DIGI

XBee®/XBee-PRO XTC DigiMesh

Radio Frequency (RF) Module

User Guide

Revision history—90001480

Revision	Date	Description
B	May 2016	Removed Australian certification information. Added the UART data rate to the performance specifications table. Added digital outputs to the physical specifications table. Revised the cyclic sleep current numbers. Added the **HS** command. Removed the indoor range specification.
C	May 2018	Added note on range estimation. Changed IC to ISED.
D	June 2019	Added FCC publication 996369 related information.
E	November 2019	Removed all references to the $\overline{\text{CONFIG}}$ line.
F	January 2020	Added IFETEL certifications.

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Product serial number (s)

Firmware version

Operating system/browser (if applicable)

Logs (from time of reported issue)

Trace (if possible)

Description of issue

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Include the document title and part number (XBee®/XBee-PRO XTend Compatible (XTC) DigiMesh RF Module User Guide, 90001480 F) in the subject line of your email.

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XBee®/XBee-PRO XTend Compatible (XTC) DigiMesh RF Module User Guide

The XBee/XBee-PRO XTend Compatible (XTC) RF module provides a radio frequency (RF) solution for the reliable delivery of critical data between remote devices. It is a 30 dBm (1 Watt) long-range original equipment manufacturer (OEM) device. We also offer a low power version of this module that offers transmit power adjustable up to 13 dBm.

The XTC module uses Frequency Hopping Spread Spectrum (FHSS) agility to avoid interference by hopping to a new frequency on every packet transmission or re-transmission. Its transmit power is software adjustable up to 30 dBm, which is the maximum output power allowable by governments that use 900 MHz as a license-free band. The XTC module is approved for use in the United States and Canada.

The XTC transfers a standard asynchronous serial data stream, operates within the ISM 900 MHz frequency band and offers two RF data rates of 10 kb/s and 125 kb/s.

As the name suggests, the XTC is over-the-air compatible with Digi's XTend module. The XTC is not a drop-in replacement for the XTend. If you require form factor compatibility, you must use the XTend vB RF Module.

For new applications, we recommend that you use the XBee/XBee-Pro SX module. It uses the same hardware as the XTC but we optimize the firmware for the best range and interference immunity. However, it is not over-the-air compatible with the XTend.

Applicable firmware

This manual supports the following firmware:

- 0x800x for XTC DigiMesh

Technical specifications

The following tables provide the device's technical specifications.

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

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		XBee XTC	XBee-PRO XTC
Frequency range		ISM 902 to 928 MHz	
RF data rate (software selectable)		10 kb/s to 125 kb/s	
Transmit power (software selectable)		Up to 13 dBm	Up to 30 dBm[1]
Channels		10 hopping sequences share 50 frequencies	
Available channel frequencies		50	
UART data rate (software selectable)		1200 - 230400 b/s	
Receiver sensitivity	10 kb/s	-110 dBm	
	125 kb/s	-100 dBm	
Outdoor range (line of sight)	10 kb/s	Up to 5 miles	up to 40 miles[2]
	125 kb/s	Up to 1.5 miles	Up to 7 miles

Power requirements

The following table describes the power requirements for the XTC RF Module.

Specification		XBee XTC	XBee-PRO XTC
Supply voltage		2.4 to 3.6 VDC, 3.3 V typical	2.6 to 3.6 VDC, 3.3 V typical
Receive current	VCC = 3.3 V	40 mA	40 mA
Transmit current	VCC = 3.3 V	55 mA @ 13 dBm	900 mA @ 30 dBm
	VCC = 3.3 V	45 mA @ 10 dBm	640 mA @ 27 dBm
	VCC = 3.3 V	35 mA @ 0 dBm	350 mA @ 21.5 dBm

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[1]30 dBm typical at 3.3 V and above. Maximum transmit power will reduce at lower voltages. See PL (TX Power Level) for more information on adjustable power levels.
[2]Estimated based on a 9 mile range test with dipole antennas.

Cyclic sleep current (mA, average)

Sleep mode	Cycle time	RF data rate	Cyclic sleep current (mA, average)
SM = 8	16 seconds	**BR** = 0	0.65
		BR = 1	0.23
SM = 7	8 seconds	**BR** = 0	1.13
		BR = 1	0.31
SM = 6	4 seconds	**BR** = 0	2.06
		BR = 1	0.46
SM = 5	2 seconds	**BR** = 0	3.77
		BR = 1	0.77
SM = 4	1 second	**BR** = 0	6.68
		BR = 1	1.36

Networking and security specifications

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

Specification	Value
Frequency	902-928 MHz, 915-928 MHz for the International variant
Spread spectrum	Frequency Hopping Spread Spectrum (FHSS)
Modulation	Frequency Shift Keying (FSK/GFSK)
Supported network topologies	Peer-to-peer (master/slave relationship not required), point-to-point, and point-to-multipoint
Channel capacity	10 hop sequences share 50 frequencies
Encryption	128-bit AES CBC encryption The **EE** command enables and disables encryption and sets the encryption key

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

Specification	Value
RoHS	Compliant
Manufacturing	ISO 9001:2000 registered standards
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 ℃ to 85 ℃
Digital outputs	Two (2) output lines

Regulatory conformity summary

This table describes the agency approvals for the devices.

Country	XBee XTC	XBee-PRO XTC
United States	FCC ID: MCQ-XBSX	FCC ID: MCQ-XBPSX
Canada	IC: 1846A-XBSX	IC: 1846A-XBPSX
Australia	RCM	RCM
Mexico	RCPDIXB19-1819	RCPDIXB19-2288

Hardware

Mechanical drawings

The following images show the XTC mechanical drawings. The XTC has the same form factor as other Digi surface-mount (SMT) XBee devices, except there is an additional copper ground pad on the bottom.
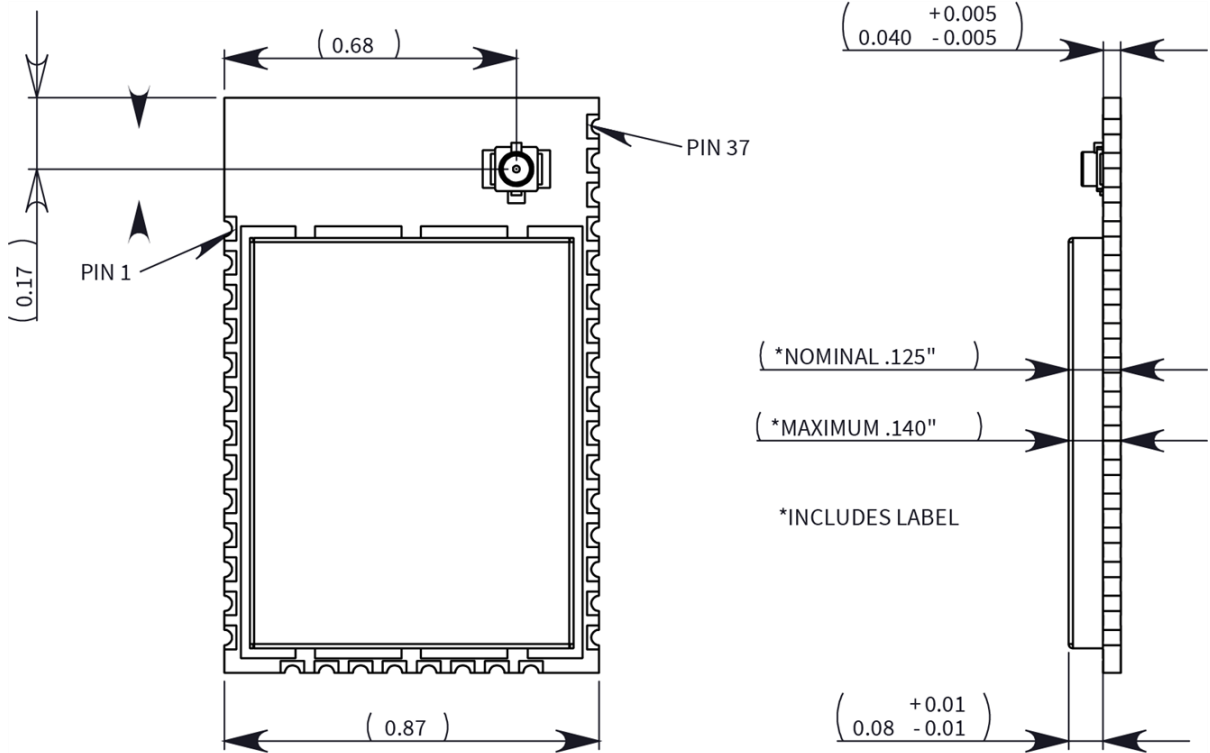
TOP VIEW

SIDE VIEW
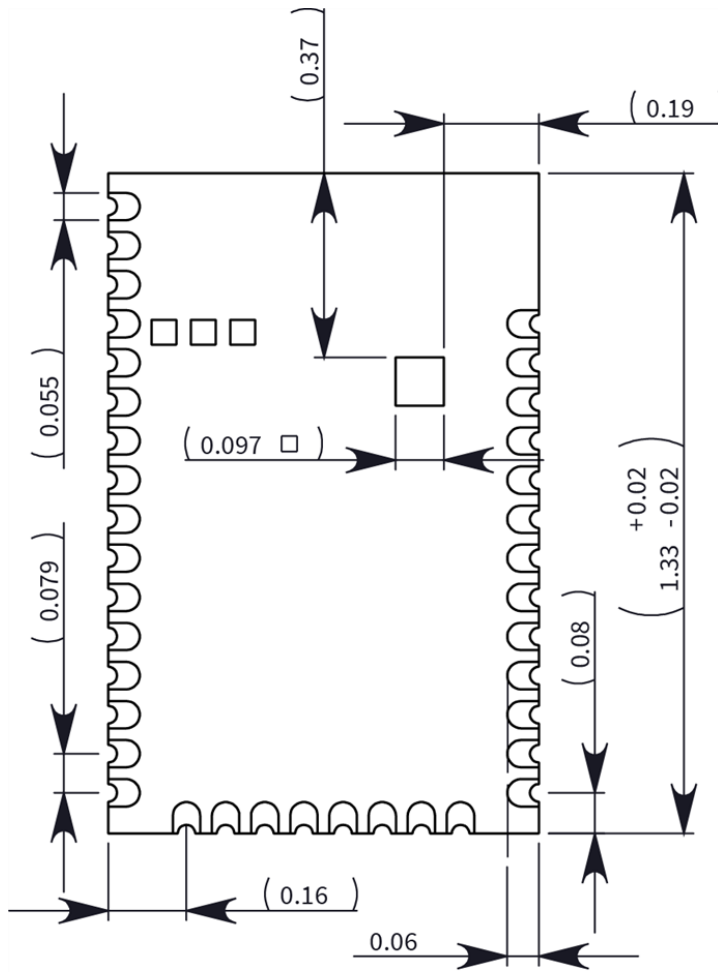
BOTTOM VIEW

Pin signals

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

Pin	Designation	I/O	Function
1	GND	-	Ground
2	VCC	I	Power supply
3	DOUT	O	UART Data Out
4	DIN	I	UART Data In

Pin	Designation	I/O	Function
5	GPO2/RX LED	O	General Purpose Output / RX LED
6	$\overline{\text{RESET}}$	I	Module reset
7	RSSI	O	RX Signal Strength Indicator
8		-	Disabled
9	Reserved	NC	Do not connect
10	SLEEP (DTR)	I	Pin Sleep Control Line
11	GND	-	Ground
12		-	Disabled
13	GND	-	Ground
14		-	Disabled
15		-	Disabled
16		-	Disabled
17		-	Disabled
18	Reserved	NC	Do not connect
19	Reserved	NC	Do not connect
20	Reserved	NC	Do not connect
21	Reserved	NC	Do not connect
22	GND	-	Ground
23	Reserved	NC	Do not connect
24		-	Disabled
25	GPO1/$\overline{\text{CTS}}$/RS-485 TX_EN	O	General Purpose Output / Clear-to-Send Flow Control / RS-485 Transmit Enable
26	ON/$\overline{\text{SLEEP}}$	O	Module sleep status indicator
27	Reserved	NC	Do not connect
28	$\overline{\text{TX}}$ _PWR	O	Transmit power
29	$\overline{\text{RTS}}$	I	Request-to-Send Flow Control
30		-	Disabled
31		-	Disabled
32		-	Disabled

Pin	Designation	I/O	Function
33	Reserved	NC	
34	Reserved	NC	
35	GND	-	Ground
36	RF	I/O	RF I/O for RF pad variant
37	NC	NC	
38	GND	-	Ground pad for heat transfer to host PCB

Note If you integrate the XTC RF Module with a host PC board, leave all lines you do not use disconnected (floating).

Recommended pin connections

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).

Modes

The XTC 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))

Transparent and API operating modes

The firmware operates in several different modes. Two top-level modes establish how the device communicates with other devices through its serial interface: Transparent operating mode and API operating mode.

Transparent operating mode

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

API operating mode

API operating mode is an alternative to Transparent mode. API mode is a frame-based protocol that allows you to direct data on a packet basis. It can be particularly useful in large networks where you need control over the operation of the radio network or when you need to know which node a data packet originated from. The device communicates UART data in packets, also known as API frames. This mode allows for structured communications with serial devices. It is helpful in managing larger networks and is more appropriate for performing tasks such as collecting data from multiple locations or controlling multiple devices remotely.

For more information, see API frame specifications.

Receive mode

This is the default mode for the XTC 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.

If a destination node receives a valid RF packet, the destination node transfers the data to its serial transmit buffer. For the serial interface to report received data on the RF network, that data must meet the following criteria:

- Network ID match
- Channel match
- Address match

Transmit mode
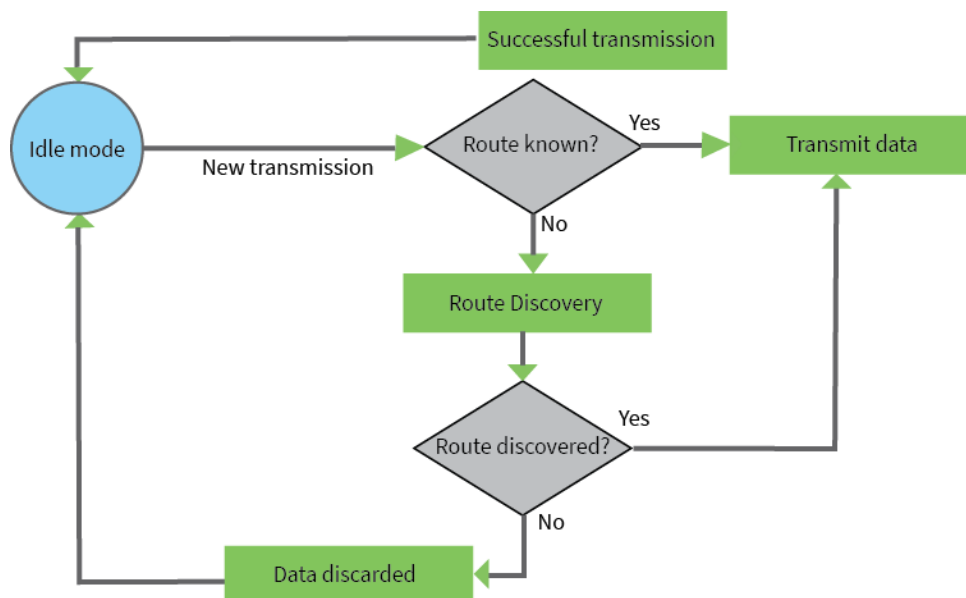
When DigiMesh data is transmitted from one node to another, the destination node transmits a network-level acknowledgment back across the established route to the source node. This acknowledgment packet indicates to the source node that the destination node received the data packet. If the source node does not receive a network acknowledgment, it retransmits the data.

For more information, see Data transmission and routing.

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 XTC 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 XTC RF Module are controlled by the AP (API Enable) 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 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 XTC 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 Character), CT (Command Mode Timeout) and GT (Guard Times).

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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).

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 (Interface Data 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.

"AT"
prefix + **ASCII**
command + **Space**
(optional) + **Parameter**
(optional, HEX) + **Carriage**
return
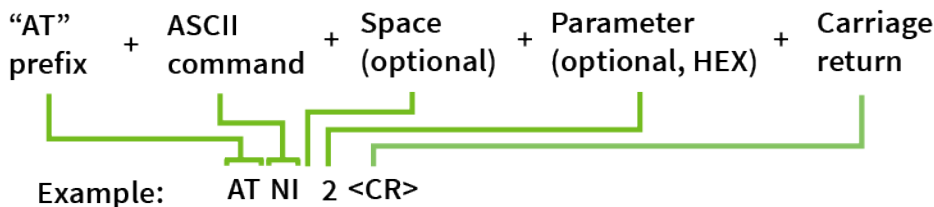
Example: **AT NI 2 <CR>**

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>**.

