Linx

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

Amplified HumPRO™ Series
900MHz Transceiver Module
Data Guide

Wireless made simple®

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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-A-900-PRO-CAS	Amplified HumPRO™ Series High Power Data Transceiver with Castellation Connection
HUM-A-900-PRO-UFL	Amplified HumPRO™ Series High Power Data Transceiver with U.FL Connector
EVM-A-900-PRO-CAS	Amplified HumPRO™ Series Carrier Board, Castellation Connection with an edge-mount RP-SMA connector
EVM-A-900-PRO-UFL	Amplified HumPRO™ Series Carrier Board, U.FL Connector
MDEV-A-900-PRO	Amplified 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		+5		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.

Amplified HumPRO™ Series Transceiver Specifications							
Parameter	Symbol	Min.	Typ.	Max.	Units	Notes
Receiver Section						
Saturation (max input level)						
@ 19.2kbps RF rate			−21		dBm	
@ 153.6kbps RF rate			−23		dBm	
IF Frequency			304.7		kHz	
Receiver Sensitivity						5
@ 19.2kbps RF rate			−108		dBm	5
@ 153.6kbps RF rate			−101		dBm	5
RSSI Dynamic Range						
@ 19.2kbps RF rate			85		dB	
@ 153.6kbps RF rate			80		dB	
Transmitter Section						
Max Output Power						
@ 19.2kbps RF rate	P_O		+25		dBm	6
@ 153.6kbps RF rate	P_O		+22		dBm	6
Minimum Output Power	P_O		−9		dBm	6
2nd Harmonic Emissions	P_H			−20	dBc	6
3rd Harmonic Emissions	P_H			-54	dBuV/m	6,15
Antenna Port						
RF Impedance	R_{IN}		50		Ω	4
Environmental						
Operating Temp. Range		−40		+85	°C	4
Timing						
Module Turn-On Time						
Via V_{CC}		87		138	ms	4
Via POWER_DOWN			6		ms	4
Via Standby			6		ms	4
Serial Command Response						
Volatile R/W			0.4	5	ms	8
NV Update			2.4	31.5	ms	8
Factory Reset		204		329	ms	14
Channel Dwell Time				400	ms	
CMD low to trigger TX with option TXnCMD	t_{TXnCMD}	2			ms	13

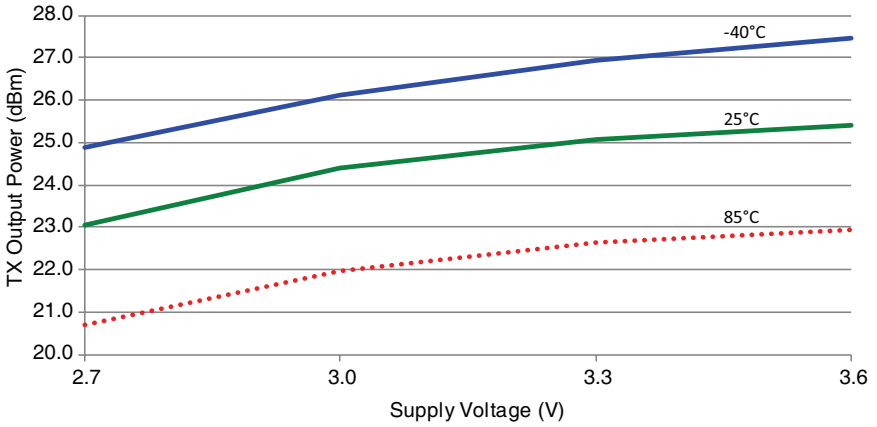## Typical Performance Graphs

Figure 5: Amplified HumPRO™ Series Transceiver Max Output Power vs. Supply Voltage

