Chipsmall Limited consists of a professional team with an average of over 10 year of expertise in the distribution of electronic components. Based in Hongkong, we have already established firm and mutual-benefit business relationships with customers from,Europe,America and south Asia,supplying obsolete and hard-to-find components to meet their specific needs.

With the principle of "Quality Parts,Customers Priority,Honest Operation,and Considerate Service",our business mainly focus on the distribution of electronic components. Line cards we deal with include Microchip,ALPS,ROHM,Xilinx,Pulse,ON,Everlight and Freescale. Main products comprise IC,Modules,Potentiometer,IC Socket,Relay,Connector.Our parts cover such applications as commercial,industrial, and automotives areas.

We are looking forward to setting up business relationship with you and hope to provide you with the best service and solution. Let us make a better world for our industry!

Contact us

Tel: +86-755-8981 8866 Fax: +86-755-8427 6832

Email & Skype: info@chipsmall.com Web: www.chipsmall.com

Address: A1208, Overseas Decoration Building, #122 Zhenhua RD., Futian, Shenzhen, China

TECHNOLOGIES

HumPRC™ Series 900MHz Remote Control Transceiver Module

Data Guide

Wireless made simple®

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

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

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

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

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

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

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

Table of Contents

HumPRC™ Series 900MHz Remote Control RF Transceiver Module

Data Guide

Description

Figure 1: Packages

The HumPRC™ Series is the most complete system to integrate bi-directional remote control into many different applications. No programming is required, and both module and finished hardware options are available, making it the easiest solution to implement.

The module provides long-range transmission at 900MHz utilizing frequency hopping and industry-standard encryption for secure and robust communications. The HumPRC™ Series interoperates with Linx's HumPRO™ family, making it the only remote control solution that simultaneously supports data applications for seamless integration with sensor and control IoT applications.

Eight status lines can be set up in any combination of inputs and outputs for the transfer of button or contact states. A selectable acknowledgement indicates that the transmission was successfully received.

Primary settings are hardware-selectable, which eliminates the need for an external microcontroller or other digital interface. For advanced features, optional software configuration is provided by a UART interface.

Housed in a compact reflow-compatible SMD package, the transceiver requires no external RF components except an antenna, which greatly simplifies integration and lowers development and assembly costs.

Features

- Add Bi-directional remote control capabilities to any product
- Pre-compiled software
- No programming required
- 128-bit AES encryption
- 8 status lines
- FHSS Algorithm
- Selectable acknowledgements
- FCC and IC Pre-certified versions
- Fully interoperable with all HumPRO™ Series devices & gateways

Revised 11/30/2017

Ordering Information

Ordering Information	
Part Number	**Description**
HUM-900-PRC	900MHz HumPRC™ Series Remote Control Transceiver, Castellation Interface, External Antenna Connection
HUM-900-PRC-CAS	900MHz HumPRC™ Series Remote Control Transceiver, Castellation Interface, External Antenna Connection, FCC & IC Certified
HUM-900-PRC-UFL	900MHz HumPRC™ Series Remote Control Transceiver, Castellation Interface, U.FL / MHF Compatible Connector, FCC & IC Certified
EVM-900-PRC-CAS	900MHz HumPRC™ Series Carrier Board, Through-Hole Pin Interface, RP-SMA Connector, FCC & IC Certified
EVM-900-PRC-UFL	900MHz HumPRC™ Series Carrier Board, Through-Hole Pin Interface, U.FL / MHF Compatible Connector, FCC & IC Certified
MDEV-900-PRC	900MHz HumPRC™ Series Master Development System

Figure 2: Ordering Information

Absolute Maximum Ratings

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

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

Figure 3: Absolute Maximum Ratings

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

Electrical Specifications

HumPRC™ Series Transceiver Specifications						
Parameter	**Symbol**	**Min.**	**Typ.**	**Max.**	**Units**	**Notes**
Power Supply						
Operating Voltage	V_{CC}	2.0		3.6	VDC	
TX Supply Current	I_{CCTX}					
900MHz at +10dBm			40.5	41.5	mA	1,2
900MHz at 0dBm			22	24	mA	1,2
RX Supply Current	I_{CCRX}		23.5	24.5	mA	1,2,3
Power-Down Current	I_{PDN}		0.7	1.4	µA	1,2
RF Section						
Operating Frequency Band	F_C	902		928	MHz	
Number of hop channels						
@ 19.2kbps RF Rate			50/64			
@ 152.34kbps RF Rate			26/32			
Channel spacing						
@ 19.2kbps RF Rate			375.9		kHz	
@ 152.34kbps RF Rate			751.81		kHz	
20 dB OBW						
@ 19.2kbps RF Rate			64		kHz	
@ 152.34kbps RF Rate			315		kHz	
Receiver BW						
@ 19.2kbps RF Rate			102		kHz	
@ 152.34kbps RF Rate			232		kHz	
FSK deviation						
@ 19.2kbps RF Rate			± 19.2		kHz	
@ 152.34kbps RF Rate			± 51		kHz	
Scan time / channel (avg)						
@ 19.2kbps RF Rate			1.2		ms	
@ 152.34kbps RF Rate			0.335		ms	
FHSS Lock time						
@ 19.2kbps RF Rate			63		ms	
@ 152.34kbps RF Rate			26		ms	
Modulation			2FSK			
Data Encoding			6/7 RLL			
Number of Hop Sequences			6			

HumPRC™ Series Transceiver Specifications						
Parameter	**Symbol**	**Min.**	**Typ.**	**Max.**	**Units**	**Notes**
Receiver Section						
Spurious Emissions				–47	dBm	
IF Frequency			304.7		kHz	
Receiver Sensitivity						5
@min rate		–98	–101		dBm	5
@max rate		–91	–94		dBm	5
RSSI Dynamic Range			85		dB	
CSMA RSSI Threshold			–70		dBm	
Transmitter Section						
Max Output Power	P_O	+8.5	+9.5		dBm	6
Harmonic Emissions	P_H		–41		dBc	6
Output Power Range		–5		9	dB	6
Antenna Port						
RF Impedance	R_{IN}		50		Ω	4
Environmental						
Operating Temp. Range		–40		+85	ºC	4
Timing						
Module Turn-On Time						
Via V_{CC}		63		173	ms	4
Via POWER_DOWN			35		ms	4
Via Standby			4		ms	4
Serial Command Response						
Volatile R/W			0.4	5	ms	8
NV Update			2.4	50	ms	8
Factory Reset		204		329	ms	13
Channel Dwell Time				400	ms	
Interface Section						
UART Data rate		9,600		115,200	bps	
Input						
Logic Low	V_{IL}			0.3*V_{CC}	VDC	
Logic High	V_{IH}	0.7*V_{CC}			VDC	

HumPRC™ Series Transceiver Specifications						
Parameter	**Symbol**	**Min.**	**Typ.**	**Max.**	**Units**	**Notes**
Output						
Logic Low, MODE_IND, ACK_OUT	V_{OLM}			0.3*V_{CC}	VDC	1,9
Logic High, MODE_IND, ACK_OUT	V_{OHM}	0.7*V_{CC}			VDC	1,9
Logic Low	V_{OL}			0.3*V_{CC}		1,10
Logic High	V_{OH}	0.7*V_{CC}				1,10
Flash (Non-Volatile) Memory Specifications						
Flash Refresh Cycles		2,000			cycles	11

1. Measured at 3.3V V_{CC}
2. Measured at 25ºC
3. Input power < -60dBm
4. Characterized but not tested
5. PER = 1%
6. Into a 50-ohm load
7. No RF interference
8. From end of command to start of response
9. 60mA source/sink
10. 6mA source/sink
11. Number of non-volatile memory refresh cycles. The number of write operations per refresh cycle varies from 8 to 150.
12. With CSMA disabled
13. Start of factory reset command to end of last ACK response

