Chipsmall Limited consists of a professional team with an average of over 10 year of expertise in the distribution of electronic components. Based in Hongkong, we have already established firm and mutual-benefit business relationships with customers from,Europe,America and south Asia,supplying obsolete and hard-to-find components to meet their specific needs.

With the principle of “Quality Parts,Customers Priority,Honest Operation,and Considerate Service”,our business mainly focus on the distribution of electronic components. Line cards we deal with include Microchip,ALPS,ROHM,Xilinx,Pulse,ON,Everlight and Freescale. Main products comprise IC,Modules,Potentiometer,IC Socket,Relay,Connector.Our parts cover such applications as commercial,industrial, and automotives areas.

We are looking forward to setting up business relationship with you and hope to provide you with the best service and solution. Let us make a better world for our industry!

Contact us

Tel: +86-755-8981 8866 Fax: +86-755-8427 6832
Email & Skype: info@chipsmall.com Web: www.chipsmall.com
Address: A1208, Overseas Decoration Building, #122 Zhenhua RD., Futian, Shenzhen, China

XBee/XBee-PRO S1 802.15.4 (Legacy)

RF Modules

User Guide

Revision history—90000982

Revision	Date	Description
S	February 2015	Updated European restrictions for transmitting below 10 dBm. Updated the warranty and certification information. Updated programming examples section. Corrected the maximum value of the IT command. Corrected P1 command parameters.
T	December 2015	Corrected $\overline{\text{RESET}}$ pin information.
U	May 2016	Noted that bit 13 of the **SC** parameter is not available for XBee-PRO devices. Corrected an error in the I/O line passing parameters table. Added S1 and Legacy to the product name. Updated the certifications.
V	October 2016	Updated and rebranded the documentation.

Trademarks and copyright

Disclaimers

Information in this document is subject to change without notice and does not represent a commitment on the part of Digi International. Digi provides this document "as is," without warranty of any kind, expressed or implied, including, but not limited to, the implied warranties of fitness or merchantability for a particular purpose. Digi may make improvements and/or changes in this manual or in the product(s) and/or the program(s) described in this manual at any time.

Warranty

To view product warranty information, go to the following website:

www.digi.com/howtobuy/terms

Send comments

Documentation feedback: To provide feedback on this document, send your comments to techcomm@digi.com.

Customer support

Digi Technical Support: Digi offers multiple technical support plans and service packages to help our customers get the most out of their Digi product. For information on Technical Support plans and pricing, contact us at +1 952.912.3444 or visit us at www.digi.com/support.

Contents

About the XBee/XBee-PRO S1 802.15.4 (Legacy) RF Modules

Operation

Configuration

AT commands

API operation

Certifications

About the XBee/XBee-PRO S1 802.15.4 (Legacy) RF Modules

The XBee and XBee-PRO RF Modules were engineered to meet IEEE 802.15.4 standards and support the unique needs of low-cost, low-power wireless sensor networks. The devices require minimal power and provide reliable delivery of data between devices.

The devices operate within the ISM 2.4 GHz frequency band and are pin-for-pin compatible with each other.

Technical specifications

XBee/XBee-PRO S1 802.15.4 (Legacy) Performance specifications

This table describes the performance specifications for the devices.

Specification	XBee	XBee-PRO
Indoor/urban range	Up to 100 ft (30 m)	Up to 300 ft. (90 m) Up to 200 ft (60 m) International variant
Outdoor RF line-of-sight range	Up to 300 ft (90 m)	Up to 1 mile (1600 m) Up to 2500 ft (750 m) international variant
Transmit power output (software selectable)	1 mW (0 dBm)	63 mW (18 dBm)* 10 mW (10 dBm) for international variant
RF data rate	250,000 b/s	250,000 b/s
Serial interface data rate (software selectable)	1200 b/s - 250 kb/s (non-standard baud rates also supported)	1200 bps - 250 kb/s (non-standard baud rates also supported)
Receiver sensitivity (typical)	-92 dBm (1% packet error rate)	100 dBm (1% packet error rate)

XBee/XBee-PRO S1 802.15.4 (Legacy) Power requirements

The following table describes the power requirements for the devices.

Specification	XBee	XBee-PRO
Supply voltage	2.8 - 3.4 V	2.8 - 3.4 V
Transmit current (typical)	45 mA (@ 3.3 V)	■ 250 mA (@3.3 V) (150 mA for international variant) RPSMA module only. ■ 340 mA (@3.3 V) (180 mA for international variant)
Idle/receive current (typical)	50 mA (@ 3.3 V)	55 mA (@ 3.3 V)
Power-down current	< 10 uA	< 10 uA

General specifications

The following table describes the general specifications for the devices.

