Reference Guide RG-00104

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Revised 3/6/14

Introduction

The HumRC™ Series transceiver has a serial Command Data Interface (CDI) that offers the option to configure and control the transceiver through software instead of through hardware. This interface consists of a standard UART with a serial command set. This allows fewer connections in applications controlled by a micro as well as more control and advanced features than available through hardware pins alone.

Connecting the Command Data Interface

The CMD_DATA_IN and CMD_DATA_OUT lines are the interface to the module's UART (Figure 1). Serial commands and responses use a standard asynchronous serial format of 1 start bit, 1 stop bit and no parity. An automatic baud rate detection system allows the interface to run at a variable data rate from 9.0kbps to 60.0kbps. The CDI is available for use when the transceiver is not in Power Down mode. CMD_DATA_IN and CMD_DATA_OUT are suitable for direct connection to a microcontroller UART (Figure 2). They operate on logic level voltages of GND to V_{CC}.

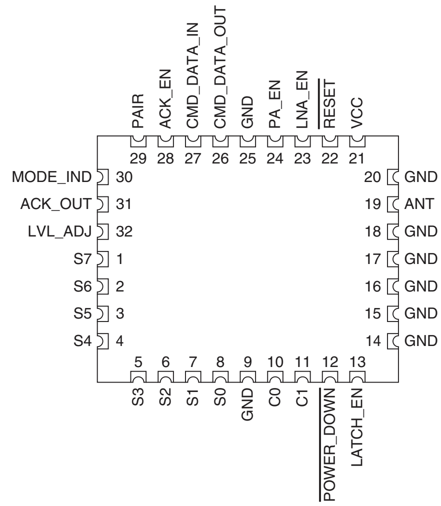

Figure 1: HumRC™ Series Transceiver Pinout (Top View)

HumRC™ Series Transceiver Pin Descriptions		
Pin #	**Name**	**Description**
26	CMD_DATA_OUT	Command Data Out. This line outputs the command data responses when configuring the module.
27	CMD_DATA_IN	Command Data In. This line is the input for command data to set up the module.

Figure 2: HUM RC Series Transceiver Pin Descriptions

The Command Data Interface Command and Response Format

The serial command format is:

[Prefix] [Payload]

Where the Prefix is one of the following formats (hexadecimal values):

Normal Prefix

[80] [55] [80+ Payload Length]

Quick-Wakeup Prefix:

[80] [Wakeup Sequence] [55] [80+ Payload Length]

Both prefixes always work. If the module is sleeping when a command is sent, the quick-wakeup prefix allows the command to be processed immediately. A command with the normal prefix only wakes the unit, requiring the command to be sent a second time within 1250ms.

Responses use only the normal prefix.

The Quick-Wakeup prefix contains a Wakeup Sequence of 0xFF bytes to allow the module to process the message that wakes it from low-power sleep mode without needing to retransmit the command. The following table shows the number of 0xFF bytes in the Wakeup Sequence needed to process the wakeup packet.

HumRC™ Series Transceiver Pin Descriptions	
Data Rate (kbps)	Minimum number of 0xFF bytes needed to process the wakeup command
9.0 – 10.0	0
10.0 – 19.6	2
19.6 – 58.0	4
58.0 – 60.0	6

Figure 3: HumRC™ Series Transceiver Pin Descriptions

The payload length is in bytes, so if there are three bytes of payload then the last prefix value is a hexadecimal 83. If there are four bytes, then the last prefix value is a hexadecimal 84.

The payload varies with the serial command that is used and is described for each command in the Command Data Interface Command Set section.

If a response is not received within the maximum response time, command bytes may have been lost. If this happens, the command should be resent.

Once the initial prefix byte is sent, the command must be completely sent within 1500ms. Partial packets are discarded 1500ms after the first byte.

After a message is received, the module waits 1250ms before allowing the module to go into sleep mode. This allows additional serial commands to be processed without needing to send wakeup transmissions. Whether the module sleeps after a command is sent depends on the selected configuration.

Bytes are sent LSB first with one start bit and one stop bit as in Figure 4.

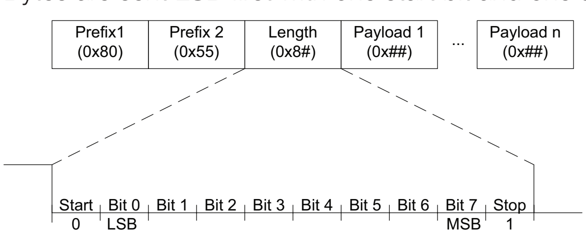

Figure 4: HUM RC Series Transceiver CDI Data Structure

The module accepts serial data rates from 9.0 to 60.0 kbps. This allows use of non-standard data rates from low-frequency processor oscillators. It also accommodates variations in RC-based oscillator frequencies over temperature.

The module operates at 57.6kbps when powered up or reset. If received bytes do not conform to the packet format, the module enters auto-baud mode after two consecutive packet failures. In this mode, the module waits for a CD_IN idle period of at least 25ms, then times the first bytes received. The first byte of a packet should be 0x80, which contains 8 consecutive zero bits. This 8-bit time period is measured and the corresponding bit rate set. The next message is read at the measured data rate and responses are sent at the same rate. Once a data rate is set, it remains unchanged until the module is reset or incoming messages are not received properly.

The Command Data Interface Command Set

The Command Data Interface has a set of commands that perform specific tasks. Parameters following a command byte specify the exact operation. These are shown in Figure 5 and Figure 6. The values are shown in hexadecimal format unless otherwise stated.

The 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 takes longer to access, but is retained when power is removed. Non-volatile memory is limited in the number of changes that can be written before wearing out.

Most configuration parameters have the working value in volatile memory. These are loaded from non-volatile memory on power-up. There are commands to read and write both locations. The Read and Write commands are associated with volatile memory and the Read NV and Program commands are associated with the non-volatile memory. The Program command changes both locations. The Write command only changes the volatile location.

Figure 6 shows where each parameter is stored and the commands that are valid with each parameter.

Command Data Interface Commands

Command	CMD Code (hex)	Response Code (Hex)	Description
Read	01	C1	Read the current value in volatile memory. If there is no volatile value, then the non-volatile value is returned.
Write	02	C0	Write a new value to volatile memory.
Read NV	03	C2	Read the value in non-volatile memory.
Program	04	C0	Program a new value to non-volatile memory.
Set Default Configuration	81	C0	Set all configuration items to their factory default values.
Erase All Addresses	82	C0	Erase all paired addresses from memory.
Transmit Control Data	83	C0	Transmit a control message.
Transmit ACK	84	C0	Transmit an acknowledgement for received data.
Transmit AWD	85	C0	Transmit an Acknowledge With Data (AWD) response with 2 bytes of custom data.
Transmit IU Packet	86	C0	Transmit a general IU packet.
NV Update	90	C0	Write all NV changes to NV memory.
Pair Control	91	C0	Initiate / Cancel RF Pairing with another module.

Figure 5: HumRC™ Series Transceiver Command Data Interface Commands

Command Data Interface Parameters				
Parameter	**Location**	**CMD**	**ItemID (hex)**	**Description**
Device Name	N	R, N	01	NULL-terminated ASCII string of up to 16 characters that identifies the module.
Firmware Version	N	R, N	02	3 byte firmware version.
Serial Number	N	R, N	03	4 byte factory-set serial number.
Local Address	N	R, N, P	10	The module's 32-bit local address.
Status Line I/O Mask	N, V	R, N, W, P	11	Status lines direction (1 = Inputs, 0 = Outputs), LSB = S0, used when enabled by Control Source.
Latch Mask	N, V	R, N, W, P	12	Latching enable for output lines, LSB = S0, used when enabled by Control Source.
TX Power Level	N, V	R, N, W, P	13	TX output power, signed nominal dBm, used when enabled by Control Source.
Control Source	N, V	R, N, W, P	14	Configures the hardware / software control options.
Message Select	N, V	R, N, W, P	15	Select message types to capture for serial readout.
Analog Input Select	N, V	R, N, W, P	16	Define analog sources, averaging, reference, and offset.
Custom Data Source	N, V	R, N, W, P	17	Source of transmitted custom data.
Paired Module Descriptor	N, V	R, N, P	18	Sets the address and permissions mask of paired modules.
Trigger Operation	N, V	R, N, W, P	19	Input Trigger operation.
Receiver Duty Cycle	N, V	R, N, W, P	1A	Receiver duty cycle control.
I/O Lines	V	R	20	Read the current state of the status and control lines.
RSSI	V	R	21	Read the RSSI of the last packet received and ambient level.
LADJ	V	R	22	Read the voltage on the LVL_ADJ line.
Module Status	V	R	23	Read the operating status of the module.
Captured Receive Packet	V	R	24	Read the last received packet.
Interrupt Mask	N, V	R, W, P	25	Sets the mask for events to generate a break on CMD_DATA_OUT.
Event Flags	V	R, W	26	Event flags that are used with the Interrupt Mask.
Analog Input Reading	V	R, W	27	Readout of the analog input lines.
Trigger Input Status	V	R	28	Status of Trigger Inputs.
Pairing Status	V	R	29	Status of Last Pair attempt since power-up.