Figure 4: Electrical Specifications

Typical Performance Graphs

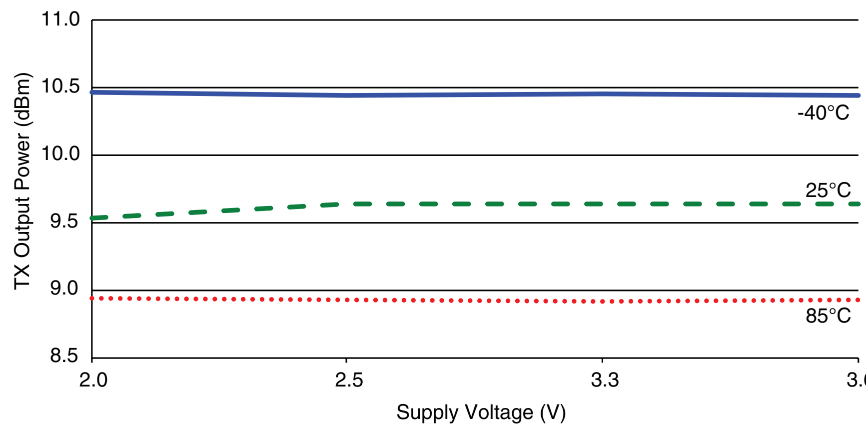

Figure 5: HumPRC™ Series Transceiver Max Output Power vs. Supply Voltage

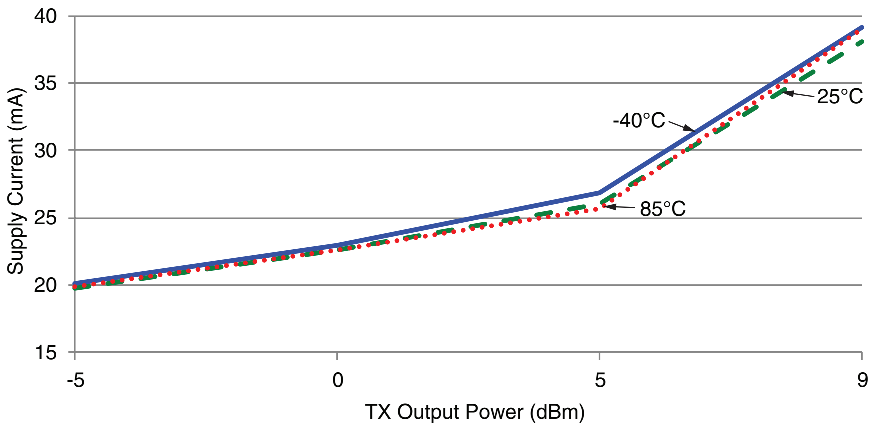

Figure 6: HumPRC™ Series Transceiver Average Current vs. Transmitter Output Power at 2.5V

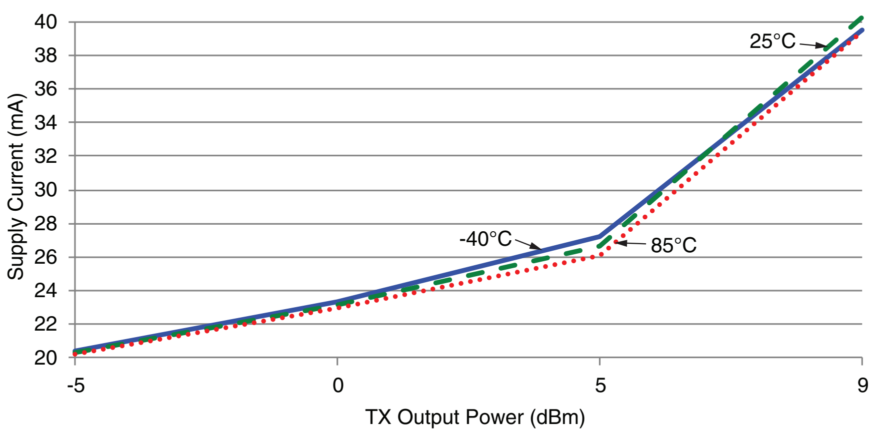

Figure 7: HumPRC™ Series Transceiver Average TX Current vs. Transmitter Output Power at 3.3V

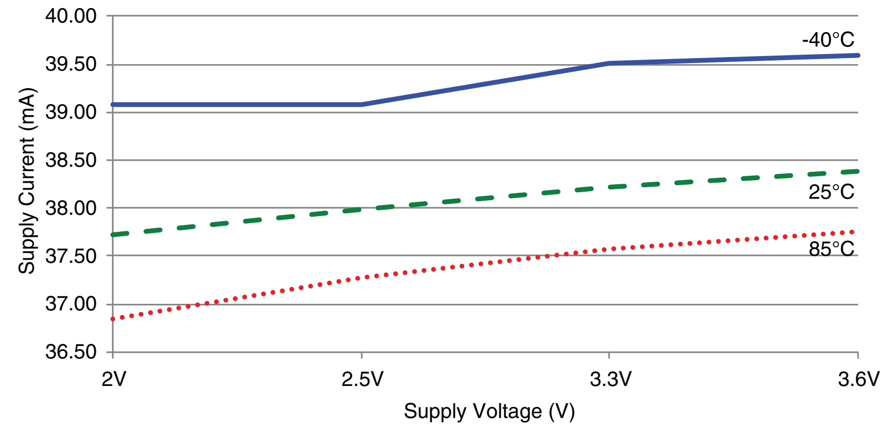

Figure 9: HumPRC™ Series Transceiver TX Current vs. Supply Voltage at Max Power

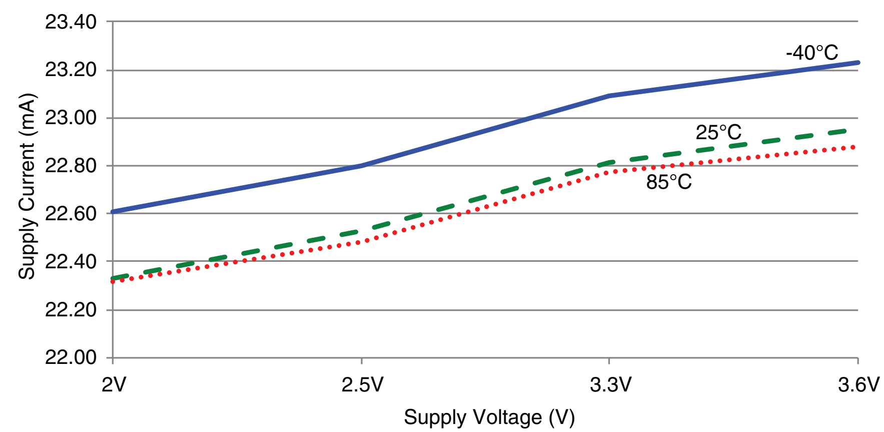

Figure 8: HumPRC™ Series Transceiver TX Current vs. Supply Voltage at 0dBm

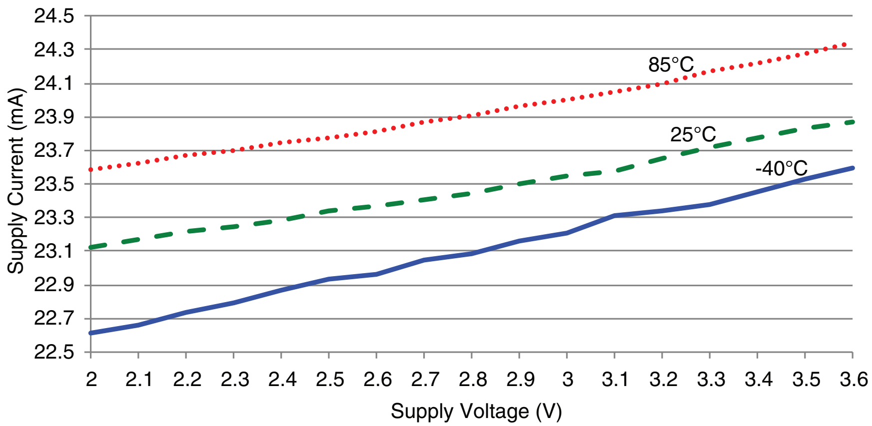

Figure 10: HumPRC™ Series Transceiver RX Scan Current vs. Supply Voltage, 9.6kbps

Current consumption while the module is scanning for a transmission. The current is approximately 0.5mA higher when receiving data at 9.6kbps.