Specification	XBee	XBee-PRO
Operating frequency band	ISM 2.4 GHz	ISM 2.4 GHz
Dimensions	0.960 in x 1.087 in (2.438 cm x 2.761 cm)	0.960 in x 1.297 in (2.438 cm x 3.294 cm)
Operating temperature	-40 to 85°C (industrial)	-40 to 85°C (industrial)
Antenna options	Integrated whip antenna, embedded PCB antenna, U.FL connector, RPSMA connector	Integrated whip antenna, embedded PCB antenna, U.FL connector, RPSMA connector

Networking and security specifications

The following table describes the networking and security specifications for the devices.

Specification	XBee	XBee-PRO
Supported network topologies	Point-to-point, point-to-multipoint and peer-to-peer	
Number of channels (software selectable)	16 direct sequence channels	12 direct sequence channels
Addressing options	PAN ID, channel and addresses	PAN ID, channel and addresses

Agency approvals

This table describes the agency approvals for the devices.

Specification	XBee	XBee-PRO
United States (FCC Part 15.247)	OUR-XBEE	OUR-XBEEPRO
Industry Canada (IC)	4214A-XBEE	4214A-XBEEPRO
Europe (CE)	Yes	Yes (Maximum 10 dBm transmit power output)[1]

[1]See Certifications or region-specific certification requirements.

Specification	XBee	XBee-PRO
Japan	R201WW07215214	R201WW08215111 (Maximum 10 dBm transmit power output)* Wire, chip, RPMSA, and U.FL versions are certified for Japan. PCB antenna version is not.
Australia/New Zealand	RCM/R-NZ	RCM/R-NZ
Brazil	ANATEL 0369-15-1209	ANATEL 0378-15-1209

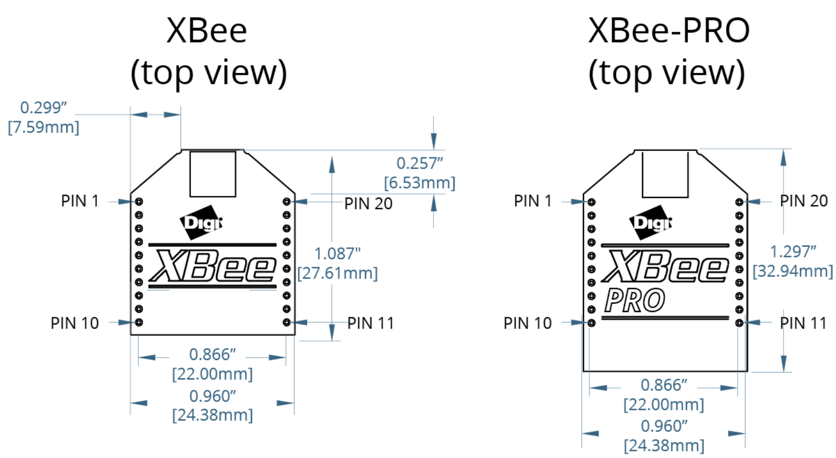
XBee/XBee-PRO S1 802.15.4 (Legacy) Antenna options

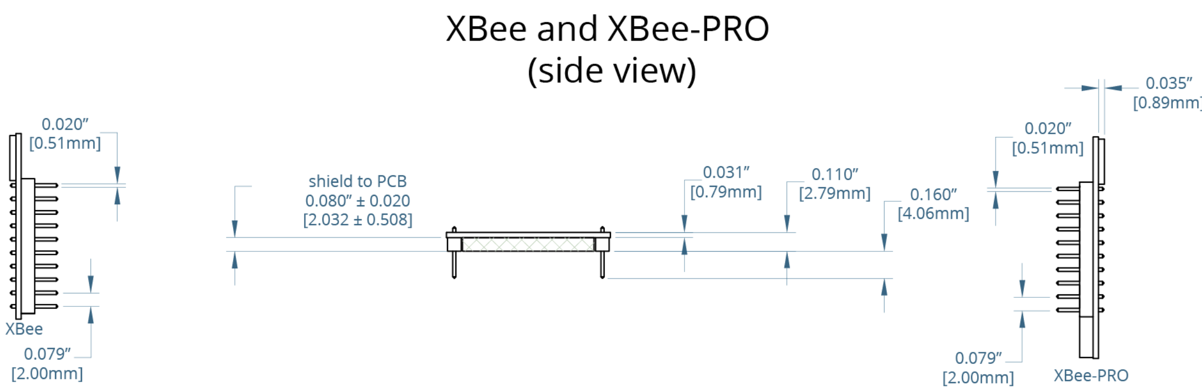
The ranges specified are typical for the integrated whip (1.5 dBi) and dipole (2.1 dBi) antennas. The printed circuit board (PCB) antenna option provides advantages in its form factor; however, it typically yields shorter range than the whip and dipole antenna options when transmitting outdoors. For more information, see XBee and XBee-PRO OEM RF Module Antenna Considerations Application Note.

