# Linx
T E C H N O L O G I E S

# HumPRO™ Series 868MHz RF Transceiver Module

## Data Guide

**Wireless made simple**®

**⚠ Warning:** Some customers may want Linx radio frequency ("RF") products to control machinery or devices remotely, including machinery or devices that can cause death, bodily injuries, and/or property damage if improperly or inadvertently triggered, particularly in industrial settings or other applications implicating life-safety concerns ("Life and Property Safety Situations").

**NO OEM LINX REMOTE CONTROL OR FUNCTION MODULE SHOULD EVER BE USED IN LIFE AND PROPERTY SAFETY SITUATIONS.** No OEM Linx Remote Control or Function Module should be modified for Life and Property Safety Situations. Such modification cannot provide sufficient safety and will void the product's regulatory certification and warranty.

Customers may use our (non-Function) Modules, Antenna and Connectors as part of other systems in Life Safety Situations, but only with necessary and industry appropriate redundancies and in compliance with applicable safety standards, including without limitation, ANSI and NFPA standards. It is solely the responsibility of any Linx customer who uses one or more of these products to incorporate appropriate redundancies and safety standards for the Life and Property Safety Situation application.

**Do not use this or any Linx product to trigger an action directly from the data line or RSSI lines without a protocol or encoder/decoder to validate the data.** Without validation, any signal from another unrelated transmitter in the environment received by the module could inadvertently trigger the action.

**All RF products are susceptible to RF interference that can prevent communication.** RF products without frequency agility or hopping implemented are more subject to interference. This module does have a frequency hopping protocol built in, but the developer should still be aware of the risk of interference.

**Do not use any Linx product over the limits in this data guide.** Excessive voltage or extended operation at the maximum voltage could cause product failure. Exceeding the reflow temperature profile could cause product failure which is not immediately evident.

**Do not make any physical or electrical modifications to any Linx product.** This will void the warranty and regulatory and UL certifications and may cause product failure which is not immediately evident.

# Ordering Information

| Ordering Information | |
|---|---|
| Part Number | Description |
| HUM-868-PRO | 868MHz HumPRO™ Series Data Transceiver |
| HUM-868-PRO-CAS | HumPRO™ Series Data Transceiver with Castellation Connection |
| HUM-868-PRO-UFL | HumPRO™ Series Data Transceiver with u.FL Connector |
| EVM-868-PRO | 868MHz HumPRO™ Series Carrier Board |
| MDEV-868-PRO | 868MHz HumPRO™ Series Master Development System |

Figure 2: Ordering Information

# Absolute Maximum Ratings

| Absolute Maximum Ratings | | | | |
|---|---|---|---|---|
| Supply Voltage $V_{cc}$ | −0.3 | to | +3.9 | VDC |
| Any Input or Output Pin | −0.3 | to | $V_{cc}$ + 0.3 | VDC |
| RF Input | | 0 | | dBm |
| Operating Temperature | −40 | to | +85 | °C |
| Storage Temperature | −40 | to | +85 | °C |

Exceeding any of the limits of this section may lead to permanent damage to the device. Furthermore, extended operation at these maximum ratings may reduce the life of this device.

Figure 3: Absolute Maximum Ratings

**Warning:** This product incorporates numerous static-sensitive components. Always wear an ESD wrist strap and observe proper ESD handling procedures when working with this device. Failure to observe this precaution may result in module damage or failure.

| HumPRO™ Series Transceiver Specifications | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Parameter | Symbol | Min. | Typ. | Max. | Units | Notes |
| Timing | | | | | | | |
| Module Turn-On Time | | | | | | | |
|   Via $V_{CC}$ | | 71 | | 190 | ms | 4 |
|   Via POWER_DOWN | | 4.00 | | 4.12 | ms | 4 |
|   Via Standby | | | 4.12 | | ms | 4 |
| Serial Command Response | | | | | | | |
|   Volatile R/W | | | 0.4 | 5 | ms | 8 |
|   NV Update | | | 2.4 | 31.5 | ms | 8 |
|   Factory Reset | | 199 | | 484 | ms | 14 |
| Channel Dwell Time | | | | 400 | ms | |
| CMD low to trigger TX with option TXnCMD | $t_{TXnCMD}$ | 2 | | | ms | 13 |
| Interface Section | | | | | | | |
| UART Data rate | | 9,600 | | 115,200 | bps | |
| Input | | | | | | | |
|   Logic Low | $V_{IL}$ | | | $0.3 {*} V_{CC}$ | VDC | |
|   Logic High | $V_{IH}$ | $0.7 {*} V_{CC}$ | | | VDC | |
| Output | | | | | | | |
|   Logic Low, MODE_IND, BE | $V_{OLM}$ | | | $0.3 {*} V_{CC}$ | VDC | 1,9 |
|   Logic High, MODE_IND, BE | $V_{OHM}$ | $0.7 {*} V_{CC}$ | | | VDC | 1,9 |
|   Logic Low | $V_{OL}$ | | | $0.3 {*} V_{CC}$ | | 1,10 |
|   Logic High | $V_{OH}$ | $0.7 {*} V_{CC}$ | | | | 1,10 |
| $\overline{CRESP}$ Hold Time | | 10 | | | Bits | 11 |
| Flash (Non-Volatile) Memory Specifications | | | | | | | |
|   Flash Write Bytes | | 16,000 | | | bytes | 12 |
|   Flash Refresh Cycles | | 2,000 | | | cycles | |

1. Measured at 3.3V $V_{CC}$
2. Measured at 25ºC
3. Input power < -60dBm
4. Characterized but not tested
5. PER = 1%
6. Into a 50-ohm load
7. No RF interference
8. From end of command to start of response
9. 60mA source/sink
10. 6mA source/sink
11. End of CMD_DATA_OUT stop bit to change in $\overline{CRESP}$
12. Number of register write operations
13. With CSMA disabled
14. Start of factory reset command to end of last ACK response
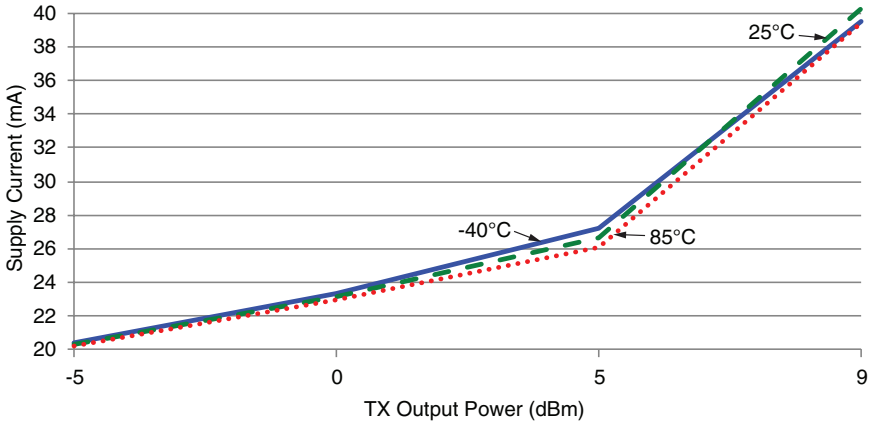
Figure 4: Electrical Specifications

Figure 8: HumPRO™ Series Transceiver Average TX Current vs. Transmitter Output Power at 3.3V -HUM-868-PRO
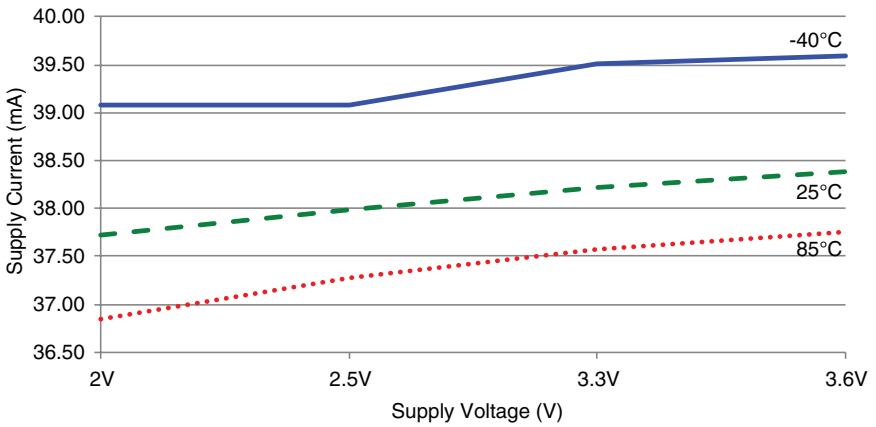


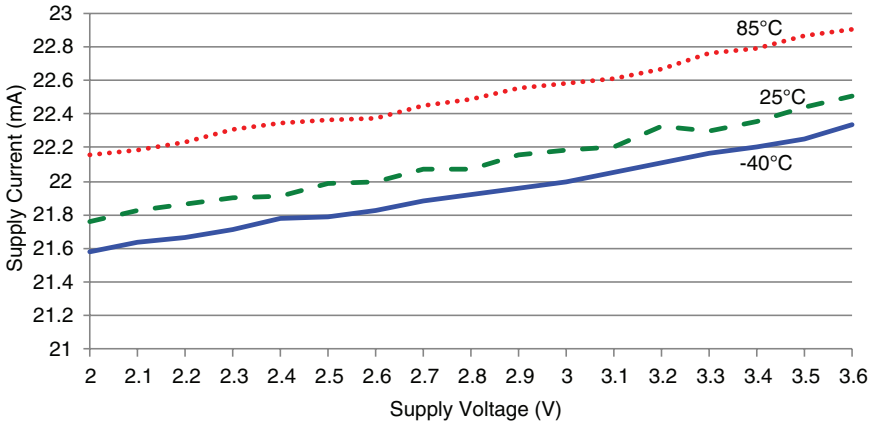Figure 7: HumPRO™ Series Transceiver TX Current vs. Supply Voltage at Max Power - HUM-868-PRO

Figure 12: HumPRO™ Series Transceiver RX Scan Current vs. Supply Voltage, 115.2kbps - HUM-868-PRO

Current consumption while the module is scanning for a transmission. The current is approximately 2mA higher when receiving data at 115.2kbps.
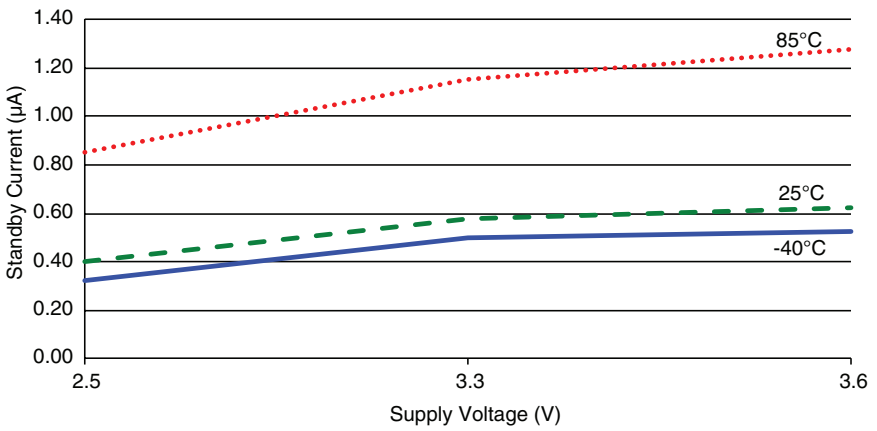


Figure 11: HumPRO™ Series Transceiver Standby Current Consumption vs. Supply Voltage - HUM-868-PRO

# Pin Assignments
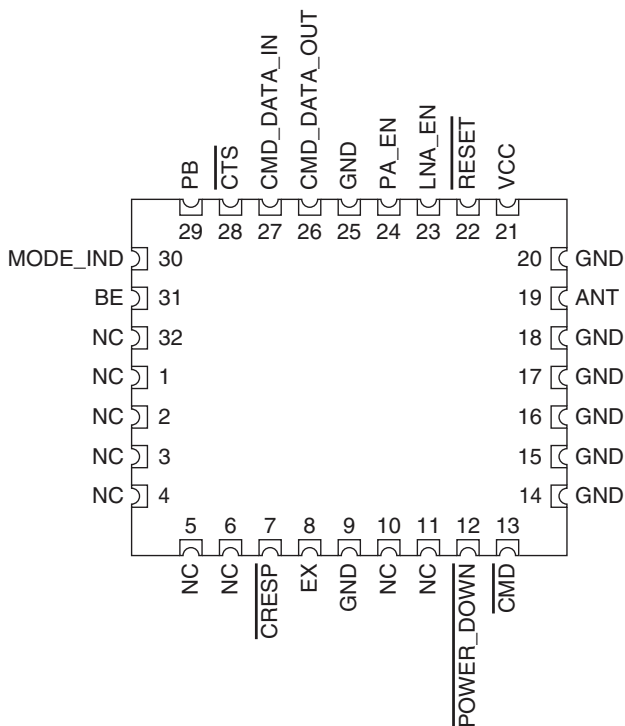


Figure 14: HumPRO™ Series Transceiver Pin Assignments (Top View)

