputs at pins 39 and 42, respectively. These two outputs are driven by hardware PWMs operating at higher pulse rate (typ. 32 kHz). The higher pulse rate reduces the requirement on the low pass filter.

Two devices that are paired (bound) will map each others I/O, and must be configured complementary. That is, pins that are inputs on one module must be configured as outputs on the other module, and vice versa. Analogue/digital selection must be equal for both modules.

Example:

	Module 1	**Module 2**
IO_MASK1	11001010b=0xCA	00110101b=0x35
IO_MASK2	11101100b=0xEC	00010011b=0x13
AD_MASK	00001111b=0x0F	00001111b=0x0F

In this example the Port 1 use 4 pins as analogue I/O, whereof two are used as inputs and two as outputs. The remaining 4 pins of Port 1 is used as digital I/O, two as inputs and two as outputs. Port 2 use 5 pins as inputs on Module 1, and 3 as inputs on Module 2.

The table below gives an overview of the available I/O.

Port	Bit	Pin	Digital	Analogue	Input	Output	Interrupt	Control registers
Port 1	7	12	Y	Y	Y	Y		IO_MASK1 AD_MASK
	6	13	Y	Y	Y	Y		
	5	14	Y	Y	Y	Y		
	4	15	Y	Y	Y	Y		
	3	16	Y	Y	Y	Y		
	2	17	Y	Y	Y	Y		
	1	18	Y	Y	Y	Y		
	0	19	Y	Y	Y	Y		

Port 2	0	21	Y		Y	Y		IO_MASK2
	1	22	Y		Y	Y		
	2	23	Y		Y	Y		
	3	24	Y		Y	Y		
	4	25	Y		Y	Y	Y*	
	5	26	Y		Y	Y	Y*	
	6	27	Y		Y	Y	Y*	
	7	28	Y		Y	Y	Y*	
Port 1	0	39		Y		Y		Additional high speed PWM
	1	42		Y		Y		

* Edge interrupt in normal mode, low level interrupt only for End Device in Sleep mode

I/O mapping scheme

The transmission of I/O data between devices can be done:

- When the UART data is transmitted (on criteria described above)
- On level change (edge interrupt) of digital inputs Port 2, bits 4-7 (pins 25-28)
- In regular intervals based on a programmable timer
- On UART, pin low level interrupt and interval with End Devices in Sleep mode

The scheme for transmitting data is configured by the MAPPING_SCHEME parameter. If regular interval transmissions are to be used the packet interval can be configured by the PACKET_INTERVAL parameter. This is a very powerful feature as it makes the module completely autonomous, doing measurements of analogue and digital sensors at regular intervals configurable from 40 ms to 43 minutes (65536 x 40 ms), in 40 ms increments.

End Devices that are set in SLEEP mode, will wake up and transmit data upon activity on the UART (MAPPING_SCHEME = 0), or on a low level interrupt at of the four digital input pins with interrupt capability (Port 2, bits 4-7, pins 25-28) (MAPPING_SCHEME = 1), or in timer configurable intervals (MAPPING_SCHEME = 2).

Note, in SLEEP mode the interval timer is configured in one second increments. That is, the minimum interval is 1 s, the maximum is 65536 s (= 18.2 hours).

Receiving I/O data on the UART

The received I/O data can optionally be appended to the UART data string and sent on the UART port in addition to simultaneously being mapped to the I/O ports. The I/O data is sent immediately after the UART data with semi-colon (";") separation for the different data fields. The format is like this:

UART data string;DIG1;DIG2;ANA0;ANA1;ANA2;ANA3;ANA4;ANA5;ANA6;ANA7

where

'UART data string' is the ASCII string that was transmitted into the UART
DIG1 is the binary value for port 1 (1 byte, not formatted as decimal ASCII)
DIG2 is the binary value for port 2 (1 byte, not formatted as decimal ASCII)
ANAn (for n=0 to 7) is the binary value for the analogue channel (2 bytes, MSB first, not formatted as decimal ASCII)

The appending of I/O data to the UART data is controlled by the APPEND_IO_DATA parameter. Enabling the appending of I/O data is useful for applications where a central computer shall collect data from many sensors. But it must be disabled (default factory setting) if a true serial cable replacement is to be implemented.

The MAC address of the source node can be added as a prefix to the data string by enabling PREPEND_SOURCE_ADDRESS. This is a very useful feature when collecting data from many nodes.

Power Down

All device types can be set in Power Down mode. Power Down mode is enabled by setting issuing the ATPD command. The Power Down mode actually turns off the device and it is not able to communicate on the air.

The device is woken up from Power Down mode by an interrupt on the UART RXD line. Any UART character (or pulse) sent to the module while in Power Down mode will wake the module.

CAUTION: A Coordinator or Router set in Power Down mode is not able to route messages, and may cause the network to break down.

An End Device set in Power Down mode is not able to transmit or receive messages, but as it is not used for routing messages it does not have an impact on the packet routing in the network.

Sleep mode

The Sleep mode is a very powerful feature to make battery operated systems with very long battery lifetimes. Only End Devices can be set in Sleep mode. When in Sleep mode, the End Device is not able to receive data. Sleep mode is enabled by setting SLEEP_MODE = 1 (ATS2=1), and issue the AT0 command.

Based on the MAPPING_SCHEME (see above) the End Device can be momentarily woken up from Sleep mode, make a data transmission and return back to Sleep mode.