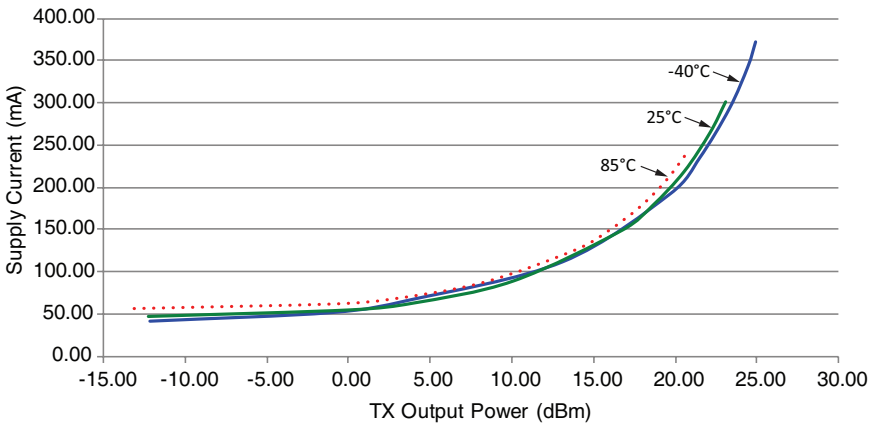Figure 6: Amplified HumPRO™ Series Transceiver Average Current vs. Transmitter Output Power at 2.7V
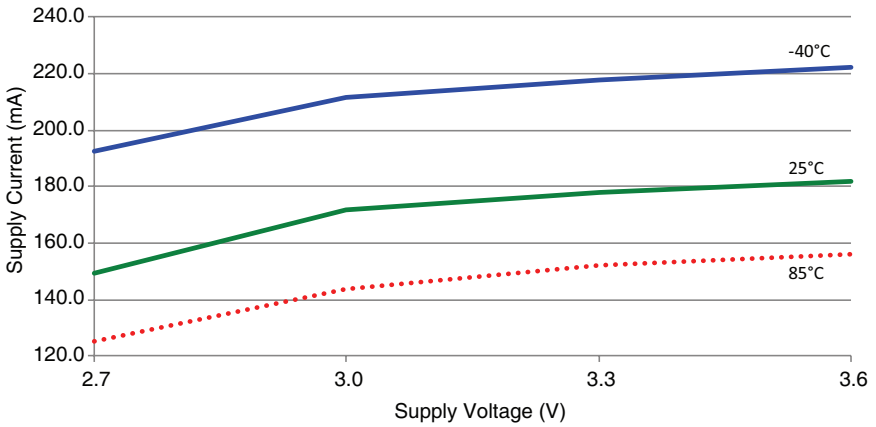
Figure 10: Amplified HumPRO™ Series Transceiver TX Current vs. Supply Voltage at 20dBm
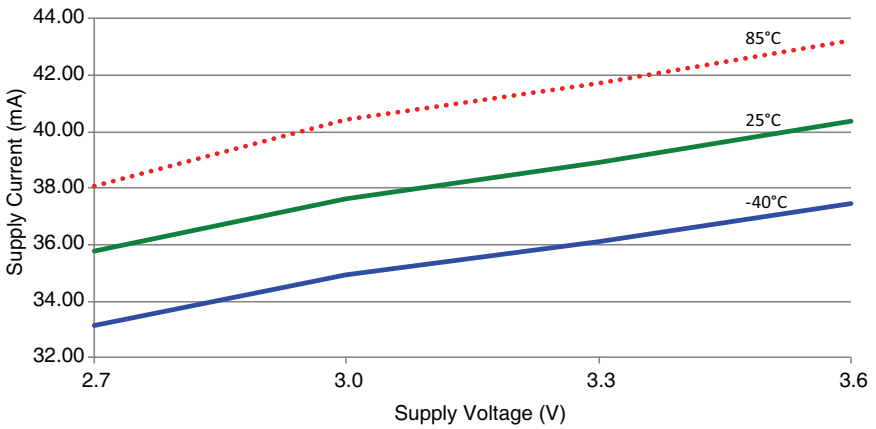

Figure 11: Amplified HumPRO™ Series Transceiver RX Scan Current vs. Supply Voltage, 115.2kbps

Current consumption while the module is scanning for a transmission. The current is approximately 0.3mA higher when receiving data at 115.2kbps.

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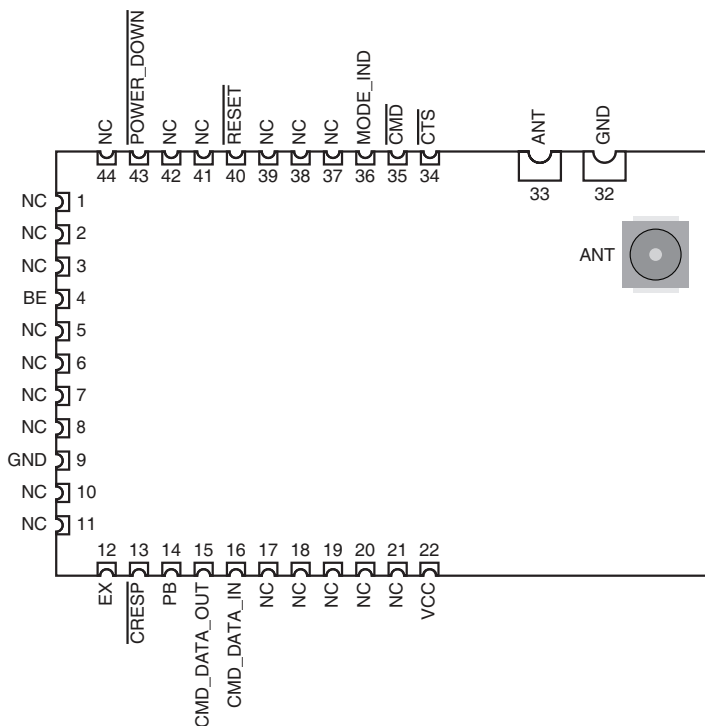
Figure 14: Amplified HumPRO™ Series Transceiver Pin Assignments (Top View)