# Pin Descriptions

| Pin Descriptions | | | |
|---|---|---|---|
| **Pin Number** | **Name** | **I/O** | **Description** |
| 1, 2, 3, 4, 5, 6, 10, 11, 32 | NC | — | No Electrical Connection. Do not connect any traces to these lines. |
| 7 | CRESP | O | Command Response. This line is low when the data on the CMD_DATA_OUT line is a response to a command and not data received over the air. |
| 8 | EX | O | Exception Output. A mask can be set to take this line high when an exception occurs. |
| 9, 14, 15, 16, 17, 18, 20, 25 | GND | — | Ground |
| 12 | POWER_DOWN | I | Power Down. Pulling this line low places the module into a low-power state. The module is not functional in this state. Pull high for normal operation. Do not leave floating. |

## Encapsulated Module Pin Assignments

The encapsulated version of the module has mostly the same pin assignments as the standard version. The antenna connection is routed to either a castellation (-CAS) or a u.FL connector (-UFL), depending on the part number ordered.
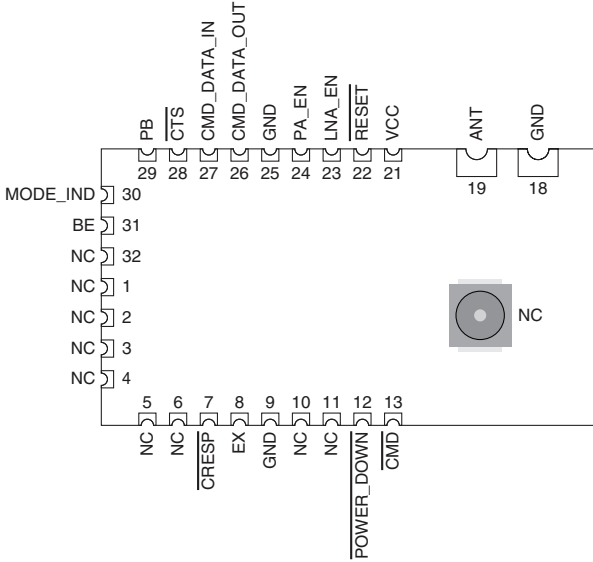


Figure 16: HumPRO™ Series Transceiver Encapsulated Version Pin Assignments - Castellation Connection (Top View)
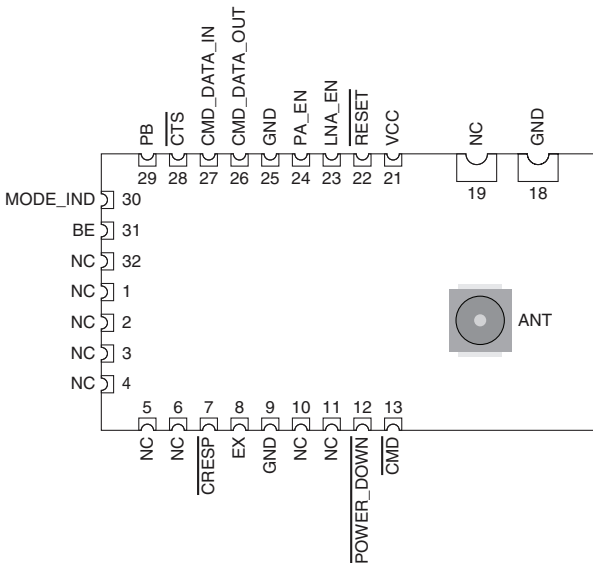


Figure 17: HumPRO™ Series Transceiver Encapsulated Version Pin Assignments - UFL Connection (Top View)

## Theory of Operation

The HumPRO™ Series transceiver is a low-cost, high-performance synthesized FSK / GFSK / MSK transceiver. Figure 20 shows the module's block diagram.
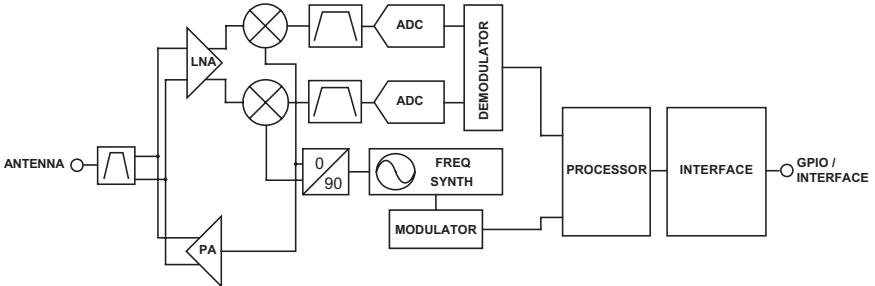


Figure 20: HumPRO™ Series Transceiver RF Section Block Diagram

The HumPRO™ Series transceiver operates in the 863 to 870MHz frequency band. The transmitter output power is programmable. The range varies depending on the antenna implementation and the local RF environment.

The RF carrier is generated directly by a frequency synthesizer that includes an on-chip VCO. The received RF signal is amplified by a low noise amplifier (LNA) and down-converted to I/Q quadrature signals. The I/Q signals are digitized by ADCs.

A low-power onboard communications processor performs the radio control and management functions including Automatic Gain Control (AGC), filtering, demodulation and packet synchronization. A control processor performs the higher level functions and controls the serial and hardware interfaces.

A crystal oscillator generates the reference frequency for the synthesizer and clocks for the ADCs and the processor.

## Overview

The HumPRO™ Series RF transceiver module offers a number of features that make it suitable for many data transfer applications. This section provides a basic overview of the features while following sections dive into them in more detail.

### Addressing

The modules have a very powerful addressing method. Each module is given a unique 16 or 32 bit address. The receiving modules use an address mask that determines how it responds to a received transmission.

The addressing and masking allow for the creation of point-to-point, many-to-one and one-to-many wireless links. This allows the creation of many network topologies, such as star, tree and mesh. The routing for the network topology is managed outside the module.

The addressing is the primary configuration when getting started with the modules. RG-00105, the HumPRO™ Addressing Mode Reference Guide has details about configuring the addressing.

### Acknowledgements and Assured Delivery

The modules support assured delivery in the form of acknowledgements and retries. When the acknowledgements are enabled, the receiving device sends an acknowledge message to let the sender know that the transmission was received. If the sender does not get an acknowledgement it resends the message up to a configurable number of retries. If there is still no acknowledgement, the module triggers an exception to let the host processor know of the error.

### Command Mode and Data Mode

The module has two main interface modes controlled by the state of the $\overline{CMD}$ line. Command mode routes the data coming in on the CMD_DATA_ IN line to the processor for configuring the module. Data mode routes the data to the transmitter for transmission over-the-air. The $\overline{CMD}$ line is normally controlled by an external microcontroller.

### Encryption

The module supports AES-128 encryption to provide a secure wireless link. All of the modules must have encryption enabled and be using the same key in order for communication to be successful. There are two ways of entering an encryption key: directly by writing the key to registers through the Command Data Interface or through a JOIN process.

## Addressing Modes

The module has very flexible addressing methods selected with the ADDMODE register. It can be changed during operation. The transmitting module addresses packets according to the addressing mode configuration. The receiving module processes all addressing types regardless of the ADDMODE configuration. If the received message matches the addressing criteria, it is output on the UART. Otherwise it is discarded. The ADDMODE configuration also enables assured delivery.

There are three addressing modes: DSN, User and Extended User. Each mode offers different communications methods, but all use source and destination addressing. The source address is for the transmitting unit, the destination address is the intended receiver. Each mode uses different registers for the source and destination addresses.

The following sections give brief descriptions of the three modes, but a detailed explanation and examples are given in RG-00105, the HumPRO™ Addressing Mode Reference Guide.

### DSN Addressing Mode

Device Serial Number Addressing mode is the simplest mode and supports point-to-point communications. Each module is programmed at the factory with a unique 4-byte serial number that cannot be changed. These bytes are found in the non-volatile read-only MYDSN registers (MYDSN[3-0]). DSN Addressing mode uses this serial number as an address. The transmitting unit's DSN is used as the source address and the intended receiver's DSN is written into the destination address registers (DESTDSN[3-0]). All modules within range hear the transmission, but only the module with the serial number that matches the destination address outputs the data on its UART. All others ignore the transmission.

## Automatic Addressing

The module supports an automatic addressing mode that reads the Source Address from a valid received packet and uses it to fill the Destination Address register. This makes sure that a response is sent to the device that transmitted the original message. This also allows the host microcontroller to read out the address of the sending unit. The automatic addressing is enabled for the different addressing modes with register AUTOADDR.

## Address Register Use

Figure 21 shows the address registers that are used with each addressing mode.

| HumPRO™ Series Transceiver Address Registers | | | | | | |
|---|---|---|---|---|---|---|
| **COMPAT** | **0x00 (Relaxed Addressing)** | | | **0x02 (Normal Addressing)** | | |
| | 0x04 (DSN) | 0x06 (User) | 0x07 (Ex User) | 0x04 (DSN) | 0x06 (User) | 0x07 (Ex User) |
| **ADDMODE** | 0x14 (DSN +ACK) | 0x16 (User +ACK) | 0x17 (ExUser +ACK) | 0x14 (DSN +ACK) | 0x16 (User +ACK) | 0x17 (ExUser +ACK) |
| UDESTID[3-0] | | | X | | | X |
| UDESTID[1-0] | | X | | | X | |
| USRC[3-0] | | | X | | X | X |
| USRC[1-0] | | X | | | | |
| UMASK[3-0] | | | X | | X | X |
| UMASK[1-0] | | X | | | | |
| DESTDSN[3-0] | X | | | X | | |

Figure 21: HumPRO™ Series Transceiver Address Register Use

## Listen Before Talk and Adaptive Frequency Agility

Europe's ETSI standards have very specific requirements for operating in the 868MHz band. The transmitter on-time is of particular note. This is specified in terms of Duty Cycle, which is the amount of time the transmitter can be active in a one-hour period. The requirements are contained in EN 300 220-1 and ERC Recommendation 70-03 summarizes the use of the 868MHz band by frequency and application.

The on-time for single channel devices depends on the specific transmit frequency and varies across the 868 to 870MHz band. It can be as low as 0.1% or 3.6 seconds per hour. It is normally up to the designer of the end product to ensure that the product cannot exceed this limit.

However, the rules also allow for higher transmit times if the radio uses intelligent or polite spectrum access techniques called Listen Before Talk (LBT) and Adaptive Frequency Agility (AFA). LBT is defined as a method where the radio listens on a channel to ensure it is clear before transmitting. AFA is defined as the capability to dynamically change channels within the available frequencies for proper operation. In other words, the radio listens to the channel to make sure it is clear. If it is occupied, it either waits for it to become clear or automatically goes to another channel.

A system that uses these spectrum access techniques is allowed more transmission time. This is advantageous for systems that need to transmit large data streams or have an unpredictable usage pattern. EN 300 220-1 has very specific requirements for LBT and transmitter on time as well as what declarations must be made by the manufacturer.

### Listen Before Talk

EN 300 220-1 has the requirements, limits and methods of testing the LBT system. The main requirements are:

- An RSSI threshold above which the channel is considered busy. This is dependent on the channel bandwidth

- A minimum listening time of 5ms plus a random time between 0 and 5ms in steps of 0.5ms.

- A maximum dead time between the end of listening and start of talking.

- A minimum transmitter off time of more than 100ms.

A provision is made for acknowledgements to a transmission that allows them to transmit immediately, without needing to listen first.

