XBEE Pro S1 Wire

This is the very popular 2.4GHz XBee XBP24-AWI-001 module from Digi. The Pro series have the same pinout and command set of the basic series with an increase output power of 60mW! These modules take the 802.15.4 stack (the basis for Zigbee) and wrap it into a simple to use serial command set. These modules allow a very reliable and simple communication between microcontrollers, computers, systems, really anything with a serial port! Point to point and multi-point networks are supported.

FEATURES:

- 3.3V @ 215mA
- 250kbps Max data rate
- 60mW output (+18dBm)
- 1 mile (1500m) range
- Built-in antenna
- Fully FCC certified
- 6 10-bit ADC input pins
- 8 digital IO pins
- 128-bit encryption
- Local or over-air configuration
- AT or API command set

OPERATION:

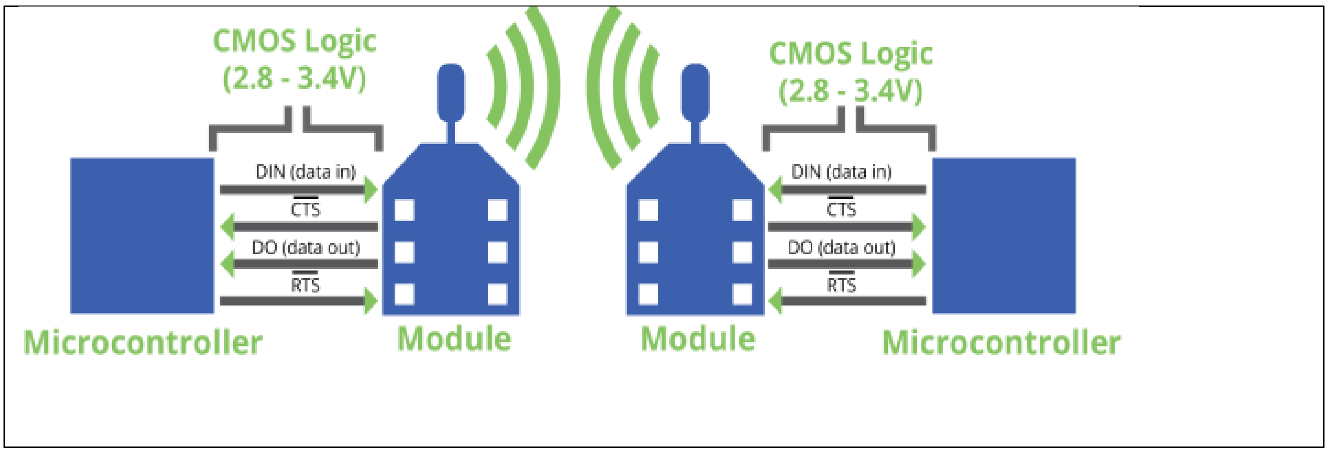
SERIAL INTERFACE:

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

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

UART DATA FLOW:

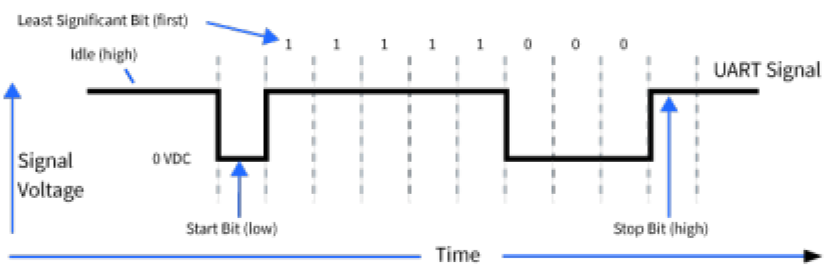
- Devices that have a UART interface connect directly to the pins of the XBee/XBee-PRO Zigbee RF Module as shown in the following figure.
- The figure shows system data flow in a UART-interfaced environment. Low-asserted signals have a horizontal line over the signal name



SERIAL DATA:

- A device sends data to the XBee/XBee-PRO Zigbee RF Module's UART through TH pin 4/SMT 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 XBee/XBee-PRO Zigbee 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.



It can configure the UART baud rate, parity, and stop bits settings on the device with the BD, NB, and SB commands respectively.

TRANSPARENT OPERATING MODE:

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

Serial-to-RF packetization:

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

- The device receives no serial characters for the amount of time determined by the RO (Packetization Timeout) parameter. If RO = 0, packetization begins when a character is received.

- The device receives the Command Mode Sequence (GT + CC + GT). Any character buffered in the serial receive buffer before the sequence is transmitted.
- The device receives the maximum number of characters that fits in an RF packet (100 bytes).

  If the device cannot immediately transmit (for example, if it is already receiving RF data), it stores the serial data in the DI buffer. The device packetizes the data and sends the data at any RO timeout or when it receives the maximum packet size (100 bytes). If the DI buffer becomes full, hardware or software flow control must be implemented in order to prevent overflow (that is, loss of data between the host and module).