Pin Descriptions

Pin Descriptions			
Pin Number	Name	I/O	Description
1, 2, 3, 5, 6, 7, 8, 10, 11, 17-21, 37, 38, 39, 41, 42, 44	NC	—	No Electrical Connection. Do not connect any traces to these lines.
4	BE	O	Buffer Empty. This line is high when the UART input buffer is empty, indicating that all data has been transmitted. If acknowledgment is active, it also indicates that the receiving module has acknowledged the data or a retry exception has occurred.
9, 32	GND	—	Ground
12	EX	O	Exception Output. A mask can be set to take this line high when an exception occurs. The line is lowered when the exception register is read (EXCEPT).

Module Pin Assignments

The module has two versions that differ in the antenna connection. The antenna connection is routed to either a castellation (-CAS) or a u.FL connector (-UFL), depending on the part number ordered.

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

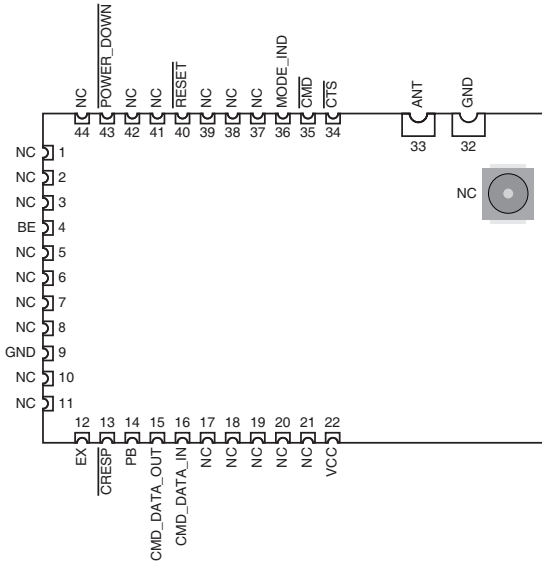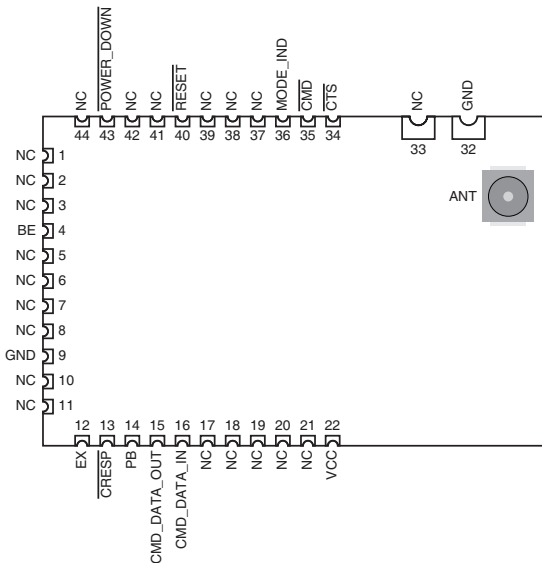Figure 17: Amplified HumPRO™ Series Transceiver Pre-certified Version Pin Assignments - UFL Connection (Top View)

Theory of Operation

The Amplified HumPRO™ Series transceiver is a low-cost, high-performance synthesized FSK transceiver. Figure 19 shows the module's block diagram.
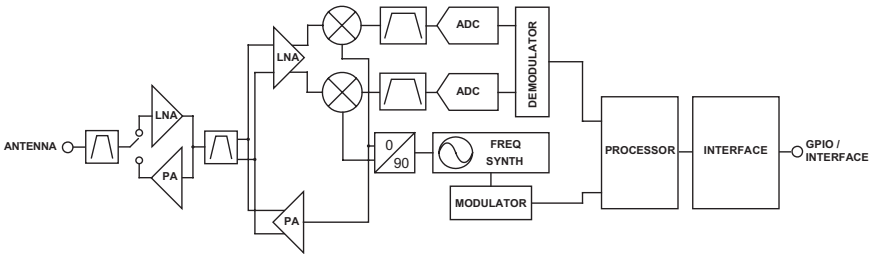
Figure 19: Amplified HumPRO™ Series Transceiver RF Section Block Diagram

The Amplified HumPRO™ Series transceiver operates in the 902 to 928MHz 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. An additional front-end power amplifier boosts the transmitter power for maximum range. The received RF signal is amplified by an initial low noise amplifier (LNA) then fed into the main receiver. It is further amplified 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 Amplified 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 $\overline{\text{CMD}}$ 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 $\overline{\text{CMD}}$ 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.