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 XTC 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.

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 Commands.

Operation

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

Serial interface

The XTC RF Module provides a serial interface to an RF link. The XTC RF Module converts serial data to RF data and sends that data to any over-the-air compatible device in an RF network. The device can communicate through its serial port with any logic and voltage compatible universal asynchronous receiver/transmitter (UART), or through a level translator to any serial device.

UART data flow

Devices that have a UART interface connect directly to the pins of the XTC 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.
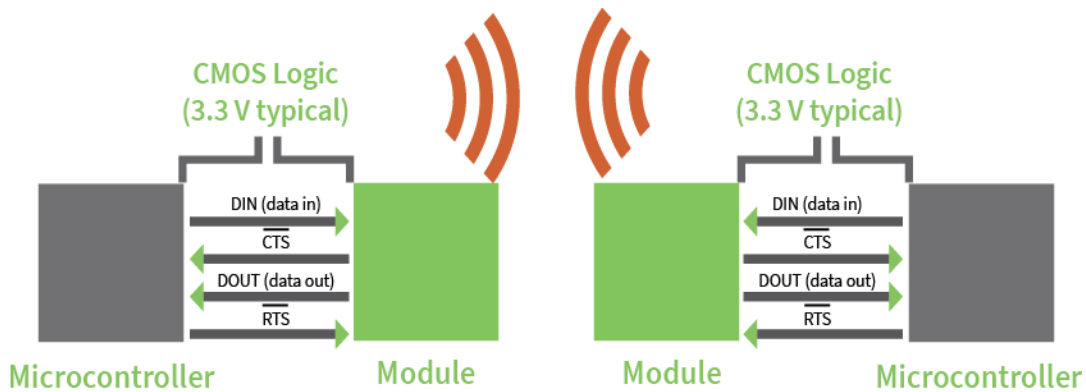
Serial data

A device sends data to the XTC 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.

For serial communication to occur, you must configure the UART of both devices (the microcontroller and the XTC 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.
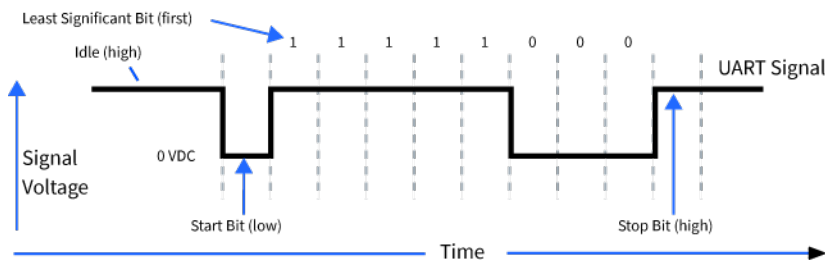
Serial flow control

The $\overline{RTS}$ and $\overline{CTS}$ device pins provide $\overline{RTS}$ and/or $\overline{CTS}$ flow control. $\overline{CTS}$ flow control signals the host to stop sending serial data to the device. $\overline{RTS}$ flow control lets the host signal the device so it will not send the data in the serial transmit buffer out the UART. Use the **D6** and **D7** commands to enable $\overline{RTS}$ and $\overline{CTS}$ flow control.

CTS flow control

CTS flow control is enabled by default; you can disable it with the **D7** command. When the serial receive buffer fills with the number of bytes specified by the **FT** parameter, the device de-asserts CTS (sets it high) to signal the host device to stop sending serial data. The device re-asserts CTS when less than FT-16 bytes are in the UART receive buffer; for more information, see FT (Flow Control Threshold).

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.

Networking methods

The MAC and PHY layers

Most network protocols use the concept of layers to separate different components and functions into independent modules that developers can assemble in different ways.

The PHY layer defines the physical and electrical characteristics of the network. It is responsible for managing the hardware that modulates and demodulates the RF bits.

The MAC layer is responsible for sending and receiving RF frames. As part of each packet, there is a MAC layer data header that has addressing information as well as packet options. This layer implements packet acknowledgments (ACKs), packet tracking to eliminate duplicates, and so forth.

- When a device is transmitting, it cannot receive packets.
- When a device is not sleeping, it is either receiving or transmitting.
- There are no beacons or master/slave requirements in the design of the MAC/PHY.

The XTC RF Module uses a patented method for scanning and finding a transmission. When a device transmits, it sends out a repeated preamble pattern, a MAC header, optionally a network header, followed by packet data. A receiving device is able to scan all the channels to find a transmission during the preamble, then once it has locked into that channel it attempts to receive the whole packet.

The following table shows the AT commands related to the MAC/PHY layers.

AT command	Function
HP	Change **HP** (Preamble ID) to make it so a group of devices will not interfere with another group of devices in the same vicinity. The advantage of changing this parameter is that a receiving device will not lock into a transmission of a transmitting device that does not have the same Preamble ID.
ID	Change **ID** (Network ID) to further keep devices from interfering with each other. The device matches this ID after it matches the preamble pattern and after it receives the MAC header. A unique network identifier distinguishes each network. For devices to communicate, they must be configured with the same network identifier. The **ID** parameter allows multiple networks to co-exist on the same physical channel.
PL	Sets the transmit (TX) power level. You can reduce the power level from the maximum to reduce current consumption or for testing. This comes at the expense of reduced radio range.
RR	Specifies the number of times a sending device attempts to get an ACK from a destination device when it sends a unicast packet.
MT	Specifies the number of times that a device repeatedly transmits a broadcast packet. This adds redundancy, which improves reliability.

64-bit addresses

We assign each device a unique IEEE 64-bit address at the factory. When a device is in API operating mode and it sends a packet, this is the source address that the receiving device returns.

- Use the **SH** and **SL** commands to read this address.
- The form of the address is: 0x0013A2XXXXXXXXXX.
- The first six digits are the Digi Organizationally Unique Identifier (OUI).
- The broadcast address is 0x000000000000FFFF.

Make a unicast transmission

To transmit to a specific device in Transparent operating mode:

- Set **DH**:**DL** to the **SH**:**SL** of the destination device.

To transmit to a specific device in API operating mode:

- In the 64-bit destination address of the API frame, enter the **SH**:**SL** address of the destination device.

Delivery methods

The TO (Transmit Options) command sets the default delivery method that the device uses when in Transparent mode. In API mode, the TxOptions field of the API frame overrides the **TO** command, if non-zero.

The XTC RF Module supports three delivery methods:

- Point-to-multipoint (**TO** = 0x40).
- Repeater (directed broadcast) (**TO** = 0x80).
- DigiMesh (**TO** = 0xC0).

Point to Point / Point to Multipoint (P2MP)

This delivery method does not use a network header, only the MAC header.

In P2MP, the sending devices always send all messages directly to the destination. Other nodes do not repeat the packet. The sending device only delivers a P2MP unicast directly to the destination device, which must be in range of the sending device.

The XTC RF Module uses patented technology that allows the destination device to receive unicast transmissions directed to it, even when there is a large amount of traffic. This works best if you keep broadcast transmissions to a minimum.

A sending node repeats a P2MP broadcast transmission **MT**+1 times, but the receiving nodes do not repeat it, so like a unicast transmission, the receiving device must be in range.

All devices that receive a P2MP broadcast transmission output the data through the serial port.

Repeater/directed broadcast

All of the routers in a network receive and repeat directed broadcast transmissions. Because it does not use ACKs, the originating node sends the broadcast multiple times. By default a broadcast transmission is sent four times—the extra transmissions become automatic retries without acknowledgments. This results in all nodes repeating the transmission four times. Sending frequent broadcast transmissions can quickly reduce the available network bandwidth, so use broadcast transmissions sparingly.

MAC layer

The MAC layer is the building block that is used to build repeater capability. To implement Repeater mode, we use a network layer header that comes after the MAC layer header in each packet. In this network layer there is additional packet tracking to eliminate duplicate broadcasts.

In this delivery method, the device sends both unicast and broadcast packets out as broadcasts that are always repeated. All repeated packets are sent to every device. The devices that receive the broadcast send broadcast data out their serial port.

When a device sends a unicast, it specifies a destination address in the network header. Then, only the device that has the matching destination address sends the unicast out its serial port. This is called a directed broadcast.

Any node that has a **CE** parameter set to router rebroadcasts the packet if its **BH** (broadcast hops) or broadcast radius values are not depleted. If a node has already seen a repeated broadcast, it ignores the broadcast.

The **NH** parameter sets the maximum number of hops that a broadcast transmission is repeated. The device always uses the **NH** value unless you specify a **BH** value that is smaller.

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.

Transmission timeout calculations for Repeater/directed broadcast mode are the same as for DigiMesh broadcast transmissions.

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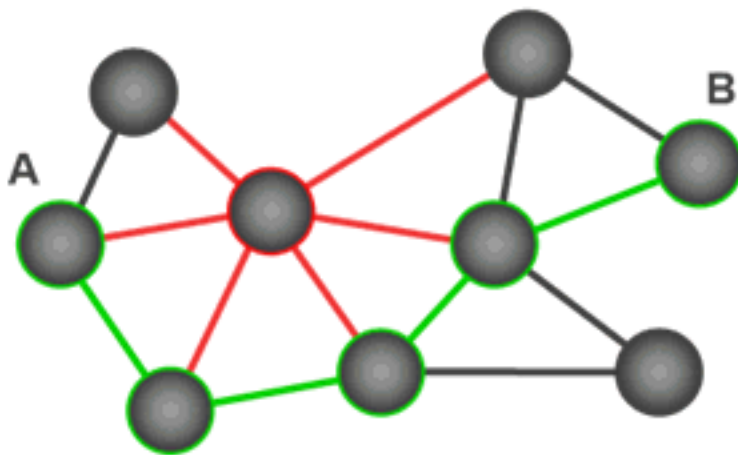
With mesh networking, the distance between two nodes does not matter as long as there are enough nodes in between to pass the message along. When one node wants to communicate with another, the network automatically calculates the best path.

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.

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.

Routing

A device within a mesh network determines 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 firmware uses an associative routing table to map a destination node address with its next hop. A device sends a message to the next hop address, and the message either reaches its destination or forwards to an intermediate router that routes the message on to its destination.

If a message has a broadcast address, it is broadcast to all neighbors, then all routers that receive the message rebroadcast the message **MT**+1 times. Eventually, the message reaches the entire network.

Packet tracking prevents a node from resending a broadcast message more than **MT**+1 times. This means that a node that relays a broadcast will only relay it after it receives it the first time and it will discard repeated instances of the same packet.

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.

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

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 Transmit Status frame - 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 **%H** 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)

AT commands

Addressing commands

The following AT commands are addressing commands.

CI (Cluster ID)

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

If you set this value to 0x12 (loopback Cluster ID), the destination node echoes any transmitted packet back to the source device.

Parameter range

0 - 0xFFFF

Default

0x11 (Transparent data cluster ID)

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.

The destination address is also used for I/O sampling in both Transparent and API modes.

To transmit using a 16-bit address, set **DH** to 0 and **DL** less than 0xFFFF.

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.

The destination address is also used for I/O sampling in both Transparent and API modes.

0x000000000000FFFF is the broadcast address.

Parameter range

0 - 0xFFFFFFFF

Default

0xFFFF

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.

- XCTU prevents you from exceeding the string limit of 20 characters for this command. If you are using another software application to send the string, you can enter longer strings, but the software on the device returns an error.

Parameter range

A string of case-sensitive ASCII printable characters from 0 to 20 bytes in length. A carriage return or a comma automatically ends the command.

Default

0x20 (an ASCII space character)

NO (Network 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.

Use **NO** to suppress or include a self-response to **ND** (Node Discover) commands. When **NO** bit 1 = 1, a device performing a Node Discover includes a response entry for itself.

Parameter range

0x0 - 0x7 (bit field)

Bit field

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 out the serial interface when **ND** is issued.
0x04	Append the RSSI of the last hop to **ND**, **FN**, and responses or API node identification frames.

Default

0x0

NT (Network Discovery Back-off)

Sets or displays the network discovery back-off parameter for a device. This sets the maximum value for the random delay that the device uses to send network discovery responses.

Parameter range

0x20 - 0x2EE0 (x 100 ms)

Default

0x82 (13 seconds)

SH (Serial Number High)

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

The 64-bit source address is always enabled. This value is read-only and it never changes.

Parameter range

0 - 0xFFFFFFFF [read-only]

Default

Set in the factory

SL (Serial Number Low)

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

The 64-bit source address is always enabled. This value is read-only and it never changes.

Parameter range

0 - 0xFFFFFFFF [read-only]

Default

Set in the factory

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 transparent transmissions. API transmissions can override this using the TxOptions field in the API frame.

Parameter range

0 - 0xFF

Bit field:

Bit	Meaning	Description
6,7	Delivery method	b'00 = <invalid option> b'01 = Point-multipoint (0x40) b'10 = Directed Broadcast (0x80) b'11 = DigiMesh (0xC0)
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

- Bits 6 and 7 cannot be set to DigiMesh on the 10k build.
- Bits 4 and 5 must be set to 0.
- Bits 1, 2, and 3 cannot be set on the 10k build.

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

Default

0xC0

Command mode options

The following commands are Command mode option commands.

CC (Command Character)

The character value the device uses to enter Command mode.

The default value (**0x2B**) is the ASCII code for the plus (**+**) character. You must enter it three times within the guard time to enter Command mode. To enter Command mode, there is also a 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

0 - 0xFF

Recommended: 0x20 - 0x7F (ASCII)

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)

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 - 0xCE4 (x 1 ms)

Default

0x3E8 (one second)

Diagnostic commands

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

%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

N/A

0x267

%V (Board Voltage)

Reads the supply voltage to the module's VCC (pin 2).

The conversion of the hex value returned by **%V** to Volts is VAL/65536 = Volts.

Example:

2.8 VDC = 2.8 * 65536 = 0x2CCCD

3.3 VDC = 3.3 * 65536 = 0x34CCD

Parameter range

[read-only]:

0x26666 - 0x39999 (2.40 to 3.60 V)

Default

N/A

%8 (MAC Broadcast One Hop Time)

Parameter range

[read-only]

Default

N/A

BC (Bytes Transmitted)

The number of RF bytes transmitted. The firmware counts every byte of every packet, including MAC/PHY headers and trailers. The purpose of this count is to estimate battery life by tracking time spent performing transmissions.

This number rolls over to **0** from **0xFFFF**.

You can reset the counter to any unsigned 16-bit value 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.

The RSSI measurement is accurate from approximately -50 to -100 dBm.

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

If the XTC RF Module has been reset and has not yet received a packet, **DB** reports **0**.

This value is volatile (the value does not persist in the device's memory after a power-up sequence).

Parameter range

0x28 - 0x6E (-40 dBm to -110 dBm) [read-only]

Default

0

EA (MAC ACK Failure Count)

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 unsigned value, append a hexadecimal parameter to the command. This value is volatile (the value does not persist in the device's memory after a power-up sequence).

Parameter range

0 - 0xFFFF

Default

0

N/A

ER (Receive Count Error)

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 value, append a hexadecimal parameter to the command. This value is volatile (the value does not persist in the device's memory after a power-up sequence).

Occasionally random noise can cause this value to increment.

The **ER** parameter is not reset by pin, serial port or cyclic sleep modes.

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. Received MAC ACK packets do not increment this counter. 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.

This value is volatile (the value does not persist in the device's memory after a power-up sequence).

Parameter range

0 - 0xFFFF

Default

0

RC (RSSI for channel)

Reads and reports the power level on a given channel.

Channel must be provided as a parameter for this command or an ERROR will be received. Channels for this command are zero based (0 = Channel 1, 0x31 = Channel 50)

Parameter range

[read-only]: 40 - 110 [dBm]

Default

N/A

R# (Reset Number)

Provides the reason for the last device reset.

Parameter range

0-5

N/A

Parameter	Description
0	Power up reset
2	Watchdog reset
3	Software reset
4	Reset line reset
5	Brownout reset

Default

0

TR (Transmit Error Count)

Parameter range

0 - 0xFFFF

Default

0

UA (Unicasts Attempted Count)

The number of unicast transmissions expecting an acknowledgment (when **RR** > 0).

This value is volatile (the value does not persist in the device's memory after a power-up sequence).

Parameter range

0 - 0xFFFF

Default

0

Firmware commands

The following AT commands are firmware commands.

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. Use the code that the device returns to determine if a node has the configuration you want.

After a firmware update this command may return a different value.

