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

868MHz HumDT™ Series
RF Transceiver Module
Data Guide

Wireless made simple®

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

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

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

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

All RF products are susceptible to RF interference that can prevent communication. RF products without frequency agility or hopping implemented are more subject to interference. This module does not have a frequency hopping protocol built in.

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

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

Ordering Information

Ordering Information	
Part Number	Description
HUM-868-DT	868MHz HumDT™ Series Transceiver
EVM-868-DT	868MHz HumDT™ Series Carrier Board
MDEV-868-DT	868MHz HumDT™ 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.

HumDT™ Series Transceiver Specifications						
Parameter	Symbol	Min.	Typ.	Max.	Units	Notes
Via POWER_DOWN				47	ms	11
Via Sleep				3	ms	11
Serial Command Response						
Status, Volatile R/W			1.5	2.5	ms	8
Analog Input Reading			10	11	ms	8
NV Update, Factory Reset			24	27	ms	8
Minimum Time between Command Packets		100			ms	
Interface Section						
Input						
Logic Low	V_{IL}			$0.3*V_{CC}$	VDC	
Logic High	V_{IH}	$0.7*V_{CC}$			VDC	
Output						
Logic Low, LED_0, LED_1	V_{OLM}			$0.3*V_{CC}$	VDC	1,9
Logic High, LED_0, LED_1	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

1. Measured at 3.3V V_{CC}
2. Measured at 25ºC
3. MAX value represents extreme of HUM family; HumDT value is lower
4. Input power < -60dBm
5. Characterized but not tested
6. PER = 1%
7. Into a 50-ohm load
8. From end of command to start of response
9. 60mA source/sink
10. 6mA source/sink
11. HUM-DT in single-channel ED mode, time to accept joining network

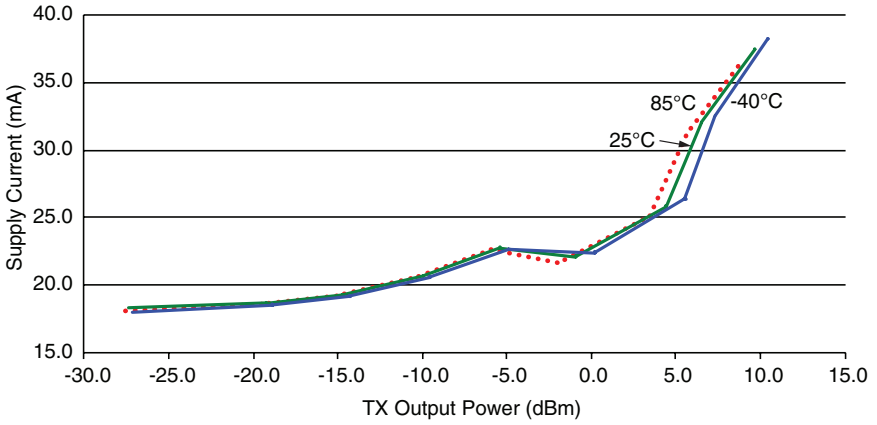Figure 4: Electrical Specifications

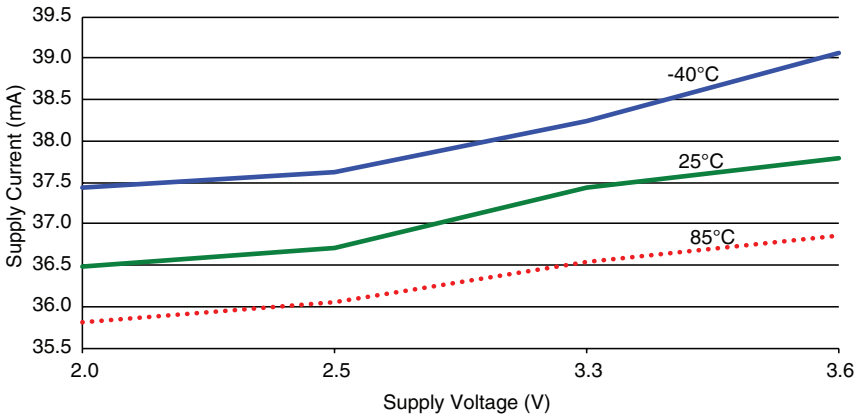Figure 8: HumDT™ Series Transceiver Average TX Current vs. Transmitter Output Power at 3.3V - HUM-900-DT