All three addressing modes can be configured to be compatible with the older 250 Series modules. The default operation has an additional level of masking on the receiving module that helps prevent interference from adjacent networks.

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

Amplified 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 20: Amplified HumPRO™ Series Transceiver Address Register Use

Frequency Hopping Spread Spectrum

The module uses Frequency Hopping Spread Spectrum to allow operation at higher power levels per regulations and to reduce interference with other transmitters. The module is configured for operation in one of 6 different hopping sequences. Each sequence uses 26 channels for the high RF data rate or 50 channels for the low RF data rate. Modules must use the same hopping sequence to communicate. Assigning different hopping sequences to multiple networks in the same area minimizes the interference.

When the module is awake and not transmitting, it rapidly scans all channels for a packet preamble. When a module starts transmitting at the beginning of a new channel, it transmits a packet with a long preamble of alternating 0 and 1 bits. This long preamble is sufficient to allow receiving modules to scan through all of the channels in the hopping sequence and find it. Modules that are scanning detect the preamble and pause on that channel, waiting for a valid packet.

If a packet is received with a valid CRC (unencrypted) or authentication (encrypted), the header is examined to determine whether the module should synchronize to the transmitter. Synchronization requires that the hop sequence matches and that the message is addressed to the receiver.

When synchronized, the receiver stays on the current channel to either transmit a packet or to receive an additional packet. Additional packets transmitted on the same channel within the time slot use short preambles since the receivers are already listening to the current channel.

At the end of the time slot for the current channel, all modules which locked to the original transmission switch to the next channel in the hop sequence. The first transmission on each new channel has a long preamble.

A receiver that has synchronized to a transmitter continues to stay in synchronism by staying on the received channel until the expiration of the time slot, then waiting on the next hop channel for the duration of the time slot. If no further packets are received, the receiver loses lock and reverts to scanning. This allows the receiver to stay synchronized for a short while if a packet is not received correctly.

The module supports the option to send the long preamble with every packet rather than just the first packet on each channel. This can be beneficial for systems that have modules asleep most of the time. It gives

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 Amplified HumPRO™ Series 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.
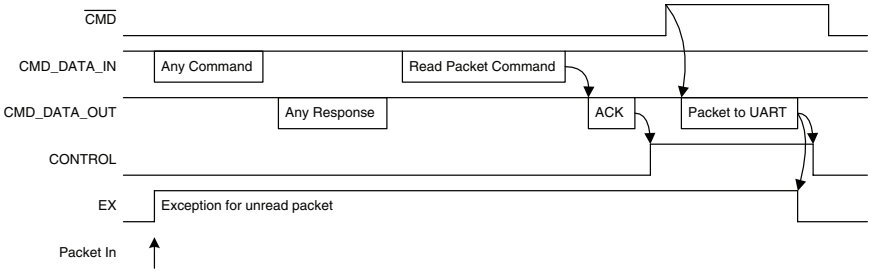
Figure 21: HumPRO-A™ Series Transceiver Received Packet Transfer Cycle

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 $\overline{CMD}$ 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 22.

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 23.

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 24. The header and data blocks returned by the module are the decrypted message contents.

Encrypted DSN Address Packet Header

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

Encrypted User Address Packet Header

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

Encrypted Packet Data

Tag 0x12	Data Length 1	Data Data Length Bytes

Figure 24: HumPRO-A™ 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 25.

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

Figure 25: Amplified 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 Amplified HumPRO™ Series 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 26 lists the exception codes and their meanings.

Amplified 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 26: Amplified HumPRO™ Series Transceiver Exception Codes

Carrier Sense Multiple Access (CSMA)

CSMA is an optional feature. It is a best-effort delivery system that listens to the channel before transmitting a message. If CSMA is enabled and the module detects another transmitter on the same channel, it waits until the active transmitter finishes before sending its payload. This helps to eliminate RF message corruption and make channel use more efficient.

When a module has data ready to transmit and CSMA is enabled, it listens on the intended transmit channel for activity. If no signal is detected, transmission is started.

If a carrier is detected with an RSSI above the CSMA threshold in the CRSSI register, transmission is inhibited. If a signal below the threshold is detected that has a compatible preamble or packet structure, transmission is also inhibited.

If the module is synchronized from a recent packet transfer, it waits for a random interval, then checks again for activity. If the detected carrier lasts longer than the time allowed for the current channel, the module hops to the next channel in the hop sequence and again waits for a clear channel before transmitting.

If the module is not synchronized, it hops to the next channel and again checks for interference. When no activity is detected it starts transmitting.