API OPERATING MODE:

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

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

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

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

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

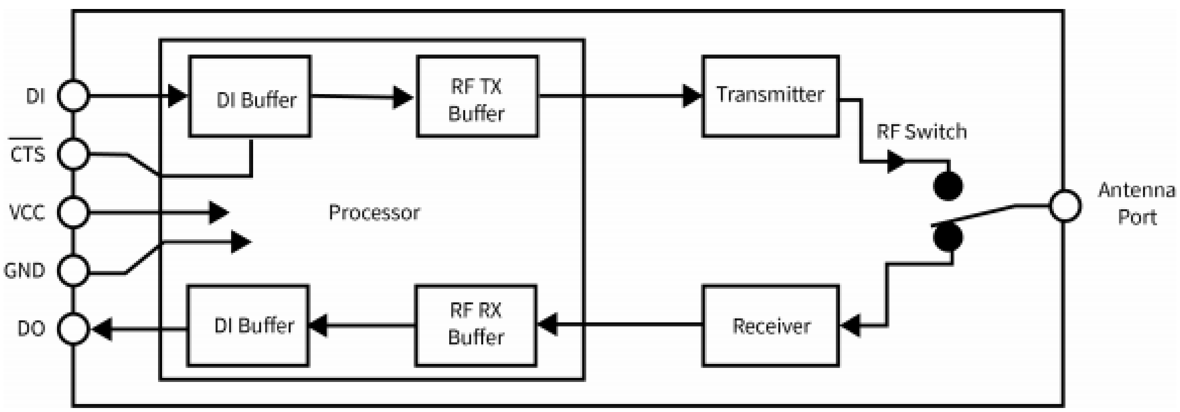
The API provides alternative means of configuring modules and routing data at the host application layer. A host application sends data frames to the device that contains address and payload information instead of using command mode to modify addresses. The device sends data frames to the application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

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

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

FLOW CONTROL:

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



DI (Data in) buffer:

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

Hardware Flow Control (CTS):

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

1. Send messages that are smaller than the DI buffer size (202 bytes).

2. Interface at a lower baud rate [BD (Interface Data Rate) parameter] than the throughput data rate.

Example where the DI buffer may become full and possibly overflow: If the device is receiving a continuous stream of RF data, it places any serial data that arrives on the DI pin in the DI buffer. The device transmits data in the DI buffer over-the-air when it is no longer receiving RF data in the network.

DO (Data out) buffer:

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

Hardware Flow Control (RTS):

If you enable RTS flow control (D6 (DIO6 Configuration) Parameter = 1), the device does not send data out the DO buffer as long as RTS (pin 16) is de-asserted. Examples where the DO buffer may become full, resulting in dropped RF packets:

1. If the RF data rate is set higher than the interface data rate of the device, the device may receive data faster than it can send the data to the host. Even occasional transmissions from a large number of devices can quickly accumulate and overflow the transmit buffer.

2. If the host does not allow the device to transmit data out from the serial transmit buffer due to being held off by hardware flow control.

ADC AND DIGITAL I/O LINE SUPPORT:

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

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

Pin function	Pin#	AT Command
AD0/DIO0	20	D0
AD1/DIO1	19	D1
AD2/DIO2	18	D2
AD3/DIO3 / (COORD_SEL)	1	D3
AD4/DIO4	11	D4
AD5/DIO5 / (ASSOCIATE)	15	D5
DIO6/(RTS)	16	D6

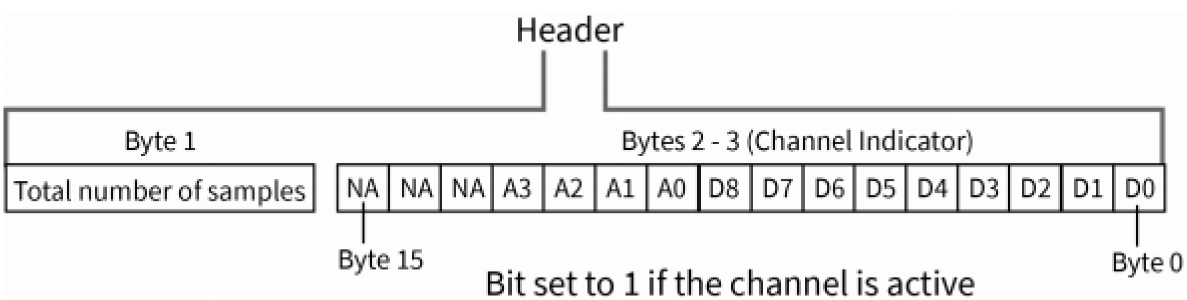
DIO7/(CTS)	12	D7
DI8/(DTR) / (Sleep_RQ)	9	D8

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

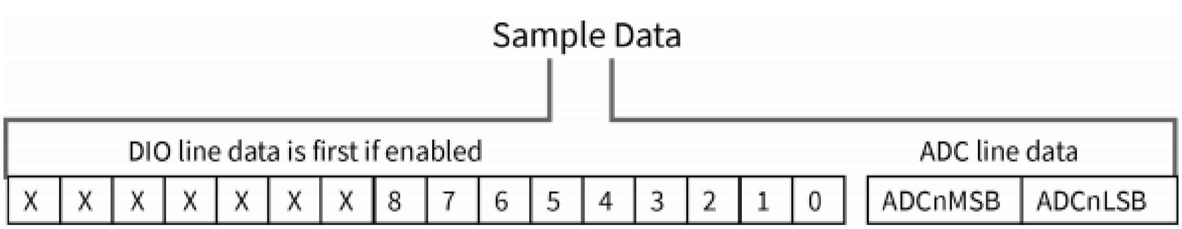
Support type	Setting
ADC support	ATDn = 2
Digital input support	ATDn = 3
Digital output low support	ATDn = 4
Digital output high support	ATDn = 5

I/O DATA FORMAT:

I/O data begins with a header. The first byte of the header defines the number of samples forthcoming. The last two bytes of the header (Channel Indicator) define which inputs are active. Each bit represents either a DIO line or ADC channel. The following figure illustrates the bits in the header.