In Sleep mode the UART RXD input will work as a pin interrupt. Any UART character (or pulse) sent to the module while in Sleep will wake the module. This first character will not be buffered or transmitted on the air. The following characters will be sent as data, except for the escape sequence ('+++') which can be used to set the module into command mode. To disable Sleep mode, the ATS2=0 command must be sent to the module when in command mode.

Network Configuration and Addressing

The modules will form a wireless mesh PAN network based on the ZigBee specification and the IEEE 802.15.4 standard. The network is controlled by the single PAN coordinator. All other devices in the net are Routers or End Devices. The Routers will take part in the routing of messages within the mesh network. The End Devices can send and receive messages to/from a Router or Coordinator, but is not used for routing messages between other devices. Therefore the End Device can be set in Power Down mode or SLEEP mode while not communicating.

The ZigBee device type is set by the NETWORK_DEVICE parameter. One and only one device can be configured as Coordinator within the network.

All devices within one network must have the same PAN ID. This is a 16 bit parameter and allows for >65000 different networks. It is configured by the PAN_ID parameter.

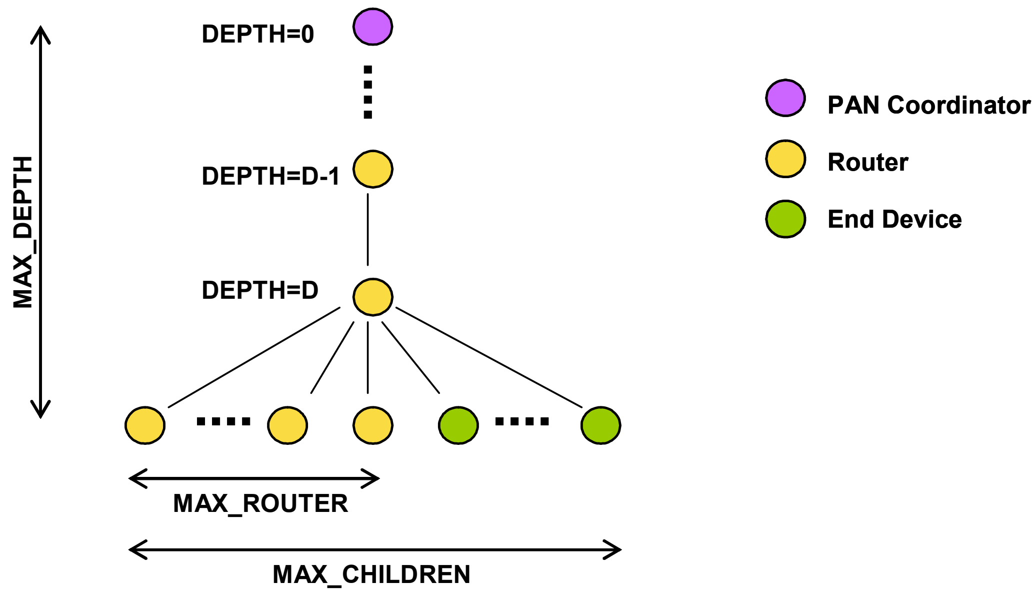
All devices within one network must also operate on the same radio channel. There are 16 channels in the 2.45 GHz band that can be used (channels 11 – 26). The radio channel is set by the RF_CHANNEL parameter.

Each device in the network must have a unique ID, and this is provided by a factory programmed 64-bit MAC address. The pre-programmed address is within the address range allocated by the IEEE to Radiocrafts. This ensures that no other ZigBee device in the world has the same address. The address is stored in the MAC_ID parameter, and should normally never be changed.

A new network is formed by first powering up the Coordinator. *All other device, Routers or End Devices, must be off at this time*. Routers and End Devices can then be powered up, and will associate to the PAN if their PAN ID and RF channel are the same as for the Coordinator, and the device is within reach of the Coordinator or a Router that was already associated. *Only one Router should be powered up at a time*. To ensure that all new nodes added to the network can reach at least one existing node in the network, Routers closest to the Coordinator should be powered up first. If a new node is too far from the excising network, an additional Router should be added to ensure connection with the network. End Devices should be powered up at last.

When new devices associate to the network, they will form a tree structure (even though the network has a mesh topology), forming a parent-to-children relation. There is a limitation in the *depth* of the network, and in the number of *children* a device (parent) can have. The child is either a Router or an End Device. Also, there is a limitation in the number of *Routers* than can be associated to one Coordinator or Router. The network depth is the maximum number of hops from an End Device or Router it takes to get to the Coordinator. These parameters are configured in MAX_CHILDREN, MAX_ROUTER and MAX_DEPTH respectively. This is illustrated in the figure below. The same set of parameters must be used for all devices in the network. It is recommended to use the default values unless other otherwise advised by Radiocrafts.

It is recommended that the Coordinator and Routers are supplied by mains power with battery backup. The battery backup will prevent that the complete network goes down in case of a power failure. After a power failure, the network must be formed again as described above.



Two devices that shall communicate must be bound or paired ("Binding" is the ZigBee terminology for this process). For the SPPIO this is done by setting the DESTINATION_MAC_ADR for the module to be equal to the unique MAC_ADR of the module is shall be bound to. The MAC address for each device in the network should therefore be read and noted, and the logical bindings done by configuring the corresponding device's destination address parameter. In this way two-and-two devices can be paired for I/O mapping or serial communication. Or also a logical tree can be configured (on top of the underlying mesh network) for data acquisition to one central station. In the latter case all devices are configured with the same destination address, that is, the unique MAC_ADR of the device being the data collector. The data collector could be the Coordinator or any other device in the network.