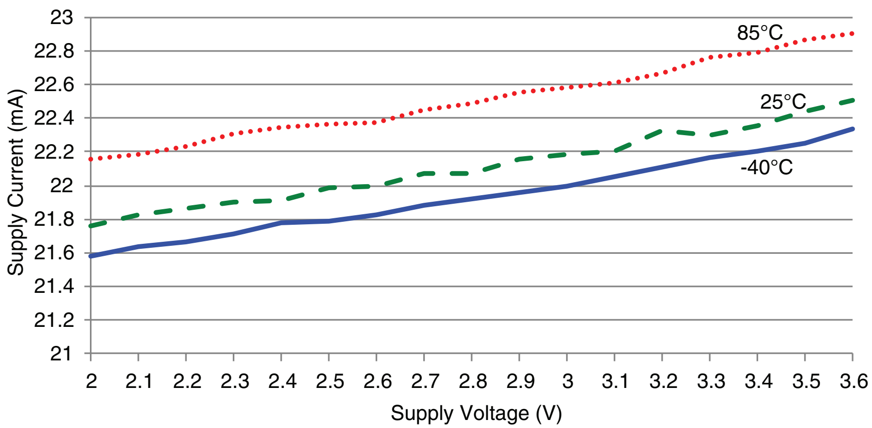

Figure 11: HumPRC™ Series Transceiver RX Scan Current vs. Supply Voltage, 115.2kbps

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

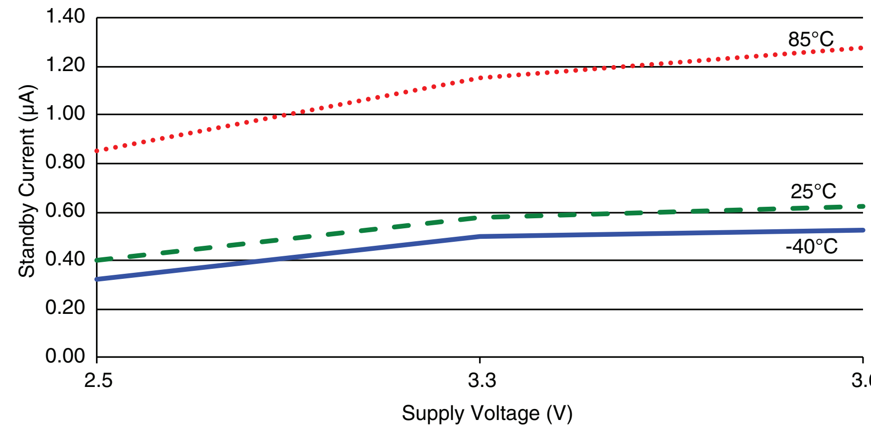

Figure 12: HumPRC™ Series Transceiver Standby Current Consumption vs. Supply Voltage

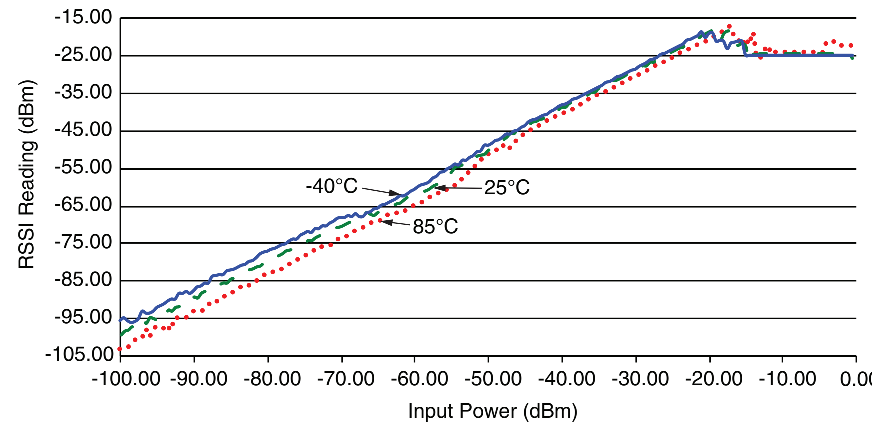

Figure 13: HumPRC™ Series Transceiver RSSI Voltage vs. Input Power

Pin Assignments

There are three version of the module. The standard version is the smallest. The other versions have mostly the same pin assignments, but the antenna is routed to either a castellation (-CAS) or a U.FL connector (-UFL), depending on the part number ordered.

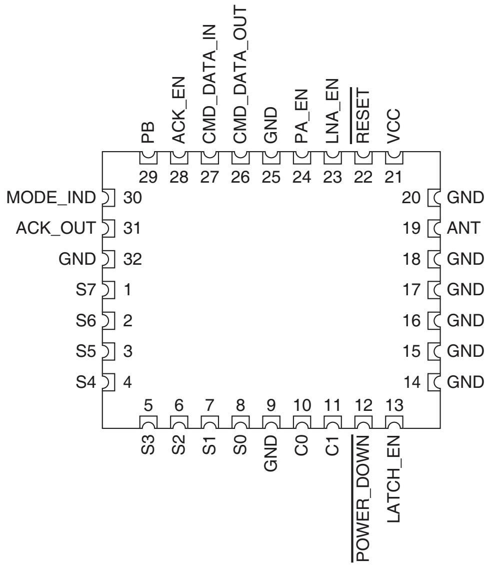

Figure 15: HumPRC™ Series Transceiver Standard Version Pin Assignments (Top View)

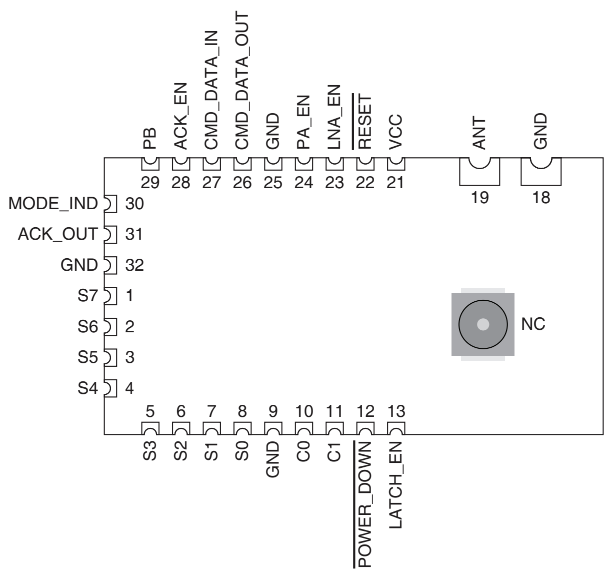

Figure 14: HumPRC™ Series Transceiver Pre-certified Version Pin Assignments - Castellation Connection (Top View)

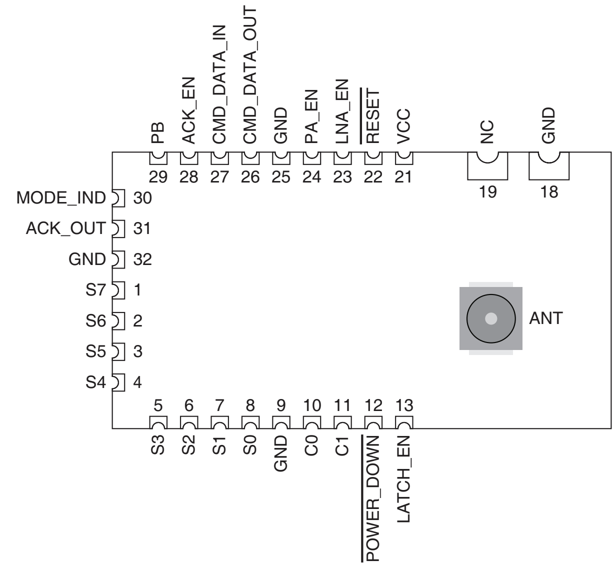

Figure 16: HumPRC™ Series Transceiver Pre-certified Version Pin Assignments - UFL Connection (Top View)

Pin Descriptions

Pin Descriptions			
Pin Number	**Name**	**I/O**	**Description**
1, 2, 3, 4, 5, 6, 7, 8	S0–S7[1]	I/O	Status Lines. Each line can be configured as either an input to register button or contact closures or as an output to control application circuitry.
9, 14, 15, 16, 17, 18, 20, 25, 32	GND	—	Ground
10	C0	I	This line sets the input/output direction for status lines S0-S3. When low, the lines are outputs; when high they are inputs. Do not leave floating.
11	C1	I	This line sets the input/output direction for status lines S4-S7. When low, the lines are outputs; when high they are inputs. Do not leave floating.
12	POWER_DOWN	I	Power Down. Pulling this line low places the module into a low-power state. The module is not functional in this state. Pull high for normal operation. Do not leave floating.