Sample data follows the header and the channel indicator frame determines how to read the sample data. If any of the DIO lines are enabled, the first two bytes are the DIO sample. The ADC data follows. ADC channel data is represented as an unsigned 10-bit value right-justified on a 16- bit boundary. The following figure illustrates the sample data bits.



API SUPPORT:

I/O data is sent out the UART using an API frame. All other data can be sent and received using Transparent Operation or API frames if API mode is enabled (AP > 0). API Operations support two RX (Receive) frame identifiers for I/O data (set 16-bit address to 0xFFFE and the device does 64-bit addressing):

- 0x82 for RX Packet: 64-bit Address I/O
- 0x83 for RX Packet: 16-bit Address I/O

The API command header is the same as shown in 64-bit Receive Packet - 0x80 and 16-bit I/O Sample Indicator - 0x83. RX data follows the format described in I/O data format.

SLEEP SUPPORT:

Set SO (Sleep Options) bit 1 to suppress automatic wake-up sampling.When a device wakes, it always performs a sample based on any active ADC or DIO lines. This allows sampling based on the sleep cycle whether it be Cyclic Sleep (SM = 4 or 5) or Pin Sleep (SM = 1). Set the IR (Sample Rate) parameter to gather more samples when awake. For Cyclic Sleep modes: If the IR parameter is set, the device stays awake until the IT (Samples before TX) parameter is met. The device stays awake for ST (Time before Sleep).

DIO PIN CHANGE DETECT:

When you use the IC (DIO Change Detect) command to enable DIO Change Detect, DIO lines 0 - 7 are monitored. When a change is detected on a DIO line, the following occurs:

1. An RF packet is sent with the updated DIO pin levels. This packet does not contain any ADC samples.

2. Any queued samples are transmitted before the change detect data. This may result in receiving a packet with less than IT (Samples before TX) samples.

SAMPLE RATE INTERVAL:

The Sample Rate (Interval) feature allows enabled ADC and DIO pins to be read periodically on devices that are not configured to operate in Sleep Mode. When one of the Sleep Modes is enabled and the IR (Sample Rate) parameter is set, the device stays awake until IT (Samples before TX) samples have been collected.

Once a particular pin is enabled, the appropriate sample rate must be chosen. The maximum sample rate that can be achieved while using one A/D line is 1 sample/ms or 1 kHz. The device cannot keep up with transmission when IR and IT are equal to 1 and we do not recommend configuring the device to sample at rates greater than once every 20 ms.

I/O LINE PASSING:

- You can set up virtual wires between XBee/XBee-PRO Modules. When a device receives an RF data packet that contains I/O data, it can be setup to update any enabled outputs (PWM and DIO) based on the data it receives.
- I/O lines are mapped in pairs. For example, AD0 can only update PWM0 and DI5 can only update DO5. The default setup is for outputs not to be updated, which results in the I/O data being sent out the UART (See the IU (I/O Output Enable) command). To enable the outputs for updating, set the IA (I/O Input Address) parameter with the address of the device that has the appropriate inputs enabled. This binds the outputs to a particular device's input.
- This does not affect the ability of the device to receive I/O line data from other modules; if affects only its ability to update enabled outputs. The IA parameter can also be set up to accept I/O data for output changes from any module by setting the IA parameter to 0xFFFF.
- When outputs are changed from their non-active state, the device can be setup to return the output level to its non-active state. Set the timers using the Tn (Dn Output Timer) and PT (PWM Output with a matching IA address. You can adjust the IC (Change Detect) and IR (Sample Rate) parameters to keep the outputs set to their active output if the system needs more time than the timers can handle.

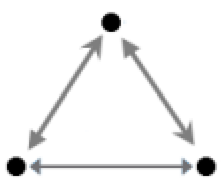
APPLICABLE COMMANDS:

- IA (I/O Input Address)
- TN (Dn Output Timeout)
- P0 (PWM0 Configuration)
- P1 (PWM1 Configuration)
- M0 (PWM0 Output Level)
- M1 (PWM1 Output Level)
- PT (PWM Output Timeout)
- RP (RSSSI PWM Timer)

NETWORKS:

Term	Definition
Association	Establishing membership between end devices and a coordinator.
Coordinator	A full-function device (FFD) that provides network synchronization by polling nodes.
End device	When in the same network as a coordinator. Devices that rely on a coordinator for synchronization and can be put into states of sleep for low-power applications.
PAN	Personal Area Network. A data communication network that includes one or more end devices and optionally a coordinator.

Peer-to-peer networks:



- By default, XBee/XBee-PRO S1 802.15.4 (Legacy) modules are configured to operate within a peer-topeer network topology and therefore are not dependent upon master/slave relationships.
- This means that devices remain synchronized without the use of master/server configurations and each device in the network shares both roles of master and slave. Our peer-to-peer architecture features fast synchronization times and fast cold start times.

- This default configuration accommodates a wide range of RF data applications. You can establish a peer-to-peer network by configuring each module to operate as an End Device (CE = 0), disabling End Device Association on all modules (A1 = 0) and setting ID and CH parameters to be identical across the network.