Figure 6: HumRC™ Series Transceiver Command Data Interface Commands

The Location column indicates where the data is stored; N = Non-volatile memory, V = Volatile memory

The CMD column indicates which commands are valid with the parameter; R = Read, W = Write, N = Read Non-volatile, P = Program

CDI Responses

The module sends a response message on CD_OUT after receiving a recognized command on CD_IN. All of the commands except Read and ReadNV return an Acknowledge response. The Read commands trigger a response that contains the requested data. If the read commands fail then an acknowledge response is returned with the error code. The responses are described with the associated commands in the following sections.

CDI Commands

Read

The Read command returns the value of the requested parameter from volatile memory. The volatile location is used in normal operation. If the parameter does not use a volatile location, then the associated non-volatile location is returned.

Command Format: [Prefix] [01] [ItemID] [Index]
01 = Read command
ItemID = the parameter to read
Index = optional byte that is used with the Paired Module Descriptor and Analog Input Select parameters

The Read command triggers a Read Active Data (RAD) response.

Reply Format: [Prefix] [C1] [ItemID] [Values]
C1 = RAD response
ItemID = the parameter that was read
Values = the parameter values being returned

If the command fails then the module returns an Acknowledge (ACK) response with the appropriate error code.

Reply Format: [Prefix] [C0] [Error Code] [Command Payload]
C0 = ACK reply
Error Code = shown in Figure 7.
Command Payload = the command that was received by the module

ACK Response Error Codes		
Command	**Code**	**Description**
ERR_NONE	00	The command succeeded. No error occurred.
ERR_CMND	F1	The command or Read/ReadNV/Write/Program ItemID field is undefined
ERR_VALU	F2	The value field is out or range for specified command or Write/Program Item field
ERR_INTN	F3	Internal error
ERR_SNFG	F4	Item is locked or read-only and cannot be written (includes inhibit during Pairing process)

Figure 7: ACK Response Error Codes

Write

The Write command sets the parameter to the specified value in volatile memory. It remains in effect until the module is reset by cycling power or taking the $\overline{\text{RESET}}$ line high. Volatile parameters are set to the corresponding non-volatile values on power-up. Unless otherwise specified, changes take effect as soon as a non-error response is sent.

Command Format: [Prefix] [02] [ItemID] [Values]
02 = Write Command
ItemID = the parameter to write
Values = One or more bytes containing new parameter values

The Write command triggers an Acknowledge (ACK) response.

Reply Format: [Prefix] [C0] [Error Code] [Command Payload]
C0 = ACK reply
Error Code = shown in Figure 7.
Command Payload = the command that was received by the module

Read NV

The Read NV command returns the value of the requested parameter that is in non-volatile memory. This command is primarily for diagnostic purposes. The Read command is recommended for normal interface since this returns the values currently being used by the module.

Command Format: [Prefix] [03] [ItemID] [Index]
03 = Read NV command
ItemID = the parameter to read
Index = optional byte that is used with the Paired Module Descriptor parameter

The ReadNV command triggers a Read Non-Volatile Data (RNVD) response.

Reply Format: [Prefix] [C2] [ItemID] [Values]
C2 = Read NV response
ItemID = the parameter that was read
Values = the parameter values being returned

If the command fails then the module returns an Acknowledge (ACK) response with the appropriate error code.

Reply Format: [Prefix] [C0] [Error Code] [Command Payload]
C0 = ACK reply
Error Code = shown in Figure 7.
Command Payload = the command that was received by the module

Program

The Program command sets the parameter to the specified value in both volatile and non-volatile memory. It remains the default value on power-up until the non-volatile parameter is rewritten or the module is reset to factory defaults. Unless otherwise specified, changes to the parameters take effect as soon as a non-error response is sent.

Although the changes caused by the Program operation take effect immediately, the changes are initially written to temporary storage. Executing the NV Update command causes the changes to be written to non-volatile memory. If power is lost after a Program command and before a NV Update command, the changed data will be lost.

Command Format: [Prefix] [04] [ItemID] [Values]
04 = Program Command
ItemID = the parameter to program
Values = One or more bytes containing new parameter values

The Program command triggers an ACK response just like the Write command.

Reply Format: [Prefix] [C0] [Error Code] [Command Payload]
C0 = ACK reply
Error Code = shown in Figure 7.
Command Payload = the command that was received by the module

Set Default Configuration

This command sets all configuration parameters to the factory default values.

Set Default Configuration

Command

Prefix	PKT LGTH	CMD	ItemID	V1
80 55	83	81	AB	7E

Response

Prefix	PKT LGTH	Code	Error	V1	V2	V3
80 55	85	C0	00	81	AB	7E

Figure 8: Set Default Configuration Command and Response

Erase All Addresses

This command erases all of the paired modules from memory.

Erase All Addresses

Command

Prefix	PKT LGTH	CMD	ItemID	V1
80 55	83	82	AB	7D

Response

Prefix	PKT LGTH	Code	Error	V1	V2	V3
80 55	85	C0	00	82	AB	7D

Figure 9: Erase All Addresses Command and Response

Transmit Control Data

This command initiates the transmission of a specified number of control packets with specified status line settings and two bytes of custom data. Multiple transmissions increase the probability that the RU will receive the data.

Transmit Control Data

Command

Prefix	PKT LGTH	CMD	ItemID	V1	V2	V3	V4
80 55	86	83	Flags	Duration	Status	CData1	CData2

Response

Prefix	PKT LGTH	Code	Error	V1	V2	V3	V4	V5	V6
80 55	88	C0	00	83	Flags	Duration	Status	CData1	CData2

Figure 10: Transmit Control Data Command and Response

Transmit Control Data Fields

Field	Description
Flags	Transmit Wait 0 = Transmit on the next slot 1 = Wait until the module completes the previous transmission
Duration	The number of packets to transmit. Multiple transmissions increase the probability that the RU will receive the data.
Status	Status line settings to transmit; bit b0 is line S0, b7 is line S7.
CData1, CData2	Custom data values to transmit with the packet.

Figure 11: Transmit Control Data Fields

If a transmit operation is in process when a new transmit command is issued, the Wait bit (FLAGS.0) determines whether the new data transmits immediately or waits until the previous packet count is complete. In both cases the transmit hop timing continues without interruption. The Wait bit has no effect if the transmitter is not active.

The TX Packet Sent event flag is set when all packets of each command have been transmitted. A series of different packets can be transmitted continuously using the wait bit and this flag to start loading the next packet. The interrupt mask can be used to generate a break when the flag is set.

When the transmit packet counter expires without new control data the IU transmitter starts shutdown timing, which terminates transmission at the end of the current channel cycle.

A previously initiated transmission can be terminated early by sending a Transmit Control Data command with Wait=0 and Duration=0. This initiates the shutdown timing.

If the module is transmitting from status line activation when this command is sent, the previous transmission data is immediately replaced with data from this command. Hardware-based transmission control resumes when the Transmit Command Data command or command series times out.

Transmit ACK

This command initiates transmission of acknowledgement for the control message currently being received. It must be initiated before the control message transmission terminates.

Transmit ACK

Command

Prefix	PKT LGTH	CMD	ItemID	V1
80 55	83	84	Qual	NPkts

Response

Prefix	PKT LGTH	Code	Error	V1	V2	V3
80 55	85	C0	00	84	Qual	NPkts

Figure 12: Transmit ACK Command and Response

Transmit Control Data Fields

Field	Description
Qual	ACK Qualifier 0 = transmit an ACK as a response to control packets in the current RU session matching the packet output by reading Captured Receive Packet. ACK transmission is cancelled by a change of received data or the end of the current RU session. 1 = transmit an ACK for any packet during the current RU session. ACK transmission is cancelled by the end of the current RU session.
NPkts	Number of Packets – maximum number of acknowledge packets to transmit, 0 = continuous for the current session.