## HumPRO™ Series Transceiver EN 300 220-1 Declarations

| Item | Description |
|------|-------------|
| Receiver Category (4.1.1) | The module incorporates a short range radio device designed for use in applications in category 2 (medium reliable) or 3 (standard reliable) |
| General Performance Criteria (4.1.2) | The appropriate performance criterion for the HUM-868-PRO is "after demodulation, a message acceptance ratio of 80%". <br><br> The test should be performed with bit 4 in the ADDMODE register (ack request) = 0. The external microcontroller normally supplies the indication for message acceptance. The MODE_IND output can be used as a packet received indication when the module is only receiving. |
| Duty Cycle (7.10.2) | The module is designed to provide up to 64% transmitter duty cycle when used with continuous demand for transmission when CSMAMODE = 2 (default). The actual duty cycle in operation, however, is primarily determined by average data rate and the size and timing of the packets containing the data. Thus, the end equipment has a critical part in determining the duty cycle and the manufacturer must declare the total duty cycle. |
| FHSS (7.4.1.2) | The module is intended to be certified as part of an AFA device, not an FHSS device. |
| Acknowledgement (7.10.2) | Acknowledgement can optionally be done at either the module level, application level, or both. If done at the module level through the use of ADDMODE bit 4, the acknowledgement causes the responding module to transmit for 4ms within less than 5ms after receiving the packet. <br><br> If acknowledgement is provided by the application, the timing is mostly determined by the product response time and length of response message. In this case the applying manufacturer is responsible for declaring the timing. |
| Minimum TX-off Time (9.2.1.2) | The minimum TX-off time is 101ms. The actual time will be more if the external controller has no data to transmit. |
| LBT Fixed Minimum Listening Time (9.2.2.2 a) | The fixed minimum listening time is 5ms. |
| LBT Pseudo-random Listening Time (9.2.2.2 b) | The pseudo-random listening time, $t_{PS}$, varies from 0 to 5ms in 0.5ms steps: <br><br> $t_{PS} = 0.5ms * int(((Timer1 \, \& \, 0x1f) + 1)/3)$ <br><br> The module serial number is added to a high-speed timer (incremented every 1.23µs) is used as a simple source of random value, due to the variation of time at which $t_{PS}$ is calculated, relative to the timer period. The lower 5 bits of that sum is incremented by 1, giving a random value 1 to 32. That value is divided by 3, giving a value 0 to 10, with the value 0 occurring with p=2/32, other values occurring with 3/32, resulting in an average value over several calculations of 5.33ms, slightly higher than the median value of 5.0. |

## Transmitting Packets

In default operation when transmitting, the host microcontroller writes bytes to the CMD_DATA_IN line while the $\overline{\text{CMD}}$ line is held high at the baud rate selected by the UARTBAUD register. The incoming bytes are buffered until one of the following conditions triggers the packet to be transmitted:

1. The number of bytes in the buffer exceeds the value in the Byte Count Trigger (BCTRIG) register.

2. The time since the last received byte exceeds the value in the Data Timeout (DATATO) register.

3. A SENDP command is written to the CMD register.

4. The $\overline{\text{CMD}}$ line is taken low with option PKOPT: TXnCMD = 1.

5. The number of buffered bytes exceeds what can be sent before the radio must hop channels.

The first four conditions can be controlled by the host microcontroller. In the last case, the module transmits what it can in the remaining time then sends the rest on the next channel. This can cause the data to be divided up into multiple packets and is not within the control of the host micro.

In cases where all data needs to be sent in the same packet or where the microcontroller needs greater control over the radio, the HumPRO™ offers explicit control of packet transmission with options in the PKTOPT register.

When the TXPKT option is enabled (PKTOPT register, bit 0 = 1), the data is held until a SENDP command is written to the CMD register. Alternatively, if option TXnCMD is enabled (PKTOPT register, bit 1 = 1), then lowering the $\overline{\text{CMD}}$ line triggers the packet transmission, reducing the number of UART transactions that are required. The BCTRIG, DATATO and hop-timing conditions are ignored when the TXPKT option is enabled.

Once triggered, the transmitted packet contains the bytes in the buffer as of the trigger event, even if more data bytes are received before the packet can be sent. Multiple outgoing packets can be buffered in this way.

If the full packet cannot be sent in the time remaining on the current channel, then it is held until the module hops to the next channel.

This option gives the host microcontroller very fine control over when packets are transmitted and what they contain.
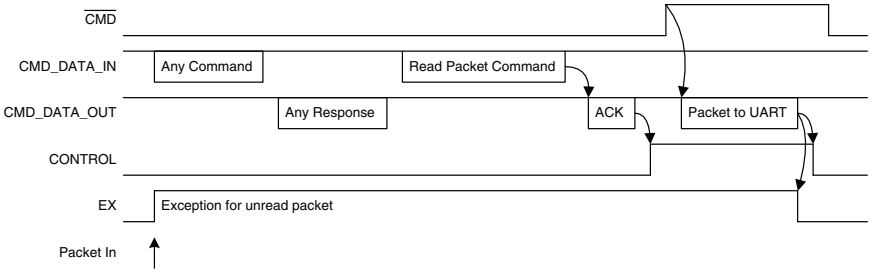
Figure 23: HumPRO™ Series Transceiver Received Packet Transfer Cycle

If a GETPH was sent and header data received, the following data can then be read by repeating the cycle with the GETPD command. If the next GETPx command is a GETPH or GETPHD, the data associated with the header read by GETPH is discarded and the header or header plus data of the following packet is returned.

If there is RF-received data waiting to be sent to the UART and the mask for EX_RXWAIT is set in the EEXMASK register, EX is raised if it is low.

If there is no packet waiting when a GETPx command is sent, the control line is still taken high and not reset until after $\overline{\text{CMD}}$ goes high, thereby performing a zero-byte transfer cycle.

The header and payload structures differ between encrypted packets and unencrypted packets. The header and data structures for explicit unencrypted packets are shown in Figure 24.

The Tag field identifies the start of the block and if it is the header information (0x01) or the packet data (0x02).

The Header Length field identifies the number of header bytes that follow.

The Frame Type field identifies what kind of packet was received. The values are shown in Figure 25.

The Hop ID field is the hop sequence number, 0 - 5.

The Sequence byte is incremented for each new packet, modulo 255. A received packet is discarded if the sequence byte matches the previously received packet to prevent delivering duplicate copies of an automatically retransmitted packet.

The header and data structures for explicit encrypted packets are shown in Figure 26. The header and data blocks returned by the module are the decrypted message contents.

Encrypted DSN Address Packet Header

| Tag | Header Length | Frame Type | Hop Key | Sequence | Dest DSN | Source DSN | EBlock Length | Payload Type |
|---|---|---|---|---|---|---|---|---|
| 0x11 | 1 | 1 | 1 | 6 | 4 | 4 | 1 | 1 |

Encrypted User Address Packet Header

| Tag | Header Length | Frame Type | Hop Key | Sequence | Dest Addr | Source Addr | Source DSN | EBlock Length | Payload Type |
|---|---|---|---|---|---|---|---|---|---|
| 0x11 | 1 | 1 | 1 | 6 | 2 or 4 | 2 or 4 | 4 | 1 | 1 |

Encrypted Packet Data

| Tag | Data Length | Data |
|---|---|---|
| 0x12 | 1 | Data Length Bytes |

Figure 26: HumPRO™ Series Transceiver Encrypted Packet Header and Data Structure

The Tag, Header Length and Frame Type fields are the same as for unencrypted packets.

The Hop Key field uses the first three low-order bits to indicate the Hop Sequence number, which is the same as unencrypted packets. The upper two bits indicate which key is being used. Either the factory-set key that is used to securely transfer the network key or a network key that has been written or created by the JOIN process. This is shown in Figure 27.

| HumPRO™ Series HopKey Byte Values | |
|---|---|
| HopKey Bit | Value |
| 0 - 3 | Hop Sequence Number, 1 to 5 |
| 4 - 5 | = 0 |
| 6 - 7 | Encryption key<br>0 = factory<br>1 = user network |

Figure 27: HumPRO™ Series HopKey Byte Values

The Sequence bytes contain a counter that is incremented for each new transmitted message. The initial value is randomized when the module is reset. The extended sequence becomes part of an initialization vector which is used to vary the encrypted contents of identical packets. A received packet is discarded if the sequence byte matches the previously received packet to prevent delivering duplicate copies of an automatically retransmitted packet.

## Exception Engine

The HumPRO™ is equipped with an internal exception engine to notify the host microcontroller of an unexpected event. If errors occur during module operation, an exception is raised. There are two methods of driving the EX pin when an exception condition exists:

1. From the EXMASK and EXCEPT registers (legacy operation)
2. From the EEXMASKx and EEXFLAGx registers (standard operation)

If EXMASK is non-zero, the first method is used, otherwise the second method is used.

For legacy operation with the 250 and 25 Series, the EX line is set and reset by the Exception (EXCEPT) register processing. It is set when an exception occurs and the exception code ANDed with the current Exception Mask (EXMASK) register is non-zero. It is reset when the EXCEPT register is read through a command. No other operations affect the state of EX. Setting EXMASK non-zero does not change the state of EX.

If an exception code is already present in the register when an error occurs, the new exception code overwrites the old value. Exception codes are organized by type for ease of masking. Figure 28 lists the exception codes and their meanings.

| HumPRO™ Series Transceiver Exception Codes | | |
|---|---|---|
| Exception Code | Exception Name | Description |
| 0x08 | EX_BUFOVFL | Incoming UART buffer overflowed. |
| 0x09 | EX_RFOVFL | Outgoing UART buffer overflowed. |
| 0x13 | EX_WRITEREGFAILED | Attempted write to register failed. |
| 0x20 | EX_NORFACK | Acknowledgement packet not received after maximum number of retries. |
| 0x40 | EX_BADCRC | Bad CRC detected on incoming packet. |
| 0x42 | EX_BADHEADER | Bad CRC detected in packet header. |
| 0x43 | EX_BADSEQID | Sequence ID was incorrect in ACK packet. |
| 0x44 | EX_BADFRAMETYPE | Attempted transmit with Invalid setting in reg:NETMODE or invalid packet type in received packet header |

Figure 28: HumPRO™ Series Transceiver Exception Codes

## Networking

The HumPRO™ Series modules can be used to create many types of wireless networks. The modules do not provide network routing since the internal memory size of the module would limit the overall network size. The HumPRO™ can work as the MAC/PHY layers of a network stack and the memory and processing speed of the external microcontroller can be sized according to the size of the network that is needed for the application.

This requires more software development, but avoids the cost of adding extra memory on the module for applications that don't need it. Linx can assist with network frameworks and concepts and can create custom designs on a contract basis. Contact Linx for more details.

## Using the $\overline{\text{CMD}}$ Line

The $\overline{\text{CMD}}$ line informs the module where incoming UART data should be routed. When the line is high, all incoming UART data is treated as payload data and is routed to the transmitter to be sent over the air. If the $\overline{\text{CMD}}$ line is low, the incoming UART data is treated as command bytes and is routed to the controller for processing.

Since the module's controller looks at UART data one byte at a time, the $\overline{\text{CMD}}$ line must be held low for the entire duration of the command plus time for ten bits as margin for processing. Leaving the line low for additional time (for example, until the ACK byte is received by the application) does not adversely affect the module. If RF packets are received while the $\overline{\text{CMD}}$ line is active, they are still processed and output on the module's UART (assuming CMDHOLD=0 and PKOPT:RXPKT=0). Figure 31 shows this timing.
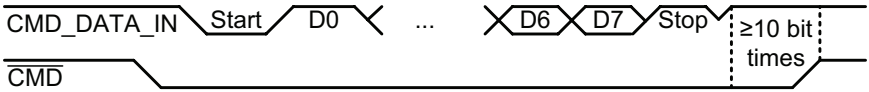


Figure 31: HumPRO™ Series Transceiver $\overline{\text{CMD}}$ Line Timing

Commands can be entered sequentially without having to raise the $\overline{\text{CMD}}$ line after each one. The $\overline{\text{CMD}}$ line just needs to be raised to be able to enter data for transmission.

If the CMDHOLD register is 0x01 then any received data is held until the $\overline{\text{CMD}}$ line is raised. This prevents received data from being intermingled with command responses.

## External Amplifier Control

The HumPRO™ Series transceiver has two output lines that are designed to control external amplifiers. The PA_EN line goes high when the module activates the transmitter. This can be used to activate an external power amplifier to boost the signal strength of the transmitter. The LNA_EN line goes high when the module activates the receiver. This can be used to activate an external low noise amplifier to boost the receiver sensitivity. These external amplifiers can significantly increase the range of the system at the expense of higher current consumption and system cost.

The states of the PA_EN and LNA_EN lines can be read in the LSTATUS register. This offers a quick way to determine the current state of the radio.

A module is set as an administrator by pressing and holding the button for 30 seconds to start the Generate Key function. While the button is held, the MODE_IND line is on. After 30s, the MODE_IND line repeats a double blink, indicating that the function has begun. When the button is released the key and address generation are complete and the module is an administrator.

When Generate Key is performed, the unit is set as the network administrator. It generates a random 128-bit AES encryption key based on ambient RF noise and scrambled by an encryption operation. If UMASK is the default value (0xFFFFFFFF), it is set to 0x000000FF, supporting up to 255 nodes, and ADDMODE is set to Extended User Address with encryption (0x27) (or without encryption (0x07) if flag PGKEY in the SECOPT register is 0). UMASK and ADDMODE are not changed if UMASK is not 0xFFFFFFFF. A random 32-bit address is generated. By default, the lower 8 bits are 0, forming the network base address. Other nodes are assigned sequential addresses, starting with network base address +1. UDESTID is set to the bitwise OR of USRCID and UMASK, which is the network broadcast address.

A module becomes a node by joining with an administrator. This is done by pressing and releasing the PB button on both units. The modules automatically search for each other using a special protocol. When they find each other, the administrator sends the node the encryption key, UMASK and its network address. The UDESTID is set to the address of the administrator. The values are encrypted using a special factory-defined key. Once the JOIN process is complete, the MODE_IND blinks on both units and they now operate together. This is shown in Figure 32 A.

If UMASK is pre-set when Generate Key is initiated, then the JOIN process uses that mask and sets the address accordingly. This can allow more nodes in the network. This is shown in Figure 32 B.  Likewise, the network key can be written to the module with the CDI interface and the JOIN process used to create an address and associate new modules. Or the administrator can be completely configured through the CDI and the JOIN process used to associate nodes in the field. This gives the system designer many options for configuration.