Parameter range

N/A

Default

N/A

DD (Device Type Identifier)

Stores the Digi device type identifier value. Use this value to differentiate between multiple XBee devices.

If you change **DD**, RE (Restore Defaults) will not restore defaults. The only way to get **DD** back to default values is to explicitly set it to defaults.

Parameter range

0 - 0xFFFFFFFF

Default

0x80000

NP (Maximum Packet Payload Bytes)

Reads the maximum number of RF payload bytes that you can send in a transmission.

Using APS encryption (API transmit option bit enabled), reduces the maximum payload size by 9 bytes.

Using source routing (**AR** < 0xFF), further reduces the maximum payload size.

Note **NP** returns a hexadecimal value. For example, if **NP** returns 0x54, this is equivalent to 84 bytes.

Parameter range

0 - 0xFFFF (bytes) [read-only]

Default

N/A

HS (Hardware Series)

Read the device's hardware series number.

Parameter range

N/A

Default

0x0A00 - set in the firmware

HV (Hardware Version)

Display the hardware version number of the device.

Parameter range

0 - 0xFFFF [read-only]

Default

Set in firmware

VL (Firmware Version - Verbose)

Reads the verbose firmware version of the device.

Parameter range

Returns a string

Default

0

VR (Firmware Version)

Reads the firmware version on a device.

Parameter range

0 - 0xFFFFFFFF [read-only]

Default

Set in firmware

I/O settings commands

The following AT commands are I/O settings commands.

CD (GP02 Configuration)

Selects or reads the behavior of the GPO2 line (pin 5).

Parameter range

0 - 4

Parameter	Configuration
0	RX LED
1	Static high
2	Static low
3	Reserved
4	RX LED (valid address only)

Default

2

CS (GP01 Configuration)

Sets or displays the behavior of the GPO1 line (pin 25). This output can provide RS-232 flow control and controls the TX enable signal for RS-485 or RS-422 operations.

By default, GP01 provides RS-232 Clear-to-Send ($\overline{\text{CTS}}$) flow control.

Parameter range

0 - 4

Parameter	Configuration
0	RS-232 $\overline{\text{CTS}}$ flow control
1	RS-485 TX enable low
2	Static high
3	RS-485 TX enable high
4	Static low

Default

0

RP (RSSI PWM Timer)

Enables a pulse-width modulated (PWM) output on the RSSI pin (pin 7). We calibrate the pin to show the difference between received signal strength and the sensitivity level of the device. PWM pulses vary from zero to 95 percent. Zero percent means the RF signal the device receives is at or below the device's sensitivity level.

A non-zero value defines the time that PWM output is active with the RSSI value of the last RF packet the device receives. After the set time when the device has not received RF packets, it sets the PWM output low (0 percent PWM) until the device receives another RF packet. It also sets PWM output low at power-up. A parameter value of 0xFF permanently enables PWM output and always reflects the value of the last received RF packet.

Parameter range

0 - 0xFF [x 100 ms]

Default

0x28 (4 seconds)

RT (GPI1 Configuration)

Sets or displays the behavior of the GPI1 pin (pin 29) of the device. You can configure the pin to enable RTS flow control.

Parameter range

0 - 2

Parameter	Configuration
0	Disabled
1	N/A
2	RTS flow control enable

Default

0 (disabled)

I/O diagnostic commands

The following AT commands are I/O diagnostic commands.

TP (Board Temperature)

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

Parameter range

0 - 0xFF [read-only]

Default

N/A

MAC/PHY commands

The following AT commands are MAC/PHY commands.

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 a device receives a packet it checks **HP** 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)

Sets or displays the Vendor Identification Number (VID) of the device. Devices must have matching VIDs in order to communicate. If the device uses OEM network IDs, 0xFFFF uses the factory value.

Parameter range

0x10 - 0x7FFF (user-settable)

0 - 0x0F and 0x8000 - 0xFFFF (factory-set)

Default

0x3332

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 - 0xF

Default

3

PL (TX Power Level)

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

For XBee, **PL** = 4, **PM** = 1 is tested at the time of manufacturing. Other power levels are approximate. On channel 26, transmitter power will not exceed -4 dBm.

The PRO XTC device requires the power supply to be above 3.3 V to ensure 30 dBm output power. The following table shows the typical values over supply voltage.

Power supply	Output power @ PL = 3
3.3 to 3.6 V	30 dBm typical
3.0 V	29 dBm typical
2.6 V	27 dBm typical

Parameter range

0 - 4

These parameters equate to the following settings for the XTC DigiMesh module:

Setting	XTC power level	XTC PRO Power level
0	0 dBm	21.5 dBm
1	10 dBm	
2	13 dBm	
3	13 dBm	27 dBm
4	13 dBm	30 dBm

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

0xA (10 retries)

Network commands

The following commands are network commands.

BH (Broadcast Hops)

The maximum transmission hops for broadcast data transmissions.

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

Parameter range

0 - 0x20

Default

　0

CE (Routing / Messaging Mode)

The routing and messaging mode of the device.

End devices do not propagate broadcasts and will not become intermediate nodes on a route.

Parameter range

　0 - 2

Parameter	Description	Routes packets
0	Standard router	Yes
1	N/A	N/A
2	End device	No

Default

　0

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.

Changing this value dramatically changes how long a route request takes.

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.

Note This command is supported in the 200k variant only.

Parameter range

　0 - 7 mesh unicast retries

Default

　1

NH (Network Hops)

Sets or displays the maximum number of hops across the network. This parameter limits the number of hops. You can use this parameter to calculate the maximum network traversal time.

You must set this parameter to the same value on all nodes in the network.

Parameter range

　1 - 20 hops

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 - 0xA network delay slots

Default

   3

Security commands

The following AT commands are security commands.

EE (Encryption Enable)

Enables or disables 128-bit Advanced Encryption Standard (AES) encryption.

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

Parameter range

   0 - 1

Parameter	Description
0	Encryption Disabled
1	Encryption Enabled

Default

   0

KY (AES Encryption Key)

Sets the 128-bit network security key value that the device uses for encryption and decryption.

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.

Parameter range

   128-bit value

Default

   N/A

   0

Serial interfacing commands

The following AT commands are serial interfacing commands.

AO (API Options)

The API data frame output format for RF packets received. This parameter applies to both the UART and SPI interfaces.

Use **AO** to enable different API output frames.

Parameter range

0 - 2

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.
2	XTend DigiMesh API Rx Indicator - 0x80

Default

2

AP (API Enable)

Set or read the API mode setting. The device can format the RF packets it receives into API frames and send them out the serial port.

When you enable API, you must format the serial data as API frames because Transparent operating mode is disabled.

Enables API Mode. The device ignores this command when using SPI. API mode 1 is always used.

Parameter range

0 - 2

Parameter	Description
0	Transparent mode, API mode is off. All UART input and output is raw data and the device uses the **RO** and **RB** parameters 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 (0x11), XOFF (0x13), Escape (0x7D), and start delimiter 0x7E as data.

Default

0

BD (Baud Rate)

To request non-standard baud rates with values above 0x80, you can use the Serial Console toolbar in XCTU to configure the serial connection (if the console is connected), or click the **Connect** button (if the console is not yet connected).

When you send non-standard baud rates to a device, it stores the closest interface data rate represented by the number in the **BD** register. Read the **BD** command by sending **ATBD** without a parameter value, and the device returns the value stored in the **BD** register.

The range between standard and non-standard baud rates (0x9 - 0x4B0) is invalid. The range between 0x2580 and 0x4AFF is also invalid.

Parameter range

Standard baud rates: 0x0 - 0x8

Non-standard baud rates: 0x4B0 - 0x1C9468 (0x2581 to 0x4AFF not supported)

Parameter	Description
0x0	1200 b/s
0x1	2400 b/s
0x2	4800 b/s
0x3	9600 b/s
0x4	19200 b/s
0x5	38400 b/s
0x6	57600 b/s
0x7	115200 b/s
0x8	230400 b/s
Non-standard rates: 0x4B0 - 0x1C9468 (0x2581 to 0x4AFF not supported)	

Default

0x03 (9600 b/s)

FT (Flow Control Threshold)

Sets or displays the flow control threshold.

De-assert $\overline{CTS}$ when the number of bytes specified by the **FT** parameter are in the DIN buffer. Re-assert CTS when less than FT - 16 bytes are in the UART receive buffer.

Parameter range

0x11 - 0x16F

Default

0x13F

NB (Parity)

Set or read the serial parity settings for UART communications.

Parameter range

0x00 - 0x04

Parameter	Description
0x00	No parity
0x01	Even parity
0x02	Odd parity
0x03	Mark parity (forced high)
0x04	Space parity (forced low)

Default

0x00

RB (Packetization Threshold)

Sets or displays the character threshold value.

RF transmission begins after a device receives data in the DIN buffer and meets either of the following criteria:

- The UART receives **RB** characters
- The UART receive lines detect **RO** character times of silence after receiving at least 1 byte of data

If a device lowers **PK** below the value of **RB**, **RB** is automatically lowered to match the PK value.

If **RO** = 0, the device must receive **RB** bytes before beginning transmission.

RB and **RO** criteria only apply to the first packet of a multi-packet transmission. If data remains in the DIN buffer after the first packet, transmissions continue in a streaming manner until there is no data left in the DIN buffer.

Parameter range

1 - 0x100 (bytes) (Maximum value equals the current value of **PK** Parameter (up to 0x100 HEX (800 decimal))

Default

0xD3

RO (Packetization Timeout)

Set or read the number of character times of inter-character silence required before transmission begins. For information on how **RO** works with the **RB** command, see RB (Packetization Threshold).

Parameter range

0 - 0xFF [x UART character times]

Default

SB (Stop Bits)

Parameter range

0 - 1

Parameter	Configuration
0	One stop bit
1	Two stop bits

Default

0

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

CN (Exit Command Mode)

Immediately exits Command Mode and applies pending changes.

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

R1 (Restored Compiled)

Restore device parameters to the compiled defaults.

Parameter range

N/A

Default

N/A

Operate in API mode

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.

API frame specifications

The firmware supports two API operating modes: without escaped characters and with escaped characters. Use the **AP** command to enable either mode. To configure a device to one of these modes, set the following **AP** parameter values:

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).

Software flow control (XON and XOFF) uses API mode 2. The XTC RF Module does not support software flow control and only supports API mode 2 for compatibility with other XBee devices. We recommend using API mode 1.

The API data frame structure differs depending on what mode you choose.

The firmware silently discards any data it receives prior to the start delimiter. If the device does not receive the frame correctly or if the checksum fails, the device discards the frame.

API operation (AP parameter = 1)

We recommend this 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 - n	API-specific structure
Checksum	n + 1	1 byte

API operation-with escaped characters (AP parameter = 2)

Set API to 2 to allow 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, refer to the following knowledge base article:

http://knowledge.digi.com/articles/Knowledge_Base_Article/Escaped-Characters-and-API-Mode-2

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	

Escape characters

When sending or receiving a UART data frame, you must escape (flag) specific data values 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'd with 0x20. If not escaped, 0x11 and 0x13 are sent as is.

Data bytes that need to be escaped:

- 0x7E – Frame delimiter
- 0x7D – Escape
- 0x11 – XON
- 0x13 – XOFF

Example - Raw UART data frame (before escaping interfering bytes): 0x7E 0x00 0x02 0x23 0x11 0xCB

0x11 needs to be escaped which results in the following frame: 0x7E 0x00 0x02 0x23 0x7D 0x31 0xCB

Note In the previous example, the length of the raw data (excluding the checksum) is 0x0002 and the checksum of the non-escaped data (excluding frame delimiter and length) is calculated as:
0xFF - (0x23 + 0x11) = (0xFF - 0x34) = 0xCB.

Start delimiter

This field indicates the beginning of a frame. It is always 0x7E. This allows the device to easily detect a new incoming frame.

Length

The length field specifies the total number of bytes included in the frame's data field. Its two-byte value excludes the start delimiter, the length, and the checksum.

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.

Checksum

Checksum is the last byte of the frame and helps test data integrity. It is calculated by taking the hash sum of all the API frame bytes that came before it, except the first three bytes (start delimiter and length).

The device does not process frames sent through the serial interface with incorrect checksums, and ignores their data.

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.

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

Byte(s)	Description
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 0xC4 (the two far right digits). Subtract 0x47 from 0xFF and you get 0x3B (0xFF - 0xC4 = 0x3B). 0x3B is the checksum for this data packet.

If an API data packet is composed with an incorrect checksum, the XTC 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

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.

API frames

The following sections document API frame types.

API frame exchanges

Every outgoing API frame has a corresponding response (or ACK) frame that indicates the success or failure of the outgoing API frame. This section details some of the common API exchanges that occur.

You can use the Frame ID field to correlate between the outgoing frames and associated responses.

Note Using a Frame ID of 0 disables responses, which can reduce network congestion for non-critical transmissions.

AT commands

The following image shows the API frame exchange that takes place at the UART when you send a 0x08 AT Command Request or 0x09 AT Command-Queue Request to read or set a device parameter. To disable the 0x88 AT Command Response, set the frame ID to 0 in the request.
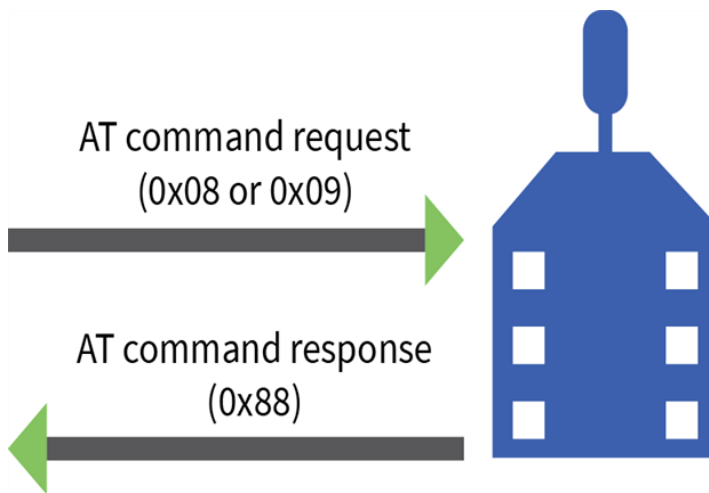
Transmit and Receive RF data

The following image shows the API exchanges that take place on the serial interface when a device sends a 0x10, or 0x11 Transmit Request to another device.
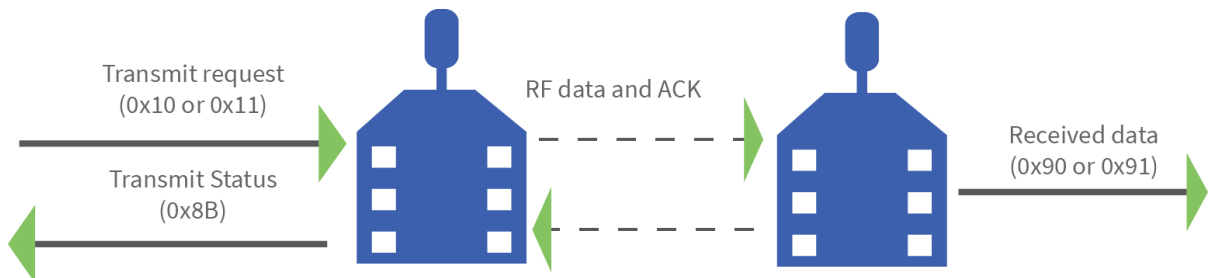
Use the **AP** command to choose the type of data frame you want to receive, either a (0x90) RX Indicator frame or a (0x91) Explicit Rx Indicator frame.