NonBeacon (with coordinator):

- You can configure a device as a Coordinator by setting the CE (Coordinator Enable) parameter to 1. Use the A2 (Coordinator Association) parameter to power up the Coordinator . In a Coordinator system, you configure the Coordinator to use direct or indirect transmissions.
- If the SP (Cyclic Sleep Period) parameter is set to 0, the Coordinator sends data immediately. Otherwise, the SP parameter determines the length of time the Coordinator retains the data before discarding it. In general, SP (Cyclic Sleep Period) and ST (Time before Sleep) parameters should be set to match the SP and ST settings of the End Devices.

Association:

- Association is the establishment of membership between End Devices and a Coordinator. Establishing membership is useful in scenarios that require a central unit (Coordinator) to relay messages to or gather data from several remote units (End Devices), assign channels, or assign PAN IDs. An RF data network that consists of one Coordinator and one or more End Devices forms a PAN (Personal Area Network).
- Each device in a PAN has a PAN Identifier (ID (PAN ID) parameter), which must be unique to prevent miscommunication between PANs. Set the Coordinator PAN ID using the ID (PAN ID) and A2 (Coordinator Association) commands. An End Device can associate to a Coordinator without knowing the address, PAN ID, or channel of the Coordinator. The A1 (End Device Association) parameter bit fields determine the flexibility of an End Device during association.
- Use the A1 parameter for an End Device to dynamically set its destination address, PAN ID, and/or channel. For example, if the PAN ID of a Coordinator is known, but the operating channel is not, set the A1 command on the End Device to enable the

'Auto_Associate' and 'Reassign_Channel' bits. Additionally, set the ID parameter to match the PAN ID of the associated Coordinator.

Coordinator / End Device setup and operation :

- To configure a module to operate as a Coordinator, set the CE (Coordinator Enable) parameter to '1'. Set the CE parameter of End Devices to '0' (default). Coordinator and End Devices should contain matching firmware versions.

NonBeacon (with Coordinator) systems:

You can configure the Coordinator to use direct or indirect transmissions. If the SP (Cyclic Sleep Period) parameter is set to '0', the Coordinator sends data immediately. Otherwise, the SP parameter determines the length of time the Coordinator retains the data before discarding it. In general, SP (Cyclic Sleep Period) and ST (Time before Sleep) parameters should be set to match the SP and ST settings of the End Devices.

Coordinator start-up:

The A2 (Coordinator Association) command governs coordinator power-up. On power-up, the Coordinator undergoes the following sequence of events:

1. **Check A2 parameter- Reassign_PANID flag**

   Set (bit 0 = 1)

- The Coordinator issues an Active Scan. The Active Scan selects one channel and transmits a request to the broadcast address (0xFFFF) and broadcast PAN ID (0xFFFF). The Coordinator then listens on that channel for beacons from any Coordinator operating on that channel. The SD (Scan Duration) parameter value determines the listen time on each channel.
- Once the time expires on that channel, the Active Scan selects another channel and again transmits the BeaconRequest as before. This process continues until all channels have been scanned, or until 5 PANs have been discovered. When the Active Scan is complete, the results include a list of PAN IDs and Channels being used by other PANs. This list is used to assign an unique PAN ID to the new Coordinator. The ID parameter will be retained if it is not found in the Active Scan results. Otherwise, the ID (PAN ID) parameter setting will be updated to a PAN ID that was not detected.

Not set (bit 0 = 0)

- The Coordinator retains its ID setting. No Active Scan is performed.

2. **Check A2 parameter - Reassign_Channel flag (bit 1)**

Set (bit 1 = 1)

- The Coordinator issues an Energy Scan. The Energy Scan selects one channel and scans for energy on that channel. The SD (Scan Duration) parameter specifies the duration of the scan. Once the scan is completed on a channel, the Energy Scan selects the next channel and begins a new scan on that channel. This process continues until all channels have been scanned.
- When the Energy Scan is complete, the results include the maximal energy values detected on each channel. This list is used to determine a channel where the least energy was detected. If an Active Scan was performed (Reassign_PANID Flag set), the channels used by the detected PANs are eliminated as possible channels. The device uses the results of the Energy Scan and the Active Scan (if performed) to find the best channel (that is, the channel with the least energy that is not used by any detected PAN). Once the device selects the best channel, the CH (Channel) parameter value is updated to that channel.

Not set (bit 1 = 0)

- The Coordinator retains its CH setting, and an Energy Scan is not performed.

3. **Start Coordinator**

- The Coordinator starts on the specified channel (CH parameter) and PAN ID (ID parameter).
  Note: These may be selected in steps 1 or 2.
- The Coordinator only allows End Devices to associate to it if the A2 parameter "AllowAssociation" flag is set. Once the Coordinator has successfully started, the Associate LED blinks 1 time per second. If the Coordinator has not started, the LED is solid.

4. **Modify coordinator:**

- Once a Coordinator has started, modifying the A2 (Reassign_Channel or Reassign_PANID bits), ID, CH or MY parameters causes the Coordinator's MAC to reset. The Coordinator RF module (including volatile RAM) is not reset. Changing the A2 AllowAssociation bit does not reset the Coordinator's MAC. In a non-beaconing system, End Devices that associated to the Coordinator prior to a MAC reset have knowledge of the new settings on the Coordinator. If the Coordinator were to change its ID, CH or MY settings, the End Devices would no longer be able to communicate with the non-beacon Coordinator. Do not change the ID, CH, MY, or A2 (Reassign_Channel or Reassign_PANID bits) once a Coordinator has started.