The SECOPT register is used to configure options related to the JOIN process. This allows the OEM to set desired values at the factory and allow final network configuration in the field. This includes disabling the ability to change the address, change the key and share the key. The built-in security prohibits changing a node to an administrator without changing the key.

## Using the MODE_IND Line

The MODE_IND line is designed to be connected to an LED to provide visual indication of the module's status and current actions. The pattern of blinks indicates the particular feedback from the module. Figure 33 shows the different blink patterns and their meanings.

| HumPRO™ Series Transceiver MODE_IND Line Timing | |
|---|---|
| **Display**<br>**[on/off time in seconds]** | **Module Status** |
| **Join Operation** | |
| Two quick blinks | Administrator Join. The administrator is looking for a node to join with. |
| One quick blink | Node Join. The node is looking for an administrator to join with. |
| Quick blink | Key Transfer Active. Key transfer is taking place (administrator and node). |
| Slow Blink | Key Transfer Complete. The module has completed a key transfer (administrator and node). |
| Temporary On | On when the PB line is high |
| Two quick blinks, one time | Join Canceled. |
| Slow blink, repeat 3 times | Failure. For Share Key or Get Key, there are multiple units attempting to pair, protocol error, or timeout without response |
| Slow blink and two quick blinks | Long Hold Acknowledgement. The long hold period for Generate Key or Reset Sequence was recognized (PB is asserted) |
| **Key Test Results** | |
| One quick blink Three times | No Key. There is no network key or network address. |
| Two quick blinks Three times | Key Set, node. The network key and network address are set on a node. |
| Three quick blinks Three times | Key Set, administrator. The network key and network address are set on an administrator. |
| **Normal operation** | |
| Off | No activity |
| Temporarily on | Transmitting or receiving packet |

Figure 33: HumPRO™ Series MODE_IND Line Timing

## Restore Factory Defaults

The transceiver is reset to factory default by taking the PB line high briefly 4 times, then holding PB high for more than 3 seconds. Each brief interval must be high 0.1 to 2 seconds and low 0.1 to 2 seconds. (1 second nominal high / low cycle). The sequence helps prevent accidental resets. Once the sequence is recognized, the MODE_IND line blinks in groups of three until the PB line goes low. After PB goes low, the non-volatile configurations are set to the factory default values and the module is restarted. The default UART data rate is 9,600bps.

If the timing on PB does not match the specified limits, the sequence is ignored. Another attempt can be made after lowering PB for at least 3 seconds.

## Using the Low Power Features

The module supports several low-power features to save current in battery-powered applications. This allows the module to be asleep most of the time, but be able to quickly wake up, send data and go back to sleep.

Taking the Power Down ($\overline{POWER\_DOWN}$) line low places the module into the lowest power state. In this mode, the internal voltage regulator and all oscillators are turned off. All circuits powered from the voltage regulator are also off. The module is not functional while in this mode and current consumption drops to below 6µA. Taking the line high wakes the module.

When the $\overline{POWER\_DOWN}$ line is high, the IDLE register determines sleep operation.

If IDLE is set to 1 during normal operation, the module sends an ACK byte, waits for completion of an active transmission, then goes into sleep mode. Unsent data in the incoming UART data buffer does not inhibit sleep. During sleep mode, the output lines are in the states in Figure 36.

A rising transition on the $\overline{POWER\_DOWN}$ or CMD_DATA_IN lines wakes the module. If a negative-going pulse is needed to generate a rising edge, the pulse width should be greater than 1 µs.

Other lines also wake the module but it immediately goes back to sleep. Floating inputs should be avoided since they may cause unintended transitions and cause the module to draw additional current.

## The Command Data Interface

The HumPRO™ Series transceiver has a serial Command Data Interface (CDI) that is used to configure and control the transceiver through software commands. This interface consists of a standard UART with a serial command set. The CMD_DATA_IN and CMD_DATA_OUT lines are the interface to the module's UART. The UART is configured for 1 start bit, 1 stop bit, 8 data bits, no parity and a serial data rate set by register UARTBAUD (default 9,600bps). The $\overline{\text{CMD}}$ line tells the module if the data on the UART is for configuration commands (low) or data transmission (high).

The module has a 256 byte buffer for incoming data. The module starts transmitting when the buffer reaches a specified limit or when the time since the last received byte on the UART reaches a specified value. This allows the designer to optimize the module for fixed length and variable length data.

If the buffer gets nearly full (about 224 bytes), the module pulls the $\overline{\text{CTS}}$ line high, indicating that the host should not send any more data. Data sent by the host while the buffer is full is lost, so the $\overline{\text{CTS}}$ line provides a warning and should be monitored. When there is outgoing data waiting to be transmitted or acknowledged the BE line is low, otherwise BE is high.

Configuration settings are stored in two types of memory inside the module. Volatile memory is quick to access, but it is lost when power is removed from the module. Non-volatile memory has a limited number of write cycles, but is retained when power is removed. When a configuration parameter has both a non-volatile and volatile register, the volatile register controls the operation unless otherwise stated. The non-volatile register holds the default value that is loaded into the volatile register on power-up.

Configuration settings are read from non-volatile memory on power up and saved in volatile memory. The volatile and non-volatile registers have different address locations, but the same read and write commands. The two locations can be changed independently.

The general serial command format for the module is:

[FF] [Length] [Command]

The Length byte is the number of bytes in the Command field. The

## Writing to Registers

To allow any byte value to be written, values of 128 (0x80) or greater can be encoded into a two-byte escape sequence of the format 0xFE, [value - 0x80]. This includes register addresses as well as values to be written to the registers. The result is that there are four possible packet structures because of the possible escape sequences. These are shown in Figure 38.

| HumPRO™ Series Write to Configuration Register Command | | | | | |
|---|---|---|---|---|---|
| **Register and Value less than 128 (0x80)** | | | | | |
| Header | Size | Address | Value | | |
| 0xFF | 0x02 | REG | V | | |
| **Register less than 128 (0x80) and a Value greater than or equal to 128 (0x80)** | | | | | |
| Header | Size | Address | Escape | Value | |
| 0xFF | 0x03 | REG | 0xFE | V-0x80 | |
| **Register greater than or equal to 128 (0x80) and a Value less than 128 (0x80)** | | | | | |
| Header | Size | Escape | Address | Value | |
| 0xFF | 0x03 | 0xFE | REG-0x80 | V | |
| **Register and Value greater than or equal to 128 (0x80)** | | | | | |
| Header | Size | Escape | Address | Escape | Value |
| 0xFF | 0x04 | 0xFE | REG-0x80 | 0xFE | V-0x80 |

Figure 38: HumPRO™ Series Write to Configuration Register Command

Generally, there are three steps to creating the command.

1. Determine the register address and the value to be written.

2. Encode the address and value as either the number (N) or the encoded number (0xFE, N-0x80) as appropriate.

3. Add the header (0xFF) and the size.

The module responds with an ACK (0x06). If the ACK is not received, the command should be resent. The module responds with a NACK (0x15) if a write is attempted to a read-only or invalid register.

As an example, to write 01 to register 0x83, send

FF 03 FE 03 01

> Note: The non-volatile memory has a life expectancy of at least 18,000 write operations.

# Example Code for Encoding Read/Write Commands

*This software example is provided as a courtesy in "as is" condition. Linx Technologies makes no guarantee, representation, or warranty, whether express, implied, or statutory, regarding the suitability of the software for use in a specific application. The company shall not, in any circumstances, be liable for special, incidental, or consequential damages, for any reason whatsoever.*

## File EncodeProCmd.c .......................................................................................

```c
/* Sample C code for encoding Hum-xxx-PRO commands
**
** Copyright 2015 Linx Technologies
**  155 Ort Lane
**  Merlin, OR, US 97532
**  www.linxtechnologies.com
**
** License:
**  Permission is granted to use and modify this code, without royalty, for
**  any purpose, provided the copyright statement and license are included.
*/

#include "EncodeProCmd.h"

/* Function:   HumProCommand
** Description: This function encodes a command byte sequence.
**           If len = 1, a read command is generated.
**           If len > 1, a write command is generated.
**               rcmd[0] = register number
**               rcmd[1..(n-1)] = bytes to write
*/
unsigned char                       /* number of encoded bytes, n+2 to 2*n+2 */
HumProCommand(
    unsigned char *ecmd,            /* out: encoded command, length >= 2*n + 2 */
    const unsigned char *rcmd,      /* in: sequence of bytes to encode */
    unsigned char n                 /* number of bytes in rcmd, 1..32 */
) {
    unsigned char dx;               /* destination index */
    unsigned char sx;               /* source index */
    unsigned char v;                /* value to be encoded */
    dx = 2;
    sx = 0;
    while (n--) {
        v = rcmd[sx++];
        if (v >= 0xf0) {
            ecmd[dx++] = 0xfe;
            v &= 0x7f;
        }
        ecmd[dx++] = v;
    }
    ecmd[0] = 0xff;
    ecmd[1] = dx - 2;
```

# The Command Data Interface Command Set

The following sections describe the registers.

| HumPRO™ Series Configuration Registers | | | | | |
|---|---|---|---|---|---|
| Name | NV Addr | Vol Addr | R/W | Default Value | Description |
| CRCERRS | | 0x40 | R/W | 0x00 | CRC Error Count |
| HOPTABLE | 0x00 | 0x4B | R/W | 0x00 | Channel Hop Table |
| TXPWR | 0x02 | 0x4D | R/W | 0x03 | Transmit Power |
| UARTBAUD | 0x03 | 0x4E | R/W | 0x01 | UART data rate |
| ADDMODE | 0x04 | 0x4F | R/W | 0x04 | Addressing mode |
| DATATO | 0x05 | 0x50 | R/W | 0x10 | Data timeout |
| MAXTXRETRY | 0x07 | 0x52 | R/W | 0x1A | Maximum Transmit Retries |
| ENCRC | 0x08 | 0x53 | R/W | 0x01 | Enable CRC checking |
| BCTRIG | 0x09 | 0x54 | R/W | 0x40 | Byte Count trigger |
| SHOWVER | 0x0A | | R/W | 0x01 | Show version on startup |
| ENCSMA | 0x0B | 0x56 | R/W | 0x02 | Enable CSMA |
| IDLE | 0x0D | 0x58 | R/W | 0x00 | Idle Mode |
| WAKEACK | 0x0E | 0x59 | R/W | 0x01 | UART Acknowledge on Wake |
| UDESTID3 | 0x0F | 0x5A | R/W | 0xFF | Destination Address for User Packet Type, extended |
| UDESTID2 | 0x10 | 0x5B | R/W | 0xFF | Destination Address for User Packet Type, extended |
| UDESTID1 | 0x11 | 0x5C | R/W | 0xFF | Destination Address for User Packet Type |
| UDESTID0 | 0x12 | 0x5D | R/W | 0xFF | Destination Address for User Packet Type |
| USRCID3 | 0x13 | 0x5E | R/W | 0xFF | Source Address for User Packet Type, extended |
| USRCID2 | 0x14 | 0x5F | R/W | 0xFF | Source Address for User Packet Type, extended |
| USRCID1 | 0x15 | 0x60 | R/W | 0xFF | Source Address for User Packet Type |
| USRCID0 | 0x16 | 0x61 | R/W | 0xFF | Source Address for User Packet Type |
| UMASK3 | 0x17 | 0x62 | R/W | 0xFF | Address Mask for User Packet Type, extended |
| UMASK2 | 0x18 | 0x63 | R/W | 0xFF | Address Mask for User Packet Type, extended |
| UMASK1 | 0x19 | 0x64 | R/W | 0xFF | Address Mask for User Packet Type |
| UMASK0 | 0x1A | 0x65 | R/W | 0xFF | Address Mask for User Packet Type |
| DESTDSN3 | 0x1D | 0x68 | R/W | 0xFF | Destination Device Serial Number |
| DESTDSN2 | 0x1E | 0x69 | R/W | 0xFF | Destination Device Serial Number |
| DESTDSN1 | 0x1F | 0x6A | R/W | 0xFF | Destination Device Serial Number |

## CRCERRS - CRC Error Count
### Volatile Address = 0x40

The value in the CRCERRS register is incremented each time a packet with a valid header is received that fails the CRC check on the payload.  This check applies only to unencrypted packets. Overflows are ignored. Writing 0x00 to this register initializes the count. Figure 40 shows the command and response.

| HumPRO™ Series CRC Error Count | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Read Command** | | | | **Read Response** | | | |
| Header | Size | Escape | Address | | ACK | Address | Value |
| 0xFF | 0x02 | 0xFE | 0x40 | | 0x06 | 0x40 | V |
| **Write Command** | | | | | | | |
| Header | Size | Address | Value | | | | |
| 0xFF | 0x02 | 0x40 | V | | | | |

Figure 40: HumPRO™ Series CRC Error Count Command and Response

## HOPTABLE - Channel Hop Table
### Volatile Address = 0x4B; Non-Volatile Address = 0x00

The module supports 6 different hop sequences with minimal correlation. The sequence is set by the value in the HOPTABLE register. Changing the hop sequence changes the band utilization, much the same way that a channel does for a non-hopping transmitter. The hop table selection must match between the transmitter and receiver. Valid values are 0-5. Figure 41 shows the command and response.