Remote AT commands

The following image shows the API frame exchanges that take place on the serial interface when you send a 0x17 Remote AT Command frame The 0x97 Remote AT Command Response is always

generated and you can use it to identify if the remote device successfully received and applied the command.
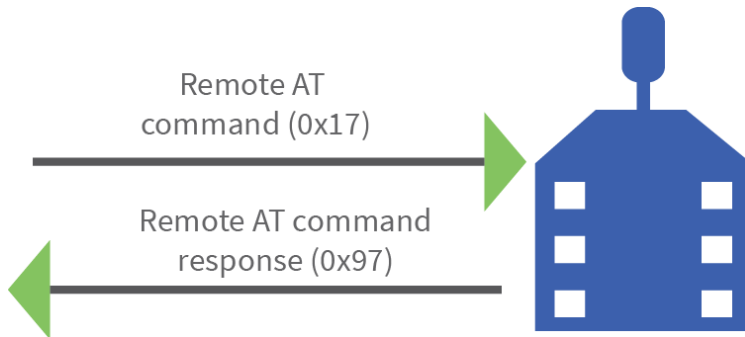
Device Registration

The following image shows the API frame exchanges that take place at the serial interface when registering a joining device to a trust center.
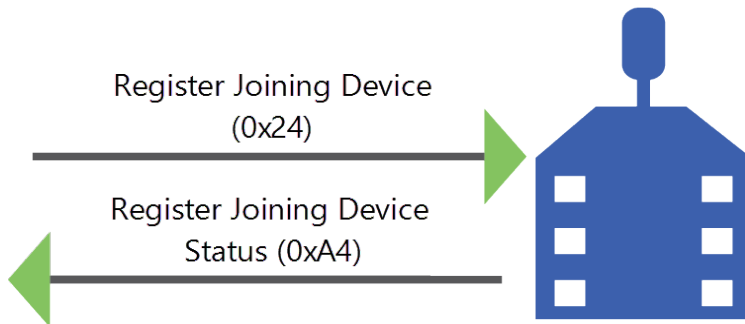
Code to support future API frames

If your software application supports the API, you should make provisions that allow for new API frames in future firmware releases. For example, you can include the following section of code on a host microprocessor that handles serial API frames that are sent out the device's DOUT pin:

```
void XBee_HandleRxAPIFrame(_apiFrameUnion *papiFrame){
      switch(papiFrame->api_id){
             case RX_RF_DATA_FRAME:
                    //process received RF data frame
                    break;

             case RX_IO_SAMPLE_FRAME:
                    //process IO sample frame
                    break;

             case NODE_IDENTIFICATION_FRAME:
                    //process node identification frame
                    break;


             default:
                    //Discard any other API frame types that are not being used
```

```
                                    break;
            }
      }
```

AT Command frame - 0x08

Description

Use this frame to query or set device parameters on the local device. This API command applies changes after running the command. You can query parameter values by sending the 0x08 AT Command frame with no parameter value field (the two-byte AT command is immediately followed by the frame checksum).

A 0x8B response frame is populated with the parameter value that is currently set on the device.

Format

The following table provides the contents of the frame. For details on frame structure, see API frame specifications.

Frame data fields	Offset	Description
Frame type	3	0x08
Frame ID	4	Identifies the data frame for the host to correlate with a subsequent ACK (0x88). If set to **0**, the device does not send a response.
AT command	5-6	Command name: two ASCII characters that identify the AT command.
Parameter value	7-n	If present, indicates the requested parameter value to set the given register. If no characters are present, it queries the register.

Example

The following example illustrates an AT Command frame when you query the device's **NH** parameter value.

Frame data fields	Offset	Example
Start delimiter	0	0x7E
Length	MSB 1	0x00
	LSB 2	0x05
Frame type	3	0x08

Frame data fields	Offset	Example
Frame ID	4	0x52
AT command	5	0x4E (N)
	6	0x48 (H)
Parameter value (**NH**2 = two network hops)	7	0x02
Checksum	8	0x0D

AT Command - Queue Parameter Value frame - 0x09

Description

This frame allows you to query or set device parameters. In contrast to the AT Command (0x08) frame, this frame queues new parameter values and does not apply them until you issue either:

- The **AT** Command (0x08) frame (for API type)
- The **AC** command

When querying parameter values, the 0x09 frame behaves identically to the 0x08 frame. The device returns register queries immediately and not does not queue them. The response for this command is also an **AT** Command Response frame (0x88).

Format

The following table provides the contents of the frame. For details on frame structure, see API frame specifications.

Frame data fields	Offset	Description
Frame type	3	0x09
Frame ID	4	Identifies the data frame for the host to correlate with a subsequent ACK (0x88). If set to **0**, the device does not send a response.
AT command	5-6	Command name: two ASCII characters that identify the AT command.
Parameter value	7-n	If present, indicates the requested parameter value to set the given register. If no characters are present, queries the register.

Example

The following example sends a command to change the baud rate (**BD**) to 115200 baud, but does not apply the changes immediately. The device continues to operate at the previous baud rate until you apply the changes.

Note In this example, you could send the parameter as a zero-padded 2-byte or 4-byte value.

Frame data fields	Offset	Example
Start delimiter	0	0x7E
Length	MSB 1	0x00
	LSB 2	0x05
Frame type	3	0x09
Frame ID	4	0x01
AT command	5	0x42 (B)
	6	0x44 (D)
Parameter value (**BD**7 = 115200 baud)	7	0x07
Checksum	8	0x68

Legacy TX Request frame - 0x00

Description

This frame causes the device to send payload data as an RF packet. This packet format is deprecated and should only be used by customers who require compatibility with legacy Digi RF products. We encourage you to use Transmit Request frame - 0x10 to initiate API transmissions.

Format

The following table provides the contents of the frame. For details on frame structure, see API frame specifications.

Frame data fields	Offset	Description
Frame type	3	0x00
Frame ID	4	Identifies the data frame for the host to correlate with a subsequent ACK (0x8B). If set to **0**, the device does not send a response.
Destination address	5-12	Set to the 64-bit address of the destination device. Also supports the following address: 0x000000000000FFFF - Broadcast address
Options	13	0 = Standard 1 = Disable ACK
RF data	14-n	Data sent to the destination device.

Example

The following example shows how to send a transmission to a device with escaping disabled (**AP** = 1), destination address 0x0013A200 4052C507, and the payload is "TxData".

Frame data fields	Offset	Example
Start delimiter	0	0x7E
Length	MSB 1	0x00
	LSB 2	0x11
Frame type	3	0x00
Frame ID	4	0x01
Destination address	MSB 5	0x00
	6	0x13
	7	0xA2
	8	0x00
	9	0x40
	10	0x52
	11	0xC5
	LSB 12	0x07
Options	13	0x00
RF data	14	0x54
	15	0x78
	16	0x44
	17	0x61
	18	0x74
	19	0x61
Checksum	20	0xA5

Transmit Request frame - 0x10

Description

This frame causes the device to send payload data as an RF packet to a specific destination.

- 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.
- Set the reserved field to **0xFFFE**.
- Query the **NP** command to read the maximum number of payload bytes.

You can set the broadcast radius from **0** up to **NH**. If set to **0**, the value of **NH** specifies the broadcast radius (recommended). This parameter is only used for broadcast transmissions.

You can read the maximum number of payload bytes with the **NP** command.

Format

The following table provides the contents of the frame. For details on the frame structure, see API frame specifications.

Frame data fields	Offset	Description
Frame type	3	0x10
Frame ID	4	Identifies the data frame for the host to correlate with a subsequent ACK (0x8B). If set to **0**, the device does not send a response.
64-bit destination address	5-12	MSB first, LSB last. Set to the 64-bit address of the destination device. Broadcast = **0x000000000000FFFF**
Reserved	13-14	Set to 0xFFFE.
Broadcast radius	15	Sets the maximum number of hops a broadcast transmission can occur. If set to **0**, the broadcast radius is set to the maximum hops value.
Transmit options	16	See the following Transmit Options table. Set all other bits to **0**.
RF data	17-n	Up to **NP** bytes per packet. Sent to the destination device.

Transmit Options bit field

Bit field:

Bit	Meaning	Description
0	Disable ACK	Disable acknowledgments on all unicasts
1	Disable RD	Disable Route Discovery on all DigiMesh unicasts
2	NACK	Enable NACK messages on all DigiMesh API packets
3	Trace route	Enable a Trace Route on all DigiMesh API packets
4	Reserved	<set this bit to 0>
5	Reserved	<set this bit to 0>
6,7	Delivery method	b'00 = <invalid option> b'01 - Point-multipoint (0x40) b'10 = Repeater mode (directed broadcast (0x80) b'11 = DigiMesh (0xC0)

Example

The example shows how to send a transmission to a device if you disable escaping (**AP** = 1), with destination address 0x0013A200 400A0127, and payload "TxData0A".

Frame data fields	Offset	Example
Start delimiter	0	0x7E
Length	MSB 1	0x00
	LSB 2	0x16
Frame type	3	0x10
Frame ID	4	0x01
64-bit destination address	MSB 5	0x00
	6	0x13
	7	0xA2
	8	0x00
	9	0x40
	10	0x0A
	11	0x01
	LSB 12	0x27
16-bit destination network address	MSB 13	0xFF
	LSB 14	0xFE
Broadcast radius	15	0x00
Options	16	0x40
RF data	17	0x54
	18	0x78
	19	0x44
	20	0x61
	21	0x74
	22	0x61
	23	0x30
	24	0x41
Checksum	25	0x13

If you enable escaping (**AP** = 2), the frame should look like:

0x7E 0x00 0x16 0x10 0x01 0x00 0x7D 0x33 0xA2 0x00 0x40 0x0A 0x01 0x27 0xFF 0xFE 0x00
0x00 0x54 0x78 0x44 0x61 0x74 0x61 0x30 0x41 0x7D 0x33

The device calculates the checksum (on all non-escaped bytes) as [0xFF - (sum of all bytes from API frame type through data payload)].

Explicit Addressing Command frame - 0x11

Description

This frame is similar to Transmit Request (0x10), but it also requires you to specify the application-layer addressing fields: endpoints, cluster ID, and profile ID.

This frame causes the device to send payload data as an RF packet to a specific destination, using specific source and destination endpoints, cluster ID, and profile ID.

- 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.
- Set the reserved field to **0xFFFE**.

Query the **NP** command to read the maximum number of payload bytes. For more information, see Firmware commands.

You can read the maximum number of payload bytes with the **NP** command.

Format

The following table provides the contents of the frame. For details on the frame structure, see API frame specifications.

Frame data fields	Offset	Description
Frame type	3	0x11
Frame ID	4	Identifies the data frame for the host to correlate with a subsequent ACK (0x8B). If set to **0**, the device does not send a response.
64-bit destination address	5-12	MSB first, LSB last. Set to the 64-bit address of the destination device. Broadcast = 0x000000000000FFFF
Reserved	13-14	Set to 0xFFFE.
Source endpoint	15	Source endpoint for the transmission.
Destination endpoint	16	Destination endpoint for the transmission.
Cluster ID	17-18	The Cluster ID that the host uses in the transmission.
Profile ID	19-20	The Profile ID that the host uses in the transmission.

Frame data fields	Offset	Description
Broadcast radius	21	Sets the maximum number of hops a broadcast transmission can traverse. If set to 0, the transmission radius set to the network maximum hops value. If the broadcast radius exceeds the value of **NH** then the devices use the value of **NH** as the radius. Only broadcast transmissions use this parameter.
Transmission options	22	See the Transmit Options table below.
Data payload	23-n	Up to **NP** bytes per packet. Sent to the destination device.

Transmit Options bit field

Bit field:

Bit	Meaning	Description
0	Disable ACK	Disable acknowledgments on all unicasts
1	Disable RD	Disable Route Discovery on all DigiMesh unicasts
2	NACK	Enable NACK messages on all DigiMesh API packets
3	Trace Route	Enable a Trace Route on all DigiMesh API packets
4	Reserved	<set this bit to 0>
5	Reserved	<set this bit to 0>
6,7	Delivery method	b'00 = <invalid option> b'01 - Point-multipoint (0x40) b'10 = Directed Broadcast (0x80) b'11 = DigiMesh (0xC0)

Set all other bits to 0.

Example

The following example sends a data transmission to a device with:

- 64-bit address: 0x0013A200 01238400
- Source endpoint: 0xE8
- Destination endpoint: 0xE8
- Cluster ID: 0x11
- Profile ID: 0xC105
- Payload: TxData

Frame data fields	Offset	Example
Start delimiter	0	0x7E
Length	MSB 1	0x00
	LSB 2	0x1A
Frame type	3	0x11
Frame ID	4	0x01
64-bit destination address	MSB 5	0x00
	6	0x13
	7	0xA2
	8	0x00
	9	0x01
	10	0x23
	11	0x84
	LSB12	0x00
Reserved	13	0xFF
	14	0xFE
Source endpoint	15	0xE8
Destination endpoint	16	0xE8
Cluster ID	17	0x00
	18	0x11
Profile ID	19	0xC1
	20	0x05
Broadcast radius	21	0x00
Transmit options	22	0x00
Data payload	23	0x54
	24	0x78
	25	0x44
	26	0x61
	27	0x74
	28	0x61
Checksum	29	0xA6

Remote AT Command Request frame - 0x17

Description

Used to query or set device 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.

Format

The following table provides the contents of the frame. For details on frame structure, see API frame specifications.

Frame data fields	Offset	Description
Frame type	3	0x17
Frame ID	4	Identifies the data frame for the host to correlate with a subsequent ACK (0x97). If set to **0**, the device does not send a response.
64-bit destination address	5-12	MSB first, LSB last. Set to the 64-bit address of the destination device.
Reserved	13-14	Set to 0xFFFE.
Remote command options	15	0x02 = Apply changes on remote. If you do not set this, you must send the **AC** command for changes to take effect. Set all other bits to 0.
AT command	16-17	Command name: two ASCII characters that identify the command.

Example

The following example sends a remote command:

- Change the broadcast hops register on a remote device to 1 (broadcasts go to 1-hop neighbors only).
- Apply changes so the new configuration value takes effect immediately.

In this example, the 64-bit address of the remote device is 0x0013A200 40401122.

Frame data fields	Offset	Example
Start delimiter	0	0x7E
Length	MSB 1	0x00
	LSB 2	0x10
Frame type	3	0x17

Frame data fields	Offset	Example
Frame ID	4	0x01
64-bit destination address	MSB 5	0x00
	6	0x13
	7	0xA2
	8	0x00
	9	0x40
	10	0x40
	11	0x11
	LSB 12	0x22
Reserved	13	0xFF
	14	0xFE
Remote command options	15	0x02 (apply changes)
AT command	16	0x42 (B)
	17	0x48 (H)
Command parameter	18	0x01
Checksum	19	0xF5

AT Command Response frame - 0x88

Description

A device sends this frame in response to an AT Command (0x08 or 0x09) frame. Some commands send back multiple frames; for example, the **ND** command.

Format

The following table provides the contents of the frame. For details on frame structure, see API frame specifications.

Frame data fields	Offset	Description
Frame type	3	0x88
Frame ID	4	Identifies the data frame for the host to correlate with a subsequent ACK. If set to **0**, the device does not send a response.
AT command	5-6	Command name: two ASCII characters that identify the command.

Frame data fields	Offset	Description
Command status	7	0 = OK 1 = ERROR 2 = Invalid command 3 = Invalid parameter
Command data	8-n	The register data in binary format. If the host sets the register, the device does not return this field.

Example

If you change the **BD** parameter on a local device with a frame ID of 0x01, and the parameter is valid, the user receives the following response.

Frame data fields	Offset	Example
Start delimiter	0	0x7E
Length	MSB 1	0x00
	LSB 2	0x05
Frame type	3	0x88
Frame ID	4	0x01
AT command	5	0x42 (B)
	6	0x44 (D)
Command status	7	0x00
Command data		(No command data implies the parameter was set rather than queried)
Checksum	8	0xF0

Modem Status frame - 0x8A

Description

Devices send the status messages in this frame in response to specific conditions.

Format

The following table provides the contents of the frame. For details on frame structure, see API frame specifications.

Frame data fields	Offset	Description
Frame type	3	0x8A
Status	4	

Example

When a device powers up, it returns the following API frame.

Frame data fields	Offset	Example
Start delimiter	0	0x7E
Length	MSB 1	0x00
LSB 2	LSB 2	0x02
Frame type	3	0x8A
Status	4	0x00
Checksum	5	0x75

Transmit Status frame - 0x8B

Description

When a Transmit Request (0x10, 0x11) completes, the device sends a Transmit Status message out of the serial interface. This message indicates if the Transmit Request was successful or if it failed.

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 specifications.

Frame data fields	Offset	Description
Frame type	3	0x8B
Frame ID	4	Identifies the serial interface data frame being reported. If Frame ID = 0 in the associated request frame, no response frame is delivered.
16-bit destination address	5	The 16-bit Network Address where the packet was delivered (if successful). If not successful, this address is 0xFFFD (destination address unknown).
	6	

Frame data fields	Offset	Description
Transmit retry count	7	The number of application transmission retries that occur.
Delivery status	8	0x00 = Success 0x01 = MAC ACK failure 0x02 = Collision avoidance failure 0x21 = Network ACK failure 0x25 = Route not found 0x31 = Internal resource error 0x32 = Internal error
Discovery status	9	0x00 = No discovery overhead 0x02 = Route discovery

Example

In the following example, the destination device reports a successful unicast data transmission successful and a route discovery occurred. The outgoing Transmit Request that this response frame uses Frame ID of 0x47.

