XBee® SX 868

Radio Frequency (RF) Module

User Guide

원문: Digi 800MHz 무선 모듈 사용설명서(영문) · 제조사 원문 자료입니다. 사양은 제조사 사정에 따라 변경될 수 있습니다.

Revision history—90001538

Revision	Date	Description
A	June 2017	Initial release.
B	September 2017	Updated power consumption values. Added the **LB** (LNA Bypass) command.
C	May 2018	Added note on range estimation.
D	March 2019	Added a receiver category to Performance specifications.
E	November 2020	Added the **C8** and **R?** commands. Added the **Sleep Immediate** and **Synchronous pulse** sections. Added information on randomizing a single I/O sample. Revised **BC**.

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Product serial number (s)

Firmware version

Operating system/browser (if applicable)

Logs (from time of reported issue)

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Description of issue

Steps to reproduce

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The XBee SX 868 RF Module is an embedded radio frequency (RF) device that provides wireless connectivity to end-point devices in mesh networks.

The XBee SX 868 RF Module delivers up to 32 mW of Effective Isotropically Radiated Power (EIRP) and has excellent receive sensitivity, low operating current, and exceptional performance in low power modes. The module's frequency hopping technology offers advanced interference immunity, affording long range data throughput even in challenging RF environments. The XBee SX 868 RF Module uses a microprocessor that supports host communication through Serial Peripheral Interface (SPI) or universal asynchronous receiver/transmitter (UART), as well as digital, analog, and pulse width modulation (PWM) lines for interfacing with peripherals.

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Applicable firmware and hardware

This manual supports the following firmware:

- 0xA00x, Europe

It supports the following hardware:

- XBee SX 868 RF Module

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Regulatory conformity summary

This table describes the agency approvals for the devices.

See Regulatory information for details.

Country	Approval
Europe (CE)	Yes

The following table shows the channel frequencies.

Operational frequency band[1]	Channel #	Frequency
K	0	863.15 MHz
	1	863.35 MHz
	2	863.55 MHz
	3	863.75 MHz
	4	863.95 MHz
	5	864.15 MHz
	6	864.35 MHz
	7	864.55 MHz
	8	864.75 MHz
	9	N/A[2]

Operational frequency band[1]	Channel #	Frequency
L	10	865.15 MHz
	11	865.35 MHz
	12	865.55 MHz
	13	865.75 MHz
	14	865.95 MHz
	15	866.15 MHz
	16	866.35 MHz
	17	866.55 MHz
	18	866.75 MHz
	19	866.95 MHz
	20	867.15 MHz
	21	867.35 MHz
	22	867.55 MHz
	23	867.75 MHz
	24	N/A[2]
M	25	868.15 MHz
	26	868.35 MHz
N	27	868.85 MHz
	28	869.05 MHz
Q/R[3]	29	869.85 MHz

[1] The operational frequency bands are in compliance with Table B.1 in ETSI EN 300 220-2 V3.1.1.
[2] Channels 9 and 24 are removed to comply with section 4.3.4 of ETSI EN 300 220-2 V3.1.1
[3] Band R applies when polite spectrum access is being used, i.e. more than one channel is enabled. Band Q applies when polite spectrum access is not used, i.e. when channel 29 is the only enabled channel.

Power requirements

The following table describes the power requirements for the XBee SX 868 RF Module.

Specification	Condition	Value
Supply voltage range		2.4 to 3.6 VDC
Typical supply voltage		3.3 V

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Specification	Condition	Value
Receive current	VCC = 3.3 V	40 mA
	VCC = 3.3 V, LNA bypass enabled	34 mA
Transmit current	VCC = 3.3 V	55 mA @ 32 mW EIRP
	VCC = 3.3 V	45 mA @ 16 mW EIRP
	VCC = 3.3 V	40 mA @ 10 mW EIRP
	VCC = 3.3 V	35 mA @ 5 mW EIRP
	VCC = 3.3 V	32 mA @ 2 mW EIRP
Sleep current	VCC 3.3 V, temperature = 25 °C	1.8 µA

Networking and security specifications

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

Specification	Value
Modulation	Gaussian Frequency Shift Keying (GFSK)
Spreading technology	Frequency Hopping Spread Spectrum (FHSS)
Supported network topologies (software selectable)	Peer-to-peer (master/slave relationship not required), point-to-point/point-to-multipoint, mesh
Encryption	Optional Advanced Encryption Standard (AES) encryption which may be operated in either electronic code book (ECB) mode or counter (CTR) mode. Use the **EE** command to enable encryption. Use the **KY** command to set the encryption key.

Performance specifications

The following table describes the performance specifications for the devices.

Note Range figure estimates are based on free-air terrain with limited sources of interference. Actual range will vary based on transmitting power, orientation of transmitter and receiver, height of transmitting antenna, height of receiving antenna, weather conditions, interference sources in the area, and terrain between receiver and transmitter, including indoor and outdoor structures such as walls, trees, buildings, hills, and mountains.

Specification	Condition	Value
Frequency range		863 to 870 MHz

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Specification	Condition	Value
RF data rate (software selectable)	Low data rate	10 kb/s
	High data rate	80 kb/s
Transmit power (software selectable)	EIRP[1]	Up to 15 dBm (32 mW)
	ERP[2]	Up to 13 dBm (20 mW)
Maximum data throughput	High data rate	38.4 kb/s
Available channel frequencies	All data rates	28
Rural range line of sight[3]	Low data rate	Up to 14.5 km (9 mi)
Urban range line of sight[4]	Low data rate	Up to 2.5 km (1.5 mi)
Receiver category		Class 2
Receiver sensitivity	Low data rate	-113 dBm
	High data rate	-106 dBm
	Low data rate, LNA bypass enabled	-100 dBm
	High data rate, LNA bypass enabled	-94 dBm
Receiver IF selectivity	Low data rate ± 200 kHz	40 dB
	Low data rate ± 400 kHz	45 dB
	High data rate ± 200 kHz	33 dB
	High data rate ± 400 kHz	40 dB
Receiver RF selectivity	Below 863 MHz and above 870 MHz	> 60 dB
UART data rate (software selectable)		1200 - 921600 baud
SPI clock rate		Up to 6 Mb/s

General specifications

The following table describes the general specifications for the devices.

Specification	Value
Dimensions	3.38 x 2.21 x 0.32 cm (1.33 x 0.87 x 0.125 in)
Weight	3 g

[1]Effective Isotropically Radiated Power (EIRP) is the device's output power plus 2.1 dBi (dipole antenna gain).
[2]Effective radiated power (ERP) is the specification tested for regulatory compliance.
[3]This number was measured with the LNA bypass disabled.
[4]This number was measured with the LNA bypass disabled.

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Specification	Value
Restriction of Hazardous Substances (RoHS)	Compliant
Manufacturing	ISO 9001:2008 registered standards
Host interface connector	37 castellated SMT pads
Antenna connector options	U.FL or RF pad
Antenna impedance	50 Ω unbalanced
Maximum input RF level at antenna port	6 dBm
Operating temperature	-40°C to 85°C
Digital I/O	13 I/O lines, 5 output lines
Analog-to-digital converter (ADC)	4 10-bit analog inputs
Pulse width modulator (PWM)	2 outputs

GPIO specifications

The following table provides the electrical specifications for the GPIO pads.

GPIO electrical specification	Value
Voltage - supply	2.4 - 3.6 V
Low Schmitt switching threshold	0.3 * VCC
High Schmitt switching threshold	0.7 * VCC
Input current for logic 0	-0.1 µA
Input current for logic 1	0.1 µA
Input pull-up resistor value	40 kΩ
Input pull-down resistor value	40 kΩ
Output voltage for logic 0	0.05 * VCC
Output voltage for logic 1	0.95 * VCC
Output source/sink current	1 mA
Total output current (for GPIO pads)	20 mA

LBT and AFA specifications

The following table provides the Listen Before Talk (LBT) and Adaptive Frequency Agility (AFA) specifications.

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Specification	Condition	Value
Channel spacing		200 kHz
Receiver bandwidth		150 kHz
Modulation bandwidth		< 300 kHz
LBT threshold	Low data rate	< -95 dBm
	High data rate	< -90 dBm
TX on time		< 1 second

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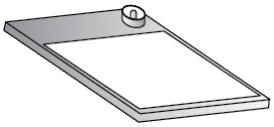
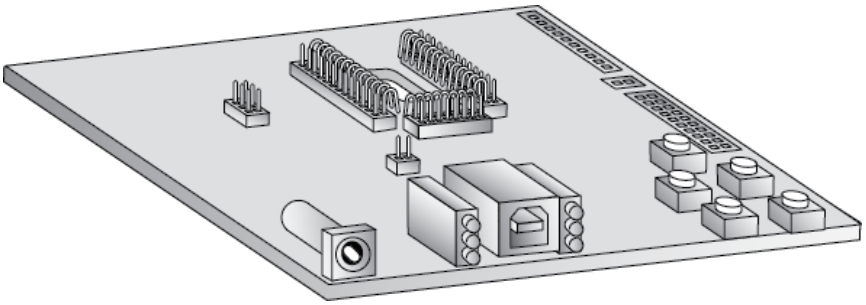
Verify kit contents

The XBee SX 868 RF Module development kit contains the following components:

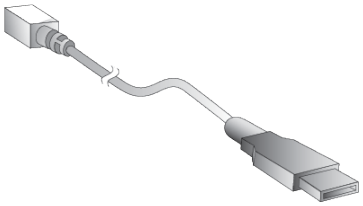
XBee U.FL module (3)



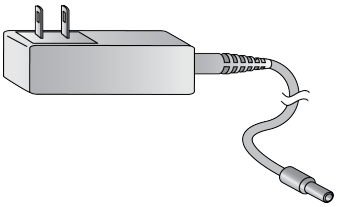
XBee development board (3)



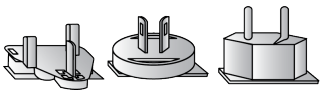
USB cable (2)



Power supply (2)



Set of power supply adapters (2)



Antenna U.FL (3)

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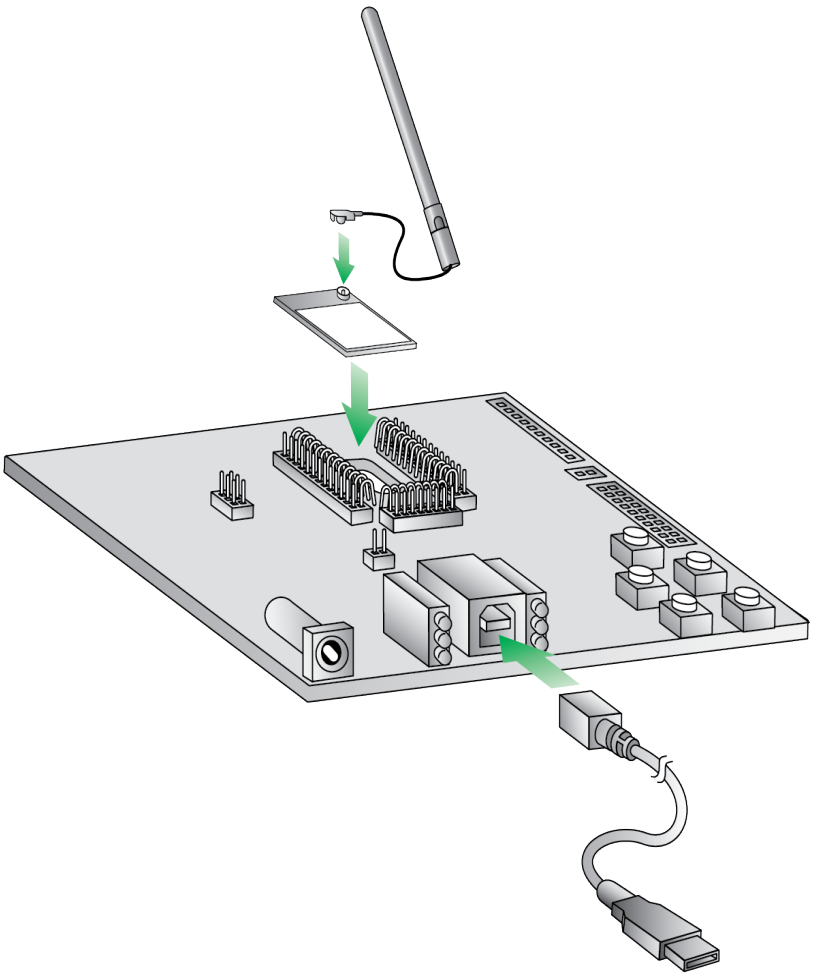
Connect the hardware

The following illustration shows you how to assemble the hardware components of the development kit.



1. Attach the XBee SX 868 RF Modules to the development boards.
2. Attach the antennas to the devices.
3. Connect the USB cables to the development boards.

CAUTION! Before you remove a device from a development board, make sure the board is not powered by a USB cable or a battery.

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Configure the device using XCTU

XBee Configuration and Test Utility (XCTU) is a multi-platform program that enables users to interact with Digi radio frequency (RF) devices through a graphical interface. The application includes built-in tools that make it easy to set up, configure, and test Digi RF devices.

For instructions on downloading and using XCTU, see the XCTU User Guide.

Click **Discover devices** and follow the instructions. XCTU should discover the connected XBee SX 868 RF Modules using the provided settings.

Click **Add selected devices**.The devices appear in the **Radio Modules** list. You can click a module to view and configure its individual settings. For more information on these items, see AT commands.

Configure the devices for a range test

For devices to communicate with each other, you must configure them so they are in the same network. To obtain all possible data from the remote device, you must also set the local device to API mode. For more information on API mode, see Operate in API mode.

For devices to communicate with each other, you configure them so they are in the same network. You also set the local device to API mode to obtain all possible data of the remote device.

When you connect the development board to a PC for the first time, the PC automatically installs drivers, which may take a few minutes to complete.

1. Add the two devices to XCTU.
2. Select the first module and click the **Load default firmware settings** button.
3. Configure the following parameters:

   ID: 2015
   NI: LOCAL_DEVICE
   AP: API Mode Without Escapes [1]
4. Click the **Write radio settings** button.
5. Select the other module and click the **Default firmware settings** button.
6. Configure the following parameters:

   ID: 2015
   NI: REMOTE_DEVICE
   AP: Transparent Mode [0]
7. Click the **Write radio settings** button.

   After you write the radio settings for each device, their names appear in the **Radio Modules** area. The Port indicates that the LOCAL_DEVICE is in API mode.
8. Disconnect REMOTE_DEVICE from the computer, remove it from XCTU, and connect it to its own power supply.
9. Leave LOCAL_DEVICE connected to the computer. Connect LOCAL_DEVICE to its own power supply.
10. Place REMOTE_DEVICE at the testing location and connect its power supply.

Configure remote devices

You can communicate with remote devices over the air through a corresponding local device. Configure the local device in API mode because remote commands only work in API mode. Configure remote devices in either API or Transparent mode.

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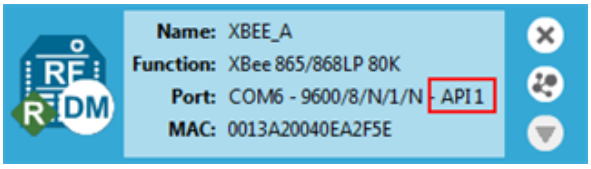
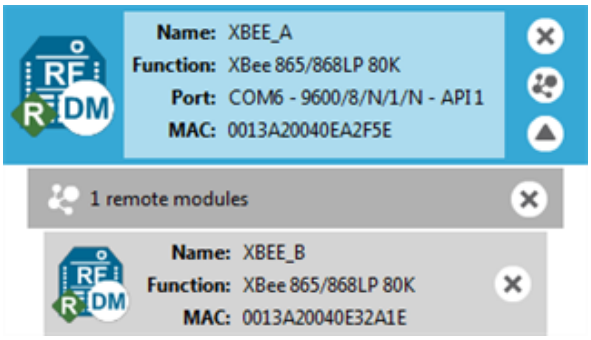
These instructions show you how to configure the LT (Associated LED Blink Time) parameter on a remote device.

1. Add two XBee devices to XCTU.
2. Configure the first device in API mode and name it **XBEE_A**.
3. Configure the second device in either API or Transparent mode, and name it **XBEE_B**.
4. Disconnect XBEE_B from your computer and remove it from XCTU.
5. Connect XBEE_B to a power supply (or laptop or portable battery).

   The **Radio Modules** area should look something like this.



6. Select **XBEE_A** and click the **Discover radio nodes in the same network** button .
7. Click **Add selected devices** in the **Discovering remote devices** dialog. The discovered remote device appears below XBEE_A.



8. Select the remote device **XBEE_B**, and configure the following parameter:

   LT: FF (hexidecimal representation for 2550 ms)

9. Click the **Write radio settings** button .

   The remote XBee device now has a different LED blink time.
10. To return to the default LED blink times, change the **LT** parameter back to 0 for XBEE_B.

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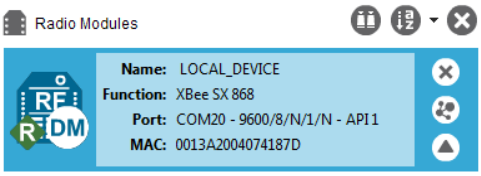
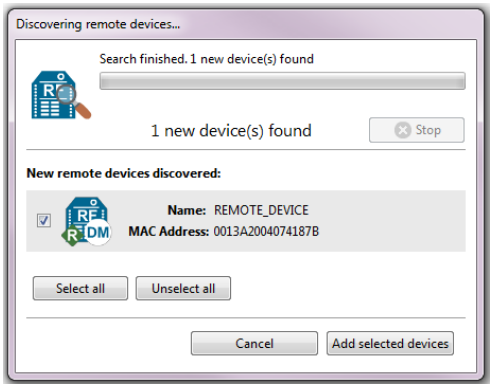
Perform a range test

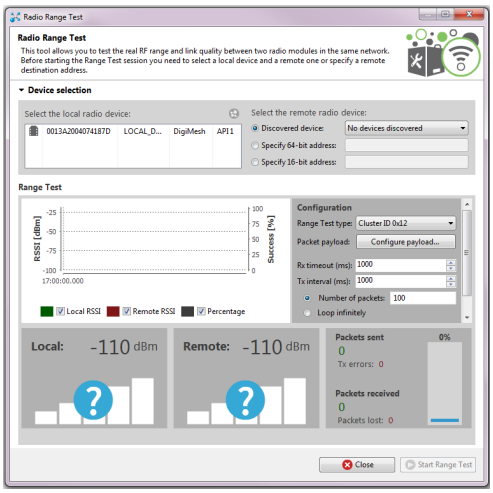
1. Go to the XCTU display for LOCAL_DEVICE.



2. Click to discover remote devices within the same network. The **Discover remote devices** dialog appears.



3. Click **Add selected devices**.
4. Click and select **Range test**. The **Radio Range Test** dialog appears.



5. In the **Select the local radio device** area, select LOCAL_DEVICE. XCTU automatically selects the **Discovered device radio** button and enables the **Start Range Test** button.

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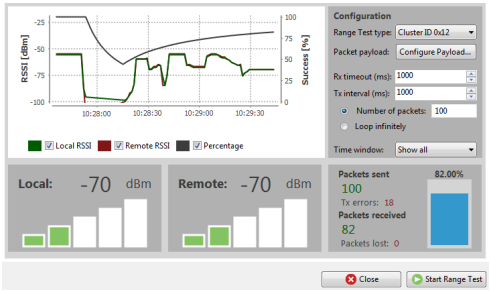
6. Click **Start Range Test** to begin the range test.

   If the test is running properly, the packets sent should match the packets received. You will also see the received signal strength indicator (RSSI) update for each radio after each reception.



7. You can move the LOCAL_DEVICE and REMOTE_DEVICE farther from each other to observe the signal strength at different distances.
8. Click **Stop Range Test** when the test is complete.
9. You can test different data rates by reconfiguring the BR (RF Data Rate) parameters on both devices and starting a new range test.

XBee Network Assistant

The XBee Network Assistant is an application designed to inspect and manage RF networks created by Digi XBee devices. Features include:

- Join and inspect any nearby XBee network to get detailed information about all the nodes it contains.
- Update the configuration of all the nodes of the network, specific groups, or single devices based on configuration profiles.
- Geo-locate your network devices or place them in custom maps and get information about the connections between them.
- Export the network you are inspecting and import it later to continue working or work offline.
- Use automatic application updates to keep you up to date with the latest version of the tool.

See the *XBee Network Assistant User Guide* for more information.

To install the XBee Network Assistant:

1. Navigate to digi.com/xbeenetworkassistant.
2. Click **General Diagnostics, Utilities and MIBs**.
3. Click the **XBee Network Assistant - Windows x86** link.
4. When the file finishes downloading, run the executable file and follow the steps in the XBee Network Assistant Setup Wizard.

XBee Multi Programmer

The XBee Multi Programmer is a combination of hardware and software that enables partners and distributors to program multiple Digi Radio frequency (RF) devices simultaneously. It provides a fast and easy way to prepare devices for distribution or large networks deployment.

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The XBee Multi Programmer board is an enclosed hardware component that allows you to program up to six RF modules thanks to its six external XBee sockets. The XBee Multi Programmer application communicates with the boards and allows you to set up and execute programming sessions. Some of the features include:

- Each XBee Multi Programmer board allows you to program up to six devices simultaneously. Connect more boards to increase the programming concurrency.
- Different board variants cover all the XBee form factors to program almost any Digi RF device.

Download the XBee Multi Programmer application from: digi.com/support/productdetail?pid=5641

See the *XBee Multi Programmer User Guide* for more information.

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Hardware

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Pin signals 31

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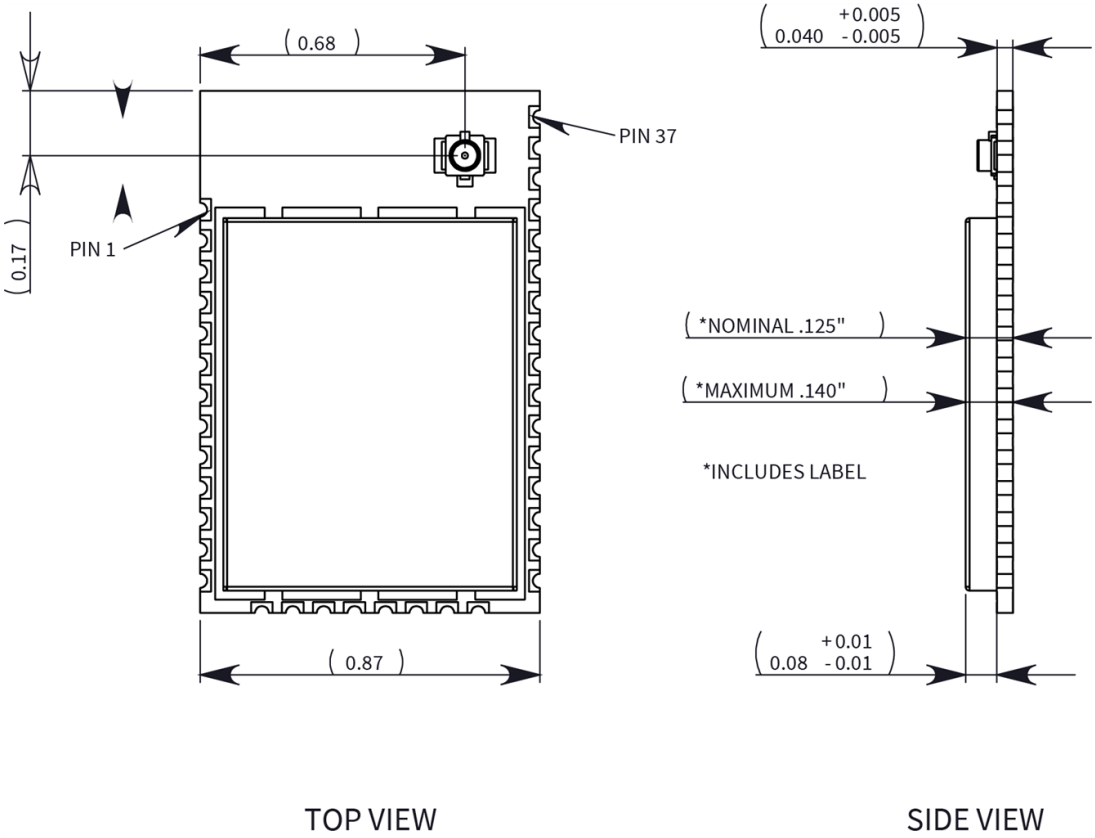
Mechanical drawings

The following figures show the XBee SX 868 RF Module mechanical drawings. All dimensions are in centimeters. The XBee SX 868 RF Module differs from other surface-mount XBee modules. It has an additional ground pad on the underside of the module used for heat dissipation. For more details, see PCB design and manufacturing.



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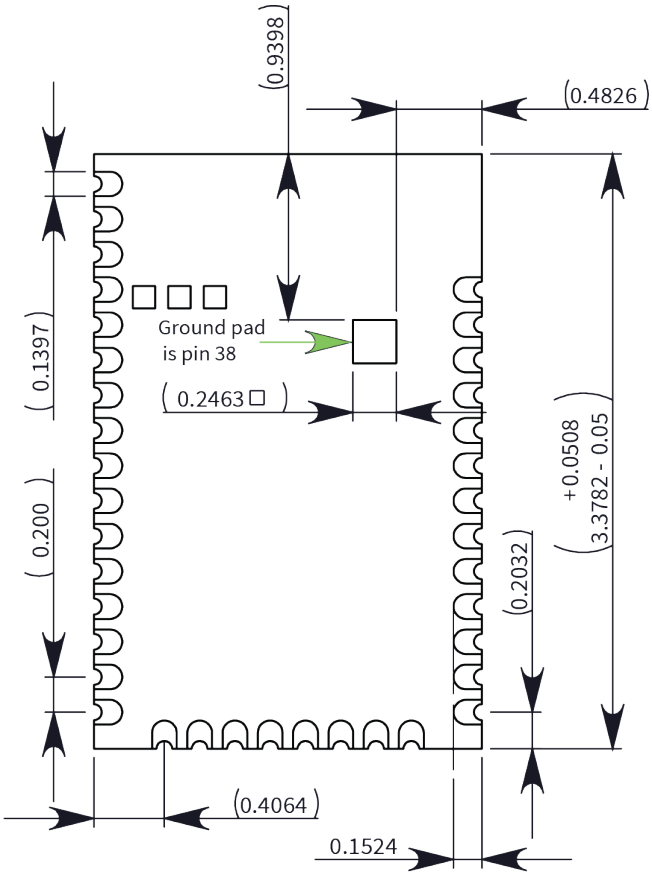

Bottom view

Pin signals

The following table describes the pin signals. Low-asserted signals are distinguished with a horizontal line over the signal name.

Pin	Name	I/O	Default state	Function
1	GND	-	-	Ground
2	VCC	I	-	Power supply
3	DOUT	I/O	Output	UART data out
4	DIN/$\overline{\text{CONFIG}}$	I/O	Input	UART data in
5	DIO12	I/O	Disabled	GPIO

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Pin	Name	I/O	Default state	Function
6	$\overline{\text{RESET}}$	I	-	Drive low to reset device. Do not drive pin high; pin may only be driven open drain or low. Pin has an internal 20k pullup resistor. The minimum reset pulse time is 100 ns.
7	DIO10/RSSI/PWM0	I/O	Output	GPIO / RX Signal Strength Indicator
8	DIO11/PWM1	I/O	Disabled	GPIO / Pulse Width Modulator
9	[Reserved]	-	-	Do not connect
10	DIO8/$\overline{\text{DTR}}$ /SLEEP_RQ	I/O	Input	GPIO / Pin Sleep Control line ($\overline{\text{DTR}}$ on the development board)
11	GND	-	-	Ground
12	DO19/SPI_$\overline{\text{ATTN}}$	O	Output	GPO / Serial Peripheral Interface (SPI) Attention or UART Data Present indicator
13	GND	-	-	Ground
14	DO18/SPI_CLK	I/O[1]	Input	GPO / SPI clock
15	DO17/SPI_$\overline{\text{SSEL}}$	I/O[2]	Input	GPO / SPI not select
16	DO16/SPI_MOSI	I/O[3]	Input	GPO / SPI Data In
17	DO15/SPI_MISO	O	Output	GPO/SPI Data Out Tri-stated when SPI_$\overline{\text{SSEL}}$ is high
18	[Reserved]	-	-	Do not connect
19	[Reserved]	-	-	Do not connect
20	[Reserved]	-	-	Do not connect
21	[Reserved]	-	-	Do not connect
22	GND	-	-	Ground
23	[Reserved]	-	-	Do not connect
24	DIO4	I/O	Disabled	GPIO
25	DIO7/$\overline{\text{CTS}}$	I/O	Output	GPIO / UART Clear to Send Flow Control
26	DIO9/ON/$\overline{\text{SLEEP}}$	I/O	Output	GPIO / Module Sleep Status Indicator

[1]Pins 14-16 are inputs in SPI mode only. In general purpose I/O pin mode you can only use them as digital outputs.
[2]Pins 14-16 are inputs in SPI mode only. In general purpose I/O pin mode you can only use them as digital outputs.
[3]Pins 14-16 are inputs in SPI mode only. In general purpose I/O pin mode you can only use them as digital outputs.

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Pin	Name	I/O	Default state	Function
27	V_{REF}	-	-	Feature not supported on this device. Used on other XBee devices for analog voltage reference.
28	DIO5/ASSOC	I/O	Output	GPIO / Associate Indicator
29	DIO6/$\overline{RTS}$	I/O	Disabled	GPIO / UART Request to Send Flow Control
30	DIO3/AD3	I/O	Disabled	GPIO / Analog Input
31	DIO2/AD2	I/O	Disabled	GPIO / Analog Input
32	DIO1/AD1	I/O	Disabled	GPIO / Analog Input
33	DIO0/AD0	I/O	Input	GPIO / Analog Input / Commissioning Pushbutton
34	[Reserved]	-	-	Do not connect
35	GND	-	-	Ground
36	RF_PAD	I/O	-	RF connection for RF pad variant
37	[Reserved]	-	-	Do not connect
38	GND	-	-	Ground pad for heat transfer to host PCB. Located on the underside of the XBee module.

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).

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Operation

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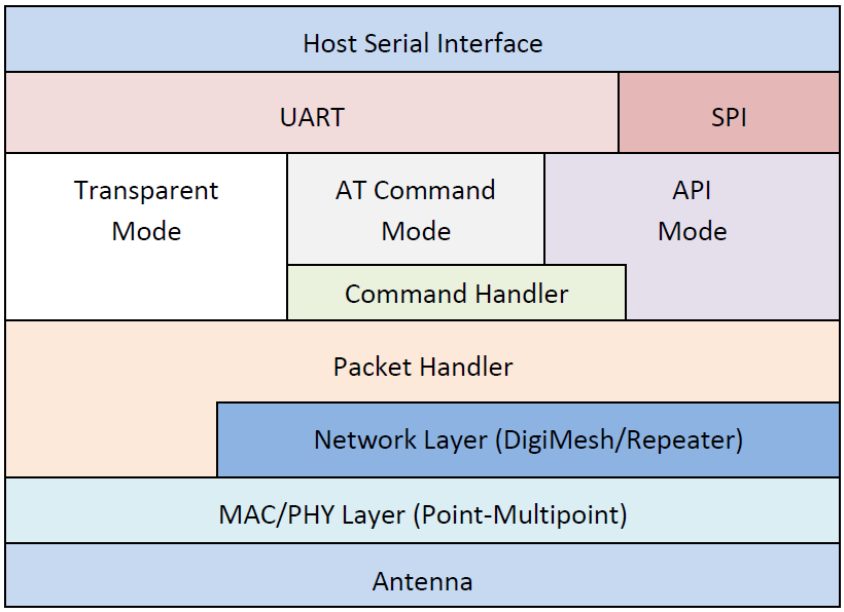
Operation

The XBee SX 868 RF Module uses a multi-layered firmware base to order the flow of data, dependent on the hardware and software configuration you choose. The following configuration block diagram shows the host serial interface as the physical starting point and the antenna as the physical endpoint for the transferred data. A block must be able to touch another block above or below it for the two interfaces to interact. For example, if the device uses SPI mode, Transparent mode is not available as shown in the following image:



The command handler code processes commands from AT Command Mode or API Mode; see API serial exchanges. The command handler also processes commands from remote devices; see Remote AT commands.

Listen Before Talk and Automatic Frequency Agility

This device implements Listen Before Talk (LBT) and Automatic Frequency Agility (AFA). The advantage of LBT with AFA is that the device bypasses the Duty Cycle requirement imposed by European standards. LBT+AFA requires that you use at least two frequencies for transmission. See Regulatory conformity summary for a complete list of channels and frequencies.

This feature provides a level of fairness to the devices in a given area. Before this device transmits, it senses a channel to determine if there is activity by taking an RSSI measurement for 5 ms. If the measurement is below the threshold, the device transmits on that channel. If there is activity, that channel is not used, and the device listens for at least 5 ms to allow transmissions to be received.

After the device transmits on a channel, it will not transmit on that channel again until the minimum TX off time has been met, which is greater than 100 ms. It is useful to have many channels in your channel mask, so transmissions are less likely to be delayed.

European requirements also state that only 100 seconds of transmission may occur over the period of an hour on 200 kHz of spectrum. This method simplifies and optimizes the calculations of spectrum use over the period of one hour. The standard states that the more channels you have, the more

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transmission time you have in a one hour period. Calculate the effective duty cycle based on the number of available channels enabled as follows:

Effective Duty Cycle = (number of channels * 100)/3600.

For example, if you enabled two channels you would have an effective duty cycle of 5.6%.

The XBee SX 868 RF Module uses a sliding bucket algorithm to calculate usage over the period of 1 hour for each channel. Each bucket accumulates for 6 minutes.

This device has a maximum of 28 AFA channels to choose from, and channels can be excluded by setting the channel mask (**CM**) to reduce them. Since not all countries allow for all of these channels, the set may be dramatically smaller for some countries. For a complete list, refer to www.digi.com.

Single frequency mode band mode

When you set the channel mask to 0x20000000, the device is in a single frequency mode, and the frequency is 869.85 MHz. In this mode:

- LBT+AFA mode is disabled.
- The device assumes no duty cycle requirement (or 100% duty cycle).
- The **PL** is automatically limited to 5 mW to comply with the single frequency mode requirements.