Figure 7: HumDT™ Series Transceiver TX Current vs. Supply Voltage at Max Power - HUM-900-DT
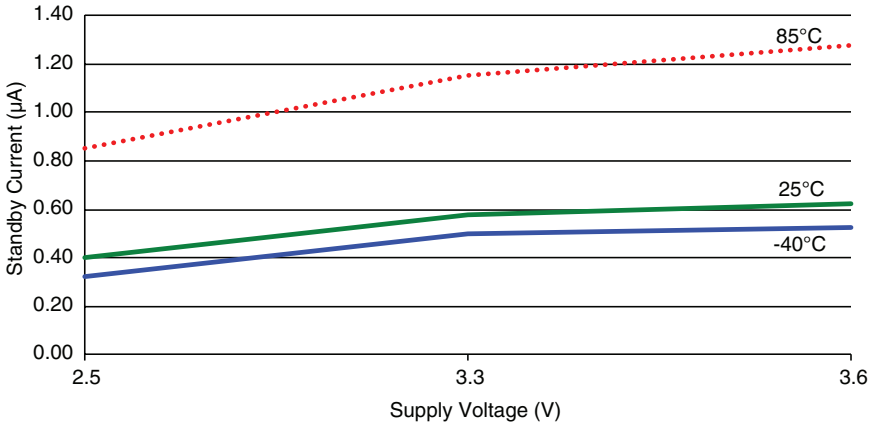
Figure 11: HumDT™ Series Transceiver Standby Current Consumption vs. Supply Voltage - HUM-900-DT
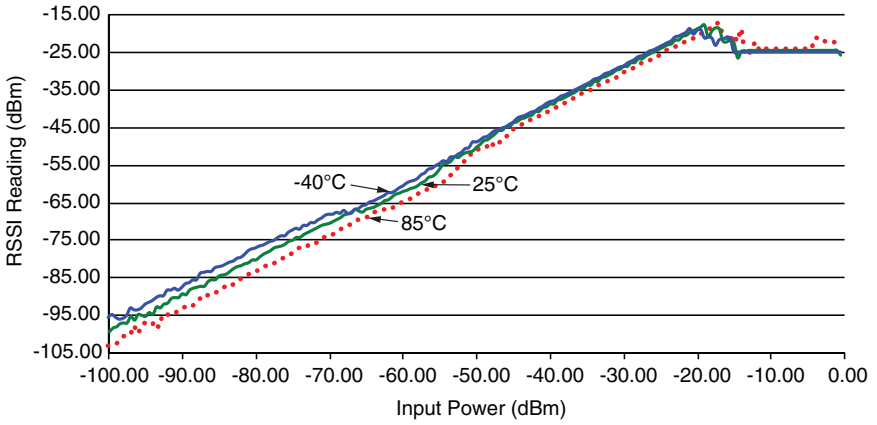

Figure 12: HumDT™ Series Transceiver RSSI Voltage vs. Input Power - HUM-900-DT
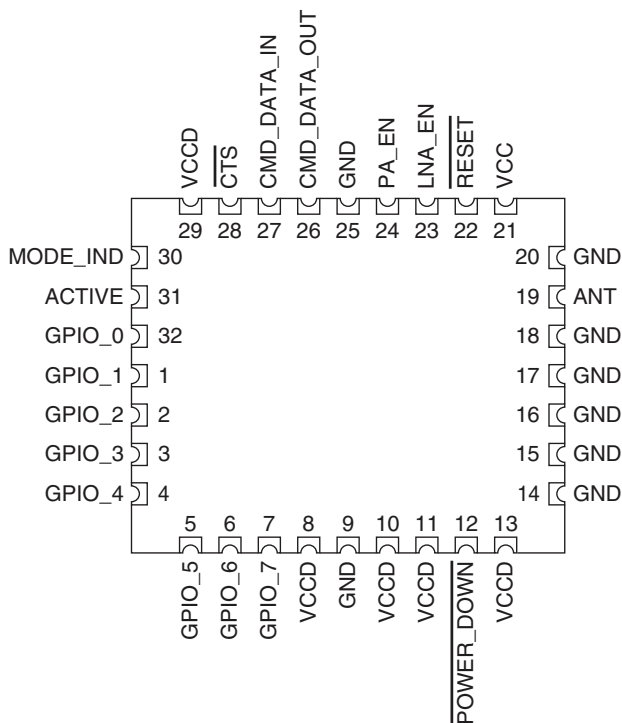
Pin Assignments

Figure 13: HumDT™ Series Transceiver Pin Assignments (Top View)

Pin Descriptions

Pin Descriptions			
Pin Number	**Name**	**I/O**	**Description**
1, 2, 3, 4, 5, 6, 7, 32	GPIO_0–GPIO_7	I/O	General Purpose I/O Lines. Each line can be configured as either an analog input, a digital input or a digital output. The digital inputs can be configured to have either a 20kΩ pull up or pull down resistance or high impedance (no resistors).
8, 10, 11, 13, 29	VCCD	—	These lines are inputs that are pulled to supply internally. They can be left unconnected, but boards in noisy environments or with noisy components in the same product are recommended to pull these lines to V_{CC}. The potential exists for random noise to affect the line and cause unexpected operation. This risk is reduced in simple, battery powered applications, but should be considered in all designs.