Figure 13: Transmit Control Data Fields

For both qualifier modes, a received control packet from the current RU session must have been read serially by using the Read command for the Captured Receive Packet parameter. The ACK transmission is terminated after NPkts packets have been transmitted or the IU stops sending control packets.

For Qual = 0, the ACK is cancelled if the received control data (Status or Custom Data field) is different from the data read by Captured Receive Packet. This mode assures that an ACK is transmitted only for the exact data which has been read from the RU. This qualifier can result in no ACKs being sent if the incoming control data changes before the first opportunity to transmit an ACK.

For Qual = 1, the ACK is not cancelled by control data changes. This mode is appropriate if status line changes during a transmission should not interrupt ACK transmission.

An ACK packet is transmitted to the IU immediately after receiving the next transmission if the qualifier condition is true. If the qualifier condition is false, the ACK transmission is cancelled. If NPkts = 0, the acknowledge message is transmitted for each incoming message of the RU session as long as the qualifier is true.

If an AWD response is active or pending when a Transmit ACK message is received, the AWD transmission request is cancelled and the Transmit ACK becomes effective.

The TX Packet Sent event flag is set when all packets of have been transmitted. The interrupt mask can be used to generate a break when the flag is set.

Transmit AWD

This command initiates transmission of an Acknowledge With Data (AWD) response to the current control messages being received. The response includes two bytes of custom data which can be read from the IU.
For qualifier modes 0 and 1, a received control packet from the current RU session must have been read serially by using the Read command for Captured Receive Packet. The AWD transmission is terminated after NPkts packets have been transmitted or the IU stops sending control packets.

Transmit AWD

Command

Prefix	PKT LGTH	CMD	ItemID	V1	V2	V3
80 55	85	85	Qual	NPkts	CData1	CData2

Response

Prefix	PKT LGTH	Code	Error	V1	V2	V3	V4	V5
80 55	87	C0	00	85	Qual	NPkts	CData1	CData2

Figure 14: Transmit AWD Command and Response

Transmit Control Data Fields

Field	Description
Qual	AWD Qualifier 0 = transmit an AWD as a response to control packets in the current RU session matching the packet output by reading Captured Receive Packet. AWD transmission is cancelled by a change of received data or the end of the current RU session. 1 = transmit an AWD for any packet during the current RU session. AWD transmission is cancelled by the end of the current RU session. 2 = transmit AWD for the next RU session. The AWD transmission is cancelled by the end of the RU session in which the AWD response was transmitted.
NPkts	Number of Packets – maximum number of acknowledge packets to transmit, 0 = continuous for the response session. It is recommended to send a minimum of 4 packets.
CData1, CData2	Custom data values to transmit with the acknowledgement packet.

Figure 15: Transmit Control Data Fields

For Qual = 0, the AWD is cancelled if the received control data (Status or Custom Data field) is different from the data read by Captured Receive Packet. This mode assures that an AWD is transmitted only for the exact data which has been read from the RU. This qualifier can result in no AWD being sent if the incoming control data changes before the first opportunity to transmit an AWD.

For Qual = 1, the AWD is not cancelled by control data changes. This mode is appropriate if status data changes during transmission should not interrupt AWD transmission.

For Qual = 2, the AWD is transmitted in response to the current RU session or, if no RU session is active, the next RU session. Unlike qualifiers 0 and 1, the response is sent for an RU session with any valid IU and any control data from the IU. The transmission is terminated by the end of the responding RU session. A pending request to transmit for the next RU session is cancelled by resetting the module through Power Down or a power cycle.

An AWD packet is transmitted to the IU immediately after receiving the next transmission if the specified qualifier condition is true. If the qualifier condition is false, the AWD transmission is cancelled. If NPkts = 0, the acknowledge message is transmitted for each incoming message of the RU session as long as the qualifier is true.

If an Acknowledge response is active when a Transmit AWD message is received, the Acknowledge transmission is cancelled and the Transmit AWD becomes effective, instead.

The TX Packet Sent event flag is set when all packets of have been transmitted. The interrupt mask can be used to generate a break when the flag is set. This can be used to send multiple AWD responses within a single ID session.

Transmit IU Packet

This command initiates the transmission of a request sample packet. This prompts a properly configured RU to automatically respond with the requested information.

Transmit IU Packet

Command

Prefix	PKT LGTH	CMD	ItemID	V1	V2	V3	V4	V5
80 55	87	86	Flags	Duration	08	MType	RUAdd1	RUAdd2

Response

Prefix	PKT LGTH	Code	Error	V1	V2	V3	V4	V5	V6	V7
80 55	89	C0	00	86	Flags	Duration	08	MType	RUAdd1	RUAdd2

Figure 16: Transmit IU Packet Command and Response

Transmit IU Packet Fields

Field	Description
Flags	Transmit Wait 0 = Transmit on the next slot 1 = Wait until the module completes the previous transmission
Duration	The number of packets to transmit. Multiple transmissions increase the probability that the RU will receive the data.
MType	The type of measurement requested. 0 = Digital Status in first byte 1 = CData contains AN1 reading 2 = CData contains AN2 reading 3 = CData contains AN1 and AN2 readings, 8 bits each
RUAdd	The last 2 bytes of the address for the module that should respond to the request.

Figure 17: Analog Input Select Fields

If a transmit operation is in process when a new transmit command is issued, the Wait bit (FLAGS.0) determines whether the new data transmits immediately or waits until the previous packet count is complete. In both cases the transmit hop timing continues without interruption. The Wait bit has no effect if the transmitter is not active.

The TX Packet Sent event flag is set when all packets of each command have been transmitted. A series of different packets can be transmitted continuously using the wait bit and the TX Packet Sent event flag to start loading the next packet. The interrupt mask can be used to generate a break when the flag is set.

When the transmit packet counter expires without new control data the IU transmitter starts shutdown timing, which terminates transmission at the end of the current channel cycle.

A previously initiated transmission can be terminated early by sending a Transmit Control Data command with Wait=0 and Duration=0. This initiates the shutdown timing.

If the module is transmitting from status line activation when this command is sent, the previous transmission data is immediately replaced with data from this command. Hardware-based transmission control resumes when the Transmit Command Data command or command series times out.

A responding unit that has the following configuration responds to this message:

1. The last two bytes of its address match the RUAdd bytes

2. Control Source byte CWord bit five (Respond to Request Remote Sample) is set to 1

The response is automatic and does not require any external activation at the RU.

This can be used to configure remote sensors. The IU in a master monitoring device can poll a number of RUs that are connected to sensors. The RUs would receive the command, take their analog readings and respond with the measured values. This eliminates the need for an external microcontroller at the RU, lowering the cost and development effort for a remote sensor unit.

NV Update

The module’s non-volatile memory is limited to approximately 1,000 write cycles, so changes made with the Program command are held in temporary memory. This command writes those changes to non-volatile memory, allowing multiple configuration parameters to be written at one time, extending the number of NV updates possible in the module and providing faster response.

NV Update

Command

Prefix	PKT LGTH	CMD
80 55	81	90

Response

Prefix	PKT LGTH	Code	Error	V1
80 55	83	C0	00	90

Figure 18: NV Update Command and Response

Although any order of Program operations results in the data being correctly stored, using an optimum sequence of Program operation prevents intermediate NV writes, which extends the number of NV updates allowed. The optimum sequence is writing ItemIDs in the following order: 10, 11, 12, 13, 14, 15, 16, 17, 19, 25 and 18. Remote Node descriptors should be written in ascending index order. Unchanged data do not have to be rewritten.

Warning: The module’s non-volatile memory is limited to approximately 1,000 write cycles. Queue up multiple changes with the Program command and then load all of the changes into non-volatile memory at one time with the NV Update command.

Pair Control

This command starts or stops the pairing process, similar to operation started by asserting the PAIR input.

Pair Control					
Command					
Prefix	PKT LGTH	CMD	ItemID		
80 55	82	91	OP		
Response					
Prefix	PKT LGTH	Code	Error	V1	V2
80 55	84	C0	00	91	OP

Figure 19: Pair Controll Command and Response

OP = 0 Cancel Pairing Process
OP = 1 Start Pairing Process

The pairing terminates after 30 seconds with no successful pairing, but can be either sooner or longer (extended by pairing node) if a pairing unit is detected.