If one device is moved out of reach of its original parent (or surroundings have changed preventing communication), this will be discovered at the *next* transmission attempt. This transmission's data packet will be lost. The orphan device will then search for a new parent and associates again if some other Router (or Coordinator) is within reach.

In summary; for the PAN network to work properly make sure:

- There is one, and only one, Coordinator in the network
- All nodes within the network have the same PAN_ID
- All nodes within the network have the same RF_CHANNEL
- Each device within the network has a unique MAC_ADR
- Devices are bound by configuring the proper DESTINATION_MAC_ADR
- When powering up the Coordinator, all other devices must be off
- Routers and End Devices must be powered up one by one
- Power up Routers closest to the Coordinator first
- End Devices are powered up last

When two devices are paired, the 'ATDR?' command can be used to read the response time to reach the destination node. The time is given in milliseconds, and will depend on the actual structure and size of the network.

Airbee-ZNMS Network Management System

[Not supported in the present release of the firmware] The Airbee-ZNMS is a network management system used to deploy and manage ZigBee networks delivered by Airbee Wireless, Inc. The SPPIO module has built-in support for exchanging network data with the ZNMS management tool. The system also manages gateways interconnecting ZigBee and IP networks. ZNMS Lite is a reduced function version on the full ZNMS.

In order to use the RC2200AT-SPPIO together with the ZNMS, the PAN Coordinator must be configured as a ZNMS gateway coordinator by setting NETWORK_DEVICE = 4. The normal UART data and I/O mapping features are not available for this coordinator. The UART is used for serial communication with the ZNMS host computer through RS232.

The ZNMS provides very useful features for commissioning and management of the network. Some of its features are:

- Remote configuration of devices
- Spotting weak links in the mesh
- Statistics for the traffic in the network

Module Configuration

The configuration of the module can be changed in-circuit from the host during operation, at the time of installation of the equipment, at the manufacturing test, or even as a stand alone module. The configuration (parameters in the Configuration Memory, or S-registers) is changed by sending AT-commands on the UART interface when the module is in Command mode.

The module enters Command mode after receiving the '+++' command sequence. The module will then respond by sending the 'STATUS05' message on the TXD pin. This indicates that the module is ready to receive AT-commands.

The exit command 'AT0' must be sent to the module in order to return to Data mode (normal operation). The module will then respond by sending the 'STATUS06' message on the TXD pin.

Note: As the '+++' sequence will set the module into Command mode, this sequence must never appear in normal data transfer. However, it is possible to change the command sequence character by setting the AT_COMMAND_CHARACTER register. Great care should be taken if the command sequence character is changed, because not knowing this character will prevent further access to the module's Command mode.

After a command is executed, the module responds with 'OK' if the command was carried out successfully, and indicating it is ready for a new command. If the command is not successful, it will send an error message. Some commands will result in warning messages or status messages.

Do not send a new command before the 'OK' response is received. The time required to execute a command can vary depending on the command (see the Timing Information section). There is no 'OK' prompt after the 'AT0' exit command, but the module will respond with 'STATUS06'.

The local echo from the module is controlled by AT_ECHO_CHARACTER. If the echo is turned on (=1), each character received by the module on its RXD line is sent back on the TDX line. In some applications this is a useful way to verify communication with the module. The local echo parameter can be set either using 'ATS21=n' or 'ATE0' / 'ATE1'.

Note: When using hand shake for file transfer, the local echo should be turned off for timing reasons.

The response after executing commands can be controlled by AT_DISPLAY_RESULT. If this parameter is set to 0, the module will not send responses on the TXD line after executing commands. In some applications this is a useful way to prevent the module from overloading the host UART. The display parameter can be set either using 'ATS22=n' or 'ATQ0' / 'ATQ1'.

AT commands

The table below gives a summary of all AT commands.

Permanent change of parameters is done by writing to the Configuration Memory (S-registers) using the 'ATS' commands. These are for example *default* radio channel, *default* output power, UART handshaking, destination address; see the Configuration Memory (S-registers) section.

The parameters that are set by commands directly (not in S-registers) take immediate effect after returning to normal Data mode, but will not be stored in non-volatile memory, and will be lost in case the supply power is turned off or if the module is reset. These parameters are for example the radio channel (ATCH) and output power (ATPW).

A list of commands is shown in the table below. Commands and arguments must be sent as ASCII characters. Some arguments use ASCII representation for hexadecimal numbers, and some for decimal, see the table below.

Parameter	Command	Argument	Note
General			
Enter AT mode	+++		Sequence is used to switch from on-line Data Mode to on-line Command Mode while in a data call.
Exit AT mode	AT0		Command is used to switch back from on-line Command Mode to on-line Data Mode.
AT test	AT		Used to verify connection to the modem. Successful communication returns 'OK'
List AT commands	AT$		Returns a list of available AT commands
Echo characters	ATEn	n=0: No Echo n=1: Echo on	Turns on/off local echo
Display Result Code	ATQn	n=0: Do not display replies n=1: Display replies	The module reply to the command with "OK" or with a result of the command if applicable. ATQn can be used to turn on/off such replies.
Product identification			
Identification	ATIn	n=0: Product code n=1: Product name n=2: Product revision n=3: Copyright n=4: Firmware revision	Command is used to read the products ID
Special registers / configuration registers (permanent change)			
Returns value of register r	ATSr?	For details, see Configuration Memory (S-register) table below	Read a special register. Special register = Configuration memory register address.
Changes value of register r to n	ATSr=n		Set special register. All permanent configuration changes are done through special registers.
Returns all special register settings	ATS?		Reads back all registers. Can be used to verify settings.
Reset all special register values to default (factory settings)	ATF		This command does NOT overwrite the IEEE address at MAC_ADR or DESTINATION_MC_ADR. Default device type is Router, and Echo is turned off.
Operating modes and test modes			
Set modem in Power Down	ATPD		Sets module in Power Down, while UART is still active. Any character or pulse on the UART