| HumPRO™ Series Channel Hop Table | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Read Command** | | | | **Read Response** | | | |
| Header | Size | Escape | Address | | ACK | Address | Value |
| 0xFF | 0x02 | 0xFE | 0x4B 0x00 | | 0x06 | 0x4B 0x00 | V |
| **Write Command** | | | | | | | |
| Header | Size | Address | Value | | | | |
| 0xFF | 0x02 | 0x4B 0x00 | V | | | | |

Figure 41: HumPRO™ Series Channel Hop Table Command and Response

Figure 42 shows the RF channels used by the HumPRO™ Series. Figure 43 shows the hop sequences referenced by channel number. The default hop sequence is 0.

| HumPRO™ Series Hop Sequences by Channel Number | | | | | | |
|---|---|---|---|---|---|---|
| Channel Index | 0 | 1 | 2 | 3 | 4 | 5 |
| 1 | 52 | 50 | 40 | 67 | 13 | 42 |
| 2 | 42 | 67 | 25 | 38 | 49 | 20 |
| 3 | 45 | 24 | 54 | 14 | 60 | 4 |
| 4 | 50 | 49 | 1 | 4 | 28 | 9 |
| 5 | 18 | 42 | 43 | 49 | 35 | 26 |
| 6 | 11 | 61 | 60 | 20 | 42 | 54 |
| 7 | 67 | 28 | 66 | 57 | 67 | 51 |
| 8 | 28 | 51 | 16 | 65 | 32 | 40 |
| 9 | 62 | 10 | 29 | 34 | 5 | 49 |
| 10 | 48 | 21 | 58 | 39 | 16 | 37 |
| 11 | 51 | 16 | 30 | 12 | 69 | 36 |
| 12 | 29 | 29 | 64 | 40 | 7 | 63 |
| 13 | 33 | 54 | 68 | 60 | 9 | 25 |
| 14 | 31 | 59 | 56 | 53 | 52 | 7 |
| 15 | 24 | 3 | 36 | 31 | 66 | 55 |
| 16 | 22 | 17 | 47 | 32 | 24 | 31 |
| 17 | 15 | 64 | 38 | 47 | 17 | 62 |
| 18 | 5 | 40 | 19 | 30 | 4 | 46 |
| 19 | 8 | 60 | 51 | 0 | 39 | 39 |
| 20 | 68 | 18 | 33 | 17 | 0 | 2 |
| 21 | 32 | 37 | 46 | 9 | 3 | 43 |
| 22 | 12 | 63 | 55 | 43 | 26 | 41 |
| 23 | 43 | 48 | 61 | 33 | 30 | 10 |
| 24 | 34 | 46 | 12 | 58 | 29 | 35 |
| 25 | 69 | 57 | 17 | 59 | 51 | 60 |
| 26 | 13 | 47 | 21 | 46 | 65 | 38 |
| 27 | 57 | 5 | 9 | 54 | 68 | 30 |
| 28 | 0 | 34 | 4 | 7 | 36 | 68 |
| 29 | 10 | 22 | 2 | 26 | 58 | 21 |
| 30 | 2 | 9 | 14 | 22 | 22 | 61 |
| 31 | 39 | 4 | 52 | 1 | 12 | 5 |
| 32 | 59 | 0 | 0 | 61 | 34 | 1 |
| 33 | 46 | 45 | 3 | 10 | 53 | 59 |
| 34 | 49 | 23 | 67 | 35 | 6 | 22 |
| 35 | 65 | 53 | 65 | 21 | 2 | 19 |
| 36 | 7 | 30 | 24 | 62 | 33 | 8 |
| 37 | 66 | 7 | 28 | 36 | 47 | 53 |
| 38 | 21 | 2 | 42 | 16 | 45 | 67 |
| 39 | 3 | 31 | 41 | 66 | 23 | 14 |
| 40 | 4 | 15 | 53 | 69 | 61 | 12 |
| 41 | 23 | 66 | 69 | 6 | 21 | 16 |
| 42 | 25 | 11 | 35 | 3 | 20 | 11 |
| 43 | 26 | 36 | 45 | 56 | 41 | 0 |
| 44 | 19 | 27 | 7 | 37 | 64 | 44 |
| 45 | 6 | 14 | 34 | 15 | 62 | 69 |
| 46 | 54 | 44 | 15 | 41 | 10 | 17 |
| 47 | 53 | 55 | 49 | 51 | 31 | 48 |
| 48 | 9 | 19 | 26 | 50 | 48 | 57 |
| 49 | 16 | 39 | 62 | 44 | 56 | 24 |

## TXPWR - Transmitter Output Power
### Volatile Address = 0x4D; Non-Volatile Address = 0x02

The value in the TXPWR register sets the module's output power. Figure 44 shows the command and response and Figure 45 available power settings and typical power outputs for the module. The default setting is 0x03.

| HumPRO™ Series Transmitter Output Power Mode | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Read Command** | | | | | **Read Response** | | | |
| Header | Size | Escape | Address | | ACK | Address | Value | |
| 0xFF | 0x02 | 0xFE | 0x4D 0x02 | | 0x06 | 0x4D 0x02 | PWR | |
| **Write Command** | | | | | | | | |
| Header | Size | Address | Value | | | | | |
| 0xFF | 0x02 | 0x4D 0x02 | PWR | | | | | |

Figure 44: HumPRO™ Series Transmitter Output Power Mode Command and Response

| HumPRO™ Series Transmitter Output Power Mode Register Settings | |
|---|---|
| **PWR** | **Typical Output Power (dBm)** |
| 0x00 | -5 |
| 0x01 | 0 |
| 0x02 | +5 |
| 0x03 | +9 |

Figure 45: HumPRO™ Series Transmitter Output Power Mode Settings

## ADDMODE - Addressing Mode
### Volatile Address = 0x4F; Non-Volatile Address = 0x04

The module supports three addressing modes: DSN, User, and Extended User, which are configured using bits 0 - 2.

If bit 3 is set, the module sends an extended preamble. This allows modules that have just awakened or have not yet synchronized to find and temporarily synchronize with the transmitting module. This can be useful in systems that require the endpoints to spend most of their time sleeping. Endpoints can awaken, receive a message from the transmitter, and go back to sleep. This message could contain scheduling information as to when to wake again for a full bi-directional communications session.

If bit 4 is set, then the receiver is instructed to transmit an acknowledgement packet for assured delivery signifying to the transmitter that the message was received.

If bit 5 is set then the module transmits data in encrypted mode.

Figure 48 shows the command and response and Figure 49 shows the valid settings.

| HumPRO™ Series Addressing Mode | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Read Command** | | | | **Read Response** | | | |
| Header | Size | Escape | Address | ACK | Address | Value | |
| 0xFF | 0x02 | 0xFE | 0x4F 0x04 | 0x06 | 0x4F 0x04 | V | |
| **Write Command** | | | | | | | |
| Header | Size | Address | Value | | | | |
| 0xFF | 0x02 | 0x4F 0x04 | V | | | | |

Figure 48: HumPRO™ Series Addressing Mode Command and Response

## DATATO - Transmit Wait Timeout
**Volatile Address = 0x50; Non-Volatile Address = 0x05**

When a byte is received from the UART, the module starts a timer that counts down every millisecond. The timer is restarted when each byte is received. The value for the DATATO register is the number of milliseconds to wait before transmitting the data in the UART receive buffer. The default setting for this register is 0x10 (~16ms delay).

If the timer reaches zero before the next byte is received from the UART, the module begins transmitting the data in the buffer. This timeout value should be greater than one byte time at the current UART baud rate with a minimum of 0x02. It should not be set any value less than one byte time as unpredictable results could occur.

If the timeout value is set to 0x00, the transmit wait timeout is deactivated. In this case, the transceiver waits until a number of bytes equal to the UART Byte Count Trigger (BCTRIG) have been received by the UART. All of the bytes are sent once the trigger has been reached. Figure 50 shows examples of the commands. Figure 51 shows the minimum timeout values based on baud rate.

| HumPRO™ Series Transmit Wait Timeout | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Read Command** | | | | **Read Response** | | | |
| Header | Size | Escape | Address | ACK | Address | Value | |
| 0xFF | 0x02 | 0xFE | 0x50 0x05 | 0x06 | 0x50 0x05 | V | |
| **Write Command** | | | | | | | |
| Header | Size | Address | Value | | | | |
| 0xFF | 0x02 | 0x50 0x05 | V | | | | |

Figure 50: HumPRO™ Series Transmit Wait Timeout Command and Response

| HumPRO™ Series Minimum DATATO Values | |
|---|---|
| **Baud Rate** | **Minimum DATATO** |
| 9,600 | 3ms |
| 19,200 | 2ms |
| 38,400 | 2ms |
| 57,600 | 2ms |
| 115,200 | 2ms |

Figure 51: HumPRO™ Series Transmit Wait Timeout Minimum Values

## ENCRC - CRC Enable
**Volatile Address = 0x53; Non-Volatile Address = 0x08**

The protocol includes a Cyclic Redundancy Check (CRC) on the received unencrypted packets to make sure that there are no errors. Encrypted packets use a key-based error detection method. Any packets with errors are discarded and not output on the UART. This feature can be disabled if it is desired to perform error checking outside the module. Set the ENCRC register to 0x01 to enable CRC checking, or 0x00 to disable it. The default CRC mode setting is enabled. Figure 54 shows examples of the commands and Figure 55 shows the available values.

| HumPRO™ Series CRC Enable | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Read Command** | | | | **Read Response** | | | |
| Header | Size | Escape | Address | ACK | Address | Value | |
| 0xFF | 0x02 | 0xFE | 0x53 0x08 | 0x06 | 0x53 0x08 | V | |
| **Write Command** | | | | | | | |
| Header | Size | Address | Value | | | | |
| 0xFF | 0x02 | 0x53 0x08 | V | | | | |

Figure 54: HumPRO™ Series CRC Enable Command and Response

| HumPRO™ Series CRC Enable Register Settings | |
|---|---|
| **V** | **Mode** |
| 0x00 | CRC Disabled |
| 0x01 | CRC Enabled |

Figure 55: HumPRO™ Series CRC Enable Register Settings

Although disabling CRC checking allows receiving packets with errors in the payload, errors in the header can still prevent packets from being output by the module.

## SHOWVER - Show Version
### Non-Volatile Address = 0x0A

Setting the SHOWVER register to 0x00 suppresses the start-up message, including firmware version, which is sent out of the UART when the module is reset. A value of 0x01 causes the message to be output after reset. By default, the module start-up message is output. Figure 57 shows examples of the commands and Figure 58 shows the available values.

| HumPRO™ Series Show Version | | | | | HumPRO™ Series Show Version | | | |
|---|---|---|---|---|---|---|---|---|
| **Read Command** | | | | | **Read Response** | | | |
| Header | Size | Escape | Address | | ACK | Address | Value | |
| 0xFF | 0x02 | 0xFE | 0x0A | | 0x06 | 0x0A | V | |
| **Write Command** | | | | | | | | |
| Header | Size | Address | Value | | | | | |
| 0xFF | 0x02 | 0x0A | V | | | | | |

Figure 57: HumPRO™ Series Show Version Command and Response

| HumPRO™ Series Show Version Register Settings | |
|---|---|
| **V** | **Meaning** |
| 0x00 | Startup message is NOT output on reset or power-up. |
| 0x01 | Startup message is output on reset or power-up. This is a blocking operation, and any incoming UART data is lost during the transmission of this message through the CMD_DATA_OUT line. All UART commands must be sent after this message has completed. |

Figure 58: HumPRO™ Series Show Version Register Settings

Example:

HUM-868-PRO v2.3.4
(C) 2015 Linx Technologies Inc. All rights reserved.

## IDLE - Idle Mode
**Volatile Address = 0x58; Non-Volatile Address = 0x0D**

The value in the IDLE register sets the operating mode of the transceiver. If the module remains properly powered, and is awakened from a low power mode properly, the volatile registers retain their values. If the volatile registers become corrupted during low power, a software reset is forced and the module reboots.

Awake is the normal operating setting. This is the only setting in which the RF circuitry is able to receive and transmit RF messages.

Sleep disables all circuitry on-board the module. This is the lowest-power setting available for the module.