End device start-up:

The A1 (End Device Association) command governs End Device power-up. On power-up, the End Device undergoes the following sequence of events:

1. **Check A1 parameter - AutoAssociate Bit**

   Set (bit 2 = 1)

   The End Device attempts to associate to a Coordinator. See 2. Discover Coordinator (if Auto-Associate Bit Set) and 3. Associate to a valid coordinator.

   Not set (bit 2 = 0)

   The End Device does not attempt to associate to a Coordinator. The End Device operates as specified by its ID, CH and MY parameters. Association is considered complete and the Associate LED blinks quickly (5 times per second).

2. **Discover Coordinator (if Auto-Associate Bit Set):**

- The end device issues an Active Scan. The Active Scan selects one channel and transmits a BeaconRequest command to the broadcast address (0xFFFF) and broadcast PAN ID (0xFFFF).
- The Active Scan then listens on that channel for beacons from any Coordinator operating on that channel. The SD parameter determines the listen time on each channel. Once the time expires on that channel, the Active Scan selects another channel and again transmits the BeaconRequest command as before. This process continues until all channels have been scanned, or until 5 PANs have been discovered. When the Active Scan is complete,

the results include a list of PAN IDs and Channels that are being used by detected PANs. The end device selects a coordinator to associate with according to the A1 parameter "Reassign_ PANID" and "Reassign_Channel" flags:

- Reassign_PANID bit set (bit 0 = 1) - End device can associate with a PAN with any ID value.
- Reassign_PANID bit not set (bit 0 = 0) - End device only associates with a PAN whose ID setting matches the ID setting of the End Device.
- Reassign_Channel bit set (bit 1 = 1) - End device can associate with a PAN with any CH value.
- Reassign_Channel bit not set (bit 1 = 0) - End device will only associate with a PAN whose CH setting matches the CH setting of the end device.

After applying these filters to the discovered coordinators, if multiple candidate PANs exist, the end device selects the PAN whose transmission link quality is the strongest. If no valid coordinator is found, the end device either goes to sleep (as dictated by its SM (Sleep Mode) parameter) or retry Association.

3. Associate to a valid coordinator:

- Once the device finds a valid coordinator (2. Discover Coordinator (if Auto-Associate Bit Set)), the end device sends an AssociationRequest message to the coordinator.
- The end device then waits for an AssociationConfirmation from the coordinator. Once it receives the Confirmation, the end device is Associated and the Associate LED blinks rapidly (two times per second). If the end device has not associated, the LED is solid.

4. End Device changes once an End Device has associated:

- Changing A1, ID or CH parameters causes the End Device to disassociate and restart the Association procedure. If the End Device fails to associate, the AI command indicates the failure

ADDRESSING:

Every RF data packet sent over-the-air contains a Source Address and Destination Address field in its header. The XBee/XBee-PRO S1 802.15.4 (Legacy) conforms to the 802.15.4 specification and supports both short 16-bit addresses and long 64-bit addresses. A unique 64-bit IEEE source address is assigned at the factory and can be read with the SL (Serial Number Low) and SH (Serial Number High) commands. You must manually configure short addressing. A device uses its unique 64-bit address as its Source Address if its MY (16-bit Source Address) value is 0xFFFF or 0xFFFE.

- To send a packet to a specific device using 64-bit addressing, set the Destination Address (DL + DH) of the sender to match the Source Address (SL + SH) of the intended destination device.
- To send a packet to a specific module using 16-bit addressing, set DL (Destination Address Low) parameter to equal the MY parameter of the intended destination module and set the DH (Destination Address High) parameter to '0.'

Unicast mode:

- By default, the XBee/XBee-PRO S1 802.15.4 (Legacy) operates in Unicast mode. Unicast Mode is the only mode that supports retries.
- While in this mode, receiving devices send an ACK (acknowledgment) of RF packet reception to the transmitter. If the transmitting device does not receive the ACK, it resends the packet up to three times or until it receives the ACK.

Short 16-bit addresses:

- You can configure the device to use short 16-bit addresses as the Source Address by setting (MY < 0xFFFE). Setting the DH parameter (DH = 0) configures the Destination Address to be a short 16-bit address (if DL < 0xFFFE).
- For two devices to communicate using short addressing, the Destination Address of the transmitter device must match the MY parameter of the receiver. The following table shows a sample network configuration that enables Unicast mode communications using short 16-bit addresses.

Parameter	RF device 1	RF device 2
MY (Source Address)	0x01	0x02
DH (Destination Address High)	0	0
DL (Destination Address Low)	0x02	0x01

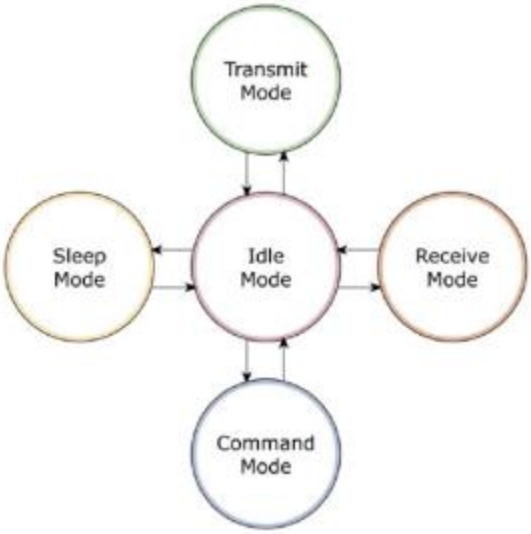
Long 64-bit addresses:

- You can use The RF device's serial number (SL parameter concatenated to the SH parameter) as a 64- bit source address when the MY (16-bit Source Address) parameter is disabled.
- When you disable the MY parameter (MY = 0xFFFF or 0xFFFE), the device's source address is set to the 64-bit IEEE address stored in the SH and SL parameters. When an End Device associates to a Coordinator, its MY parameter is set to 0xFFFE to enable 64-bit addressing. The 64-bit address of the device is stored as SH and SL parameters. To send a packet to a specific device, the Destination Address (DL + DH) on the sender must match the Source Address (SL + SH) of the receiver.