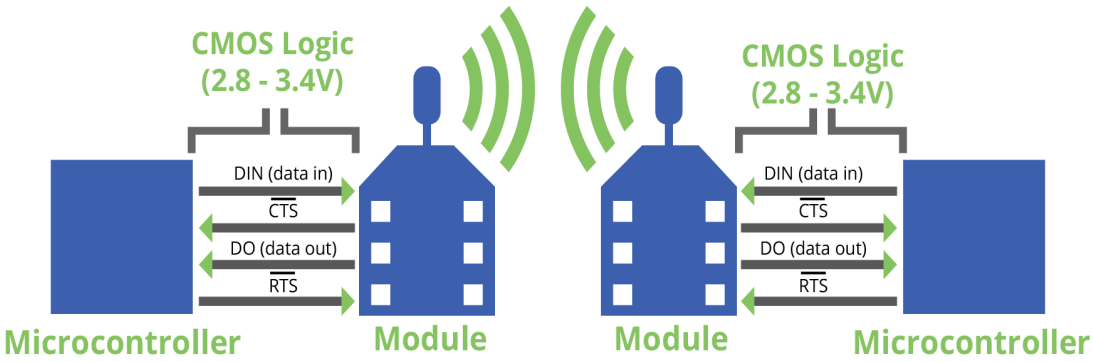
Serial communications

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 SX 868 RF Module 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 SX 868 RF Module's UART through pin 4 DIN as an asynchronous serial signal. When the device is not transmitting data, the signals should idle high.

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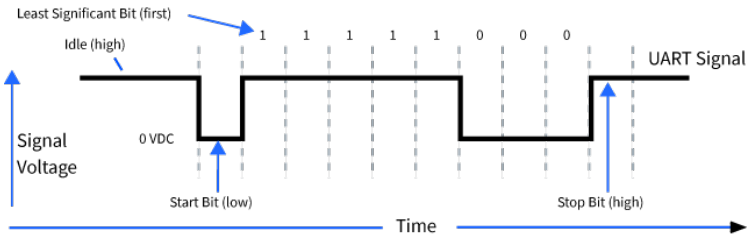
For serial communication to occur, you must configure the UART of both devices (the microcontroller and the XBee SX 868 RF Module) with compatible settings for the baud rate, parity, start bits, stop bits, and data bits.

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.



SPI communications

The XBee SX 868 RF Module supports SPI communications in slave mode. Slave mode receives the clock signal and data from the master and returns data to the master. The following table shows the signals that the SPI port uses on the device.

Signal	Function
SPI_MOSI (Master Out, Slave In)	Inputs serial data from the master
SPI_MISO (Master In, Slave Out)	Outputs serial data to the master
SPI_SCLK (Serial Clock)	Clocks data transfers on MOSI and MISO
SPI_$\overline{\text{SSEL}}$ (Slave Select)	Enables serial communication with the slave
SPI_$\overline{\text{ATTN}}$ (Attention)	Alerts the master that slave has data queued to send. The XBee SX 868 RF Module asserts this pin as soon as data is available to send to the SPI master and it remains asserted until the SPI master has clocked out all available data.

In this mode:

- Data is most significant bit (MSB) first.
- Frame Format mode 0 is used. This means CPOL= 0 (idle clock is low) and CPHA = 0 (data is sampled on the clock's leading edge).
- The SPI port only supports API Mode (**AP** = **1**).

The following diagram shows the frame format mode 0 for SPI communications.

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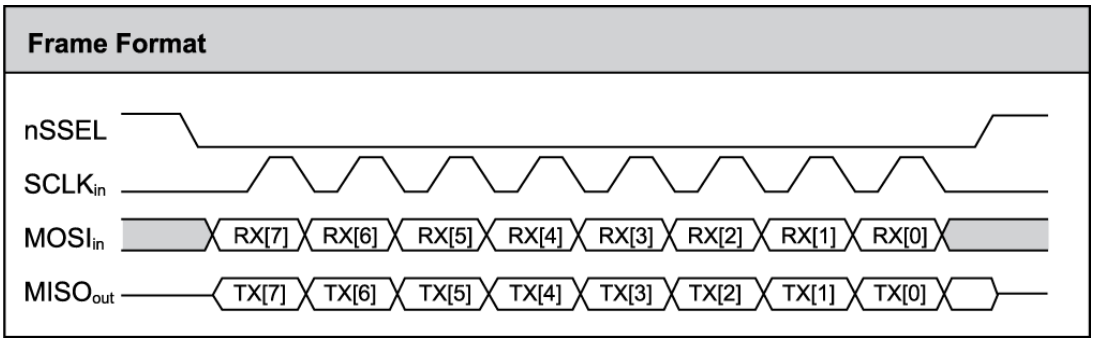

SPI operation

This section specifies how SPI is implemented on the device, what the SPI signals are, and how full duplex operations work.

SPI implementation

The XBee SX 868 RF Module operates as a SPI slave only. This means an external master provides the clock and decides when to send data. The XBee SX 868 RF Module supports an external clock rate of up to 6 Mhz (6 Mb/s).

The device transmits and receives data with the most significant bit first using SPI mode 0. This means the CPOL and CPHA are both 0. We chose Mode 0 because it is the typical default for most microcontrollers and simplifies configuring the master.

SPI signals

The XBee SX 868 RF Module supports SPI communications in slave mode. Slave mode receives the clock signal and data from the master and returns data to the master. The SPI port uses the following signals on the device:

Signal	Pin number	Applicable AT command
SPI_MOSI (Master out, Slave in)	17	**P5**
SPI_MISO (Master in, Slave out)	16	**P6**
SPI_SCLK (Serial clock)	15	**P7**
SPI_$\overline{\text{SSEL}}$ (Slave select)	14	**P8**
SPI_$\overline{\text{ATTN}}$ (Attention)	12	**P9**

By default, the inputs have pull-up resistors enabled. Use the **PR** command to disable the pull-up resistors. When the SPI pins are not connected but the pins are configured for SPI operation, then the device requires the pull-ups for proper UART operation.

Signal description

SPI_MISO: When SPI_$\overline{\text{SSEL}}$ is asserted (low) and SPI_CLK is active, the device outputs the data on this line at the SPI_CLK rate. When SPI_$\overline{\text{SSEL}}$ is de-asserted (high), you should tri-state this output such that another slave device can drive the line.

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SPI_MOSI: The SPI master outputs data on this line at the SPI_CLK rate after it selects the desired slave. When you configure the device for SPI operations, this pin is an input.

SPI_SCLK: The SPI master outputs a clock on this pin, and the rate must not exceed the maximum allowed, 6 Mb/s. When you configure the device for SPI operations, this pin is an input. This signal enables serial communication with the slave.

SPI_SSEL: The SPI master outputs a low signal on this line to select the desired slave. When you configure the device for SPI operations, this pin is an input. This signal clocks data transfers on MOSI and MISO.

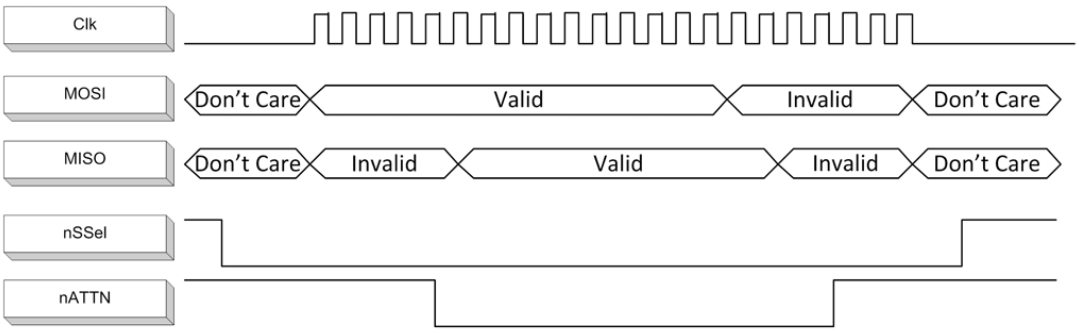
SPI_ATTN: The device asserts this pin low when it has data to send to the SPI master. When you configure this pin for SPI operations, it is an output (not tri-stated). This signal alerts the master that the slave has data queued to send. The device asserts this pin as soon as data is available to send to the SPI master and it remains asserted until the SPI master has clocked out all available data.

Full duplex operation

SPI on the XBee SX 868 RF Module requires that you use API mode (without escaping) to packetize data. By design, SPI is a full duplex protocol even when data is only available in one direction. This means that when a device receives data, it also transmits and that data is normally invalid. Likewise, when the device transmits data, invalid data is probably received. To determine whether or not received data is invalid, we packetize the data with API packets.

SPI allows for valid data from the slave to begin before, at the same time, or after valid data begins from the master. When the master is sending data to the slave and the slave has valid data to send in the middle of receiving data from the master, this allows a true full duplex operation where data is valid in both directions for a period of time. Not only must the master and the slave both be able to keep up with the full duplex operation, but both sides must honor the protocol as specified.

The following diagram illustrates the SPI interface while valid data is being sent in both directions.



Low power operation

Sleep modes generally work the same on SPI as they do on UART. However, due to the addition of SPI mode, there is an option of another sleep pin, as described below.

By default, Digi configures DIO8 (SLEEP_REQUEST) as a peripheral and during pin sleep it wakes the device and puts it to sleep. This applies to both the UART and SPI serial interfaces.

If SLEEP_REQUEST is not configured as a peripheral and SPI_SSEL is configured as a peripheral, then pin sleep is controlled by SPI_SSEL rather than by SLEEP_REQUEST. Asserting SPI_SSEL (pin 15) by driving it low either wakes the device or keeps it awake. Negating SPI_SSEL by driving it high puts the device to sleep.

Using SPI_SSEL to control sleep and to indicate that the SPI master has selected a particular slave device has the advantage of requiring one less physical pin connection to implement pin sleep on SPI.

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It has the disadvantage of putting the device to sleep whenever the SPI master negates SPI_$\overline{\text{SSEL}}$ (meaning time is lost waiting for the device to wake), even if that was not the intent.

If the user has full control of SPI_$\overline{\text{SSEL}}$ so that it can control pin sleep, whether or not data needs to be transmitted, then sharing the pin may be a good option in order to make the SLEEP_REQUEST pin available for another purpose.

If the device is one of multiple slaves on the SPI, then the device sleeps while the SPI master talks to the other slave, but this is acceptable in most cases.

If you do not configure either pin as a peripheral, then the device stays awake, being unable to sleep in **SM**1 mode.

Configuration considerations

The configuration considerations are:

- How do you select the serial port? For example, should you use the UART or the SPI port?
- If you use the SPI port, what data format should you use in order to avoid processing invalid characters while transmitting?
- What SPI options do you need to configure?

Serial port selection

In the default configuration both the UART and SPI ports are configured for serial port operation. In this case, serial data goes out the UART until the host device asserts the SPI_$\overline{\text{SSEL}}$ signal. Thereafter all serial communications operate only on the SPI interface until a reset occurs.

If you enable only the UART, the XBee SX 868 RF Module uses only the UART, and ignores the SPI_$\overline{\text{SSEL}}$.

If you enable only the SPI, the XBee SX 868 RF Module uses only the SPI, and ignores UART communications.

Data format

SPI only operates in API mode 1. The XBee SX 868 RF Module does not support Transparent mode or API mode 2 (which escapes control characters). This means that the AP configuration only applies to the UART, and the device ignores it while using SPI.

SPI parameters

Most host processors with SPI hardware allow you to set the bit order, clock phase and polarity. For communication with all XBee SX 868 RF Modules, the host processor must set these options as follows:

- Bit order: send MSB first
- Clock phase (CPHA): sample data on first (leading) edge
- Clock polarity (CPOL): first (leading) edge rises

All XBee SX 868 RF Modules use SPI mode 0 and MSB first. Mode 0 means that data is sampled on the leading edge and that the leading edge rises. MSB first means that bit 7 is the first bit of a byte sent over the interface.

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Serial buffers

To enable the UART port, DIN and DOUT must be configured as peripherals. To enable the SPI port, SPI_MISO, SPI_MOSI, SPI_SSEL, and SPI_CLK must be enabled as peripherals. If both ports are enabled, output goes to the UART until the first input on SPI. This is the default configuration.

When input occurs on either port, that port is selected as the active port and no input or output is allowed on the other port until the next reset of the module.

If you change the configuration to configure only one port, that port is the only one enabled or used. If the parameters are written with only one port enabled, the port that is not enabled is not used even temporarily after the next reset.

If both ports are disabled on reset, the device uses the UART regardless of the incorrect configuration to ensure that at least one serial port is operational.

Serial receive buffer

When serial data enters the device through the DIN pin (or the MOSI pin), it stores the data in the serial receive buffer until the device can process it. Under certain conditions, the device may not be able to process data in the serial receive buffer immediately. If large amounts of serial data are sent to the device such that the serial receive buffer would overflow, then it discards new data. If the UART is in use, you can avoid this by the host side honoring $\overline{\text{CTS}}$ flow control.

If the SPI is the serial port, no hardware flow control is available. It is your responsibility to ensure that the receive buffer does not overflow. One reliable strategy is to wait for a TX_STATUS response after each frame sent to ensure that the device has had time to process it.

Serial transmit buffer

When the device receives RF data, it moves the data into the serial transmit buffer and sends it out the UART or SPI port. If the serial transmit buffer becomes full and the system buffers are also full, then it drops the entire RF data packet. Whenever the device receives data faster than it can process and transmit the data out the serial port, there is a potential of dropping data.

UART flow control

You can use the $\overline{\text{RTS}}$ and $\overline{\text{CTS}}$ pins to provide $\overline{\text{RTS}}$ and/or $\overline{\text{CTS}}$ flow control. $\overline{\text{CTS}}$ flow control provides an indication to the host to stop sending serial data to the device. RTS flow control allows the host to signal the device to not send data in the serial transmit buffer out the UART. To enable RTS/CTS flow control, use the **D6** and **D7** commands.

Note Serial port flow control is not possible when using the SPI port.

$\overline{\text{CTS}}$ flow control

If you enable CTS flow control (**D7** command), when the serial receive buffer is 17 bytes away from being full, the device de-asserts $\overline{\text{CTS}}$ (sets it high) to signal to the host device to stop sending serial data. The device reasserts $\overline{\text{CTS}}$ after the serial receive buffer has 34 bytes of space. See FT (Flow Control Threshold) for the buffer size.

In either case, $\overline{\text{CTS}}$ is not re-asserted until the serial receive buffer has **FT**-17 or less bytes in use.

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RTS flow control

If you send the **D6** command to enable RTS flow control, the device does not send data in the serial transmit buffer out the DOUT pin as long as RTS is de-asserted (set high). Do not de-assert RTS for long periods of time or the serial transmit buffer will fill. If the device receives an RF data packet and the serial transmit buffer does not have enough space for all of the data bytes, it discards the entire RF data packet.

The UART Data Present Indicator is a useful feature when using RTS flow control. When enabled, the DIO19 line asserts (low asserted) when UART data is queued to be transmitted from the device. For more information, see P9 (DIO19/SPI_ATTN).

If the device sends data out the UART when RTS is de-asserted (set high) the device could send up to five characters out the UART port after RTS is de-asserted.

Serial interface protocols

The XBee SX 868 RF Module supports both Transparent and Application Programming Interface (API) serial interfaces.

Transparent operating mode

When operating in Transparent mode, the devices act as a serial line replacement. The device queues up all UART data received through the DIN pin for RF transmission. When RF data is received, the device sends the data out through the serial port. Use the Command mode interface to configure the device configuration parameters.

Note Transparent operation is not provided when using SPI.

The device buffers data in the serial receive buffer and packetizes and transmits the data when it receives the following:

- No serial characters for the amount of time determined by the **RO** (Packetization Timeout) parameter. If **RO** = 0, packetization begins when the device received a character.
- Command Mode Sequence (**GT** + **CC** + **GT**). Any character buffered in the serial receive buffer before the device transmits the sequence.
- Maximum number of characters that fit in an RF packet.

API operating mode

API operating mode is an alternative to Transparent operating mode. The frame-based API extends the level to which a host application can interact with the networking capabilities of the device. When in API mode, the device contains all data entering and leaving in frames that define operations or events within the device.

The API provides alternative means of configuring devices and routing data at the host application layer. A host application can send data frames to the device that contain 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 and payload information from received data packets.

The API operation option facilitates many operations such as:

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

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Remote configuration commands

The API firmware has provisions to send configuration commands to remote devices using the Remote Command Request API frame (see Operate in API mode). Use the API frame to send commands to a remote device to read or set command parameters.

Send a remote command

To send a remote command, populate the Remote Command Request frame with:

- 64-bit address of the remote device
- Correct command options value
- Command and parameter data (optional)

If you want a command response, set the Frame ID set to a non-zero value. Only unicasts of remote commands are supported, and remote commands cannot be broadcast.

Apply changes on remote devices

When you use remote commands to change command parameter settings on a remote device, parameter changes do not take effect until you apply the changes. For example, changing the **BD** parameter does not change the serial interface on the remote until the changes are applied. To apply changes, do one of the following:

- Set the apply changes option bit in the API frame.
- Issue an **AC** (Apply Changes) command to the remote device.
- Issue a **WR** + **FR** command to the remote device to save changes and reset the device.

Remote command responses

If the remote device receives a remote command request transmission, and the API frame ID is non-zero, the remote sends a remote command response transmission back to the device that sent the remote command. When a remote command response transmission is received, a device sends a remote command response API frame out its serial port. The remote command response indicates the status of the command (success, or reason for failure), and in the case of a command query, it includes the register value. The device that sends a remote command will not receive a remote command response frame if either of the following conditions exist:

- The destination device could not be reached.
- The frame ID in the remote command request is set to 0.

Network commissioning and diagnostics

We call the process of discovering and configuring devices in a network for operation, "network commissioning." Devices include several device discovery and configuration features. In addition to configuring devices, you must develop a strategy to place devices to ensure reliable routes. To accommodate these requirements, modules include features to aid in placing devices, configuring devices, and network diagnostics.

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Configure devices

You can configure XBee devices locally through serial commands (AT or API) or remotely through remote API commands. API devices can send configuration commands to set or read the configuration settings of any device in the network.

Network link establishment and maintenance

Build aggregate routes

In many applications it is necessary for many or all of the nodes in the network to transmit data to a central aggregator node. In a new DigiMesh network the overhead of these nodes discovering routes to the aggregator node can be extensive and taxing on the network. To eliminate this overhead, use the **AG** command to automatically build routes to an aggregate node in a DigiMesh network.

Send a unicast

To send a unicast, devices configured for Transparent mode (**AP** = **0**) must set their **DH**/**DL** registers to the MAC address of the node which they need to transmit to. In networks of Transparent mode devices which transmit to an aggregator node, it is necessary to set every device's **DH**/**DL** registers to the MAC address of the aggregator node. Use the **AG** command to set the **DH**/**DL** registers of all the nodes in a DigiMesh network to that of the aggregator node.

Use the AG command

Upon deploying a DigiMesh network, send the **AG** command on the desired aggregator node to cause all nodes in the network to build routes to the aggregator node. You can use the command to automatically update the **DH**/**DL** registers to match the MAC address of the aggregator node.

The **AG** command requires a 64-bit parameter. The parameter indicates the current value of the **DH**/**DL** registers on a device which should be replaced by the 64-bit address of the node sending the **AG** broadcast. If it is not desirable to update the **DH**/**DL** of the device receiving the **AG** broadcast, you can use the invalid address of 0xFFFE. API enabled devices output an Aggregate Addressing Update - 0x8E if they update their **DH**/**DL** address.

All devices that receive an **AG** broadcast update their routing table information to build a route to the sending device, regardless of whether or not their **DH**/**DL** address is updated. This routing information will be used for future transmissions of DigiMesh unicasts.

Example 1: To update the **DH**/**DL** registers of all modules in the network to be equal to the MAC address of an aggregator node with a MAC address of **0x0013a2004052c507** after network deployment the following technique could be employed:

1. Deploy all devices in the network with the default **DH**/**DL** of 0xFFFF.
2. Send an **ATAGFFFF** command on the aggregator node.

Following the preceding sequence would result in all of the nodes in the network which received the **AG** broadcast to have a **DH** of **0x0013a200** and a **DL** of **0x4052c507**. These nodes would have automatically built a route to the aggregator.

Example 2: To cause all nodes in the network to build routes to an aggregator node with a MAC address of **0x0013a2004052c507** without affecting the **DH**/**DL** of any nodes in the network, send the **AGFFFE** command on the aggregator node. This sends an **AG** broadcast to all nodes in the network.

All of the nodes will update their internal routing table information to contain a route to the aggregator node. None of the nodes update their **DH**/**DL** registers, because none of the registers are set to an address of **0xFFFE**.

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Node replacement

You can also use the AG command to update the routing table and **DH**/**DL** registers in the network after a device is replaced, and you can update the **DH**/**DL** registers of nodes in the network.

- To update only the routing table information without affecting the **DH**/**DL** registers, use Example 2.
- To update the **DH**/**DL** registers of the network, use the method in the following example.

Example: Use the device with serial number 0x0013a2004052c507 as a network aggregator and replace it with a device with serial number 0x0013a200f5e4d3b2. Issue the AG0013a2004052c507 command on the new module. This causes all devices with a **DH**/**DL** register setting of 0x0013a2004052c507 to update their **DH**/**DL** register setting to the MAC address of the sending device (0x0013a200f5e4d3b2).

Place devices

For a network installation to be successful, installers must be able to determine where to place individual XBee devices to establish reliable links throughout the network.

RSSI indicators

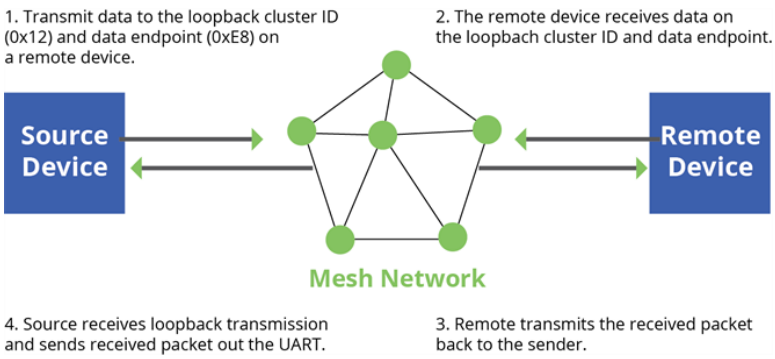
It is possible to measure the received signal strength on a device using the **DB** command. **DB** returns the RSSI value (measured in -dBm) of the last received packet. However, this number can be misleading in DigiMesh networks. The **DB** value only indicates the received signal strength of the last hop. If a transmission spans multiple hops, the **DB** value provides no indication of the overall transmission path, or the quality of the worst link; it only indicates the quality of the last link.

Determine the **DB** value in hardware using the RSSI/PWM device pin (pin 7). If you enable the RSSI PWM functionality (**P0** command), when the device receives data, it sets the RSSI PWM to a value based on the RSSI of the received packet (this value only indicates the quality of the last hop). You could connect this pin to an LED to indicate if the link is stable or not.

Test links in a network - loopback cluster

To measure the performance of a network, you can send unicast data through the network from one device to another to determine the success rate of several transmissions. To simplify link testing, the devices support a Loopback cluster ID (0x12) on the data endpoint (0xE8). The cluster ID on the data endpoint sends any data transmitted to it back to the sender.

The following figure demonstrates how you can use the Loopback cluster ID and data endpoint to measure the link quality in a mesh network.



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The configuration steps for sending data to the loopback cluster ID depend on what mode the device is in. For details on setting the mode, see AP (API Mode). The following sections list the steps based on the device's mode.

Transparent operating mode configuration (AP = 0)

To send data to the loopback cluster ID on the data endpoint of a remote device:

1. Set the **CI** command to **0x12**.
2. Set the **SE** and **DE** commands to **0xE8** (default value).
3. Set the **DH** and **DL** commands to the address of the remote (**0** for the coordinator, or the 64-bit address of the remote).

After exiting Command mode, the device transmits any serial characters it received to the remote device, which returns those characters to the sending device.

API operating mode configuration (AP = 1 or AP = 2)

Send an Explicit Addressing Command Request - 0x11 using **0x12** as the cluster ID and **0xE8** as both the source and destination endpoint.

The remote device echoes back the data packets it receives to the sending device.

Test Link cluster

The primary difference between the Loopback cluster ID (0x12) and the Test Link cluster (0x14) is the number of hops. With the Loopback cluster you can verify that a route exists across one or more hops between any two nodes in the network.

With the Test Link cluster you can determine the signal strength between any two nodes without using intermediate nodes. If the two nodes are too far apart, you can expect 100% failure. If they are close together, you can expect 100% success.

When placing nodes, the following sequence could occur:

1. You can use the Loopback cluster to verify that a route exists between all nodes of interest; for example, between the aggregator and each of the other nodes.
2. If step 1 fails, you could perform a trace route on any pair of nodes that failed in step 1. The trace route indicates the failing link.
3. Once a weak link is identified, you can run Test Link to exercise that link to determine how strong and reliable it is.
4. Now that the problem has been isolated, you can place nodes apropriately to resolve the connectivity problems.

Device discovery

Network discovery

Use the network discovery command to discover all devices that have joined a network. Issuing the **ND** command sends a broadcast network discovery command throughout the network. All devices that receive the command send a response that includes:

- Device addressing information
- Node identifier string (see NI (Node Identifier))
- Other relevant information

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You can use this command for generating a list of all module addresses in a network.

When a device receives the network discovery command, it waits a random time before sending a response. The device sets the maximum time delay on the **ND** sender with the **NT** command. The **ND** originator includes its **NT** setting in the transmission to provide a delay window for all devices in the network. Large networks may need to increase **NT** to improve network discovery reliability. The default **NT** value is .

Neighbor polling

Use the neighbor poll command to discover the modules which are immediate neighbors (within RF range) of a particular node. You can use this command to determining network topology and determining possible routes.

The device sends the command using the **FN** command. You can initiate the **FN** command locally on a node using AT command mode or by using a local AT command request frame. You can also initiate the command remotely by sending the target node an **FN** command using a remote AT command request API frame.

A node that executes an **FN** command sends a broadcast to all of its immediate neighbors. All devices that receive this broadcast send an RF packet to the node that initiated the **FN** command. In an instance where the device initiates the command remotely, it sends the responses directly to the node which sent the **FN** command to the target node. The device outputs the response packet on the initiating radio in the same format as a network discovery frame.

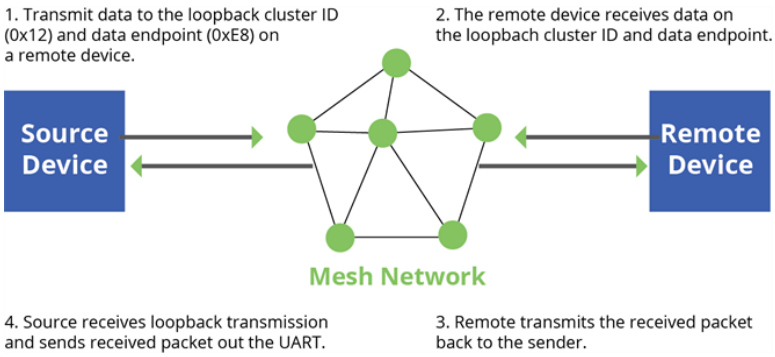
Link reliability

To install a successful mesh network, you must be able to determine where to place individual XBee devices to establish reliable links throughout the mesh network.

Network link testing

To determine the success rate of many transmissions, send unicast data through the network from one device to another to measure the performance of the mesh network.

To simplify link testing, the modules support a loopback cluster ID (0x12) on the data endpoint (0xE8). The device transmits any data sent to this cluster ID on the data endpoint back to the sender as illustrated in the following figure:



The configuration steps to send data to the loopback cluster ID depend on the AP setting.

AT configuration (AP=0)

To send data to the loopback cluster ID on the data endpoint of a remote device, set the **CI** command value to 0x12. Set the **SE** and **DE** commands set to 0xE8 (default value). Set the **DH** and **DL** commands

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to the address of the remote. After exiting command mode, the source device transmits any received serial characters to the remote device, and returned to the sender.

API configuration (AP=1 or AP=2)

Send an Explicit Addressing Command API frame (0x11) using 0x12 as the cluster ID and 0xE8 as the source and destination endpoint. The remote device echoes any data packets it receives to the sender.

Link testing between adjacent devices

To test the quality of a link between two adjacent nodes in a network, use the Test Link Request Cluster ID send a number of test packets between any two nodes in a network.

Initiate a link test using an Explicit TX Request frame. Address the command frame to the Test Link Request Cluster ID (0x0014) on destination endpoint 0xE6 on the device to execute the test link. The Explicit TX Request frame contains a 12 byte payload with the following format:

Number of bytes	Field name	Description
8	Destination address	The address the device tests its link with.
2	Payload size	The size of the test packet. Use the MP command to query the maximum payload size for this device.
2	Iterations	The number of packets to send. Use a number between 1 and 4000.

After completing the transmissions of the test link packets, the executing device sends the following data packet to the requesting device's Test Link Result Cluster (0x0094) on endpoint (0xE6). If the requesting device is operating in API mode, the device outputs the following information as an API Explicit RX Indicator Frame:

Number of bytes	Field name	Description
8	Destination address	The address where the device tested its link.
2	Payload size	The size of the test packet sent to test the link.
2	Iterations	The number of packets sent.
2	Success	The number of packets successfully acknowledged.
2	Retries	The total number of MAC retries to transfer all the packets.
1	Result	0x00 - command was successful. 0x03 - invalid parameter used.
1	RR	The maximum number of MAC retries allowed.
1	maxRSSI	The strongest RSSI reading observed during the test.

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Number of bytes	Field name	Description
1	minRSSI	The weakest RSSI reading observed during the test.
1	avgRSSI	The average RSSI reading observed during the test.

Example

Suppose that the link between device A (**SH**/**SL** = 0x0013a20040521234) and device B (**SH**/**SL**=0x0013a2004052abcd) is being tested by transmitting 1,000 40 byte packets. Send the following API packet to the serial interface of the device outputting the results, device C. Note that device C can be the same device as device A or B (Whitespace delineates fields and bold text is the payload portion of the packet):

7E 0020 11 01 0013A20040521234 FFFE E6 E6 0014 C105 00 00 0013A2004052ABCD 0028 03E8 EB

And the following is a possible packet returned:

7E 0027 91 0013A20040521234 FFFE E6 E6 0094 C105 00 0013A2004052ABCD 0028 03E8 03E7 0064 00 0A 50 53 52 9F

(999 out of 1000 packets successful, 100 retries used, RR=10, maxRSSI= **-** 80 dBm, minRSSI= **-** 83 dBm, avgRSSI= **-** 82 dBm)

If the result field is not equal to zero then an error occurred. Ignore the other fields in the packet. If the Success field is equal to zero then ignore the RSSI fields.

Trace routing

Determining the route a DigiMesh unicast takes to its destination is useful when setting up a network or diagnosing problems within a network. Use the Trace Route API option of Tx Request Packets to transmit routing information packets to the originator of a DigiMesh unicast by the intermediate nodes. For a description of the API frames, see API operating mode.

When a unicast is sent with the Trace Route API option enabled, the unicast is sent to its destination radios which forward the unicast to its eventual destination and transmit a Route Information (RI) packet back along the route to the unicast originator. For more information, see API operating mode.

Example:

Suppose you unicast a data packet with the trace route enabled from radio A to radio E, through radios B, C, and D. The following sequence occurs:

- After the successful MAC transmission of the data packet from A to B, A outputs an RI Packet indicating that the transmission of the data packet from A to E was successfully forwarded one hop from A to B.
- After the successful MAC transmission of the data packet from B to C, B transmits a RI Packet to A. Then, A outputs this RI packet out its serial interface.
- After the successful MAC transmission of the data packet from C to D, C transmits a RI Packet to A (through B). Then, A outputs this RI packet out its serial interface.
- After the successful MAC transmission of the data packet from D to E, D transmits an RI Packet to A (through C and B). Then, A outputs this RI packet out its serial interface.

Route Information packets are not guaranteed to arrive in the same order as the unicast packet took. It is also possible Route Information packets that are transferred on a weak route to fail before arriving at the unicast originator.

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Because of the large number of Route Information packets that can be generated by a unicast with Trace Route enabled, we suggest that the Trace Route option only be used for occasional diagnostic purposes and not for normal operations.

NACK messages

Transmit Request (0x10 and 0x11) frames contain a negative-acknowledge character (NACK) API option (Bit 2 of the Transmit Options field).

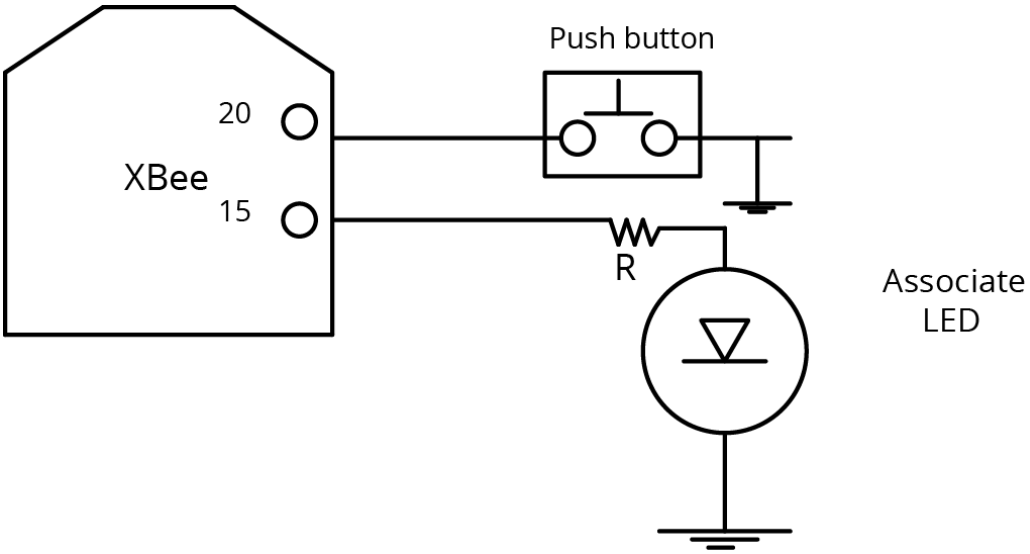
If you use this option when transmitting data, when a MAC acknowledgment failure occurs on one of the hops to the destination device, the device generates a Route Information Packet (0x8D) frame and sends it to the originator of the unicast.

This information is useful because it allows you to identify and repair marginal links.

Commissioning pushbutton and associate LED

XBee devices support a set of commissioning pushbutton and LED behaviors to aid in device deployment and commissioning. These include the commissioning push button definitions and associate LED behaviors. The following features can be supported in hardware:

TH RF Module



A pushbutton and an LED can be connected to the XBee SX 868 RF Module pins 33 and 28 (SMT), or pins 20 and 15 (TH) respectively to support the commissioning pushbutton and associate LED functionalities.

Commissioning pushbutton

The commissioning pushbutton definitions provide a variety of simple functions to help with deploying devices in a network. Enable the commissioning button functionality on pin 20 by setting the **D0** command to 1 (enabled by default).