Please see the Low Power States section for more details. Figure 61 shows examples of the commands and Figure 62 shows the available values.

| HumPRO™ Series Idle Mode | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Read Command** | | | | **Read Response** | | | |
| Header | Size | Escape | Address | | ACK | Address | Value |
| 0xFF | 0x02 | 0xFE | 0x58 0x0D | | 0x06 | 0x58 0x0D | V |
| **Write Command** | | | | | | | |
| Header | Size | Address | Value | | | | |
| 0xFF | 0x02 | 0x58 0x0D | V | | | | |

Figure 61: HumPRO™ Series Idle Mode Command and Response

| HumPRO™ Series Idle Mode Register Settings | |
|---|---|
| **V** | **Mode** |
| 0x00 | Awake |
| 0x01 | Sleep |

Figure 62: HumPRO™ Series Idle Mode Register Settings

## UDESTID - User Destination Address
### Volatile Address = 0x5A-0x5D; Non-Volatile Address = 0x0F-0x12

These registers contain the address of the destination module when User Addressing mode or Extended User Addressing mode are enabled. User Addressing mode uses bytes 0 and 1 to determine the destination address. Extended User Addressing mode uses all four bytes. These registers are automatically filled with the source address from a received message if the received message address type matches the value in AUTOADDR. Please see the Addressing Modes section for more details. Each register byte is read and written separately. Figure 65 shows the User Destination ID registers.

| HumPRO™ Series User Destination Address Registers | | | |
|---|---|---|---|
| Name | Volatile Address | Non-Volatile Address | Description |
| UDESTID3 | 0x5A | 0x0F | MSB of the extended destination address |
| UDESTID2 | 0x5B | 0x10 | Byte 2 of the extended destination address |
| UDESTID1 | 0x5C | 0x11 | Byte 1 of the extended destination address, MSB of the short destination address |
| UDESTID0 | 0x5D | 0x12 | LSB of the extended destination address and short destination address |

Figure 65: HumPRO™ Series User Destination Address Registers

## UMASK - User ID Mask
**Volatile Address = 0x62-0x65; Non-Volatile Address = 0x17-0x1A**

These registers contain the user ID mask when User Addressing mode or Extended User Addressing mode are enabled. Please see the Addressing Modes section for more details. Each register byte is read and written separately.

Figure 67 shows the User ID Mask registers.

| Name | Volatile Address | Non-Volatile Address | Description |
|---|---|---|---|
| **HumPRO™ Series User ID Mask Registers** | | | |
| UMASK3 | 0x62 | 0x17 | MSB of the extended mask |
| UMASK2 | 0x63 | 0x18 | Byte 2 of the extended mask |
| UMASK1 | 0x64 | 0x19 | Byte 1 of the extended mask MSB of the short mask |
| UMASK0 | 0x65 | 0x1A | LSB of the extended mask and short mask |

Figure 67: HumPRO™ Series User ID Mask Registers

## DESTDSN - Destination Serial Number
**Volatile Address = 0x68-0x6B; Non-Volatile Address = 0x1D-0x20**

These registers contain the serial number of the destination module when DSN Addressing Mode is enabled. Please see the Addressing Modes section for more details. Each register byte is read and written separately.

Figure 68 shows the Destination DSN registers.

| Name | Volatile Address | Non-Volatile Address | Description |
|---|---|---|---|
| **HumPRO™ Series Destination DSN Registers** | | | |
| DESTDSN3 | 0x68 | 0x1D | MSB of the destination DSN |
| DESTDSN2 | 0x69 | 0x1E | Byte 2 of the destination DSN |
| DESTDSN1 | 0x6A | 0x1F | Byte 1 of the destination DSN |
| DESTDSN0 | 0x6B | 0x20 | LSB of the destination DSN |

Figure 68: HumPRO™ Series Destination DSN Registers

## CMDHOLD - C̅M̅D̅ Halts Traffic
**Volatile Address = 0x6E; Non-Volatile Address = 0x23**

A CMDHOLD register setting of 0x01 causes the module to store incoming RF traffic (up to the RF buffer size) while the C̅M̅D̅ line is low. When the C̅M̅D̅ line is returned high, the module outputs all buffered data. A register value of 0 allows received bytes to be output on the UART immediately with C̅R̅E̅S̅P̅ high to indicate that the bytes are received data. See Using the Command Response (C̅R̅E̅S̅P̅) Line section for details. This register setting is overridden when PKOPT:RXPKT=1.

Figure 71 shows examples of the commands and Figure 72 shows the available values.

| HumPRO™ Series C̅M̅D̅ Halts Traffic | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Read Command** | | | | **Read Response** | | | |
| Header | Size | Escape | Address | | ACK | Address | Value |
| 0xFF | 0x02 | 0xFE | 0x6E 0x23 | | 0x06 | 0x6E 0x23 | V |
| **Write Command** | | | | | | | |
| Header | Size | Address | Value | | | | |
| 0xFF | 0x02 | 0x6E 0x23 | V | | | | |

Figure 71: HumPRO™ Series Transceiver C̅M̅D̅ Halts Traffic Command and Response

| HumPRO™ Series C̅M̅D̅ Halts Traffic Register Settings | |
|---|---|
| **V** | **Mode** |
| 0x00 | Disable Halt (received data is sent to the UART immediately) |
| 0x01 | Enable Halt (received data is sent when the C̅M̅D̅ line is high) |

Figure 72: HumPRO™ Series C̅M̅D̅ Halts Traffic Register Settings

## AUTOADDR - Auto Addressing
### Volatile Address = 0x71; Non-Volatile Address = 0x26

When the AUTOADDR feature is enabled, the module reads the Source Address from a received packet and uses it to fill the Destination Address registers (UDESTID or DESTDSN, depending on the addressing mode of the received message). This ensures that a response is sent to the device that transmitted the original message. The response ADDMODE should be the same as ADDMODE used to send the original message.

The non-volatile register only uses the lower 4 bits to configure the automatic addressing. The upper 4 bits must be set to 0.

The volatile register is split in half with the lower 4 bits configuring the automatic addressing, the same as the non-volatile register. The upper 4 bits indicate the type of the last received packet satisfying the AUTOADDR mask.  These bits must be written as 0. This indication is the same as the Addressing Mode register setting. These bits are not used by the module and are only written by the module after successfully receiving a packet.

As an example, if AUTOADDR is set to 0x0F (Any Auto Address) and a DSN packet is received from another module, then AUTOADDR reads back as 0x4F. The lower 4 bits (0xF) indicate that the module is set to any auto address (0xF). The upper 4 bits (0x4) indicate that the packet that was just received was a DSN Addressing Mode packet.

Figure 75 summarizes the configuration values for the lower 4 bits of the register.

Figure 76 shows the Addressing Mode values that the module writes to the upper 4 bits after successfully receiving a packet.

## MYDSN - Local Device Serial Number
### Non-Volatile Address = 0x34-0x37

These registers contain the factory-programmed read-only Device Serial Number. This address is unique for each module and is included in all packet types as a unique origination address.

Figure 77 shows the Device Serial Number registers.

| HumPRO™ Series DSN Registers | | |
|---|---|---|
| Name | Non-Volatile Address | Description |
| MYDSN3 | 0x34 | MSB of the serial number |
| MYDSN2 | 0x35 | Byte 2 of the serial number |
| MYDSN1 | 0x36 | Byte 1 of the serial number |
| MYDSN0 | 0x37 | LSB of the serial number |

Figure 77: HumPRO™ Series DSN Registers

## CUSTID - Customer ID
### Non-Volatile Address = 0x39-0x3A

These registers contain the factory-programmed customer ID. A unique value is assigned to a specific customer and that value is programmed into that customer's modules. The unencrypted User and Extended User Addressing modes use these bytes as part of the addressing. The unique value ensures that the custom modules will not communicate with any other systems. Contact Linx for details. Figure 78 shows the Customer ID registers.

| HumPRO™ Series Customer ID Registers | | |
|---|---|---|
| Name | Non-Volatile Address | Description |
| CUSTID1 | 0x39 | MSB of the customer ID |
| CUSTID0 | 0x3A | LSB of the customer ID |

Figure 78: HumPRO™ Series Transceiver Customer ID Registers

## RELEASE - Release Number
### Non-Volatile Address = 0x78

This register contains a number designating the firmware series and hardware platform. Figure 80 shows examples of the commands and Figure 81 lists current releases to date.

| HumPRO™ Series Release Number | | | | | | | |
|---|---|---|---|---|---|---|---|
| Read Command | | | | | Read Response | | |
| Header | Size | Escape | Address | | ACK | Address | Value |
| 0xFF | 0x02 | 0xFE | 0x78 | | 0x06 | 0x78 | V |

Figure 80: HumPRO™ Series Transceiver Release Number Command and Response

| HumPRO™ Series Release Number Register Settings | |
|---|---|
| V | Release Number |
| 0x20 | HUM-900-PRO |
| 0x22 | HUM-868-PRO |

Figure 81: HumPRO™ Series Transceiver Release Number Register Settings

A more detailed firmware version is available for versions 0x20 and above in the FWVER register.

## PRSSI - Last Good Packet RSSI
### Volatile Address = 0x7B

This register holds the received signal strength in dBm of the last successfully received packet. A successful packet reception is one that causes payload data to be output on the UART interface. The value in this register is overwritten each time a new packet is successfully processed. The register value is an 8-bit signed integer representing the RSSI in dBm. It is accurate to ±3dB.

| HumPRO™ Series Last Good Packet RSSI | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Read Command** | | | | **Read Response** | | | |
| Header | Size | Escape | Address | | ACK | Address | Value |
| 0xFF | 0x02 | 0xFE | 0x7B | | 0x06 | 0x7B | V |

Figure 84: HumPRO™ Series Transceiver Last Good Packet RSSI Command and Response

## ARSSI - Ambient RSSI
### Volatile Address = 0x7C

This register returns the ambient receive signal strength on the current channel in dBm. The signal strength is measured as soon as the command is received. The register value is an 8-bit signed integer representing the RSSI in dBm. It is accurate to ±3dB at the high RF data rate, and +3 to -20 dB at the low RF data rate. The channel being read may be any of the channels in the selected hopping sequence.

| HumPRO™ Series Ambient RSSI | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Read Command** | | | | **Read Response** | | | |
| Header | Size | Escape | Address | | ACK | Address | Value |
| 0xFF | 0x02 | 0xFE | 0x7C | | 0x06 | 0x7C | V |

Figure 85: HumPRO™ Series Transceiver Ambient RSSI Command and Response

## NVCYCLE - Non-Volatile Refresh Cycles
## Non-Volatile Address = 0xC4-0xC5

These read-only non-volatile registers contain the number of lifetime refresh cycles performed for the non-volatile memory. The minimum lifetime refreshes is 2,000 refresh cycles. Beyond this the refreshes may not be complete and the module's operation can become unpredictable.

| HumPRO™ Series Non-Volatile Refresh Cycles Registers | | |
|---|---|---|
| Name | Non-Volatile Address | Description |
| NVCYCLE1 | 0xC4 | MSB of the number of refresh cycles |
| NVCYCLE0 | 0xC5 | LSB of the number of refresh cycles |

Figure 87: HumPRO™ Series Non-Volatile Refresh Cycles Registers

Between 8 and 150 non-volatile write operations can be made before a refresh cycle is necessary. Writing the registers from lowest to highest address maximizes the number of write operations per refresh cycle.

It is recommended to write the desired default values to non-volatile memory and use the volatile registers for values that change frequently.

These registers show the total number of refresh cycles that have occurred. This gives an indication of the remaining life expectancy of the memory. Figure 87 shows the Non-Volatile Refresh Cycles registers.

## CMD - Command Register
### Volatile Address = 0xC7

This volatile write-only register is used to issue special commands.

| HumPRO™ Series Command Register | | | | |
|---|---|---|---|---|
| **Write Command** | | | | |
| Header | Size | Escape | Address | Value |
| 0xFF | 0x03 | 0xFE | 0x47 | V |

Figure 90: HumPRO™ Series Transceiver Command Register Command and Response

Value V is chosen from among the options in Figure 91.

| HumPRO™ Series CMD Values | |
|---|---|
| **CMD Value** | **Operation** |
| 0x01 | SENDP – Send Packet |
| 0x02 | GETPH – Get Packet Header |
| 0x03 | GETPD – Get Packet Data |
| 0x04 | GETPHD – Get Packet Header and Data |
| 0x05 | CLRRXP – Clear Received Packet |
| 0x06 | CLROB – Clear Outbound Buffer |
| 0x07 | CLRIB – Clear Input Buffer |
| 0x10 | JOINCTL – Join Process Control |
| 0x11 | WRKEY – Write Key |
| 0x12 | CLRKEY – Clear Key |
| 0x13 | RLDKEY – Reload Key |
| 0x20 0xAA 0xBB | NVRESET – Reset non-volatile registers to factory default |

Figure 91: HumPRO™ Series Command Register Values

The **Send Packet** command starts data transmission. Operation differs depending on whether option TXPKT is set in the PKTOPT register.

- TXPKT = 0; this command operates the same as a data timeout with DATATO. All waiting data, up to the maximum allowed in the remaining channel time, is transmitted.

- TXPKT = 1; this command marks the end of an explicit packet in the outgoing buffer. All bytes in the packet are transmitted together. Following bytes are sent in the next packet. The max packet length is 192 bytes. Multiple packets can be queued with this command.

The **Join Process Control** command allows the software to initiate or stop the secure JOIN process. It has the following subcommands.

| HumPRO™ Series JOINCTL Subcommand Values | |
|---|---|
| **Subcommand Value** | **Operation** |
| 0 | Halt JOIN operation |
| 1 | Generate a random network key and address. This sets the module as the network administrator (SECOPT:KEYRCV=0) |
| 2 | Perform the JOIN operation with another module |

Figure 92: HumPRO™ Series JOINCTL Subcommand Values

These operations are equivalent to the push-button initiated operation. If a JOIN operation is started by the serial command (CMD:JOINCTL[2]), push-button operation is ignored until the JOIN operation finishes.