Theory of Operation

The HumDT™ Series transceiver is a low-cost, high-performance synthesized MSK transceiver. Figure 15 shows the module's block diagram.
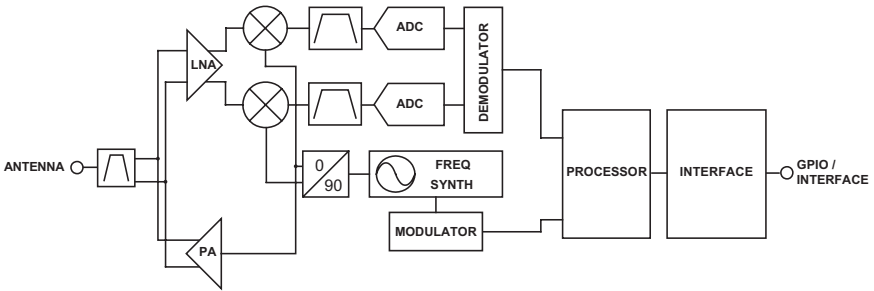

Figure 15: HumDT™ Series Transceiver RF Section Block Diagram

The HumDT™ Series transceiver operates in the 863 to 870MHz and 902 to 928MHz frequency bands. The transmitter output power is programmable. The range varies depending on the module's frequency band, 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.

Networking

Each module can be configured as one of three device types; Access Point (AP), Range Extender (RE), and End Device (ED). These device types play a specific role in creating a star network.

The AP acts as the hub in a star network. It is an always-on device and only one AP is permitted per network. It receives all packets within its range and is capable of relaying messages from one ED to another.

The REs are always-on devices that extend the radio range on a network. They retransmit all received messages from devices in its network that are within range. This relaying of data extends the range of the network. Networks are limited to a maximum of four REs.

EDs are the simplest devices. They perform the actions in the network, such as remote control handhelds, sensors and actuators. The EDs may be battery powered and can be put into a low power mode to save current consumption.

There can be a maximum of 50 EDs in each network, with 1 AP and up to 4 REs.
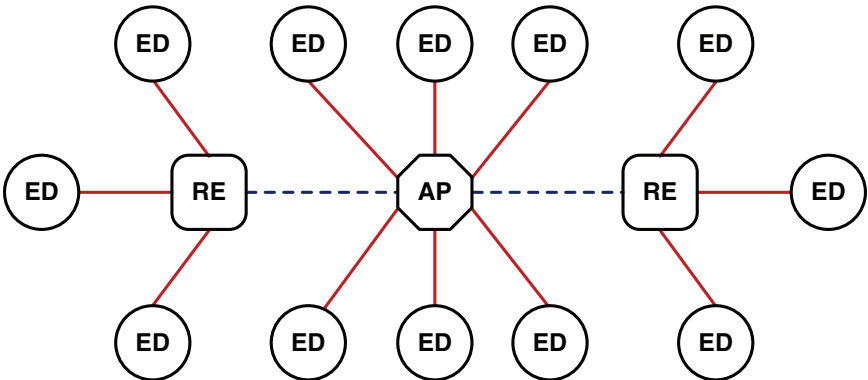
Figure 16: HumDT™ Series Transceiver Star Network

Each ED communicates with the AP either directly or through an RE. The AP can output the received data from the ED or forward the data on to another ED, depending on the addressing in the packet.

The AP sends out a beacon message about every 30 seconds to maintain the network. This is an automatic message and is not output by the module, though the MODE_IND line indicates the activity.

Addressing

There are two addresses used by the modules; the module address and the network ID. The module address is a 4 byte number that identifies the specific module in the network. This number is unique to the module and cannot be repeated within a network.

The network ID is a 4 byte number that is used to identify which network the module is in. This is shared by all modules within the network.

Modules that have different network IDs can have the same module address. No module should have the same module address and network ID. If this happens, the first module that contacts the AP is accepted into the network and the second is rejected and cannot communicate with the AP.

Each module is programmed with a unique 4 byte serial number at the factory. This can be used as the module address by reading it out through the CDI and writing it back as the local address. The serial number cannot be changed. This can ensure that every module in the system has a unique address rather than having to track addresses separately.

If two networks are operating in proximity, then it is possible for modules to hear transmissions from the other network. If the network ID in the received packet does not match the module's local network ID, then the packet is ignored and discarded.

Each module can also report out the modules it is linked to in the network. EDs only return the address of the AP. The AP outputs the addresses for all of the EDs that it has joined and linked to in the network. This is accomplished with a serial command through the module's Command Data Interface. This is a convenient way to quickly establish the entire network from the AP.

The REs do not have the intelligence to record all of the modules in its range. They respond with 0 associated modules.