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Button Presses	Sleep configuration and sync status	Action
1	Not configured for sleep	Immediately sends a Node Identification broadcast transmission. All devices that receive this transmission blink their Associate LED rapidly for 1 second. All API devices that receive this transmission send a Node Identification frame out their serial interface (API ID 0x95).
1	Configured for synchronous sleep	Wakes the module for 30 seconds. Immediately sends a Node Identification broadcast transmission. All devices that receive this transmission blink their Associate LED rapidly for 1 second. All API devices that receive this transmission send a Node Identification frame out their serial interface (API ID 0x95).
1	Configured for synchronous sleep	Wakes the module for 30 seconds (or until the synchronized network goes to sleep). Queues a Node Identification broadcast transmission sent at the beginning of the next network wake cycle. All devices receiving this transmission blink their Associate LEDs rapidly for 1 second. All API devices that receive this transmission will send a Node Identification frame out their serial interface (API ID 0x95).
2	Not configured for synchronous sleep	No effect.
2	Configured for synchronous sleep	Causes a node configured with sleeping router nomination enabled (see the **SO** command in Sleep modes to immediately nominate itself as the network sleep coordinator.
4	Any	Issues an ATRE to restore module parameters to default values.

Use the **CB** command to simulate button presses in the software. Issue a **CB** command with a parameter set to the number of button presses you want executee. For example, sending **CB1** executes the actions associated with a single button press.

The node identification frame is similar to the node discovery response frame; it contains the device's address, node identifier string (**NI** command), and other relevant data. All API devices that receive the node identification frame send it out their serial interface as an API Node Identification Indicator frame (0x95).

Associate LED

The Associate pin (pin 15) provides an indication of the device's sleep status and diagnostic information. To take advantage of these indications, connect an LED to the Associate pin.

To enable the Associate LED functionality, set the **D5** command to 1; it is enabled by default. If enabled, the Associate pin is configured as an output. This section describes the behavior of the pin.

Use the **LT** command to override the blink rate of the Associate pin. If you set **LT** to 0, the device uses the default blink time: 500 ms for a sleep coordinator, 250 ms otherwise.

The following table describes the Associate LED functionality.

Sleep mode	LED status	Meaning
0	On, blinking	The device has power and is operating properly
1, 4, 5	Off	The device is in a low power mode
1, 4, 5	On, blinking	The device has power, is awake and is operating properly
7	On, solid	The network is asleep, or the device has not synchronized with the network, or has lost synchronization with the network
7, 8	On, slow blinking (500 ms blink time)	The device is acting as the network sleep coordinator and is operating properly
7, 8	On, fast blinking (250 ms blink time)	The device is properly synchronized with the network
8	Off	The device is in a low power mode
8	On, solid	The device has not synchronized or has lost synchronization with the network

Diagnostics support

The Associate pin works with the Commissioning Pushbutton to provide additional diagnostic behaviors to aid in deploying and testing a network. If you press the Commissioning Pushbutton once, the device transmits a broadcast Node Identification Indicator (0x95) frame at the beginning of the next wake cycle if the device is sleep compatible, or immediately if the device is not sleep compatible. If you enable the Associate LED functionality using the **D5** command, a device that receives this transmission blinks its Associate pin rapidly for one second.

I/O line monitoring

I/O samples

The XBee SX 868 RF Module supports both analog input and digital I/O line modes on several configurable pins.

Pin configurations

The following table provides typical parameters for the pin configuration commands (**D0** - **D9**, **P0** - **P2**).

Pin configuration commands include the following parameters:

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Pin command parameter	Description
0	Unmonitored digital input
1	Reserved for pin-specific alternate functionality
2	Analog input (A/D pins) or PWM output (PWM pins)
3	Digital input, monitored
4	Digital output, low
5	Digital output, high
7	Alternate functionality, where applicable

The following table provides the pin configurations when you set the configuration command for a particular pin.

Device pin name	Device pin number	Configuration command
DIO12	5	**P2**
PWM0 / RSSI / DIO10	7	**P0**
PWM1 / DIO11	8	**P1**
$\overline{\text{DTR}}$ / SLEEP_RQ / DIO8	10	**D8**
DIO4	24	**D4**
$\overline{\text{CTS}}$ / DIO7	25	**D7**
ON/$\overline{\text{SLEEP}}$ / DIO9	26	**D9**
ASSOC / AD5 / DIO5	15	**D5**
$\overline{\text{RTS}}$ / DIO6	29	**D6**
AD3 / DIO3	30	**D3**
AD2 / DIO2	31	**D2**
AD1 / DIO1	32	**D1**
AD0 / DIO0 / Commissioning Pushbutton	33	**D0**

Use the **PR** command to enable internal pull up/down resistors for each digital input. Use the **PD** command to determine the direction of the internal pull up/down resistor.

Queried sampling

You can use the **IS** command to query the current state of all digital input and ADC lines on the device. If no inputs are defined, the command returns with an ERROR.

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Field	Name	Description
1	Sample sets	Number of sample sets in the packet. Always set to 1.
2	Digital channel mask	Indicates which digital I/O lines have sampling enabled. Each bit corresponds to one digital I/O line on the device. bit 0 = AD0/DIO0 bit 1 = AD1/DIO1 bit 2 = AD2/DIO2 bit 3 = AD3/DIO3 bit 4 = DIO4 bit 5 = ASSOC/DIO5 bit 6 = RTS/DIO6 bit 7 = CTS/GPIO7 bit 8 = DTR / SLEEP_RQ / DIO8 bit 9 = ON_SLEEP / DIO9 bit 10 = RSSI/DIO10 bit 11 = PWM/DIO11 bit 12 = CD/DIO12 For example, a digital channel mask of 0x002F means DIO0,1,2,3, and 5 are enabled as digital I/O.
1	Analog channel mask	Indicates which lines have analog inputs enabled for sampling. Each bit in the analog channel mask corresponds to one analog input channel. bit 0 = AD0/DIO0 bit 1 = AD1/DIO1 bit 2 = AD2/DIO2 bit 3 = AD3/DIO3 bit 4 = AD4/DIO4 bit 5 = ASSOC/AD5/DIO5
Variable	Sampled data set	If you enable any digital I/O lines, the first two bytes of the data set indicate the state of all enabled digital I/O. Only digital channels that you enable in the Digital channel mask bytes have any meaning in the sample set. If do not enable any digital I/O on the device, it omits these two bytes. Following the digital I/O data (if there is any), each enabled analog channel returns two bytes. The data starts with AIN0 and continues sequentially for each enabled analog input channel up to AIN5.

If you issue the **IS** command using a a local or remote AT Command API frame, then the device returns an AT Command Response (0x88) frame with the I/O data included in the command data portion of the packet.

Example	Sample AT response
0x01	[1 sample set]
0x0C0C	[Digital Inputs: DIO 2, 3, 10, 11 enabled]

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Example	Sample AT response
0x03	[Analog Inputs: A/D 0, 1 enabled]
0x0408	[Digital input states: DIO 3, 10 high, DIO 2, 11 low]
0x03D0	[Analog input: ADIO 0 = 0x3D0]
0x0124	[Analog input: ADIO 1 =0x120]

Periodic I/O sampling

Periodic sampling allows a device to take an I/O sample and transmit it to a remote device at a periodic rate. Use the **IR** command to set the periodic sample rate.

- To disable periodic sampling, set **IR** to **0**.
- For all other **IR** values, the firmware samples data when **IR** milliseconds elapse and the sample data transmits to a remote device.

The **DH** and **DL** commands determine the destination address of the I/O samples.

Only devices with API operating mode enabled send I/O data samples out their serial interface. Devices that are in Transparent mode (**AP** = **0**) discard the I/O data samples they receive.

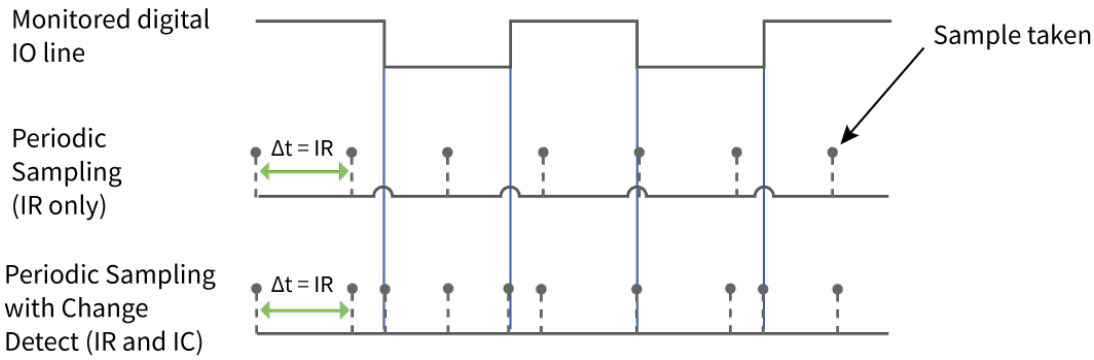
A device with sleep enabled transmits periodic I/O samples at the **IR** rate until the **ST** time expires and the device can resume sleeping.

Detect digital I/O changes

When the network is setup for synchronous sleep there is an option to randomize a single I/O sample by setting **SO** bit 10—enables random I/O samples—and setting **IR** to zero where the sample will be randomized over the **ST** time period. In addition you can use **IR** in conjunction with **SO** bit 10 which will randomize the first I/O sample over the **IR** time period and thereafter I/O samples will occur on the **IR** interval sending x samples or x samples - 1. If the **IR** interval is greater than the **ST** time period then **ST** time will be used to randomize the I/O sample.

You can configure devices to transmit a data sample immediately whenever a monitored digital I/O pin changes state. The **IC** command is a bitmask that you use to set which digital I/O lines to monitor for a state change. If you set one or more bits in **IC**, the device transmits an I/O sample as soon it observes a state change in one of the monitored digital I/O lines using edge detection.

The figure below shows how I/O change detection can work with periodic sampling.



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Enabling edge detection forces an immediate sample of all monitored digital I/O lines if any digital I/O lines change state.

Note Use caution when combining Change Detect sampling with sleep modes. **IC** only causes a sample to be generated if the change takes place during a wake period. If the device is sleeping when the digital input transition occurs, then no change is detected and an I/O sample is not generated. Use **IR** in conjunction with **IC** in this instance, since **IR** generates an I/O sample upon wakeup and ensures that the change is properly observed.

I/O line passing

You can configure XBee SX 868 RF Modules to perform analog and digital line passing. When a device receives an RF I/O sample data packet, you can set up the receiving device to update any enabled outputs (PWM and DIO) based on the data it receives.

Digital I/O lines are mapped in pairs; pins configured as digital input on the transmitting device affect the corresponding digital output pin on the receiving device. For example: DI5 (pin 25) can only update DO5 (pin 25).

For Analog Line Passing, the XBee SX 868 RF Module has two PWM output pins that simulate the voltage measured by the ADC lines AD0 and AD1. For example, when configured as an ADC, AD0 (pin 33) updates PWM0 (pin 7); AD1 (pin 32) updates PWM1 (pin 8).

The default setup is for outputs to not be updated. Instead, a device sends I/O sample data out the serial interface if the device is configured for API mode (**AP** = 1 or 2). You can use the **IU** command to disable sample data output.

To enable updating the outputs, set the **IA** (I/O Input Address) parameter with the address of the device that has the appropriate inputs enabled. This effectively binds the outputs to a particular device's input. This does not affect the ability of the device to receive I/O line data from other devices - only its ability to update enabled outputs. Set the **IA** parameter to 0xFFFF (broadcast address) to set up the device to accept I/O data for output changes from any device on the network.

For line passing to function, the device configured with inputs must generate sample data.

When outputs are changed from their non-active state, the device can be setup to return the output level to its non-active state. The timers are set using the **T*n*** (**D*n*** Output Timer) and **PT** (PWM Output Timeout) commands. The timers are reset every time the device receives a valid I/O sample packet with a matching **IA** address. You can adjust the **IC** (Change Detect) and **IR** (Sample Rate) parameters on the transmitting device to keep the outputs set to their active output if the system needs more time than the timers can handle.

Configuration example

As an example for a simple digital and analog link, you could set a pair of RF devices as follows:

Command	Description	Device A	Device B
SH	Serial Number High	0x0013A200	0x0013A200
SL	Serial Number Low	0x12345678	0xABCDABCD
DH	Destination High	0x0013A200	0x00000000
DL	Destination Low	0xABCDABCD	0x0000FFFF (broadcast)
IA	I/O Input Address	0x0013A200ABCDABCD	0x0013A20012345678

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Command	Description	Device A	Device B
IR	Sample Rate	0x7D0 (2 seconds)	0 (disabled)
IC	DIO Change Detect	0 (disabled)	0x1000 (DIO3 only)
D1	DIO1/AD1	2 : ADC input	N/A
P1	DIO11/PWM1	N/A	2: PWM1 output
PT	PWM Output Timeout	N/A	0x1E (3 seconds)
D2	DIO2/AD2	3: Digital input	5: Digital output, HIGH
D3	DIO3/AD3	5: Digital output, HIGH	3: Digital input
T3	DIO3 Timeout	0x64 (10 seconds)	N/A

Command	Description	Device A	Device B
SH	Serial Number High	0x0013A200	0x0013A200
SL	Serial Number Low	0x12345678	0xABCDABCD
DH	Destination High	0x0013A200	0x00000000
DL	Destination Low	0xABCDABCD	0x0000FFFF (broadcast)
IA	I/O Input Address	0x0013A200ABCDABCD	0x0013A20012345678
IR	Sample Rate	0x7D0 (2 seconds)	0 (disabled)
IC	DIO Change Detect	0 (disabled)	0x8 (DIO3 only)
D1	DIO1/AD1	2 : ADC input	N/A
P1	DIO11/PWM1	N/A	2: PWM1 output
PT	PWM Output Timeout	N/A	0x1E (3 seconds)
D2	DIO2/AD2	3: Digital input	5: Digital output, HIGH
D3	DIO3/AD3	5: Digital output, HIGH	3: Digital input
T3	DIO3 Timeout	0x64 (10 seconds)	N/A

In the example, both devices have I/O Line Passing enabled with appropriate inputs and outputs configured. The **IA** parameter determines which device on the network is allowed to affect the device's outputs.

Device A takes a periodic sample of all I/O lines every two seconds and transmits it as a unicast transmission to the address defined by **DH** and **DL** (in this case, Device B). Device B does not periodically sample, instead it monitors DIO3 for a binary change. When it detects a change on that pin, it generates a sample and transmits it as a broadcast to all devices on the network.

When Device B receives a sample packet from Device A:

- DIO2 on Device B outputs the state of DIO2 from Device A.
- PWM1 outputs a duty cycle equivalent to the analog voltage read on AD1 of Device A.

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- A PWM timeout has been set to three seconds; if no sample is received, PWM1 returns to 0 V after this period.

When Device A receives a sample packet from Device B:

- DIO3 on Device A outputs the state of DIO3 from Device B.
- A DIO3 timeout has been set to 10 seconds; if no sample is received, DIO3 reverts to a HIGH state after this period.

Note By default, all Digital I/O lines have internal pull-up resistors enabled with the **PR** command. This causes inputs to float high. You can use the **PD** command to change the direction of the internal pull-up/down resistors. The XBee SX 868 RF Module uses an internal reference voltage of 2.5 V for ADC lines, but you can use the **AV** command to set it to 1.25 VDC.

General Purpose Flash Memory

XBee SX 868 RF Modules provide 61 2048-byte blocks of flash memory that an application can read and write to. This memory provides a non-volatile data storage area that an application uses for many purposes. Some common uses of this data storage include:

- Storing logged sensor data
- Buffering firmware update data for a host microcontroller
- Storing and retrieving data tables needed for calculations performed by a host microcontroller

The General Purpose Memory (GPM) is also used to store a firmware update file for over-the-air firmware updates of the device itself.

Access General Purpose Flash Memory

To access the GPM of a target node locally or over-the-air, send commands to the MEMORY_ACCESS cluster ID (0x23) on the DIGI_DEVICE endpoint (0xE6) of the target node using explicit API frames. For a description of Explicit API frames, see Operate in API mode.

To issue a GPM command, format the payload of an explicit API frame as follows:

Byte offset in payload	Number of bytes	Field name	General field description
0	1	GPM_CMD_ID	Specific GPM commands are described in detail in the topics that follow.
1	1	GPM_OPTIONS	Command-specific options.
2	2*	GPM_BLOCK_NUM	The block number addressed in the GPM.
4	2*	GPM_START_INDEX	The byte index within the addressed GPM block.

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Byte offset in payload	Number of bytes	Field name	General field description
6	2*	GPM_NUM_BYTES	The number of bytes in the GPM_DATA field, or in the case of a READ, the number of bytes requested.
8	varies	GPM_DATA	
* Specify multi-byte parameters with big-endian byte ordering.			

When a device sends a GPM command to another device via a unicast, the receiving device sends a unicast response back to the requesting device's source endpoint specified in the request packet. It does not send a response for broadcast requests. If the source endpoint is set to the DIGI_DEVICE endpoint (0xE6) or Explicit API mode is enabled on the requesting device, then the requesting node outputs a GPM response as an explicit API RX indicator frame (assuming it has API mode enabled).

The format of the response is similar to the request packet:

Byte offset in payload	Number of bytes	Field name	General field description
0	1	GPM_CMD_ID	This field is the same as the request field.
1	1	GPM_STATUS	Status indicating whether the command was successful.
2	2*	GPM_BLOCK_NUM	The block number addressed in the GPM.
4	2*	GPM_START_INDEX	The byte index within the addressed GPM block.
6	2*	GPM_NUM_BYTES	The number of bytes in the GPM_DATA field.
8	varies	GPM_DATA	
* Specify multi-byte parameters with big-endian byte ordering.			

General Purpose Flash Memory commands

This section provides information about commands that interact with GPM:

PLATFORM_INFO_REQUEST (0x00)

A PLATFORM_INFO_REQUEST frame can be sent to query details of the GPM structure.

Field name	Command-specific description
GPM_CMD_ID	Should be set to PLATFORM_INFO_REQUEST (0x00).
GPM_OPTIONS	This field is unused for this command. Set to 0.

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Field name	Command-specific description
GPM_BLOCK_NUM	This field is unused for this command. Set to 0.
GPM_START_INDEX	This field is unused for this command. Set to 0.
GPM_NUM_BYTES	This field is unused for this command. Set to 0.
GPM_DATA	No data bytes should be specified for this command.

PLATFORM_INFO (0x80)

When a PLATFORM_INFO_REQUEST command request has been unicast to a node, that node sends a response in the following format to the source endpoint specified in the requesting frame.

Field name	Command-specific description
GPM_CMD_ID	Should be set to PLATFORM_INFO (0x80).
GPM_STATUS	A 1 in the least significant bit indicates an error occurred. All other bits are reserved at this time.
GPM_BLOCK_NUM	Indicates the number of GPM blocks available.
GPM_START_INDEX	Indicates the size, in bytes, of a GPM block.
GPM_NUM_BYTES	The number of bytes in the GPM_DATA field. For this command, this field will be set to 0.
GPM_DATA	No data bytes are specified for this command.

Example

A PLATFORM_INFO_REQUEST sent to a device with a serial number of 0x0013a200407402AC should be formatted as follows (spaces added to delineate fields):

7E 001C 11 01 0013A200407402AC FFFE E6 E6 0023 C105 00 00 00 00 0000 0000 0000 24

Assuming all transmissions were successful, the following API packets would be output the source node's serial interface:

7E 0007 8B 01 FFFE 00 00 00 76

7E 001A 91 0013A200407402AC FFFE E6 E6 0023 C105 C1 80 00 0077 0200 0000 EB

ERASE (0x01)

The ERASE command erases (writes all bits to binary 1) one or all of the GPM flash blocks. You can also use the ERASE command to erase all blocks of the GPM by setting the GPM_NUM_BYTES field to 0.

Field name	Command-specific description
GPM_CMD_ID	Should be set to ERASE (0x01).
GPM_OPTIONS	There are currently no options defined for the ERASE command. Set this field to 0.

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Field name	Command-specific description
GPM_BLOCK_NUM	Set to the index of the GPM block that should be erased. When erasing all GPM blocks, this field is ignored (set to 0).
GPM_START_INDEX	The ERASE command only works on complete GPM blocks. The command cannot be used to erase part of a GPM block. For this reason GPM_START_INDEX is unused (set to 0).
GPM_NUM_BYTES	Setting GPM_NUM_BYTES to 0 has a special meaning. It indicates that every flash block in the GPM should be erased (not just the one specified with GPM_BLOCK_NUM). In all other cases, the GPM_NUM_BYTES field should be set to the GPM flash block size.
GPM_DATA	No data bytes are specified for this command.

ERASE_RESPONSE (0x81)

When an ERASE command request has been unicast to a node, that node sends a response in the following format to the source endpoint specified in the requesting frame.

Field name	Command-specific description
GPM_CMD_ID	Should be set to ERASE_RESPONSE (0x81).
GPM_STATUS	A 1 in the least significant bit indicates an error occurred. All other bits are reserved at this time.
GPM_BLOCK_NUM	Matches the parameter passed in the request frame.
GPM_START_INDEX	Matches the parameter passed in the request frame.
GPM_NUM_BYTES	The number of bytes in the GPM_DATA field. For this command, this field will be set to 0.
GPM_DATA	No data bytes are specified for this command.

Example

To erase flash block 42 of a target radio with serial number of 0x0013a200407402ac format an ERASE packet as follows (spaces added to delineate fields):

7E 001C 11 01 0013A200407402AC FFFE E6 E6 0023 C105 00 C0 01 00 002A 0000 0800 31

Assuming all transmissions were successful, the following API packets would be output the source node's serial interface:

7E 0007 8B 01 FFFE 00 00 00 76

7E 001A 91 0013A200407402AC FFFE E6 E6 0023 C105 C1 81 00 002A 0000 0000 39

WRITE (0x02) and ERASE_THEN_WRITE (0x03)

The WRITE command writes the specified bytes to the GPM location specified. Before writing bytes to a GPM block it is important that the bytes have been erased previously. The ERASE_THEN_WRITE command performs an ERASE of the entire GPM block specified with the GPM_BLOCK_NUM field prior to doing a WRITE.

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Field name	Command-specific description
GPM_CMD_ID	Should be set to WRITE (0x02) or ERASE_THEN_WRITE (0x03).
GPM_OPTIONS	There are currently no options defined for this command. Set this field to 0.
GPM_BLOCK_NUM	Set to the index of the GPM block that should be written.
GPM_START_INDEX	Set to the byte index within the GPM block where the given data should be written.
GPM_NUM_BYTES	Set to the number of bytes specified in the GPM_DATA field. Only one GPM block can be operated on per command. For this reason, GPM_START_INDEX + GPM_NUM_BYTES cannot be greater than the GPM block size. The number of bytes sent in an explicit API frame (including the GPM command fields) cannot exceed the maximum payload size of the device. The maximum payload size can be queried with the **NP** command.
GPM_DATA	The data to be written.

WRITE _RESPONSE (0x82) and ERASE_THEN_WRITE_RESPONSE (0x83)

When a WRITE or ERASE_THEN_WRITE command request has been unicast to a node, that node sends a response in the following format to the source endpoint specified in the requesting frame.

Field name	Command-specific description
GPM_CMD_ID	Should be set to WRITE_RESPONSE (0x82) or ERASE_THEN_WRITE_RESPONSE (0x83)
GPM_STATUS	A 1 in the least significant bit indicates an error occurred. All other bits are reserved at this time
GPM_BLOCK_NUM	Matches the parameter passed in the request frame
GPM_START_INDEX	Matches the parameter passed in the request frame
GPM_NUM_BYTES	The number of bytes in the GPM_DATA field. For this command, this field will be set to 0
GPM_DATA	No data bytes are specified for these commands

Example

To write 15 bytes of incrementing data to flash block 22 of a target radio with serial number of 0x0013a200407402ac a WRITE packet should be formatted as follows (spaces added to delineate fields):

7E 002B 11 01 0013A200407402AC FFFE E6 E6 0023 C105 00 C0 02 00 0016 0000 000F 0102030405060708090A0B0C0D0E0F C5

Assuming all transmissions were successful and that flash block 22 was previously erased, the following API packets would be output the source node's serial interface:

7E 0007 8B 01 FFFE 00 00 00 76

7E 001A 91 0013A200407402AC FFFE E6 E6 0023 C105 C1 82 00 0016 0000 0000 4C

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READ (0x04)

You can use the READ command to read the specified number of bytes from the GPM location specified. Data can be queried from only one GPM block per command.

Field name	Command-specific description
GPM_CMD_ID	Should be set to READ (0x04).
GPM_OPTIONS	There are currently no options defined for this command. Set this field to 0.
GPM_BLOCK_NUM	Set to the index of the GPM block that should be read.
GPM_START_INDEX	Set to the byte index within the GPM block where the given data should be read.
GPM_NUM_BYTES	Set to the number of data bytes to be read. Only one GPM block can be operated on per command. For this reason, GPM_START_INDEX + GPM_NUM_BYTES cannot be greater than the GPM block size. The number of bytes sent in an explicit API frame (including the GPM command fields) cannot exceed the maximum payload size of the device. You can query the maximum payload size with the **NP** AT command.
GPM_DATA	No data bytes should be specified for this command.

READ_RESPONSE (0x84)

When a READ command request has been unicast to a node, that node sends a response in the following format to the source endpoint specified in the requesting frame.

Field name	Command-specific description
GPM_CMD_ID	Should be set to READ_RESPONSE (0x84).
GPM_STATUS	A 1 in the least significant bit indicates an error occurred. All other bits are reserved at this time.
GPM_BLOCK_NUM	Matches the parameter passed in the request frame.
GPM_START_INDEX	Matches the parameter passed in the request frame.
GPM_NUM_BYTES	The number of bytes in the GPM_DATA field.
GPM_DATA	The bytes read from the GPM block specified.

Example

To read 15 bytes of previously written data from flash block 22 of a target radio with serial number of 0x0013a200407402ac a READ packet should be formatted as follows (spaces added to delineate fields):

7E 001C 11 01 0013A200407402AC FFFE E6 E6 0023 C105 00 C0 04 00 0016 0000 000F 3B

Assuming all transmissions were successful and that flash block 22 was previously written with incrementing data, the following API packets would be output the source node's serial interface:

7E 0007 8B 01 FFFE 00 00 00 76

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7E 0029 91 0013A200407402AC FFFE E6 E6 0023 C105 C1 84 00 0016 0000 000F 0102030405060708090A0B0C0D0E0F C3

FIRMWARE_VERIFY (0x05) and FIRMWARE_VERIFY_AND_INSTALL(0x06)

Use the FIRMWARE_VERIFY and FIRMWARE_VERIFY_AND_INSTALL commands when remotely updating firmware on a device. For more inoformation about firmware updates. These commands check if the GPM contains a valid over-the-air update file. For the FIRMWARE_VERIFY_AND_INSTALL command, if the GPM contains a valid firmware image then the device resets and begins using the new firmware.

Field name	Command-specific description
GPM_CMD_ID	Should be set to FIRMWARE_VERIFY (0x05) or FIRMWARE_ VERIFY_AND_INSTALL (0x06)
GPM_OPTIONS	There are currently no options defined for this command. Set this field to 0.
GPM_BLOCK_NUM	This field is unused for this command. Set to 0.
GPM_START_INDEX	This field is unused for this command. Set to 0.
GPM_NUM_BYTES	This field is unused for this command. Set to 0.
GPM_DATA	This field is unused for this command

FIRMWARE_VERIFY_RESPONSE (0x85)

When a FIRMWARE_VERIFY command request has been unicast to a node, that node sends a response in the following format to the source endpoint specified in the requesting frame.

Field name	Command-specific description
GPM_CMD_ID	Should be set to FIRMWARE_VERIFY_RESPONSE (0x85)
GPM_STATUS	A 1 in the least significant bit indicates the GPM does not contain a valid firmware image. A 0 in the least significant bit indicates the GPM does contain a valid firmware image. All other bits are reserved at this time.
GPM_BLOCK_NUM	This field is unused for this command. Set to 0.
GPM_START_INDEX	This field is unused for this command. Set to 0.
GPM_NUM_BYTES	This field is unused for this command. Set to 0.
GPM_DATA	This field is unused for this command

FIRMWARE_VERIFY _AND_INSTALL_RESPONSE (0x86)

When a FIRMWARE_VERIFY_AND_INSTALL command request has been unicast to a node, that node sends a response in the following format to the source endpoint specified in the requesting frame only if the GPM memory does not contain a valid image. If the image is valid, the device resets and begins using the new firmware.

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Field name	Command-specific description
GPM_CMD_ID	Should be set to FIRMWARE_VERIFY_AND_INSTALL_RESPONSE (0x86).
GPM_STATUS	A 1 in the least significant bit indicates the GPM does not contain a valid firmware image. All other bits are reserved at this time.
GPM_BLOCK_NUM	This field is unused for this command. Set to 0.
GPM_START_INDEX	This field is unused for this command. Set to 0.
GPM_NUM_BYTES	This field is unused for this command. Set to 0.
GPM_DATA	This field is unused for this command.

Example

To verify a firmware image previously loaded into the GPM on a target device with serial number 0x0013a200407402ac, format a FIRMWARE_VERIFY packet as follows (spaces added to delineate fields):

7E 001C 11 01 0013A200407402AC FFFE E6 E6 0023 C105 00 00 05 00 0000 0000 0000 1F

Assuming all transmissions were successful and that the firmware image previously loaded into the GPM is valid, the following API packets would be output the source node's serial interface:

7E 0007 8B 01 FFFE 00 00 00 76

7E 001A 91 0013A200407402AC FFFE E6 E6 0023 C105 C1 85 00 0000 0000 0000 5F

Work with flash memory

When working with the General Purpose Memory, observe the following limitations:

- Flash memory write operations are only capable of changing binary 1s to binary 0s. Only the erase operation can change binary 0s to binary 1s. For this reason, you should erase a flash block before performing a write operation.
- When performing an erase operation, you must erase the entire flash memory block—you cannot erase parts of a flash memory block.
- Flash memory has a limited lifetime. The flash memory on which the GPM is based is rated at 20,000 erase cycles before failure. Take care to ensure that the frequency of erase/write operations allows for the desired product lifetime. Digi's warranty does not cover products that have exceeded the allowed number of erase cycles.
- Over-the-air firmware upgrades erase the entire GPM. Any user data stored in the GPM will be lost during an over-the-air upgrade.

Over-the-air firmware updates

There are two methods of updating the firmware on the device. You can update the firmware locally with XCTU using the device's serial port interface. You can also update firmware using the device's RF interface (over-the-air updating.)

The over-the-air firmware update method provided is a robust and versatile technique that you can tailor to many different networks and applications. OTA updates are reliable and minimize disruption of normal network operations.

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In the following sections, we refer to the node that will be updated as the target node. We refer to the node providing the update information as the source node. In most applications the source node is locally attached to a computer running update software.

There are three phases of the over-the-air update process:

1. Distribute the new application
2. Verify the new application
3. Install the application

Distribute the new application

The first phase of performing an over-the-air update on a device is transferring the new firmware file to the target node. Load the new firmware image in the target node's GPM prior to installation. XBee SX 868 RF Modules use an encrypted binary (.ebin) file for both serial and over-the-air firmware updates. These firmware files are available on the Digi Support website and via XCTU.

Send the contents of the .ebin file to the target device using general purpose memory WRITE commands. Erase the entire GPM prior to beginning an upload of an .ebin file. The contents of the .ebin file should be stored in order in the appropriate GPM memory blocks. The number of bytes that are sent in an individual GPM WRITE frame is flexible and can be catered to the user application.

Example

The example firmware version has an .ebin file of 55,141 bytes in length. Based on network traffic, we determine that sending a 128 byte packet every 30 seconds minimizes network disruption. For this reason, you would divide and address the .ebin as follows:

GPM_BLOCK_NUM	GPM_START_INDEX	GPM_NUM_BYTES	.ebin bytes
0	0	128	0 to 127
0	128	128	128 to 255
0	256	128	256 to 383
0	384	128	384 to 511
1	0	128	512 to 639
1	128	128	640 to 767
-	-	-	-
-	-	-	-
-	-	-	-
107	0		54784 to 54911
107	128		54912 to 55039
107	256	101	55040 to 55140

Verify the new application

For an uploaded application to function correctly, every single byte from the .ebin file must be properly transferred to the GPM. To guarantee that this is the case, GPM VERIFY functions exist to ensure that

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all bytes are properly in place. The FIRMWARE_VERIFY function reports whether or not the uploaded data is valid. The FIRMWARE_VERIFY_AND_INSTALL command reports if the uploaded data is invalid. If the data is valid, it begins installing the application. No installation takes place on invalid data.

Install the application

When the entire .ebin file is uploaded to the GPM of the target node, you can issue a FIRMWARE_VERIFY_AND_INSTALL command. Once the target receives the command it verifies the .ebin file loaded in the GPM. If it is valid, then the device installs the new firmware. This installation process can take up to eight seconds. During the installation the device is unresponsive to both serial and RF communication. To complete the installation, the target module resets. AT parameter settings which have not been written to flash using the **WR** command will be lost.

Important considerations

The firmware upgrade process requires that the device resets itself. Write all parameters with the **WR** command before performing a firmware update. Packet routing information is also lost after a reset. Route discoveries are necessary for DigiMesh unicasts involving the updated node as a source, destination, or intermediate node.

Because explicit API Tx frames can be addressed to a local node (accessible via the SPI or UART) or a remote node (accessible over the RF port) the same process can be used to update firmware on a device in either case.

Software libraries

One way to communicate with the XBee SX 868 RF Module is by using a software library. The libraries available for use with the XBee SX 868 RF Module include:

- XBee Java library
- XBee Python library

The XBee Java Library is a Java API. The package includes the XBee library, its source code and a collection of samples that help you develop Java applications to communicate with your XBee devices.

The XBee Python Library is a Python API that dramatically reduces the time to market of XBee projects developed in Python and facilitates the development of these types of applications, making it an easy process.

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Networking methods

This section explains the basic layers and the three networking methods available on the XBee SX 868 RF Modules, building from the simplest to the most complex.

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Directed Broadcast/Repeater mode

In this delivery method, the device sends all outgoing transmissions as broadcasts. Unicast messages are sent as broadcasts, but are addressed to a specific receiver. Only the specified device will emit the received frame out of the serial port.

- Directed broadcast over hops is only available when operating at the 80k RF data rate (**BR** = **1**). The 10k data rate will only address adjacent devices and does not repeat received packets.
- By default the **CE** parameter is set to route all broadcasts. As such, all nodes that receive a repeated packet will repeat it. If you change the **CE** parameter, you can limit which nodes repeat packets, which helps dense networks from becoming overly congested while packets are being repeated.

Point to Point/Multipoint mode

In this mode, there is a permanent link between two endpoints. Switched point-to-point topologies are the basic model of conventional telephony. The value of a permanent point-to-point network is unimpeded communications between the two endpoints. The value of an on-demand point-to-point connection is proportional to the number of potential pairs of subscribers.

Permanent (dedicated)

One of the variations of point-to-point topology is a point-to-point communications channel that appears, to the user, to be permanently associated with the two endpoints. Within many switched telecommunications systems, it is possible to establish a permanent circuit. One example might be a telephone in the lobby of a public building that is programmed to ring only the number of a telephone dispatcher. “Nailing down” a switched connection saves the cost of running a physical circuit between the two points. The resources in such a connection can be released when it is no longer needed.

Switched

Using circuit-switching or packet-switching technologies, you can set up a point-to-point circuit dynamically and dropped when no longer needed.