XBee/XBee-PRO S1 802.15.4 (Legacy) Mechanical drawings

The following graphics show the mechanical drawings of the XBee / XBee-PRO OEM RF Modules. The XBee and XBee-PRO RF Modules are pin-for-pin compatible.

Note The antenna options not shown.

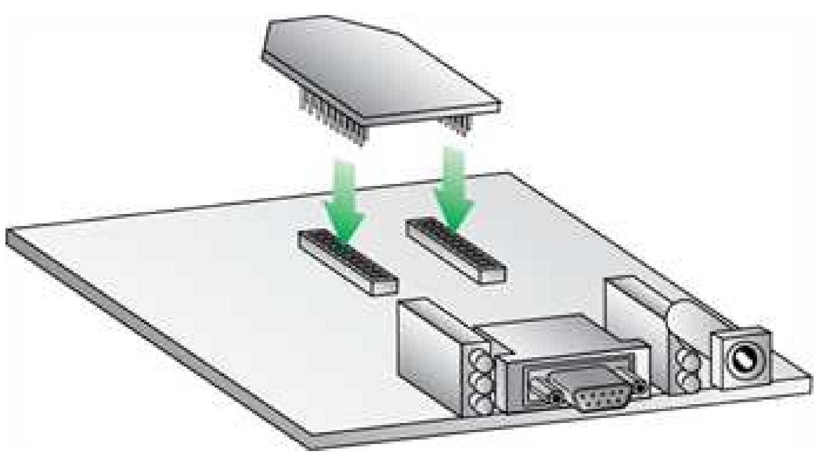




Mounting considerations

We design the through-hole module to mount into a receptacle so that you do not have to solder the module when you mount it to a board. The development kits may contain RS-232 and USB interface boards that use two 20-pin receptacles to receive modules.

The following illustration shows the module mounting into the receptacle on the RS-232 interface board.



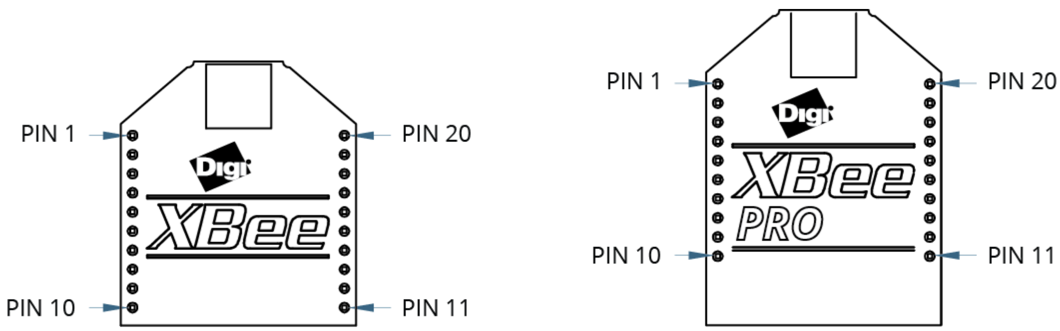
Century Interconnect manufactures the receptacles used on Digi development boards. Several other manufacturers provide comparable mounting solutions; however, Digi currently uses the following receptacles:

- Through-hole single-row receptacles: Samtec part number: MMS-110-01-L-SV (or equivalent)
- Surface-mount double-row receptacles: Century Interconnect part number: CPRMSL20-D-0-1 (or equivalent)
- Surface-mount single-row receptacles: Samtec part number: SMM-110-02-SM-S

> **Note** We recommend that you print an outline of the module on the board to indicate the correct orientation for mounting the module.

Pin signals

The following graphic shows the XBee/XBee-PRO S1 802.15.4 (Legacy) RF Modules pin number for the devices, with the top sides shown; shields are on the bottom:



The following table describes the pin assignments for the devices. A horizontal line above the signal name indicates low-asserted signals.

Pin#	Name	Direction	Description
1	VCC	-	Power supply
2	DOUT	Output	UART data out
3	DIN/$\overline{\text{CONFIG}}$	Input	UART data In
4	DO8[1]	Either	Digital output 8
5	$\overline{\text{RESET}}$	Input/Open drain output	Device reset (reset pulse must be at least 200 ns). This must be driven as an open drain/collector. The device drives this line low when a reset occurs. Never drive this line high.
6	PWM0/RSSI	Either	PWM output 0 / RX signal strength indicator
7	PWM1	Either	PWM output 1

[1]Function is not supported at the time of this release.