Register write operations are inhibited when a JOIN process is active except that a Halt JOIN command is never inhibited. A Halt JOIN operation completes before the ACK is sent.

When the JOIN operation is started the KEYRCV flag in the SECOPT register determines whether the module is an administrator or node and whether a key can be sent or changed. The JOIN process uses and modifies the non-volatile address registers. After a successful JOIN, the modified non-volatile registers are copied to the corresponding volatile registers.

The **Write Key** command writes a 16-byte AES key to the selected key register. As with most of the registers, the encryption key has both volatile and non-volatile registers. The volatile register is used during run time, but is lost on a power cycle or reset. When the module powers up, the volatile register is loaded from the non-volatile register. This makes the non-volatile register value the default on power-up.

The key value of all zero bytes is reserved as a "no key" indication.

| HumPRO™ Series Write Key Command | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Write Command** | | | | | | | | |
| Header | Size | Escape | Address | Value | KeyN | Key0 | ... | Key15 |
| 0xFF | Size | 0xFE | 0x47 | 0x11 | KeyN | Key0 | ... | Key15 |

Figure 93: HumPRO™ Series Transceiver Write Key Command

## SECSTAT - Security Status
### Volatile Address = 0xC9

This volatile read-only register provides status of the security features.

| HumPRO™ Series Security Status | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Read Command** | | | | | | **Read Response** | | |
| Header | Size | Escape | Escape | Address | | ACK | Address | Value |
| 0xFF | 0x03 | 0xFE | 0xFE | 0x49 | | 0x06 | 0xC9 | V |

Figure 95: HumPRO™ Series Transceiver Security Status Command and Response

The command returns a single byte. Figure 96 shows the meanings of the bits in the returned value byte.

| HumPRO™ Series Security Status Value | |
|---|---|
| **Bit** | **Status** |
| 0 | Reserved |
| 1 | 0 = No volatile key is set<br>1 = A volatile key is set |
| 2 | 0 = No non-volatile key is set<br>1 = A non-volatile key is set |
| 3 | Reserved |
| 4 | Reserved |
| 5 | Reserved |
| 6 | Reserved |
| 7 | Reserved |

Figure 96: HumPRO™ Series Security Status Values

## EEXFLAG - Extended Exception Flags ......................................................
## Volatile Address = 0xCD - 0xCF

These volatile registers contain flags for various events. Similar to the EXCEPT register, they provide a separate bit for each exception.

| HumPRO™ Series Extended Exception Flags Registers | | |
|---|---|---|
| Name | Volatile Address | Description |
| EEXFLAG2 | 0xCD | Byte 2 of the extended exception flags |
| EEXFLAG1 | 0xCE | Byte 1 of the extended exception flags |
| EEXFLAG0 | 0xCF | LSB of the extended exception flags |

Figure 99: HumPRO™ Series Transceiver Extended Exception Code Registers

When an exception occurs, the associated bit is set in this register. If the corresponding bit in the EEXMASK is set and EXMASK is zero, the EX status line is set. Reading an EEXFLAG register does not clear the register.

Writing to an EEXFLAG register causes the register to be set to the BIT_AND(current_value, new_value). This provides a way of clearing bits that have been serviced without clearing a bit that has been set since the flag register was read. This prevents a loss of notification of an exception.

Register bits can only be cleared, not set, from the write command though some flags are also cleared internally. Unless otherwise noted, exceptions are cleared by writing a zero to the corresponding register bit.

Flag **EX_TXDONE** is set when a data packet has been transmitted. If the packet was sent with acknowledgement enabled, this flag indicates that the acknowledgment has also been received.

Flag **EX_RXWAIT** is 1 when there are buffered incoming data bytes which have not been sent to the UART. It is cleared by reading or discarding all data bytes.

Flag **EX_UNENCRYPT** is 1 when a received packet is not encrypted. This can only occur when SECOPT:EN_UNC=1.

Flag **EX_SEQDEC** is 1 when a received encrypted packet has a smaller sequence number than the previously received packet. Possible causes are an attempt to replay a previous message by an attacker, receiving a message from a different transmitter or restarting the transmitter.

## PKTOPT - Packet Options
## Volatile Address = 0xD3; Non-Volatile Address = 0x83

This register selects options for transfering packet data.

| HumPRO™ Series Packet Options | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Read Command** | | | | | **Read Response** | | | |
| Header | Size | Escape | Escape | Address | ACK | Address | Value | |
| 0xFF | 0x03 | 0xFE | 0xFE | 0x53 0x03 | 0x06 | 0xD3 0x83 | V | |
| **Write Command** | | | | | | | | |
| Header | Size | Escape | Address | Value | | | | |
| 0xFF | 0x03 | 0xFE | 0x53 0x03 | V | | | | |

Figure 101: HumPRO™ Series Transceiver Packet Options Command and Response

Each bit in the register sets an option as shown in Figure 102.

| HumPRO™ Series Transceiver Packet Option Codes | | |
|---|---|---|
| Bit | Name | Description |
| 0 | TXPKT | Packet Transmit |
| 1 | TXnCMD | Transmit when nCMD Lowered |
| 2 | RXPKT | Packet Receive |
| 3 | RXP_CTS | Use CTS for RXPKT Transfer |
| 4 - 7 | Reserved | Reserved (must be 0) |

Figure 102: HumPRO™ Series Transceiver Packet Option Codes

The **TXPKT** option allows the module to transmit data in explicit packets.

- TXPKT = 0 (default); a packet transmission is enabled when the number of waiting bytes reaches BCTRIG bytes, the time since the last received byte exceeds DATATO ms, the number of waiting bytes exceeds the number that can be sent within the remaining slot time, or a Send Packet command is written to the CMD register.

- TXPKT = 1; all bytes written to the module are held until a SENDP command is written to the CMD register or the CMD line is lowered with TXnCMD = 1. The DATATO or BCTRIG conditions are ignored with this option. The transmitted packet consists of the bytes in the buffer at the time a packet is triggered, even if more data bytes are received before the packet can be sent.

## SECOPT - Security Options
### Volatile Address = 0xD4; Non-Volatile Address = 0x84

This register selects options for security features.

| HumPRO™ Series Security Options | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Read Command** | | | | | | **Read Response** | | |
| Header | Size | Escape | Escape | Address | | ACK | Address | Value |
| 0xFF | 0x03 | 0xFE | 0xFE | 0x54 0x04 | | 0x06 | 0xD4 0x84 | V |
| **Write Command** | | | | | | | | |
| Header | Size | Escape | Address | Value | | | | |
| 0xFF | 0x03 | 0xFE | 0x54 0x04 | V | | | | |

Figure 103: HumPRO™ Series Transceiver Packet Options Command and Response

Each bit in the register sets an option as shown in Figure 104. Unlike other registers, the non-volatile register (0x84) affects all Join operations. The EN_UNENC bit in the volatile register affects data packet reception.

| HumPRO™ Series Transceiver Security Option Codes | | |
|---|---|---|
| Bit | Name | Description |
| 0 | PB_RESET | Permit factory reset from PB input sequence |
| 1 | PSHARE | Permit key sharing |
| 2 | PGKEY | Permit clearing key and changing key |
| 3 | CHGADDR | Permit changing an address |
| 4 | KEYRCV | 1: Receive key and address during JOIN operation (node) 0: Send key and address during JOIN operation (admin) |
| 5 | EN_UNENC | Enable receiving unencrypted packets |
| 6 | Reserved | Reserved (must be 1) |
| 7 | EN_CHANGE | Enable changes to security options |

Figure 104: HumPRO™ Series Transceiver Security Option Codes

When PB_RESET is 1 the Factory Reset function is enabled from the PB input. This allows a user to reset the module configurations back to the factory defaults with 4 short presses and a 3 second hold of a button connected to the PB input.

When PSHARE is 1 the Share Network Key function is enabled during the JOIN process. This allows an administrator to share the encryption key it created. When 0, a JOIN process sends the network address, but no key.

## EEXMASK - Extended Exception Mask
## Volatile Address = 0xD0-0xD2; Non-Volatile Address = 0x80-0x82

These registers contain a mask for the events in EEXFLAG, using the same offset and bit number.

| HumPRO™ Series Extended Exception Mask Registers | | | |
|------|------|------|------|
| Name | Volatile Address | Non-Volatile Address | Description |
| EEXMASK2 | 0xD0 | 0x80 | Byte 2 of the extended exception mask |
| EEXMASK1 | 0xD1 | 0x81 | Byte 1 of the extended exception mask |
| EEXMASK0 | 0xD2 | 0x82 | LSB of the extended exception mask |

Figure 105: HumPRO™ Series Transceiver Extended Exception Mask Registers

To use this value, register EXMASK must be zero. If EXMASK is non-zero, this register has no effect on the EX line.

When an exception bit is set in EEXFLAG, the corresponding EEXMASK bit is set, and EXMASK is zero, the EX status line is set, otherwise the EX line is reset. Mask bits for unassigned flags should be zero for future compatibility.

## LASTNETAD - Last Network Address Assigned
## Non-Volatile Address = 0x8C-0x8F

These bytes contain the last address assigned using the JOIN process. When a new unit joins the network, it is assigned the next address and this value is incremented in the administrator. It is initially set to the administrator address when a network key is generated.

| HumPRO™ Series Extended Exception Mask Registers | | |
|------|------|------|
| Name | Non-Volatile Address | Description |
| LASTNETAD3 | 0x8C | MSB of the last network address assigned |
| LASTNETAD2 | 0x8D | Byte 2 of the last network address assigned |
| LASTNETAD1 | 0x8E | Byte 1 of the last network address assigned |
| LASTNETAD0 | 0x8F | LSB of the last network address assigned |

Figure 106: HumPRO™ Series Transceiver Extended Exception Mask Registers

## Power Supply Requirements

The module does not have an internal voltage regulator, therefore it requires a clean, well-regulated power source. The power supply noise should be less than 20mV. Power supply noise can significantly affect the module's performance, so providing a clean power supply for the module should be a high priority during design.
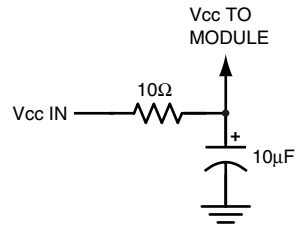
Figure 108: Supply Filter

A 10Ω resistor in series with the supply followed by a 10μF tantalum capacitor from $V_{cc}$ to ground helps in cases where the quality of supply power is poor (Figure 108). This filter should be placed close to the module's supply lines. These values may need to be adjusted depending on the noise present on the supply line.

## Antenna Considerations

The choice of antennas is a critical and often overlooked design consideration. The range, performance and legality of an RF link are critically dependent upon the antenna. While adequate antenna performance can often be obtained by trial and error methods, antenna design and matching is a complex

Figure 109: Linx Antennas

task. Professionally designed antennas such as those from Linx (Figure 109) help ensure maximum performance and FCC and other regulatory compliance.

Linx transmitter modules typically have an output power that is higher than the legal limits. This allows the designer to use an inefficient antenna such as a loop trace or helical to meet size, cost or cosmetic requirements and still achieve full legal output power for maximum range. If an efficient antenna is used, then some attenuation of the output power will likely be needed.

It is usually best to utilize a basic quarter-wave whip until your prototype product is operating satisfactorily. Other antennas can then be evaluated based on the cost, size and cosmetic requirements of the product. Additional details are in Application Note AN-00500.

## Pad Layout

The pad layout diagrams below are designed to facilitate both hand and automated assembly. Figure 110 shows the footprint for the smaller version and Figure 111 shows the footprint for the encapsulated version.
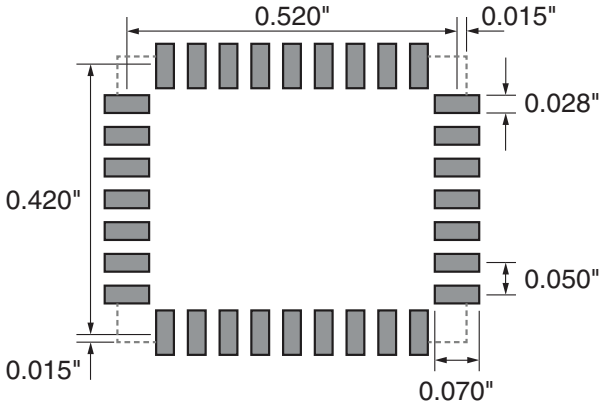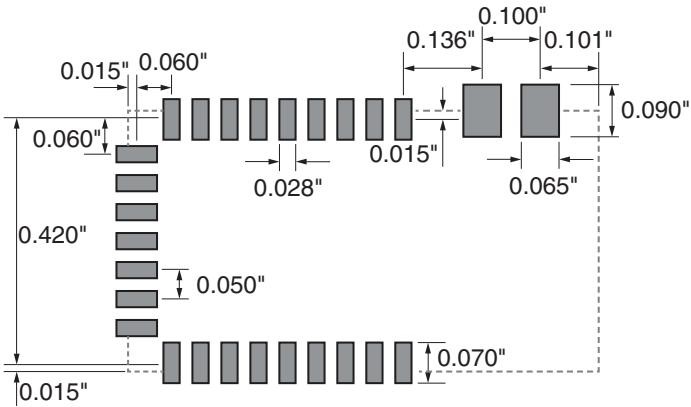
Figure 110: HUM-***-PRO Recommended PCB Layout

Figure 111: HUM-***-PRO-UFL/CAS Recommended PCB Layout

## Board Layout Guidelines

The module's design makes integration straightforward; however, it is still critical to exercise care in PCB layout. Failure to observe good layout techniques can result in a significant degradation of the module's performance. A primary layout goal is to maintain a characteristic 50-ohm impedance throughout the path from the antenna to the module. Grounding, filtering, decoupling, routing and PCB stack-up are also important considerations for any RF design. The following section provides some basic design guidelines.