DigiMesh networking

A mesh network is a topology in which each node in the network is connected to other nodes around it. Each node cooperates in transmitting information. Mesh networking provides these important benefits:

- **Routing**. With this technique, the message is propagated along a path by hopping from node to node until it reaches its final destination.
- **Ad-hoc network creation**. This is an automated process that creates an entire network of nodes on the fly, without any human intervention.
- **Self-healing**. This process automatically figures out if one or more nodes on the network is missing and reconfigures the network to repair any broken routes.
- **Peer-to-peer architecture**. No hierarchy and no parent-child relationships are needed.
- **Quiet protocol**. Routing overhead will be reduced by using a reactive protocol similar to AODV.

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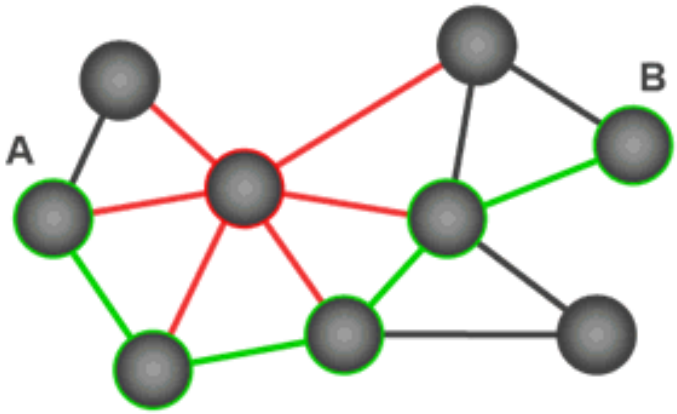
- **Route discovery**. Rather than maintaining a network map, routes will be discovered and created only when needed.
- **Selective acknowledgments**. Only the destination node will reply to route requests.
- **Reliable delivery**. Reliable delivery of data is accomplished by means of acknowledgments.
- **Sleep modes.** Low power sleep modes with synchronized wake are supported with variable sleep and wake times.



With mesh networking, the distance between two nodes does not matter as long as there are enough nodes in between to pass the message along. When one node wants to communicate with another, the network automatically calculates the best path.

A mesh network is also reliable and offers redundancy. For example, If a node can no longer operate because it has been removed from the network or because a barrier blocks its ability to communicate, the rest of the nodes can still communicate with each other, either directly or through intermediate nodes.

Note Mesh networks use more bandwidth for administration and therefore have less available for payloads.

DigiMesh feature set

DigiMesh contains the following features:

- **Self-healing**
  Any node may enter or leave the network at any time without causing the network as a whole to fail.
- **Peer-to-peer architecture**
  No hierarchy and no parent-child relationships are needed.
- **Quiet protocol**
  Routing overhead will be reduced by using a reactive protocol similar to AODV.
- **Route discovery**
  Rather than maintaining a network map, routes will be discovered and created only when needed.

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  Only the destination node will reply to route requests.
- **Reliable delivery**
  Reliable delivery of data is accomplished by means of acknowledgments.
- **Sleep modes**
  Low power sleep modes with synchronized wake are supported with variable sleep and wake times.

Networking concepts

This section provides information on configuring DigiMesh devices and network identifiers.

Device Configuration

You can configure DigiMesh devices to act as routers or end devices with the **CE** command. By default, all devices in a DigiMesh network act as routers. Devices configured as routers actively relay network unicast and broadcast traffic.

Network ID

DigiMesh networks are defined with a unique network identifier. Set the identifier using the **ID** command. For devices to communicate they must be configured with the same network identifier. The **ID** parameter allows multiple DigiMesh networks to co-exist on the same physical channel.

Data transmission and routing

This section provides information on data transmission, routing, throughput, and transmission timeouts.

Unicast addressing

When devices transmit using DigiMesh unicast, the network uses retries and acknowledgments (ACKs) for reliable data delivery. In a retry and acknowledgment scheme, for every data packet that a device sends, the receiving device must send an acknowledgment back to the transmitting device to let the sender know that the data packet arrived at the receiver. If the transmitting device does not receive an acknowledgment then it re-sends the packet. It sends the packet a finite number of times before the system times out.

The **MR** (Mesh Network Retries) parameter determines the number of mesh network retries. The sender device transmits RF data packets up to **MR** + 1 times across the network route, and the receiver transmits ACKs when it receives the packet. If the sender does not receive a network ACK within the time it takes for a packet to traverse the network twice, the sender retransmits the packet.

To send unicast messages while in Transparent operating mode, set the **DH** and **DL** on the transmitting device to match the corresponding **SH** and **SL** parameter values on the receiving device.

Broadcast addressing

All of the routers in a network receive and repeat broadcast transmissions. Broadcast transmissions do not use ACKs, so the sending device sends the broadcast multiple times. By default, the sending device sends a broadcast transmission four times. The transmissions become automatic retries without acknowledgments. This results in all nodes repeating the transmission four times as well.

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In order to avoid RF packet collisions, the network inserts a random delay before each router relays the broadcast message. You can change this random delay time with the **NN** parameter.

Sending frequent broadcast transmissions can quickly reduce the available network bandwidth. Use broadcast transmissions sparingly.

The broadcast address is a 64 bit address with the lowest 16 bits set to 1. The upper bits are set to 0. To send a broadcast transmission:

- Set **DH** to 0.
- Set **DL** to 0xFFFF.

In API operating mode, this sets the destination address to 0x000000000000FFFF.

Routing

Devices within a mesh network determine reliable routes using a routing algorithm and table. The routing algorithm uses a reactive method derived from Ad-hoc On-demand Distance Vector (AODV). The device uses an associative routing table to map a destination node address with its next hop. By sending a message to the next hop address, the message reaches its destination or is forwarded to an intermediate router which routes the message on to its destination.

The device broadcasts a message with a broadcast address to all neighbors. All routers receiving the message rebroadcast the message **MT**+1 times and eventually the message reaches all corners of the network. Packet tracking prevents a node from resending a broadcast message more than **MT**+1 times.

Route discovery

Route discovery is a process that occurs when:

1. The source node does not have a route to the requested destination.
2. A route fails. This happens when the source node uses up its network retries without receiving an ACK.

Route discovery begins by the source node broadcasting a route request (RREQ). We call any router that receives the RREQ and is not the ultimate destination, an intermediate node.

Intermediate nodes may either drop or forward a RREQ, depending on whether the new RREQ has a better route back to the source node. If so, the node saves, updates and broadcasts the RREQ.

When the ultimate destination receives the RREQ, it unicasts a route reply (RREP) back to the source node along the path of the RREQ. It does this regardless of route quality and regardless of how many times it has seen an RREQ before.

This allows the source node to receive multiple route replies. The source node selects the route with the best round trip route quality, which it uses for the queued packet and for subsequent packets with the same destination address.

DigiMesh throughput

Throughput in a DigiMesh network can vary due to a number of variables, including:

- The number of hops.
- If you enable or disable encryption.
- Sleeping end devices.
- Failures and route discoveries.

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The following table shows the results of this test with various configurations. All measurements were acquired by streaming 10,000 bytes of data in Transparent mode from the transmitter to the receiver at a baud rate of 115,200 b/s.

Configuration	Data throughput
Point to Point, encryption disabled	34.63 kb/s
Point to Point, encryption enabled	34.48 kb/s
Mesh unicast, one hop, encryption disabled	27.54 kb/s
Mesh unicast, one hop, encryption enabled	27.3 kb/s
Mesh unicast, three hops, encryption disabled	9.55 kb/s
Mesh unicast, three hops, encryption enabled	9.38 kb/s

The following table shows the latency (in ms) for 10000 Bytes at 115200 b/s serial data rate.

Configuration	Latency
Point to Point, encryption disabled	69.8 ms
Point to Point, encryption enabled	69.99 ms
Mesh, encryption disabled	94.31 ms
Mesh, encryption enabled	95.06 ms

Note We made the data throughput measurements by setting the serial interface rate to 115200 b/s, and measuring the time taken to send 10000 bytes from source to destination. During the test, no route discoveries or failures occurred.

Transmission timeouts

When a device in API operating mode receives a Transmit Request (0x10, 0x11) frame, or a device in Transparent operating mode meets the packetization requirements (**RO**, **RB**), the time required to route the data to its destination depends on:

- A number of configured parameters.
- Whether the transmission is a unicast or a broadcast.
- If the route to the destination address is known.

Timeouts or timing information is provided for the following transmission types:

- Broadcast transmission
- Unicast transmission on a known route
- Unicast transmission on an unknown route
- Unicast transmission on a broken route

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Note The timeouts in this documentation are theoretical timeouts and are not precisely accurate. Your application should pad the calculated maximum timeouts by a few hundred milliseconds. When you use API operating mode, use Extended Transmit Status - 0x8B as the primary method to determine if a transmission is complete.

Unicast one hop time

unicastOneHopTime is a building block of many of the following calculations. It represents the amount of time it takes to send a unicast transmission between two adjacent nodes. The amount of time depends on the parameter.

Transmit a broadcast

All of the routers in a network must relay a broadcast transmission.

The maximum delay occurs when the sender and receiver are on the opposite ends of the network.

The **NH** and **%H** parameters define the maximum broadcast delay as follows:

BroadcastTxTime = NH * NN * %8

Unless **BH** < **NH**, in which case the formula is:

BroadcastTxTime = BH * NN * %8

Transmit a unicast with a known route

When a device knows a route to a destination node, the transmission time is largely a function of the number of hops and retries. The timeout associated with a unicast assumes that the maximum number of hops is necessary, as specified by the **NH** command.

You can estimate the timeout in the following manner:

knownRouteUnicastTime=2*NH*MR*unicastOneHopTime

Transmit a unicast with an unknown route

If the transmitting device does not know the route to the destination, it begins by sending a route discovery. If the route discovery is successful, then the transmitting device transmits data. You can estimate the timeout associated with the entire operation as follows:

unknownRouteUnicastTime=BroadcastTxTime+
(**NH***unicastOneHopTime)+knownRouteUnicastTime

Transmit a unicast with a broken route

If the route to a destination node changes after route discovery completes, a node begins by attempting to send the data along the previous route. After it fails, it initiates route discovery and, when the route discovery finishes, transmits the data along the new route. You can estimate the timeout associated with the entire operation as follows:

brokenRouteUnicastTime=BroadcastTxTime+(NH*unicastOneHopTime)+
(2*knownRouteUnicastTime)

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Modes

The XBee SX 868 RF Module is in Receive Mode when it is not transmitting data. The device shifts into the other modes of operation under the following conditions:

- Transmit mode (Serial data in the serial receive buffer is ready to be packetized)
- Sleep mode
- Command Mode (Command mode sequence is issued (not available when using the SPI port))

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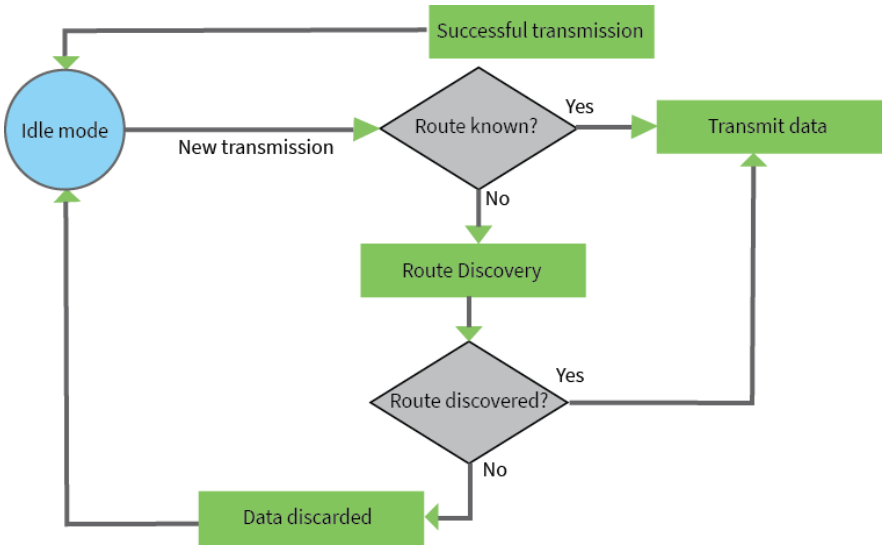
Transmit mode

When the device receives serial data and is ready to packetize it, the device attempts to transmit the serial data. The destination address determines which node(s) will receive and send the data.

In the following diagram, route discovery applies only to DigiMesh transmissions. Once route discovery establishes a route, the device transmits the data. If route discovery fails to establish a route, the device discards the packet.



For more information, see Data transmission and routing.

Receive mode

This is the default mode for the XBee SX 868 RF Module. The device is in Receive mode when it is not transmitting data. If a destination node receives a valid RF packet, the destination node transfers the data to its serial transmit buffer.

Command mode

Command mode is a state in which the firmware interprets incoming characters as commands. It allows you to modify the device's configuration using parameters you can set using AT commands. When you want to read or set any parameter of the XBee SX 868 RF Module using this mode, you have to send an AT command. Every AT command starts with the letters **AT** followed by the two characters that identify the command and then by some optional configuration values.

The operating modes of the XBee SX 868 RF Module are controlled by the AP (API Mode) setting, but Command mode is always available as a mode the device can enter while configured for any of the operating modes.

Command mode is available on the UART interface for all operating modes. You cannot use the SPI interface to enter Command mode.

Enter Command mode

To get a device to switch into Command mode, you must issue the following sequence: **+++** within one second. There must be at least one second preceding and following the **+++** sequence. Both the

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command character (**CC**) and the silence before and after the sequence (**GT**) are configurable. When the entrance criteria are met the device responds with **OK\r** on UART signifying that it has entered Command mode successfully and is ready to start processing AT commands.

If configured to operate in Transparent operating mode, when entering Command mode the XBee SX 868 RF Module knows to stop sending data and start accepting commands locally.

Note Do not press **Return** or **Enter** after typing **+++** because it interrupts the guard time silence and prevents you from entering Command mode.

When the device is in Command mode, it listens for user input and is able to receive AT commands on the UART. If **CT** time (default is 10 seconds) passes without any user input, the device drops out of Command mode and returns to the previous operating mode. You can force the device to leave Command mode by sending CN (Exit Command Mode).

You can customize the command character, the guard times and the timeout in the device's configuration settings. For more information, see CC (Command Sequence Character), CT (Command Mode Timeout) and GT (Guard Times).

Troubleshooting

Failure to enter Command mode is often due to baud rate mismatch. Ensure that the baud rate of the connection matches the baud rate of the device. By default, BD (Baud Rate) = **3** (9600 b/s).

There are two alternative ways to enter Command mode:

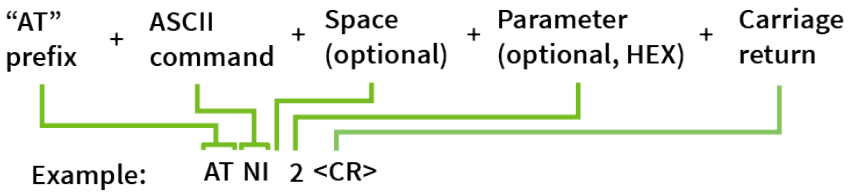
- A serial break for six seconds enters Command mode. You can issue the "break" command from a serial console, it is often a button or menu item.
- Asserting DIN (serial break) upon power up or reset enters Command mode. XCTU guides you through a reset and automatically issues the break when needed.

Both of these methods temporarily set the device's baud rate to 9600 and return an **OK** on the UART to indicate that Command mode is active. When Command mode exits, the device returns to normal operation at the baud rate that **BD** is set to.

Send AT commands

Once the device enters Command mode, use the syntax in the following figure to send AT commands. Every AT command starts with the letters **AT**, which stands for "attention." The AT is followed by two characters that indicate which command is being issued, then by some optional configuration values.

To read a parameter value stored in the device's register, omit the parameter field.



The preceding example changes NI (Node Identifier) to **My XBee**.

Multiple AT commands

You can send multiple AT commands at a time when they are separated by a comma in Command mode; for example, **ATNIMy XBee,AC<cr>**.

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The preceding example changes the **NI (Node Identifier)** to **My XBee** and makes the setting active through AC (Apply Changes).

Parameter format

Refer to the list of AT commands for the format of individual AT command parameters. Valid formats for hexidecimal values include with or without a leading **0x** for example **FFFF** or **0xFFFF**.

Response to AT commands

When using AT commands to set parameters the XBee SX 868 RF Module responds with **OK<cr>** if successful and **ERROR<cr>** if not.

For devices with a file system:

ATAP1<cr>

OK<cr>

When reading parameters, the device returns the current parameter value instead of an **OK** message.

ATAP<cr>

1<cr>

Apply command changes

Any changes you make to the configuration command registers using AT commands do not take effect until you apply the changes. For example, if you send the **BD** command to change the baud rate, the actual baud rate does not change until you apply the changes. To apply changes:

1. Send AC (Apply Changes).
2. Send WR (Write).
   or:
3. Exit Command mode.

Make command changes permanent

Send a WR (Write) command to save the changes. **WR** writes parameter values to non-volatile memory so that parameter modifications persist through subsequent resets.

Send as RE (Restore Defaults) to wipe settings saved using **WR** back to their factory defaults.

Note You still have to use **WR** to save the changes enacted with **RE**.

Exit Command mode

1. Send CN (Exit Command Mode) followed by a carriage return.
   or:
2. If the device does not receive any valid AT commands within the time specified by CT (Command Mode Timeout), it returns to Transparent or API mode. The default Command mode timeout is 10 seconds.

For an example of programming the device using AT Commands and descriptions of each configurable parameter, see AT commands.

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Sleep mode

Sleep modes allow the device to enter states of low power consumption when not in use. The XBee SX 868 RF Module supports both pin sleep (Sleep mode entered on pin transition) and cyclic sleep (device sleeps for a fixed time).

Sleep modes allow the device to enter states of low power consumption when not in use. XBee devices support both pin sleep, where the device enters sleep mode upon pin transition, and cyclic sleep, where the device sleeps for a fixed time. For more information, see Sleep modes.

Force UART operation

Condition

You configure a device with only the SPI enabled and no SPI master is available to access the SPI slave port

Solution

Use the following steps to recover the device to UART operation:

1. Hold the DIN/CONFIG low at reset time.
2. DIN/CONFIG forces a default configuration on the UART at 9600 baud and brings up the device in Command Mode on the UART port.

   You can send the appropriate commands to the device to configure it for UART operation.
3. If you write these parameters to the device, the module comes up with the UART enabled on the next reset.

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Sleep modes

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About sleep modes

A number of low-power modes exist to enable devices to operate for extended periods of time on battery power. Use the **SM** command to enable these sleep modes. The sleep modes are characterized as either:

- Asynchronous (**SM** = 1, 4, 5).
- Synchronous (**SM** = 7, 8).

Asynchronous modes

- Do not use asynchronous sleep modes in a synchronous sleeping network, and vice versa.
- Use the asynchronous sleep modes to control the sleep state on a device by device basis.
- Do not use devices operating in asynchronous sleep mode to route data.
- We strongly encourage you to set asynchronous sleeping devices as end-devices using the **CE** command. This prevents the node from attempting to route data.

Synchronous modes

Synchronous sleep makes it possible for all nodes in the network to synchronize their sleep and wake times. All synchronized cyclic sleep nodes enter and exit a low power state at the same time.

This forms a cyclic sleeping network.

- A device acting as a sleep coordinator sends a special RF packet called a sync message to synchronize nodes.
- To make a device in the network a coordinator, a node uses several resolution criteria.
- The sleep coordinator sends one sync message at the beginning of each wake period. The coordinator sends the sync message as a broadcast and every node in the network repeats it.
- You can change the sleep and wake times for the entire network by locally changing the settings on an individual device. The network uses the most recently set sleep settings.

Normal mode

Set **SM** to 0 to enter Normal mode.

Normal mode is the default sleep mode. If a device is in this mode, it does not sleep and is always awake.

Use mains-power for devices in Normal mode.

A device in Normal mode synchronizes to a sleeping network, but does not observe synchronization data routing rules; it routes data at any time, regardless of the network's wake state.

When synchronized, a device in Normal mode relays sync messages that sleep-compatible nodes generate, but does not generate sync messages itself.

Once a device in Normal mode synchronizes with a sleeping network, you can put it into a sleep-compatible sleep mode at any time.

Asynchronous pin sleep mode

Set **SM** to 1 to enter asynchronous pin sleep mode.

Pin sleep allows the device to sleep and wake according to the state of the $\overline{\text{SLEEP_RQ}}$ pin (pin 10).

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When you assert SLEEP_RQ (high), the device finishes any transmit or receive operations and enters a low-power state.

When you de-assert SLEEP_RQ (low), the device wakes from pin sleep.

Asynchronous cyclic sleep mode

Set **SM** to 4 to enter asynchronous cyclic sleep mode.

Cyclic sleep allows the device to sleep for a specific time and wake for a short time to poll.

If the device receives serial or RF data while awake, it extends the time before it returns to sleep by the specific amount the **ST** command provides. Otherwise, it enters sleep mode immediately.

The $\overline{\text{ON_SLEEP}}$ line asserts (high) when the device wakes, and is de-asserted (low) when the device sleeps.

If you use the **D7** command to enable hardware flow control, the $\overline{\text{CTS}}$ pin asserts (low) when the device wakes and can receive serial data, and de-asserts (high) when the device sleeps.

If the sleeping node does not receive a poll response from the indirect messaging sleep coordinator, then it stays awake waiting for that poll for an extended period of time waiting for that poll response. This time is about 8 seconds if **BR** (RF Data Rate) is **0** and RR (Unicast Mac Retries) is **0x0A**.

Therefore, to save battery life it is important to configure an indirect messaging sleep coordinator (CE (Node Messaging Options) **1**) within range of the sleeping node. Also the sleeping node (**CE 6**) needs to point to the indirect messaging sleep coordinator with **DH**/**DL** set to the **SH**/**SL** of the indirect messaging sleep coordinator.

When SO (Sleep Options) bit 8 is set (**0x100**), the device stays awake for the maximum of **ST** and the minimum wake time. When **BR** is **0** and **RR** is **0x0A**, the minimum wake time is about 8 seconds, which may be more than **ST**.

Asynchronous cyclic sleep with pin wake up mode

Set **SM** to 5 to enter Asynchronous cyclic sleep with pin wake up mode.

This mode is a slight variation on (**SM** = 4) that allows the device to wake prematurely by asserting the SLEEP_RQ pin (pin 9). In (**SM** =5), the device wakes after the sleep period expires, or if a high-to-low transition occurs on the SLEEP_RQ pin.

Synchronous sleep support mode

Set **SM** to 7 to enter synchronous sleep support mode.

A device in synchronous sleep support mode synchronizes itself with a sleeping network but will not itself sleep. At any time, the device responds to new devices that are attempting to join the sleeping network with a sync message. A sleep support device only transmits normal data when the other devices in the sleeping network are awake. You can use sleep support devices as preferred sleep coordinator devices and as aids in adding new devices to a sleeping network.

Synchronous cyclic sleep mode

Set **SM** to 8 to enter synchronous cyclic sleep mode.

A device in synchronous cyclic sleep mode sleeps for a programmed time, wakes in unison with other nodes, exchanges data and sync messages, and then returns to sleep. While asleep, it cannot receive RF messages or receive data (including commands) from the UART port.

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Generally, the network's sleep coordinator specifies the sleep and wake times based on its **SP** and **ST** settings. The device only uses these parameters at startup until the device synchronizes with the network.

When a device has synchronized with the network, you can query its sleep and wake times with the **OS** and **OW** commands respectively.

If **D9** = 1 (ON_SLEEP enabled) on a cyclic sleep node, the ON_SLEEP line asserts when the device is awake and de-asserts when the device is asleep.

If **D7** = 1, the device de-asserts CTS while asleep.

A newly-powered, unsynchronized, sleeping device polls for a synchronized message and then sleeps for the period that the **SP** command specifies, repeating this cycle until it synchronizes by receiving a sync message. Once it receives a sync message, the device synchronizes itself with the network.

Note Configure all nodes in a synchronous sleep network to operate in either synchronous sleep support mode or synchronous cyclic sleep mode. asynchronous sleeping nodes are not compatible with synchronous sleeping nodes.

Wake timer

In asynchronous cyclic sleep mode (**SM** = **4** or **SM** = **5**), if a device receives serial or RF data, it starts a sleep timer (time until sleep). Any data received serially or by RF link resets the timer. Use ST (Wake Time) to set the timer duration. While the device is awake, it sends regular poll requests to its parent to check for buffered data. If the RF data rate is 80 kb/s (**BR** = **1**), the poll occurs every 100 ms. Otherwise, (**BR** = **0**), the poll occurs every 300 ms. The device returns to sleep when the sleep timer expires.

Indirect messaging and polling

To enable reliable communication with sleeping devices, you can use the **CE** (Routing/Messaging Mode) command to enable indirect messaging and polling.

Indirect messaging

Indirect messaging is a communication mode designed for communicating with asynchronous sleeping devices. A device can enable indirect messaging by making itself an indirect messaging coordinator with the **CE** command. An indirect messaging coordinator does not immediately transmit a P2MP unicast when it is received over the serial port. Instead the device holds onto the data until it is requested via a poll. On receiving a poll, the indirect messaging coordinator sends a queued data packet (if available) to the requestor.

Because it is possible for a polling device to be eliminated, a mechanism is in place to purge unrequested data packets. If the coordinator holds an indirect data packet for an indirect messaging poller for more than 2.5 times its **SP** value, then the packet is purged. We suggest setting the **SP** of the coordinator to the same value as the highest **SP** time that exists among the pollers in the network. If the coordinator is in API mode, a TxStatus message is generated for a purged data packet with a status of 0x75 (**INDIRECT_MESSAGE_UNREQUESTED**).

An indirect messaging coordinator queues up as many data packets as it has buffers available. After the coordinator uses all of its available buffers, it holds transmission requests unprocessed on the serial input queue. After the serial input queue is full, the device de-asserts CTS (if hardware flow control is enabled). After receiving a poll or purging data from the indirect messaging queue the buffers become available again.

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Indirect messaging only functions with P2MP unicast messages. Indirect messaging has no effect on P2MP broadcasts, directed broadcasts, repeater packets, or DigiMesh packets. These messages are sent immediately when received over the serial port and are not put on the indirect messaging queue.

Polling

Polling is the automatic process by which a node can request data from an indirect messaging coordinator. To enable polling on a device, configure it as an end device with the **CE** command. When you enable polling, the device sends a poll request a minimum of once every polling interval, where the polling interval is 100 ms for the 80 Kb/s data rate and it is 300 ms for the 10 Kb/s data rate. When the device sends normal data to the destination specified by the **DH**/**DL** of end device module, the data also functions as a poll.

When a polling device is also an asynchronous sleeping device, that device sends a poll shortly after waking from sleep. After that first poll is sent, the device sends polls in the normal manner described previously until it returns to sleep.

Sleeping routers

The Sleeping Router feature of DigiMesh makes it possible for all nodes in the network to synchronize their sleep and wake times. All synchronized cyclic sleep nodes enter and exit a low power state at the same time. This forms a cyclic sleeping network.

Devices synchronize by receiving a special RF packet called a sync message sent by a device acting as a sleep coordinator. A device in the network becomes a sleep coordinator through a process called nomination. The sleep coordinator sends one sync message at the beginning of each wake period. The device sends a sync message as a broadcast that is repeated by every device in the network. To change the sleep and wake times for the entire network, change the settings on an individual node locally. The network uses the most recently set sleep settings.

For more information, see Become a sleep coordinator.

Sleep coordinator sleep modes in the DigiMesh network

In a synchronized sleeping network, one node acts as the sleep coordinator. During normal operations, at the beginning of a wake cycle the sleep coordinator sends a sync message as a broadcast to all nodes in the network. This message contains synchronization information and the wake and sleep times for the current cycle. All cyclic sleep nodes that receive a sync message remain awake for the wake time and then sleep for the specified sleep period.

The sleep coordinator sends one sync message at the beginning of each cycle with the current wake and sleep times. All router nodes that receive this sync message relay the message to the rest of the network. If the sleep coordinator does not hear a rebroadcast of the sync message by one of its immediate neighbors, then it re-sends the message one additional time.

If you change the **SP** or **ST** parameters, the network does not apply the new settings until the beginning of the next wake time. For more information, see Change sleep parameters.

A sleeping router network is robust enough that an individual node can go several cycles without receiving a sync message, due to RF interference, for example. As a node misses sync messages, the time available for transmitting messages during the wake time reduces to maintain synchronization accuracy. By default, a device reduces its active sleep time progressively as it misses sync messages.

Synchronization messages

A sleep coordinator regularly sends sync messages to keep the network in sync. Unsynchronized nodes also send messages requesting sync information.

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Sleep compatible nodes use Deployment mode when they first power up and the sync message has not been relayed. A sleep coordinator in Deployment mode rapidly sends sync messages until it receives a relay of one of those messages. Deployment mode:

- Allows you to effectively deploy a network.
- Allows a sleep coordinator that resets to rapidly re-synchronize with the rest of the network.

If a node exits deployment mode and then receives a sync message from a sleep coordinator that is in Deployment mode, it rejects the sync message and sends a corrective sync to the sleep coordinator.

Use the **SO** (sleep options) command to disable deployment mode. This option is enabled by default.

A sleep coordinator that is not in deployment mode sends a sync message at the beginning of the wake cycle. The sleep coordinator listens for a neighboring node to relay the sync. If it does not hear the relay, the sleep coordinator sends the sync one additional time.

A node that is not a sleep coordinator and has never been synchronized sends a message requesting sync information at the beginning of its wake cycle. Synchronized nodes which receive one of these messages respond with a synchronization packet.

If you use the **SO** command to configure nodes as non-coordinators, and if the non-coordinators go six or more sleep cycles without hearing a sync, they send a message requesting sync at the beginning of their wake period.

The following diagram illustrates the synchronization behavior of sleep compatible devices.

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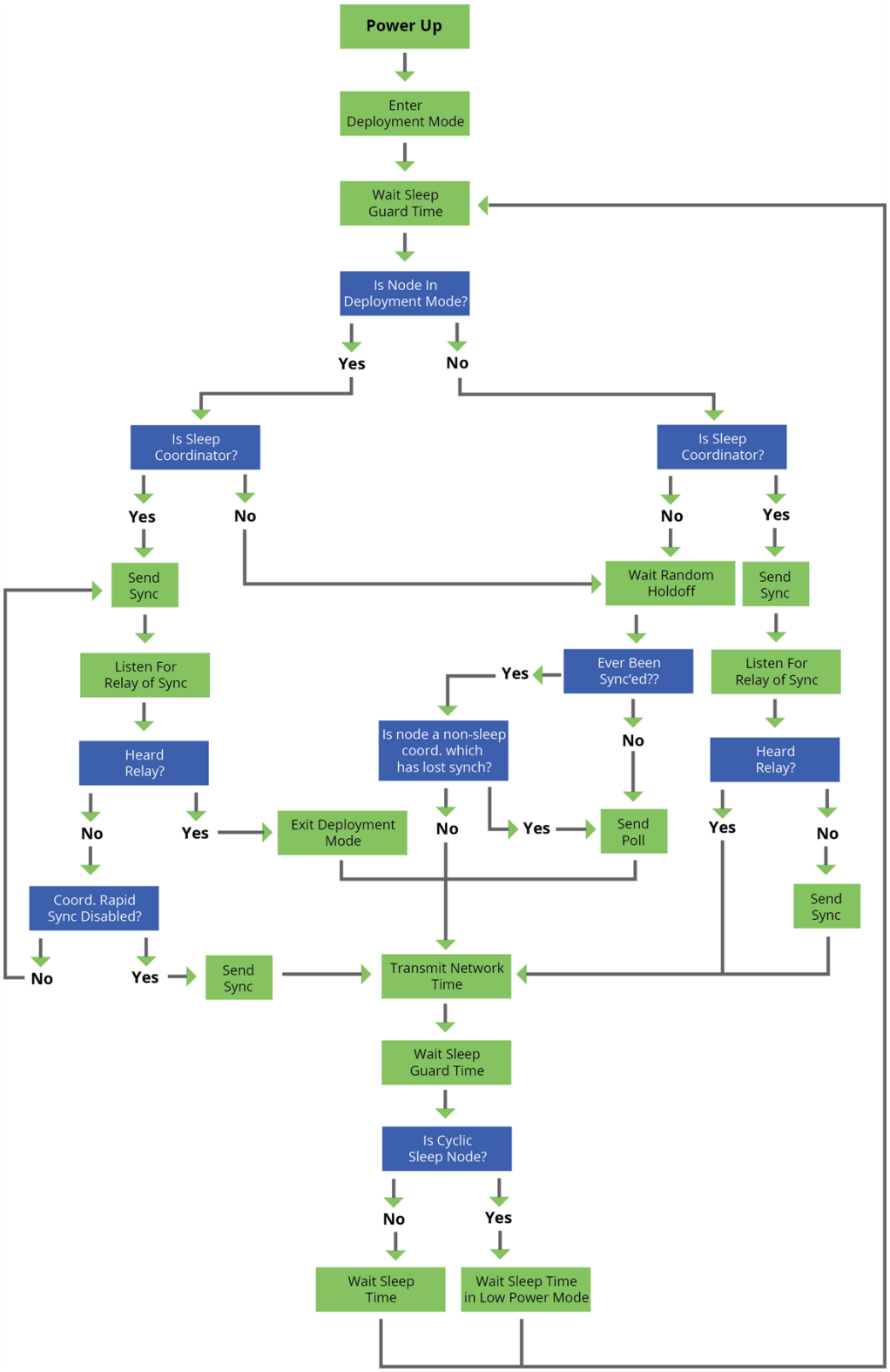
Sleep modes

Sleep coordinator sleep modes in the DigiMesh network



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Become a sleep coordinator

In DigiMesh networks, a device can become a sleep coordinator in one of four ways:

- Define a preferred sleep coordinator
- A potential sleep coordinator misses three or more sync messages
- Press the Commissioning Pushbutton twice on a potential sleep coordinator
- Change the sleep timing values on a potential sleep coordinator

Preferred sleep coordinator option

You can specify that a node always act as a sleep coordinator. To do this, set the preferred sleep coordinator bit (bit 0) in the **SO** command to 1.

A node with the sleep coordinator bit set always sends a sync message at the beginning of a wake cycle. To avoid network congestion and synchronization conflicts, do not set this bit on more than one node in the network.

A node that is centrally located in the network can serve as a good sleep coordinator, because it minimizes the number of hops a sync message takes to get across the network.

A sleep support node and/or a node that is mains powered is a good candidate to be a sleep coordinator.

CAUTION! Use the preferred sleep coordinator bit with caution. The advantages of using the option become weaknesses if you use it on a node that is not in the proper position or configuration. Also, it is not valid to have the sleep coordinator option bit set on more than one node at a time.

You can also use the preferred sleep coordinator option when you set up a network for the first time. When you start a network, you can configure a node as a sleep coordinator so it will begin sending sleep messages. After you set up the network, it is best to disable the preferred sleep coordinator bit.