Frame Fields	Offset	Example
Start delimiter	0	0x7E
Length	MSB 1	0x00
	LSB 2	0x07
Frame type	3	0x8B
Frame ID	4	0x47
Reserved	5	0xFF
	6	0xFE
Transmit retry count	7	0x00
Delivery status	8	0x00
Discovery status	9	0x02
Checksum	10	0x2E

Legacy TX Status frame - 0x89

Description

When a Legacy TX Request (0x00) is complete, the device sends a Legacy TX Status frame. This message indicates if the packet transmitted successfully or if there was a failure.

Format

The following table provides the contents of the frame. For details on frame structure, see API frame specifications.

Frame data fields	Offset	Description
Frame type	3	0x89
Frame ID	4	Identifies the Legacy TX Request frame being reported.
Status	5	0x00 = standard 0x01 = no ACK received

Example

The following example shows a successful status received.

Frame data fields	Offset	Example
Start delimiter	0	0x7E
Length	MSB 1	0x00
	LSB 2	0x03
Frame type	3	0x89
Frame ID	4	0x01
Status	5	0x00
Checksum	6	0x75

Route Information Packet frame - 0x8D

Description

If you enable NACK or the Trace Route option on a DigiMesh unicast transmission, a device can output this frame for the transmission.

Format

The following table provides the contents of the frame. For details on frame structure, see API frame specifications.

Frame data fields	Offset	Description
Frame type	3	0x8D

Frame data fields	Offset	Description
Source event	4	0x11 = NACK 0x12 = Trace route
Length	5	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.
Timestamp	6-9	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.
ACK timeout count	10	The number of MAC ACK timeouts that occur.
TX blocked count	11	The number of times the transmission was blocked due to reception in progress.
Reserved	12	Reserved, set to 0s.
Destination address	13-20	The address of the final destination node of this network-level transmission.
Source address	21-28	Address of the source node of this network-level transmission.
Responder address	29-36	Address of the node that generates this Route Information packet after it sends (or attempts to send) the packet to the next hop (the Receiver node).
Receiver address	37-44	Address of the node that the device sends (or attempts to send) the data packet.

Example

The following example represents a possible Route Information Packet. A device receives the packet when it performs a trace route on a transmission from one device (serial number 0x0013A200 4052AAAA) to another (serial number 0x0013A200 4052DDDD).

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).

Frame data fields	Offset	Example
Start delimiter	0	0x7E
Length	MSB 1	0x00
	LSB 2	0x2A
Frame type	3	0x8D
Source event	4	0x12
Length	5	0x27

Frame data fields	Offset	Example
Timestamp	MSB 6	0x9C
	7	0x93
	8	0x81
	LSB 9	0x7F
ACK timeout count	10	0x00
TX blocked count	11	0x00
Reserved	12	0x00
Destination address	MSB 13	0x00
	14	0x13
	15	0xA2
	16	0x00
	17	0x40
	18	0x52
	19	0xAA
	LSB 20	0xAA
Source address	MSB 21	0x00
	22	0x13
	23	0xA2
	24	0x00
	25	0x40
	26	0x52
	27	0xDD
	LSB 28	0xDD

Frame data fields	Offset	Example
Responder address	MSB 29	0x00
	30	0x13
	31	0xA2
	32	0x00
	33	0x40
	34	0x52
	35	0xBB
	LSB 36	0xBB
Receiver address	MSB 37	0x00
	38	0x13
	39	0xA2
	40	0x00
	41	0x40
	42	0x52
	43	0xCC
	LSB 44	0xCC
Checksum	45	0xD2

Aggregate Addressing Update frame - 0x8E

Description

The device sends out an Aggregate Addressing Update frame on the serial interface of an API-enabled node when an address update frame (generated by the **AG** command being issued on a node in the network) causes the node to update its **DH** and **DL** registers.

For more information, refer to Establish and maintain network links.

Format

The following table provides the contents of the frame. For details on frame structure, see API frame specifications.

Frame data fields	Offset	Description
Frame type	3	0x8E
Format ID	4	Byte reserved to indicate the format of additional packet information which may be added in future firmware revisions. In the current firmware revision, this field returns 0x00.
New address	5-12	Address to which **DH** and **DL** are being set.
Old address	13-20	Address to which **DH** and **DL** were previously set.

Example

In the following example, a device with destination address (**DH**/**DL**) of 0x0013A200 4052AAAA updates its destination address to 0x0013A200 4052BBBB.

Frame data fields	Offset	Example
Start delimiter	0	0x7E
Length	MSB 1	0x00
	LSB 2	0x12
Frame type	3	0x8E
Format ID	4	0x00
New address	MSB 5	0x00
	6	0x13
	7	0xA2
	8	0x00
	9	0x40
	10	0x52
	11	0xBB
	LSB 12	0xBB

Frame data fields	Offset	Example
Old address	13	0x00
	14	0x13
	15	0xA2
	16	0x00
	17	0x40
	18	0x52
	19	0xAA
	20	0xAA
Checksum	21	0x19

Legacy RX Indicator frame - 0x80

Description

When a device in Legacy Packet Mode (**AO** = 2) receives an RF data packet, it sends this frame out the serial interface.

Format

The following table provides the contents of the frame. For details on frame structure, see API frame specifications.

Frame data fields	Offset	Description
Frame type	3	0x80
64-bit source address	4-11	The sender's 64-bit address. MSB first, LSB last.
RSSI	12	Received Signal Strength Indicator of the last hop. The Hexadecimal equivalent of (-dBm) value. For example if RX signal strength is -40 dBm, then 0x28 (40 decimal) is returned.

Frame data fields	Offset	Description

Options	13	Bit field:
		bit 0: Packet was acknowledged
		bit 1: Broadcasted packet
		bits 6,7:
		
		       b'01 - Point-Multipoint
		       b'10 - Repeater mode (directed broadcast)
		       b'11 - DigiMesh
		
		Ignore all other bits.

Received data	14-n	Received RF data

Example

In the following example, a device with a 64-bit address of 0x0013A200 4052C507 sends a unicast data transmission to a remote device with payload RxData. If **AO** = 2 on the receiving device, it sends the following frame out its serial interface.

Frame data fields	Offset	Example
Start delimiter	0	0x7E
Length	MSB 1	0x00
	LSB 2	0x11
Frame type	3	0x80
64-bit source address	MSB 4	0x00
	5	0x13
	6	0xA2
	7	0x00
	8	0x40
	9	0x52
	10	0xC5
	LSB 11	0x07
RSSI	12	0x28
Options	13	0x01

Frame data fields	Offset	Example
Received data	14	0x52
	15	0x78
	16	0x44
	17	0x61
	18	0x74
	19	0x61
Checksum	20	0xFF

RX Indicator frame - 0x90

Description

When a device configured with a standard API Rx Indicator (**AO** = **0**) receives an RF data packet, it sends it out the serial interface using this message type.

Format

The following table provides the contents of the frame. For details on frame structure, see API frame specifications.

Frame data fields	Offset	Description
Frame type	3	0x90
64-bit source address	4-11	The sender's 64-bit address. MSB first, LSB last.
Reserved	12-13	Reserved.

Receive options	14	Bit field:
		0x01 = Packet acknowledged
		0x02 = Packet was a broadcast packet
		0x06, 0x07:
		
		       b'01 = Point-Multipoint
		       b'10 = Repeater mode (directed broadcast)
		       b'11 = DigiMesh
		
		Ignore all other bits.

Received data	15-n	The RF data the device receives.

Example

In the following example, a device with a 64-bit address of 0x0013A200 40522BAA sends a unicast data transmission to a remote device with payload RxData. If **AO**=0 on the receiving device, it sends the following frame out its serial interface.

Frame data fields	Offset	Example
Start delimiter	0	0x7E
Length	MSB 1	0x00
	LSB 2	0x12
Frame type	3	0x90
64-bit source address	MSB 4	0x00
	5	0x13
	6	0xA2
	7	0x00
	8	0x40
	9	0x52
	10	0x2B
	LSB 11	0xAA
Reserved	12	0xFF
	13	0xFE
Receive options	14	0x01
Received data	15	0x52
	16	0x78
	17	0x44
	18	0x61
	19	0x74
	20	0x61
Checksum	21	0x11

Explicit Rx Indicator frame - 0x91

Description

When a device configured with explicit API Rx Indicator (**AO** = **1**) receives an RF packet, it sends it out the serial interface using this message type.

Note If a Transmit Request frame - 0x10 is sent to a device with **AO** = **1**, the receiving device receives a 0x91 frame with the Source endpoint (SE), Destination endpoint (DE), and Cluster ID (CI) that were set on the transmitting device in Transparent mode, and not the default values.

The Cluster ID and endpoints must be used to identify the type of transaction that occurred.

Format

The following table provides the contents of the frame. For details on frame structure, see API frame specifications.

Frame data fields	Offset	Description
Frame type	3	0x91
64-bit source address	4-11	MSB first, LSB last. The sender's 64-bit address.
Reserved	12-13	Reserved.
Source endpoint	14	Endpoint of the source that initiates transmission.
Destination endpoint	15	Endpoint of the destination where the message is addressed.
Cluster ID	16-17	The Cluster ID where the frame is addressed.
Profile ID	18-19	The Profile ID where the fame is addressed.
Receive options	20	Bit field: 0x01 = Packet acknowledged 0x02 = Packet was a broadcast packet Ignore all other bits.
Received data	21-n	Received RF data.

Example

In the following example, a device with a 64-bit address of 0x0013A200 40522BAA sends a broadcast data transmission to a remote device with payload RxData.

If a device sends the transmission:

- With source and destination endpoints of 0xE0
- Cluster ID = 0x2211
- Profile ID = 0xC105

If **AO** = **1** on the receiving device, it sends the following frame out its serial interface.

Frame data fields	Offset	Example
Start delimiter	0	0x7E
Length	MSB 1	0x00
	LSB 2	0x18
Frame type	3	0x91

Frame data fields	Offset	Example
64-bit source address	MSB 4	0x00
	5	0x13
	6	0xA2
	7	0x00
	8	0x40
	9	0x52
	10	0x2B
	LSB 11	0xAA
Reserved	12	0xFF
	13	0xFE
Source endpoint	14	0xE0
Destination endpoint	15	0xE0
Cluster ID	16	0x22
	17	0x11
Profile ID	18	0xC1
	19	0x05
Receive options	20	0x02
Received data	21	0x52
	22	0x78
	23	0x44
	24	0x61
	25	0x74
	26	0x61
Checksum	27	0x68

Node Identification Indicator frame - 0x95

Description

A device receives this frame when:

- it transmits a node identification message to identify itself
- **AO** = **0**

Format

The following table provides the contents of the frame. For details on frame structure, see API frame specifications.

Frame data fields	Offset	Description
Frame type	3	0x95
64-bit source address	4-11	MSB first, LSB last. The sender's 64-bit address.
Reserved	12-13	Reserved.

Receive options	14	Bit field:
		0x00 = Packet acknowledged
		0x01 = Packet was a broadcast packet
		0x06, 0x07:
		
		    b'01 = Point-Multipoint
		    b'10 = Repeater mode (directed broadcast)
		    b'11 = DigiMesh
		
		Ignore all other bits

Reserved	15-16	Reserved.
64-bit remote address	17-24	Indicates the 64-bit address of the remote device that transmitted the Node Identification Indicator frame.
NI string	25-26	Node identifier string on the remote device. The NI string is terminated with a NULL byte (0x00).
Reserved	27-28	Reserved.
Device type	29	0 = Coordinator 1 = Normal Mode 2 = End Device For more options, see NO (Network Discovery Options).
Source event	30	1 = Frame sent by node identification pushbutton event.
Digi Profile ID	31-32	Set to the Digi application profile ID.
Digi Manufacturer ID	33-34	Set to the Digi Manufacturer ID.
Digi DD value (optional)	35-38	Reports the **DD** value of the responding device. Use the **NO** command to enable this field.
RSSI (optional)	39	Received signal strength indicator. Use the **NO** command to enable this field.

Example

If you press the commissioning pushbutton on a remote device with 64-bit address 0x0013A200407402AC and a default **NI** string sends a Node Identification, all devices on the network receive the following node identification indicator:

A remote device with 64-bit address 0x0013A200407402AC and a default **NI** string sends a Node Identification, all devices on the network receive the following node identification indicator:

If you press the commissioning button on a remote router device with 64-bit address 0x0013A200 40522BAA, 16-bit address 0x7D84, and default **NI** string, devices on the network receive the node identification indicator.

Frame data fields	Offset	Example
Start delimiter	0	0x7E
Length	MSB 1	0x00
	LSB 2	0x25
Frame type	3	0x95
64-bit source address	MSB 4	0x00
	5	0x13
	6	0xA2
	7	0x00
	8	0x40
	9	0x74
	10	0x02
	LSB 11	0xAC
Reserved	12	0xFF
	13	0xFE
Receive options	14	0xC2
Reserved	15	0xFF
	16	0xFE

Frame data fields	Offset	Example
64-bit remote address	MSB 17	0x00
	18	0x13
	19	0xA2
	20	0x00
	21	0x40
	22	0x74
	23	0x02
	LSB 24	0xAC
NI string	25	0x20
	26	0x00
Reserved	27	0xFF
	28	0xFE
Device type	29	0x01
Source event	30	0x01
Digi Profile ID	31	0xC1
	32	0x05
Digi Manufacturer ID	33	0x10
	34	0x1E
Digi DD value (optional)	35	0x00
	36	0x0C
	37	0x00
	38	0x00
RSSI (optional)	39	0x2E
Checksum	40	0x33

Remote Command Response frame - 0x97

Description

If a device receives this frame in response to a Remote Command Request (0x17) frame, the device sends an AT Command Response (0x97) frame out the serial interface.

Some commands, such as the **ND** command, may send back multiple frames.

Format

The following table provides the contents of the frame. For details on frame structure, see API frame specifications.

Frame data fields	Offset	Description
Frame type	3	0x97
Frame ID	4	This is the same value that is passed in to the request.
64-bit source (remote) address	5-12	The address of the remote device returning this response.
Reserved	13-14	Reserved.
AT commands	15-16	The name of the command.
Command status	17	0 = OK 1 = ERROR 2 = Invalid Command 3 = Invalid Parameter 4 = No response The most significant nibble is a bit field as follows: 0x40 = The RSSI field is invalid and should be ignored. 0x80 = Response is a remote command
Command data	18-n	The value of the requested register.

Example

If a device sends a remote command to a remote device with 64-bit address 0x0013A200 40522BAA to query the **SL** command, and if the frame ID = 0x55, the response would look like the following example.

Frame data fields	Offset	Example
Start delimiter	0	0x7E
Length	MSB 1	0x00
	LSB 2	0x13
Frame type	3	0x97
Frame ID	4	0x55

Frame data fields	Offset	Example
64-bit source (remote) address	MSB 5	0x00
	6	0x13
	7	0xA2
	8	0x00
	9	0x40
	10	0x52
	11	0x2B
	LSB 12	0xAA
Reserved	13	0xFF
	14	0xFE
16-bit source (remote) address	MSB 13	0x7D
	LSB 14	0x84
AT commands	15	0x53 (S)
	16	0x4C (L)
Command status	17	0x00
Command data	18	0x40
	19	0x52
	20	0x2B
	21	0xAA
Checksum	22	0xF4

Work with networked devices

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.

Local configuration

You can configure devices locally using serial commands in Transparent or API mode, or remotely using remote API commands. Devices that are in API mode can send configuration commands to set or read the configuration settings of any device in the network.

Remote configuration

When you do not have access to the device's serial port, you can use a separate device in API mode to remotely configure it. To remotely configure devices, use the following steps.

Send a remote command

To send a remote command, populate the Remote AT Command Request frame - 0x17 with:

1. The 64-bit address of the remote device.
2. The correct command options value.
3. Optionally, the command and parameter data.
4. If you want a command response, set the Frame ID field to a non-zero value.

The firmware only supports unicasts of remote commands. You cannot broadcast remote commands.

XCTU has a Frames Generator tool that can assist you with building and sending a remote AT frame; see Frames generator tool in the *XCTU User Guide*.

Apply changes on remote devices

When you use remote commands to change the command parameter settings on a remote device, you must apply the parameter changes or they do not take effect. For example, if you change the **BD** parameter, the actual serial interface rate does not change on the remote device until you apply the changes. You can apply the changes using remote commands in one of three ways:

1. Set the apply changes option bit in the API frame.
2. Send an **AC** command to the remote device.
3. Send the **WR** command followed by the **FR** command to the remote device to save the changes and reset the device.

Remote command response

If a local device sends a command request to a remote device, and the API frame ID is non-zero, the remote device sends a remote command response transmission back to the local device.