Broadcast mode :

- Any RF device within range accepts a packet that contains a broadcast address. When configured to operate in Broadcast Mode, receiving devices do not send ACKs (acknowledgments) and transmitting devices do not automatically re-send packets as is the case in Unicast Mode. To send a broadcast packet to all devices regardless of 16-bit or 64-bit addressing, set the destination addresses of all the devices as shown below.
- Sample Network Configuration (All modules in the network):
  - DL (Destination Low Address) = 0x0000FFFF If RR is set to 0, only one packet is broadcast. If RR > 0, (RR + 2) packets are sent in each broadcast. No acknowledgments are returned. For more information, see RR (XBee Retries).
  - DH (Destination High Address) = 0x00000000 (default value) When you are programming the device, enter the parameters in hexadecimal notation (without the "0x" prefix). Leading zeros may be omitted.

MODES OF OPERATION:



IDLE MODE:

When not receiving or transmitting data, the device is in Idle mode. The device shifts into the other modes of operation under the following conditions:

- Transmit mode (serial data is received in the DI buffer).
- Receive mode (valid RF data received through the antenna).
- Sleep mode (Sleep mode condition is met).
- Command mode (Command mode sequence issued).

Transmit/Receive modes :

This section provides information about the different types of transmit and receive modes

RF data packets :

Each transmitted data packet contains a Source Address and Destination Address field. The Source Address matches the address of the transmitting device as specified by the MY (Source Address) parameter (if MY ≥ 0xFFFE), the SH (Serial Number High) parameter or the SL (Serial Number Low) parameter. The field is created from the DH (Destination Address High) and DL (Destination Address Low) parameter values. The Source Address and/or Destination Address fields either contain a 16-bit short or long 64-bit long address. The RF data packet structure follows the 802.15.4 specification. For more information, see Addressing.

Direct and indirect transmission:

There are two methods to transmit data:

- **Direct transmission**: data is transmitted immediately to the Destination Address
- **Indirect transmission:** a packet is retained for a period of time and is only transmitted after the destination device (source address = destination address) requests the data. Indirect transmissions can only occur on a Coordinator. Thus, if all nodes in a network are End Devices, only direct transmissions occurs. Indirect transmissions are useful to ensure packet delivery to a sleeping node. The Coordinator currently is able to retain up to two indirect messages.

Direct transmission:

A Coordinator can be configured to use only direct transmission by setting the SP (Cyclic Sleep Period) parameter to 0. Also, a Coordinator using indirect transmissions reverts to direct transmission if it knows the destination device is awake. To enable this behavior, the ST (Time before Sleep) value of the Coordinator must be set to match the ST value of the End Device. Once the End Device either transmits data to the Coordinator or polls the Coordinator for data, the Coordinator uses direct transmission for all subsequent data transmissions to that device address until ST time occurs with no activity (at which point it reverts to using indirect transmissions for that device address). "No activity" means no transmission or reception of messages with a specific address. Broadcast messages do not reset the ST timer.

Indirect transmission :

To configure Indirect Transmissions in a Personal Area Network (PAN), the SP (Cyclic Sleep Period) parameter value on the Coordinator must be set to match the longest sleep value of any End Device. The sleep period value on the Coordinator determines how long (time or number of beacons) the Coordinator retains an indirect message before discarding it. An End Device must poll the Coordinator once it wakes from Sleep to determine if the Coordinator has an indirect message for it. For Cyclic Sleep Modes, this is done automatically every time the device wakes (after SP time). For Pin Sleep Modes, the A1 (End Device Association) parameter value must be set to enable Coordinator polling on pin wake-up . Alternatively, an End Device can use the FP (Force Poll) command to poll the Coordinator as needed.

Clear Channel Assessment (CCA) :

Prior to transmitting a packet, the device performs a CCA (Clear Channel Assessment) on the channel to determine if the channel is available for transmission. The detected energy on the channel is compared with the CA (Clear Channel Assessment) parameter value. If the detected energy exceeds the CA parameter value, the device does not transmit the packet. Also, the device inserts a delay before a transmission takes place. You can set this delay using the RN (Backoff Exponent) parameter. If you set RN to 0, then there is no delay before the first CCA is performed. The RN parameter value is the equivalent of the "minBE" parameter in the 802.15.4 specification. The transmit sequence follows the 802.15.4 specification. By default, the MM (MAC Mode) parameter = 0. On a CCA failure, the device attempts to re-send the packet up to two additional times. When in Unicast packets with RR (Retries) = 0, the device executes two CCA retries. Broadcast packets always get two CCA retries.