Resolution criteria and selection option

There is an optional selection process with resolution criteria that occurs on a node if it loses contact with the network sleep coordinator. By default, this process is disabled. Use the **SO** command to enable this process. This process occurs automatically if a node loses contact with the previous sleep coordinator.

If you enable the process on any sleep compatible node, it is eligible to become the sleep coordinator for the network.

A sleep compatible node may become a sleep coordinator if it:

- Misses three or more sync messages.
- It is not configured as a non-coordinator by setting bit 1 of **SO**.

If such a node wins out in the selection process, it becomes the new network sleep coordinator.

It is possible for multiple nodes to declare themselves as the sleep coordinator. If this occurs, the firmware uses the following resolution criteria to identify the sleep coordinator from among the nodes using the selection process:

1. Newer sleep parameters always take priority over older sleep parameters. The age of the sleep parameters is determined by a sequence number that increments when an overriding

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sync is sent.

2. Otherwise, the node with the preferred sleep coordinator bit set takes precedence.
3. Otherwise, a sleep support node—**SM 7**—takes priority over a node that is not a sleep support node—**SM 8**.
4. Otherwise, the node with highest serial number becomes the sleep coordinator.

Commissioning Pushbutton option

If you enable the Commissioning Pushbutton functionality, you can immediately select a device as a sleep coordinator by pressing the Commissioning Pushbutton twice or by issuing the **CB2** command. The device you select in this manner is still subject to the resolution criteria process.

Only potential sleep coordinator nodes honor Commissioning Pushbutton nomination requests. A node configured as a non-sleep coordinator ignores commissioning button nomination requests.

Overriding syncs

Any sleep compatible node in the network that does not have the non-coordinator sleep option set can send an overriding sync and become the network sleep coordinator. An overriding sync effectively changes the synchronization of all nodes in the network to the **ST** and **SP** values of the node sending the overriding sync. It also selects the node sending the overriding sync as the network sleep coordinator. While this is a powerful operation, it may be an undesired side effect because the current sleep coordinator may have been carefully selected and it is not desired to change it. Additionally the current wake and sleep cycles may be desired rather than the parameters on the node sending the overriding sync. For this reason, it is important to know what kicks off an overriding sync.

An overriding sync occurs whenever **ST** or **SP** is changed to a value different than **OW** or **OS** respectively. For example no overriding sync will occur if **SP** is changed from **190** to **C8** if the network was already operating with **OS** at **C8**. On the other hand, if **SP** is changed from **190** to **190**—meaning no change—and **OS** is **C8**, than an overriding sync will occur because the network parameters are being changed.

Even parameters that seem unrelated to sleep can kick off an overriding sync. These are **NH**, **NN**, **RN**, and **MT**. When any of these parameters are changed, they can affect network traversal time. If such changes cause the configured value of **ST** to be smaller than the value needed for network traversal, then **ST** is increased and if that increased value is different than **OW**, then an overriding sync will occur.

For most applications, we recommend configuring the **NH**, **NN**, **RN**, and **MT** network parameters during initial deployment only. The default values of **NH** and **NN** are optimized to work for most deployments. Additionally, it would be best to set **ST** and **SP** the same on all nodes in the network while keeping **ST** sufficiently large so that it will not be affected by an inadvertent change of **NH**, **NN**, **RN**, or **MT**.

Sleep guard times

To compensate for variations in the timekeeping hardware of the various devices in a sleeping router network, the network allocates sleep guard times at the beginning and end of the wake period. The size of the sleep guard time varies based on the sleep and wake times you select and the number of sleep cycles that elapse since receiving the last sync message. The sleep guard time guarantees that a destination module will be awake when the source device sends a transmission. As a node misses more and more consecutive sync messages, the sleep guard time increases in duration and decreases the available transmission time.

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Auto-early wake-up sleep option

Similar to the sleep guard time, the auto early wake-up option decreases the sleep period based on the number of sync messages a node misses. This option comes at the expense of battery life.

Use the **SO** command to disable auto-early wake-up sleep. This option is enabled by default.

Select sleep parameters

Choosing proper sleep parameters is vital to creating a robust sleep-enabled network with a desirable battery life. To select sleep parameters that will be good for most applications, follow these steps:

1. Choose **NH**.

   Based on the placement of the nodes in your network, select the appropriate values for the **NH** (Network Hops) parameter .

   We optimize the default values of **NH** to work for the majority of deployments. In most cases, we suggest that you do not modify these parameters from their default values. Decreasing these parameters for small networks can improve battery life, but take care to not make the values too small.

2. Calculate the Sync Message Propagation Time (SMPT).

   This is the maximum amount of time it takes for a sleep synchronization message to propagate to every node in the network. You can estimate this number with the following formula:
   SMPT = **NH***(**MT**+1)*18 ms.

3. Select the duty cycle you want.
4. Choose the sleep period and wake time.

   The wake time must be long enough to transmit the desired data as well as the sync message. The **ST** parameter automatically adjusts upwards to its minimum value when you change other AT commands that affect it (**SP**, and **NH**).

   Use a value larger than this minimum. If a device misses successive sync messages, it reduces its available transmit time to compensate for possible clock drift. Budget a large enough **ST** time to allow for the device to miss a few sync messages and still have time for normal data transmissions.

Sleep immediate

In order to ensure that the needed messages have time to traverse the network, **ST** must be sufficiently large. Additionally, your application is a factor in determining what **ST** should be. When **ST**/**SP** increases, the batteries burn out faster. Yet, **ST** must be large enough for a functional network.

To mitigate this problem, the Sleep Immediate command is available (in version **0x9009** and newer). The Sleep Immediate (**SI**) command can be sent by your application after it determines that all needed transmissions are completed. This not only puts the node that issues the command asleep, but it also sends a broadcast to put the whole network to sleep. The network will then remain asleep for the remainder of the wake time and the subsequent sleep time. Then the entire network will awaken again, resuming the same sleep cycle as before.

In the event that one or more nodes fail to receive the sleep immediate broadcast, they will not get the power savings, but they will still remain synchronized to the network because the sleep cycle would not have changed.

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Synchronous pulse

The Synchronous pulse feature supports user applications that desire synchronizing operations across multiple devices in a network. This is done by pulsing the **DIO9**—ON_SLEEP—pin simultaneously on all devices in the network. Typically, this feature is used with a mains-powered application and transmissions are not inhibited except during the small window of time allocated for sending synchronization messages throughout the network.

Configuration

Generally, synchronous pulse is configured the same way as synchronous sleep. See the table below:

AT Command	Value	Description
D9	6	This causes a synchronous pulse line to be toggled low and then high on the **DIO9** pin throughout the network. Note that **D9** must be set to **1** for the ON_SLEEP indicator. This means that it is not possible to have both a synchronous pulse and an ON_SLEEP indicator. However, if a synchronously sleeping network is desired, **D9** may still be used as a synchronous pulse with the obvious limitation that the network will not be able to transmit while it is asleep.
SM	7 or 8	Setting **SM** to **7** or **8** allows the synchronization messages to be sent. They will not be sent and this feature will be disabled if **SM** is set to any other value.
SP	0	Even with **SM** set to **8**, the network still stays awake by setting **SP** to **0** on the sleep coordinator.
ST	??	Set **ST** to the frequency desired for the synchronous pulse. If it is set too small, it is rounded up to a value that allows a synchronous pulse to be output every time **DIO9** pulses. Some parameters—such as **NH**—can be made smaller in order to reduce the minimum value for **ST**. If it still is not possible to get synchronous pulses at small enough intervals to satisfy the application, then the microcontroller connected to **DIO9** will be responsible for subdividing the time between each synchronous pulse.

Accuracy

Due to variations is traffic patterns and hopping patterns, perfect accuracy cannot be guaranteed. However, this feature is usually accurate within + or - 100 micro-seconds. If greater accuracy than that is required, this solution will not work for your application.

Start a sleeping synchronous network

By default, all new nodes operate in normal (non-sleep) mode. To start a synchronous sleeping network, follow these steps:

1. Set **SO** to 1 to enable the preferred sleep coordinator option on one of the nodes.
2. Set its **SM** to a synchronous sleep compatible mode (7 or 8) with its **SP** and **ST** set to a quick cycle time. The purpose of a quick cycle time is to allow the network to send commands quickly through the network during commissioning.

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3. Power on the new nodes within range of the sleep coordinator. The nodes quickly receive a sync message and synchronize themselves to the short cycle **SP** and **ST** set on the sleep coordinator.
4. Configure the new nodes to the sleep mode you want, either cyclic sleeping modes or sleep support modes.
5. Set the **SP** and **ST** values on the sleep coordinator to the values you want for the network.
6. In order to reduce the possibility of an unintended overriding sync, set **SP** and **ST** to the intended sleep/wake cycle on all nodes in the network. Be sure that **ST** is large enough to prevent it from being inadvertently increased by changing **NN**, **NH**, or **MT**.
7. Wait a sleep cycle for the sleeping nodes to sync themselves to the new **SP** and **ST** values.
8. Disable the preferred sleep coordinator option bit on the sleep coordinator unless you want a preferred sleep coordinator.
9. Deploy the nodes to their positions.

Alternatively, prior to deploying the network you can use the **WR** command to set up nodes with their sleep settings pre-configured and written to flash. If this is the case, you can use the Commissioning Pushbutton and associate LED to aid in deployment:

1. If you are going to use a preferred sleep coordinator in the network, deploy it first.
2. If there will not be a preferred sleep coordinator, select a node for deployment, power it on and press the Commissioning Pushbutton twice. This causes the node to begin emitting sync messages.
3. Verify that the first node is emitting sync messages by watching its associate LED. A slow blink indicates that the node is acting as a sleep coordinator.
4. Power on nodes in range of the sleep coordinator or other nodes that have synchronized with the network. If the synchronized node is asleep, you can wake it by pressing the Commissioning Pushbutton once.
5. Wait a sleep cycle for the new node to sync itself.
6. Verify that the node syncs with the network. The associate LED blinks when the device is awake and synchronized.
7. Continue this process until you deploy all of the nodes.

Add a new node to an existing network

To add a new node to the network, the node must receive a sync message from a node already in the network. On power-up, an unsynchronized, sleep compatible node periodically sends a broadcast requesting a sync message and then sleeps for its **SP** period. Any node in the network that receives this message responds with a sync. Because the network can be asleep for extended periods of time, and cannot respond to requests for sync messages, there are methods you can use to sync a new node while the network is asleep.

1. Power the new node on within range of a sleep support node. Sleep support nodes are always awake and able to respond to sync requests promptly.
2. You can wake a sleeping cyclic sleep node in the network using the Commissioning Pushbutton. Place the new node in range of the existing cyclic sleep node. Wake the existing node by holding down the Commissioning Pushbutton for two seconds, or until the node wakes. The existing node stays awake for 30 seconds and responds to sync requests while it is awake.

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If you do not use one of these two methods, you must wait for the network to wake up before adding the new node.

Place the new node in range of the network with a sleep/wake cycle that is shorter than the wake period of the network.

The new node periodically sends sync requests until the network wakes up and it receives a sync message.

Change sleep parameters

To change the sleep and wake cycle of the network, select any sleep coordinator capable node in the network and change the **SP** and/or **ST** of the node to values different than those the network currently uses.

- If you use a preferred sleep coordinator or if you know which node acts as the sleep coordinator, we suggest that you use this node to make changes to network settings.
- If you do not know the network sleep coordinator, you can use any node that does not have the non-sleep coordinator sleep option bit set. For details on the bit, see SO (Sleep Options).

When you make changes to a node's sleep parameters, that node becomes the network's sleep coordinator unless it has the non-sleep coordinator option selected. It sends a sync message with the new sleep settings to the entire network at the beginning of the next wake cycle. The network immediately begins using the new sleep parameters after it sends this sync.

Changing sleep parameters increases the chances that nodes will lose sync. If a node does not receive the sync message with the new sleep settings, it continues to operate on its old settings. To minimize the risk of a node losing sync and to facilitate the re-syncing of a node that does lose sync, take the following precautions:

1. Whenever possible, avoid changing sleep parameters.
2. Enable the missed sync early wake up sleep option in the **SO** command. This option is enabled by default. This command tells a node to wake up progressively earlier based on the number of cycles it goes without receiving a sync. This increases the probability that the un-synced node will be awake when the network wakes up and sends the sync message.

Note Using this sleep option increases reliability but may decrease battery life. Nodes using this sleep option that miss sync messages increase their wake time and decrease their sleep time during cycles where they miss the sync message. This increases power consumption.

When you are changing between two sets of sleep settings, choose settings so that the wake periods of the two sleep settings occur at the same time. In other words, try to satisfy the following equation:

$$(SP_1 + ST_1) = N * (SP_2 + ST_2)$$

where SP_1/ST_1 and SP_2/ST_2 are the desired sleep settings and N is an integer.

Rejoin nodes that lose sync

DigiMesh networks get their robustness from routing redundancies which may be available. We recommend architecting the network with redundant mesh nodes to increase robustness.

If a scenario exists where the only route connecting a subnet to the rest of the network depends on a single node, and that node fails or the wireless link fails due to changing environmental conditions (a catastrophic failure condition), then multiple subnets may arise using the same wake and sleep intervals. When this occurs the first task is to repair, replace, and strengthen the weak link with new and/or redundant devices to fix the problem and prevent it from occurring in the future.

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When you use the default DigiMesh sleep parameters, separated subnets do not drift out of phase with each other. Subnets can drift out of phase with each other if you configure the network in one of the following ways:

- If you disable the non-sleep coordinator bit in the **SO** command on multiple devices in the network, they are eligible for the network to nominate them as a sleep coordinator. For more details, see SO (Sleep Options).
- If the devices in the network do not use the auto early wake-up sleep option.

If a network has multiple subnets that drift out of phase with each other, get the subnets back in phase with the following steps:

1. Place a sleep support node in range of both subnets.
2. Select a node in the subnet that you want the other subnet to sync with.
3. Use this node to slightly change the sleep cycle settings of the network, for example, increment **ST**.
4. Wait for the subnet's next wake cycle. During this cycle, the node you select to change the sleep cycle parameters sends the new settings to the entire subnet it is in range of, including the sleep support node that is in range of the other subnet.
5. Wait for the out of sync subnet to wake up and send a sync. When the sleep support node receives this sync, it rejects it and sends a sync to the subnet with the new sleep settings.
6. The subnets will now be in sync. You can remove the sleep support node.
7. You can also change the sleep cycle settings back to the previous settings.

If you only need to replace a few nodes, you can use this method:

1. Reset the out of sync node and set its sleep mode to Synchronous Cyclic Sleep mode (**SM** = 8).
2. Set up a short sleep cycle.
3. Place the node in range of a sleep support node or wake a sleeping node with the Commissioning Pushbutton.
4. The out of sync node receives a sync from the node that is synchronized to the network. It then syncs to the network sleep settings.

Diagnostics

The following diagnostics are useful in applications that manage a sleeping router network:

Query sleep cycle

Use the **OS** and **OW** commands to query the current operational sleep and wake times that a device uses.

Sleep status

Use the **SS** command to query useful information regarding the sleep status of the device. Use this command to query if the node is currently acting as a network sleep coordinator.

Missed sync messages command

Use the **MS** command to query the number of cycles that elapsed since the device received a sync message.

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Sleep status API messages

When you use the **SO** command to enable this option, a device that is in API operating mode outputs modem status frames immediately after it wakes up and prior to going to sleep.

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Special commands

The following commands are special commands.

AC (Apply Changes)

Immediately applies new settings without exiting Command mode.

Parameter range

N/A

Default

N/A

FR (Software Reset)

Resets the device. The device responds immediately with an **OK** and performs a reset 100 ms later. If you issue **FR** while the device is in Command Mode, the reset effectively exits Command mode.

Parameter range

N/A

Default

N/A

RE (Restore Defaults)

Restore device parameters to factory defaults.

Parameter range

N/A

Default

N/A

WR (Write)

Writes parameter values to non-volatile memory so that parameter modifications persist through subsequent resets.

Note Once you issue a **WR** command, do not send any additional characters to the device until after you receive the **OK** response.

Parameter range

N/A

Default

N/A

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MAC/PHY commands

The following AT commands are MAC/PHY commands.

CM (Channel Mask)

CM allows you to selectively enable or disable channels used for RF communication. This is useful to avoid using frequencies that experience unacceptable levels of RF interference, or to operate two networks of radios on separate frequencies.

This mask limits the channels where the device transmits. See Technical specifications for the list of frequencies. Channel 0 is bit 0. You must enable at least two channels, except when using only a single frequency of 869.85 MHz. When you use this mode (use 0x20000000), LBT+AFA is disabled and the power level is automatically limited to 5 dBm.

This command is a bitfield.

Exactly MF (Minimum Frequency Count) number of channels must be made available for the device to communicate on.

The **CM** command does not limit receive channels. If two devices have mutually exclusive values for **CM** (for example 0x0000FF00 and 0x000000FF), then communication is possible because both devices still listen on all possible channels, while limiting the transmission channels to those specified in the **CM** command.

The **CM** channel mask no longer supports channels 9 and 24 due to regulatory requirements.

Parameter range

3 - 0x3EFFFDFF [bitfield]

Default

Europe: 0x3EFFFDFF (channels 0 - 29, 863.15 - 869.85 MHz), excluding channels 9 and 24

Europe (single frequency mode): 0x20000000 (channel 29, 869.85 MHz)

HP (Preamble ID)

The preamble ID for which the device communicates. Only devices with matching preamble IDs can communicate with each other. Different preamble IDs minimize interference between multiple sets of devices operating in the same vicinity. When receiving a packet, the device checks this before the network ID, as it is encoded in the preamble, and the network ID is encoded in the MAC header.

Parameter range

0 - 9

Default

0

ID (Network ID)

Set or read the user network identifier.

Devices must have the same network identifier to communicate with each other.

When receiving a packet, the device check this after the preamble ID. If you are using Original equipment manufacturer (OEM) network IDs, **0xFFFF** uses the factory value.

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Parameter range

0 - 0x7FFF

Default

0x7FFF

MT (Broadcast Multi-Transmits)

Set or read the number of additional MAC-level broadcast transmissions. All broadcast packets are transmitted **MT**+1 times to ensure they are received.

Parameter range

0 - 5

Default

3

BR (RF Data Rate)

Sets and reads the device's RF data rate (the rate at which the device transmits and receives RF data over-the-air).

DigiMesh and synchronized sleep are not supported when **BR** = **0**. All devices on the network must have the same **BR** value set in order to communicate. **BR** directly affects the range of the device. The higher the RF data rate, the lower the receive sensitivity.

Parameter range

0 - 1

Parameter	RF data rate	Receiver sensitivity
0	10 kb/s	-113 dBm
1	80 kb/s	-106 dBm

Default

1

PL (TX Power Level)

Sets or displays the power level at which the device transmits conducted power. Power levels are approximate.

Parameter range

0 - 4

Setting	Power level*
0	2 mW EIRP
1	5 mW EIRP

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Setting	Power level*
2	10 mW EIRP
3	16 mW EIRP
4	32 mW EIRP
* EIRP stands for Effective Isotropically Radiated Power, which is the device's output power plus 2.1 dBi (dipole antenna gain).	

Default

4

RR (Unicast Mac Retries)

Set or read the maximum number of MAC level packet delivery attempts for unicasts. If **RR** is non-zero, the sent unicast packets request an acknowledgment from the recipient. Unicast packets can be retransmitted up to **RR** times if the transmitting device does not receive a successful acknowledgment.

Parameter range

0 - 0xF

Default

0x0A (decimal 10)

ED (Energy Detect)

Starts an energy detect scan. This command accepts an argument to specify the time in milliseconds to scan all channels. The device loops through all the available channels until the time elapses. It returns the maximal energy on each channel, a comma follows each value, and the list ends with a carriage return. The values returned reflect the energy level that **ED** detects in -dBm units.

Parameter range

0 - 0xFF

Default

0x10

LB (LNA Bypass)

Sets or reads the LNA bypass enable of the device. If the LNA bypass is enabled, the RX current draw improves by 6 mA while the RX sensitivity degrades by approximately 12 dB.

Range

0 - 1

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Parameter	Mode
0	LNA Bypass Disabled
1	LNA Bypass Enabled

Default

0

Diagnostic commands

The following AT commands are diagnostic commands. Diagnostic commands are typically volatile and will not persist across a power cycle.

BC (Bytes Transmitted)

The number of RF bytes transmitted. The firmware counts bytes in every retry and retransmission. A packet includes not only the payload, but also the preamble, the MAC header, the network header, the application header, encryption overhead, and the CRC. The purpose of this count is to estimate battery life by tracking time spent performing transmissions.

BC stops counting when it reaches a max value of **0xffffFFFF**. But, you can reset the counter to any 32-bit value—for example **0**—by appending a hexadecimal parameter to the command.

Parameter range

0 - 0xFFFF

Default

0

DB (Last Packet RSSI)

Reports the RSSI in -dBm of the last received RF data packet. **DB** returns a hexadecimal value for the -dBm measurement.

For example, if **DB** returns 0x60, then the RSSI of the last packet received was -96 dBm.

DB only indicates the signal strength of the last hop. It does not provide an accurate quality measurement for a multihop link.

Parameter range

0 - 0xFF [read-only]

Default

0

ER (Received Error Count)

This count increments when a device receives a packet that contains integrity errors of some sort. When the number reaches 0xFFFF, the firmware does not count further events.

To reset the counter to any 16-bit unsigned value, append a hexadecimal parameter to the **ER** command.

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Parameter range

0 - 0xFFFF

Default

0

GD (Good Packets Received)

This count increments when a device receives a good frame with a valid MAC header on the RF interface. Once the number reaches 0xFFFF, it does not count further events.

To reset the counter to any 16-bit unsigned value, append a hexadecimal parameter to the command.

Parameter range

0 - 0xFFFF

Default

0

EA (MAC ACK Timeouts)

This count increments whenever a MAC ACK timeout occurs on a MAC-level unicast. When the number reaches **0xFFFF**, the firmware does not count further events.

To reset the counter to any 16-bit value, append a hexadecimal parameter to the command.

Parameter range

0 - 0xFFFF

Default

0

TR (Transmission Errors)

This count increments whenever a MAC transmission attempt exhausts all MAC retries without ever receiving a MAC acknowledgment message from the destination node. Once the number reaches **0xFFFF**, it does not count further events.

To reset the counter to any 16-bit value, append a hexadecimal parameter to the command.

Parameter range

0 - 0xFFFF

Default

0

UA (MAC Unicast Transmission Count)

This count increments whenever a MAC unicast transmission occurs that requests an ACK. Once the number reaches 0xFFFF, it does not count further events.

You can reset the counter to any 16-bit unsigned value by appending a hexadecimal parameter to the command.

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Parameter range

0 - 0xFFFF

Default

0

%H (MAC Unicast One Hop Time)

The MAC unicast one hop time timeout in milliseconds. If you change the MAC parameters it can change this value.

Parameter range

[read-only]

Default

0x267

0xF3

%8 (MAC Broadcast One Hop Time)

The MAC broadcast one hop time timeout in milliseconds. If you change MAC parameters, it can change this value.

Parameter range

[read-only]

Default

0x204

Network commands

The following commands are network commands.

CE (Node Messaging Options)

The routing and messaging mode bit field of the device.

A routing device repeats broadcasts. Indirect Messaging Coordinators do not transmit point-to-multipoint unicasts until an end device requests them. Setting a device as an end device causes it to regularly send polls to its Indirect Messaging Coordinator. Nodes can also be configured to route, or not route, multi-hop packets.

Parameter range

0 - 6

Parameter	Description	Routes packets
0	Standard router	Yes
1	Indirect message coordinator	Yes

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Parameter	Description	Routes packets
2	Non-routing device	No
3	Non-routing coordinator	No
4	Indirect message poller	Yes
5	N/A	N/A
6	Non-routing poller	No

Default

0

C8 (Compatibility Options)

Sets or displays the operational compatibility with older versions of the firmware.

Parameter range

4

Bit field:

Bit	Meaning	Setting	Description
2	Encryption compatibility	0	When encryption is enabled, AES Counter mode is used with a 256-bit key.
		1	When encryption is enabled AES ECB mode is used with a 128-bit key. This bit must be set when using encryption with versions of the firmware prior to 9009. It may be used in all circumstances if set consistently throughout the network, but it disables the more secure counter mode encryption.

All other bits should be 0 for future compatibility.

Default

0x04

BH (Broadcast Hops)

The number of hops for broadcast data transmissions.

Set the value to **0** for the maximum number of hops.

If you set **BH** greater than **NH**, the device uses the value of **NH**.

Parameter range

0 - 0x20

Default

0

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NH (Network Hops)

The maximum number of hops expected to be seen in a network route. This value does not limit the number of hops allowed, but it is used to calculate timeouts waiting for network acknowledgments.

Parameter range

1 - 0x20

Default

7

NN (Network Delay Slots)

Set or read the maximum random number of network delay slots before rebroadcasting a network packet.

Parameter range

1 - 5

Default

3

MR (Mesh Unicast Retries)

Set or read the maximum number of network packet delivery attempts. If **MR** is non-zero, the packets a device sends request a network acknowledgment, and can be resent up to **MR**+1 times if the device does not receive an acknowledgment.

We recommend that you set this value to **1**.

If you set this parameter to **0**, it disables network ACKs. Initially, the device can find routes, but a route will never be repaired if it fails.

Parameter range

0 - 7

Default

1

Addressing commands

The following AT commands are addressing commands.

SH (Serial Number High)

Displays the upper 32 bits of the unique IEEE 64-bit extended address assigned to the XBee in the factory.

Parameter range

0 - 0xFFFFFFFF [read-only]

Default

Set in the factory

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SL (Serial Number Low)

Displays the lower 32 bits of the unique IEEE 64-bit RF extended address assigned to the XBee in the factory.

Parameter range

0 - 0xFFFFFFFF [read-only]

Default

Set in the factory

DH (Destination Address High)

Set or read the upper 32 bits of the 64-bit destination address. When you combine **DH** with **DL**, it defines the destination address that the device uses for transmissions in Transparent mode. **0x000000000000FFFF** is the broadcast address.

Parameter range

0 - 0xFFFFFFFF

Default

0

DL (Destination Address Low)

Set or display the lower 32 bits of the 64-bit destination address. When you combine **DH** with **DL**, it defines the destination address that the device uses for transmissions in Transparent mode.

Parameter range

0 - 0xFFFFFFFF

Default

0x0000FFFF

TO (Transmit Options)

The bitfield that configures the transmit options for Transparent mode.

The device's transmit options. The device uses these options for all transmissions. You can override these options using the TxOptions field in the API TxRequest frames.

Parameter range

0 - 0xFF

Bit	Meaning	Description
6,7	Delivery method	b’00 = <invalid option> b’01 = Point-multipoint b'10 = Repeater mode—directed broadcast of packets b’11 = DigiMesh—not available when **BR** = **0**

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Bit	Meaning	Description
5	Reserved	<set this bit to 0>
4	Reserved	<set this bit to 0>
3	Trace Route	Enable a Trace Route on all DigiMesh API packets
2	NACK	Enable a NACK messages on all DigiMesh API packets
1	Disable RD	Disable Route Discovery on all DigiMesh unicasts
0	Disable ACK	Disable acknowledgments on all unicasts

When you set **BR** to **0** the **TO** option has the DigiMesh and Repeater mode disabled automatically.

Default

0x40 When **BR** = **0**

0xC0 When **BR** = **1**

NI (Node Identifier)

Stores the node identifier string for a device, which is a user-defined name or description of the device. This can be up to 20 ASCII characters.

- The command automatically ends when the maximum bytes for the string have been entered.
- To set **NI**to its default value of one ASCII space, type **ATNI**followed by a space and press **Enter**.

Use the **ND** (Network Discovery) command with this string as an argument to easily identify devices on the network.

The **DN** command also uses this identifier.

Parameter range

A string of case-sensitive ASCII printable characters from 1 to 20 bytes in length. The string cannot start with the space character. A carriage return or a comma automatically ends the command.

Default

One ASCII space character (0x20)

NT (Node Discover Timeout)

Sets the amount of time a base node waits for responses from other nodes when using the ND (Network Discover), DN (Discover Node), and FN (Find Neighbors) commands. When a discovery is performed, the broadcast transmission includes the **NT** value to provide all remote devices with a response timeout. Remote devices wait a random time, less than **NT**, before sending their response to avoid collisions.

The **N?** command should be used to determine how long the actual discovery timeout will be based on current device configuration.

Parameter range

0x20 - 0x2EE0 (x 100 ms)

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Default

0x82 (13 seconds)

NO (Node Discovery Options)

Set or read the network discovery options value for the **ND** (Network Discovery) command on a particular device. The options bit field value changes the behavior of the **ND** command and what optional values the local device returns when it receives an **ND** command or API Node Identification Indicator (0x95) frame.

These options also apply to FN (Find Neighbors) command responses.

Parameter range

0x0 - 0x7 (bit field)

Option	Description
0x01	Append the **DD** (Digi Device Identifier) value to **ND** or **FN** responses or API node identification frames.
0x02	Local device returns own **ND** response frame when a **ND** or **FN** is issued.
0x04	Append the RSSI of the last hop to **ND**, **FN** responses or API node identification frames.
Option	**Description**
0x01	Append the **DD** (Digi Device Identifier) value to **ND** responses or API node identification frames.
0x02	Local device sends **ND** response frame when the **ND** is issued.

Default

0x0

CI (Cluster ID)

The application layer cluster ID value. The device uses this value as the cluster ID for all data transmissions.

Parameter range

0 - 0xFFFF

Default

0x11

DE (Destination Endpoint)

Sets or displays the application layer destination ID value. The value is used as the destination endpoint for all data transmissions. The default value (0xE8) is the Digi data endpoint.

Parameter range

0 - 0xFF

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Default

0xE8

SE (Source Endpoint)

Sets or displays the application layer source endpoint value. The value is used as the source endpoint for all data transmissions. The default value (0xE8) is the Digi data endpoint.

This command only affects outgoing transmissions in transparent mode (**AP** = **0**).

0xE8 is the Digi data endpoint used for outgoing data transmissions.

0xE6 is the Digi device object endpoint used for configuration and commands.

Parameter range

0 - 0xFF

Default

0xE8

Addressing discovery/configuration commands

AG (Aggregator Support)

The **AG** command sends a broadcast through the network that has the following effects on nodes that receive the broadcast:

- The receiving node establishes a DigiMesh route back to the originating node, if there is space in the routing table.
- The **DH** and **DL** of the receiving node update to the address of the originating node if the **AG** parameter matches the current **DH**/**DL** of the receiving node.
- API-enabled devices with updated **DH** and **DL** send an Aggregate Addressing Update frame (0x8E) out the serial port.

Parameter range

Any 64-bit address

Default

N/A

DN (Discover Node)

Resolves an **NI** (Node identifier) string to a physical address (case sensitive).

The following events occur after **DN** discovers the destination node:

When **DN** is sent in Command mode:

1. The device sets **DL** and **DH** to the extended (64-bit) address of the device with the matching **NI** string.
2. The receiving device returns **OK** (or **ERROR**).
3. The device exits Command mode to allow for immediate communication. If an **ERROR** is received, the device does not exit Command mode.

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When **DN** is sent as an API frame, the receiving device returns 0xFFFE followed by its 64-bit extended addresses in an API Command Response frame.

Parameter range

20-byte ASCII string

Default

N/A

ND (Network Discover)

Discovers and reports all of the devices it finds on a network. If you send **ND** through a local API frame, each network node returns a separate Local AT Command Response - 0x88 or Remote AT Command Response- 0x97 frame, respectively.

The command reports the following information after a jittered time delay.

SH<CR> (4 bytes)

SL<CR> (4 bytes)

DB<CR> (Contains the detected signal strength of the response in negative dBm units)

NI <CR> (variable, 0-20 bytes plus 0x00 character)

DEVICE_TYPE<CR> (1 byte: **0** = Coordinator, **1** = Router, **2** = End Device)

STATUS<CR> (1 byte: reserved)

PROFILE_ID<CR> (2 bytes)

MANUFACTURER_ID<CR> (2 bytes)

DIGI DEVICE TYPE<CR> (4 bytes. Optionally included based on **NO** settings.)

RSSI OF LAST HOP<CR> (1 byte. Optionally included based on **NO** settings.)

After (**NT** * 100) milliseconds, the command ends by returning a <CR>.

If you send **ND** through a Local AT Command Request - 0x08 frame, each network node returns a separate Local AT Command Response - 0x88 or Remote AT Command Response- 0x97 frame, respectively. The data consists of the bytes listed above without the carriage return delimiters. The **NI** string ends in a **0x00** null character.

Broadcast an **ND** command to the network. If the command includes an optional node identifier string parameter, only those devices with a matching **NI** string respond without a random offset delay. If the command does not include a node identifier string parameter, all devices respond with a random offset delay.

The NT (Node Discover Timeout) setting determines the range of the random offset delay. The NO (Node Discovery Options) setting sets options for the Node Discovery. For more information about options that affect the behavior of **ND** see the description of **NO**.

WARNING! If the **NT** setting is small relative to the number of devices on the network, responses may be lost due to channel congestion. Regardless of the **NT** setting, because the random offset only mitigates transmission collisions, getting responses from all devices in the network is not guaranteed.

Parameter range

N/A

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Default

N/A

FN (Find Neighbors)

Discovers and reports all devices found within immediate (1 hop) RF range. **FN** reports the following information for each device it discovers:

MY<CR> (always 0xFFFE)

SH<CR>

SL<CR>

NI<CR> (Variable length)

PARENT_NETWORK ADDRESS<CR> (2 bytes) (always 0xFFFE)

DEVICE_TYPE<CR> (1 byte: **0** = Coordinator, **1** = Router, **2** = End Device)

STATUS<CR> (1 byte: reserved)

PROFILE_ID<CR> (2 bytes)

MANUFACTURER_ID<CR> (2 bytes)

DIGI DEVICE TYPE<CR> (4 bytes. Optionally included based on NO (Node Discovery Options) settings.)

RSSI OF LAST HOP<CR> (1 byte. Optionally included based on NO (Node Discovery Options) settings.)

<CR>

If you send the **FN** command in Command mode, after (**NT***100) ms + overhead time, the command ends by returning a carriage return, represented by <CR>.

If you send the **FN** command through a local API frame, each response returns as a separate Local or Remote AT Command Response API packet, respectively. The data consists of the bytes in the previous list without the carriage return delimiters. The **NI** string ends in a 0x00 null character.

Parameter range

N/A

Default

N/A

Diagnostic - addressing commands

The following AT command is a Diagnostic - addressing command.

N? (Network Discovery Timeout)

The maximum response time, in milliseconds, for **ND** (Network Discovery) responses and **DN** (Discover Node) responses. The timeout is the sum of **NT** (Network Discovery Back-off Time) and the network propagation time.

Parameter range

[read-only]

Default

N/A

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Security commands

The following AT commands are security commands.

EE (Security Enable)

Enables or disables Advanced Encryption Standard (AES) encryption.

Set this command parameter the same on all devices in a network.

See C8 (Compatibility Options) that affects whether to use ECB mode or CTR mode encryption. A 128-bit AES key is used for ECB mode and a 256-bit key is used for CTR mode.