Pin#	Name	Direction	Description
8	[reserved]	-	Do not connect
9	$\overline{\text{DTR}}$/SLEEP_RQ/DI8	Either	Pin sleep control line or digital input 8
10	GND	-	Ground
11	AD4/DIO4	Either	Analog input 4 or digital I/O 4
12	$\overline{\text{CTS}}$ /DIO7	Either	Clear-to-send flow control or digital I/O 7
13	ON/$\overline{\text{SLEEP}}$	Output	Device status indicator
14	VREF	Input	Voltage reference for A/D inputs
15	Associate/AD5/DIO5	Either	Associated indicator, analog input 5 or digital I/O 5
16	$\overline{\text{RTS}}$/DIO6	Either	Request-to-send flow control, or digital I/O 6
17	AD3/DIO3	Either	Analog input 3 or digital I/O 3
18	AD2/DIO2	Either	Analog input 2 or digital I/O 2
19	AD1/DIO1	Either	Analog input 1 or digital I/O 1
20	AD0/DIO0	Either	Analog input 0, digital I/O 0

Notes:

- Minimum connections: VCC, GND, DOUT and DIN
- Minimum connections for updating firmware: VCC, GND, DIN, DOUT, RTS and DTR
- Signal direction is specified with respect to the module
- The module includes a 50 kΩ pull-up resistor attached to $\overline{\text{RESET}}$
- You can configure several of the input pull-ups using the PR command
- Leave any unused pins disconnected

Design notes

The XBee modules do not specifically require any external circuitry specific connections for proper operation. However, there are some general design guidelines that we recommend for help in troubleshooting and building a robust design.

Power supply design

A poor power supply can lead to poor device performance, especially if you do not keep the supply voltage within tolerance or if it is excessively noisy. To help reduce noise, place a 1.0 µF and 8.2 pF capacitor as near as possible to pin 1 on the PCB. If you are using a switching regulator for the power supply, switch the frequencies above 500 kHz. Limit the power supply ripple to a maximum 100 mV peak to peak.

Board layout

We design XBee devices to be self sufficient and have minimal sensitivity to nearby processors, crystals or other printed circuit board (PCB) components. Keep power and ground traces thicker than signal traces and make sure that they are able to comfortably support the maximum current specifications. There are no other special PCB design considerations to integrate XBee devices, with the exception of antennas.

Antenna performance

Antenna location is important for optimal performance. The following suggestions help you achieve optimal antenna performance. Point the antenna up vertically (upright). Antennas radiate and receive the best signal perpendicular to the direction they point, so a vertical antenna's omnidirectional radiation pattern is strongest across the horizon.

Position the antennas away from metal objects whenever possible. Metal objects between the transmitter and receiver can block the radiation path or reduce the transmission distance. Objects that are often overlooked include:

- metal poles
- metal studs
- structure beams
- concrete, which is usually reinforced with metal rods

If you place the device inside a metal enclosure, use an external antenna. Common objects that have metal enclosures include:

- vehicles
- elevators
- ventilation ducts
- refrigerators
- microwave ovens
- batteries
- tall electrolytic capacitors

Do not place XBee devices with the chip or integrated PCB antenna inside a metal enclosure.

Do not place any ground planes or metal objects above or below the antenna.

For the best results, mount the device at the edge of the host PCB. Ensure that the ground, power, and signal planes are vacant immediately below the antenna section.

Pin connection recommendations

The only required pin connections are VCC, GND, DOUT and DIN. To support serial firmware updates, you should connect VCC, GND, DOUT, DIN, RTS, and SLEEP (DTR).

Leave all unused pins disconnected. Pull all inputs on the device high with internal pull-up resistors using the **PR** command. You do not need a specific treatment for unused outputs.

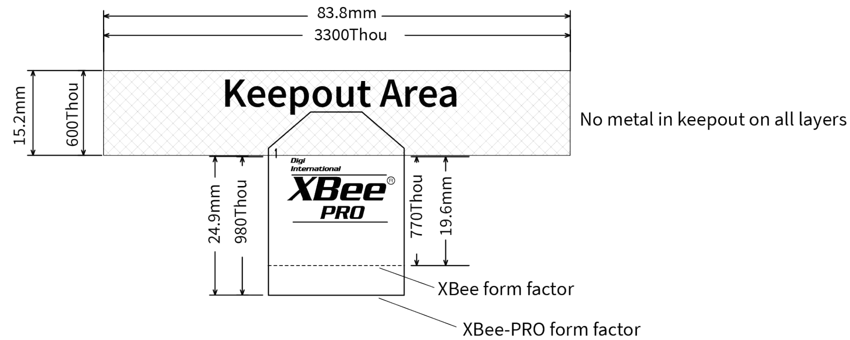
Other pins may be connected to external circuitry for convenience of operation including the Associate LED pin (pin 15). The Associate LED flashes differently depending on the state of the device.