When the local device receives a remote command response transmission, it sends a remote command response API frame out its UART. The remote command response indicates:

1. The status of the command, which is either success or the reason for failure.

2. In the case of a command query, it includes the register value.

The device that sends a remote command does not receive a remote command response frame if:

1. It could not reach the destination device.

2. You set the frame ID to 0 in the remote command request.

Establish and maintain network links

Build aggregate routes

In many applications, many or all of the nodes in the network must 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, you can use the **AG** command to automatically build routes to an aggregate node in a DigiMesh network.

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

Upon deploying a DigiMesh network, you can 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 optionally use the **AG** 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; typically you should replace this value with the 64-bit address of the node sending the **AG** broadcast. However, if you do not want to update the **DH**/**DL** of the device receiving the **AG** broadcast you can use the invalid address of 0xFFFE. The receiving nodes that are configured in API mode output an Aggregator Update API frame (0x8E) if they update their **DH**/**DL** address; for a description of the frame, see Aggregate Addressing Update frame - 0x8E.

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. The devices use this routing information for future DigiMesh unicast transmissions.

DigiMesh routing examples

Example one:

In a scenario where you deploy a network, and then you want to update the **DH** and **DL** registers of all the devices in the network so that they use the MAC address of the aggregator node, which has the MAC address 0x0013A200 4052C507, you could use the following technique.

1. Deploy all devices in the network with the default **DH**/**DL** of 0xFFFF.

2. Serially, send an ATAGFFFF command to the aggregator node so it sends the broadcast transmission to the rest of the nodes.

All the nodes in the network that receive the **AG** broadcast set their **DH** to 0x0013A200 and their **DL** to 0x4052C507. These nodes automatically build a route to the aggregator node.

Example two:

If you want all of the nodes in the network to build routes to an aggregator node with a MAC address of 0x0013A200 4052C507 without affecting the **DH** and **DL** registers of any nodes in the network:

1. Send the ATAGFFFE command to the aggregator node. This sends an **AG** broadcast to all of the nodes in the network.
2. All of the nodes internally update only their routing table information to contain a route to the aggregator node.
3. None of the nodes update their **DH** and **DL** registers because none of the registers are set to the 0xFFFE address.

Replace nodes

You can use the **AG** command to update the routing table and **DH**/**DL** registers in the network after you replace a device. To update only the routing table information without affecting the **DH** and **DL** registers, use the process in example two, above.

To update the **DH** and **DL** registers of the network, use example three, below.

Example three:

This example shows how to cause all devices to update their **DH** and **DL** registers to the MAC address of the sending device. In this case, assume you are using a device with a serial number of 0x0013A200 4052C507 as a network aggregator, and the sending device has a MAC address of 0x0013A200 F5E4D3B2 To update the **DH** and **DL** registers to the sending device's MAC address:

1. Replace the aggregator with 0x0013A200 F5E4D3B2.
2. Send the ATAG0013A200 4052C507 command to the new device.

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.

1. Transmit data to the loopback cluster ID (0x12) and data endpoint (0xE8) on a remote device.

2. The remote device receives data on the loopbach cluster ID and data endpoint.

Mesh Network

4. Source receives loopback transmission and sends received packet out the UART.

3. Remote transmits the received packet back to the sender.
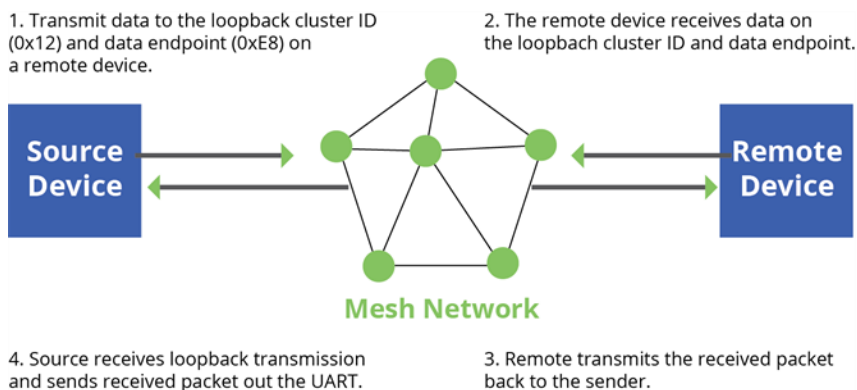
The configuration steps for sending data to the loopback cluster ID depend on what mode the device is in. For details on setting the mode, see AP (API Enable). The following sections list the steps based on the device's mode.

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 **DH** and **DL** commands to the address of the remote device.

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 frame - 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 links between adjacent devices

It often helps to test the quality of a link between two adjacent modules in a network. You can use the Test Link Request Cluster ID to send a number of test packets between any two devices in a network. To clarify the example, we refer to "device A" and "device B" in this section.

To request that device B perform a link test against device A:

1. Use device A in API mode (**AP** = **1**) to send an Explicit Addressing Command (0x11) frame to device B.
2. Address the frame to the Test Link Request Cluster ID (0x0014) and destination endpoint: 0xE6.
3. Include a 12-byte payload in the Explicit Addressing Command frame with the following format:

Number of bytes	Field name	Description
8	Destination address	The address the device uses to test its link. For this example, use the device A address.
2	Payload size	The size of the test packet. Use the **NP** command to query the maximum payload size for the device.
2	Iterations	The number of packets to send. This must be a number between 1 and 4000.

4. Device B should transmit test link packets.
5. When device B completes transmitting the test link packets, it sends the following data packet to device A's Test Link Result Cluster (0x0094) on endpoint (0xE6).
6. Device A outputs the following information as an API Explicit RX Indicator (0x91) frame:

Number of bytes	Field name	Description
8	Destination address	The address the device used to test its link.
2	Payload size	The size of the test packet device A sent to test the link.
2	Iterations	The number of packets that device A sent.
2	Success	The number of packets that were successfully acknowledged.
2	Retries	The number of MAC retries used to transfer all the packets.
1	Result	0x00 - the 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.
1	minRSSI	The weakest RSSI reading observed during the test.
1	avgRSSI	The average RSSI reading observed during the test.

Example

Suppose that you want to test the link between device A (**SH**/**SL** = 0x0013A200 40521234) and device B (**SH**/**SL**=0x0013A 200 4052ABCD) by transmitting 1000 40-byte packets:

Send the following API packet to the serial interface of device A.

In the following example packet, whitespace marks fields, 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

When the test is finished, the following API frame may be received:

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

This means:

- 999 out of 1000 packets were successful.
- The device made 100 retries.
- **RR** = 10.
- maxRSSI = -80 dBm.
- minRSSI = -83 dBm.
- avgRSSI = -82 dBm.

If the Result field does not equal zero, an error has occurred. Ignore the other fields in the packet.

If the Success field equals zero, ignore the RSSI fields.

The device that sends the request for initiating the Test link and outputs the result does not need to be the sender or receiver of the test. It is possible for a third node, "device C", to request device A to perform a test link against device B and send the results back to device C to be output. It is also possible for device B to request device A to perform the previously mentioned test. In other words, the

frames can be sent by either device A, device B or device C and in all cases the test is the same: device A sends data to device B and reports the results.

RSSI indicators

The received signal strength indicator (RSSI) measures the amount of power present in a radio signal. It is an approximate value for signal strength received on an antenna.

You can use the **DB** command to measure the RSSI on a device. **DB** returns the RSSI value measured in -dBm of the last packet the device received. This number can be misleading in multi-hop 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.

To determine the **DB** value in hardware:

1. Use the RSSI module pin (pin 7). When the device receives data, it sets the RSSI PWM duty cycle to a value based on the RSSI of the packet it receives.

This value only indicates the quality of the last hop of a multi-hop transmission. You could connect this pin to an LED to indicate if the link is stable or not.

Discover all the devices on a network

You can use the **ND** (Network Discovery) command to discover all devices on a network. When you send the **ND** command:

1. The device sends a broadcast **ND** command through the network.
2. All devices that receive the command send a response that includes their addressing information, node identifier string and other relevant information. For more information on the node identifier string, see NI (Node Identifier).

ND is useful for generating a list of all device addresses in a network.

When a device receives the network discovery command, it waits a random time before sending its own response. You can use the **NT** command to set the maximum time delay on the device that you use to send the **ND** command.

- The device that sends the **ND** includes its **NT** setting in the transmission to provide a delay window for all devices in the network.
- On large networks, you may need to increase **NT** to improve the reliability of network discovery.
- The default **NT** value is 0x82 (13 seconds).

Discover devices within RF range

- You can use the **FN** (Find Neighbors) command to discover the devices that are immediate neighbors (within RF range) of a particular device.
- **FN** is useful in determining network topology and determining possible routes.

You can send **FN** locally on a device in Command mode or you can use a local AT Command frame - 0x08.

To use **FN** remotely, send the target node a Remote AT Command Request frame - 0x17 using **FN** as the name of the AT command.

The device you use to send **FN** transmits a zero-hop broadcast to all of its immediate neighbors. All of the devices that receive this broadcast send an RF packet to the device that transmitted the **FN** command. If you sent **FN** remotely, the target devices respond directly to the device that sent the **FN** command. The device that sends **FN** outputs a response packet in the same format as an AT Command Response frame - 0x88.

Trace route option

In many networks, it is useful to determine the route that a DigiMesh unicast takes to its destination; particularly, when you set up a network or want to diagnose problems within a network.

Note Because of the large number of Route Information Packet frames that a unicast with trace route enabled can generate, we suggest you only use the trace route option for occasional diagnostic purposes and not for normal operations.

The Transmit Request (0x10) frame contains a trace route option, which transmits routing information packets to the originator of the unicast using the intermediate nodes.

When a device sends a unicast with the trace route option enabled, the unicast transmits to its destination devices, which forward the unicast to its eventual destination. The destination device transmits a Route Information Packet (0x8D) frame back along the route to the unicast originator.

The Route Information Packet frame contains:

- Addressing information for the unicast.
- Addressing information for the intermediate hop.
- Other link quality information.

For a full description of the Route Information Packet frame, see Route Information Packet frame - 0x8D.

Trace route example

Suppose that you successfully unicast a data packet with trace route enabled from device A to device E, through devices B, C, and D. The following sequence would occur:

- After the data packet makes a successful MAC transmission from device A to device B, device A outputs a Route Information Packet frame indicating that the transmission of the data packet from device A to device E was successful in forwarding one hop from device A to device B.
- After the data packet makes a successful MAC transmission from device B to device C, device B transmits a Route Information Packet frame to device A. When device A receives the Route Information packet, it outputs it over its serial interface.
- After the data packet makes a successful MAC transmission from device C to device D, device C transmits a Route Information Packet frame to device A (through device B). When device A receives the Route Information packet, it outputs it over its serial interface.
- After the data packet makes a successful MAC transmission from device D to device E, device D transmits a Route Information Packet frame to device A (through device C and device B). When device A receives the Route Information packet, it outputs it over its serial interface.

There is no guarantee that Route Information Packet frames will arrive in the same order as the route taken by the unicast packet. On a weak route, it is also possible for the transmission of Route Information Packet frames to fail before arriving at the unicast originator.

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.

Regulatory information

FCC (United States)

These RF modules comply with Part 15 of the FCC rules and regulations. Compliance with the labeling requirements, FCC notices and antenna usage guidelines is required.

In order to operate under Digi's FCC Certification, integrators must comply with the following regulations:

1. The integrator must ensure that the text provided with this device (in the labeling requirements section that follows) is placed on the outside of the final product and within the final product operation manual.

2. The device may only be used with antennas that have been tested and approved for use with this device; refer to FCC antenna certifications.

OEM labeling requirements

> ⚠ **WARNING!** The Original Equipment Manufacturer (OEM) must ensure that FCC labeling requirements are met. This includes a clearly visible label on the outside of the final product enclosure that displays the text shown in the figure below.

The following text is the required FCC label for OEM products containing the XBee-PRO SX RF Module:

Contains FCC ID: MCQ-XBPSX
The enclosed device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: *(i.)* this device may not cause harmful interference and *(ii.)* this device must accept any interference received, including interference that may cause undesired operation.

The following text is the required FCC label for OEM products containing the XBee SX RF Module:

Contains FCC ID: MCQ-XBSX
The enclosed device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: *(i.)* this device may not cause harmful interference and *(ii.)* this device must accept any interference received, including interference that may cause undesired operation.

FCC notices

IMPORTANT: These RF modules have been certified by the FCC for use with other products without any further certification (as per FCC section 2.1091). Modifications not expressly approved by Digi could void the user's authority to operate the equipment.

IMPORTANT: Integrators must test final product to comply with unintentional radiators (FCC sections 15.107 & 15.109) before declaring compliance of their final product to Part 15 of the FCC rules.

IMPORTANT: These RF modules have been certified for remote and base radio applications. If the module will be used for portable applications, the device must undergo SAR testing.

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation.

If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures: Re-orient or relocate the receiving antenna,

Increase the separation between the equipment and receiver, Connect equipment and receiver to outlets on different circuits, or Consult the dealer or an experienced radio/TV technician for help.

RF exposure statement

This statement must be included as a CAUTION statement in integrator product manuals.

WARNING! This equipment is approved only for mobile and base station transmitting devices. Antenna(s) used for this transmitter must be installed to provide a separation distance of at least 34 cm from all persons and must not be co-located or operating in conjunction with any other antenna or transmitter.

FCC antenna certifications

WARNING! This device has been tested with the antennas listed in the tables of this section. When integrated into products, fixed antennas require installation preventing end users from replacing them with non-approved antennas. Antennas not listed in the tables must be tested to comply with FCC Section 15.203 (unique antenna connectors) and Section 15.247 (emissions).

Fixed base station and mobile applications

Digi devices are pre-FCC approved for use in fixed base station and mobile applications. When the antenna is mounted at least 34 cm from nearby persons, the application is considered a mobile application.

Portable applications and SAR testing

When the antenna is mounted closer than 34 cm to nearby persons, then the application is considered "portable" and requires an additional test be performed on the final product. This test is called Specific Absorption Rate (SAR) testing and measures the emissions from the device and how they affect the person.

RF exposure statement

This statement must be included as a CAUTION statement in integrator product manuals.

WARNING! This equipment is approved only for mobile and base station transmitting devices. Antenna(s) used for this transmitter must be installed to provide a separation distance of at least 34 cm from all persons and must not be co-located or operating in conjunction with any other antenna or transmitter.

XBee-PRO XTC antenna options

The following tables cover the antennas that are approved for use with the XBee-PRO XTC RF modules. If applicable, the tables show the required cable loss between the device and the antenna.

Digi does not carry all of these antenna variants. Contact Digi Sales for available antennas.

Dipole antennas

All antenna part numbers followed by an asterisk (*) are not available from Digi. Consult with an antenna manufacturer for an equivalent option.

Part number	Type	Connector	Gain	Required antenna cable loss	Application
A09-HSM-7 [1]	Straight half-wave	RPSMA	2.1 dBi	0.4 dB	Fixed / mobile
A09-HASM-675	Articulated half-wave	RPSMA	2.1 dBi	0.4 dB	Fixed / mobile
A09-HABMM-P5I	Swivel half wave with 5" pigtail	MMCX	2.1 dBi	0.4 dB	Fixed / mobile
A09-HBMM-P5I	Straight half-wave with 6" pigtail	MMCX	2.1 dBi	0.4 dB	Fixed / mobile
A09-HASM-7*	Articulated half-wave	RPSMA	2.1 dBi	0.4 dB	Fixed
A09-HRSM*	Right angle half-wave	RPSMA	2.1 dBi	0.4 dB	Fixed
A09-HG*	Glass mounted half-wave	RPSMA	2.1 dBi	0.4 dB	Fixed
A09-HATM*	Articulated half-wave	RPTNC	2.1 dBi	0.4 dB	Fixed
A09-H*	Half-wave dipole	RPSMA	2.1 dBi	0.4 dB	Fixed

Yagi antennas

All antenna part numbers followed by an asterisk (*) are not available from Digi. Consult with an antenna manufacturer for an equivalent option.

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[1]Installers should apply additional torque to screw on the antenna.