Parameter range

0 - 1

Parameter	Description
0	Encryption Disabled
1	Encryption Enabled

Default

0

KY (AES Encryption Key)

Sets the network security key value that the device uses for encryption and decryption.

When using ECB (compatibility) mode, the LS 128 bits of the specified **KY** value are used. Otherwise, all 256 bits are used.

This command is write-only. If you attempt to read **KY**, the device returns an **OK** status.

Set this command parameter the same on all devices in a network.

The value passes in as hex characters when you set it from AT command mode, and as binary bytes when you set it in API mode.

Parameter range

256-bit value (64 Hexadecimal digits)

Default

N/A

Serial interfacing commands

BD (Interface Data Rate)

Sets and reads the serial interface data rate (baud rate) between the device and the host. The baud rate is the rate that the host sends serial data to the device.

When you make an update to the interface data rate, the change does not take effect until the host issues the **CN** command and the device returns the **OK** response.

The **BD** parameter does not affect the RF data rate. If you set the interface data rate higher than the RF data rate, you may need to implement a flow control configuration.

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Non-standard interface data rates

The firmware interprets any value within 0x4B0 - 0x2580 and 0x4B00 - 0x1C9468 as an actual baud rate. When the host sends a value above 0x4B0, the firmware stores the closest interface data rate represented by the number in the **BD** register. For example, to set a rate of 19200 b/s, send the following command line: **ATBD4B00**.

Note When using XCTU, you can only set and read non-standard interface data rates using the XCTU Serial Console tool. You cannot access non-standard rates through the configuration section of XCTU.

When you send the **BD** command with a non-standard interface data rate, the UART adjusts to accommodate the interface rate you request. In most cases, the clock resolution causes the stored **BD** parameter to vary from the sent parameter. Sending **ATBD** without an associated parameter value returns the value actually stored in the device's **BD** register.

The following table provides the parameters sent versus the parameters stored.

BD parameter sent (HEX)	Interface data rate (b/s)	BD parameter stored (HEX)
0	1200	0
4	19,200	4
7	115,200	7
1C200	115,200	1B207

Parameter ranges

0 - 8 (standard rates)

0x100 to 0x1C9468 (non-standard rates)

Parameter	Configuration (b/s)
0	1200
1	2400
2	4800
3	9600
4	19200
5	38400
6	57600
7	115200
8	230400

Default

3

NB (Parity)

Set or read the serial parity settings for UART communications.

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Parameter range

0x00 - 0x02

Parameter	Description
0x00	No parity
0x01	Even parity
0x02	Odd parity

Parameter	Description
0	No parity
1	Even parity
2	Odd parity

Default

0x00

SB (Stop Bits)

Sets or displays the number of stop bits for UART communications.

Parameter range

0 - 1

Parameter	Configuration
0	One stop bit
1	Two stop bits

Default

0

RO (Packetization Timeout)

Set or read the number of character times of inter-character silence required before transmission begins when operating in Transparent mode.

Set **RO** to **0** to transmit characters as they arrive instead of buffering them into one RF packet.

Parameter range

0 - 0xFF (x character times)

Default

3

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FT (Flow Control Threshold)

Set or display the flow control threshold.

The device de-asserts CTS and/or send XOFF when **FT** bytes are in the UART receive buffer. It re-asserts CTS when less than **FT**-16 bytes are in the UART receive buffer.

Parameter range

0x1A - 0x166 bytes

Default

0x11D

AP (API Mode)

Sets or reads the UART API mode.

Parameter range

0 - 2

The following settings are allowed:

Parameter	Description
0	Transparent mode, API mode is off. All UART input and output is raw data and the device uses the **RO** parameter to delineate packets.
1	API Mode Without Escapes. The device packetizes all UART input and output data in API format, without escape sequences.
2	API Mode With Escapes. The device is in API mode and inserts escaped sequences to allow for control characters. The device passes XON, XOFF, Escape, and the 0x7E delimiter as data.

Default

0

AO (API Options)

The API data frame output format for RF packets received.

Parameter range

0, 1

Parameter	Description
0	API Rx Indicator - 0x90, this is for standard data frames.
1	API Explicit Rx Indicator - 0x91, this is for Explicit Addressing data frames.

Default

0

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I/O settings commands

The following AT commands are I/O settings commands.

CB (Commissioning Pushbutton)

Use **CB** to simulate commissioning pushbutton presses in software.

Set the parameter value to the number of button presses that you want to simulate. For example, send **CB1** to perform the action of pressing the Commissioning Pushbutton once.

See The Commissioning Pushbutton.

See Commissioning pushbutton.

Parameter range

0 - 4

Default

N/A

D0 (DIO0/AD0)

Sets or displays the DIO0/AD0 configuration (pin 33).

Parameter range

0 - 5

Parameter	Description
0	Disabled
1	Commissioning Pushbutton
2	ADC
3	Digital input
4	Digital output, low
5	Digital output, high

Default

1

D1 (DIO1/AD1)

Sets or displays the DIO1/AD1 configuration (pin 32).

Parameter range

0, 2 - 5

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Parameter	Description
0	Disabled
1	N/A
2	ADC
3	Digital input
4	Digital output, low
5	Digital output, high

Default

0

D2 (DIO2/AD2)

Sets or displays the DIO2/AD2 configuration (pin 31).

Parameter range

0, 2 - 5

Parameter	Description
0	Disabled
1	N/A
2	ADC
3	Digital input
4	Digital output, low
5	Digital output, high

Default

0

D3 (DIO3/AD3)

Sets or displays the DIO3/AD3 configuration (pin 30).

Parameter range

0, 2 - 5

Parameter	Description
0	Disabled
1	N/A

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Parameter	Description
2	ADC
3	Digital input
4	Digital output, low
5	Digital output, high

Default

0

D4 (DIO4)

Sets or displays the DIO4 configuration (pin 24).

Parameter range

0, 3 - 5

Parameter	Description
0	Disabled
1	N/A
2	N/A
3	Digital input
4	Digital output, low
5	Digital output, high

Default

0

D5 (DIO5/ASSOCIATED_INDICATOR)

Sets or displays the DIO5/AD5/ASSOCIATED_INDICATOR configuration (pin 28).

Parameter range

0, 1, 3 - 5

Parameter	Description
0	Disabled
1	Associate LED indicator
2	N/A
3	Digital input

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Parameter	Description
4	Digital output, default low
5	Digital output, default high

Default

1

D6 (DIO6/RTS)

Sets or displays the DIO6/$\overline{\text{RTS}}$ configuration (pin 29).

Parameter range

0, 1, 3 - 5

Parameter	Description
0	Disabled
1	$\overline{\text{RTS}}$ flow control
2	N/A
3	Digital input
4	Digital output, low
5	Digital output, high

Default

0

D7 (DIO7/CTS)

Parameter range

0, 1, 3 - 7

Parameter	Description
0	Disabled
1	$\overline{\text{CTS}}$ flow control
2	N/A
3	Digital input
4	Digital output, low
5	Digital output, high
6	RS-485 Tx enable, low Tx (0 V on transmit, high when idle)
7	RS-485 Tx enable high, high Tx (high on transmit, 0 V when idle)

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Default

0x1

D8 (DIO8/DTR/SLEEP_REQUEST)

Sets or displays the DIO8/SLEEP_REQUEST configuration (pin 10).

Parameter range

0, 1, 3 - 5

Parameter	Description
0	Disabled
1	Sleep request
2	N/A
3	Digital input
4	Digital output, low
5	Digital output, high

Default

1

D9 (DIO9/ON_SLEEP)

Sets or displays the DIO9/ON_$\overline{\text{SLEEP}}$ configuration (pin 26).

Parameter range

0, 1, 3 - 6

Parameter	Description
0	Disabled
1	ON/$\overline{\text{SLEEP}}$ output
2	N/A
3	Digital input
4	Digital output, low
5	Digital output, high
6	Synchronous pulse output

Default

1

P0 (DIO10/RSSI/PWM0 Configuration)

Sets or displays the PWM0/RSSI/DIO10 configuration (pin 7).

Parameter range

0 - 5

Parameter	Description
0	Disabled
1	RSSI PWM0 output
2	PWM0 output
3	Digital input
4	Digital output, low
5	Digital output, high

Default

1

P1 (DIO11/PWM1 Configuration)

Sets or displays the DIO11/PWM1 configuration (pin 8).

Parameter range

0 - 5

Parameter	Description
0	Disabled
1	32.768 kHz clock output
2	PWM1 output
3	Digital input
4	Digital output, low
5	Digital output, high

Default

0

P2 (DIO12 Configuration)

Sets or displays the DIO12 configuration (pin 5).

Parameter range

0, 3 - 5

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Parameter	Description
0	Disabled
1	N/A
2	N/A
3	Digital input
4	Digital output, low
5	Digital output, high

Default

0

P3 (DOUT)

Sets or displays the DOUT configuration (pin 3).

Parameter range

0, 1

Parameter	Description
0	Disabled
1	UART DOUT enabled

Default

1

P4 (DIN/CONFIG)

Sets or displays the DIN/$\overline{\text{CONFIG}}$ configuration (pin 4).

Parameter range

Parameter	Description
0	Disabled
1	UART DIN/$\overline{\text{CONFIG}}$ enabled

Default

1

P5 (DIO15/SPI_MISO Configuration)

Sets or displays the DIO15/SPI_MISO configuration (pin 17).

Parameter range

0, 1, 4, 5

Parameter	Description
0	Disabled
1	SPI_MISO
2	N/A
3	N/A
4	Digital output low
5	Digital output high

Default

1

P6 (SPI_MOSI Configuration)

Sets or displays the DIO16/SPI_MOSI configuration (pin 16).

Parameter range

0, 1, 4, 5

Parameter	Description
0	Disabled
1	SPI_MOSI
2	N/A
3	N/A
4	Digital output low
5	Digital output, high

Default

1

P7 (DIO17/SPI_SSEL)

Sets or displays the DIO17/SPI_$\overline{\text{SSEL}}$ configuration (pin 15).

Parameter range

0, 1, 4, 5

Parameter	Description
0	Disabled
1	SPI_$\overline{\text{SSEL}}$
2	N/A
3	N/A
4	Digital output low
5	Digital output, high

Default

1

P8 (DIO18/SPI_SCLK)

Sets or displays the DIO18/SPI_SCLK configuration (pin 14).

Parameter range

0, 1, 4, 5

Parameter	Description
0	Disabled
1	SPI_SCLK
2	N/A
e	N/A
4	Digital output low
5	Digital output high

Default

1

P9 (DIO19/SPI_ATTN)

Sets or displays the DIO19/SPI_$\overline{\text{ATTN}}$ configuration (pin 12).

Parameter range

0, 1, 4 - 6

Parameter	Description
0	Disabled
1	SPI_$\overline{\text{ATTN}}$

Parameter	Description
2	N/A
3	N/A
4	Digital output low
5	Digital output high
6	UART data present indicator

Default

1

PD (Pull Up/Down Direction)

The resistor pull direction bit field (1 = pull-up, 0 = pull-down) for corresponding I/O lines that are set by the **PR** command.

Parameter range

0x0 - 0xFFFFF

Default

0xFFFFF

PR (Pull-up/Down Resistor Enable)

The bit field that configures the internal pull-up resistor status for the I/O lines.

- If you set a **PR** bit to 1, it enables the pull-up/down resistor
- If you set a **PR** bit to 0, it specifies no internal pull-up/down resistor.

PR and **PD** only affect lines that are configured as digital inputs or disabled.
The following table defines the bit-field map for **PR** and **PD** commands.

Parameter range

0 - 0xFFFFF (bit field)

Default

0xFFFFF

M0 (PWM0 Duty Cycle)

The duty cycle of the PWM0 line (pin 7).
Use the **P0** command to configure the line as a PWM output.

Parameter range

0 - 0x3FF

Default

0

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M1 (PWM1 Duty Cycle)

The duty cycle of the PWM1 line (pin 8).

Use the **P1** command to configure the line as a PWM output.

Parameter range

0 - 0x3FF

Default

0

LT (Associated LED Blink Time)

Set or read the Associate LED blink time. If you use the **D5** command to enable the Associate LED functionality (DIO5/Associate pin), this value determines the on and off blink times for the LED when the device has joined the network.

If **LT** = **0**, the device uses the default blink rate: 500 ms for a sleep coordinator, 250 ms for all other nodes.

Parameter range

0x14 - 0xFF (x 10 ms)

Default

0

RP (RSSI PWM Timer)

The PWM timer expiration in 0.1 seconds. **RP** sets the duration of pulse width modulation (PWM) signal output on the RSSI pin.

When **RP** = **0xFF**, the output is always on.

Parameter range

0 - 0xFF (x 100 ms)

Default

0x28 (four seconds)

I/O sampling commands

The following AT commands configure I/O sampling parameters.

AV (Analog Voltage Reference)

The analog voltage reference used for A/D sampling.

Parameter range

0, 1

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Parameter	Description
0	1.25 V reference
1	2.5 V reference

Default

1

IC (DIO Change Detection)

Set or read the digital I/O pins to monitor for changes in the I/O state.

IC works with the individual pin configuration commands (**D0** - **D9**, **P0** - **P2**) . If you enable a pin as a digital I/O, you can use the **IC** command to force an immediate I/O sample transmission when the DIO state changes. IC is a bitmask that you can use to enable or disable edge detection on individual channels.

Set unused bits to 0.

Bit	I/O line
0	DIO0
1	DIO1
2	DIO2
3	DIO3
4	DIO4
5	DIO5
6	DIO6
7	DIO7
8	DIO8
9	DIO9
10	DIO10
11	DIO11
12	DIO12

Parameter range

0 - 0xFFFF (bit field)

Default

0

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IF (Sleep Sample Rate)

Set or read the number of sleep cycles that must elapse between periodic I/O samples. This allows the firmware to take I/O samples only during some wake cycles. During those cycles, the firmware takes I/O samples at the rate specified by **IR**.

In addition, setting **IF** to zero allows I/O samples to occur before the device goes to sleep and to occur thereafter every wake cycle specified by **IR**.

To enable periodic sampling, set **IR** to a non-zero value, and enable the analog or digital I/O functionality of at least one device pin. The sample rate is measured in milliseconds. For more information, see the following commands:

- D0 (DIO0/AD0) through D9 (DIO9/ON_SLEEP)
- P0 (DIO10/RSSI/PWM0 Configuration) through P2 (DIO12 Configuration)

Parameter range

0 - 0xFF

Default

1

IR (I/O Sample Rate)

Set or read the I/O sample rate to enable periodic sampling.

If you set the I/O sample rate to greater than **0**, the device samples all enabled digital I/O and analog inputs at a specified interval. Samples are sent to the address specified by the **DH** and **DL** commands.

To enable periodic sampling, set **IR** to a non-zero value, and enable the analog or digital I/O functionality of at least one device pin. The sample rate is measured in milliseconds.

WARNING! If you set **IR** to 1 or 2, the device will not keep up and many samples will be lost.

Parameter range

0 - 0xFFFF (x 1 ms)

Default

0

TP (Temperature)

The current module temperature in degrees Celsius in 8-bit two's compliment format. For example 0x1A = 26 °C, and 0xF6 = -10 °C.

Parameter range

0 - 0xFF [read-only]

Default

N/A

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IS (Force Sample)

Forces a read of all enabled digital and analog input lines.

Parameter range

N/A

Default

N/A

%V (Voltage Supply Monitoring)

Displays the supply voltage of the device in mV units.

Parameter range

This is a read-only parameter

Default

N/A

I/O line passing commands

The following AT commands are I/O line passing commands.

I/O Line Passing allows the digital and analog inputs of a remote device to affect the corresponding outputs of the local device.

You can perform Digital Line Passing on any of the Digital I/O lines. Digital Inputs directly map to Digital Outputs of each digital pin.

Analog Line Passing can be performed only on the first two ADC lines:

- ADC0 corresponds with PWM0
- ADC1 corresponds with PWM1

IU (I/O Output Enable)

Enable or disable I/O data received to be sent out UART/SPI using an API frame when **AP** = 1 or 2 and when I/O line passing is enabled.

Enable or disable the serial output of received I/O sample data when I/O line passing is enabled. **IU** only affects the device's behavior when **IA** is set to a non-default value.

When **IU** is enabled, any received I/O sample data is sent out the UART/SPI interface using an API frame. Sample data is only generated if the local device is operating in API mode (**AP** = 1 or 2).

Parameter range

0 - 1

Parameter	Description
0	Disabled
1	Enabled

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Default

1

IA (I/O Input Address)

The source address of the device to which outputs are bound. Setting all bytes to 0xFF disables I/O line passing. Setting **IA** to 0xFFFF allows any I/O packet addressed to this device (including broadcasts) to change the outputs.

The source address of the device to which outputs are bound. If an I/O sample is received from the address specified, any pin that is configured as a digital output or PWM changes its state to match that of the I/O sample.

Set **IA** to 0xFFFFFFFFFFFFFFFF to disable I/O line passing.

Set **IA** to 0xFFFF to allow any I/O packet addressed to this device (including broadcasts) to change the outputs.

Parameter range

0 - 0xFFFF FFFF FFFF FFFF

Default

0xFFFFFFFFFFFFFFFF (I/O line passing disabled)

T0 (D0 Timeout)

Specifies how long pin D0 holds a given value before it reverts to configured value. If set to 0, there is no timeout.

Parameter range

0 - 0x1770 (x 100 ms)

Default

0

T1 (D1 Output Timeout)

Specifies how long pin D1 holds a given value before it reverts to configured value. If set to 0, there is no timeout.

Parameter range

0 - 0x1770 (x 100 ms)

Default

0

T2 (D2 Output Timeout)

Specifies how long pin D2 holds a given value before it reverts to configured value. If set to 0, there is no timeout.

Parameter range

0 - 0x1770 (x 100 ms)

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Default

0

T3 (D3 Output Timeout)

Specifies how long pin D3 holds a given value before it reverts to configured value. If set to 0, there is no timeout.

Parameter range

0 - 0x1770 (x 100 ms)

Default

0

T4 (D4 Output Timeout)

Specifies how long pin D4 holds a given value before it reverts to configured value. If set to 0, there is no timeout.

Parameter range

0 - 0x1770 (x 100 ms)

Default

0

T5 (D5 Output Timeout)

Specifies how long pin D5 holds a given value before it reverts to configured value. If set to 0, there is no timeout.

Parameter range

0 - 0x1770 (x 100 ms)

Default

0

T6 (D6 Output Timeout)

Specifies how long pin D6 holds a given value before it reverts to configured value. If set to 0, there is no timeout.

Parameter range

0 - 0x1770 (x 100 ms)

Default

0

T7 (D7 Output Timeout)

Specifies how long pin D7 holds a given value before it reverts to configured value. If set to 0, there is no timeout.

Parameter range

0 - 0x1770 (x 100 ms)

Default

0

T8 (D8 Timeout)

Specifies how long pin D8 holds a given value before it reverts to configured value. If set to 0, there is no timeout.

Parameter range

0 - 0x1770 (x 100 ms)

Default

0

T9 (D9 Timeout)

Specifies how long pin D9 holds a given value before it reverts to configured value. If set to **0**, there is no timeout.

Parameter range

0 - 0x1770 (x 100 ms)

Default

0

Q0 (P0 Timeout)

Specifies how long pin **P0** holds a given value before it reverts to configured value. If set to 0, there is no timeout.

Parameter range

0 - 0x1770 (x 100 ms)

Default

0

Q1 (P1 Timeout)

Specifies how long pin P1 holds a given value before it reverts to configured value. If set to 0, there is no timeout.

Parameter range

0 - 0x1770 (x 100 ms)

Default

0

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Q2 (P2 Timeout)

Specifies how long pin P2 holds a given value before it reverts to configured value. If set to 0, there is no timeout.

Parameter range

0 - 0x1770 (x 100 ms)

Default

0

Q3 (P3 Timeout)

Specifies how long pin P3 holds a given value before it reverts to configured value. If set to 0, there is no timeout.

Parameter range

0 - 0x1770 (x 100 ms)

Default

0

Q4 (P4 Timeout)

Specifies how long pin P4 holds a given value before it reverts to configured value. If set to 0, there is no timeout.

Parameter range

0 - 0x1770 (x 100 ms)

Default

0

PT (PWM Output Timeout)

Specifies how long both PWM outputs (**P0**, **P1**) output a given PWM signal before it reverts to zero. If set to 0, there is no timeout. This timeout only affects these pins when they are configured as PWM output.

Parameter range

0 - 0x1770 (x 100 ms)

Default

0xFF

Sleep commands

The following AT commands are sleep commands.

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SM (Sleep Mode)

Sets or displays the sleep mode of the device.

Parameter range

0, 1, 4, 5, 7, 8

Parameter	Description
0	Normal - always awake.
1	Pin sleep. In this mode, the sleep/wake state of the module is controlled by the SLEEP_REQUEST line.
4	Asynchronous Cyclic Sleep. In this mode, the device periodically sleeps and wakes based on the **SP** and **ST** commands.
5	Asynchronous cyclic sleep with pin wake-up. In this mode, the device behaves similar to asynchronous cyclic sleep, but the device also terminates a sleep period when it detects a falling edge of the SLEEP_REQUEST line.
7	Sleep Support—this may also be used for synchronous pulse.
8	Synchronized Cyclic Sleep—this may also be used for synchronous pulse.

Default

0

SO (Sleep Options)

Set or read the sleep options bit field of a device. This command is a bitmask.

You cannot set bit 0 and bit 1 at the same time.

Parameter range

0 - 0x13E

For synchronous sleep devices, the following sleep bit field options are defined:

Bit	Option
0	Preferred sleep coordinator; setting this bit causes a sleep compatible device to always act as sleep coordinator
1	Non-sleep coordinator; setting this bit causes a device to never act as a sleep coordinator
2	Enable API sleep status messages
3	Disable early wake-up for missed syncs
4	Enable node type equality (disables seniority based on device type)
5	Disable coordinator rapid sync deployment mode
8	Always wake for **ST** time.
10	Enable sync sleep randomize I/O sampling

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Bit	Option
0	Preferred sleep coordinator; setting this bit causes a sleep compatible device to always act as sleep coordinator
1	Non-sleep coordinator; setting this bit causes a device to never act as a sleep coordinator
2	Enable API sleep status messages
3	Disable early wake-up for missed syncs
4	Enable node type equality (disables seniority based on device type)
5	Disable coordinator rapid sync deployment mode
8	Always wake for **ST** time
10	Enable sync sleep randomize I/O sampling

Default

0x2 (non-sleep coordinator)

SN (Number of Sleep Periods)

Set or read the number of sleep periods value. This command controls the number of sleep periods that must elapse between assertions of the ON_SLEEP line during the wake time of Asynchronous Cyclic Sleep.

During cycles when ON_SLEEP is de-asserted, the device wakes up and checks for any serial or RF data. If it receives any such data, then it asserts the ON_SLEEP line and the device wakes up fully. Otherwise, the device returns to sleep after checking.

This command does not work with synchronous sleep devices.

Parameter range

1 - 0xFFFF

Default

1

SP (Sleep Period)

Sets or displays the device's sleep time. This command defines the amount of time the device sleeps per cycle.

A time of **0** is used to indicate no sleep at all and is used for synchronous pulse on **DIO9**.

For a node operating as an Indirect Messaging Coordinator, this command defines the amount of time that it will hold an indirect message for an end device. The coordinator will hold the message for (2.5 * **SP**).

Parameter range

0 - 0x15F900 (x 10 ms) (4 hours)

Default

0x190 (4 seconds)

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ST (Wake Time)

Sets or displays the wake time of the device.

For devices in asynchronous sleep, **ST** defines the amount of time that a device stays awake after it receives RF or serial data.

For devices in synchronous sleep or synchronous pulse, **ST** defines the amount of time that a device stays awake when operating in cyclic sleep mode. The command adjusts the value upwards automatically if it is too small to function properly based on other settings.

For devices in synchronous sleep or synchronous pulse, the minimum wake time is a function of **MT**, **SP**, **NH**, **NN**, and platform dependent values. If you increase **SP**, **NH**, **NN**, or **MT**, the **ST** value raises automatically. The maximum value is one hour (0x36EE80 ms).

Parameter range

0x1 - 0x36EE80 (x 1 ms) (one hour)

Default

0x1F40 (8 seconds)

WH (Wake Host)

Sets or displays the wake host timer value.

If you set **WH** to a non-zero value, this timer specifies a time in milliseconds that the device delays after waking from sleep before sending data out the UART or transmitting an I/O sample. If the device receives serial characters, the **WH** timer stops immediately.

When in synchronous sleep, the device shortens its sleep period by the **WH** value to ensure it is prepared to communicate when the network wakes up. When in this sleep mode, the device always stays awake for the **WH** time plus the amount of time it takes to transmit a one-hop unicast to another node.

Parameter range

0 - 0xFFFF (x 1 ms)

Default

0

Diagnostic - sleep status/timing commands

The following AT commands are Diagnostic sleep status/timing commands.

SS (Sleep Status)

Queries a number of Boolean values that describe the device's status.

Bit	Description
0	This bit is true when the network is in its wake state.
1	This bit is true if the node currently acts as a network sleep coordinator.

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Bit	Description
2	This bit is true if the node ever receives a valid sync message after it powers on.
3	This bit is true if the node receives a sync message in the current wake cycle.
4	This bit is true if you alter the sleep settings on the device so that the node nominates itself and sends a sync message with the new settings at the beginning of the next wake cycle.
5	This bit is true if you request that the node nominate itself as the sleep coordinator using the Commissioning Pushbutton or the **CB**2 command.
6	This bit is true if the node is currently in deployment mode.
All other bits	Reserved. Ignore all non-documented bits.

Parameter range

[read-only]

Default

0x40

OS (Operating Sleep Time)

Reads the current network sleep time that the device is synchronized to, in units of 10 milliseconds. If the device has not been synchronized, then **OS** returns the value of **SP**.

If the device synchronizes with a sleeping router network, **OS** may differ from **SP**.

Parameter range

[read-only]

Default

0x190

OW (Operating Wake Time)

Reads the current network wake time that a device is synchronized to, in 1 ms units.

If the device has not been synchronized, then **OW** returns the value of **ST**.

If the device synchronizes with a sleeping router network, **OW** may differ from **ST**.

Parameter range

[read-only]

Default

0x1F40

MS (Missed Sync Messages)

Reads the number of sleep or wake cycles since the device received a sync message.

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Parameter range

[read-only]

Default

0

SQ (Missed Sleep Sync Count)

Counts the number of sleep cycles in which the device does not receive a sleep sync.

Set the value to 0 to reset this value.

When the value reaches 0xFFFF it does not increment anymore.

Parameter range

0 - 0xFFFF

Default

0

Command mode options

The following commands are Command mode option commands.

CC (Command Sequence Character)

Sets or displays the character the device uses between guard times of the Command mode sequence. The Command mode sequence causes the device to enter Command mode.

Note We recommend using the a value within the rage of 0x20 - 0x7F as those are ASCII characters.

Parameter range

0 - 0xFF

Default

0x2B (the ASCII plus character: **+**)

CT (Command Mode Timeout)

Sets or displays the Command mode timeout parameter. If a device does not receive any valid commands within this time period, it returns to Idle mode from Command mode.

Parameter range

2 - 0x1770 (x 100 ms)

Default

0x64 (10 seconds)

CN (Exit Command Mode)

Immediately exits Command Mode and applies pending changes.

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Parameter range

N/A

Default

N/A

GT (Guard Times)

Set the required period of silence before and after the command sequence characters of the Command mode sequence (**GT** + **CC** + **GT**). The period of silence prevents inadvertently entering Command mode.

Parameter range

0x2 - 0x95C (x 1 ms)

Default

0x3E8 (one second)

Firmware commands

The following AT commands are firmware commands.

VL (Version Long)

Shows detailed version information including the application build date and time.

Parameter range

[read-only]

Default

N/A

VR (Firmware Version)

Reads the firmware version on a device.

Parameter range

0 - 0xFFFFFFFF [read-only]

Default

Set in firmware

HV (Hardware Version)

Display the hardware version number of the device.

Parameter range

0 - 0xFFFF [read-only]

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Default

Set in firmware

HS (Hardware Series)

Read the device's hardware series number.

Parameter range

0 - 0xFFFF [read-only]

Default

Set in the firmware

DD (Device Type Identifier)

Stores the Digi device type identifier value. Use this value to differentiate between multiple XBee devices.

Parameter range

0 - 0xFFFFFFFF

Default

0x110000

NP (Maximum Packet Payload Bytes)

Reads the maximum number of RF payload bytes that you can send in a transmission.

Parameter range

0 - 0xFFFF (bytes) [read-only]

Default

0x100

CK (Configuration CRC)

Displays the cyclic redundancy check (CRC) of the current AT command configuration settings. This command allows you to detect an unexpected configuration change on a device.

Parameter range

N/A

Default

N/A

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Operate in API mode

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API mode overview

As an alternative to Transparent operating mode, you can use API operating mode. API mode provides a structured interface where data is communicated through the serial interface in organized packets and in a determined order. This enables you to establish complex communication between devices without having to define your own protocol. The API specifies how commands, command responses and device status messages are sent and received from the device using the serial interface or the SPI interface.

We may add new frame types to future versions of firmware, so build the ability to filter out additional API frames with unknown frame types into your software interface.

Use the AP command to set the operation mode

Use AP (API Mode) to specify the operation mode:

AP command setting	Description
AP = 0	Transparent operating mode, UART serial line replacement with API modes disabled. This is the default option.
AP = 1	API operation.
AP = 2	API operation with escaped characters (only possible on UART).

The API data frame structure differs depending on what mode you choose.

API frame format

An API frame consists of the following:

- Start delimeter
- Length
- Frame data
- Checksum

API operation (AP parameter = 1)

This is the recommended API mode for most applications. The following table shows the data frame structure when you enable this mode:

Frame fields	Byte	Description
Start delimiter	1	0x7E
Length	2 - 3	Most Significant Byte, Least Significant Byte
Frame data	4 - number (n)	API-specific structure
Checksum	n + 1	1 byte

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Any data received prior to the start delimiter is silently discarded. If the frame is not received correctly or if the checksum fails, the XBee replies with a radio status frame indicating the nature of the failure.

API operation with escaped characters (AP parameter = 2)

Setting API to 2 allows escaped control characters in the API frame. Due to its increased complexity, we only recommend this API mode in specific circumstances. API 2 may help improve reliability if the serial interface to the device is unstable or malformed frames are frequently being generated.

When operating in API 2, if an unescaped 0x7E byte is observed, it is treated as the start of a new API frame and all data received prior to this delimiter is silently discarded. For more information on using this API mode, see the Escaped Characters and API Mode 2 in the Digi Knowledge base.

API escaped operating mode works similarly to API mode. The only difference is that when working in API escaped mode, the software must escape any payload bytes that match API frame specific data, such as the start-of-frame byte (0x7E). The following table shows the structure of an API frame with escaped characters:

Frame fields	Byte	Description	
Start delimiter	1	0x7E	
Length	2 - 3	Most Significant Byte, Least Significant Byte	Characters escaped if needed
Frame data	4 - n	API-specific structure	
Checksum	n + 1	1 byte	

Start delimiter field

This field indicates the beginning of a frame. It is always 0x7E. This allows the device to easily detect a new incoming frame.

Escaped characters in API frames

If operating in API mode with escaped characters (**AP** parameter = 2), when sending or receiving a serial data frame, specific data values must be escaped (flagged) so they do not interfere with the data frame sequencing. To escape an interfering data byte, insert 0x7D and follow it with the byte to be escaped (XOR'ed with 0x20).

The following data bytes need to be escaped:

- 0x7E: start delimiter
- 0x7D: escape character
- 0x11: XON
- 0x13: XOFF

To escape a character:

1. Insert 0x7D (escape character).
2. Append it with the byte you want to escape, XOR'ed with 0x20.

In API mode with escaped characters, the length field does not include any escape characters in the frame and the firmware calculates the checksum with non-escaped data.

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Example: escape an API frame

To express the following API non-escaped frame in API operating mode with escaped characters:

Start delimiter	Length	Frame type	Frame Data	Checksum
			Data	
7E	00 0F	17	01 00 13 A2 00 40 AD 14 2E FF FE 02 4E 49	6D

You must escape the 0x13 byte:

1. Insert a 0x7D.
2. XOR byte 0x13 with 0x20: 13 ⊕ 20 = 33

The following figure shows the resulting frame. Note that the length and checksum are the same as the non-escaped frame.

Start delimiter	Length	Frame type	Frame Data	Checksum
			Data	
7E	00 0F	17	01 00 7D 33 A2 00 40 AD 14 2E FF FE 02 4E 49	6D

The length field has a two-byte value that specifies the number of bytes in the frame data field. It does not include the checksum field.

Length field

The length field is a two-byte value that specifies the number of bytes contained in the frame data field. It does not include the checksum field.

Frame data

This field contains the information that a device receives or will transmit. The structure of frame data depends on the purpose of the API frame:

Start delimiter	Length		Frame data									Checksum
			Frame type	Data								
1	2	3	4	5	6	7	8	9	...	n		n+1
0x7E	MSB	LSB	API frame type	Data								Single byte

- **Frame type** is the API frame type identifier. It determines the type of API frame and indicates how the Data field organizes the information.
- **Data** contains the data itself. This information and its order depend on the what type of frame that the Frame type field defines.

Multi-byte values are sent big-endian.

Calculate and verify checksums

To calculate the checksum of an API frame:

1. Add all bytes of the packet, except the start delimiter 0x7E and the length (the second and third bytes).
2. Keep only the lowest 8 bits from the result.
3. Subtract this quantity from 0xFF.

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To verify the checksum of an API frame:

1. Add all bytes including the checksum; do not include the delimiter and length.
2. If the checksum is correct, the last two digits on the far right of the sum equal 0xFF.

Example

Consider the following sample data packet: **7E 00 0A 01 01 50 01 00 48 65 6C 6C 6F B8**+

Byte(s)	Description
7E	Start delimiter
00 0A	Length bytes
01	API identifier
01	API frame ID
50 01	Destination address low
00	Option byte
48 65 6C 6C 6F	Data packet
B8	Checksum

To calculate the check sum you add all bytes of the packet, excluding the frame delimiter **7E** and the length (the second and third bytes):

7E 00 0A 01 01 50 01 00 48 65 6C 6C 6F B8

Add these hex bytes:

01 + 01 + 50 + 01 + 00 + 48 + 65 + 6C + 6C + 6F = 247

Now take the result of 0x247 and keep only the lowest 8 bits which in this example is 0x47 (the two far right digits). Subtract 0x47 from 0xFF and you get 0xB8 (0xFF - 0x47 = 0xB8). 0xB8 is the checksum for this data packet.

If an API data packet is composed with an incorrect checksum, the XBee SX 868 RF Module will consider the packet invalid and will ignore the data.

To verify the check sum of an API packet add all bytes including the checksum (do not include the delimiter and length) and if correct, the last two far right digits of the sum will equal FF.