Pin Descriptions			
Pin Number	Name	I/O	Description
13	LATCH_EN	I	If this line is high, then the status line outputs are latched (a received command to activate a status line toggles the output state). If this line is low, then the output lines are momentary (active for as long as a valid signal is received). Do not leave floating.
19	ANTENNA	—	50-ohm RF Antenna Port
21	VCC	—	Supply Voltage
22	$\overline{\text{RESET}}$[2]	I	This line resets the module when pulled low. It should be pulled high for normal operation. Leave unconnected to minimize leakage current.
23	LNA_EN	0	Low Noise Amplifier Enable. This line is driven high when receiving. It is intended to activate an optional external LNA.
24	PA_EN	O	Power Amplifier Enable. This line is driven high when transmitting. It is intended to activate an optional external power amplifier.
26	CMD_DATA_OUT	O	Command Data Out. Output line for the serial interface commands
27	CMD_DATA_IN	I	Command Data In. Input line for the serial interface commands. If serial control is not used, this line should be tied to supply to minimize current consumption.
28	ACK_EN	I	Pull this line high to enable the module to send an acknowledgement message after a valid control message has been received. Do not leave floating.
29	PB[1]	I	A high on this line initiates the Join process, which causes two units to accept each other's transmissions. It is also used with a special sequence to reset the module to factory default configuration.
30	MODE_IND	O	This line indicates module activity. It can source enough current to drive a small LED, causing it to flash. The duration of the flashes indicates the module's current state.
31	ACK_OUT	O	This line goes high when the module receives an acknowledgement message from another module after sending a control message.

1. These lines have an internal 20kΩ pull-down resistor
2. These lines have an internal 10kΩ pull-up resistor

Figure 17: HumPRC™ Series Transceiver Pin Descriptions

Module Dimensions

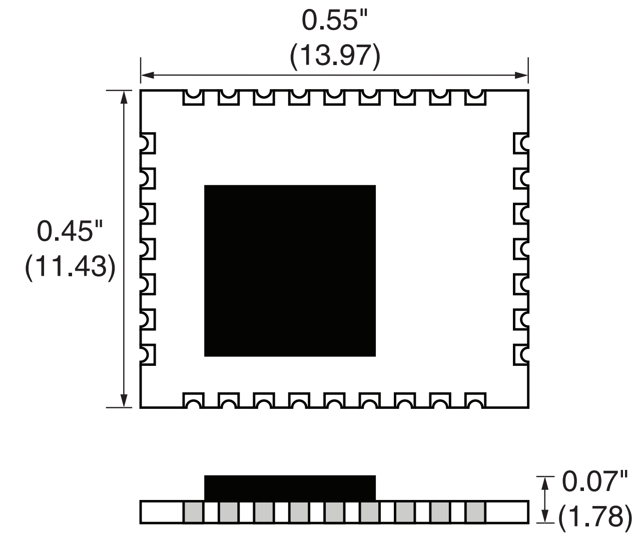

Figure 18: HumPRC™ Series Transceiver Dimensions

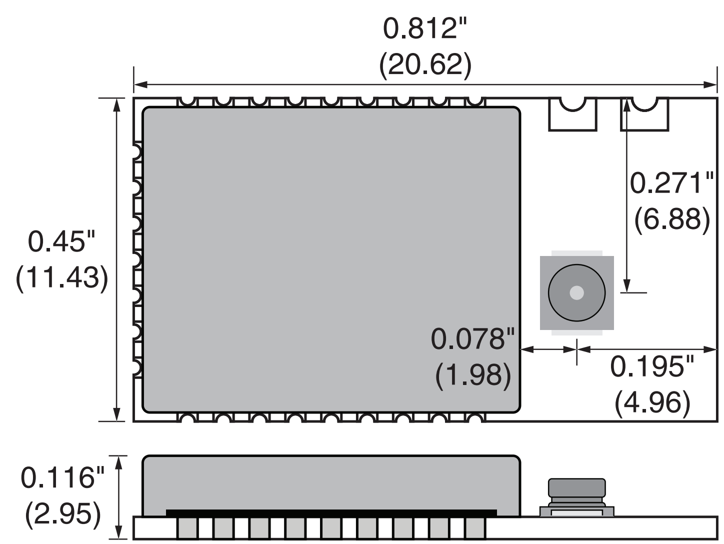

Figure 19: HumPRC™ Series Transceiver Pre-certified Version Dimensions

Theory of Operation

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

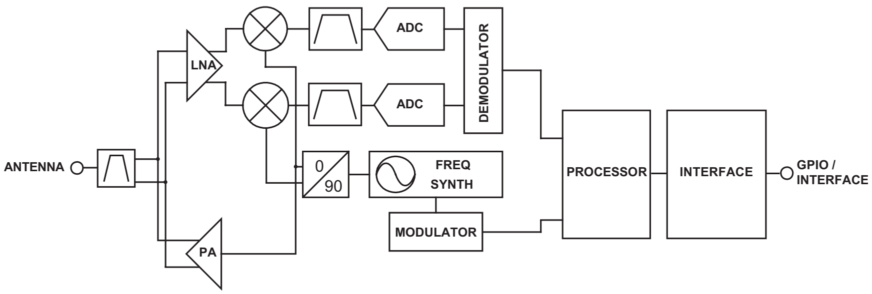

Figure 20: HumPRC™ Series Transceiver RF Section Block Diagram

The HumPRC™ 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. The received RF signal is amplified by a low noise amplifier (LNA) and down-converted to I/Q quadrature signals. The I/Q signals are digitized by ADCs.

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

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

Module Description

The HumPRC™ Series remote control transceiver module is a completely integrated RF transceiver and processor that is designed to send the logic state of its inputs to a remote unit and replicate the logic states of the remote unit's inputs. This allows for the easy creation of basic remote control systems.

The module operates through a series of dedicated I/O lines, resulting in a solution that does not need any software development. The module does have a serial interface that allows for some configuration in applications that need specific control. This interface is likely not needed for basic remote control applications.

Since this module can act as both transmitter and receiver, terminology and descriptions are important. This guide uses the term Initiating Unit (IU) to describe a module that is transmitting commands. Responding Unit (RU) is used to describe a module that is receiving commands.

The module has 8 status lines numbered S0 through S7. These can be set as inputs for buttons or contacts or as outputs to drive application circuitry. When S0 is taken high on the IU, S0 goes high on the RU, and so forth. A line that is an input on one side needs to be set as an output on the other side.

The HumPRC™ Series adds a remote control application layer to the HumPRO™ Series data modem protocol stack. This enables the simple creation of remote control systems that benefit from the robust feature set of the protocol stack, such as a fast locking Frequency Hopping Spread Spectrum (FHSS) algorithm, AES128 encryption, 32-bit addressing, assured delivery and a simple Join Process for associating multiple modules with each other.

As a result, much of the HumPRC™ Series terminology is the same as the HumPRO™ Series. Likewise, most of the software registers are the same though some do not apply to the remote control application.

A result of this common protocol stack is that HumPRC™ Series transmissions can be received by another HumPRC™ Series module for simple remote control applications or by a HumPRO™ Series module for applications that want to combine data transmissions (such as sensor values) with remote control functionality.

Transceiver Operation

The transceiver has two roles: Initiating Unit (IU) that transmits control messages and Responding Unit (RU) that receives control messages. If all of the status lines are set as inputs, then the module is set as an IU only. In this role, the module stays in a low power sleep mode until a status line goes high, starting the Transmit Operation.

If all of the status lines are set as outputs, then the module is set as an RU only. It stays in Receive Operation looking for a valid transmission from a paired IU.

A module with both input and output status lines can operate as an IU and an RU. The module idles in Receive Operation until either a valid transmission is received or a status line input goes high, initiating the Transmit operation.

When an input goes high, the transceiver captures the logic state of each of the status lines. The line states are placed into a packet and transmitted using the configured addressing mode, hop sequence and encryption key (if enabled).

An associated RU receives the packet and sets its status line outputs according to the received packet. It then stays synchronized with the IU and updates the states of its outputs with every packet. Its outputs can be connected to external circuitry that activates when the lines go high.

The RU can also send an acknowledgement back to the IU. If the ACK_EN line is high when a valid control packet is received, the RU sends back an acknowledgement. When the IU receives the acknowledgement, it raises its ACK_OUT line. The ACK_EN line can be connected to ground to disable acknowledgements, connected to the power supply to acknowledge on receipt of the valid command or controlled by external circuitry to acknowledge when an action has taken place.

The ACK_EN can be connected to an LED as an indication to the user or used by the system in other ways, such as updating a display or being used to deactivate an automated system.

> Note: Although the functionality of the HumPRC™ is very similar to the HumRC™, the underlying protocol and operation are very different. The two families are not compatible.

Transmit Operation

When a status line input goes high, the module enters the Initiating Unit role. In this role, the module captures the logic states of the status line inputs and automatically creates a REMOTE_ACTIVATE packet. The packet is transmitted every 140ms nominally (240ms max) for as long as a status line input is held high. After each transmission, the module listens for a REMOTE_CONFIRM reply from the RU. This continues for as long as any status line input is high.