The command response is send immediately after starting a pairing process.

The pairing process can be cancelled by sending the command with OP = 0.

The results of the pairing process can be read from the Pairing Status ItemID.

CDI Parameters

Device Name - ItemID = 01

This ASCII value starts with "HUM-xxx-RC" to indicate an RC Series Transceiver where "xxx" is a frequency designator (915 = 902-928 MHz). The characters "HUM-xxx-RC" may be followed by additional characters indicating factory model or configuration codes. The variable-length name is terminated with a null byte (00).

Device Name

Read Command

Prefix	PKT LGTH	CMD	ItemID
80 55	82	01	01

Read Response

Prefix	PKT LGTH	Code	ItemID	V1	V2	V3	V4	V5	V6	V7
80 55	89	C1	01	52	43	2D	32	50	34	00

Figure 20: Device Name Command and Response

Firmware Version - ItemID = 02

These three bytes contain the major, minor and incremental fields of the firmware version number.

Firmware Version

Read Command

Prefix	PKT LGTH	CMD	ItemID
80 55	82	01	02

Read Response

Prefix	PKT LGTH	Code	ItemID	V1	V2	V3
80 55	85	C1	02	FWH	FWL	FWI

Figure 21: Firmware Version Command and Response

Each byte is a hexadecimal value: 12 03 01 indicates version 18.3.1.
FWH = major version number
FWL = minor version number
FWI = incremental version number

Serial Number - ItemID = 03

This parameter is the factory-set 32-bit serial number for the module.

Serial Number

Read Command

Prefix	PKT LGTH	CMD	ItemID
80 55	82	01	03

Read Response

Prefix	PKT LGTH	Code	ItemID	V1	V2	V3	V4
80 55	86	C1	03	SER1	SER2	SER3	SER4

Figure 22: Serial Number Command and Response

SER1 is the MSB and SER4 is the LSB of the serial number. This number is factory set and cannot be changed.

Local Address - ItemID = 10

This four-byte value is the local address for the module, which is transmitted with every control message. It is preset to a unique value at the factory, but can be changed. An address of 0xFFFFFFFF designates "no address" and is not allowed.

Local Address

Read Command

Prefix	PKT LGTH	CMD	ItemID
80 55	82	01	10

Read Response

Prefix	PKT LGTH	Code	ItemID	V1	V2	V3	V4
80 55	86	C1	10	ADR1	ADR2	ADR3	ADR4

Program Command

Prefix	PKT LGTH	CMD	ItemID	V1	V2	V3	V4
80 55	86	04	10	ADR1	ADR2	ADR3	ADR4

Program Response

Prefix	PKT LGTH	Code	Error	V1	V2	V3	V4	V5	V6
80 55	88	C0	00	04	10	ADR1	ADR2	ADR3	ADR4

Figure 23: Local Address Command and Response

Status Line I/O Mask - ItemID = 11

This byte sets the input / output direction for the eight status lines. This item is enabled when Control Source byte CWord.3 = 1. It has no effect when CWord.3 = 0. This parameter value is independent of the C0 and C1 lines.

A 1 bit configures the corresponding status line as an input, 0 for output. The least significant bit configures line S0. The factory default is FF, making all lines inputs. Status lines that change from input to output are initially driven low.

Status Line I/O Mask

Read Command

Prefix	PKT LGTH	CMD	ItemID
80 55	82	01	11

Read Response

Prefix	PKT LGTH	Code	ItemID	V1
80 55	83	C1	11	SMask

Write Command

Prefix	PKT LGTH	CMD	ItemID	V1
80 55	83	02	11	SMask

Write Response

Prefix	PKT LGTH	Code	Error	V1	V2	V3
80 55	85	C0	00	02	11	SMask

Program Command

Prefix	PKT LGTH	CMD	ItemID	V1
80 55	83	04	11	SMask

Program Response

Prefix	PKT LGTH	Code	Error	V1	V2	V3
80 55	85	C0	00	04	11	SMask

Figure 24: Status Line I/O Mask Command and Response

Latch Mask - ItemID = 12

This byte selects latching mode for the status line outputs. This item is enabled when Control Source byte CWord.4 = 1. When CWord.4 = 0, the latched or momentary configuration is set by the LATCH_EN line.

When Control Source byte CWord.4 = 1, the status line outputs with a corresponding 1 bit in the mask operate in latching mode. A 0 bit configures them for momentary operation. The least significant bit configures line S0. The factory default is 00, making all lines momentary.

Latch Mask

Read Command

Prefix	PKT LGTH	CMD	ItemID
80 55	82	01	12

Read Response

Prefix	PKT LGTH	Code	ItemID	V1
80 55	83	C1	12	LMask

Write Command

Prefix	PKT LGTH	CMD	ItemID	V1
80 55	83	02	12	LMask

Write Response

Prefix	PKT LGTH	Code	Error	V1	V2	V3
80 55	85	C0	00	02	12	LMask

Program Command

Prefix	PKT LGTH	CMD	ItemID	V1
80 55	83	04	12	LMask

Program Response

Prefix	PKT LGTH	Code	Error	V1	V2	V3
80 55	85	C0	00	04	12	LMask

Figure 25: Latch Mask Command and Response

TX Power Level - ItemID = 13

This signed byte sets the module's RF output power in dBm.

TX Power Level

Read Command

Prefix	PKT LGTH	CMD	ItemID
80 55	82	01	13

Read Response

Prefix	PKT LGTH	Code	ItemID	V1
80 55	83	C1	13	TXPower

Write Command

Prefix	PKT LGTH	CMD	ItemID	V1
80 55	83	02	13	TXPower

Write Response

Prefix	PKT LGTH	Code	Error	V1	V2	V3
80 55	85	C0	00	02	13	TXPower

Program Command

Prefix	PKT LGTH	CMD	ItemID	V1
80 55	83	04	13	TXPower

Program Response

Prefix	PKT LGTH	Code	Error	V1	V2	V3
80 55	85	C0	00	04	13	TXPower

Figure 26: TX Power Level Command and Response

This is enabled when Control Source byte CWORD.0 = 1. It is set and read independently of the LVL_ADJ input. The value is signed twos compliment (e.g. -4 is set as FC). The effective range varies with the frequency band of the module. A value larger than the maximum module value results in the maximum output value. This value is approximate and doesn't reflect the antenna connection or efficiency. The factory default is 0. Changes take effect on the start of the next IU session.

Control Source - ItemID = 14

This item selects between the hardware line operation and software operation. It also contains the custom 2 data bytes that are sent with control messages.

Control Source

Read Command

Prefix	PKT LGTH	CMD	ItemID
80 55	82	01	14

Read Response

Prefix	PKT LGTH	Code	ItemID	V1	V2	V3
80 55	85	C1	14	CWord	CData1	CData2

Write Command

Prefix	PKT LGTH	CMD	ItemID	V1	V2	V3
80 55	85	02	14	CWord	CData1	CData2

Write Response

Prefix	PKT LGTH	Code	Error	V1	V2	V3	V4	V5
80 55	87	C0	00	02	14	CWord	CData1	CData2

Program Command

Prefix	PKT LGTH	CMD	ItemID	V1	V2	V3
80 55	85	04	14	CWord	CData1	CData2

Program Response

Prefix	PKT LGTH	Code	Error	V1	V2	V3	V4	V5
80 55	87	C0	00	04	14	CWord	CData1	CData2

Figure 27: Control Source Command and Response

CWord has control bits that determine which aspects of operation are controlled by control lines, and which are controlled by internal configuration. Figure 28 shows the definition of the CWord bits.

CData is a two-byte value for the custom data field that is transmitted with each Control Data message initiated by a status input line. The default value is 0. Different values for CData can be sent by the Transmit Control Data serial command or by setting a non-default option with the Custom Data Source parameter. Changes to the power level source take effect on the start of the next IU session. Other control changes take effect immediately.

CWord Definition	
CWord Bit	**Description**
0	TX RF Power Level Source 0 = TX output power is set by the voltage on LVL_ADJ at startup (default) 1 = TX output power is set by the TX Power Level Serial Command
1	Enable Status Lines 0 = Hardware lines disabled, transmit only on serial command or Triggered Input Transmit Control 1 = Hardware lines enabled, transmit when active (default)
2	Enable Receiver 0 = Receiver Off 1 = Receiver Active (default)
3	Status Line Direction Control 0 = Direction Set by C0 and C1 (default) 1 = Direction Set by Status Line I/O Mask
4	Output Latch Control 0 = All outputs are latched if LATCH_EN is high, unlatched if low (default) 1 = Set by Latch Mask
5	Respond to Request Remote Sample 0 = Response is disabled 1 = Response is enabled (default)
6–7	Reserved, set to 0

Figure 28: CWord Byte Definition

Message Select - ItemID = 15

This byte selects which received packet types are captured for readout with Captured Receive Packet.