01 + 01 + 50 + 01 + 00 + 48 + 65 + 6C + 6C + 6F + B8 = 2FF

API serial exchanges

You can use the Frame ID field to assign an identifier to each outgoing API frame. This Frame ID, if non-zero, can correlate between the outgoing frames and the associated responses.

AT command frames

The following image shows the API frame exchange that takes place at the interface when sending an AT command request to read or set an XBee parameter. To disable the response, set the frame ID to 0 in the request.

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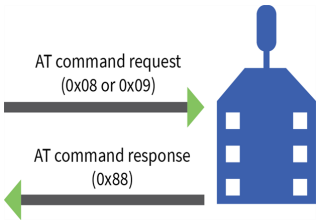
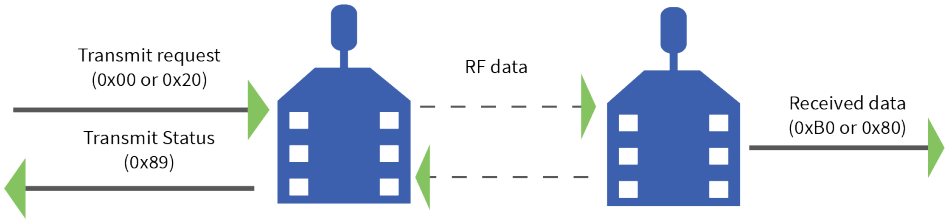


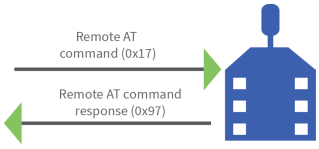
Transmit and receive RF data

The following image shows the API exchanges that take place at the serial interface when sending RF data to another device. The transmit status frame is always sent at the end of a data transmission unless the frame ID is set to 0 in the TX request. If the packet cannot be delivered to the destination, the transmit status frame indicates the cause of failure. The received data frame type (standard 0x90, or explicit 0x91) is set by the **AP** command.



Remote AT commands

The following image shows the API frame exchanges that take place at the serial interface when sending a remote AT command. A remote command response frame is not sent out the serial interface if the remote device does not receive the remote command.



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Frame descriptions

The following sections describe the API frames.

Local AT Command Request - 0x08 149
Queue Local AT Command Request - 0x09 151
Transmit Request - 0x10 153
Explicit Addressing Command Request - 0x11 156
Remote AT Command Request - 0x17 160
Local AT Command Response - 0x88 163
Modem Status - 0x8A 165
Modem status codes 166
Extended Transmit Status - 0x8B 168
Route Information - 0x8D 170
Aggregate Addressing Update - 0x8E 172
Receive Packet - 0x90 173
Explicit Receive Indicator - 0x91 175
I/O Sample Indicator - 0x92 177
Node Identification Indicator - 0x95 180
Remote AT Command Response- 0x97 183

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Local AT Command Request - 0x08

Response frame: Local AT Command Response - 0x88

Description

This frame type is used to query or set command parameters on the local device. Any parameter that is set with this frame type will apply the change immediately. If you wish to queue multiple parameter changes and apply them later, use the Queue Local AT Command Request - 0x09 instead.

When querying parameter values, this frame behaves identically to Queue Local AT Command Request - 0x09: You can query parameter values by sending this frame with a command but no parameter value field—the two-byte AT command is immediately followed by the frame checksum. When an AT command is queried, a Local AT Command Response - 0x88 frame is populated with the parameter value that is currently set on the device. The Frame ID of the 0x88 response is the same one set by the command in the 0x08 request frame.

Format

The following table provides the contents of the frame. For details on frame structure, see API frame format.

Offset	Size	Frame Field	Description
0	8-bit	Start Delimiter	Indicates the start of an API frame.
1	16-bit	Length	Number of bytes between the length and checksum.
3	8-bit	**Frame type**	Local AT Command Request - **0x08**
4	8-bit	**Frame ID**	Identifies the data frame for the host to correlate with a subsequent response. If set to**0**, the device will not emit a response frame.
5	16-bit	**AT command**	The two ASCII characters that identify the AT Command.
7-n	variable	**Parameter value (optional)**	If present, indicates the requested parameter value to set the given register. If no characters are present, it queries the current parameter value and returns the result in the response.
EOF	8-bit	Checksum	0xFF minus the 8-bit sum of bytes from offset 3 to this byte (between length and checksum).

Examples

Each example is written without escapes (**AP** = **1**) and all bytes are represented in hex format. For brevity, the start delimiter, length, and checksum fields have been excluded.

Set the local command parameter

Set the **NI** string of the radio to "**End Device**".

The corresponding Local AT Command Response - 0x88 with a matching Frame ID will indicate whether the parameter change succeeded.

```
7E 00 0E 08 A1 4E 49 45 6E 64 20 44 65 76 69 63 65 38
```


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Frame type	Frame ID	AT command	Parameter value
0x08	0xA1	0x4E49	0x456E6420446576696365
Request	*Matches response*	*"NI"*	*"End Device"*

Query local command parameter

Query the temperature of the module—**TP** command.

The corresponding Local AT Command Response - 0x88 with a matching Frame ID will return the temperature value.

```
7E 00 04 08 17 54 50 3C
```

Frame type	Frame ID	AT command	Parameter value
0x08	0x17	0x5450	(omitted)
Request	*Matches response*	*"TP"*	*Query the parameter*

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Queue Local AT Command Request - 0x09

Response frame: Local AT Command Response - 0x88

Description

This frame type is used to query or set queued command parameters on the local device. In contrast to Local AT Command Request - 0x08, this frame queues new parameter values and does not apply them until you either:

- Issue a Local AT Command using the 0x08 frame
- Issue an **AC** command—queued or otherwise

When querying parameter values, this frame behaves identically to Local AT Command Request - 0x08: You can query parameter values by sending this frame with a command but no parameter value field—the two-byte AT command is immediately followed by the frame checksum. When an AT command is queried, a Local AT Command Response - 0x88 frame is populated with the parameter value that is currently set on the device. The Frame ID of the 0x88 response is the same one set by the command in the 0x09 request frame.

Format

The following table provides the contents of the frame. For details on frame structure, see API frame format.

Offset	Size	Frame Field	Description
0	8-bit	Start Delimiter	Indicates the start of an API frame.
1	16-bit	Length	Number of bytes between the length and checksum.
3	8-bit	**Frame type**	Queue Local AT Command Request - **0x09**
4	8-bit	**Frame ID**	Identifies the data frame for the host to correlate with a subsequent response. If set to**0**, the device will not emit a response frame.
5	16-bit	**AT command**	The two ASCII characters that identify the AT Command.
7-n	variable	**Parameter value (optional)**	If present, indicates the requested parameter value to set the given register at a later time. If no characters are present, it queries the current parameter value and returns the result in the response.
EOF	8-bit	Checksum	0xFF minus the 8-bit sum of bytes from offset 3 to this byte (between length and checksum).

Examples

Each example is written without escapes (**AP** = **1**) and all bytes are represented in hex format. For brevity, the start delimiter, length, and checksum fields have been excluded.

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Queue setting local command parameter

Set the UART baud rate to 115200, but do not apply changes immediately.

The device will continue to operate at the current baud rate until the change is applied with a subsequent **AC** command.

The corresponding Local AT Command Response - 0x88 with a matching Frame ID will indicate whether the parameter change succeeded.

```
7E 00 05 09 53 42 44 07 16
```

Frame type	Frame ID	AT command	Parameter value
0x09	0x53	0x4244	0x07
Request	*Matches response*	*"BD"*	*7 = 115200 baud*

Query local command parameter

Query the temperature of the module (**TP** command).

The corresponding Local AT Command Response - 0x88 frame with a matching Frame ID will return the temperature value.

```
7E 00 04 09 17 54 50 3B
```

Frame type	Frame ID	AT command	Parameter value
0x09	0x17	0x5450	(omitted)
Request	*Matches response*	*"TP"*	*Query the parameter*

Transmit Request - 0x10

Response frame: Extended Transmit Status - 0x8B

Description

This frame type is used to send payload data as an RF packet to a specific destination. This frame type is typically used for transmitting serial data to one or more remote devices.

The endpoints used for these data transmissions are defined by the **SE** and **EP** commands and the cluster ID defined by the **CI** command—excluding 802.15.4. To define the application-layer addressing fields on a per-packet basis, use the Explicit Addressing Command Request - 0x11 instead.

Query the **NP** command to read the maximum number of payload bytes that can be sent.

64-bit addressing

- For broadcast transmissions, set the 64-bit destination address to **0x000000000000FFFF**
- For unicast transmissions, set the 64-bit address field to the address of the desired destination node

Format

The following table provides the contents of the frame. For details on frame structure, see API frame format.

Offset	Size	Frame Field	Description
0	8-bit	Start Delimiter	Indicates the start of an API frame.
1	16-bit	Length	Number of bytes between the length and checksum.
3	8-bit	**Frame type**	Transmit Request - **0x10**
4	8-bit	**Frame ID**	Identifies the data frame for the host to correlate with a subsequent response frame. If set to **0**, the device will not emit a response frame.
5	64-bit	**64-bit destination address**	Set to the 64-bit IEEE address of the destination device. Broadcast address is **0x000000000000FFFF**.
13	16-bit	**Reserved**	Unused, but this field is typically set to **0xFFFE**.
15	8-bit	**Broadcast radius**	Sets the maximum number of hops a broadcast transmission can traverse. This parameter is only used for broadcast transmissions. If set to**0**—recommended—the value of **NH**specifies the broadcast radius.

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Offset	Size	Frame Field	Description
16	8-bit	**Transmit options**	See the Transmit options bit field table below for available options. If set to **0**, the value of **TO** specifies the transmit options.
17-n	variable	**Payload data**	Data to be sent to the destination device. Up to **NP** bytes per packet.
EOF	8-bit	Checksum	0xFF minus the 8-bit sum of bytes from offset 3 to this byte (between length and checksum).

Transmit options bit field

The available transmit options vary depending on the protocol being used. Bitfield options can be combined. Set all unused bits to **0**.

0	Disable ACK [**0x01**]	Disable acknowledgments on all unicasts.
1	Disable route discoveries [**0x02**]	Disable Route Discovery on all DigiMesh unicasts.
2	Unicast NACK [**0x04**]	Enable unicast NACK messages on DigiMesh transmissions When set, a failed transmission will generate a Route Information - 0x8D frame for diagnosis.
3	Unicast trace route [**0x08**]	Enable a unicast Trace Route on DigiMesh transmissions When set, the transmission will generate a Route Information - 0x8D frame.
5	Reserved	<set this bit to 0>
6,7	Delivery method	b'00 = If **BR** = **0** then packet type will be Point-multipoint otherwise it will be DigiMesh b'01 = Point-multipoint [**0x40**] b'10 = Repeater mode, Directed Broadcast [**0x80**] b'11 = DigiMesh—not available when **BR** = **0** [**0xC0**]

Examples

Each example is written without escapes (**AP**=**1**) and all bytes are represented in hex format. For brevity, the start delimiter, length, and checksum fields have been excluded.

64-bit unicast

Sending a unicast transmission to a device with the 64-bit address of **0013A20012345678** with the serial data "**TxData**". Transmit options are set to **0**, which means the transmission will send using the options set by the **TO** command.

The corresponding Legacy TX Status frame - 0x89 response with a matching Frame ID will indicate whether the transmission succeeded.

```
7E 00 14 10 52 00 13 A2 00 12 34 56 78 FF FE 00 00 54 78 44 61 74 61 91
```


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Frame type	Frame ID	64-bit dest	Reserved	Bcast radius	Options	RF data
0x10	0x52	0x0013A200 12345678	0xFFFE	0x00	0x00	0x547844617461
Request	*Matches response*	*Destination*	*Unused*	*N/A*	*Will use **TO***	*"TxData"*

64-bit broadcast

Sending a broadcast transmission of the serial data "**Broadcast**" to neighboring devices and suppressing the corresponding response by setting Frame ID to **0**.

```
7E 00 17 10 00 00 00 00 00 00 00 FF FF FF FE 01 00 42 72 6F 61 64 63 61 73 74 60
```

Frame type	Frame ID	64-bit dest	Reserved	Bcast radius	Tx Options	RF data
0x10	0x00	0x00000000 0000FFFF	0xFFFE	0x01	0x00	0x42726F616463617374
Request	*Suppress response*	*Broadcast address*	*Unused*	*Single hop broadcast*	*Will use **TO***	*"Broadcast"*

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Explicit Addressing Command Request - 0x11

Response frame: Extended Transmit Status - 0x8B

Description

This frame type is used to send payload data as an RF packet to a specific destination using application-layer addressing fields. The behavior of this frame is similar to Transmit Request - 0x10, but with additional fields available for user-defined endpoints, cluster ID, and profile ID.

This frame type is typically used for OTA updates, and serial data transmissions.

Query NP (Maximum Packet Payload Bytes) to read the maximum number of payload bytes that can be sent.

64-bit addressing

- For broadcast transmissions, set the 64-bit destination address to **0x000000000000FFFF**
- For unicast transmissions, set the 64-bit address field to the address of the desired destination node

Reserved endpoints

For serial data transmissions, the **0xE8** endpoint should be used for both source and destination endpoints.

The active Digi endpoints are:

- **0xE8** - Digi Data endpoint
- **0xE6** - Digi Device Object (DDO) endpoint
- **0xE4** - XBee3 - Secure Session Client endpoint

Reserved cluster IDs

For serial data transmissions, the **0x0011** cluster ID should be used.

The following cluster IDs can be used on the **0xE8** data endpoint:

- **0x0011**- Transparent data cluster ID
- **0x0012** - Loopback cluster ID:The destination node echoes any transmitted packet back to the source device. Cannot be used on XBee 802.15.4 firmware.

Reserved profile IDs

The Digi profile ID of **0xC105** should be used when sending serial data between XBee devices.

Format

The following table provides the contents of the frame. For details on the frame structure, see API frame format.

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Offset	Size	Frame Field	Description
0	8-bit	Start Delimiter	Indicates the start of an API frame.
1	16-bit	Length	Number of bytes between the length and checksum.
3	8-bit	**Frame type**	Explicit Addressing Command Request - **0x11**
4	8-bit	**Frame ID**	Identifies the data frame for the host to correlate with a subsequent response. If set to**0**, the device will not emit a response frame.
5	64-bit	**64-bit destination address**	Set to the 64-bit IEEE address of the destination device. Broadcast address is **0x000000000000FFFF**. Zigbee coordinator address is **0x0000000000000000**. When using 16-bit addressing, set this field to **0xFFFFFFFFFFFFFFFF**.
13	16-bit	**Reserved**	Unused, but this field is typically set to **0xFFFE**.
15	8-bit	**Source Endpoint**	Source endpoint for the transmission. Serial data transmissions should use **0xE8**.
16	8-bit	**Destination Endpoint**	Destination endpoint for the transmission. Serial data transmissions should use **0xE8**.
17	16-bit	**Cluster ID**	The Cluster ID that the host uses in the transmission. Serial data transmissions should use **0x11**.
19	16-bit	**Profile ID**	The Profile ID that the host uses in the transmission. Serial data transmissions between XBee devices should use **0xC105**.
21	8-bit	**Broadcast radius**	Sets the maximum number of hops a broadcast transmission can traverse. This parameter is only used for broadcast transmissions. If set to **0** (recommended), the value of **NH** specifies the broadcast radius.
22	8-bit	**Transmit options**	See the Transmit options bit field table below for available options. If set to **0**, the value of **TO** specifies the transmit options.
23-n	variable	**Command data**	Data to be sent to the destination device. Up to **NP** bytes per packet.
EOF	8-bit	Checksum	0xFF minus the 8-bit sum of bytes from offset 3 to this byte (between length and checksum).

Transmit options bit field

The available transmit options vary depending on the protocol being used. Bitfield options can be combined. Set all unused bits to **0**.

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0	Disable ACK [**0x01**]	Disable acknowledgments on all unicasts.
1	Disable route discoveries [**0x02**]	Disable Route Discovery on all DigiMesh unicasts.
2	Unicast NACK [**0x04**]	Enable unicast NACK messages on DigiMesh transmissions When set, a failed transmission will generate a Route Information - 0x8D frame for diagnosis.
3	Unicast trace route [**0x08**]	Enable a unicast Trace Route on DigiMesh transmissions When set, the transmission will generate a Route Information - 0x8D frame.
5	Reserved	<set this bit to 0>
6,7	Delivery method	b'00 = If **BR** = **0** then packet type will be Point-multipoint otherwise it will be DigiMesh b'01 = Point-multipoint [**0x40**] b'10 = Repeater mode, Directed Broadcast [**0x80**] b'11 = DigiMesh—not available when **BR** = **0** [**0xC0**]

Examples

Each example is written without escapes (**AP** = **1**) and all bytes are represented in hex format. For brevity, the start delimiter, length, and checksum fields have been excluded.

64-bit unicast

Sending a unicast transmission to an XBee device with the 64-bit address of **0013A20012345678** with the serial data "**TxData**". Transmit options are set to **0**, which means the transmission will send using the options set by the **TO** command. This transmission is identical to a Transmit Request - 0x10 using default settings.

The corresponding Extended Transmit Status - 0x8B response with a matching Frame ID will indicate whether the transmission succeeded.

```
7E 00 1A 11 87 00 13 A2 00 12 34 56 78 FF FE E8 E8 00 11 C1 05 00 00 54 78 44 61
74 61 B4
```

Frame type	Frame ID	64-bit dest	Reserved	Source EP	Dest EP	Cluster	Profile	Bcast radius	Tx options	Command data
0x11	0x87	0x0013A200 12345678	0xFFFE	0xE8	0xE8	0x0011	0xC105	0x00	0x00	0x547844617461
Explicit request	*Matches response*	*Destination*	*Unused*	*Digi data*	*Digi data*	*Data*	*Digi profile*	*N/A*	*Use **TO***	*"TxData"*

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Loopback Packet

Sending a loopback transmission to an device with the 64-bit address of **0013A20012345678** using Cluster ID **0x0012**. To better understand the raw performance, retries and acknowledgements are disabled.

The corresponding Extended Transmit Status - 0x8B response with a matching Frame ID can be used to verify that the transmission was sent.

The destination will not emit a receive frame, instead it will return the transmission back to the sender. The source device will emit the receive frame—the frame type is determined by the value of **AO**—if the packet looped back successfully.

```
7E 00 1A 11 F8 00 13 A2 00 12 34 56 78 FF FE E8 E8 00 12 C1 05 00 01 54 78 44 61
74 61 41
```

Frame type	Frame ID	64-bit dest	Reserved	Source EP	Dest EP	Cluster	Profile	Bcast radius	Tx options	Command data
0x11	0xF8	0x0013A200 12345678	0xFFFE	0xE8	0xE8	0x0012	0xC105	0x00	0x01	0x5478446174 61
Explicit request	*Matches response*	*Destination*	*Unused*	*Digi data*	*Digi data*	*Data*	*Digi profile*	*N/A*	*Disable retries*	*"TxData"*

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Remote AT Command Request - 0x17

Response frame: Remote AT Command Response- 0x97

Description

This frame type is used to query or set AT command parameters on a remote device.

For parameter changes on the remote device to take effect, you must apply changes, either by setting the **Apply Changes** options bit, or by sending an **AC** command to the remote.

When querying parameter values you can query parameter values by sending this framewith a command but no parameter value field—the two-byte AT command is immediately followed by the frame checksum. When an AT command is queried, a Remote AT Command Response- 0x97 frame is populated with the parameter value that is currently set on the device. The Frame ID of the 0x97 response is the same one set by the command in the 0x17 request frame.

Note Remote AT Command Requests should only be issued as unicast transmissions to avoid potential network disruption. Broadcasts are not acknowledged, so there is no guarantee all devices will receive the request. Responses are returned immediately by all receiving devices, which can cause congestion on a large network.

Format

The following table provides the contents of the frame. For details on frame structure, see API frame format.

Offset	Size	Frame Field	Description
0	8-bit	Start Delimiter	Indicates the start of an API frame.
1	16-bit	Length	Number of bytes between the length and checksum.
3	8-bit	**Frame type**	Remote AT Command Request - **0x17**.
4	8-bit	**Frame ID**	Identifies the data frame for the host to correlate with a subsequent response. If set to **0**, the device will not emit a response frame.
5	64-bit	**64-bit destination address**	Set to the 64-bit IEEE address of the destination device.
13	16-bit	**Reserved**	Unused, but this field is typically set to **0xFFFE**.

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Offset	Size	Frame Field	Description
15	8-bit	**Remote command options**	Bit field of options that apply to the remote AT command request: ■ **Bit 0**: Disable ACK [**0x01**] ■ **Bit 1**: Apply changes on remote [**0x02**] • If not set, changes will not applied until the device receives an **AC** command or a subsequent command change is received with this bit set ■ Bit 2: Reserved (set to 0) ■ Bit 3: Reserved (set to 0) ■ **Bit 4**: Send the remote command securely [**0x10**] **Note** Option values may be combined. Set all unused bits to 0.
16	16-bit	**AT command**	The two ASCII characters that identify the AT Command.
18-n	variable	**Parameter value (optional)**	If present, indicates the requested parameter value to set the given register. If no characters are present, it queries the current parameter value and returns the result in the response.
EOF	8-bit	Checksum	0xFF minus the 8-bit sum of bytes from offset 3 to this byte (between length and checksum).

Examples

Each example is written without escapes—**AP** = **1**—and all bytes are represented in hex format. For brevity, the start delimiter, length, and checksum fields have been excluded.

Set remote command parameter

Set the **NI** string of a device with the 64-bit address of **0013A20012345678** to "**Remote**" and apply the change immediately.

The corresponding Remote AT Command Response- 0x97 with a matching Frame ID will indicate success.

```
7E 00 15 17 27 00 13 A2 00 12 34 56 78 FF FE 02 4E 49 52 65 6D 6F 74 65 F6
```

Frame type	Frame ID	64-bit dest	Reserved	Command options	AT command	Parameter value
0x17	0x27	0x0013A200 12345678	0xFFFE	0x02	0x4E49	0x52656D6F7465
Request	*Matches response*		*Unused*	*Apply Change*	*"NI"*	*"Remote"*

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Queue remote command parameter change

Change the PAN ID of a remote device so it can migrate to a new PAN, since this change would cause network disruption, the change is queued so that it can be made active later with a subsequent **AC** command or written to flash with a queued **WR** command so the change will be active after a power cycle.

The corresponding Remote AT Command Response- 0x97 with a matching Frame ID will indicate success.

```
7E 00 11 17 68 00 13 A2 00 12 34 56 78 FF FE 00 49 44 04 51 D8
```

Frame type	Frame ID	64-bit dest	Reserved	Command options	AT command	Parameter value
0x17	0x68	0x0013A200 12345678	0xFFFE	0x00	0x4944	0x0451
Request	*Matches response*		*Unused*	*Queue Change*	*"ID"*	

Query remote command parameter

Query the temperature of a remote device—**TP** command.

The corresponding Remote AT Command Response- 0x97 with a matching Frame ID will return the temperature value.

```
7E 00 0F 17 FA 00 13 A2 00 12 34 56 78 FF FE 00 54 50 84
```

Frame type	Frame ID	64-bit dest	Reserved	Command options	AT command	Parameter value
0x17	0xFA	0x0013A200 12345678	0xFFFE	0x00	0x5450	(omitted)
Request	*Matches response*		*Unused*	*N/A*	*"TP"*	*Query the parameter*

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Local AT Command Response - 0x88

Request frames:

- Local AT Command Request - 0x08
- Queue Local AT Command Request - 0x09

Description

This frame type is emitted in response to a local AT Command request. Some commands send back multiple response frames; for example, ND (Network Discover). Refer to individual AT command descriptions for details on API response behavior.

This frame is only emitted if the Frame ID in the request is non-zero.

Format

Offset	Size	Frame Field	Description
0	8-bit	Start Delimiter	Indicates the start of an API frame.
1	16-bit	Length	Number of bytes between the length and checksum.
3	8-bit	**Frame type**	Local AT Command Response - **0x88**
4	8-bit	**Frame ID**	Identifies the data frame for the host to correlate with a prior request.
5	16-bit	**AT command**	The two ASCII characters that identify the AT Command.
7	8-bit	**Command status**	Status code for the host's request: **0** = OK **1** = ERROR **2** = Invalid command **3** = Invalid parameter
8-n	variable	**Command data (optional)**	If the host requested a command parameter change, this field will be omitted. If the host queried a command by omitting the parameter value in the request, this field will return the value currently set on the device.
EOF	8-bit	Checksum	0xFF minus the 8-bit sum of bytes from offset 3 to this byte (between length and checksum).

Examples

Each example is written without escapes (**AP** = **1**) and all bytes are represented in hex format. For brevity, the start delimiter, length, and checksum fields have been excluded.

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Set local command parameter

Host set the NI string of the local device to "**End Device**" using a 0x08 request frame.

The corresponding Local AT Command Response - 0x88 with a matching Frame ID is emitted as a response:

```
7E 00 05 88 01 4E 49 00 DF
```

Frame type	Frame ID	AT command	Command Status	Command data
0x88	0xA1	0x4E49	0x00	(omitted)
Response	*Matches request*	*"NI"*	*Success*	*Parameter changes return no data*

Query local command parameter

Host queries the temperature of the local device—**TP** command—using a 0x08 request frame.

The corresponding Local AT Command Response - 0x88 with a matching Frame ID is emitted with the temperature value as a response:

```
7E 00 07 88 01 54 50 00 FF FE D5
```

Frame type	Frame ID	AT command	Command Status	Command data
0x88	0x17	0x5450	0x00	0xFFFE
Response	*Matches request*	*"TP"*	*Success*	*-2 ℃*

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Modem Status - 0x8A

Description

This frame type is emitted in response to specific conditions. The status field of this frame indicates the device behavior.

Format

The following table provides the contents of the frame. For details on frame structure, see API frame format.

Offset	Size	Frame Field	Description
0	8-bit	Start Delimiter	Indicates the start of an API frame.
1	16-bit	Length	Number of bytes between the length and checksum.
3	8-bit	**Frame type**	Modem Status - **0x8A**

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Offset	Size	Frame Field	Description
4	8-bit	**Modem status**	Complete list of modem statuses: **0x00** = Hardware reset or power up **0x01** = Watchdog timer reset **0x02** = Joined network **0x03** = Left network **0x06** = Coordinator started **0x07** = Network security key was updated **0x0B** = Network woke up **0x0C** = Network went to sleep **0x0D** = Voltage supply limit exceeded **0x0E** = Remote Manager connected **0x0F** = Remote Manager disconnected **0x11** = Modem configuration changed while join in progress **0x12** = Access fault **0x13** = Fatal error **0x3B** = Secure session successfully established **0x3C** = Secure session ended **0x3D** = Secure session authentication failed **0x3E** = Coordinator detected a PAN ID conflict but took no action **0x3F** = Coordinator changed PAN ID due to a conflict **0x32** = BLE Connect **0x33** = BLE Disconnect **0x34** = Bandmask configuration failed **0x35** = Cellular component update started **0x36** = Cellular component update failed **0x37** = Cellular component update completed **0x38** = XBee firmware update started **0x39** = XBee firmware update failed **0x3A** = XBee firmware update applying **0x40** = Router PAN ID was changed by coordinator due to a conflict **0x42** = Network Watchdog timeout expired **0x80** through **0xFF** = Stack error Refer to the tables below for a filtered list of status codes that are appropriate for specific devices.
EOF	8-bit	Checksum	0xFF minus the 8-bit sum of bytes from offset 3 to this byte (between length and checksum).

Modem status codes

Statuses for specific modem types are listed here.

Examples

Each example is written without escapes (**AP** = **1**) and all bytes are represented in hex format. For brevity, the start delimiter, length, and checksum fields have been excluded.

Boot status

When a device powers up, it returns the following API frame:

```
7E 00 02 8A 00 75
```


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Frame type	Modem Status
0x8A	0x00
Status	*Hardware Reset*

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Extended Transmit Status - 0x8B

Request frames:

- Transmit Request - 0x10
- Explicit Addressing Command Request - 0x11

Description

This frame type is emitted when a network transmission request completes. The status field of this frame indicates whether the request succeeded or failed and the reason. This frame type provides additional networking details about the transmission.

This frame is only emitted if the Frame ID in the request is non-zero.

Note Broadcast transmissions are not acknowledged and always return a status of **0x00**, even if the delivery failed.

Format

The following table provides the contents of the frame. For details on frame structure, see API frame format.

Offset	Size	Frame Field	Description
0	8-bit	Start Delimiter	Indicates the start of an API frame.
1	16-bit	Length	Number of bytes between the length and checksum.
3	8-bit	**Frame type**	Transmit Status - **0x8B**
4	8-bit	**Frame ID**	Identifies the data frame for the host to correlate with a prior request.
5	16-bit	**Reserved**	Unused, but this field is typically set to **0xFFFE**.
7	8-bit	**Transmit retry count**	The number of application transmission retries that occur.
8	8-bit	**Delivery status**	Complete list of delivery statuses: **0x00** = Success **0x01** = MAC ACK failure **0x02** = CCA/LBT failure **0x03** = Indirect message unrequested / no spectrum available **0x21** = Network ACK failure **0x25** = Route not found **0x31** = Internal resource error **0x32** = Resource error lack of free buffers, timers, etc. **0x74** = Data payload too large **0x75** = Indirect message unrequested

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Offset	Size	Frame Field	Description
9	8-bit	**Discovery status**	Complete list of delivery statuses: **0x00** = No discovery overhead **0x02** = Route discovery
EOF	8-bit	Checksum	0xFF minus the 8-bit sum of bytes from offset 3 to this byte (between length and checksum).

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Route Information - 0x8D

Request frames:

- Transmit Request - 0x10
- Explicit Addressing Command Request - 0x11

Description

This frame type contains the DigiMesh routing information for a remote device on the network. This route information can be used to diagnose marginal links between devices across multiple hops.

This frame type is emitted in response to a DigiMesh unicast transmission request which has Trace Routing or NACK enabled. See Trace route option and NACK messages for more information.

Format

Offset	Size	Frame Field	Description
0	8-bit	Start Delimiter	Indicates the start of an API frame.
1	16-bit	Length	Number of bytes between the length and checksum.
3	8-bit	**Frame type**	Route Information - **0x8D**
4	8-bit	**Source event**	Event that caused the route information to be generated: **0x11** = NACK **0x12** = Trace route
5	8-bit	**Data length**	The number of bytes that follow, excluding the checksum. If the length increases, new items have been added to the end of the list for future revisions.
6	32-bit	**Timestamp**	System timer value on the node generating the Route Information Packet.The timestamp is in microseconds. Only use this value for relative time measurements because the time stamp count restarts approximately every hour.
10	8-bit	**ACK timeout count**	The number of MAC ACK timeouts that occur.
11	8-bit	**TX blocked count**	The number of times the transmission was blocked due to reception in progress.
12	8-bit	**Reserved**	Not used.
14	64-bit	**Destination address**	The 64-bit IEEE address of the final destination node of this network-level transmission.
21	64-bit	**Source address**	The 64-bit IEEE address of the source node of this network-level transmission.

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Offset	Size	Frame Field	Description
29	64-bit	**Responder address**	The 64-bit IEEE address of the node that generates this Route Information packet after it sends (or attempts to send) the data packet to the next hop (the Receiver node).
37	64-bit	**Receiver address**	The 64-bit IEEE address of the node that the device sends (or attempts to send) the data packet.
EOF	8-bit	Checksum	0xFF minus the 8-bit sum of bytes from offset 3 to this byte (between length and checksum).

Examples

Each example is written without escapes (**AP** = **1**) and all bytes are represented in hex format. For brevity, the start delimiter, length, and checksum fields have been excluded.

Routing information

The following example represents a possible Route Information Packet. A device emits this frame when it performs a trace route enabled transmission from one device—serial number 0x0013A200 4052AAAA—to another—serial number 0x0013A200 4052DDDD—across a DigiMesh network.

This particular frame indicates that the network successfully forwards the transmission from one device—serial number 0x0013A200 4052BBBB—to another device—serial number 0x0013A200 4052CCCC.

```
7E 00 2A 8D 12 27 6B EB CA 93 00 00 00 00 13 A2 00 40 52 DD DD 00 13 A2 00 40 52
AA AA 00 13 A2 00 40 52 BB BB 00 13 A2 00 40 52 CC CC 4E
```

Frame type	Source event	Data length	Timestamp	ACK timeout	TX Blocked	Reserved	Dest address	Source address	Responder address	Receiver address
0x8D	0x12	0x27	0x6BEB CA93	0x00	0x00	0x00	0x0013A200 4052DDDD	0x0013A200 4052AAAA	0x0013A200 4052BBBB	0x0013A200 4052CCCC
Route	*Trace Route*		*~30 minutes*	*No retries this hop*	*No error*	*N/A*	*Destination*	*Source*	*Node that sent this information*	*Next hop*

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Aggregate Addressing Update - 0x8E

Description

This frame type is emitted on devices that update it addressing information in response to a network aggregator issuing an addressing update. A network aggregator is defined by a device on the network who has had the AG (Aggregator Support) command issued. A device on the network who's current **DH** and **DL** matches the address provided in the **AG** command request will update **DH** and **DL** and emit this frame.

Format

Offset	Size	Frame Field	Description
0	8-bit	Start Delimiter	Indicates the start of an API frame.
1	16-bit	Length	Number of bytes between the length and checksum.
3	8-bit	**Frame type**	Aggregate Addressing Update - **0x8E**
4	8-bit	**Reserved**	Reserved for future functionality. This field returns 0.
5	64-bit	**New address**	Address to which **DH** and **DL** are being set.
13	64-bit	**Old address**	Address to which **DH** and **DL** were previously set.
EOF	8-bit	Checksum	0xFF minus the 8-bit sum of bytes from offset 3 to this byte (between length and checksum).

Examples

Each example is written without escapes (**AP** = **1**) and all bytes are represented in hex format. For brevity, the start delimiter, length, and checksum fields have been excluded.

Aggregate address update

In the following example, a device with destination address (**DH**/**DL**) of 0x0013A200 4052AAAA updates its destination address to 0x0013A200 4052BBBB.

```
7E 00 12 8E 00 00 13 A2 00 40 52 BB BB 00 13 A2 00 40 52 AA AA 19
```

Frame type	Reserved	New address	Old address
0x8E	0x00	0x0013A200 4052BBBB	0x0013A200 4052AAAA
Update	*N/A*	*What **DH**/**DL** is now set to*	*What **DH**/**DL** was set to*

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Receive Packet - 0x90

Request frames:

- Transmit Request - 0x10
- Explicit Addressing Command Request - 0x11

Description

This frame type is emitted when a device configured with standard API output—AO (API Options) = **0**—receives an RF data packet.

Typically this frame is emitted as a result of a device on the network sending serial data using the Transmit Request - 0x10 or Explicit Addressing Command Request - 0x11 addressed either as a broadcast or unicast transmission.

Format

The following table provides the contents of the frame. For details on frame structure, see API frame format.

Offset	Size	Frame Field	Description
0	8-bit	Start Delimiter	Indicates the start of an API frame.
1	16-bit	Length	Number of bytes between the length and checksum.
3	8-bit	**Frame type**	Receive Packet - **0x90**
4	64-bit	**64-bit source address**	The sender's 64-bit address.
12	16-bit	**Reserved**	Unused, but this field is typically set to **0xFFFE**.