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 29 shows this timing.
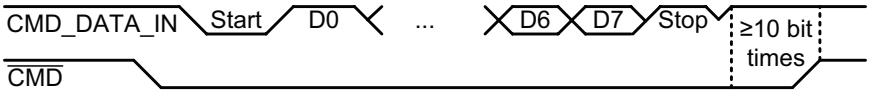
Figure 29: Amplified HumPRO™ Series Transceiver $\overline{\text{CMD}}$ Line Timing

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.

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 30 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 30 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 31 shows the different blink patterns and their meanings.

Display [on/off time in seconds]	Module Status
Amplified HumPRO™ Series MODE_IND Line Timing	
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 31: Amplified 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 1µA. 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 34.

A rising transition on the PB, $\overline{POWER\_DOWN}$ 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 1µs.

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 Amplified 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 36.

Amplified 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 36: Amplified 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 16,000 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.

Amplified 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	0x09	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	0x01	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 38 shows the command and response.

Amplified 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 38: Amplified 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 39 shows the command and response.

Amplified 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 39: Amplified HumPRO™ Series Channel Hop Table Command and Response

Figure 40 shows the RF channels used by the Amplified HumPRO™ Series. When the baud rate is set to 9,600 or 19,200 bps, the module uses 50

HumPRO™ Series Hop Sequences by Channel Number, 19,200bps and below					
0	1	2	3	4	5
25	30	11	58	52	35
63	60	12	11	10	23
28	59	0	52	54	41
26	14	62	37	62	45
16	16	23	36	21	7
61	32	43	42	33	42
4	4	25	25	44	63
29	47	34	15	51	24
0	26	61	1	61	9
44	43	26	55	36	27
46	1	24	2	34	10
22	25	6	12	2	17
36	36	31	26	57	20
34	15	7	27	50	22
24	57	32	41	12	18
2	10	55	9	29	32
21	48	39	8	6	3
11	21	1	31	8	8
27	8	41	49	46	15
1	17	29	13	48	4
35	37	15	47	11	0
37	45	57	14	39	48
55	44	3	33	4	13
8	13	42	48	45	61
10	33	47	38	22	31
54	0	2	45	56	56
13	46	56	59	18	52
32	62	33	3	43	54
43	34	9	46	60	55
12	7	14	0	31	62
23	24	30	39	47	6
48	22	21	57	0	37
14	58	4	56	20	36
39	42	54	5	37	38
40	50	59	40	59	51
15	12	51	23	35	59
57	20	22	62	7	5
18	39	38	24	15	43
60	27	58	54	25	21
41	2	60	17	16	40
9	35	52	22	23	14
49	5	45	32	42	12
58	28	37	7	24	30
38	49	13	61	32	16
45	29	35	34	28	34
56	18	36	63	26	46
50	38	8	50	13	60
42	3	46	30	3	39
62	52	40	43	5	58
47	40	49	28	49	33

Figure 41: Amplified HumPRO™ Series Hop Sequences for UART rate of 19,200bps and below

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

The value in the TXPWR register sets the module's output power. Figure 43 shows the command and response and Figure 44 available power settings and typical power outputs for the module. The default setting is 0x09.

Amplified HumPRO™ Series Transmitter Output Power Mode

Read Command

Header	Size	Escape	Address
0xFF	0x02	0xFE	0x4D 0x02

Read Response

ACK	Address	Value
0x06	0x4D 0x02	PWR

Write Command

Header	Size	Address	Value
0xFF	0x02	0x4D 0x02	PWR

Figure 43: Amplified HumPRO™ Series Transmitter Output Power Mode Command and Response

Amplified HumPRO™ Series Transmitter Output Power Mode Register Settings

PWR	Typical Output Power 19.2kbps RF Rate (dBm)	Typical Output Power 153.6kbps RF Rate (dBm)
0x00	-9.2	-9.2
0x01	-9.2	-9.2
0x02	3.2	3.2
0x03	7.0	7.0
0x04	12.7	12.7
0x05	18.5	18.5
0x06	20.3	20.3
0x07	22.4	22.4
0x08	24.0	22.4
0x09	25.0	22.4
0x0A	25.0	22.4

Figure 44: Amplified HumPRO™ Series Transmitter Output Power Mode Settings

Note: The maximum transmitter output power allowed by regulations is 24dBm (TXPWR = 0x07) if the UART rate is set to 38,400bps or higher (UARTBAUD = 0x03 or higher). All power levels are allowed if the UART rate is 19,200bps or less (UARTBAUD = 0x01 or 0x02). The module automatically restricts the max power based on the UARTBAUD value.