Message Select

Read Command

Prefix	PKT LGTH	CMD	ItemID
80 55	82	01	15

Read Response

Prefix	PKT LGTH	Code	ItemID	V1
80 55	83	C1	15	MSel

Write Command

Prefix	PKT LGTH	CMD	ItemID	V1
80 55	83	02	15	MSel

Write Response

Prefix	PKT LGTH	Code	Error	V1	V2	V3
80 55	85	C0	00	02	15	MSel

Program Command

Prefix	PKT LGTH	CMD	ItemID	V1
80 55	83	04	15	MSel

Program Response

Prefix	PKT LGTH	Code	Error	V1	V2	V3
80 55	85	C0	00	04	15	MSel

Figure 29: Message Select Command and Response

A message is captured for readout with Captured Receive Packet if it matches the selected type, any previously captured message has been read, and

1. It is the first message captured, or
2. It is different from the previously captured message, or
3. It is from a newer control session than the previously captured message

Once captured, it remains available for readout until the module is reset.

Setting the Interrupt Mask bit 0 (IMask.0) to a 1 enables an interrupt event when a new message of the selected type is captured. This tells an external processor that a new message is available to be read. Please see the Interrupt Mask section for more information.

The interrupt event is useful when reading the packets directly rather than using the status line outputs to drive circuitry. An example is if a system needs more than 40 paired devices, then setting Message Select to 6 causes the module to accept any HumRC-compatible packet. When the Notify Event occurs, the Captured Receive Packet item can be used to pass the message to an external device with more memory to handle the address verification. The custom data bytes can be used for further verification of the system or additional control.

Message Select Definition	
MSel Value	**Description**
0	None (default)
1	New control message from a paired source
2	New received response message (packet type 4, 5, or 9[1]) during IU TX operation
3	Types 1 and 2
4	New valid control message from any address
5	New valid control, Acknowledge, or AWD message from any address
6	Any new message with RC-compatible modulation, sync, length code, and CRC

1. See the Captured Receive Packet item for the packet type definitions.

Figure 30: Message Select Definition

Note: A captured message must be read through the Last Receive Packet Captured parameter or EVFLG.0 in Event Flags must be cleared in order to clear a received-message interrupt and allow future interrupts.

Analog Input Select - ItemID = 16

Two of the status lines can be configured as analog inputs, designated AN1 and AN2. This ItemID configures analog inputs.

Analog Input Select

Read Command

Prefix	PKT LGTH	CMD	ItemID	ACX
80 55	83	01	16	01

Read Response

Prefix	PKT LGTH	Code	ItemID	V1	V2	V3	V4	V5	V6
80 55	88	C1	16	ACX	AChan	ARead	ARef	AOfs1	AOfs2

Write Command

Prefix	PKT LGTH	CMD	ItemID	V1	V2	V3	V4	V5	V6
80 55	88	02	16	ACX	AChan	ARead	ARef	AOfs1	AOfs2

Write Response

Prefix	PKT LGTH	Code	Error	V1	V2	V3	V4	V5	V6	V5	V6
80 55	8A	C0	00	02	16	ACX	AChan	ARead	ARef	AOfs1	AOfs2

Program Command

Prefix	PKT LGTH	CMD	ItemID	V1	V2	V3	V4	V5	V6
80 55	88	04	16	ACX	AChan	ARead	ARef	AOfs1	AOfs2

Program Response

Prefix	PKT LGTH	Code	Error	V1	V2	V3	V4	V5	V6	V5	V6
80 55	8A	C0	00	04	16	ACX	AChan	ARead	ARef	AOfs1	AOfs2

Figure 31: Analog Input Select Command and Response

Analog Input Select Fields

Field	Description
ACX	Analog Configuration Index, 1 or 2
AChan	Analog input Channel 4-7 = S4-S7 FE = temperature sensor FF = none (default)
ARead	Number of readings averaged, 1 - 16 (default = 1)
ARef	Analog Voltage Reference Source 0 = Vcc (default) 1 = 1.25V internal reference
AOfs	Offset value added to all readings (MSB first, default = 00 00)

Figure 32: Analog Input Select Fields

The ACX byte identifies the analog source configuration. The analog channels must be configured one at a time.

AChan defines the analog channel that is used. This selects between the 4 possible status lines (S4, S5, S6 or S7), the internal temperature sensor or turns the channel off.

ARead configures the number of readings for the 12-bit Analog-to-Digital Converter (ADC) to take. These readings are averaged and the average value is returned. This averaging helps to eliminate noise and fluctuations on the line at the expense of more time.

ARef selects the voltage reference source for the ADC, either the supply voltage or the internal precision 1.25V source. The voltage selected by this field is used in the equation below. The ADC cannot read values larger than the selected reference.

The offset parameter AOfs allows modules to apply adjustments to compensate for variations in either the module or the external system. This allows for the analog channel to be calibrated for each product.

The two-byte returned value (Readout) is given by the following equation.

$$\text{Readout} = (V_{IN} / V_{REF} * 65{,}536) + \text{AOfs}$$

Where

V_{IN} = non-negative input voltage
V_{REF} = selected reference voltage
AOfs = specified integer
Readout = two-byte result

The temperature sensor is linear with a gain of 2.43mV/°C and approximate 0°C voltage of 0.733 V. Some part-to-part variation is typical, so calibrating the offset improves the temperature measurement accuracy.

The readout is unsigned. Negative voltages read as 0. Voltages > V_{REF} read as FFE0.

Example commands:

1. 80 55 83 01 16 01 Read analog source 1 configuration

2. 80 55 88 02 16 02 04 10 00 00 00 Set analog configuration 2, in volatile RAM, to read S4, average 16 readings, use Vcc as full-scale reference, and add 0 to the measured result (no added offset).

Custom Data Source - ItemID = 17

This parameter selects the custom data values transmitted with IU messages initiated by taking status line inputs high.

Custom Data Source

Read Command

Prefix	PKT LGTH	CMD	ItemID
80 55	82	01	17

Read Response

Prefix	PKT LGTH	Code	ItemID	V1
80 55	83	C1	17	CDS

Write Command

Prefix	PKT LGTH	CMD	ItemID	V1
80 55	83	02	17	CDS

Write Response

Prefix	PKT LGTH	Code	Error	V1	V2	V3
80 55	85	C0	00	02	17	CDS

Program Command

Prefix	PKT LGTH	CMD	ItemID	V1
80 55	83	04	17	CDS

Program Response

Prefix	PKT LGTH	Code	Error	V1	V2	V3
80 55	85	C0	00	04	17	CDS

Figure 33: Custom Data Source Command and Response

Custom Data Source Fields

Field	Description
CDS	Source of custom data transmitted with Control message: 0 – Control Source: CData1 and CData2 (default) 1 – Analog Input AN1 reading, MSB first 2 – Analog input AN2 reading, MSB first 3 – AN1 reading 8 MSB, AN2 reading 8 MSB

Figure 34: Custom Data Source Fields

This command enables the custom data fields to be automatically filled in without using one of the transmit commands. This can be configured once and then a microcontroller is not required on the end product. The selected custom data is included with every transmission initiated by activating a status line input.

Paired Module Descriptor - ItemID = 18

Reading or Programming this item reads or sets the descriptor for a single item in the Paired Module List. The descriptor contains the paired unit's address and Permissions Mask

Paired Module Descriptor

Read Command

Prefix	PKT LGTH	CMD	ItemID	Index
80 55	83	01	18	NX

Read Response

Prefix	PKT LGTH	Code	ItemID	V1	V2	V3	V4	V5	V6
80 55	88	C1	18	NX	ADR1	ADR2	ADR3	ADR4	PER

Program Command

Prefix	PKT LGTH	CMD	ItemID	V1	V2	V3	V4	V5	V6
80 55	88	04	18	NX	ADR1	ADR2	ADR3	ADR4	PER

Program Response

Prefix	PKT LGTH	Code	Error	V1	V2	V3	V4	V5	V6	V7	V8
80 55	8A	C0	00	04	18	NX	ADR1	ADR2	ADR3	ADR4	PER

Figure 35: Paired Module Descriptor Command and Response

Paired Module Descriptor Fields

Field	Range	Description
NX	1 – 40 (decimal)	The index of the Paired Module List row to be accessed
ADDRESS	00000000 – FFFFFFFF	The address of a paired module. FFFFFFFF indicates an empty row
PERMISSIONS	00 – FF	The Permission Mask of the paired module

Figure 36: Paired Module Descriptor Fields

Writing a Paired Module Descriptor

NX is the index of the row in the Paired Module List to be written. The following data is written into that location in the table, replacing the existing values. The address must be unique in the list. An ERR_VALU error response is returned if the address matches the address in any row other than NX. The order of the rows in the list does not affect the module's operation.