If analog sampling is desired, attach the VRef (pin 14) to a voltage reference.

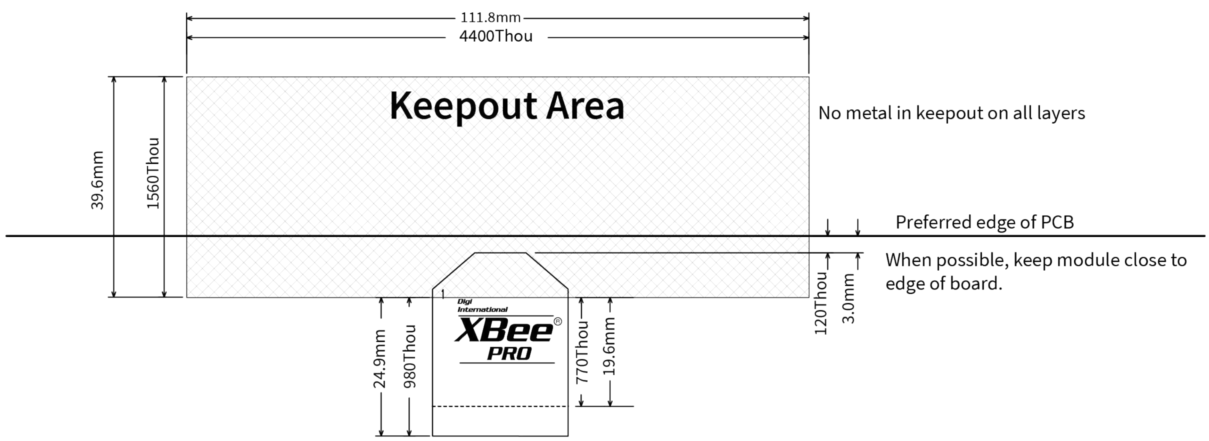
Keepout area

We recommend that you allow a “keepout” area, as shown in the following drawing.

Minimum Keepout Area (All PCB layers)



Recommended Keepout Area (All PCB layers)



The antenna performance improves with a larger keepout area

Notes

1. We recommend non-metal enclosures. For metal enclosures, use an external antenna.
2. Keep metal chassis or mounting structures in the keepout area at least 2.54 cm (1 in) from the antenna.
3. Maximize the distance between the antenna and metal objects that might be mounted in the keepout area.
4. These keepout area guidelines do not apply for wire whip antennas or external RF connectors. Wire whip antennas radiate best over the center of a ground plane.

Electrical characteristics

The following tables list the electrical characteristics of the XBee/XBee-PRO XBee/XBee-PRO S1 802.15.4 (Legacy) RF Modules.

DC Characteristics (VCC = 2.8 - 3.4 VDC)

Symbol	Characteristic	Condition	Min	Typical	Max	Unit
V_{IL}	Input low voltage	All Digital Inputs	-	-	0.35 * VCC	V
V_{IH}	Input high voltage	All Digital Inputs	0.7 * VCC	-	-	V
V_{OL}	Output low voltage	I_{OL} = 2 mA, VCC >= 2.7 V	-	-	0.5	V
V_{OH}	Output high voltage	I_{OH} = -2 mA, VCC >= 2.7 V	VCC - 0.5	-	-	V
II_{IN}	Input leakage Current	VIN = VCC or GND, all inputs, per pin	-	0.025	1	µA
II_{OZ}	High impedance leakage current	VIN = VCC or GND, all I/O High-Z, per pin	-	0.025	1	µA
TX	Transmit current	VCC = 3.3 V	-	45 (XBee) 215, 140 (XBee-PRO, International)	-	mA
RX	Receive current	VCC = 3.3 V	-	50 (XBee) 55 (XBee-PRO)	-	mA
PWR-DWN	Power-down current	SM parameter = 1	-	<10	-	µA

ADC characteristics (operating)

Symbol	Characteristic	Condition	Min	Typical	Max	Unit
V_{REFH}	VREF - analog-to-digital converter reference range		2.08	-	V_{DDAD}[1]	V
I_{REF}	VREF - reference supply current	Enabled	-	200	-	µA
		Disabled or Sleep Mode	-	<0.01	0.02	µA
V_{INDC}	Analog input voltage[2]		V_{SSAD} - 0.3		V_{DDAD} + 0.3	V

1. V_{DDAD} is connected to VCC.
2. Maximum electrical operating range, not valid conversion range.

ADC timing/performance characteristics[1]