			RXD line will wake the module.
Set Power Up/Idle	ATIDLE		"Normal mode", used to wake up after Power Down, and clear the test modes ATTX and ATRX. When waking from Power Down any character can be used.
Set TX Mode	ATTX		Test mode only. TX mode with PN9 modulation
Set RX Mode	ATRX		Test mode only. RX mode with un-buffered data DIO and DCLK available at external pins
Change operational parameters (non-permanent)			
Set Channel (Frequency)	ATCHnn	nn = 11 – 26	Used to change radio channel without programming default value in S-register
Set Output Power	ATPWn	n = 1 – 5	Used to change radio output power without programming default value in S-register
Set Destination Address	ATDA=XX	XX = 00-15-20-12-34-56-78	Used to change destination address without programming default value in S-register. Use IEEE MAC address format
Get Destination Address	ATDA?		Used to read the current destination address. Uses IEEE MAC address format
Get Destination Response time	ATDR?		Used to read the time required for reliable data transmission to the paired devices. Value returned in ms.
I/O ports			
Get ADC	ATAr?	R = 0 – 7	Read local ADC channel r
Set DAC	ATAr=n	r = 0 – 7 n = 0 – 1023	Set local DAC channel r to n
Get general I/O port	ATDr?	R = 1 – 2	Read digital I/O from port r (1 or 2)
Set general I/O port	ATDr=n	r = 1 – 2 n = 0 – 255	Set digital I/O on port r (1 or 2) to n

Status messages, error messages and warnings

The status messages, error messages and warnings are shown in the tables below.

Status code	Message	Note
STATUS01	Entered Init State	After Reset
STATUS02	Exited Init State	After successful booting
STATUS03	Network Formation Complete	When Coordinator has formed a new network
STATUS04	Network Join Complete	When Router or End Device has joined a network
STATUS05	Entered Command Mode	After '+++'
STATUS06	Entered Data Mode	After AT0
STATUS07	Device Paired Successfully	After successful pairing with node with destination address
STATUS08	Device Pairing Failure	If pairing with node with destination address fails
STATUS09	Entered Power Down mode	After ATPD
STATUS10	Exited Power Down mode	After UART port interrupt
STATUS11	Entered Sleep mode	After ATS2=1 and AT0
STATUS12	Exited Sleep mode	After UART port interrupt
STATUS13	Enter Route Discovery process	
STATUS14	Exit Route Discovery	

	process Successfully	

Error code	Message	Possible cause for error message
WARNG01	Test mode warning	This warning message will be displayed when the commands ATTX, ATRX and ATPD are issued to indicate that command ATIDLE should be issued to return back to normal mode
WARNG02	No paired device warning	This warning message may be displayed when the command AT0 is issued. This warning indicates that the device is not paired successfully and thereby does not enable Data transfer. Data transfer is supported only when it is paired successfully with another device.
WARNG03	End Device in sleep mode warning	This warning message will be displayed for any AT command (except for AT0 and ATS2=0) issued to an end device that is in sleep mode following an external interrupt through UART. The device should be put back to normal state by issuing AT0 or ATS2=0.
WARNG04	End Device sleep mode not paired warning	This warning message will be displayed when the command ATS2 =1 is issued in RFD and the device is not paired successfully and thereby does not enable Sleep mode. Sleep mode is supported only when it is paired successfully with another device.
WARNG05	PAN ID conflict	This warning message will be displayed is there is a PAN ID conflict.
ERROR01	Bad command	If the first character is a value other than ‘A’, or if the <Enter> key is pressed before the first character
ERROR02	<Reserved>	<Reserved for future use>
ERROR03	Not allowed	If ATS2=1 is executed on a FFD (Coordinator or Router), or if Packet Interval value is set to 0
ERROR04	Parse failure	Wrong AT command, or some undefined character
ERROR05	Value already set	When a device is to be set to sleep mode (ATS2=1), when already in sleep mode.
ERROR06	Illegal port operation	If the command ATAr=n is issued when the port pin is not configured as analogue pins.
ERROR07	Illegal port operation	If the command ATAr=n or ATDr=n is issued when the port pin is set as input pin.

ERROR08	Invalid Value	Value is out of range
ERROR09	Illegal format or value	When destination MAC address (ATS5) is issued in an invalid format, or the address of the device (local address) is given as the destination MAC address.
ERROR10	Illegal format	When the address of the device (ATS4) is issued in an invalid format.
ERROR11	Illegal configuration	When the device is to be configured as a coordinator (ATS3=1), when it is in Sleep Mode.
ERROR12	Illegal command	When any other command other than ATIDLE is issued after ATTX, ATRX and ATPD commands.
ERROR13	Illegal configuration	N.A.
ERROR14	NLME Reset failure	
ERROR15	Discovery failure	No suitable parent available in the network
ERROR16	Join failure	No suitable parent available in the network
ERROR17	Formation failure	A network with same PAN ID is already present
ERROR18	Application acknowledgement not received	Application acknowledgement has not been received
ERROR19	ATT table in Coordinator is full	The Application Topology Table if full. That is, maximum number of bindings in the network has been reached.
ERROR20	Route Discovery failure	

Configuration Memory (S-registers)

The table below shows the complete list of configurable parameters stored in non-volatile Configuration Memory referred to as S-registers. These values can be read/written using the 'ATS' commands. All arguments must be sent as binary values to the module (not as ASCII representation for hex or decimal).