Reading a Paired Module Descriptor

When a read operation is performed, the RNVD response returns the data from row NX in the Paired Module List.

A 1 bit in the Permission Mask indicates that the paired module with the corresponding address is allowed to change the corresponding status line output. A 0 bit means that the paired module cannot change the status line output. Bits in the permission mask corresponding to status line inputs have no effect.

The least significant bit configures line S0. The pair process sets the mask to FF by default, allowing the paired unit to control all lines.

Trigger Operation - ItemID = 19

This item enables input trigger operation. This causes the IU to transmit as soon as a configured status line input goes high, but stop transmissions based on a configuration selection. Normal operation is to continuously transmit for as long as the status line input is high. Trigger operation allows timed or periodic transmissions for simple transmit-on-event conditions without an external microcontroller or other timing logic. This reduces the required energy and potential interference with other RF units when automatically transmitting.

Trigger Operation

Read Command

Prefix	PKT LGTH	CMD	ItemID
80 55	82	01	19

Read Response

Prefix	PKT LGTH	Code	ItemID	V1	V2	V3	V4	V5
80 55	87	C1	19	TMask	TFlag	SDur	IScale	IVal

Write Command

Prefix	PKT LGTH	CMD	ItemID	V1	V2	V3	V4	V5
80 55	87	02	19	TMask	TFlag	SDur	IScale	IVal

Write Response

Prefix	PKT LGTH	Code	Error	V1	V2	V3	V4	V5	V6	V7
80 55	89	C0	00	02	19	TMask	TFlag	SDur	IScale	IVal

Program Command

Prefix	PKT LGTH	CMD	ItemID	V1	V2	V3	V4	V5
80 55	87	04	19	TMask	TFlag	SDur	IScale	IVal

Program Response

Prefix	PKT LGTH	Code	Error	V1	V2	V3	V4	V5	V6	V7
80 55	89	C0	00	04	19	TMask	TFlag	SDur	IScale	IVal

Figure 37: Trigger Operation Command and Response

Trigger Operation Fields

Field	Description	
TMask	Trigger Mask that configures which lines are triggered inputs. 1 = triggered; 0 = normal. Default = 0.	
TFlag	Bit	Value
	0-1	Acknowledgment Action 0 = none 1 = cancel hop session (default) 2 = cancel series
	2	CancelOnLow – cancel series when all trigger inputs are low, default = 1
	3-7	Reserved, set to 0
SDur	Session Duration in hop cycles, default = 1	
IScale	Interval scale 0 = none (default) 1 = seconds 2 = minutes 3 = hours	
IVal	Interval Value, default = 0	

Figure 38: Trigger Operation Fields

TMask selects the status lines which operate in trigger input mode. If none are selected, trigger input mode is disabled. One bits in this byte must correspond to status lines which are set as digital inputs (cannot be analog inputs and cannot be outputs). The LSB corresponds to status line S0.

SDur contains the duration of the transmission burst session in the number of hop cycles. A value of 0 designates continuous transmission.

IScale and IVal specify the interval between the start of successive transmission bursts. This sets up a periodic series of transmissions as shown in Figure 39.

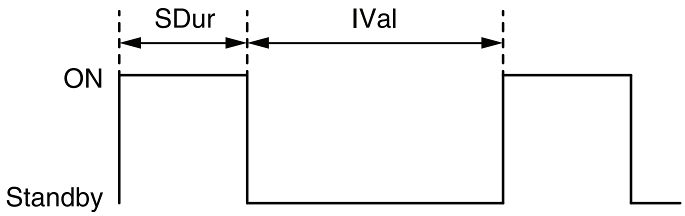

Figure 39: Trigger Operation Periodic Transmission

If IScale is 0, periodic transmission is disabled. If IScale is non-zero then IVal must also be non-zero. Ending the periodic transmission is set with some options, as described below.

TFlag has two fields. The acknowledgement action field specifies what happens when an acknowledgement response is received to a triggered message. Option 1 cancels the current hop session, but continues the series operation if periodic operation is configured. In other words, the hop duration is stopped as soon as an ACK is received, but the module transmits again at the next transmit interval.

Option 2 cancels the trigger series until all trigger inputs are low. In this case, all triggered transmissions are stopped until the all of the triggered lines go low. The next triggered line that goes high starts the transmissions again.

The CancelOnLow field specifies what happens when the triggered line goes low. If this is on (1) the transmissions stop as soon as the line goes low. If it is off (0) the transmission continues for the specified duration even if the line goes low before the duration time expires.

The periodic transmissions are subject to some conditions to make sure that the series stops. Setting CancelOnLow to 1 stops transmissions when the triggered input goes low. Setting the Acknowledgement Action to 2 cancels the series when an acknowledgement is received.

If CancelOnLow = 0, IScale must be 0 to disable periodic transmissions and SDur must be non-zero to disable continuous transmissions since inputs which are not terminated by a low input must terminate at the end of a single session.

The trigger operation offers a great advantage for automatic transmissions without any external circuitry. The option is highly configurable for different applications. Figure 40 gives some examples of different configurations and their resulting operation.

Trigger Operation Configurations	
Configuration	**Description**
CancelOnLow = 1 SDur = 0 IVal = 0 acknowledge = 0	Transmission occurs for as long as the triggered input is high. This is the same as normal, non-triggered operation.
CancelOnLow = 0 SDur = duration count IVal = 0 acknowledge = 0	Transmission lasts for the specified duration after a high-going edge, then stops until the next high-going edge.
CancelOnLow = 1 SDur = duration count IVal = 0 acknowledge = 0	Transmission starts when an input goes high, stopping when the input goes low or the specified duration elapses, whichever occurs first. No further trigger transmission occurs until the trigger status line goes low, then high again.
CancelOnLow = 1 SDur = duration count IVal = IU interval acknowledge = 0	Transmission is periodic, with configured duration and interval, as long as the trigger status line is high. No further trigger transmission occurs until the trigger status line goes low, then high again.
CancelOnLow = 1 SDur = 0 IVal = 0 acknowledge = 2 (cancel series)	Transmission occurs for as long as the triggered input is high or until an acknowledgement is received from the RU.
CancelOnLow = 0 SDur = duration count IVal = 0 acknowledge = 2 (cancel series)	Transmission lasts for the specified duration after a high-going edge or until an acknowledgement is received from the RU. The next high-going edge triggers a new transmission session.
CancelOnLow = 1 SDur = duration count IVal = 0 acknowledge = 2 (cancel series)	Transmission starts when an input goes high, stopping when the input goes low, the specified duration elapses or an acknowledgement is received, whichever occurs first. No further trigger transmission occurs until the trigger status line goes low, then high again.
CancelOnLow = 1 SDur = duration count IVal = IU interval acknowledge = 2 (cancel series)	Transmission is periodic with configured duration and interval as long as the trigger status line is high. An acknowledgement cancels the transmission series, so no further trigger transmission occurs until the trigger status line goes low, then high again.
CancelOnLow = 1 SDur = duration count IVal = IU interval acknowledge = 1 (cancel session)	The transmission is periodic with configured duration and interval, but each transmission duration is terminated by receiving an acknowledgement. Transmission resumes at the next interval. The series is ended when the triggered status line goes low.

Figure 40: Trigger Operation Configurations

Receiver Duty Cycle - ItemID = 1A

This item configures the RU receiver to turn on periodically to lower the average DC power. The factory-reset default value for DCycle is 0, which disables duty cycling, giving the fastest response time.