The REMOTE_CONFIRM packet contains two values. One indicates how long the ACK_OUT line should go high on the IU (20ms by default) and the other indicates if the IU should stay awake after the status line inputs go low (go to sleep by default). The module activates the ACK_OUT line for as long as instructed and loops back to check the status line inputs and send another REMOTE_ACTIVATE packet.

When all status line inputs go low, the module transmits two REMOTE_ACTIVATE packets indicating that all lines are low. If all status lines are inputs, it then goes to sleep after 760ms unless a REMOTE_CONFIRM packet is received instructing the IU to stay awake longer.

Receive Operation

When the module is awake and not in transmit operation, it is in receive operation listening for valid packets. When a REMOTE_ACTIVATE packet is received, the module enters the Responding Unit role and processes the received status line states. It remains in the RU mode until 760ms elapses without an incoming REMOTE_ACTIVATE message.

Unlatched status line outputs are set to match the corresponding bit state in the received packet.

For latched outputs, the line changes state (off ➞ on or on ➞ off) whenever the corresponding bit changes from 0 to 1. All other combinations of the new and old status bit do not change the status line. This normally changes the output state every time that the associated transmitter input changes from 0 to 1.

If the ACK_EN line is high when a valid message is received, a REMOTE_CONFIRM message is transmitted to the IU with values to set the ACK_OUT high for 20ms and go to sleep after the default 760ms. These values cannot be changed in the HumPRC™ Series, but a packet with different values can be generated using the HumPRO™ Series and a microcontroller.

System Operation

Transmitters and receivers are paired using the built-in Join Process (see the Join Process for details). One device is configured as an Administrator and creates the network address and encryption key. When Nodes join, the Administrator sends them the encryption key, network address and their unique address within the network. The addressing method used by the HumPRC™ Series modules can support up to hundreds of nodes, depending on the use model (duration of activations and how often they are sent).

It is up to the designer to determine which device makes the most sense as the Administrator in the final system, but there are some common configurations. In a system with one transmitter and one receiver, it does not matter which is the Administrator. In a system where one transmitter is going to activate several receivers, the transmitter is normally the Administrator (Figure 21 a). In a system with one receiver and multiple transmitters, the receiver is normally the Administrator (Figure 21 b).

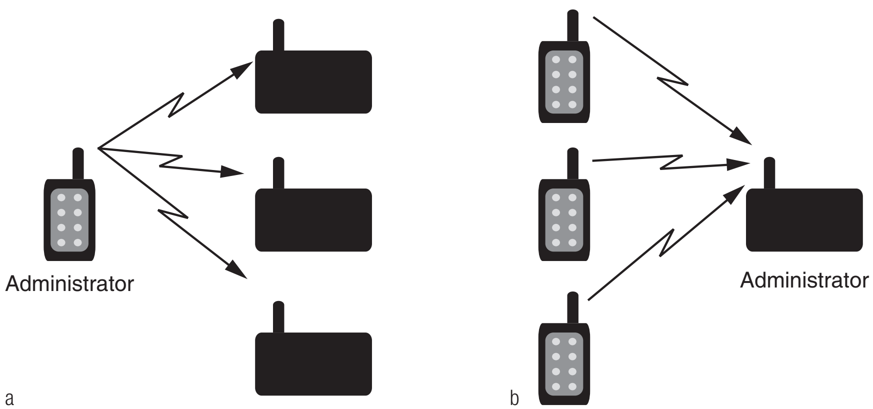

Figure 21: HumPRC™ Series Transceiver Transmitter to Receiver Ratios

A system with multiple transmitters and receivers can use any of the devices as an Administrator (Figure 22 a) or may use a separate device that is only used to join new devices to the network (Figure 22 b). Once all system nodes have received the key and their address, the Administrator node operates the same as any other node.

By default, the Administrator and all Nodes broadcast to the entire network. All transmitters can activate all receivers in the network. An external microcontroller can be used to change the UDESTID0 register to activate a specific Node in the network. This is a more advanced operation and requires the microcontroller and custom firmware.

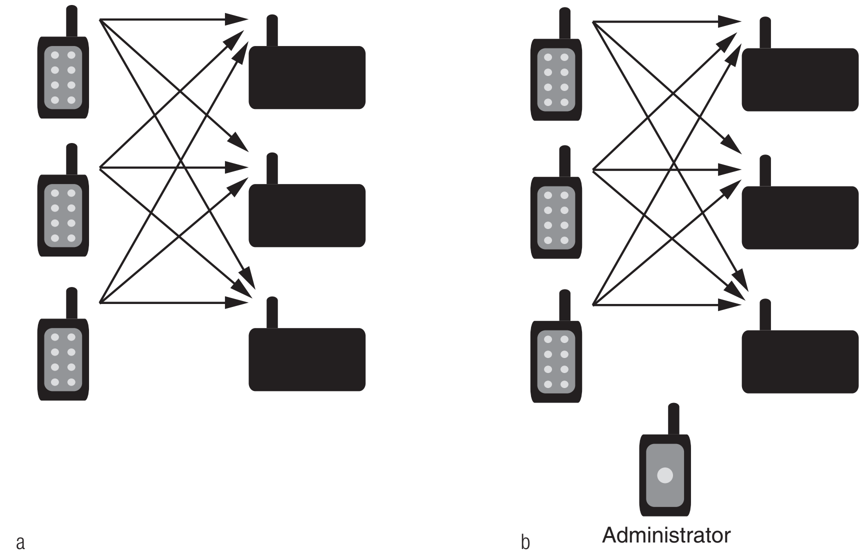

Figure 22: HumPRC™ Series Transceiver Multiple TX and RX

Reading the Transmitter Address

The HumPRC™ Series modules do not require any software for basic operation. There is no compiler to get, no code to write and download into the module. However, the built-in Command Data Interface (CDI) can be used to add additional or advanced functionality to a system.

One such feature is the ability to read out of the receiver the identity of the transmitter that sent the commands. This allows an external processor to log access attempts or set additional controls over which transmitters are allowed to activate the product outside of the module.

By default, the module automatically configures itself to respond to the transmitting module (AUTOADDR = 0x07). This configuration takes the source address from the received packet and writes it to the UDESTID registers UDESTID[0-3]. Reading these registers after a valid transmission has been received indicates the transmitter that sent the command.

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 RF data rate and 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.

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.

Extended User Addressing mode uses the customer ID bytes (CUSTID[1-0]) for unencrypted messages and the four user destination address bytes (UDESTID[3-0]) as a destination address. The module's local address is contained in the four user source ID registers (USRCID[3-0]).

In normal operation, each module has a user ID mask (UMASK[3-0]) that splits the 32 address bits into up to three fields to provide a network address and address fields for sub-networks, supporting both individual addressing and broadcast addressing within the user's network.

The HumPRC™ Series is normally configured using the Join Process, which sets the addressing mode to Extended User mode. The other modes would normally only be used if the HumPRC™ Series is being implemented in a mixed system that also uses the HumPRO™ Series modules.

Please see the HumPRO™ Series data guide for a description of the other addressing modes. A detailed explanation and examples for each addressing mode are given in Reference Guide RG-00105.

AES Encryption

HumPRC™ Series modules offer 128-bit AES encryption. Encryption algorithms are complex mathematical calculations that use a large number called a key to scramble data before transmission. This is done so that unauthorized persons who may intercept the signal cannot access the data. To decrypt the data, the receiver must use the same key that was used to encrypt it. It performs the same calculations as the transmitter and if the key is the same, the data is recovered.

The HumPRC™ Series module has the option to use AES encryption, arguably the most common encryption algorithm on the market. This is implemented in a secure mode of operation to ensure the secrecy of the transmitted data. It uses a 128-bit key to encrypt the transmitted data. The source and destination addresses are sent in the clear.

There are two ways to enable encryption and set the key: sending serial commands and using the Join Process.

Writing an encryption key to the module with the CDI

The module has no network key when shipped from the factory. An encryption key can be written to the module using the CDI. The CMD register is used to write or clear a key. The key cannot be read.

The same key must be written to all modules that are to be used together. If they do not have the same key, then they will not communicate in encrypted mode.

The Join Process

The Join Process can be used to generate and distribute the encryption key and addresses through a series of button presses. The key is stored in an Administrator device and the process uses a factory key to distribute the key to node devices in a secure manner. See the Join Process section for more information on this feature.