Parameter	Description	Address	Argument dec	Factory setting hex (dec)	Comment
Radio configuration					
RF_CHANNEL	Default RF channel	0	11-26	18	16 channels as specified by IEEE 802.15.4. See page 29 for corresponding frequencies.
RF_POWER	Default Output power	1	1-5	5	See page 29 for corresponding output power.
SLEEP_MODE	Sleep mode enable for End Device	2	0: Disabled 1: Sleep and wake on interrupt	0	For End Device only. Wake from sleep mode on UART interrupt, I/O pin low level interrupt (4 pins only), timer interrupt
Device type, addressing and network management					
NETWORK_DEVICE	ZigBee device type	3	1: Coordinator 2: Router 3: End device [4: Reserved]	2	Takes effect at Reset.
MAC_ADR	MAC address	4	0015200000000000-001520FFFFFFFFFFh (hexadecimal)	Unique value programmed from factory	IEEE 802.3 MAC address. The ATF command does NOT overwrite this address. Read/write format is: "00-15-20-00-00-00-00-00" Takes effect at Reset
DESTINATION_MAC_ADR	Default destination address	5	0015200000000000-001520FFFFFFFFFFh (hexadecimal)	0015200000000000	IEEE 802.3 MAC address of destination device. The ATF command does NOT overwrite this address. Read/write format is: "00-15-20-00-00-00-00-00" (The ATDA command can be used not writing to EEPROM)
PAN_ID		6	0000-FFFF (hexadecimal)	0	
MAX_CHILDREN		24	1-5	5	Do not change
MAX_ROUTER		25	1-3	3	Do not change
MAX_DEPTH		26	1-7	7	Do not change
Serial port configuration					
PACKET_LENGTH		7	1-60	60	Max packet length. When buffer is full, modem will transmit data
PACKET_TIMEOUT	Time before modem time-out and transmit buffered data	8	0-255 0: None 1: 40 ms 2: 80 ms 25: 1 s 255: 10 s	25	None means packet timeout is disabled (not 0 s), and module will transmit on packet length or end character instead. Timeout value is PACKET_TIMOEOUT x 40 ms
PACKET_END_CHARACTER		9	0-255 0: None 13: CR 10: LF 90: 'Z'	0	ASCII character

Parameter	Description	Address	Argument dec	Factory setting hex (dec)	Comment
APPEND_IO_DATA		27	0: Disabled 1: Enabled	0	Set to 0 for true serial data wire replacement. When enabled all remote I/O data readings are sent on the receiver end UART
PREPEND_SOURCE_ADDRESS		28	0: Disabled 1: Enabled	0	Set to 0 for true serial data wire replacement. When enabled the source MAC address for the incoming data are sent on the receiver end UART as a prefix
I/O port mapping configuration					
MAPPING_SCHEME		10	0: on UART 1: on pin change 2: on interval	0	Determines when to start a transmission of the I/O mapping
PACKET_INTERVAL	Interval between automatic transmissions of IO data	11	1-255 1: 40 ms (1 s) 2: 80 ms (2 s) 25: 1 s (25 s) 255: 10 s (255 s) 65536: 2621 s (18.2 hours)	25	Used for MAPPING_SCHEME = 2. Interval value is PACKET_INTERVAL x 40 ms. The maximum value is 43.7 minutes. In SLEEP mode the interval value is PACKET_INTERVAL x 1 s. The maximum value is 18.2 hours. Values in brackets apply in SLEEP mode.
IO_MASK1		12	00-FF 00 = all outputs FF = all inputs (hexadecimal)	0xFF	Port 1, digital or analogue 0 = output 1= input
IO_MASK2		13	00-FF 00 = all outputs FF = all inputs (hexadecimal)	0xFF	Port 2, digital only 0 = output 1= input
AD_MASK		14	00-FF '00=all digital FF=all analogue (hexadecimal)	0xFF	Port 1 only 0= digital 1= analogue
UART Serial Port					
UART_BAUD_RATE	Baud rate	15	0: Auto 1: 1200 2: 2400 3. 4800 4: 9600 5: 14400 6: 19200 7: 28800 8: 38400 9: 57600 10: 115200	6: 19200	BE CAREFUL IFCHANGING AS HOST MAY LOOSE CONTACT WITH MODEM! Takes effect at Reset
UART_NUMBER_OF_BITS	Number of bits	16	7: 7 data bits 8: 8 data bits	8	Takes effect at Reset
UART_PARITY	Parity	17	0: None 1: Odd 2:Even	0	Takes effect at Reset
UART_STOP_BITS	Number of stop bits	18	1: One 2: Two	1	Takes effect at Reset
UART_FLOW_CTRL	UART flow control	19	0: None 1:CTS only 2:CTS/RTS 3: N.A. 4:RXTX(RS485)	0	Takes effect at Reset
AT command interface					

Parameter	Description	Address	Argument dec	Factory setting hex (dec)	Comment
AT_COMMAND_CHARACTER	Command sequence character	20	2Bh: '+' [20h-7Fh]	2Bh: '+'	Default is '+', so that AT mode can be entered sending '+++'.
AT_ECHO _CHARACTER		21	0: Do not echo 1: Echo	0	Turn echo on/off, affects AT commands only
AT_DISPLAY _RESULT		22	0: Do not display result 1: Display	1	Turn reply on/off, affects AT commands only
PRODUCT_ID	Product identifier with revisions	23	Product name, Hardware rev., Software rev.	"RC2200, 1.00, 1.00 "	ASCII text string. Comma is used as separator.