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

Amplified HumPRO™ Series Addressing Mode

Read Command

Header	Size	Escape	Address
0xFF	0x02	0xFE	0x4F 0x04

Read Response

ACK	Address	Value
0x06	0x4F 0x04	V

Write Command

Header	Size	Address	Value
0xFF	0x02	0x4F 0x04	V

Figure 47: Amplified 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 49 shows examples of the commands. Figure 50 shows the minimum timeout values based on baud rate.

Amplified 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 49: Amplified HumPRO™ Series Transmit Wait Timeout Command and Response

Amplified 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 50: Amplified 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 53 shows examples of the commands and Figure 54 shows the available values.

Amplified HumPRO™ Series CRC Enable

Read Command

Header	Size	Escape	Address
0xFF	0x02	0xFE	0x53 0x08

Read Response

ACK	Address	Value
0x06	0x53 0x08	V

Write Command

Header	Size	Address	Value
0xFF	0x02	0x53 0x08	V

Figure 53: Amplified HumPRO™ Series CRC Enable Command and Response

Amplified HumPRO™ Series CRC Enable Register Settings

V	Mode
0x00	CRC Disabled
0x01	CRC Enabled

Figure 54: Amplified 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 56 shows examples of the commands and Figure 57 shows the available values.

Amplified 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 56: Amplified HumPRO™ Series Show Version Command and Response

Amplified 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 57: Amplified HumPRO™ Series Show Version Register Settings

Example:

HUM-900-PRO v1.2.3
(C) 2014 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 60 shows examples of the commands and Figure 61 shows the available values.

Amplified 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 60: Amplified HumPRO™ Series Idle Mode Command and Response

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

Figure 61: Amplified 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 64 shows the User Destination ID
registers.

Amplified 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 64: Amplified 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 66 shows the User ID Mask registers.

Name	Volatile Address	Non-Volatile Address	Description
Amplified 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 66: Amplified 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 67 shows the Destination DSN registers.

Name	Volatile Address	Non-Volatile Address	Description
Amplified 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 67: Amplified HumPRO™ Series Destination DSN Registers

CMDHOLD - $\overline{\text{CMD}}$ 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 $\overline{\text{CMD}}$ line is low. When the $\overline{\text{CMD}}$ 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 $\overline{\text{CRESP}}$ high to indicate that the bytes are received data. See Using the Command Response ($\overline{\text{CRESP}}$) Line section for details. This register setting is overridden when PKOPT:RXPKT=1.

Figure 70 shows examples of the commands and Figure 71 shows the available values.

Amplified HumPRO™ Series $\overline{\text{CMD}}$ 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 70: Amplified HumPRO™ Series Transceiver $\overline{\text{CMD}}$ Halts Traffic Command and Response

Amplified HumPRO™ Series $\overline{\text{CMD}}$ 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 $\overline{\text{CMD}}$ line is high)

Figure 71: Amplified HumPRO™ Series $\overline{\text{CMD}}$ 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 74 summarizes the configuration values for the lower 4 bits of the register.

Figure 75 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 76 shows the Device Serial Number registers.

Amplified 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 76: Amplified 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 77 shows the Customer ID registers.

Amplified 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 77: Amplified 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 79 shows examples of the commands and Figure 80 lists current releases to date.

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

Figure 79: Amplified HumPRO™ Series Transceiver Release Number Command and Response

Amplified HumPRO™ Series Release Number Register Settings	
V	**Release Number**
0x20	HUM-900-PRO
0x22	HUM-868-PRO
0x26	HUM-A-900-PRO

Figure 80: Amplified 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 at 25ºC.

Amplified 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 83: Amplified 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 at 25ºC. The channel being read may be any of the channels in the selected hopping sequence.

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

Figure 84: Amplified 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.

Amplified 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 86: Amplified 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 86 shows the Non-Volatile Refresh Cycles registers.

CMD - Command Register
Volatile Address = 0xC7

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

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

Figure 89: Amplified HumPRO™ Series Transceiver Command Register Command and Response

Value V is chosen from among the options in Figure 90.

Amplified 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 90: Amplified 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.

Amplified 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 91: Amplified 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.

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

Figure 92: Amplified HumPRO™ Series Transceiver Write Key Command

SECSTAT - Security Status
Volatile Address = 0xC9

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

Amplified 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 94: Amplified HumPRO™ Series Transceiver Security Status Command and Response

The command returns a single byte. Figure 95 shows the meanings of the bits in the returned value byte.

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

Figure 95: Amplified 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.

Name	Volatile Address	Description
Amplified HumPRO™ Series Extended Exception Flags Registers		
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 98: Amplified 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 transferring packet data.

Amplified 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 100: Amplified HumPRO™ Series Transceiver Packet Options Command and Response

Each bit in the register sets an option as shown in Figure 101.