The Join Process

The Join Process is a method of generating a random encryption key and random network base address, then distributing the key and addresses to associated modules through a series of button presses. This makes it very simple to establish an encrypted network in the field or add new nodes to an existing network without any additional equipment. It is also possible to trigger the Join Process through commands on the Command Data Interface.

All modules configured from the same administrator using the Join Process can communicate with each other. Other modules are added to the network one at a time.

The hardware required is a pushbutton that is connected to the PB line. This takes the line to VCC when it is pressed and ground when it is released. An LED connected to the MODE_IND line provides visual indication of the module's state.

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 is selected. When the button is released the key and address generation are performed and the module becomes an administrator.

An alternative way to set a module as administrator is by briefly pressing the button twice before holding it for 30 seconds. This method selects the high UART (57600 bps) data rate and high RF data rate. When other units are Joined, they will also be set to the high data rates.

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 254 nodes, and ADDMODE is set to Extended User Address with encryption (0x27) (or without encryption (0x07) if flag PGKEY in the SECOPT register was set to 0 by serial command). 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 network broadcast address. 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 23 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 23 B. Likewise, the network key can be written to the module with the CDI interface. If the PGKEY bit in the SECOPT register is also set to 0, the Generate Key process will generate a network address without changing the preset key. 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, share the key or perform a factory reset through the PB line. The built-in security prohibits changing a node to an administrator without changing the key.

Please see Reference Guide RG-00107, The HumPRO™ Series Join Process for more details and examples of the Join Process.

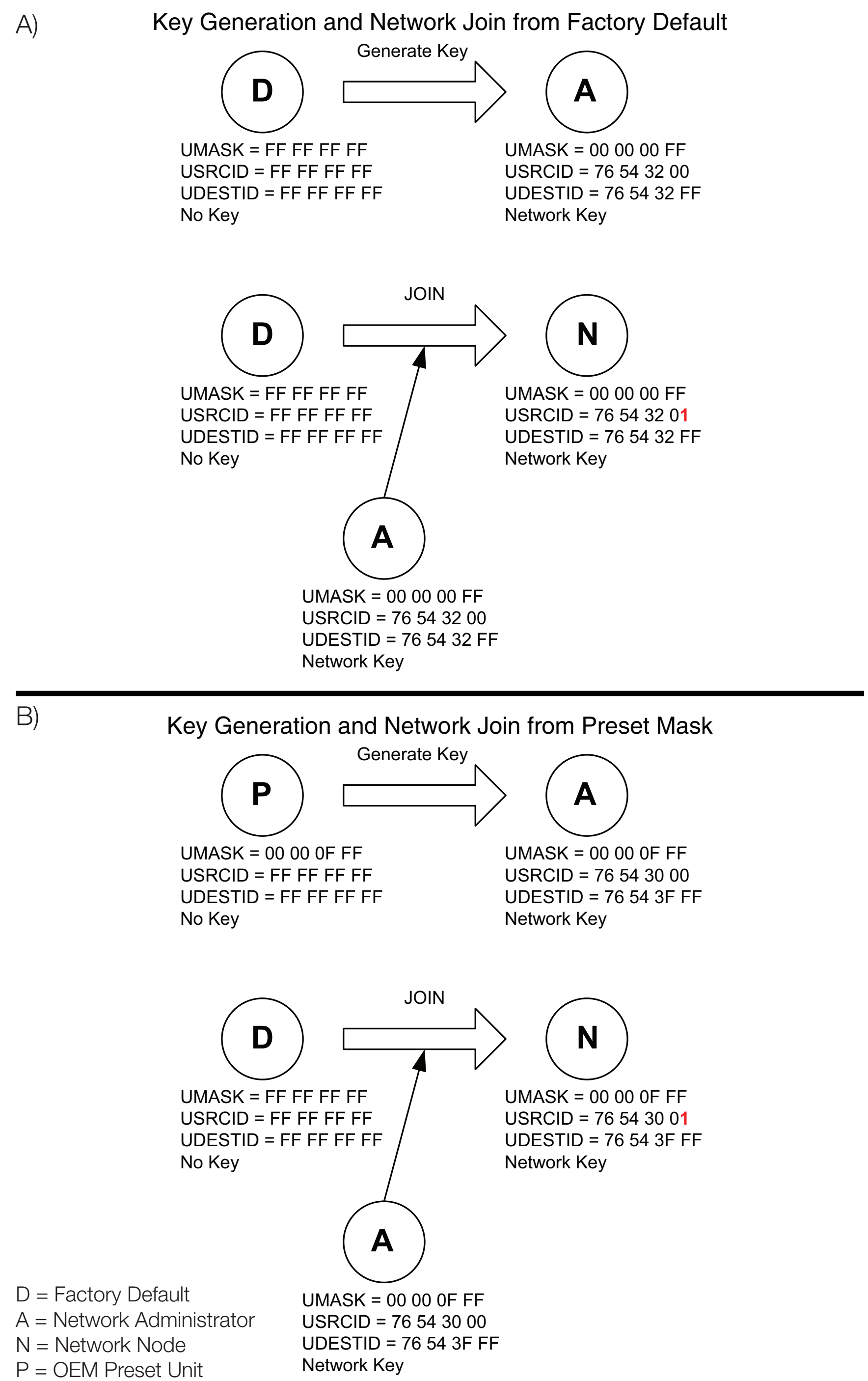

Figure 23: HumPRC™ Series and HumPRC™ Series Join Process Examples

Operation with the HumPRO™ Series

The commands from the HumPRC™ Series module can be received by a HumPRO™ Series transceiver and vice versa. The modules should be joined using the normal Join Process. The IU sends a REMOTE_ACTIVATE packet and accepts a REMOTE_CONFIRM reply.

A microcontroller connected to the HumPRO™ Series can be programmed to take action based on the STATUS byte in a REMOTE_ACTIVATE packet that is received from a HumPRC™ Series module. It can also read out the packet header and know the address of the sending module and respond with a REMOTE_CONFIRM packet to activate the ACK_OUT line on the HumPRC™ module.

Likewise, the microcontroller can be programmed to send a REMOTE_ACTIVATE packet to a HumPRC™ Series module. This opens up many options for creative mixed-mode design.

Remote Activation

The REMOTE_ACTIVATE packet consists of six bytes:

0x03 0x00 0x00 0x00 0x10 <STATUS>

The first byte is 0x03 with the next three bytes 0x00. Byte five is 0x10 which indicates a Remote Activation. Byte six is the STATUS byte, which is a bit map of the status line states. Bit 0 corresponds to status line S0 and so forth. Each bit is 1 if the corresponding line is high.

Remote Confirm

The REMOTE_CONFIRM packet has the following format:

0x03 0x00 0x00 0x00 0x11 <DURATION> <ALIVE>

The first byte is 0x03 with the next three bytes 0x00. Byte five is 0x11 and indicates that the packet is a remote confirm packet.

The DURATION byte indicates the amount of time that the ACK_OUT line should be held high. This value is multiplied by 10ms. If the value is 0, the output is immediately taken low. The default value is 0x02 for 20ms. This value overrides the effect of a previously received REMOTE_CONFIRM packet.

The ALIVE byte indicates how long after the transmission the IU module should stay awake in receive mode. This value is multiplied by 0.1s. Once this duration expires, the module returns to sleep mode.

This message is transmitted to the IU's address. It must be received by the IU within one second of initial transmission or within the ALIVE interval of the previous REMOTE_CONFIRM packet.

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 CSRSSI 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.

This feature is disabled by default in the HumPRC™ so that the fastest response time is obtained. Enabling it can impact transmission timing, so care should be taken with its use.

Acknowledgement

A responding module is able to send an acknowledgement to the transmitting module. This allows the initiating module to know that the responding side received the command.

When the Responding Unit receives a valid REMOTE_ACTIVATE packet, it immediately checks the state of the ACK_EN line. If it is high the module sends a REMOTE_CONFIRM packet.

When the Initiating Unit receives a REMOTE_CONFIRM packet, it pulls the ACK_OUT line high for an amount of time specified by the REMOTE_CONFIRM packet (20ms by default).

Connecting the ACK_EN line to V_{CC} causes the RU to transmit REMOTE_CONFIRM packets as soon as it receives a valid REMOTE_ACTIVATE packet. Alternately this line can be controlled by an external circuit that raises the line when a specific action has taken place. This confirms to the IU that the action took place rather than just acknowledging receipt of the signal.

Note: Only one RU should be enabled to transmit an acknowledgement response for a given IU since multiple acknowledgements will interfere with each other.

External Amplifier Control

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

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

Note: Adding an external power amplifier and/or low noise amplifier to the pre-certified module will invalidate its regulatory certifications.