Receiver Duty Cycle

Read Command

Prefix	PKT LGTH	CMD	ItemID
80 55	82	01	1A

Read Response

Prefix	PKT LGTH	Code	ItemID	V1	V2
80 55	84	C1	1A	DCycle	KeepOn

Write Command

Prefix	PKT LGTH	CMD	ItemID	V1	V2
80 55	84	02	1A	DCycle	KeepOn

Write Response

Prefix	PKT LGTH	Code	Error	V1	V2	V3	V4
80 55	86	C0	00	02	1A	DCycle	KeepOn

Program Command

Prefix	PKT LGTH	CMD	ItemID	V1	V2
80 55	84	04	1A	DCycle	KeepOn

Program Response

Prefix	PKT LGTH	Code	Error	V1	V2	V3	V4
80 55	86	C0	00	04	1A	DCycle	KeepOn

Figure 41: Receiver Duty Cycle Command and Response

Receiver Duty Cycle Fields

Field	Range	Description
DCycle	0 (default, constant receive) 1 - 255	The duty cycle interval between receiver turn-on points, seconds.
KeepOn	0 - 255	The keep on period, seconds (default = 0)

Figure 42: Receiver Duty Cycle Fields

When a non-zero duty cycle period is set, the RU turns on the receiver every duty cycle period. If a valid control packet is received, the RU keeps the receiver turned on while packets are being received. This is shown in Figure 43.

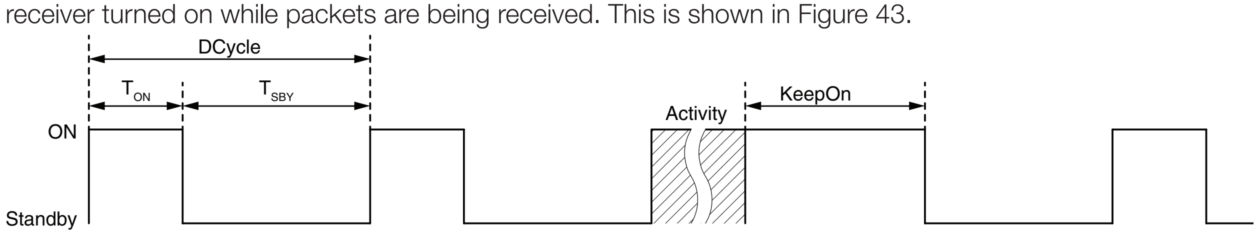

Figure 43: Receiver Duty Cycle

If RU activity occurs, the receiver stays on for at least KeepOn seconds after the last valid packet is received or data has been transmitted, allowing a quick response to successive controls or response transmissions. After KeepOn seconds have elapsed with no valid activity, the receiver is turned off and the module resumes the duty cycle operation by going into a low power mode for DCycle seconds. KeepOn has no effect if DCycle = 0.

Receiver duty cycling is inactive during the Pair operation and transmission. Setting Control Source CWord bit 2 = 0 (receiver off) overrides receiver duty cycling. When the receiver is cycled off, the module starts transmitting immediately when a status line input goes high. After the transmission is complete, the receiver stays on for KeepOn seconds before resuming duty cycle operation.

The receiver average current consumption is given by the following:

$$I_{AVG} = \frac{(T_{ON} \times I_{RX}) + (T_{SBY} \times I_{SBY})}{DCycle}$$

Where
I_{AVG} = average current when duty cycling active (mA)
I_{RX} = receiver-on current (mA)
I_{SBY} = receiver-standby current (mA)
T_{ON} = receiver-monitor duration (seconds)
T_{SBY} = duration in standby mode (seconds) = DCycle - T_{ON}

T_{ON} = 0.340s and is a fixed value. Approximate values with Vcc = 2.5V are:

I_{RX} = 26mA
I_{sby} = 0.002mA.

IO Lines - ItemID = 20

This parameter is the state of status lines and control lines.

IO Lines

Read Command

Prefix	PKT LGTH	CMD	ItemID
80 55	82	01	20

Read Response

Prefix	PKT LGTH	Code	ItemID	V1	V2
80 55	84	C1	20	Status	Control

Figure 44: IO Lines Command and Response

Status = Status lines, S0 - S7. S0 is the LSB.
Control = Control and output lines. The bits in this field represent the current logic state of the control input lines and the ACK_OUT and MODE_IND output lines. The bit definitions are in Figure 45.

Control Bit Definitions

Bit	Description
0	LATCH_EN
1	C0
2	C1
3	PAIR
4	ACK_EN
5	ACK_OUT
6	MODE_IND
7	Unused

Figure 45: Control Bit Definitions

RSSI - ItemID = 21

This read-only parameter is the signal strength of the last accepted packet and the current ambient level. The ambient power is read once per second when waiting for a control packet. Both values are initialized on reset to 80. Accurate results are limited to approximately –112dBm to –36dBm.

RSSI

Read Command

Prefix	PKT LGTH	CMD	ItemID
80 55	82	01	21

Read Response

Prefix	PKT LGTH	Code	ItemID	V1	V2
80 55	84	C1	21	LRSSI	CRSSI

Figure 46: RSSI Command and Response

LRSSI = RF power of the last accepted packet in dBm. This is a signed value.

CRSSI = Current ambient RF power on the current channel in dBm. This is a signed value.

LADJ - ItemID = 22

This read-only parameter is the voltage on the LADJ line. A separate voltage measurement is taken each time this item is read.

LADJ

Read Command

Prefix	PKT LGTH	CMD	ItemID
80 55	82	01	22

Read Response

Prefix	PKT LGTH	Code	ItemID	V1
80 55	83	C1	22	LADJV

Figure 47: LADJ Command and Response

The formula to calculate the voltage on the LADJ line is:

$V_{LADJ} = (LADJV / 256) * V_{CC}$

Module Status - ItemID = 23

This item describes the current operating status of the module.

Module Status

Read Command

Prefix	PKT LGTH	CMD	ItemID
80 55	82	01	23

Read Response

Prefix	PKT LGTH	Code	ItemID	V1	V2	V3	V4
80 55	86	C1	23	SFlag	TXP	SLM	LAM

Figure 48: Module Status Command and Response

Module Status Fields

Field	Bit	Description	
SFlag	0 – 2	Value	Operating Mode
		0	Idle
		1	Receiver Ready
		2	RU Cycle (receiving)
		3	IU Cycle (transmitting)
		4	Pairing process
		5 – 7	Reserved
	3	Reserved	
	4-6	Value	RUResp Response from RU during last IU transmission
		0	None
		1	ACK received during last IU transmission
		2	AWD received during last IU transmission
		3	SAMR, sample response
		4-7	Reserved
	7	Module interrupt flag (see Interrupt Mask)	
TXP	Currently selected transmit power level in dBm (signed byte)		
SLM	Current Status Line I/O Mask (set by the C0 and C1 lines or the Status Line I/O Mask, as determined by CWord.3)		
LAM	Current Latch Mask (set by the LATCH_EN line or the Latch Mask, as determined by CWord.4)		

Figure 49: Module Status Fields

SFlag.2 – This field shows the current operation of the module.

SFlag.4 - 6 – Set to 0 when the module is reset and at the beginning of an IU session. It is set whenever a valid response is received. If an IU session contains more than one type of response, this shows the last response type received in the current or last IU session.

SFlag.7 – This flag is set when an Event Flags bit = 1 with a corresponding Interrupt Mask bit = 1. This bit must be 0 to enable notify events.

Captured Receive Packet - ItemID = 24

This read-only item contains the last unread received control packet which was selected by the Message Select parameter and captured for serial output. The default selection type is off (no messages are captured).

Captured Receive Packet

Command

Prefix	PKT LGTH	CMD	ItemID
80 55	82	01	24

Response

Prefix	PKT LGTH	Code	ItemID	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10
80 55	8C	C1	24	Class	RSSI	Type	ADR1	ADR2	ADR3	ADR4	Status	CData1	CData2

Figure 50: Captured Receive Packet Command and Response

Captured Receive Packet Fields

Field	Description	
Class	Bit	Description
	0	If set, the message is from a paired device
	1	If set, the RU session is active
RSSI	RSSI, the signal strength in dBm	
Type	Value	Packet Type
	1 or 2	Control (1) or terminating control (2) packet
	4	Acknowledge packet
	5	Acknowledge With Data packet
	6	Pair packet
	8	Request Sample
	9	Sample Response
ADRx	Packet Type	Description
	1, 2, 4, 5	Four byte address of the IU, MSB first
	9	Four byte address of the RU, MSB first
Status	Packet Type	Description
	1, 2, 4, 5	Status line settings of the IU
	9	Type of response data from Type 8 request message
CData1, 2	Packet Type	Description
	1 or 2	Two bytes of custom data from the IU
	4 or 5	Two bytes of custom data from the RU
	9	Requested data specified by MType in the Transmit IU Packet command

Figure 51: Captured Receive Packet Fields

Reading this item has no effect on hardware-based operation and response.