Part number	Type	Gain	Connector	Required antenna cable loss	Application
A09-Y6NF*	2 element Yagi	6.1 dBi	N	2.0 dB	Fixed/mobile
A09-Y7NF*	3 element Yagi	7.1 dBi	N	3.0 dB	Fixed/mobile
A09-Y8NF	4 element Yagi	8.1 dBi	N	4.0 dB	Fixed/mobile
A09-Y9NF*	4 element Yagi	9.1 dBi	N	5.0 dB	Fixed/mobile
A09-Y10NF*	5 element Yagi	10.1 dBi	N	6.0 dB	Fixed/mobile
A09-Y11NF	6 element Yagi	11.1 dBi	N	7.0 dB	Fixed/mobile
A09-Y12NF*	7 element Yagi	12.1 dBi	N	8.0 dB	Fixed/mobile
A09-Y13NF*	9 element Yagi	13.1 dBi	N	9.0 dB	Fixed/mobile
A09-Y14NF*	14 element Yagi	14.0 dBi	N	9.9 dB	Fixed/mobile
A09-Y6TM*	2 element Yagi	6.1 dBi	RPTNC	2.0 dB	Fixed/mobile
A09-Y7TM*	3 element Yagi	7.1 dBi	RPTNC	3.0 dB	Fixed/mobile
A09-Y8TM*	4 element Yagi	8.1 dBi	RPTNC	4.0 dB	Fixed/mobile
A09-Y9TM*	4 element Yagi	9.1 dBi	RPTNC	5.0 dB	Fixed/mobile
A09-Y10TM-P10I	5 element Yagi	10.1 dBi	RPTNC	6.0 dB	Fixed/mobile
A09-Y11TM*	6 element Yagi	11.1 dBi	RPTNC	7.0 dB	Fixed/mobile
A09-Y12TM*	7 element Yagi	12.1 dBi	RPTNC	8.0 dB	Fixed/mobile
A09-Y13TM*	9 element Yagi	13.1 dBi	RPTNC	9.0 dB	Fixed/mobile
A09-Y14TM*	14 element Yagi	14.0 dBi	RPTNC	9.9 dB	Fixed/mobile

Omni-directional base station antennas

All antenna part numbers followed by an asterisk (*) are not available from Digi. Consult with an antenna manufacturer for an equivalent option.

Part number	Type	Gain	Connector	Required antenna cable loss	Application
A09-F0NF*	Fiberglass base station	0 dBi	N	-	Fixed
A09-F1NF*	Fiberglass base station	1.0 dBi	N	-	Fixed
A09-F2NF-M	Fiberglass base station	2.1 dBi	N	-	Fixed
A09-F3NF*	Fiberglass base station	3.1 dBi	N	-	Fixed
A09-F4NF*	Fiberglass base station	4.1 dBi	N	-	Fixed
A09-F5NF-M	Fiberglass base station	5.1 dBi	N	-	Fixed
A09-F6NF*	Fiberglass base station	6.1 dBi	N	0.9 dB	Fixed
A09-F7NF*	Fiberglass base station	7.1 dBi	N	1.9 dB	Fixed
A09-F8NF-M	Fiberglass base station	8.1 dBi	N	2.9 dB	Fixed
A09-F0SM*	Fiberglass base station	0 dBi	RPSMA	-	Fixed
A09-F1SM*	Fiberglass base station	1.0 dBi	RPSMA	-	Fixed
A09-F2SM*	Fiberglass base station	2.1 dBi	RPSMA	-	Fixed
A09-F3SM*	Fiberglass base station	3.1 dBi	RPSMA	-	Fixed
A09-F4SM*	Fiberglass base station	4.1 dBi	RPSMA	-	Fixed
A09-F5SM*	Fiberglass base station	5.1 dBi	RPSMA	-	Fixed
A09-F6SM*	Fiberglass base station	6.1 dBi	RPSMA	0.9 dB	Fixed
A09-F7SM*	Fiberglass base station	7.1 dBi	RPSMA	1.9 dB	Fixed
A09-F8SM*	Fiberglass base station	8.1 dBi	RPSMA	2.9 dB	Fixed
A09-F0TM*	Fiberglass base station	0 dBi	RPTNC	-	Fixed
A09-F1TM*	Fiberglass base station	1.0 dBi	RPTNC	-	Fixed
A09-F2TM*	Fiberglass base station	2.1 dBi	RPTNC	-	Fixed

Part number	Type	Gain	Connector	Required antenna cable loss	Application
A09-F3TM*	Fiberglass base station	3.1 dBi	RPTNC	-	Fixed
A09-F4TM*	Fiberglass base station	4.1 dBi	RPTNC	-	Fixed
A09-F5TM*	Fiberglass base station	5.1 dBi	RPTNC	-	Fixed
A09-F6TM*	Fiberglass base station	6.1 dBi	RPTNC	0.9 dB	Fixed
A09-F7TM*	Fiberglass base station	7.1 dBi	RPTNC	1.9 dB	Fixed
A09-F8TM*	Fiberglass base station	8.1 dBi	RPTNC	2.9 dB	Fixed
A09-W7*	Wire base station	7.1 dBi	RPN	1.9 dB	Fixed
A09-W7SM*	Wire base station	7.1 dBi	RPSMA	1.9 dB	Fixed
A09-W7TM*	Wire base station	7.1 dBi	RPTNC	1.9 dB	Fixed

Dome antennas

All antenna part numbers followed by an asterisk (*) are not available from Digi. Consult with an antenna manufacturer for an equivalent option.

Part number	Type	Gain	Connector	Required antenna cable loss	Application
A09-D3PNF*	Omnidirectional permanent mount	3.0 dBi	N	0.4 dB	Fixed/mobile
A09-D3NF*	Omnidirectional magnetic mount	3.0 dBi	N	0.4 dB	Fixed/mobile
A09-D3PTM*	Omnidirectional permanent mount	3.0 dBi	RPTNC	0.4 dB	Fixed/mobile
A09-D3PSM*	Omnidirectional permanent mount	3.0 dBi	RPSMA	0.4 dB	Fixed/mobile

Monopole antennas

All antenna part numbers followed by an asterisk (*) are not available from Digi. Consult with an antenna manufacturer for an equivalent option.

Part number	Type	Gain	Connector	Required antenna cable loss	Application
A09-QRAMM	3" Quarter wave wire	2.1 dBi	MMCX	-	Fixed/mobile
A09-QRSM-2.1*	Quarter wave 2.1" right angle	3.3 dBi	RPSMA	0.4 dB	Fixed/mobile
A09-QW*	Quarter wave wire	1.9 dBi	Permanent	-	Fixed/mobile
A09-QSM-3*	Quarter wave straight	1.9 dBi	RPSMA	-	Fixed/mobile
A09-QSM-3H*	Heavy duty quarter wave straight	1.9 dBi	RPSMA	-	Fixed/mobile
A09-QBMM-P6I*	Quarter wave w/ 6" pigtail	1.9 dBi	MMCX	-	Fixed/mobile
A09-QHSM-2*	2" straight	1.9 dBi	RPSMA	-	Fixed/mobile
A09-QHRSM-2*	2" right angle	1.9 dBi	RPSMA	-	Fixed/mobile
A09-QHRSM-170*	1.7" right angle	1.9 dBi	RPSMA	-	Fixed/mobile
A09-QRSM-380*	3.8" right angle	1.9 dBi	RPSMA	-	Fixed/mobile
A09-QAPM-520*	5.2" articulated screw mount	1.9 dBi	Permanent	-	Fixed/mobile
A09-QSPM-3*	3" straight screw mount	1.9 dBi	Permanent	-	Fixed/mobile
A09-QAPM-3*	3" articulated screw mount	1.9 dBi	Permanent	-	Fixed/mobile
A09-QAPM-3H*	3" articulated screw mount	1.9 dBi	Permanent	-	Fixed/mobile

XBee XTC antenna options

The following tables cover the antennas that are approved for use with the XBee XTC RF modules. If applicable, the tables show the required cable loss between the device and the antenna.

Digi does not carry all of these antenna variants. Contact Digi Sales for available antennas.

Dipole antennas

All antenna part numbers followed by an asterisk (*) are not available from Digi. Consult with an antenna manufacturer for an equivalent option.

Part number	Type	Connector	Gain	Required antenna cable loss	Application
A09-HSM-7 [1]	Straight half-wave	RPSMA	2.1 dBi	0.4 dB	Fixed/mobile
A09-HASM-675	Articulated half-wave	RPSMA	2.1 dBi	0.4 dB	Fixed/mobile
A09-HABMM-P5I	Swivel half wave with 5" pigtail	MMCX	2.1 dBi	0.4 dB	Fixed/mobile
A09-HBMM-P5I	Straight half-wave with 6" pigtail	MMCX	2.1 dBi	0.4 dB	Fixed/mobile
A09-HASM-7*	Articulated half-wave	RPSMA	2.1 dBi	0.4 dB	Fixed
A09-HRSM*	Right angle half-wave	RPSMA	2.1 dBi	0.4 dB	Fixed
A09-HG*	Glass mounted half-wave	RPSMA	2.1dBi	0.4 dB	Fixed
A09-HATM*	Articulated half-wave	RPTNC	2.1 dBi	0.4 dB	Fixed
A09-H*	Half-wave dipole	RPSMA	2.1 dBi	0.4 dB	Fixed

Yagi antennas

All antenna part numbers followed by an asterisk (*) are not available from Digi. Consult with an antenna manufacturer for an equivalent option.

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[1]Installers should apply additional torque to screw on the antenna.

Part number	Type	Gain	Connector	Required antenna cable loss	Application
A09-Y6NF*	2 element Yagi	6.1 dBi	N	-	Fixed/mobile
A09-Y7NF*	3 element Yagi	7.1 dBi	N	-	Fixed/mobile
A09-Y8NF	4 element Yagi	8.1 dBi	N	-	Fixed/mobile
A09-Y9NF*	4 element Yagi	9.1 dBi	N	-	Fixed/mobile
A09-Y10NF*	5 element Yagi	10.1 dBi	N	-	Fixed/mobile
A09-Y11NF	6 element Yagi	11.1 dBi	N	-	Fixed/mobile
A09-Y12NF*	7 element Yagi	12.1 dBi	N	-	Fixed/mobile
A09-Y13NF*	9 element Yagi	13.1 dBi	N	-	Fixed/mobile
A09-Y14NF*	10 element Yagi	14.1 dBi	N	-	Fixed/mobile
A09-Y14NF-ALT*	12 element Yagi	14.1 dBi	N	-	Fixed/mobile
A09-Y15NF	13 element Yagi	15.1 dBi	N	0.7 dB	Fixed/mobile
A09-Y15NF-ALT*	15 element Yagi	15.1 dBi	N	0.7 dB	Fixed/mobile
A09-Y6TM*	2 element Yagi	6.1 dBi	RPTNC	-	Fixed/mobile
A09-Y7TM*	3 element Yagi	7.1 dBi	RPTNC	-	Fixed/mobile
A09-Y8TM*	4 element Yagi	8.1 dBi	RPTNC	-	Fixed/mobile
A09-Y9TM*	4 element Yagi	9.1 dBi	RPTNC	-	Fixed/mobile
A09-Y10TM-P10*	5 element Yagi	10.1 dBi	RPTNC	-	Fixed/mobile
A09-Y11TM*	6 element Yagi	11.1 dBi	RPTNC	-	Fixed/mobile
A09-Y12TM*	7 element Yagi	12.1 dBi	RPTNC	-	Fixed/mobile
A09-Y13TM*	9 element Yagi	13.1 dBi	RPTNC	-	Fixed/mobile
A09-Y14TM*	10 element Yagi	14.1 dBi	RPTNC	-	Fixed/mobile

Part number	Type	Gain	Connector	Required antenna cable loss	Application
A09-Y14TM-ALT*	12 element Yagi	14.1 dBi	RPTNC	-	Fixed/mobile
A09-Y15TM*	13 element Yagi	15.1 dBi	RPTNC	0.7 dB	Fixed/mobile
A09-Y15TM-P10I	15 element Yagi	15.1 dBi	RPTNC	0.7 dB	Fixed/mobile

Omni-directional base station antennas

All antenna part numbers followed by an asterisk (*) are not available from Digi. Consult with an antenna manufacturer for an equivalent option.

Part number	Type	Gain	Connector	Required antenna cable loss	Application
A09-F0NF*	Fiberglass Base Station	0 dBi	N	-	Fixed
A09-F1NF*	Fiberglass Base Station	1.0 dBi	N	-	Fixed
A09-F2NF-M*	Fiberglass Base Station	2.1 dBi	N	-	Fixed
A09-F3NF*	Fiberglass Base Station	3.1 dBi	N	-	Fixed
A09-F4NF*	Fiberglass Base Station	4.1 dBi	N	-	Fixed
A09-F5NF-M	Fiberglass Base Station	5.1 dBi	N	-	Fixed
A09-F6NF*	Fiberglass Base Station	6.1 dBi	N	-	Fixed
A09-F7NF*	Fiberglass Base Station	7.1 dBi	N	-	Fixed
A09-F8NF-M	Fiberglass Base Station	8.1 dBi	N	0.7 dB	Fixed
A09-F0SM*	Fiberglass Base Station	0 dBi	RPSMA	-	Fixed
A09-F1SM*	Fiberglass Base Station	1.0 dBi	RPSMA	-	Fixed
A09-F2SM*	Fiberglass Base Station	2.1 dBi	RPSMA	-	Fixed
A09-F3SM*	Fiberglass Base Station	3.1 dBi	RPSMA	-	Fixed
A09-F4SM*	Fiberglass Base Station	4.1 dBi	RPSMA	-	Fixed

Part number	Type	Gain	Connector	Required antenna cable loss	Application
A09-F5SM*	Fiberglass Base Station	5.1 dBi	RPSMA	-	Fixed
A09-F6SM*	Fiberglass Base Station	6.1 dBi	RPSMA	-	Fixed
A09-F7SM*	Fiberglass Base Station	7.1 dBi	RPSMA	-	Fixed
A09-F8SM*	Fiberglass Base Station	8.1 dBi	RPSMA	0.7 dB	Fixed
A09-F0TM*	Fiberglass Base Station	0 dBi	RPTNC	-	Fixed
A09-F1TM*	Fiberglass Base Station	1.0 dBi	RPTNC	-	Fixed
A09-F2TM*	Fiberglass Base Station	2.1 dBi	RPTNC	-	Fixed
A09-F3TM*	Fiberglass Base Station	3.1 dBi	RPTNC	-	Fixed
A09-F4TM*	Fiberglass Base Station	4.1 dBi	RPTNC	-	Fixed
A09-F5TM*	Fiberglass Base Station	5.1 dBi	RPTNC	-	Fixed
A09-F6TM*	Fiberglass Base Station	6.1 dBi	RPTNC	-	Fixed
A09-F7TM*	Fiberglass Base Station	7.1 dBi	RPTNC	-	Fixed
A09-F8TM*	Fiberglass Base Station	8.1 dBi	RPTNC	0.7 dB	Fixed
A09-W7*	Wire Base Station	7.1 dBi	RPN	-	Fixed
A09-W7SM*	Wire Base Station	7.1 dBi	RPSMA	-	Fixed
A09-W7TM*	Wire Base Station	7.1 dBi	RPTNC	-	Fixed

Dome antennas

All antenna part numbers followed by an asterisk (*) are not available from Digi. Consult with an antenna manufacturer for an equivalent option.

Part number	Type	Gain	Connector	Required antenna cable loss	Application
A09-D3PNF*	Omnidirectional permanent mount	3.0 dBi	N	0.4 dB	Fixed/mobile

Part number	Type	Gain	Connector	Required antenna cable loss	Application
A09-D3NF*	Omnidirectional magnetic mount	3.0 dBi	N	0.4 dB	Fixed/mobile
A09-D3PTM*	Omnidirectional permanent mount	3.0 dBi	RPTNC	0.4 dB	Fixed/mobile
A09-D3PSM*	Omnidirectional permanent mount	3.0 dBi	RPSMA	0.4 dB	Fixed/mobile

Monopole antennas

All antenna part numbers followed by an asterisk (*) are not available from Digi. Consult with an antenna manufacturer for an equivalent option.

Part number	Type	Gain	Connector	Required antenna cable loss	Application
A09-QRAMM	3" Quarter wave wire	2.1 dBi	MMCX	-	Fixed/mobile
A09-QRSM-2.1*	Quarter wave 2.1" right angle	3.3 dBi	RPSMA	0.4 dB	Fixed/mobile
A09-QW*	Quarter wave wire	1.9 dBi	Permanent	-	Fixed/mobile
A09-QSM-3*	Quarter wave straight	1.9 dBi	RPSMA	-	Fixed/mobile
A09-QSM-3H*	Heavy duty quarter wave straight	1.9 dBi	RPSMA	-	Fixed/mobile
A09-QBMM-P6I*	Quarter wave w/ 6" pigtail	1.9 dBi	MMCX	-	Fixed/mobile
A09-QHSM-2*	2" straight	1.9 dBi	RPSMA	-	Fixed/mobile
A09-QHRSM-2*	2" right angle	1.9 dBi	RPSMA	-	Fixed/mobile
A09-QHRSM-170*	1.7" right angle	1.9 dBi	RPSMA	-	Fixed/mobile
A09-QRSM-380*	3.8" right angle	1.9 dBi	RPSMA	-	Fixed/mobile
A09-QAPM-520*	5.2" articulated screw mount	1.9 dBi	Permanent	-	Fixed/mobile
A09-QSPM-3*	3" straight screw mount	1.9 dBi	Permanent	-	Fixed/mobile
A09-QAPM-3*	3" articulated screw mount	1.9 dBi	Permanent	-	Fixed/mobile
A09-QAPM-3H*	3" articulated screw mount	1.9 dBi	Permanent	-	Fixed/mobile

FCC publication 996369 related information

In publication 996369 section D03, the FCC requires information concerning a module to be presented by OEM manufacturers. This section assists in answering or fulfilling these requirements.