Channel Frequencies					
Channel Number	Frequency (MHz)	Duty Cycle	Channel Number	Frequency (MHz)	Duty Cycle
0	863.15	0.10%	35	866.65	0.10%
1	863.25	0.10%	36	866.75	0.10%
2	863.35	0.10%	37	866.85	0.10%
3	863.45	0.10%	38	866.95	0.10%
4	863.55	0.10%	39	867.05	0.10%
5	863.65	0.10%	40	867.15	0.10%
6	863.75	0.10%	41	867.25	0.10%
7	863.85	0.10%	42	867.35	0.10%
8	863.95	0.10%	43	867.45	0.10%
9	864.05	0.10%	44	867.55	0.10%
10	864.15	0.10%	45	867.65	0.10%
11	864.25	0.10%	46	867.75	0.10%
12	864.35	0.10%	47	867.85	0.10%
13	864.45	0.10%	48	867.95	0.10%
14	864.55	0.10%	49	868.05	1.00%
15	864.65	0.10%	50	868.15	1.00%
16	864.75	0.10%	51	868.25	1.00%
17	864.85	0.10%	52	868.35	1.00%
18	864.95	0.10%	53	868.45	1.00%
19	865.05	0.10%	54	868.55	1.00%
20	865.15	0.10%	55	868.65	0.10%
21	865.25	0.10%	56	868.75	0.10%
22	865.35	0.10%	57	868.85	0.10%
23	865.45	0.10%	58	868.95	0.10%
24	865.55	0.10%	59	869.05	0.10%
25	865.65	0.10%	60	869.15	0.10%
26	865.75	0.10%	61	869.25	0.10%
27	865.85	0.10%	62	869.35	0.10%
28	865.95	0.10%	63	869.45	10.00%
29	866.05	0.10%	64	869.55	10.00%
30	866.15	0.10%	65	869.65	NA
31	866.25	0.10%	66	869.75	None / 1%
32	866.35	0.10%	67	869.85	None / 1%
33	866.45	0.10%	68	869.95	None / 1%
34	866.55	0.10%			

Figure 17: HumDT™ Series Transceiver Channel Frequencies

GPIO Configuration

The module has 8 General Purpose Input / Output lines that can be configured and controlled through the Command Data Interface. They can be set in one of three ways.

- Digital Input - can be queried to see if the line is logical high or low.
- Digital Output - can be set to either logical high or low.
- Analog Input - connected to an internal Analog to Digital Converter (ADC). This provides a digital number that is proportional to the voltage on the line referenced to V_{CC} (0V to VCC range, 12 bits resolution).

Digital input lines have an internal pull-up to V_{CC} of approximately 20kOhm by default. The digital inputs can be configured to have either pull up or pull down resistors or be tri-state to fit different user hardware implementations.

Please see the Command Data Interface section for details on how to configure the GPIO settings.

Baud Rate

The module supports multiple serial baud rates on the UART for the Command Data Interface. The module uses the serial rate that is selected to automatically select one of its four RF baud bands. These baud bands determine the internal filter settings and the over-the-air data rate. Figure 19 shows the serial baud rate and the resulting baud band and RF baud rate.

Baud Rate Configuration		
Serial Baud Rate (kbps)	RF Baud Band	RF Baud Rate (kbps)
1.2	0	26
2.4	0	26
4.8	0	26
9.6	0	26
14.4	1	80
19.2	1	80
28.8	1	80
38.4	1	80
57.6	2	250
115.2	2	250
reserved	3	500

Figure 19: Baud Rate Configuration

Encryption

The module implements AES encryption in ECB mode. The packet header information is sent in the clear and the payload data is encrypted.

Encryption algorithms are complex mathematical equations that use a number, called a key, to encrypt data before transmission. This is done so that unauthorized persons who may intercept the transmission cannot access the data. In order to decrypt the transmission, the receiver must use the same key that was used to encrypt it. The receiver performs the same calculations as the encoder and, if the key is the same, recovers the data.

The AES encryption algorithm is widely used, from basic wireless data links to Internet traffic to government communications. It is considered highly secure and reliable. The AES algorithm supports key lengths of 128, 192 and 256 bits. The HumDT™ module only supports 128 bits. The larger key lengths are more subject to government import and export regulations, though the user will need to confirm that 128 bits is allowable in their industry.

The strength of the encryption algorithm and the length of the key are only two factors in a secure system. The ultimate requirement is the secrecy of the key. The HumDT™ module only allows the key to be read out of the Access Point. It can be written into an End Device, but is otherwise inaccessible.

The AP should be kept in a secure location to prevent physical access by unauthorized persons. If the key is stored outside the system, such as in a database or list, then it should also be kept secure.

Command Data Interface

The DT 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 no flow control.

The general serial command format for the module is:

[Start Delimiter] [Command] [Parameters] [Data] [End Delimiter]

The Start Delimiter has a fixed value of 0x3C (the '<' ASCII character).