Acknowledgment:

If the transmission is not a broadcast message, the device expects to receive an acknowledgment from the destination node. If an acknowledgment is not received, the packet is resent up to three more times. If the acknowledgment is not received after all transmissions, an ACK failure is recorded

SLEEP MODE:

Sleep modes enable the device to enter states of low-power consumption when not in use. In order to enter Sleep mode, one of the following conditions must be met (in addition to the device having a nonzero SM parameter value):

- SLEEP_RQ is asserted and the device is in a pin sleep mode (SM = 1, 2, or 5)
- The device is idle (no data transmission or reception) for the amount of time defined by the ST (Time before Sleep) parameter.

Note:ST is only active when SM = 4 or 5.

The following table shows the sleep mode configurations.

Sleep mode setting	**Transition into sleep mode**	**Transition out of sleep mode (wake)**	**Characteristics**	**Related commands**	**Power consumption**
Pin hibernate SM 1	Assert (high) Sleep_RQ (pin 9)	De-assert (low) Sleep_ RQ	Pin/Hostcontrolled/NonBeacon systems only/Lowest Power	(SM)	< 10 µA (@3.0 VCC)
Pin doze SM 2	Assert (high) Sleep_RQ (pin 9)	De-assert (low) Sleep_ RQ	Pin/Hostcontrolled/NonBeacon systems only/Fastest wake-up	(SM)	< 50 µA
Cyclic Sleep SM 4	Automatic transition to Sleep Mode as defined by the SM (Sleep Mode) and ST (Time before Sleep) parameters	Transition occurs after the cyclic sleep time interval elapses. The time interval is defined by the SP (Cyclic Sleep Period) parameter	RF module wakes in pre-determined time intervals to detect if RF data is present/When SM = 5	(SM), SP, ST	< 50 µA when sleeping
Cyclic Sleep SM 5	Automatic transition to Sleep Mode as defined by the SM (Sleep Mode) and ST (Time before Sleep) parameters or on a falling edge transition of the	Transition occurs after the cyclic sleep time interval elapses. The time interval is defined by the SP (Cyclic Sleep Period) parameter.	RF module wakes in pre-determined time intervals to detect if RF data is present. Module also wakes on a falling edge of SLEEP_RQ.	(SM), SP, ST	< 50 µA when sleeping

	SLEEP_RQ pin				

The SM command is central to setting Sleep mode configurations. By default, Sleep modes are disabled (SM = 0) and the device remains in Idle/Receive Mode. When in this state, the device is constantly ready to respond to serial or RF activity.

Pin/Host-controlled sleep modes:

The transient current when waking from pin sleep (SM = 1 or 2) does not exceed the idle current of the module. The current ramps up exponentially to its idle current.

Pin hibernate (SM=1)

- Pin/Host-controlled
- Typical power-down current: < 10 µA (@3.0 VCC)
- Typical wake-up time: 10.2 ms

- Pin Hibernate Mode minimizes quiescent power (power consumed when in a state of rest or inactivity). This mode is voltage level-activated. When the device assterts Sleep_RQ (pin 9), it finishes any transmit, receive or association activities, enters Idle Mode, and then enters a state of sleep.
- The device does not respond to either serial or RF activity while in pin sleep. To wake a sleeping device operating in Pin Hibernate Mode, de-assert Sleep_RQ (pin 9). The device wakes when Sleep_RQ is de-asserted and is ready to transmit or receive when the CTS line is low. When waking the device, the pin must be de-asserted at least two 'byte times' after CTS goes low. This assures that there is time for the data to enter the DI buffer.

Pin doze (SM = 2):

- Pin/Host-controlled n Typical power-down current: < 50 µA
- Typical wake-up time: 2.6 ms

- Pin doze mode functions the same as Pin hibernate mode. However, Pin doze features faster wake-up time and higher power consumption.
- To wake a sleeping device operating in Pin Doze Mode, de-assert Sleep_RQ (pin 9). The device wakes when Sleep_RQ is de-asserted and is ready to transmit or receive when the CTS line is low. When waking the device, the pin must be de-asserted at least two 'byte

times' after CTS goes low. This assures that there is time for the data to enter the DI buffer.

Cyclic sleep modes:

This section provides information on the different types of cyclic sleep modes.

Cyclic Sleep Remote (SM = 4)

- Typical Power-down Current: < 50 µA (when asleep)
- Typical wake-up time: 2.6 ms

- The Cyclic Sleep modes allow devices to periodically check for RF data. When the SM parameter is set to 4, the XBee/XBee-PRO S1 802.15.4 (Legacy) is configured to sleep, then wakes once per cycle to check for data from a from a device configured as a Cyclic Sleep Coordinator (SM = 0, CE = 1).
- The Cyclic Sleep Remote sends a poll request to the coordinator at a specific interval set by the SP (Cyclic Sleep Period) parameter. The coordinator transmits any queued data addressed to that specific remote upon receiving the poll request. If no data is queued for the remote, the coordinator does not transmit and the remote returns to sleep for another cycle. If the device transmits queued data back to the remote, it stays awake to allow for back and forth communication until the ST (Time before Sleep) timer expires. If configured, $\overline{\text{CTS}}$ goes low each time the remote wakes, allowing for communication initiated by the remote host if desired.

Cyclic Sleep Remote with Pin Wake-up (SM = 5):

- Use this mode to wake a sleeping remote device through either the RF interface or by de-asserting SLEEP_RQ for event-driven communications. The cyclic sleep mode works as described previously with the addition of a pin-controlled wake-up at the remote device. The Sleep_RQ pin is edge-triggered, not level-triggered. The device wakes when a low is detected then set CTS low as soon as it is ready to transmit or receive.
- Any activity resets the ST (Time before Sleep) timer, so the device goes back to sleep only after there is no activity for the duration of the timer. Once the device wakes (pin-

controlled), it ignores further pin activity. The device transitions back into sleep according to the ST time regardless of the state of the pin.