Configuring the Status Lines

Each of the eight status lines can operate as a digital input or output. The line direction is determined by bit 0 (ENC01) in the RCCTL register. By default, this bit is 1, meaning that the status line directions are determined by the logic states of the C0 and C1 lines.

When C0 is low, S0 through S3 are outputs; when high, they are inputs. Likewise, when C1 is low, S4 through S7 are outputs; when high, they are inputs. This is shown in Figure 24. The C0 and C1 lines are sensed at power-up and when the RCCTL register is changed.

HumPRC™ Series Transceiver Status Line Direction Configuration		
Line	**0**	**1**
C0	S0 through S3 are outputs	S0 through S3 are inputs
C1	S4 through S7 are outputs	S4 through S7 are inputs

Figure 24: HumPRC™ Series Transceiver Status Line Direction Configuration

When the ENC01 bit is 0 the status line direction is determined by the RCDIR register. This register acts as a bit map of the status lines. When bit n is 1, status line Sn is an input line. When bit n is 0, status line Sn is an output line.

Using the LATCH_EN Line

The LATCH_EN line sets the outputs to either momentary operation or latched operation. During momentary operation, the outputs go high for as long as control messages are received instructing the module to take the lines high. As soon as the control messages stop, the outputs go low.

During latched operation, when a signal is received to make a particular status line high, it remains high until a separate activation is received to make it go low. The controlling line on the IU must go low then high to toggle the latched output on the RU.

Latch operation is controlled by bit 1 in the RCCTL register. When this bit is a 1 all outputs are latched. When it is a 0, the state of the LATCH_EN line sets the latching status. In this case, when the LATCH_EN line is high, all of the outputs are latched.

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 25 shows the different blink patterns and their meanings.

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

Figure 25: HumPRC™ Series MODE_IND Line Timing

Figure 26 shows the MODE_IND displays in a graphical format.

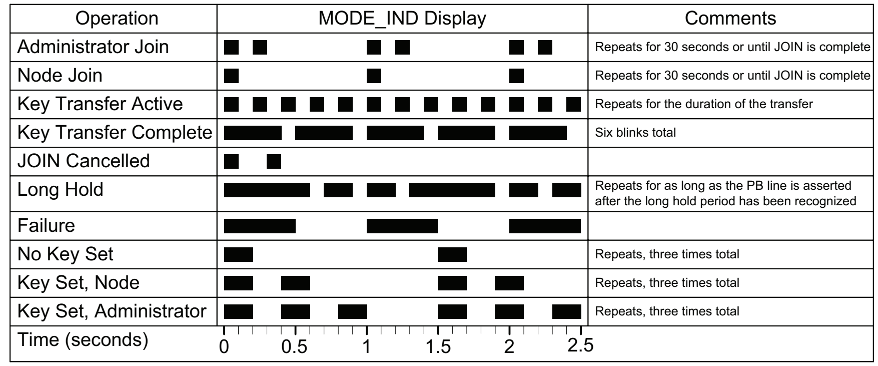

Figure 26: HumPRC™ Series MODE_IND Displays

Using the PB Line

The PB Line is used to trigger functions associated with the Join Process. This line should be connected to a momentary pushbutton that pulls the line to VCC when it is pressed and opens the circuit when it is released.

The sequence of presses determines which function is triggered. Figure 27 shows the sequences.

HumPRC™ Series Transceiver PB Line Operation	
Function	**Sequence**
Join a network	1 short pulse
Cancel a Join Process that is in progress	1 short pulse
Generate a network key and address; 9,600bps	Hold high for 30 seconds
Generate a network key and address; 57,600bps	2 short pulses and hold high for 30 seconds
Reset to factory defaults	4 short pulses and hold high for 3 seconds
Test key and address	3 short pulses
A short pulse is a logic high that is between 100 and 2,000ms in duration.	

Figure 27: HumPRC™ Series PB Line Operation

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 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 a sleep state to save current in battery-powered applications. During the sleep state, no module activity occurs and no packets can be received but current consumption is less than 1µA typical.

There are two ways of putting the module to sleep. First, pulling the Power Down ($\overline{\text{POWER\_DOWN}}$) line low puts the module to sleep. Taking the line high wakes the module. Second, all of the following should be true:

1. There is no transmission in progress

2. All status lines are low and either
    - IDLE = 1 (default) and all status lines are configured as inputs, or
    - IDLE = 2 (allows sleeping when incoming control message can be missed)

3. The internal KeepAlive timer has expired.

The internal KeepAlive timer is set by the following events:

1. On wakeup from a transition on the CMD_DATA_IN line, KeepAlive is set to 2s. This allows time for an external unit to change IDLE to 0 to keep the unit awake.

2. On each transmission, KeepAlive is set to 760ms if the remaining KeepAlive time is less. [max(760ms, KeepAlive)]

3. On reception of a REMOTE_CONFIRM packet, KeepAlive is set to received ALIVE value multiplied by 0.1s if the remaining KeepAlive time is less. The KeepAlive can be extended indefinitely by periodic reception of REMOTE_CONFIRM messages. max(REMOTE_CONFIRM.keepAlive * 100ms, KeepAlive)

During sleep mode, the output lines are in the states in Figure 28.

HumPRC™ Series Transceiver Output Line Sleep States	
Output Line	**Sleep State**
S0 - S7 output	Low
LNA_EN	Low
PA_EN	Low
CMD_DATA_OUT	Low
MODE_IND	Low
ACK_OUT	Low

Figure 28: HumPRC™ Series Output Line Sleep States

When the $\overline{\text{POWER\_DOWN}}$ line is high, the module awakens when a status line input goes high, the PB line goes high or there is a change on the CMD_DATA_IN lines. If a negative-going pulse is needed to generate a rising edge, the pulse width should be greater than 1 µs.

If the volatile registers have been corrupted during sleep, a software reset is performed. This restarts the module as if power were cycled. This can be caused by power surges or brownout among other things.

Pulsing $\overline{\text{RESET}}$ low causes the module to restart rather than continue from sleep.

IDLE = 1 is used when the module is an IU only. This puts it to sleep when all status line inputs are low.

IDLE = 2 is used when the module is primarily an IU, but can accept activation commands from remote units. In this case, the module stays asleep until a status line input goes high. While awake, the module can receive activation commands and will remain awake while commands are received. As soon as all status line inputs and outputs go low, the module returns to sleep.

The Command Data Interface

The HumPRC™ 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).

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 Command field contains the register address that is to be accessed and, in the case of a write command, the value to be written. Neither Length nor Command can contain a 0xFF byte.

Byte values of 128 (0x80) or greater can be sent as a two-byte escape sequence of the format:

0xFE, [value - 0x80]

For example, the value 0x83 becomes 0xFE, 0x03. The Length count includes the added escape bytes.

A response is returned for all valid commands. The first response byte is CMD_ACK (0x06) or CMD_NACK (0x15). Additional bytes may follow, as determined by the specific command.

Reading from Registers

A register read command is constructed by placing an escape character (0xFE) before the register number. The module responds by sending an ACK (0x06) followed by the register number and register value. The register value is sent unmodified, so if the register value is 0x83, 0x83 is returned. If the register number is invalid, the module responds with a NACK (0x15). The command and response are shown in Figure 29.

HumPRC™ Series Read From Configuration Register

Command

Header	Size	Escape	Address
0xFF	0x02	0xFE	REG

Response

ACK	Address	Value
0x06	REG	V

Command for an Address greater than 128 (0x80)

Header	Size	Escape	Addr1	Addr2
0xFF	0x03	0xFE	0xFE	REG-80

Response

ACK	Address	Value
0x06	REG	V

Figure 29: HumPRC™ Series Read from Configuration Register Command and Response

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 30.

HumPRC™ 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 30: HumPRC™ 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 with a limited number of refresh cycles. Please see the electrical specifications.

Command Length Optimization

Some commands may be shortened by applying the following rules:

1. Escape sequences are not required for byte values 0x00 to 0xEF (besides 0xFE and 0xFF, bytes 0xF0 – 0xFD are reserved for future use).
2. An escape byte inverts bit 7 of the following data byte.
3. The 0xFE as the first byte of the Read Register Command field is an escape byte.
4. Two consecutive escape bytes cancel unless the following data byte is 0xf0-0xff.