The Command codes are shown in Figure 21. The Command Data Interface Command Set section goes into the commands in detail.

The Data field is only available with the Send Data Packet and Send Broadcast Packet commands. This is the data that is transmitted over the air. The maximum number of data bytes in one data packet is 32 bytes.

The End Delimiter has a fixed value of 0x3E (the '>' ASCII character).

If a command sent to the module is successful, a response is returned. The general serial command response format is:

[Start Delimiter] [Response] [Parameters] [End Delimiter]

The Start Delimiter has a fixed value of 0x3C (the '<' ASCII character).

The Response Type code for each command is the same as the Command Type code. All the available Command Types are shown in Figure 21.

The Response Parameters for each type of response are detailed in the Command Data Interface Command Set section along with the corresponding command.

The End Delimiter has a fixed value of 0x3E (the '>' ASCII character).

All values are in hexadecimal format.

The Command Data Interface Command Set

The following sections describe the commands and parameters.

> Note: All values are shown in hexadecimal format unless otherwise stated.

The module has two forms of memory, volatile and non-volatile. Volatile memory is temporary and all values are lost when power is removed from the module. However, it is faster to access and the module typically uses the values in volatile memory during operation.

Non-volatile memory is retained when power is removed from the module. This is where default values are stored. When the module powers on, it pulls some values from non-volatile memory and loads them into volatile memory for use during normal operation.

There is one command to read (Command Code = 22) and one command to write (Command Code = 23) all of the configurations in non-volatile memory. The non-volatile memory has a life expectancy of about 1,000 writes, so using one command for all settings helps extend the life time.

Volatile settings have separate commands for each setting since it has a much larger life expectancy. This makes it easier to change just one configuration value.

Send Data Packet - Command Code = 21

This command instructs the module to transmit a data packet over the air.

Send Data Packet Command and Response								
Command								
Start	Cmd	Param 1	Param 2	Param 3	Param 4	Param 5	Data	End
3C	21	DestAdr3	DestAdr2	DestAdr1	DestAdr0	LEN	DATA	3E
Response								
Start	Rsp	Param1	End					
3C	21	Status	3E					

Figure 22: Send Data Packet Command and Response

The first four bytes consist of the destination address for the data packet with the DestAdr3 (Param 1 byte) being the Most Significant Byte (MSB). The Len byte (Param 5) is the total number of bytes in the Parameter and Data fields (5 bytes plus the number of data bytes).

Read Non-volatile Configurations - Command Code = 22

This command reads all of the configurations that are stored in the module's non-volatile memory.

Read Non-volatile Configurations Command and Response						
Command						
Start	Command	End				
3C	22	3E				
Response						
Start	Response	Param 1	. . .	Param 55	End	
3C	22	DType	. . .	Status	3E	

Figure 24: Read Non-volatile Configurations Command and Response

The response contains 55 bytes of configuration parameters. The full list of parameters are shown in Figure 25 followed by descriptions of each one.

Note that this command reads out the configurations stored in non-volatile memory. Any configurations that have been changed in volatile memory are not read by this command.

Parameter 1 is the device type. This indicates whether the module is acting as an Access Point (31), Range Extender (32) or End Device (33).

Parameters 2 through 4 are the module's local address that uniquely identifies it within the network. No other module in the same network can have the same address.

Parameter 6 is the UART serial baud rate. The codes for this are shown in Figure 26.

Parameter 7 configures the default channel number. The channels are shown in Figure 17.

Parameter 9 controls the transmitter output power level. Figure 27 shows the power level codes and the approximate output power. The actual output power may differ slightly from part-to-part.

Parameters 10 through 13 set the ID of the network that the module is to join. Other modules respond only if they have this same network ID.

Baud Rate Codes	
Serial Baud Rate (kbps)	Baud Rate Code
1.2	0
2.4	1
4.8	2
9.6	3
14.4	4
19.2	5
28.8	6
38.4	7
57.6	8
115.2	9
reserved	N/A

Figure 26: Baud Rate Codes

Transmitter Output Power Codes	
Power Level Code	HUM-868-DT TX Output Power (dBm)
00	−30
01	−20
02	−15
03	−10
04	−5
05	0
06	5
07	7
08	10

Figure 27: Transmitter Output Power Codes

Parameter 14 configures the GPIO lines to be either analog or digital. The byte is a bit map with each bit corresponding to a single line; bit 0 corresponds to GPIO_0 and bit 7 corresponds to GPIO_7. Setting a bit to 0 makes that GPIO line digital and setting it to 1 makes the line analog.

Write Non-volatile Configurations - Command Code = 23

This command writes all of the configurations that are stored in the module's non-volatile memory.