2.1 General

No requirements are associated with this section.

2.2 List of applicable FCC rules

This module conforms to FCC Part 15.247.

2.3 Summarize the specific operational use conditions

Certain approved antennas require attenuation for operation. For the XBee XTC DigiMesh RF Module, see XBee XTC antenna options. For the XBee-PRO XTC DigiMesh RF Module, see XBee-PRO XTC antenna options.

Host product user guides should include the antenna table if end customers are permitted to select antennas.

2.4 Limited module procedures

Not applicable.

2.5 Trace antenna designs

While it is possible to build a trace antenna into the host PCB, this requires at least a Class II permissive change to the FCC grant which includes significant extra testing and cost. If an embedded trace or chip antenna is desired, contact a Digi sales representative for information on how to engage with a lab to get the modified FCC grant.

2.6 RF exposure considerations

For RF exposure considerations see RF exposure statement, XBee XTC antenna options, and XBee-PRO XTC antenna options.

Host product manufacturers need to provide end-users a copy of the "RF Exposure" section of the manual: RF exposure statement.

2.7 Antennas

A list of approved antennas is provided for the XTC product. For the XBee XTC DigiMesh RF Module, see XBee XTC antenna options. For the XBee-PRO XTC, see XBee-PRO XTC antenna options.

2.8 Label and compliance information

Host product manufacturers need to follow the sticker guidelines outlined in OEM labeling requirements.

2.9 Information on test modes and additional testing requirements

Contact a Digi sales representative for information on how to configure test modes for the the XBee XTC DigiMesh and XBee-PRO XTC DigiMesh modules.

2.10 Additional testing, Part 15 Subpart B disclaimer

All final host products must be tested to be compliant to FCC Part 15 Subpart B standards. While the XBee XTC DigiMesh and XBee-PRO XTC DigiMesh modules were tested to be complaint to FCC unintentional radiator standards, FCC Part 15 Subpart B compliance testing is still required for the final host product. This testing is required for all end products, and XBee XTC DigiMesh/XBee-PRO XTC DigiMesh Part 15 Subpart B compliance does not affirm the end product's compliance.

See FCC notices for more details.

ISED (Innovation, Science and Economic Development Canada)

This device complies with Industry Canada license-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes : (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Labeling requirements

XBee XTC

Labeling requirements for Industry Canada are similar to those of the FCC. A clearly visible label on the outside of the final product must display the following text:

Contains Model XBSX Radio, IC: 1846A-XBSX

The integrator is responsible for its product to comply with IC ICES-003 and FCC Part 15, Sub. B - Unintentional Radiators. ICES-003 is the same as FCC Part 15 Sub. B and Industry Canada accepts FCC test report or CISPR 22 test report for compliance with ICES-003.

XBee-PRO XTC

Labeling requirements for Industry Canada are similar to those of the FCC. A clearly visible label on the outside of the final product must display the following text:

Contains Model XBPSX Radio, IC: 1846A-XBPSX

The integrator is responsible for its product to comply with IC ICES-003 and FCC Part 15, Sub. B - Unintentional Radiators. ICES-003 is the same as FCC Part 15 Sub. B and Industry Canada accepts FCC test report or CISPR 22 test report for compliance with ICES-003.

Transmitters for detachable antennas

This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the tables in FCC antenna certifications with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device. The required antenna impedance is 50 ohms.

Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés ci-dessous et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur.

Detachable antennas

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (EIRP) is not more than that necessary for successful communication.

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut

choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire àl'établissement d'une communication satisfaisante.

IFETEL (Mexico)

Mexico IFETEL
Manufacturer: Digi International
Country: USA
Brand: Digi
Tariff Code (HS): 8517-62-14

Model: XBPSX

IFETEL (IFT) number RCPDIXB19-2288 applies to these XBee-PRO XTC radios:

- XBP9XT-DPRS-001, XBP9XT-DPUS-001

Model: XBSX

IFETEL (IFT) number RCPDIXB19-1819 applies to these XBee XTC radios:

- XB9XT-DPRS-001, XB9XT-DPUS-001

OEM labeling requirements

WARNING! The Original Equipment Manufacturer (OEM) must ensure that Mexico IFT labeling requirements are met. This includes a clearly visible label on the outside of the final product enclosure that displays the text shown below.

The IFETEL number for the XBee-PRO XTC product must be listed either on the end product, on the packaging, in the manual, or in the software with the following phrase:

"*Este equipo contiene el módulo XBP9X con Número IFETEL*: RCPDIXB19-2288"

OR

"Este equipo contiene el módulo XBP9X con IFT #: RCPDIXB19-2288"

The IFETEL number for the XBee XTC product must be listed either on the end product, on the packaging, in the manual, or in the software with the following phrase:

"*Este equipo contiene el módulo XBPModel: XB9X con Número IFETEL*: RCPDIXB19-1819"

OR

"Este equipo contiene el módulo XB9X con IFT #: RCPDIXB19-1819"

The following paragraph must also be present in the User Manual for the end product:

"La operación de este equipo está sujeta a las siguientes dos condiciones: (1) es posible que este equipo o dispositivo no cause interferencia perjudicial y (2) este equipo o dispositivo debe aceptar cualquier interferencia, incluyendo la que pueda causar su operación no deseada."

PCB design and manufacturing

The XTC 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.

Recommended footprint and keepout

We designed the XTC 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.
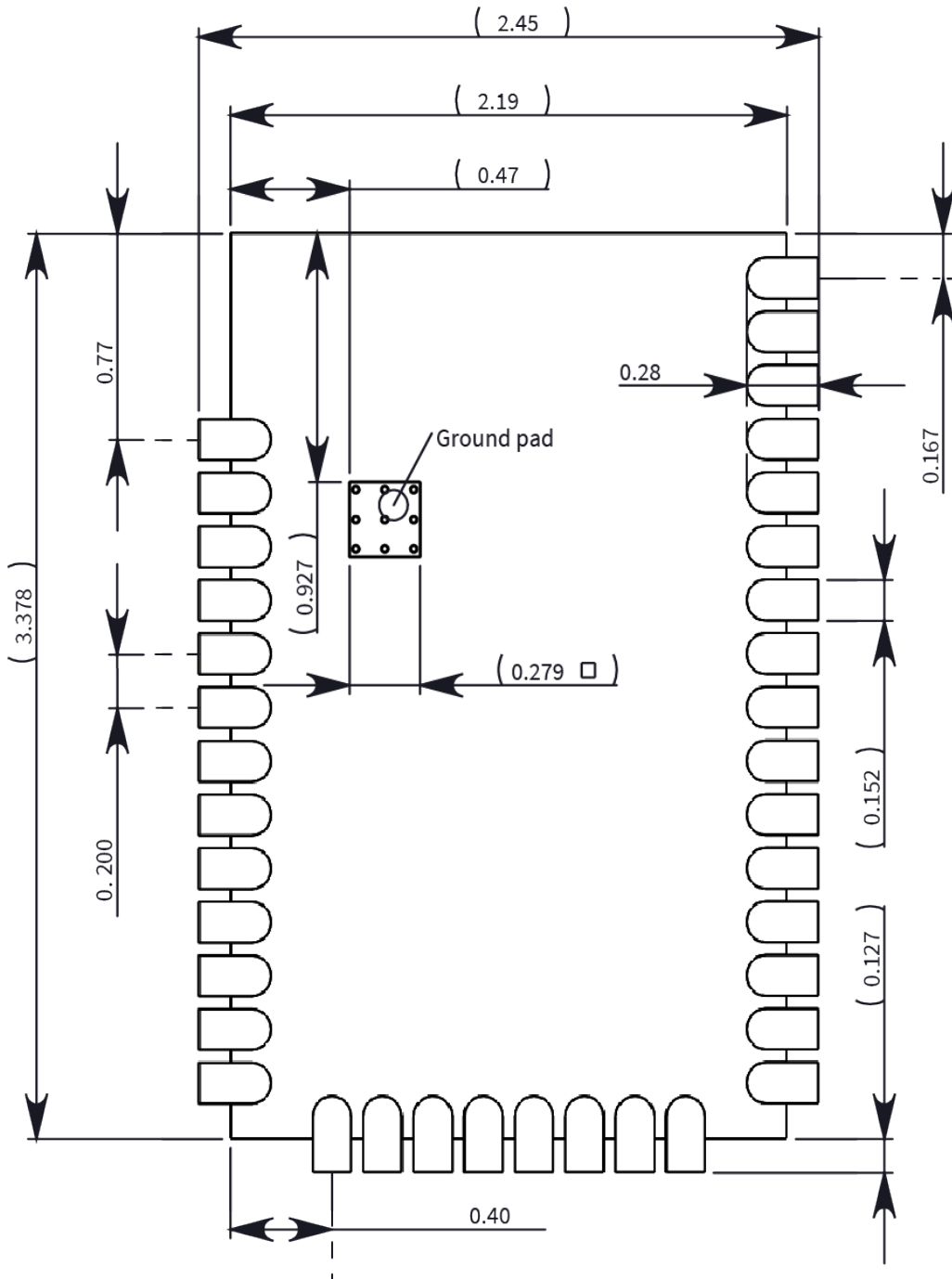
The recommended footprint includes an additional ground pad that you must solder to the corresponding pad on the device. This ground pad transfers heat generated during transmit mode away from the device's power amplifier. The pad must connect through vias to a ground plane on the host PCB. Connecting 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.

0.368 0.647 0.160

Copper keepout

0.632
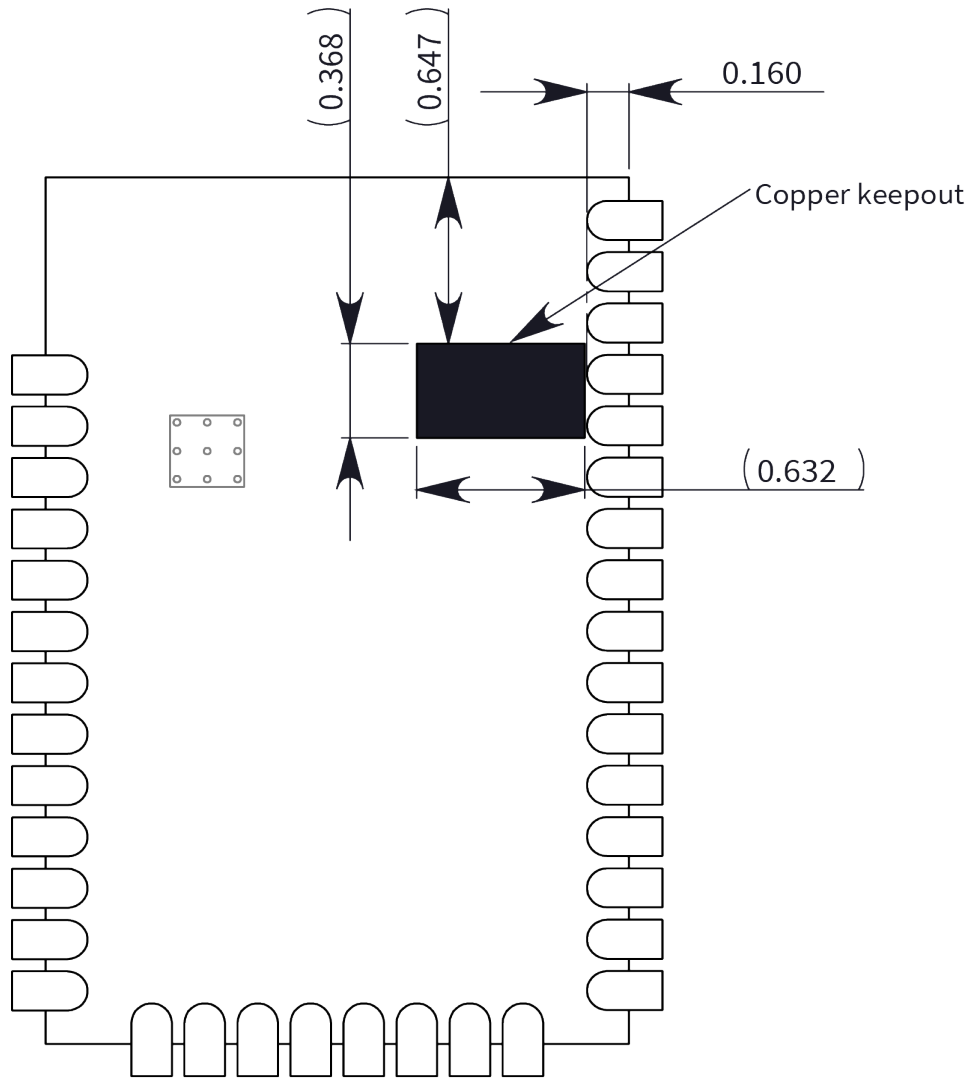
Design notes

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 (pin 2) 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.

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 36 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.

PCB LAYER 1

PCB LAYER 2
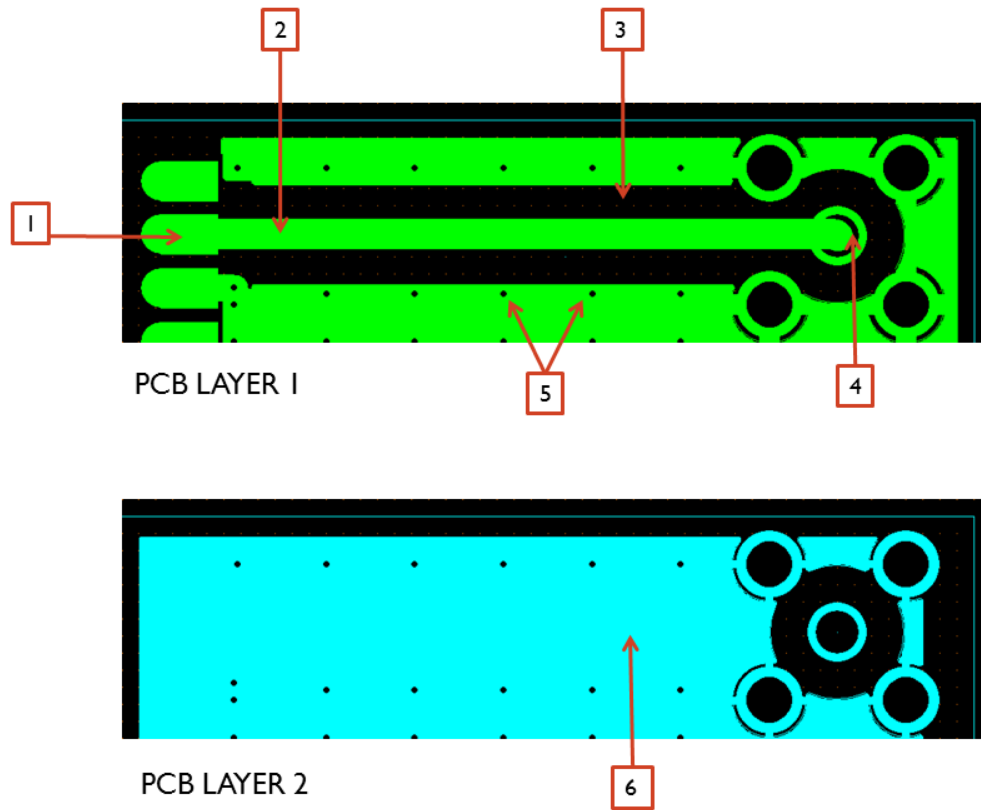
Number	Description
1	XBee pin 36
2	50 Ω microstrip trace
3	Back off ground fill at least twice the distance between layers 1 and 2
4	RF connector
5	Stitch vias near the edges of the ground plane
6	Pour a solid ground plane under the RF trace on the reference layer

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.

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 ℃.

The XTC device will reflow during this cycle, and therefore must not be reflowed upside down. Take care not to jar the XTC 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 ℃ and < 90% relative humidity (RH).

    b. Environmental condition during the production: 30 ℃ /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 ℃.

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 XTC device (for example, removing it from the host PCB).

> ⚠ **CAUTION!** Any modification to the device voids the warranty coverage and certifications.