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Offset	Size	Frame Field	Description
14	8-bit	**Receive options**	Bit field of options that apply to the received message: ■ **Bit 0**: Packet was Acknowledged [**0x01**] ■ **Bit 1**: Packet was sent as a broadcast [**0x02**] ■ **Bit 2**: Reserved ■ **Bit 3**: Reserved ■ **Bit 4**: Reserved ■ **Bit 5**: Reserved ■ **Bit 6**: Reserved ■ **Bit 6, 7**: DigiMesh delivery method • b'00 = <invalid option> • b'01 = Point-multipoint [**0x40**] • b'10 = Directed Broadcast [**0x80**] • b'11 = DigiMesh [**0xC0**] **Note** Option values may be combined.
15-n	variable	**Received data**	The RF payload data that the device receives.
EOF	8-bit	Checksum	0xFF minus the 8-bit sum of bytes from offset 3 to this byte (between length and checksum).

Examples

Each example is written without escapes (**AP** = **1**) and all bytes are represented in hex format. For brevity, the start delimiter, length, and checksum fields have been excluded.

64-bit unicast

A device with the 64-bit address of **0013A20041AEB54E** sent a unicast transmission to a specific device with the payload of "**TxData**". The following frame is emitted if the destination is configured with **AO** = **0**.

```
7E 00 12 90 00 13 A2 00 41 AE B5 4E FF FE C1 54 78 44 61 74 61 C4
```

Frame type	64-bit source	Reserved	Rx options	Received data
0x90	0x0013A200 41AEB54E	0x5614	0xC1	0x547844617461
Output		*Unused*	*ACK was sent in DigiMesh mode*	*"TxData"*

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Explicit Receive Indicator - 0x91

Request frames:

- Transmit Request - 0x10
- Explicit Addressing Command Request - 0x11

Description

This frame type is emitted when a device configured with explicit API output—AO (API Options) bit1 set—receives a packet.

Typically this frame is emitted as a result of a device on the network sending serial data using the Transmit Request - 0x10 or Explicit Addressing Command Request - 0x11 addressed either as a broadcast or unicast transmission.

Format

The following table provides the contents of the frame. For details on frame structure, see API frame format.

Offset	Size	Frame Field	Description
0	8-bit	Start Delimiter	Indicates the start of an API frame.
1	16-bit	Length	Number of bytes between the length and checksum.
3	8-bit	**Frame type**	Explicit Receive Indicator - **0x91**
4	64-bit	**64-bit source address**	The sender's 64-bit address.
12	16-bit	**Reserved**	Unused, but this field is typically set to **0xFFFE**.
14	8-bit	**Source endpoint**	Endpoint of the source that initiated transmission.
15	8-bit	**Destination endpoint**	Endpoint of the destination that the message is addressed to.
16	16-bit	**Cluster ID**	The Cluster ID that the frame is addressed to.
18	16-bit	**Profile ID**	The Profile ID that the fame is addressed to.

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Offset	Size	Frame Field	Description
20	8-bit	**Receive options**	Bit field of options that apply to the received message for packets sent using Digi endpoints (0xDC-0xEE): ■ **Bit 0**: Packet was Acknowledged [**0x01**] ■ **Bit 1**: Packet was sent as a broadcast [**0x02**] ■ **Bit 2**: Reserved ■ **Bit 3**: Reserved ■ **Bit 4**: Reserved ■ **Bit 5**: Reserved ■ **Bit 6**: Reserved ■ **Bit 6, 7**: DigiMesh delivery method • b'00 = <invalid option> • b'01 = Point-multipoint [**0x40**] • b'10 = Directed Broadcast [**0x80**] • b'11 = DigiMesh [**0xC0**] **Note** Option values may be combined.
21-n	variable	**Received data**	The RF payload data that the device receives.
EOF	8-bit	Checksum	0xFF minus the 8-bit sum of bytes from offset 3 to this byte (between length and checksum).

Examples

Each example is written without escapes (**AP** = **1**) and all bytes are represented in hex format. For brevity, the start delimiter, length, and checksum fields have been excluded.

64-bit unicast

A device with the 64-bit address of **0013A20087654321** sent a unicast transmission to a specific device with the payload of "**TxData**". The following frame is emitted if the destination is configured with **AO** > **1**.

```
7E 00 18 91 00 13 A2 00 41 AE B5 4E FF FE E8 E8 00 11 C1 05 C1 54 78 44 61 74 61
1C
```

Frame type	64-bit source	Reserved	Source EP	Dest EP	Cluster	Profile	Rx options	Received data
0x91	0x0013A20041AEB54E	0x87BD	0xE8	0xE8	0x0011	0xC105	0xC1	0x547844617461
Explicit output		*Unused*	*Digi data*	*Digi data*	*Data*	*Digi profile*	*ACK was sent in DigiMesh network*	*"TxData"*

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I/O Sample Indicator - 0x92

Description

This frame type is emitted when a device configured with standard API output—AO (API Options) = **0**—receives an I/O sample frame from a remote device. Only devices running in API mode will send I/O samples out the serial port.

Format

Offset	Size	Frame Field	Description
0	8-bit	Start Delimiter	Indicates the start of an API frame.
1	16-bit	Length	Number of bytes between the length and checksum.
3	8-bit	**Frame type**	I/O Sample Indicator - **0x92**
4	64-bit	**64-bit source address**	The sender's 64-bit IEEE address.
12	16-bit	**Reserved**	Unused, but typically **0XFFFE**.
14	8-bit	**Receive options**	Bit field of options that apply to the received message: ■ **Bit 0**: Packet was Acknowledged [**0x01**] ■ **Bit 1**: Packet was sent as a broadcast [**0x02**] Note Option values may be combined.
15	8-bit	**Number of samples**	The number of sample sets included in the payload. This field typically reports 1 sample.

Offset	Size	Frame Field	Description
16	16-bit	**Digital sample mask**	Bit field that indicates which I/O lines on the remote are configured as digital inputs or outputs, if any: **bit 0**: DIO0 **bit 1**: DIO1 **bit 2**: DIO2 **bit 3**: DIO3 **bit 4**: DIO4 **bit 5**: DIO5 **bit 6**: DIO6 **bit 7**: DIO7 **bit 8**: DIO8 **bit 9**: DIO9 **bit 10**: DIO10 **bit 11**: DIO11 **bit 12**: DIO12 **bit 13**: DIO13 **bit 14**: DIO14 bit 15: N/A For example, a digital channel mask of **0x002F** means DIO **0**, **1**, **2**, **3**, and **5** are enabled as digital I/O.
18	8-bit	**Analog sample mask**	Bit field that indicates which I/O lines on the remote are configured as analog input, if any: **bit 0**: AD0 **bit 1**: AD1 **bit 2**: AD2 **bit 3**: AD3 **bit 7**: Supply Voltage (enabled with **V+** command)
19	16-bit	**Digital samples (if included)**	If the sample set includes any digital I/O lines (**Digital channel mask** > **0**), this field contain samples for all enabled digital I/O lines. If no digital lines are configured as inputs or outputs, this field will be omitted. DIO lines that do not have sampling enabled return 0. Bits in this field are arranged the same as they are in the Digital channel mask field.
22	16-bit variable	**Analog samples (if included)**	If the sample set includes any analog I/O lines (Analog channel mask > 0), each enabled analog input returns a 16-bit value indicating the ADC measurement of that input. Analog samples are ordered sequentially from AD0 to AD3.
EOF	8-bit	Checksum	0xFF minus the 8-bit sum of bytes from offset 3 to this byte (between length and checksum).

Examples

Each example is written without escapes (**AP** = **1**) and all bytes are represented in hex format. For brevity, the start delimiter, length, and checksum fields have been excluded.

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I/O sample

A device with the 64-bit address of **0013A20012345678** is configured to periodically send I/O sample data to a particular device. The device is configured with DIO3, DIO4, and DIO5 configured as digital I/O, and AD1 and AD2 configured as an analog input.

The destination will emit the following frame:

```
7E 00 16 92 00 13 A2 00 12 34 56 78 FF FE C1 01 00 38 06 00 28 02 25 00 F8 E8
```

Frame type	64-bit source	Reserved	Rx options	Num samples	Digital channel mask	Analog channel mask	Digital samples	Analog sample 1	Analog sample 2
0x92	0x0013A200 12345678	0x87AC	0xC1	0x01	0x0038	0x06	0x0028	0x0225	0x00F8
Sample		*Unused*	*ACK was sent in mesh network*	*Single sample (typical)*	*b'00**111**000 DIO3, DIO4, and DIO5 enabled*	*b'0**11**0 AD1 and AD2 enabled*	*b'00**101**000 DIO3 and DIO5 are HIGH; DI04 is LOW*	*AD1 data*	*AD2 data*

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Node Identification Indicator - 0x95

Description

This frame type is emitted when a node identification broadcast is received. The node identification indicator contains information about the identifying device, such as address, identifier string (**NI**), and other relevant data.

A node identifies itself to the network under these conditions:

- The commissioning button is pressed once.
- A **CB 1** command is issued.
- A synchronous sleep node stays awake for 30 seconds in order to receive a sync message. It also sends out an identifying message.

See ND (Network Discover) for information on the payload formatting.

See NO (Node Discovery Options) for configuration options that modify the output of this frame.

Format

Offset	Size	Frame Field	Description
0	8-bit	Start Delimiter	Indicates the start of an API frame.
1	16-bit	Length	Number of bytes between the length and checksum.
3	8-bit	**Frame type**	Node Identification Indicator - **0x95**
4	64-bit	**64-bit source address**	The sender's 64-bit address.
12	16-bit	**Reserved**	Unused, but this field is typically set to **0xFFFE**.
14	8-bit	**Options**	Bit field of options that apply to the received message: ■ Bit 0: Packet was Acknowledged [**0x01**] ■ **Bit 1**: Packet was sent as a broadcast [**0x02**] ■ **Bit 2**: Reserved ■ Bit 4: Reserved ■ Bit 5: Reserved ■ **Bit 6, 7**: DigiMesh delivery method • b'00 = <invalid option> • b'01 = Point-multipoint [**0x40**] • b'10 = Directed Broadcast [**0x80**] • b'11 = DigiMesh [**0xC0**] **Note** Option values may be combined.

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Offset	Size	Frame Field	Description
15	16-bit	**Reserved**	Unused, but this field is typically set to **0xFFFE**.
17	64-bit	**64-bit remote address**	The 64-bit address of the device that sent the Node Identification.
25	variable (2-byte minimum)	**Node identification string**	Node identification string on the remote device set by NI (Node Identifier). The identification string is terminated with a NULL byte (0x00).
27+NI	16-bit	**Reserved**	Unused, but this field is typically set to **0xFFFE**.
29+NI	8-bit	**Network device type**	What type of network device the remote identifies as: 0 = Coordinator 1 = Router 2 = End Device
30+NI	8-bit	**Source event**	The event that caused the node identification broadcast to be sent. 0 = Reserved 1 = Frame sent by node identification pushbutton event—see D0 (DIO0/AD0).
31+NI	16-bit	**Digi Profile ID**	The Digi application Profile ID—**0xC105**.
33+NI	16-bit	**Digi Manufacturer ID**	The Digi Manufacturer ID—**0x101E**.
35+NI	32-bit	**Device type identifier (optional)**	The user-defined device type on the remote device set by DD (Device Type Identifier). Only included if the receiving device has the appropriate NO (Node Discovery Options) bit set.
EOF-1	8-bit	**RSSI (optional)**	The RSSI of the last hop that relayed the message. Only included if the receiving device has the appropriate NO (Node Discovery Options) bit set.
EOF	8-bit	Checksum	0xFF minus the 8-bit sum of bytes from offset 3 to this byte—between length and checksum.

Examples

Each example is written without escapes (**AP** = **1**) and all bytes are represented in hex format. For brevity, the start delimiter, length, and checksum fields have been excluded.

Identify remote device

A technician is replacing a DigiMesh device in the field and needs to have the its entry removed from a cloud server's database. The technician pushes the commissioning button on the old device once to send an identification broadcast. The server can use the broadcast to identify which device is being replaced and perform the necessary action.

When the node identification broadcast is sent, every device that receives the message will flash the association LED and emit the following information frame:

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Frame descriptions *Node Identification Indicator - 0x95*

```
7E 00 27 95 00 13 A2 00 12 34 56 78 FF FE C2 FF FE 00 13 A2 00 12 34 56 78 4C 48
37 35 00 FF FE 01 01 C1 05 10 1E 00 14 00 08 0D
```

Frame type	64-bit source	Reserved	Options	64-bit remote	NI String	Reserved	Device type	Event	Profile ID	MFG ID
0x95	0x0013A200 12345678	0xFFFE	0xC2	0x0013A200 12345678	0x4C483735 00	0xFFFE	0x01	0x01	0xC105	0x101E
Identification		*Unused*	*DigiMesh broadcast*		*"LH75" + null*	*Unused*	*Router*	*Button press*	*Digi*	*Digi*

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Remote AT Command Response- 0x97

Request frame: Remote AT Command Request - 0x17

Description

This frame type is emitted in response to a Remote AT Command Request - 0x17. Some commands send back multiple response frames; for example, the **ND** command. Refer to individual AT command descriptions for details on API response behavior.

This frame is only emitted if the Frame ID in the request is non-zero.

Format

The following table provides the contents of the frame. For details on frame structure, see API frame format.

Offset	Size	Frame Field	Description
0	8-bit	Start Delimiter	Indicates the start of an API frame.
1	16-bit	Length	Number of bytes between the length and checksum.
3	8-bit	**Frame type**	Remote AT Command Response - **0x97**
4	8-bit	**Frame ID**	Identifies the data frame for the host to correlate with a prior request.
5	64-bit	**64-bit source address**	The sender's 64-bit address.
13	16-bit	**Reserved**	Unused, but this field is typically set to **0xFFFE**.
15	16-bit	**AT command**	The two ASCII characters that identify the AT Command.
17	8-bit	**Command status**	Status code for the host's request: **0x00** = OK **0x01** = ERROR **0x02** = Invalid command **0x03** = Invalid parameter **0x04** = Transmission failure **0x0C** = Encryption error
18-n	variable	**Parameter value (optional)**	If the host requested a command parameter change, this field will be omitted. If the host queried a command by omitting the parameter value in the request, this field will return the value currently set on the device.
EOF	8-bit	Checksum	0xFF minus the 8-bit sum of bytes from offset 3 to this byte (between length and checksum).

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Examples

Each example is written without escapes (**AP** = **1**) and all bytes are represented in hex format. For brevity, the start delimiter, length, and checksum fields have been excluded.

Set remote command parameter

Host set the **NI** string of a remote device to "**Remote**" using a Remote AT Command Request - 0x17.

The corresponding 0x97 Remote AT Command Response with a matching Frame ID is emitted as a response:

```
7E 00 0F 97 27 00 13 A2 00 12 34 56 78 12 7E 4E 49 00 51
```

Frame type	Frame ID	64-bit source	Reserved	AT command	Command Status	Command data
0x97	0x27	0x0013A200 12345678	0x127E	0x4E49	0x00	(omitted)
Response	*Matches request*		*Unused*	*"NI"*	*Success*	*Parameter changes return no data*

Transmission failure

Host queued the the PAN ID change of a remote device using a Remote AT Command Request - 0x17. Due to existing network congestion, the host will retry any failed attempts.

The corresponding 0x97 Remote AT Command Response with a matching Frame ID is emitted as a response:

```
7E 00 0F 97 27 00 13 A2 00 12 34 56 78 FF FE 49 44 04 EA
```

Frame type	Frame ID	64-bit source	Reserved	AT command	Command Status	Command data
0x97	0x27	0x0013A200 12345678	0xFFFE	0x4944	0x04	(omitted)
Response	*Matches request*		*Unused*	*"ID"*	*Transmission failure*	*Parameter changes return no data*

Query remote command parameter

Query the temperature of a remote device—TP (Temperature).

The corresponding 0x97 Remote AT Command Response with a matching Frame ID is emitted with the temperature value as a response:

```
7E 00 11 97 27 00 13 A2 00 12 34 56 78 FF FE 54 50 00 00 2F A8
```


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Frame descriptions *Remote AT Command Response- 0x97*

Frame type	Frame ID	64-bit source	Reserved	AT command	Command Status	Command data
0x97	0x27	0x0013A200 12345678	0x0013A200 12345678	0x4944	0x00	0x002F
Response	*Matches request*		*Unused*	*"TP"*	*Success*	*+47 °C*

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Europe (CE)

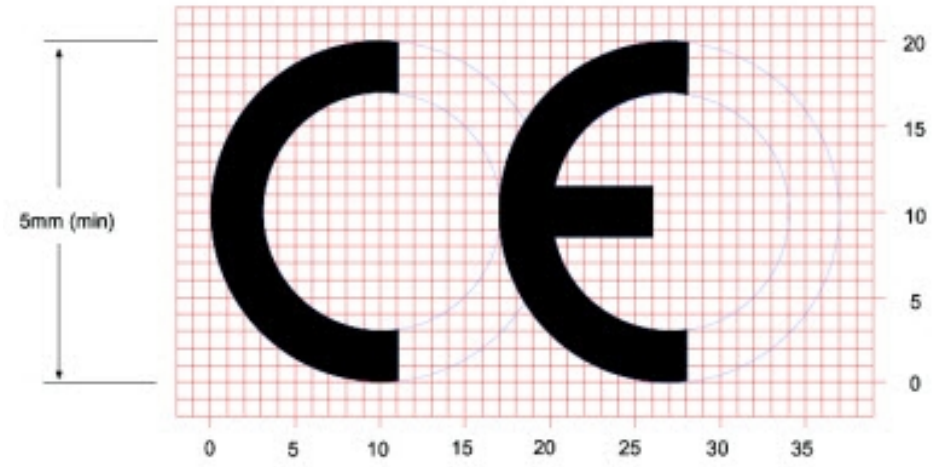
The XBee SX 868 RF Module has been tested for use in several European countries. For a complete list, refer to www.digi.com/resources/certifications.

If XBee SX 868 RF Modules are incorporated into a product, the manufacturer must ensure compliance of the final product with articles 3.1a and 3.1b of the Radio Equipment Directive. A Declaration of Conformity must be issued for each of these standards and kept on file as described in the Radio Equipment Directive.

Furthermore, the manufacturer must maintain a copy of the XBee SX 868 RF Module user guide documentation and ensure the final product does not exceed the specified power ratings, antenna specifications, and/or installation requirements as specified in the user guide.

OEM labeling requirements

The “CE” marking must be affixed to a visible location on the OEM product. The following figure shows CE labeling requirements.



The CE mark shall consist of the initials “CE” taking the following form:

- If the CE marking is reduced or enlarged, the proportions given in the above graduated drawing must be respected.
- The CE marking must have a height of at least 5 mm except where this is not possible on account of the nature of the apparatus.
- The CE marking must be affixed visibly, legibly, and indelibly.

Important note

Digi customers assume full responsibility for learning and meeting the required guidelines for each country in their distribution market. Refer to the radio regulatory agency in the desired countries of operation for more information.

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Declarations of conformity

Digi has issued Declarations of Conformity for the XBee RF Modules concerning emissions, EMC, and safety. For more information, see www.digi.com/resources/certifications.

Antennas

The following antennas have been tested and approved for use with the XBee SX 868 RF Module:

Dipole (2.1 dBi), Digi PN A08-HABUF-P5I*

All antenna part numbers followed by an asterisk (*) are not available from Digi. Consult with an antenna manufacturer for an equivalent option.

PCB design and manufacturing

The XBee SX 868 RF Module is designed for surface-mount on the OEM PCB. It has castellated pads to allow for easy solder attach inspection. The pads are all located on the edge of the module, so there are no hidden solder joints on these modules.

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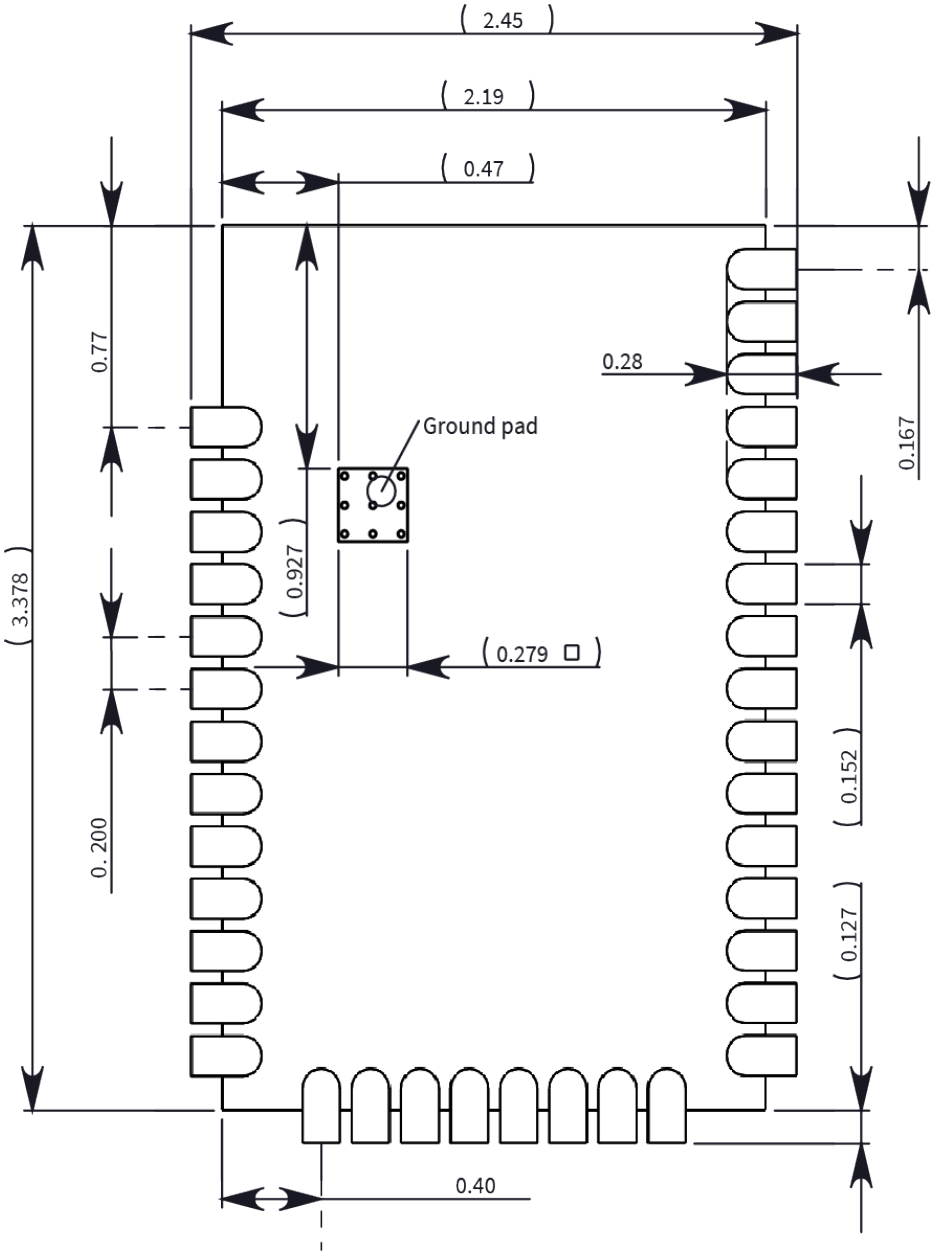
Recommended footprint and keepout

We designed the XBee SX 868 RF Module for surface-mounting on the OEM printed circuit board (PCB). It has castellated pads around the edges and one ground pad on the bottom. Mechanical drawings includes a detailed mechanical drawing.

We recommend that you use the following PCB footprint for surface-mounting. Dimensions are in centimeters.



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The recommended footprint includes an additional ground pad that you must solder to the corresponding pad on the device. This ground pad transfers heat generated during transmit mode away from the device's power amplifier. The pad must connect through vias to a ground plane on the host PCB. Connecting to planes on multiple layers will further improve the heat transfer performance and we recommend doing this for applications that will be in transmit mode for sustained periods. We recommend using nine 0.030 cm diameter vias in the pad as shown. Plug vias with epoxy or solder mask them on the opposite side to prevent solder paste from leaking through the holes during reflow. Do not mask over the ground pad.

Note The ground pad is unique to the XBee/XBee-PRO XTC and SX modules. This footprint is not compatible with other SMT XBees.

Although the underside of the device is mostly coated with solder mask, we recommend that you leave the copper layer directly below the device open to avoid unintended contacts. Most importantly, copper or vias must not interfere with the three exposed RF test points on the bottom of the device shown in the following keepout drawing. Observe the copper keepout on all layers of the host PCB, to avoid the possibility of capacitive coupling that could impact RF performance.

Match the solder footprint to the copper pads, but you may need to adjust it depending on the specific needs of assembly and product standards. We recommend a stencil thickness of 0.15 mm (0.005 in). Place the component last and set the placement speed to the slowest setting.

The following drawing show the SMT footprint, with the required copper keepout (all layers). Dimensions are in centimeters.

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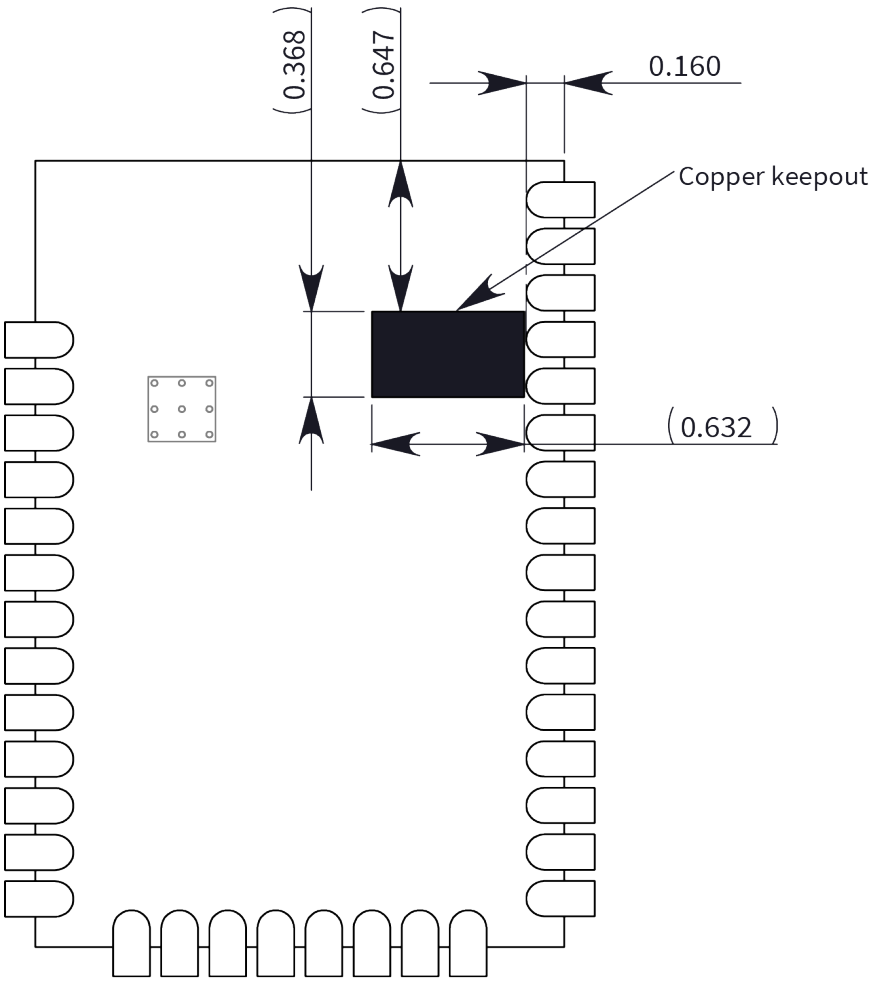

Design notes

The following guidelines help to ensure a robust design.

Host board design

A good power supply design is critical for proper device operation. If the supply voltage is not kept within tolerance, or is excessively noisy, it may degrade device performance and reliability. To help reduce noise, we recommend placing both a 1 uF and 100 pF capacitor as near to VCC as possible. If you use a switching regulator, we recommend switching frequencies above 500 kHz and you should limit power supply ripple to a maximum 50 mV peak to peak.

As with all PCB designs, make power and ground traces thicker than signal traces and make them able to comfortably support the maximum current specifications. Ground planes are preferable.

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Improve antenna performance

The choice of antenna and antenna location is important for optimal performance. In general, antenna elements radiate perpendicular to the direction they point. Thus a vertical antenna, such as a dipole, emit across the horizon.

Metal objects near the antenna cause parasitic coupling and detuning, preventing the antenna from radiating efficiently. Metal objects between the transmitter and receiver can also block the radiation path or reduce the transmission distance, so position external antennas away from them as much as possible. Some objects that are often overlooked are:

- Metal poles
- Metal studs or beams in structures
- Concrete (reinforced with metal rods)
- Metal enclosures
- Vehicles
- Elevators
- Ventilation ducts
- Large appliances
- Batteries
- Tall electrolytic capacitors

RF pad version

The RF pad is a soldered antenna connection. The RF signal travels from pin on the module to the antenna through a single ended RF transmission line on the PCB. This line should have a controlled impedance of 50 Ω.

For the transmission line, we recommend either a microstrip or coplanar waveguide trace on the PCB. We provide a microstrip example below, because it is simpler to design and generally requires less area on the host PCB than coplanar waveguide.

We do not recommend using a stripline RF trace because that requires routing the RF trace to an inner PCB layer, and via transitions can introduce matching and performance problems.

The following figure shows a layout example of a microstrip connecting an RF pad module to a through-hole RPSMA RF connector.

- The top two layers of the PCB have a controlled thickness dielectric material in between. The second layer has a ground plane which runs underneath the entire RF pad area. This ground plane is a distance *d*, the thickness of the dielectric, below the top layer.
- The top layer has an RF trace running from pin 36 of the device to the RF pin of the RPSMA connector. The RF trace's width determines the impedance of the transmission line with relation to the ground plane. Many online tools can estimate this value, although you should consult the PCB manufacturer for the exact width. Assuming d = 0.025 in, and that the dielectric has a relative permittivity of 4.4, the width in this example will be approximately 0.045 in for a 50 Ω trace. This trace width is a good fit with the module footprint's 0.060 in pad width.

We do not recommend using a trace wider than the pad width, and using a very narrow trace can cause unwanted RF loss. You can minimize the length of the trace by placing the RPSMA jack close to the module. All of the grounds on the jack and the module are connected to the ground planes directly or through closely placed vias. Space any ground fill on the top layer at least twice the distance *d* (in this case, at least 0.050 in) from the microstrip to minimize their interaction.

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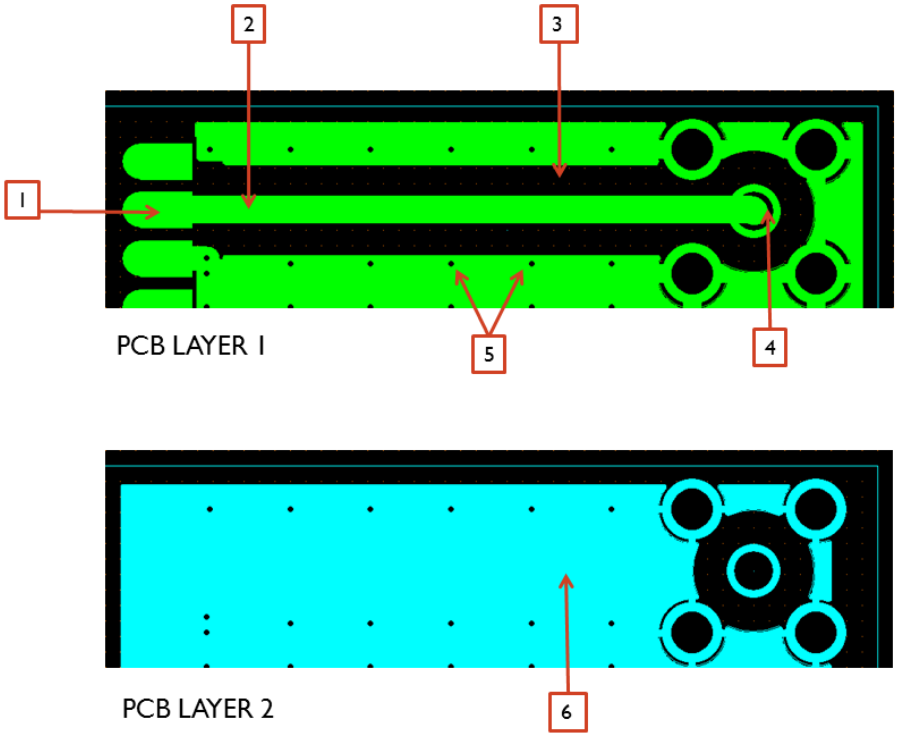

Number	Description
1	XBee pin 36
2	50 Ω microstrip trace
3	Back off ground fill at least twice the distance between layers 1 and 2
4	RF connector
5	Stitch vias near the edges of the ground plane
6	Pour a solid ground plane under the RF trace on the reference layer

Implementing these design suggestions helps ensure that the RF pad device performs to specifications.

Recommended solder reflow cycle

The following table provides the recommended solder reflow cycle. The table shows the temperature setting and the time to reach the temperature; it does not show the cooling cycle.

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Time (seconds)	Temperature (degrees C)
30	65
60	100
90	135
120	160
150	195
180	240
210	260

The maximum temperature should not exceed 260 °C.

The SX device will reflow during this cycle, and therefore must not be reflowed upside down. Take care not to jar the device while the solder is molten, as this can remove components under the shield from their required locations.

The device has a Moisture Sensitivity Level (MSL) of 3. When using this product, consider the relative requirements in accordance with standard IPC/JEDEC J-STD-020.

In addition, note the following conditions:

a. Calculated shelf life in sealed bag: 12 months at < 40 °C and < 90% relative humidity (RH).
b. Environmental condition during the production: 30 °C /60% RH according to IPC/JEDEC J-STD-033C, paragraphs 5 through 7.
c. The time between the opening of the sealed bag and the start of the reflow process cannot exceed 168 hours if condition b) is met.
d. Baking is required if conditions b) or c) are not met.
e. Baking is required if the humidity indicator inside the bag indicates a RH of 10% more.
f. If baking is required, bake modules in trays stacked no more than 10 high for 4-6 hours at 125 °C.

Flux and cleaning

We recommend that you use a “no clean” solder paste in assembling these devices. This eliminates the clean step and ensures that you do not leave unwanted residual flux under the device where it is difficult to remove. In addition:

- Cleaning with liquids can result in liquid remaining under the device or in the gap between the device and the host PCB. This can lead to unintended connections between pads.
- The residual moisture and flux residue under the device are not easily seen during an inspection process.

Rework

Once you mount the device, do not perform rework on the SX device (for example, removing it from the host PCB).

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TS-TL-DGI-041

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CAUTION! Any modification to the device voids the warranty coverage and certifications.

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