Symbol	Characteristic	Condition	Min	Typical	Max	Unit
R_{AS}	Source impedance at input[2]	-		-	-	kW
V_{AIN}	Analog input voltage[3]	-	V_{REFL}	-	V_{REFL}	V
RES	Ideal resolution (1 LSB)[4]	2.08V < VDDAD < 3.6V	2.031	-	3.516	mV
DNL	Differential non-linearity[5]	-	-	±0.5	±1.0	LSB
INL	Integral non-linearity[6]	-	-	±0.5	±1.0	LSB
E_{ZS}	Zero-scale error[7]	-	-	±0.4	±1.0	LSB
F_{FS}	Full-scale error[8]	-	-	±0.4	±1.0	LSB
E_{IL}	Input leakage error[9]	-	-	±0.05	±5.0	LSB
E_{TU}	Total unadjusted error[10]	-	-	±1.1	±2.5	LSB

1. All accuracy numbers are based on the processor and system being in WAIT state (very little activity and no I/O switching) and that adequate low-pass filtering is present on analog input pins (filter with 0.01 µF to 0.1 µF capacitor between analog input and VREFL). Failure to observe these guidelines may result in system or microcontroller noise causing accuracy errors which will vary based on board layout and the type and magnitude of the activity. Data transmission and reception during data conversion may cause some degradation of these specifications, depending on the number and timing of packets. We advise testing the ADCs in your installation if best accuracy is required.
2. R_{AS} is the real portion of the impedance of the network driving the analog input pin. Values greater than this amount may not fully charge the input circuitry of the ATD resulting in accuracy error.
3. Analog input must be between V_{REFL} and V_{REFH} for valid conversion. Values greater than V_{REFH} will convert to $3FF.
4. The resolution is the ideal step size or 1LSB = $(V_{REFH}–V_{REFL})/1024$.
5. Differential non-linearity is the difference between the current code width and the ideal code width (1LSB). The current code width is the difference in the transition voltages to and from the current code.
6. Integral non-linearity is the difference between the transition voltage to the current code and the adjusted ideal transition voltage for the current code. The adjusted ideal transition voltage is (Current Code–1/2)*(1/((VREFH+EFS)–(VREFL+EZS))).
7. Zero-scale error is the difference between the transition to the first valid code and the ideal transition to that code. The Ideal transition voltage to a given code is (Code–1/2)*(1/(VREFH–VREFL)).

8. Full-scale error is the difference between the transition to the last valid code and the ideal transition to that code. The ideal transition voltage to a given code is (Code–1/2)*(1/(VREFH–VREFL)).
9. Input leakage error is error due to input leakage across the real portion of the impedance of the network driving the analog pin. Reducing the impedance of the network reduces this error.
10. Total unadjusted error is the difference between the transition voltage to the current code and the ideal straight-line transfer function. This measure of error includes inherent quantization error (1/2LSB) and circuit error (differential, integral, zero-scale, and full-scale) error. The specified value of ETU assumes zero EIL (no leakage or zero real source impedance).

Operation

WARNING! When operating at 1 W power output, observe a minimum separation distance of 6 ft (2 m) between devices. Transmitting in close proximity of other devices can damage the device's front end.

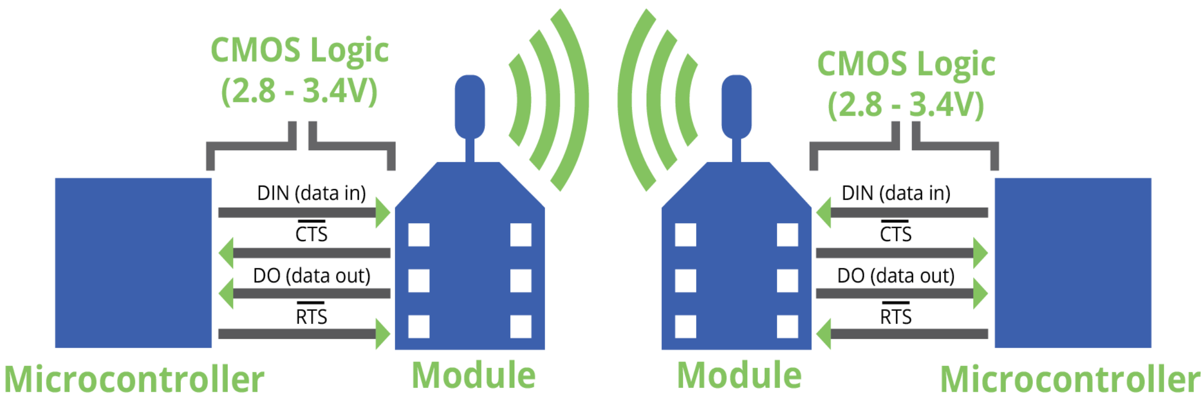
Serial communications

RF Modules interface to a host device through a serial port. Using its serial port, the device communicates with any of the following:

- Logic and voltage compatible UART
- Level translator to any serial device (for example, through an RS-232 or USB interface board)

UART data flow

Devices that have a UART interface connect directly to the pins of the XBee/XBee-PRO S1 802.15.4 (Legacy) as shown in the following figure. The figure shows system data flow in a UART-interfaced environment. Low-asserted signals have a horizontal line over the signal name.