Write Non-volatile Configurations Command and Response					
Command					
Start	Command	Param 1	. . .	Param 54	End
3C	23	DType	. . .	Rsv	3E
Response					
Start	Response	Param 1	End		
3C	23	Status	3E		

Figure 28: Write Non-volatile Configurations Command and Response

This command follows the Parameters shown in Figure 25 with the exception of Parameter 55. That byte is a read-only and is not included in the Write command.

Once written, the non-volatile configurations can be read out immediately. A power cycle is required for them to take effect.

The module uses the values in volatile memory during operation. The module loads the values from non-volatile to volatile memory when it initializes after power-up, so a power cycle is necessary for the module to use the new values.

Read Analog Voltage Value - Command Code = 26

This command reads the analog voltage on a specific GPIO line.

Read Analog Voltage Value Command and Response							
Command							
Start	Command	Param 1	Param 2	End			
3C	26	00	GPIO	3E			
Response							
Start	Response	Param 1	Param 2	Param 3	Param 4	Param 5	End
3C	26	00	GPIO	ADC1	ADC2	Status	3E

Figure 30: Read Analog Voltage Value Command and Response

Parameter 1 is set to 0x00. Parameter 2 is the GPIO number to be queried, where 0 corresponds to GPIO_0 and 7 is GPIO_7 and so forth.

The response returns four parameter bytes. Parameter 1 is set to 0x00 and Parameter 2 returns the GPIO number that is being read. Param 3 and Param 4 return the voltage value on the pin. The voltage on the pin is calculated using the formula below.

$$\text{Voltage (V)} = [(\text{Param 3}) * 16 + (\text{Param 4})] / 2047 * V_{CC}$$

For example, if a Read ADC Value command returns the following response and V_{CC} is 3.0V,

$$\text{0x3C 0x26 0x00 0x07 0x21 0x0E 0x00 0x3E}$$

This means that the voltage on GPIO_7 can be calculated as

$$[(0x21) * 16 + (0x0E)] / 2047 * 3.0 = 0.794V$$

The GPIO line being read must be configured as an analog input before the ADC value can be read.

Parameter 5 indicates if the command was successful (00) or if there was an error (01).

Write Digital Output Value - Command Code = 28

This command sets the digital output value on a specific GPIO line.

Write Digital Outputs Command and Response					
Command					
Start	Command	Param 1	Param 2	Param 3	End
3C	28	00	GPIO	DOVal	3E
Response					
Start	Response	Param 1	End		
3C	28	Status	3E		

Figure 32: Write Digital Outputs Value Command and Response

Parameter 1 is set to 0x00 and Parameter 2 is the GPIO number that is being written. Parameter 3 sets the output state (High = 01; Low = 00). The configuration made in volatile memory overwrites the configuration read from the non-volatile memory until a power reset.

The GPIO to be written must be configured as a digital output before the value can be written.

The response parameter indicates if the command was successful (00) or if there was an error (01).

Read TX Power Level - Command Code = 2B

This command reads the current TX output power level from RAM.

Read TX Power Level Command and Response			
Command			
Start	Command	End	
3C	2B	3E	
Response			
Start	Response	Param 1	End
3C	2B	TXPower	3E

Figure 35: Read TX Power Level Command and Response

The TX output power levels are shown in Figure 36. This command reads the TX output power level setting stored in volatile memory, which may be different from that stored in non-volatile memory.

Transmitter Output Power Codes	
Power Level Code	**HUM-868-DT** **TX Output Power (dBm)**
00	−30
01	−20
02	−15
03	−10
04	−5
05	0
06	5
07	7
08	10

Figure 36: Transmitter Output Power Codes

Read Radio State - Command Code = 2D

This command reads the current radio state.

Read Radio State Command and Response			
Command			
Start	Command	End	
3C	2D	3E	
Response			
Start	Response	Param 1	End
3C	2D	RState	3E

Figure 38: Read Radio State Command and Response

The response returns the Radio State Code for the radio's current working state. The module can be in one of the five states shown in Figure 39.

Radio State Codes		
RState Code	**Radio State**	**Description**
0x00	Unknown	An error has happened
0x01	Sleep	The radio is in sleep mode (turned off).
0x02	Idle	The radio is turned on in an idle mode (neither TX nor RX)
0x03	RX On	The radio is in RX mode.
0x04	TX On	TX state is automatically entered when data is input to the module.

Figure 39: Radio State Codes

The Unknown state indicates an error has happened.

The Sleep state is a low-power state where the radio is powered off, but some microcontroller blocks are running.

The Idle state is a state where the RX section of the radio is turned off. However, the module can still switch to the TX On state when it has something to send. The microcontroller is running.

The RX On mode is where the radio is in receive mode and the microcontroller is running.

The TX On state is where the radio is in transmit mode and the microcontroller is running.

Read Ambient RSSI - Command Code = 2F

This command reads the current RSSI value. This indicates how quiet the current ambient RF environment is.