Cyclic Sleep Coordinator (SM = 6):

- Typical current = Receive current
- Always awake

This mode configures a device to wake cyclic sleeping remotes through RF interfacing. The Coordinator accepts a message addressed to a specific remote 16 or 64-bit address and holds it in a buffer until the remote wakes and sends a poll request. Messages not sent directly (buffered and requested) are called "Indirect messages". The Coordinator only queues one indirect message at a time. The Coordinator holds the indirect message for a period 2.5 times the sleeping period indicated by the SP (Cyclic Sleep Period) parameter. Set the Coordinator's SP parameter to match the value used by the remotes.

COMMAND MODE:

Command mode is a state in which the firmware interprets incoming characters as commands. The XBee/XBee-PRO S1 802.15.4 (Legacy) supports two Command mode options: AT commands and API operation.

AT Command Mode:

This section provides information about entering, sending, and exiting Command Mode.

Enter Command mode:

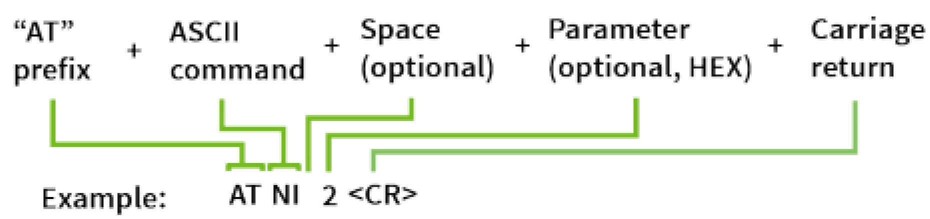
Send the three-character command sequence +++ and observe guard times before and after the command characters. Default AT Command Mode Sequence (for transition to Command mode):

- No characters sent for one second [GT (Guard Times) parameter = 0x3E8]
- Input three plus characters (“+++”) within one second [CC (Command Sequence Character) parameter = 0x2B]
- No characters sent for one second [GT (Guard Times) parameter = 0x3E8]

You can modify all parameter values in the sequence to reflect user preferences. Failure to enter AT Command Mode is most commonly due to a baud rate mismatch. Ensure the Baud setting on the PC Settings tab matches the interface data rate of the RF module. By default, the BD (Baud Rate) parameter = 3 (9600 b/s).

Send AT commands:

Once the device enters Command mode, use the syntax in the following figure to send AT commands. Every AT command starts with the letters AT, which stands for "attention."
The AT is followed by two characters that indicate which command is being issued, then by some optional configuration values. To read a parameter value stored in the device's register, omit the parameter field.



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

Multiple AT commands:

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

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.

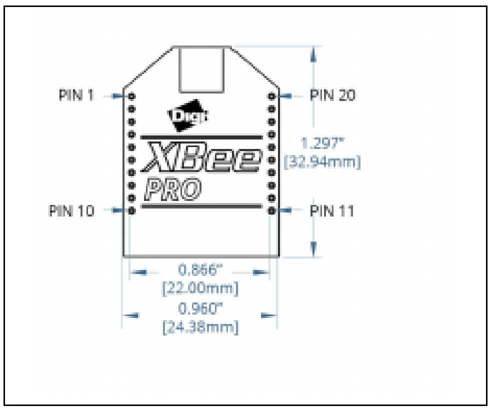
PIN FUNCTION:

The following table shows the pin signals and their descriptions for the through-hole module.

Pin No	Name	Direction	Description
1	VCC	-	Power supply
2	DOUT	Output	UART data out
3	DIN/$\overline{\text{CONFIG}}$	Input	UART data in
4	DO81	Either	Digital output 8
5	$\overline{\text{RESET}}$	Input/Open drain output	Device reset (reset pulse must be at least 200 ns). This must be driven as an open drain/collector. The device drives this line low when a reset occurs. Never drive this line high.
6	PWM0/RSSI	Either	PWM output 0 / RX signal strength indicator
7	PWM1	Either	PWM output 1
8	[reserved]	-	Do not connect
9	$\overline{\text{DTR}}$/SLEEP_RQ/ DIO8	Either	Pin sleep control line or digital input 8
10	GND	-	Ground
11	AD4/DIO4	Either	Analog input 4 or digital I/O 4
12	$\overline{\text{CTS}}$/DIO7	Either	Clear-to-send flow control or digital I/O 7
13	ON_$\overline{\text{SLEEP}}$	Output	Device status indicator
14	VREF	Input	Voltage reference for A/D inputs
15	ASSOCIATE/AD5/DIO5	Either	Associated indicator, analog input 5 or digital I/O 5

16	$\overline{RTS}$/DIO6	Either	Request-to-send flow control, or digital I/O 6
17	AD3/DIO3	Either	Analog input 3 or digital I/O 3
18	AD2 /DIO2	Either	Analog input 2 or digital I/O 2
19	AD1/DIO1	Either	Analog input 1 or digital I/O 1
20	AD0/DIO0	Either	Analog input 0, digital I/O 0

DIMENSION:



APPLICATIONS:

- Remote industrial control and monitoring
- Long-range remote control
- Wireless data acquisition
- Wireless networking

PACKAGE INCLUDES:

1 x Zigbee XBee Pro S1 Wire