All register values can be listed using the 'ATS?' command. A list of all parameters with comma spacing is then returned. This command can be used to verify and check the module configuration.

Individual registers can be read using the 'ATSr?' command, where n is the register address (in decimal ASCII representation).

Registers can be changed by using the 'ATSr=n' command, where r is the register address (in decimal ASCII representation) and n is the new value (in hex or decimal ASCII representation, see table above).

The format for setting a new MAC address (MAC_ADR and DESTINATION_MAC_ADR) is somewhat different. The format for the 64 bit code is: '01-23-45-67-89-AB-CD-EF', where each pair of digits represent the hex ASCII representation. A hyphen is used between each pair of digits in order to improve the readability, following the IEEE recommendation.

Factory defaults can be restored using the 'ATF' command. This command revert all registers to their factory default setting, except for the MAC addresses (MAC_ADR and DESTINATOIN_MAC_ADR) which are not altered.

Example:
To change the default RF_CHANNEL (at address 0x00) and set it to 18, send the following sequence:

ATS1=18

To change the local digital I/O port 2 and set the four lowest bits, clearing the four upper bits, send the following sequence:

ATD2=0F

(Note: 0F is the hexadecimal ASCII representation for the binay value 00001111)

Power Management

There are two means for power saving, either using Power Down mode or Sleep mode.

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.

Power Down mode

The module can be set in *Power Down* (PD) mode in order to reduce the power consumption by using the ATPD command. The module is not able to work as a part of the network when in PD mode, and needs to re-associate when it is turned back on (set to IDLE mode). When in PD mode, the device is woken up from Power Down mode by an interrupt on the UART RXD line. Any UART character (or pulse) sent to the module while in Power Down mode will wake the module. See page 13 for more information.

Sleep mode

End Devices are allowed to sleep even when they are associated to the network. Co-ordinators or Routers are not allowed to sleep as they have to route messages from other nodes within the mesh network.

The low power *Sleep mode* is entered by setting the SLEEP_MODE parameter to 1. The module will then only wake up and transmit messages on interrupts. That is, either when data is entered at the UART, when one of the four digital I/O pins generates an interrupt or on interval timer interrupt. See page 13 for more information.

With an End Device using the Sleep mode, a very low power alarm supervision system can be made. Only when an alarm occurs and generates a pin interrupt, the module is active. The rest of the time the module is in a very low power sleep mode.

Supply voltage off

To completely shut down the module, the supply voltage can be turned off. In order to ensure that the internal Power On Reset (POR) operates correctly, the maximum rise-time specification for VCC must be met (see Electrical Specifications). If longer rise-time is expected it is recommended to use an external POR circuit attached to the RESET pin (see Application Note AN001). Slow VCC rise-time or short power interruptions may cause improper operation that is not handled by the internal POR. In this case the RESET should be activated in order to ensure proper start-up.

Timing Information

The table below shows the timing information for the module when changing between different operating states and transmitting data. Do note that events depending on over-the-air communication will have a spread in timing due to noise, network load and number of hops. The table also show the status message response.

Symbol	Value (typical)	Description / Note
$t_{OFF-DATA}$	C: 1 s R: 1 s ED: 1 s	From switching supply power on to Data Mode C: STATUS01, STATUS03, STATUS02 R/ED: STATUS01, STATUS04, STATUS07, STATUS02
$t_{RESET-DATA}$	C: 1 s R: 1 s ED: 1 s	From Reset to Data Mode C: STATUS01, STATUS03, STATUS02 R/ED: STATUS01, STATUS04, STATUS07, STATUS02
$T_{PD-DATA}$	70 ms	From Power Down to Data Mode. Including STATUS10 message
$T_{SLEEP-DATA}$	18 ms	From Sleep Mode to Data Mode, End Device only. Including STATUS12 message
$T_{DATA-CONFIG}$	8 ms	From ‘+++’ is sent to Configuration Mode. Including STATUS05
$T_{CONFIG-DATA}$	8 ms	From ‘AT0’ is sent to Data Mode. Including STATUS06
$T_{ATDA-PAIRED}$	25 ms	From ‘ATDA’ is sent until device is paired (STATUS07)
t_{TX}	7.5 – 15 ms	From last character received on UART RXD until first character send on the UART TXD. One hop.
T_{SLEEP_INT}	Min 1.5 ms	Minimum pulse length for low level pin interrupt from ED sleep mode.

C: Coordinator, R: Router, ED: End Device

Firmware upgrade

Firmware upgrades can be done by using the built-in bootstrap loader (BSL). The bootstrap loader uses the UART serial port for uploading new software from a PC running a command line BSL application. The BSL application will be made available together with any firmware upgrades.

The BSL require access to pin 3, PG0. This pin must be pulled low when the device is reset in order to enter BSL mode.