Amplified 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 101: Amplified 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.

Amplified 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 102: Amplified HumPRO™ Series Transceiver Packet Options Command and Response

Each bit in the register sets an option as shown in Figure 103. Unlike other registers, the non-volatile register (0x84) affects all Join operations. The EN_UNENC bit in the volatile register affects data packet reception.

Amplified 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 103: Amplified 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.

Amplified 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	Byte 0 of the extended exception mask

Figure 104: Amplified 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.

Amplified 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 105: Amplified HumPRO™ Series Transceiver Extended Exception Mask Registers

Usage Guidelines for FCC Compliance

The pre-certified versions of the HumPRO-A™ Series module (HUM-A-900-PRO-UFL and HUM-A-900-PRO-CAS) are provided with an FCC and Industry Canada Modular Certification. This certification shows that the module meets the requirements of FCC Part 15 and Industry Canada license-exempt RSS standards for an intentional radiator. The integrator does not need to conduct any further intentional radiator testing under these rules provided that the following guidelines are met:

- An approved antenna must be directly coupled to the module's U.FL connector through an approved coaxial extension cable or to the module's castellation pad using an approved reference design and PCB layer stack.

- Alternate antennas can be used, but may require the integrator to perform certification testing.

- The module must not be modified in any way. Coupling of external circuitry must not bypass the provided connectors.

- End product must be externally labeled with "Contains FCC ID: OJM-HUMA-900 / IC: 5840A-HUMA900".

- The end product's user's manual must contain an FCC statement equivalent to that listed on page 97 of this data guide.

- The antenna used for this transceiver must not be co-located or operating in conjunction with any other antenna or transmitter.

- The integrator must not provide any information to the end-user on how to install or remove the module from the end-product.

Any changes or modifications not expressly approved by Linx Technologies could void the user's authority to operate the equipment.

Additional Testing Requirements

The HUM-A-900-PRO-UFL and HUM-A-900-PRO-CAS have been tested for compliance as an intentional radiator, but the integrator is required to perform unintentional radiator testing on the final product per FCC sections 15.107 and 15.109 and Industry Canada license-exempt RSS standards. Additional product-specific testing might be required. Please contact the FCC or Industry Canada regarding regulatory requirements for the application. Ultimately is it the integrator's responsibility to show that their product complies with the regulations applicable to their product.

Product Labeling

The end product containing the HUM-A-900-PRO-UFL or HUM-A-900-PRO-CAS must be labeled to meet the FCC and IC product label requirements. It must have the below or similar text:

Contains FCC ID: OJM-HUMA-900 / IC: 5840A-HUMA900

The label must be permanently affixed to the product and readily visible to the user. "Permanently affixed" means that the label is etched, engraved, stamped, silkscreened, indelibly printed, or otherwise permanently marked on a permanently attached part of the equipment or on a nameplate of metal, plastic, or other material fastened to the equipment by welding, riveting, or a permanent adhesive. The label must be designed to last the expected lifetime of the equipment in the environment in which the equipment may be operated and must not be readily detachable.

FCC RF Exposure Statement

To satisfy RF exposure requirements, this device and its antenna must operate with a separation distance of at least 20cm from all persons and must not be co-located or operating in conjunction with any other antenna or transmitter.

Antenna Selection

Under FCC and Industry Canada regulations, the HUM-A-900-PRO-UFL and HUM-A-900-PRO-CAS radio transmitters may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by the FCC and Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication.

The HUM-A-900-PRO-UFL and HUM-A-900-PRO-CAS radio transmitters have been approved by the FCC and Industry Canada to operate with the antenna types listed in Figure 107 with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

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

Power Supply Requirements

The transceiver incorporates a precision low-dropout regulator which allows operation over a wide input voltage range. Despite this regulator, it is still important to provide a supply that is free of noise. 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.

Consider the module's max supply current of 380mA when designing the power delivery network. Thin traces for the supply and ground connections may not be able to supply enough current and may degrade the module's performance.

Helpful Application Notes from Linx

It is not the intention of this manual to address in depth many of the issues that should be considered to ensure that the modules function correctly and deliver the maximum possible performance. We recommend reading the application notes listed in Figure 108 which address in depth key areas of RF design and application of Linx products. These applications notes are available online at www.linxtechnologies.com or by contacting the Linx literature department.