Read Ambient RSSI Command and Response			
Command			
Start	Command	End	
3C	2F	3E	
Response			
Start	Response	Param 1	End
3C	2F	RSSI	3E

Figure 42: Read Ambient RSSI Command and Response

The RSSI value is returned in 2's complement hex format. The RSSI value in dBm can be calculated based on the formula shown below.

$$RSSI \text{ (dBm)} = RSSI\_value \text{ (in the response)} - 256$$

This command only returns the ambient RSSI. The RSSI for a received packet is included with the packet data. The response is only valid when the radio state is set to RX On.

Read Firmware Version - Command Code = 32

This command reads out the module's firmware version.

Read Firmware Version Command and Response						
Command						
Start	Command	End				
3C	32	3E				
Response						
Start	Response	Param 1	Param 2	Param 3	Param 4	End
3C	32	FW3	FW2	FW1	FW0	3E

Figure 45: Read Firmware Version Command and Response

FW3 is the MSB and FW0 is the LSB in the number.

Read Module Serial Number - Command Code = 33

This command reads out the module's serial number.

Read Module Serial Number Command and Response						
Command						
Start	Command	End				
3C	33	3E				
Response						
Start	Response	Param 1	Param 2	Param 3	Param 4	End
3C	33	SN3	SN2	SN1	SN0	3E

Figure 46: Read Module Serial Number Command and Response

The serial number is set at the factory and cannot be changed. Every DT Series module manufactured by Linx has a unique serial number. This is different from the module address. SN3 is the MSB and SN0 is the LSB in the number.

Read Associated Modules - Command Code = 3A

This command reads out all of the modules that are associated with the current module.

Read Associates List Command and Response						
Command						
Start	Command	End				
3C	3A	3E				
Response 1						
Start	Response	Param 1	End			
3C	3A	NumMod	3E			
Response 2						
Start	Response	Param 1	Param 2	Param 3	Param 4	End
3C	3A	SrcAdr3	SrcAdr2	SrcAdr1	SrcAdr0	3E
. . .						
Response n						
Start	Response	Param 1	Param 2	Param 3	Param 4	End
3C	3A	SrcAdr3	SrcAdr2	SrcAdr1	SrcAdr0	3E

Figure 49: Read Associates List Command and Response

If the current module is an ED or RE, then the only associated node is the AP. An AP can have up to 50 associated EDs in a single network. Due to the lack of intelligence in an RE, this command does not provide the RE information.

The first response contains the number of modules associated with the current module. The module then outputs one response for each associated module that contains that module's address.

Read Associated Module Count - Command Code = 3D

This command reads the total number of modules associated with the current module.

Read Associated Module Count Command and Response			
Command			
Start	Command	End	
3C	3D	3E	
Response			
Start	Response	Param 1	End
3C	3D	Count	3E

Figure 52: Read Associated Module Count Command and Response

For an ED, the only associated module is the AP, so the count will always be 1. An AP outputs the number of EDs associated with it. The lack of intelligence in an RE prevents it from being counted. An RE always outputs a 0 because it lacks the intelligence to store its associated AP.

Read AES Key - Command Code = 43

This command reads out the AES key currently being used by the module. This can only be read out if the module is an Access Point. It cannot be read out of End Devices or Range Extenders.

Read AES Key Command and Response						
Command						
Start	Command	End				
3C	43	3E				
Response						
Start	Response	Param 1	...	Param 16	End	
3C	43	KeyMSB	...	KeyLSB	3E	

Figure 54: Read AES Key Command and Response

This reads out the key in volatile memory, which is what is currently being used to encrypt packets. This can be different from what is in non-volatile memory if the Write AES Key command has been used to change it.

If an error occurs, such as trying to read the key from an ED, the response is 3C 43 01 3E.

Write AES Key - Command Code = 44

This command writes the AES key into the module's volatile memory. This key is used to encrypt packets as soon as the write is completed.

Write AES Key Command and Response						
Command						
Start	Command	Param 1	...	Param 16	End	
3C	44	KeyMSB	...	KeyLSB	3E	
Response						
Start	Response	Param 1	End			
3C	44	Status	3E			

Figure 55: Write AES Key Command and Response

The key is written MSB first. The response parameter indicates if the command was successful (00) or if there was an error (01).

Initialization Complete Message - Response Code = 7A

Once the module has completed its power-up initialization routines and joined the network, it outputs the message shown in Figure 57.

Initialization Complete Message			
Start	Response	Param 1	End
3C	7A	DType	3E

Figure 57: Initialization Complete Message

The DType parameter is the device type that the module has assumed during initialization. These codes are shown in Figure 58.

Device Type Codes	
Device Type	Device Type Code (hex)
Access Point (AP)	31
Range Extender (RE)	32
End Device (ED)	33

Figure 58: Baud Rate Codes

The microcontroller can confirm that this is the correct device type for the application and make changes as necessary.