Examples:

- FF 02 FE 02 (read nv:TXPWR) is equivalent to FF 01 82.
- FF 03 FE FE 53 (read v:PKOPT) is equivalent to FF 01 53.
- FF 03 1A FE 7F (write FF to nv:UMASK0) cannot be shortened.
- FF 03 1A FE 40 (write C0 to nv:UMASK0) is equivalent to FF 02 1A C0.

These rules are implemented in the sample code file EncodeProCmd.c, which can be downloaded from the Linx website.

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

```
/* Sample C code for encoding HUM-fff-PRO commands
**
** Copyright 2015 Linx Technologies
**  159 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;
   return dx;
}

/* Function:    HumProRead
** Description: This function encodes a read command to the specified
**              register address.
*/
unsigned char                        /* number of encoded bytes, 3 to 4 */
HumProRead(
   unsigned char *cmd,               /* out: encoded read command, length >= 4 */
   unsigned char reg                 /* register number to read, 0..0xff */
) {
   unsigned char ra;                 /* read register byte */

   ra = reg ^ 0x80;
   return HumProCommand(cmd, &ra, 1);
}

/* Function:    HumProWrite
** Description: This function encodes a command to write a single byte to
**              a specified register address.
*/
unsigned char                        /* number of encoded bytes, 4 to 6 */
HumProWrite(
   unsigned char *cmd,               /* out: encoded read command, length >= 6 */
   unsigned char reg,                /* register number to write, 0..0xff */
   unsigned char val                 /* value byte, 0..0xff */
) {
   unsigned char cs[2];
   cs[0] = reg;
   cs[1] = val;
   return HumProCommand(cmd, &cs, 2);
}
```

The Command Data Interface Command Set

The following sections describe the registers.

HumPRC™ 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	0xFF	Channel Hop Table
TXPWR	0x02	0x4D	R/W	0x03	Transmit Power
UARTBAUD	0x03	0x4E	R/W	0x01	UART data rate
ADDMODE	0x04	0x4F	R/W	0x0F	Addressing mode
DATATO	0x05	0x50	R/W	0x10	Data timeout
MAXTXRETRY	0x07	0x52	R/W	0x02	Maximum Transmit Retries
ENCRC	0x08	0x53	R/W	0x01	Enable CRC checking
BCTRIG	0x09	0x54	R/W	0x40	Byte Count trigger
ENCSMA	0x0B	0x56	R/W	0x01	Enable CSMA
IDLE	0x0D	0x58	R/W	0x01	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
DESTDSN0	0x20	0x6B	R/W	0xFF	Destination Device Serial Number
RCCTL	0x22	0x6D	R/W	0x01	RC control
CMDHOLD	0x23	0x6E	R/W	0x01	Hold RF data when nCMD pin is low
RCDIR	0x24	0x6F	R/W	0xFF	RC status line direction select
COMPAT	0x25	0x70	R/W	0x02	Compatibility
AUTOADDR	0x26	0x71	R/W	0x07	Automatic Reply Address
MYDSN3	0x34		R		Factory programmed Serial Number
MYDSN2	0x35		R		Factory programmed Serial Number
MYDSN1	0x36		R		Factory programmed Serial Number
MYDSN0	0x37		R		Factory programmed Serial Number
CUSTID1	0x39		R	0xFF	Factory programmed customer ID
CUSTID0	0x3A		R	0xFF	Factory programmed customer ID
CSRSSI	0x3F		R/W	0xBA	Carrier Sense minimum RSSI
RELEASE	0x78		R		Release number
RCSLS		0x7A	R	0x00	RC status line state
PRSSI		0x7B	R	0x00	Packet RSSI
ARSSI		0x7C	R	0x00	Ambient RSSI
FWVER3	0xC0		R		Firmware version, major
FWVER2	0xC1		R		Firmware version, minor
FWVER1	0xC2		R		Firmware version, increment
FWVER0	0xC3		R		Firmware version, suffix
NVCYCLE1	0xC4		R		NV Refresh Cycles, MS
NVCYCLE0	0xC5		R		NV Refresh Cycles, LS
LSTATUS		0xC6	R		Status lines
CMD		0xC7	W	0x00	Command register
SECSTAT		0xC9	R		Security Status
JOINST		0xCA	R	0x00	Join Status
EEXFLAG2		0xCD	R/W	0x00	Extended exception flags
EEXFLAG1		0xCE	R/W	0x00	Extended exception flags
EEXFLAG0		0xCF	R/W	0x00	Extended exception flags
EEXMASK2	0x80	0xD0	R/W	0x00	Extended exception mask
EEXMASK1	0x81	0xD1	R/W	0x00	Extended exception mask
EEXMASK0	0x82	0xD2	R/W	0x00	Extended exception mask
PKTOPT	0x83	0xD3	R/W	0x01	Packet options
SECOPT	0x84	0xD4	R/W	0xFF	Security Options
LASTNETAD[3]	0x8C		R/W	0x00	Last Network Address Assigned
LASTNETAD[2]	0x8D		R/W	0x00	Last Network Address Assigned
LASTNETAD[1]	0x8E		R/W	0x00	Last Network Address Assigned
LASTNETAD[0]	0x8F		R/W	0x00	Last Network Address Assigned

Figure 31: HumPRC™ Series Configuration Registers

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 32 shows the command and response.

HumPRC™ Series CRC Error Count

Read Command

Header	Size	Escape	Address
0xFF	0x02	0xFE	0x40

Read Response

ACK	Address	Value
0x06	0x40	V

Write Command

Header	Size	Address	Value
0xFF	0x02	0x40	V

Figure 32: HumPRC™ 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. The default value of 0xFF must be changed before communication can occur. This is normally done by the Join Process. Figure 33 shows the command and response.

HumPRC™ Series Channel Hop Table

Read Command

Header	Size	Escape	Address
0xFF	0x02	0xFE	0x4B 0x00

Read Response

ACK	Address	Value
0x06	0x4B 0x00	V

Write Command

Header	Size	Address	Value
0xFF	0x02	0x4B 0x00	V

Figure 33: HumPRC™ Series Channel Hop Table Command and Response

Figure 34 shows the RF channels used by the HumPRC™ Series. When the baud rate is set to 9,600 or 19,200 bps, the module uses 50 hopping channels. Figure 35 shows the hop sequences referenced by channel number. When the baud rate is 38,400bps and higher, the module uses 26 hopping channels and only even channels are used. Figure 36 shows the hop sequences referenced by channel number. The default hop sequence is 0.

HumPRC™ Series RF Channels

Channel Number	Frequency (MHz)	Channel Number	Frequency (MHz)
0	902.971	32	915.000
1	903.347	33	915.376
2	903.723	34	915.752
3	904.099	35	916.128
4	904.475	36	916.504
5	904.851	37	916.880
6	905.227	38	917.255
7	905.602	39	917.631
8	905.978	40	918.007
9	906.354	41	918.383
10	906.730	42	918.759
11	907.106	43	919.135
12	907.482	44	919.511
13	907.858	45	919.887
14	908.234	46	920.263
15	908.610	47	920.639
16	908.986	48	921.014
17	909.361	49	921.390
18	909.737	50	921.766
19	910.113	51	922.142
20	910.489	52	922.518
21	910.865	53	922.894
22	911.241	54	923.270
23	911.617	55	923.646
24	911.993	56	924.022
25	912.369	57	924.398
26	912.745	58	924.773
27	913.120	59	925.149
28	913.496	60	925.525
29	913.872	61	925.901
30	914.248	62	926.277
31	914.624	63	926.653

Figure 34: HumPRC™ Series RF Channels

HumPRC™ Series Hop Sequences by Channel Number for 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 35: HumPRC™ Series Hop Sequences for UART rate of 19,200bps and below

HumPRC™ Series Hop Sequences by Channel Number for 38,400bps and Above

0	1	2	3	4	5
32	30	6	56	44	18
2	60	40	22	14	48
4	58	42	20	16	46
10	52	48	14	22	40
20	42	58	4	32	30
42	20	16	46	54	8
22	40	60	2	34	28
46	16	20	42	58	4
28	34	2	60	40	22
58	4	32	30	6	56
54	8	28	34	2	60
44	18	18	44	56	6
24	38	62	0	36	26
48	14	22	40	60	2
34	28	8	54	46	16
6	56	44	18	18	44
14	48	52	10	26	36
30	32	4	58	42	20
62	0	36	26	10	52
60	2	34	28	8	54
56	6	30	32	4	58
50	12	24	38	62	0
38	24	12	50	50	12
12	50	50	12	24	38
26	36	0	62	38	24
52	10	26	36	0	62

Figure 36: HumPRC™ Series Hop Sequences for UART rates of 38,400bps and above