Helpful Application Note Titles	
Note Number	Note Title
AN-00100	RF 101: Information for the RF Challenged
AN-00126	Considerations for Operation Within the 902–928MHz Band
AN-00130	Modulation Techniques for Low-Cost RF Data Links
AN-00140	The FCC Road: Part 15 from Concept to Approval
AN-00500	Antennas: Design, Application, Performance
AN-00501	Understanding Antenna Specifications and Operation
RG-00105	HumPRO™ Series Addressing Mode Reference Guide
RG-00106	Basic Configurations for the HumPRO™ Series
RG-00107	The HumPRO™ Series Join Process
RG-00110	The Amplified HumPRO™ Series PCB Layout Guide

Figure 108: Helpful Application Note Titles

Pad Layout

The pad layout diagrams below are designed to facilitate both hand and automated assembly. Figure 109 shows the footprint for the module.
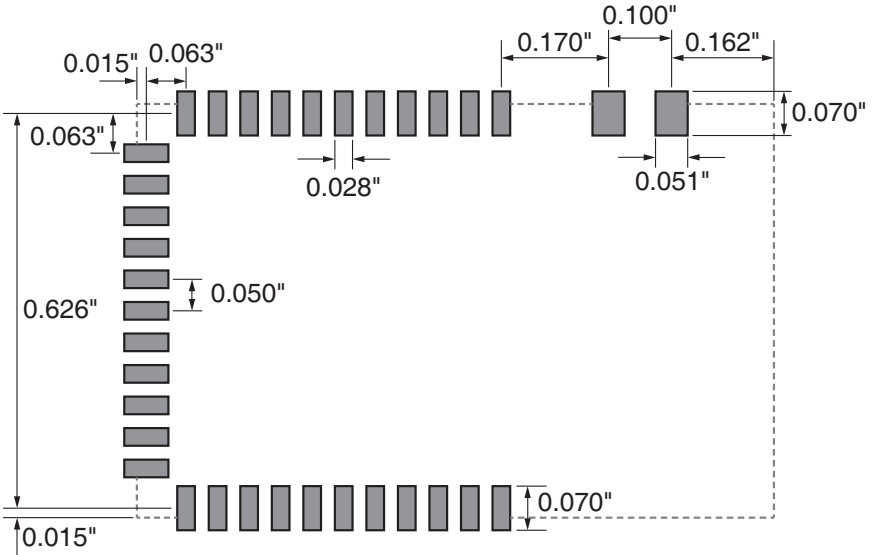

Figure 109: HUM-A-***-PRO-ttt Recommended PCB Layout

Castellation Version Reference Design

The castellation connection for the antenna on the module allows the use of embedded antennas as well as removes the cost of a cable assembly for the u.FL connector. However, **the PCB design and layer stack must follow specific reference designs for the certification on the HUM-A-900-PRO-CAS to be valid.** Please see RG-110, HUM-A-900-PRO PCB Trace Layout Reference Guide, for details on the PCB requirements

> **Note:** The PCB design and layer stack for the HUM-A-900-PRO-CAS must follow the reference design for the pre-certification to be valid.
>
> The HUM-900-PRO-CAS must use one of the antennas in Figure 107 in order for the certification to be valid.
>
> All modules require unintentional radiator compliance testing in the end product as it will go to market.

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 (generally the next layer down). 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 113). 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
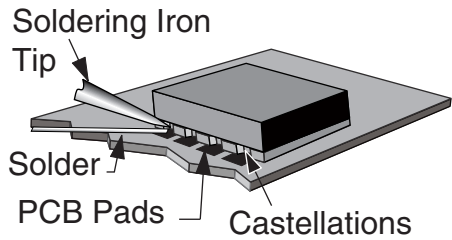
Figure 113: Soldering Technique

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 114.

> **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 115) |

Figure 114: 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 116). 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.

OPTIMUM

USABLE

NOT RECOMMENDED
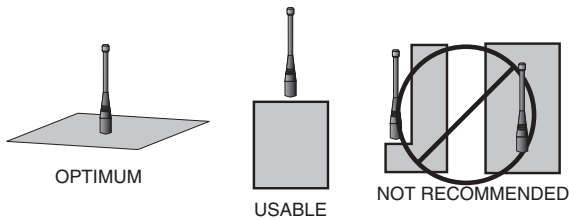
Figure 116: Ground Plane Orientation

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 117). 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

VERTICAL λ/4 GROUNDED ANTENNA (MARCONI)

DIPOLE ELEMENT

λ/4

GROUND PLANE VIRTUAL λ/4 DIPOLE
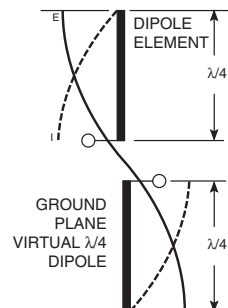
λ/4

Figure 117: 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 119) 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 119: 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 120. It is also possible to reduce the overall height of the antenna by

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

Figure 120:
L = length in feet of quarter-wave length
F = operating frequency in megahertz

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.

Specialty Styles

Linx offers a wide variety of specialized antenna styles (Figure 121). 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 121: 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.

Notes

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