Power Supply Requirements

The module does not have an internal voltage regulator, therefore it requires a clean, well-regulated power source. The power supply noise should be less than 20mV. Power supply noise can significantly affect the module's performance, so providing a clean power supply for the module should be a high priority during design.
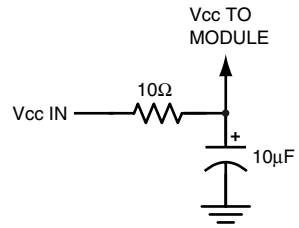
Figure 60: Supply Filter

A 10Ω resistor in series with the supply followed by a 10μF tantalum capacitor from V_{cc} to ground helps in cases where the quality of supply power is poor (Figure 60). This filter should be placed close to the module's supply lines. These values may need to be adjusted depending on the noise present on the supply line.

Antenna Considerations

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

Figure 61: Linx Antennas

Professionally designed antennas such as those from Linx (Figure 61) help ensure maximum performance and FCC and other regulatory compliance.

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

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

Interference Considerations

The RF spectrum is crowded and the potential for conflict with unwanted sources of RF is very real. While all RF products are at risk from interference, its effects can be minimized by better understanding its characteristics.

Interference may come from internal or external sources. The first step is to eliminate interference from noise sources on the board. This means paying careful attention to layout, grounding, filtering and bypassing in order to eliminate all radiated and conducted interference paths. For many products, this is straightforward; however, products containing components such as switching power supplies, motors, crystals and other potential sources of noise must be approached with care. Comparing your own design with a Linx evaluation board can help to determine if and at what level design-specific interference is present.

External interference can manifest itself in a variety of ways. Low-level interference produces noise and hashing on the output and reduces the link's overall range.

High-level interference is caused by nearby products sharing the same frequency or from near-band high-power devices. It can even come from your own products if more than one transmitter is active in the same area. It is important to remember that only one transmitter at a time can occupy a frequency, regardless of the coding of the transmitted signal. This type of interference is less common than those mentioned previously, but in severe cases it can prevent all useful function of the affected device.

Although technically not interference, multipath is also a factor to be understood. Multipath is a term used to refer to the signal cancellation effects that occur when RF waves arrive at the receiver in different phase relationships. This effect is a particularly significant factor in interior environments where objects provide many different signal reflection paths. Multipath cancellation results in lowered signal levels at the receiver and shorter useful distances for the link.

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

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

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

Each of the module's ground pins should have short traces tying immediately to the ground plane through a via.

Bypass caps should be low ESR ceramic types and located directly adjacent to the pin they are serving.

A 50-ohm coax should be used for connection to an external antenna. A 50-ohm transmission line, such as a microstrip, stripline or coplanar waveguide should be used for routing RF on the PCB. The Microstrip Details section provides additional information.

In some instances, a designer may wish to encapsulate or "pot" the product. There are a wide variety of potting compounds with varying dielectric properties. Since such compounds can considerably impact RF performance and the ability to rework or service the product, it is the responsibility of the designer to evaluate and qualify the impact and suitability of such materials.

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 66). 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
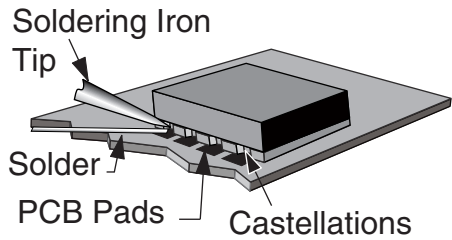
Figure 66: Soldering Technique

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 67.

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 71)

Figure 67: 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 69). 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
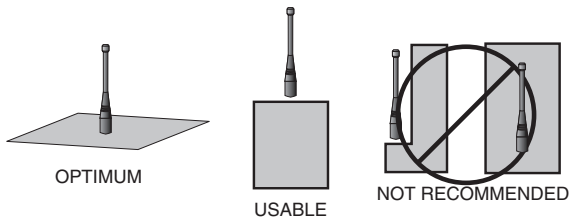
Figure 69: Ground Plane Orientation

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 70). 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
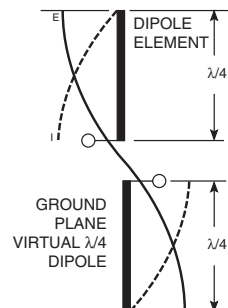
λ/4

GROUND PLANE VIRTUAL λ/4 DIPOLE

λ/4

Figure 70: 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 72) 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 72: 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 73. It is also possible to reduce the overall height of the antenna by using a helical winding. This reduces the antenna's bandwidth but is a great way to minimize the antenna's physical size for compact applications. This also means that the physical appearance is not always an indicator of the antenna's frequency.

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

Figure 73:
L = length in feet of quarter-wave length
F = operating frequency in megahertz

Specialty Styles

Linx offers a wide variety of specialized antenna styles (Figure 74). 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 74: 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.

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