The table below show the BSL pin mapping.

Signal	Pin
RXD1	9 or 47
TXD1	8 or 48
PG0 (BSL Enable)	3

Supply and ground must also be connected during BSL programming.

Important note: Firmware upgrade by use of JTAG or ISP interface is not supported. The following description of JTAG and ISP interface are for information only. However, these interfaces could be used to ensure the possibility for doing future upgrades of the BSL itself, or loading new application profiles. The ISP interface should be made available at the end application board in order to enable the JTAG interface fuses, and the JTAG interface for firmware upgrade and debugging.

JTAG Interface

The module offers a JTAG interface for Flash and EEPROM programming, as well as for debugging.

Programming through the JTAG interface requires control of the four JTAG specific pins: TCK, TMS, TDI, and TDO. Control of the reset and clock pins is not normally required. To be able to use the JTAG interface, the JTAGEN Fuse must be programmed. The device is default shipped with the JTAG interface disabled in order to use these pins as general I/O. To enable the JTAG interface the ISP interface must be used. For further information, please refer to the respective MCU data sheet.

The table below show the JTAG pin mapping.

Signal	Pin
TDI	12
TDO	13
TMS	14
TCK	15
RESET	44

Supply and ground must also be connected during programming.

ISP Interface

The module offers an In-System Programming (ISP) interface for Flash and EEPROM memory programming. The fastest way to do firmware downloading in manufacturing is through the ISP interface rather then the JTAG interface. The ISP interface must be used to enable the JTAG interface if it was disabled.

The memory arrays can be programmed using the serial interface bus while RESET is pulled to GND. The serial interface consists of pins SCK, PDI/MOSI (input) and PDO/MISO (output).

After RESET is set low, the Programming Enable instruction needs to be executed first before program/erase operations can be executed. More information is available in the respective MCU data sheets.

The table below show the pin mapping for ISP programming.

Signal	Pin
PDI	21
PDO	22
SCK	36
RESET	44

Supply and ground must also be connected during programming.

RF Channel, Output Power Levels and Radio Regulations

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 output power level can be configured in the range -25 to 0 dBm as shown in the table below.

RF_POWER	Output power
1	-25 dBm
2	-15 dBm
3	-10 dBm
4	- 5 dBm
5	0 dBm

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 RC2200-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. Still, in some countries a formal approval of the end product may be required. In the US a formal FCC approval is required.

Antenna and Range Considerations

The module is delivered with an integrated antenna, as this gives a very compact solution containing all the critical RF parts within the module.

Range testing using the integrated antenna shows these typical distances:

- 110 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%.

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%.

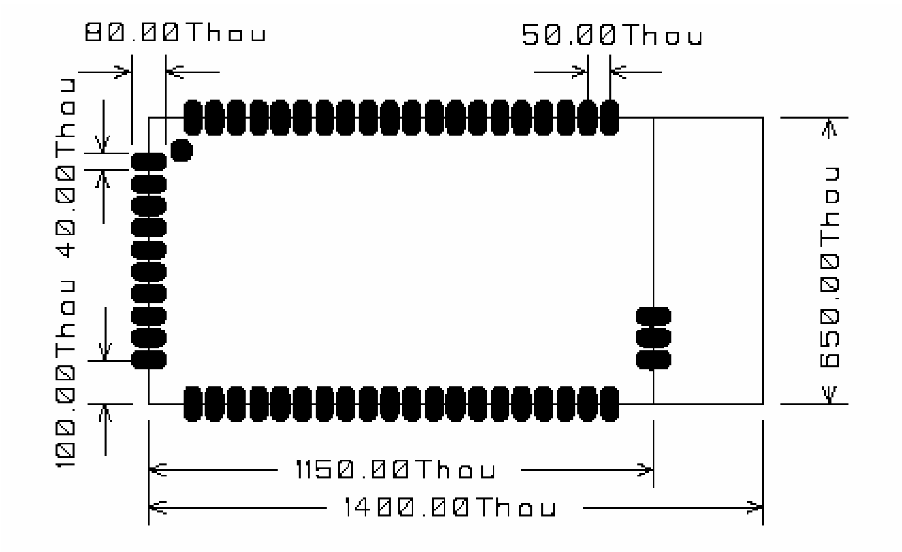
The antenna should be kept away (> 10mm) from metallic or other conductive and dielectric materials, and should never be used inside a metallic enclosure.

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. Please consult Radiocrafts in this case for recommendations.

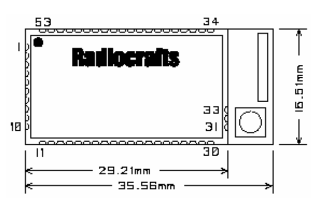
PCB Layout Recommendations

The recommended layout pads for the module are shown in the figure below (top view, pin 1 is in upper left corner, see pin assignment at page 5). 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 (pin 31) can be soldered, but the pad should not be connected further. The two ground pads (pin 30 and 32 on the right side) should be grounded.

Mechanical Drawing



Mechanical Dimensions

The module size is 0.65” x 1.4” x 0.14” (16.5 x 35.6 x 3.5 mm) including the antenna.