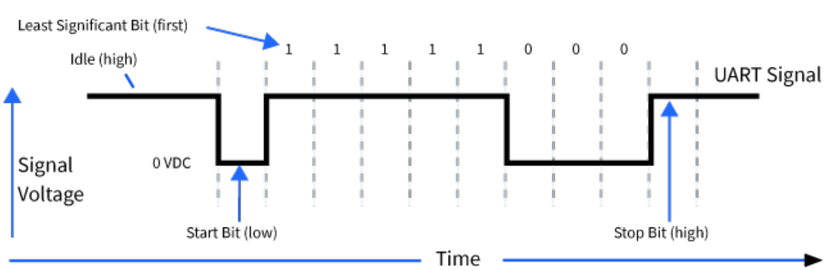


Serial data

A device sends data to the XBee/XBee-PRO S1 802.15.4 (Legacy)'s UART through pin 3 (DIN) as an asynchronous serial signal. When the device is not transmitting data, the signal idles high.

For serial communication to occur, you must configure the UART of both devices (the microcontroller and the XBee/XBee-PRO S1 802.15.4 (Legacy)) with compatible settings for the baud rate, parity, start bits, stop bits, and data bits.

Each data byte consists of a start bit (low), 8 data bits (least significant bit first) and a stop bit (high). The following diagram illustrates the serial bit pattern of data passing through the device. The diagram shows UART data packet 0x1F (decimal number 31) as transmitted through the device.



Serial communications depend on the two UARTs (the microcontroller and the RF device) to be configured with compatible settings, including baud rate, parity, start bits, stop bits, and data bits.

The UART baud rate and parity settings on the XBee module can be configured with the BD and NB commands, respectively. For more information, see AT commands.

Transparent operating mode

Devices operate in this mode by default. The device acts as a serial line replacement when it is in Transparent operating mode. The device queues all UART data it receives through the DIN pin for RF transmission. When a device receives RF data, it sends the data out through the DOUT pin. You can set the configuration parameters using Command mode.

Serial-to-RF packetization

The device buffers data in the serial receive buffer until one of the following causes the data to be packetized and transmitted:

- The device receives no serial characters for the amount of time determined by the **RO** (Packetization Timeout) parameter. If **RO** = 0, packetization begins when a character is received.
- The device receives the Command Mode Sequence (**GT** + **CC** + **GT**). Any character buffered in the serial receive buffer before the sequence is transmitted.
- The device receives the maximum number of characters that fits in an RF packet (100 bytes).

If the device cannot immediately transmit (for example, if it is already receiving RF data), it stores the serial data in the DI buffer. The device packetizes the data and sends the data at any **RO** timeout or when it receives the maximum packet size (100 bytes).

If the DI buffer becomes full, hardware or software flow control must be implemented in order to prevent overflow (that is, loss of data between the host and module).

API operating mode

API (Application Programming Interface) operating mode is an alternative to the default Transparent operating mode. The frame-based API extends the level to which a host application can interact with the networking capabilities of the module.

When in API mode, all data entering and leaving the device is contained in frames that define operations or events within the module.

Transmit data frames (received through the DI pin (pin 3)) include:

- RF Transmit data frame
- Command frame (equivalent to AT commands)

Receive Data frames (sent out the DO pin (pin 2)) include:

- RF-received data frame
- Command response
- Event notifications such as reset, associate, disassociate, and so on

The API provides alternative means of configuring modules and routing data at the host application layer. A host application sends data frames to the device that contains address and payload information instead of using command mode to modify addresses. The device sends data frames to the application containing status packets, as well as source, RSSI, and payload information from received data packets.