During prototyping, the module should be soldered to a properly laid-out circuit board. The use of prototyping or "perf" boards results in poor performance and is strongly discouraged. Likewise, the use of sockets can have a negative impact on the performance of the module and is discouraged.

The module should, as much as reasonably possible, be isolated from other components on your PCB, especially high-frequency circuitry such as crystal oscillators, switching power supplies, and high-speed bus lines.

When possible, separate RF and digital circuits into different PCB regions.

Make sure internal wiring is routed away from the module and antenna and is secured to prevent displacement.

Do not route PCB traces directly under the module. There should not be any copper or traces under the module on the same layer as the module, just bare PCB. The underside of the module has traces and vias that could short or couple to traces on the product's circuit board.

The Pad Layout section shows a typical PCB footprint for the module. A ground plane (as large and uninterrupted as possible) should be placed on a lower layer of your PC board opposite the module. This plane is essential for creating a low impedance return for ground and consistent stripline performance.

Use care in routing the RF trace between the module and the antenna or connector. Keep the trace as short as possible. Do not pass it under the module or any other component. Do not route the antenna trace on multiple PCB layers as vias add inductance. Vias are acceptable for tying together ground layers and component grounds and should be used in multiples.

## Production Guidelines

The module is housed in a hybrid SMD package that supports hand and automated assembly techniques. Since the modules contain discrete components internally, the assembly procedures are critical to ensuring the reliable function of the modules. The following procedures should be reviewed with and practiced by all assembly personnel.

## Hand Assembly

Pads located on the bottom of the module are the primary mounting surface (Figure 115). Since these pads are inaccessible during mounting, castellations that run up the side of the module have been provided to facilitate solder wicking to the module's underside. This allows for very
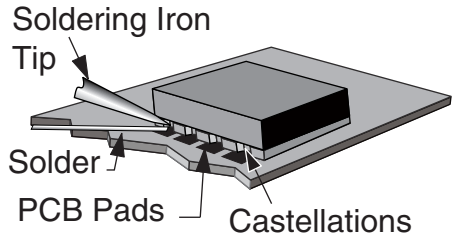


Figure 115: Soldering Technique

quick hand soldering for prototyping and small volume production. If the recommended pad guidelines have been followed, the pads will protrude slightly past the edge of the module. Use a fine soldering tip to heat the board pad and the castellation, then introduce solder to the pad at the module's edge. The solder will wick underneath the module, providing reliable attachment. Tack one module corner first and then work around the device, taking care not to exceed the times in Figure 116.

> **Warning:** Pay attention to the absolute maximum solder times.
>
> | Absolute Maximum Solder Times |
> | --- |
> | Hand Solder Temperature: +427ºC for 10 seconds for lead-free alloys |
> | Reflow Oven: +255ºC max (see Figure 117) |

Figure 116: Absolute Maximum Solder Times

## Automated Assembly

For high-volume assembly, the modules are generally auto-placed. The modules have been designed to maintain compatibility with reflow processing techniques; however, due to their hybrid nature, certain aspects of the assembly process are far more critical than for other component types. Following are brief discussions of the three primary areas where caution must be observed.

## General Antenna Rules

The following general rules should help in maximizing antenna performance.

1. Proximity to objects such as a user's hand, body or metal objects will cause an antenna to detune. For this reason, the antenna shaft and tip should be positioned as far away from such objects as possible.

2. Optimum performance is obtained from a ¼- or ½-wave straight whip mounted at a right angle to the ground plane (Figure 118). In many cases, this isn't desirable for practical or ergonomic reasons, thus, an alternative antenna style such as a helical, loop or patch may be utilized and the corresponding sacrifice in performance accepted.
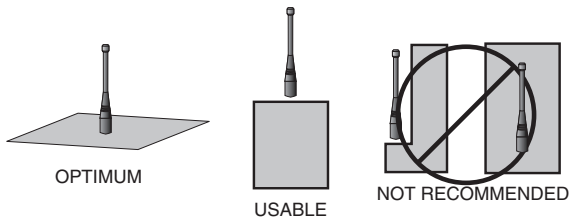


Figure 118: Ground Plane Orientation

3. If an internal antenna is to be used, keep it away from other metal components, particularly large items like transformers, batteries, PCB tracks and ground planes. In many cases, the space around the antenna is as important as the antenna itself. Objects in close proximity to the antenna can cause direct detuning, while those farther away will alter the antenna's symmetry.

4. In many antenna designs, particularly ¼-wave whips, the ground plane acts as a counterpoise, forming, in essence, a ½-wave dipole (Figure 119). For this reason, adequate ground plane area is essential. The ground plane can be a metal case or ground-fill areas on a circuit board. Ideally, it should have a surface area less than or equal to the overall length of the ¼-wave radiating element. This is often not practical due to size and configuration constraints. In these instances, a designer must make the best use of the area available to create as much ground
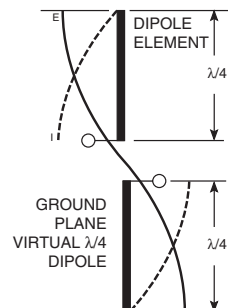


Figure 119: Dipole Antenna

# Common Antenna Styles

There are hundreds of antenna styles and variations that can be employed with Linx RF modules. Following is a brief discussion of the styles most commonly utilized. Additional antenna information can be found in Linx Application Notes AN-00100, AN-00140, AN-00500 and AN-00501. Linx antennas and connectors offer outstanding performance at a low price.

## Whip Style

A whip style antenna (Figure 121) provides outstanding overall performance and stability. A low-cost whip can be easily fabricated from a wire or rod, but most designers opt for the consistent performance and cosmetic appeal of a professionally-made model. To meet this need, Linx offers a wide variety of straight and reduced height whip style antennas in permanent and connectorized mounting styles.



Figure 121: Whip Style Antennas

The wavelength of the operational frequency determines an antenna's overall length. Since a full wavelength is often quite long, a partial ½- or ¼-wave antenna is normally employed. Its size and natural radiation resistance make it well matched to Linx modules. The proper length for a straight ¼-wave can be easily determined using the formula in Figure 122. It is also possible to reduce the overall height of the antenna by using a helical winding. This reduces the antenna's bandwidth but is a great way to minimize the antenna's physical size for compact applications. This also means that the physical appearance is not always an indicator of the antenna's frequency.

$$L = \frac{234}{F_{MHz}}$$

Figure 122:
L = length in feet of quarter-wave length
F = operating frequency in megahertz

## Specialty Styles

Linx offers a wide variety of specialized antenna styles (Figure 123). Many of these styles utilize helical elements to reduce the overall antenna size while maintaining reasonable performance. A helical antenna's bandwidth is often quite narrow and the antenna can detune in proximity to other objects, so care must be exercised in layout and placement.



Figure 123: Specialty Style Antennas

## Regulatory Considerations

Note: Linx RF modules are designed as component devices that require external components to function. The purchaser understands that additional approvals may be required prior to the sale or operation of the device, and agrees to utilize the component in keeping with all laws governing its use in the country of operation.

When working with RF, a clear distinction must be made between what is technically possible and what is legally acceptable in the country where operation is intended. Many manufacturers have avoided incorporating RF into their products as a result of uncertainty and even fear of the approval and certification process. Here at Linx, our desire is not only to expedite the design process, but also to assist you in achieving a clear idea of what is involved in obtaining the necessary approvals to legally market a completed product.

For information about regulatory approval, read AN-00142 on the Linx website or call Linx. Linx designs products with worldwide regulatory approval in mind.

In the United States, the approval process is actually quite straightforward. The regulations governing RF devices and the enforcement of them are the responsibility of the Federal Communications Commission (FCC). The regulations are contained in Title 47 of the United States Code of Federal Regulations (CFR). Title 47 is made up of numerous volumes; however, all regulations applicable to this module are contained in Volume 0-19. It is strongly recommended that a copy be obtained from the FCC's website, the Government Printing Office in Washington or from your local government bookstore. Excerpts of applicable sections are included with Linx evaluation kits or may be obtained from the Linx Technologies website, www.linxtechnologies.com. In brief, these rules require that any device that intentionally radiates RF energy be approved, that is, tested for compliance and issued a unique identification number. This is a relatively painless process. Final compliance testing is performed by one of the many independent testing laboratories across the country. Many labs can also provide other certifications that the product may require at the same time, such as UL, CLASS A / B, etc. Once the completed product has passed, an ID number is issued that is to be clearly placed on each product manufactured.

Linx Technologies

159 Ort Lane

Merlin, OR, US 97532

Phone: +1 541 471 6256

Fax: +1 541 471 6251

www.linxtechnologies.com

## Disclaimer

Linx Technologies is continually striving to improve the quality and function of its products. For this reason, we reserve the right to make changes to our products without notice. The information contained in this Data Guide is believed to be accurate as of the time of publication. Specifications are based on representative lot samples. Values may vary from lot-to-lot and are not guaranteed. "Typical" parameters can and do vary over lots and application. Linx Technologies makes no guarantee, warranty, or representation regarding the suitability of any product for use in any specific application. It is the customer's responsibility to verify the suitability of the part for the intended application. NO LINX PRODUCT IS INTENDED FOR USE IN ANY APPLICATION WHERE THE SAFETY OF LIFE OR PROPERTY IS AT RISK.

Linx Technologies DISCLAIMS ALL WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. IN NO EVENT SHALL LINX TECHNOLOGIES BE LIABLE FOR ANY OF CUSTOMER'S INCIDENTAL OR CONSEQUENTIAL DAMAGES ARISING IN ANY WAY FROM ANY DEFECTIVE OR NON-CONFORMING PRODUCTS OR FOR ANY OTHER BREACH OF CONTRACT BY LINX TECHNOLOGIES. The limitations on Linx Technologies' liability are applicable to any and all claims or theories of recovery asserted by Customer, including, without limitation, breach of contract, breach of warranty, strict liability, or negligence. Customer assumes all liability (including, without limitation, liability for injury to person or property, economic loss, or business interruption) for all claims, including claims from third parties, arising from the use of the Products. The Customer will indemnify, defend, protect, and hold harmless Linx Technologies and its officers, employees, subsidiaries, affiliates, distributors, and representatives from and against all claims, damages, actions, suits, proceedings, demands, assessments, adjustments, costs, and expenses incurred by Linx Technologies as a result of or arising from any Products sold by Linx Technologies to Customer. Under no conditions will Linx Technologies be responsible for losses arising from the use or failure of the device in any application, other than the repair, replacement, or refund limited to the original product purchase price. Devices described in this publication may contain proprietary, patented, or copyrighted techniques, components, or materials. Under no circumstances shall any user be conveyed any license or right to the use or ownership of such items.

# X-ON Electronics

Largest Supplier of Electrical and Electronic Components

*Click to view similar products for* Sub-GHz Modules *category:*

*Click to view products by* Linx Technologies *manufacturer:*

Other Similar products are found below :

HMC-C024  nRF24L01P-MODULE-SMA  CMD-KEY2-418-CRE  V640-A90  SM1231E868  HMC-C582  SM-MN-00-HF-RC  HMC-C031  LoRa Node Kit(US)  Sierra HL7588 4G KIT(US)  WISE-4610-S672NA  EC21AUFA-MINIPCIE  EC21EUGA-MINIPCIE  CS-EASYSWITCH-25  EC21JFB-MINIPCIE  E28-2G4M27S  DL-RFM95-915M  DL-RFM96-433M  Ra-07H-V1.1  Ra-07  Ra-01SH  Ra-01S-T  Ra-01SH-T  CMD-HHCP-418-MD  CMD-HHCP-433-MD  CMD-HHLR-418-MD  2095000000200  XB9X-DMRS-031  20911051101  COM-13909  HMC-C033  COM-13910  WRL-14498  SX1276RF1KAS  HMC-C004  HMC-C011  HMC-C014  HMC-C010  HMC-C050  HMC-C001  HMC-C006  HMC-C029  HMC-C030  HMC-C019  HMC-C021  HMC-C041  HMC-C042  HMC-C048  HMC-C051  HMC-C071