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
56 mm	20 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 16 channels 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 (on air)		250		kbit/s	
DSSS chip rate		2		Mc/s	
Frequency stability			+/-40	ppm	
Transmit power	-25		0	dBm	Programmable in 5 steps
Harmonics 2nd harmonic 3rd harmonic		 -37 -51			
Spurious emission, TX 30 – 1000 MHz 1-12.75 GHz 1.8-1.9 GHz 5.15-5.3 GHz			 -36 -30 -47 -47	 dBm	Complies with EN 300 328, EN 300 440, FCC CRF47 Part 15 and ARIB STD-T66
Sensitivity		-94		dBm	PER = 1%
Adjacent channel rejection +/- 5 MHz		 46/39		 dB	At -82 dBm, PER = 1%. 0 dB for IEEE 802.15.4 compliance
Alternate channel selectivity +/- 10 MHz		 58/55		 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	 -50 -45 -40 -30	 -24 -24 -24 -23		 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

Supply voltage	2.7		3.6	V	
Supply voltage rise time			150	us	If appropriate rise time can not be guaranteed, the RESET pin should be activated after supply voltage is stable.
Current consumption, RX		30		mA	
Current consumption, TX		27		mA	At 0 dBm output power.
Current consumption, PD		13		µA	Power Down mode
Current consumption, Sleep Mapping scheme 0 and 1 Mapping scheme 2		20 40		µA	Current consumption in sleep mode depend on mapping scheme.
Digital I/O Input logic level, low Input logic level, high Output logic level, low (10 mA) Output logic level, high(-10 mA)	-0.5 0.6 VCC 0 2.4		0.2 VCC VCC + 0.5 0.5 3.0	V	
RESET pin Input logic level, low Input logic level, high	-0.5 0.85 VCC		0.2 VCC VCC + 0.5	V	
Internal RESET pull-up resistor	30		60	kOhm	
1.8V regulated voltage at pin 29	1.7	1.8	1.9	V	

Ordering Information

Ordering Part Number	Description
RC2200AT-SPPIO	ZigBee-based RF module, integrated antenna, with SPPIO application profile.
RC2200MM-SPPIO	ZigBee-based RF module, MMCX connector, with SPPIO application profile. *Available on special request.*
RC2200-SPPIO	ZigBee-based RF module, integrated antenna, with SPPIO application profile. *Available on special request.*
RC2200DK-SPPIO	Demo kit with SPPIO application profile

RC2200AT-SPPIO

Document Revision History

Document Revision	Changes
0.2	First draft
0.3	Second draft
0.4	Added ATDA command Added Status, Error and Warning messages Added information on the bootstrap loader Added information on power up and network formation sequencing
0.5	Added ATDA? Command Added Status, Error and Warning messages
0.6	Added Error and Warning messages Added End Device specification Added information on Power Down and Sleep mode
0.7	Added explanations on MAX_DEPTH, MAX_CHILDREN and MAX_ROUTER Added timing information Ordering information for FFD and RFD variants Minor corrections and clarifications
0.8	ATDR command added FFD and RFD implemented in same build Added information on mapping scheme in Sleep mode Sleep mode current consumption updated
1.0	First release

Appendix: ASCII Table

HEX	DEC	CHR	CTRL
0	0	NUL	^@
1	1	SOH	^A
2	2	STX	^B
3	3	ETX	^C
4	4	EOT	^D
5	5	ENQ	^E
6	6	ACK	^F
7	7	BEL	^G
8	8	BS	^H
9	9	HT	^I
0A	10	LF	^J
0B	11	VT	^K
0C	12	FF	^L
0D	13	CR	^M
0E	14	SO	^N
0F	15	SI	^O
10	16	DLE	^P
11	17	DC1	^Q
12	18	DC2	^R
13	19	DC3	^S
14	20	DC4	^T
15	21	NAK	^U
16	22	SYN	^V
17	23	ETB	^W
18	24	CAN	^X
19	25	EM	^Y
1A	26	SUB	^Z
1B	27	ESC	
1C	28	FS	
1D	29	GS	
1E	30	RS	
1F	31	US	
20	32	SP	
21	33	!	
22	34	"	
23	35	#	
24	36	$	
25	37	%	
26	38	&	
27	39	'	
28	40	(	
29	41	)	
2A	42	*	
2B	43	+	
2C	44	,	
2D	45	—	
2E	46	.	
2F	47	/	
30	48	0	
31	49	1	
32	50	2	
33	51	3	
34	52	4	
35	53	5	
36	54	6	
37	55	7	
38	56	8	
39	57	9	
3A	58	:	
3B	59	;	
3C	60	<	
3D	61	=	
3E	62	>	
3F	63	?	

HEX	DEC	CHR
40	64	@
41	65	A
42	66	B
43	67	C
44	68	D
45	69	E
46	70	F
47	71	G
48	72	H
49	73	I
4A	74	J
4B	75	K
4C	76	L
4D	77	M
4E	78	N
4F	79	O
50	80	P
51	81	Q
52	82	R
53	83	S
54	84	T
55	85	U
56	86	V
57	87	W
58	88	X
59	89	Y
5A	90	Z
5B	91	[
5C	92	\
5D	93	]
5E	94	^
5F	95	_
60	96	`
61	97	a
62	98	b
63	99	c
64	100	d
65	101	e
66	102	f
67	103	g
68	104	h
69	105	i
6A	106	j
6B	107	k
6C	108	l
6D	109	m
6E	110	n
6F	111	o
70	112	p
71	113	q
72	114	r
73	115	s
74	116	t
75	117	u
76	118	v
77	119	w
78	120	x
79	121	y
7A	122	z
7B	123	{
7C	124	|
7D	125	}
7E	126	~
7F	127	DEL

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.
	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.
X	**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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