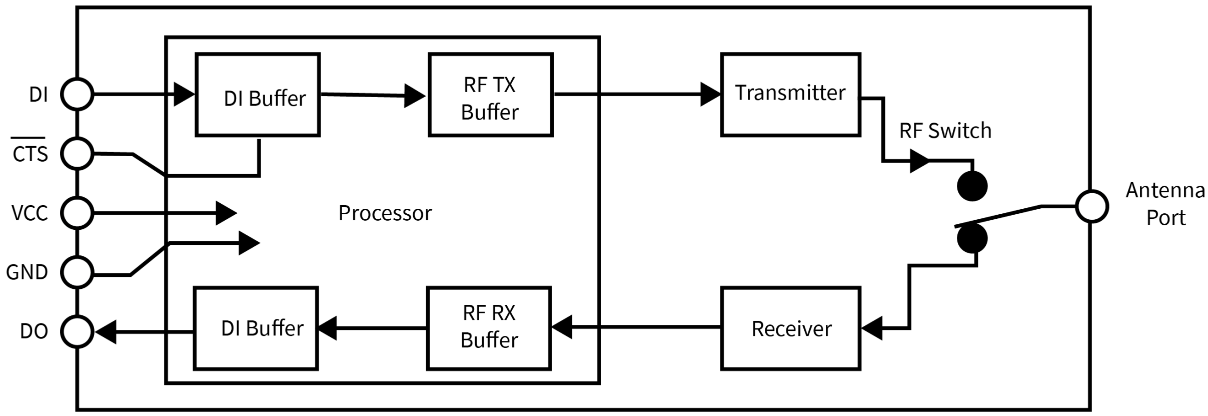
The API operation option facilitates many operations such as the following examples:

- Transmitting data to multiple destinations without entering Command Mode
- Receiving success/failure status of each transmitted RF packet
- Identifying the source address of each received packet

To implement API operation, see API operation.

Flow control

The XBee/XBee-PRO S1 802.15.4 (Legacy) maintains buffers to collect serial and RF data that it receives. The serial receive buffer collects incoming serial characters and holds them until the device can process them. The serial transmit buffer collects the data it receives via the RF link until it transmits that data out the serial port. The following figure shows the process of device buffers collecting received serial data.



DI (Data in) buffer

When serial data enters the RF module through the DI pin (pin 3), the device stores data in the DI buffer until it can be processed.

Hardware Flow Control (CTS)

If you enable CTS flow control (by setting **D7** to 1), when the DI buffer is 17 bytes away from being full, the device de-asserts CTS (sets it high) to signal to the host device to stop sending serial data. The device reasserts CTS after the serial receive buffer has 34 bytes of space.

To eliminate the need for flow control:

1. Send messages that are smaller than the DI buffer size (202 bytes).
2. Interface at a lower baud rate [BD (Interface Data Rate) parameter] than the throughput data rate.

Example where the DI buffer may become full and possibly overflow:

If the device is receiving a continuous stream of RF data, it places any serial data that arrives on the DI pin in the DI buffer. The device transmits data in the DI buffer over-the-air when it is no longer receiving RF data in the network.

For more information, see the following command descriptions:

- RO (Packetization Timeout)
- BD (Interface Data Rate)
- D7 (DIO7 Configuration)

DO (Data out) buffer

When RF data is received, the data enters the DO buffer and is sent out the serial port to a host device. Once the DO Buffer reaches capacity, any additional incoming RF data is lost.

Hardware Flow Control ($\overline{RTS}$)

If you enable $\overline{RTS}$ flow control (D6 (DIO6 Configuration) Parameter = 1), the device does not send data out the DO buffer as long as RTS (pin 16) is de-asserted.

Examples where the DO buffer may become full, resulting in dropped RF packets:

1. If the RF data rate is set higher than the interface data rate of the device, the device may receive data faster than it can send the data to the host. Even occasional transmissions from a large number of devices can quickly accumulate and overflow the transmit buffer.
2. If the host does not allow the device to transmit data out from the serial transmit buffer due to being held off by hardware flow control.

See the D6 (DIO6 Configuration) command description for more information.

ADC and Digital I/O line support

The XBee/XBee-PRO RF Modules support ADC (analog-to-digital conversion) and digital I/O line passing. The following pins support multiple functions:

- Pin functions and their associated pin numbers and commands
- AD = Analog-to-Digital Converter, DIO = Digital Input/Output

Note Pin functions in parentheses are not applicable to this section.

Pin function	Pin#	AT Command
AD0/DIO0	20	**D0**
AD1/DIO1	19	**D1**
AD2/DIO2	18	**D2**
AD3/DIO3 / (COORD_SEL)	1	**D3**
AD4/DIO4	11	**D4**
AD5/DIO5 / (ASSOCIATE)	15	**D5**
DIO6/(RTS)	16	**D6**
DIO7/(CTS)	12	**D7**
DI8/(DTR) / (Sleep_RQ)	9	**D8**

Use the following setting to enable ADC and DIO pin functions:

Support type	Setting
ADC support	ATDn = 2
Digital input support	ATDn = 3
Digital output low support	ATDn = 4
Digital output high support	ATDn = 5