Once a message is captured, no further messages are captured until this item is read by a serial command. Reading this item with no message is available returns a Read response with no data in the Value fields.

A break can be enabled on message capture by setting the Interrupt Mask bit 0

to 1.
Reading the Captured Receive Packet clears the received message buffer, so that no message is available through the serial interface until another selected packet is received.

As an example, the module gives the following response:

80 55 8C C1 24 03 C0 01 12 34 56 78 05 10 20

Class = 03 so the IU which sent the message is paired with the connected module and the session is currently active.

RSSI = C0, so the RSSI is –64dBm.

Type = 01, so the message is a control packet

ADRx = 12345678, which is the IU address.

Status = 05, so IU status lines S0 and S2 are high.

CData1, 2 = 10 and 20, which are the custom data values sent by the IU.

This item is useful when reading the packets directly rather than using the status line outputs to drive circuitry. An example is if a system needs more than 40 paired devices, then setting Message Select to 6 causes the module to accept any HumRC-compatible packet. When the Notify Event occurs, the Captured Receive Packet item can be used to pass the message to an external device with more memory to handle the address verification. The custom data bytes can also be used for further verification of the system or additional control.

Interrupt Mask - ItemID = 25

This item contains control bits that enable a break condition on CD_OUT (logic low for 2ms which can be interpreted as an interrupt to an external controller) when a selected event occurs. See interrupts and event notification for more details.

Interrupt Mask

Read Command

Prefix	PKT LGTH	CMD	ItemID
80 55	82	01	25

Read Response

Prefix	PKT LGTH	Code	ItemID	V1
80 55	83	C1	25	IMask

Write Command

Prefix	PKT LGTH	CMD	ItemID	V1
80 55	83	02	25	IMask

Write Response

Prefix	PKT LGTH	Code	Error	V1	V2	V3
80 55	85	C0	00	02	25	IMask

Program Command

Prefix	PKT LGTH	CMD	ItemID	V1
80 55	83	04	25	IMask

Program Response

Prefix	PKT LGTH	Code	Error	V1	V2	V3
80 55	85	C0	00	04	25	IMask

Figure 52: Interrupt Mask Command and Response

The definitions for the Interrupt Mask bits are show in Figure 53. By default, no interrupts are set.

Interrupt Mask Definitions

Bit	Description
0	Selected message ready
1	Status input line change
2	Control input change
3	Operating mode change (module status)
4	TX packets sent
5 – 7	Not used, set to 0

Figure 53: Interrupt Mask Definitions

When any bit of Event Flags is set and the corresponding bit of the Interrupt Mask is set, the Module Interrupt Flag (Module Status: SFlag.7) is set. When the Module Interrupt Flag changes from 0 to 1, a Notify Event (break condition on CD_OUT) is generated.

Please see the Interrupts and Event Notifications section for more information.

Event Flags - ItemID = 26

This item contains flags showing events which have occurred since the bit was cleared. These bits are set independently of the Interrupt Mask bits.

Event Flags

Read Command

Prefix	PKT LGTH	CMD	ItemID
80 55	82	01	26

Read Response

Prefix	PKT LGTH	Code	ItemID	V1
80 55	83	C1	26	EVFLG

Write Command

Prefix	PKT LGTH	CMD	ItemID	V1
80 55	83	02	26	EVFLG

Write Response

Prefix	PKT LGTH	Code	Error	V1	V2	V3
80 55	85	C0	00	02	26	EVFLG

Figure 54: Event Flags Command and Response

Bits are only set when module detects the corresponding change, regardless of the Interrupt Mask settings. If interrupts are not used, it is not necessary to clear the Event Flags.

Any bit in the EVFLG byte that is a 1 that has a corresponding bit in the IMask byte that is also a 1 indicates an unprocessed interrupt event.

Events are cleared by either reading the resetting ItemID or writing a 0 to the bits to be cleared. Writing a 1 leaves the status unchanged.

Event flag 4 is set after all packets specified by a transmit command (83 – 87), have been transmitted. The bit is cleared when another transmit command is issued. This allows double buffering of packet data with a transmit command.

Event Flag Definitions

Bit	Description	Resetting ItemID
0	Selected message ready	24 (Captured Receive Packet)
1	Status input line change	20 (IO Lines)
2	Control input change	20 (IO Lines)
3	Operating mode change	23 (Module Status)
4	TX packets sent	Write command 83 - 87 (transmit commands)
5 – 7	Not used, set to 0	

Figure 55: Event Flag Definitions

Please see the Interrupts and Event Notifications section for more information.

Analog Input Reading - ItemID = 27

This read-only item returns the readout for analog channels AN1 and AN2.

Analog Input Reading

Read Command

Prefix	PKT LGTH	CMD	ItemID
80 55	82	01	27

Read Response

Prefix	PKT LGTH	Code	ItemID	V1	V2	V3	V4
80 55	86	C1	27	AN1-0	AN1-1	AN2-0	AN2-1

Figure 56: Analog Input Reading Command and Response

Each analog channel returns a 2-byte value with the first byte being the most significant. The readout uses the averaging, voltage reference and offset specified by Analog Input Select item. The readout is left-justified, with a full-scale reading of 0xFFFF. An un-configured analog channel returns 0.

The following formula can be used to convert the readout to a voltage.

$VIN = ((AN\# - AOfs) \times V_{REF}) / 65{,}536$

Where,

V_{IN} = the input voltage measured by the module
AN# = the digital value returned by reading this item. This is the two bytes concatenated. # is the analog channel number, 1 or 2.
V_{REF} is the voltage reference selected by the ARef field in the Analog Input Select item.
AOfs = offset value programmed in using the Analog Input Select parameter.

Trigger Input Status - ItemID = 28

This read-only item shows the trigger input status.

Trigger Input Status

Read Command

Prefix	PKT LGTH	CMD	ItemID
80 55	82	01	28

Read Response

Prefix	PKT LGTH	Code	ItemID	V1	V2	V3
80 55	85	C1	28	TState	RSDur	RIVal

Figure 57: Trigger Input Status Command and Response

Trigger Input Status Fields

Name	Description	
TState	Trigger State	Description
	0 = disabled	Trigger operation is disabled.
	1 = Ready for activation	Trigger operation is enabled, but no line has been triggered.
	2 = Active Transmit	Actively transmitting a triggered session.
	3 = Active Delay	A line has been triggered, but pausing for the transmission interval before the next session.
	4 = Active Pending	A line has been triggered, but waiting for an RU session to complete before transmitting.
	5 = Wait Clear	Triggered transmission complete, but waiting for the triggered inputs to go low and reset.
RSDur	Remaining hop cycles for this session	
RIVal	Remaining interval delay value for periodic transmission, IScale units	

Figure 58: Trigger Input Status Fields

Pairing Status - ItemID = 29

This read-only item shows the results of the last Pairing process since power-up from either asserting the PAIR input or sending the Start Pairing command.

Pairing Status

Read Command

Prefix	PKT LGTH	CMD	ItemID
80 55	82	01	29

Read Response

Prefix	PKT LGTH	Code	ItemID	V1	V2
80 55	84	C1	29	PState	PAddr

Figure 59: Pairing Status Command and Response

Pairing Status Fields

Name	Description
PState	Pairing State 0 = Pairing not attempted 1 = Seeking Pair node 2 = Node found, pairing in process 3 = Pairing terminated without detecting another pairing node 4 = Error: Address table full 5 = Error: Other node address table full 6 = Pairing successful, not stored for IU 7 = Pairing successful, existing entry updated 8 = Pairing successful, new entry stored
RSDur	Address of the Pairing Unit or 0xFFFFFFFF if Pairing was not successful.

Figure 60: Pairing Status Fields

Interrupts and Event Notifications

One of the advanced features offered by the module's serial interface is the ability to notify an external processor when an event has occurred. A Notify Event is an approximately 2ms pulse on the CD_OUT line. This condition is normally detected as a break condition or a null byte with a frame error by an external controller. The transceiver delays sending the Notify Event until any currently active message on CD_IN is finished and a reply is sent, plus an additional delay of at least 1.5ms.

The Interrupt Mask configuration parameter defines the interrupt conditions that generate a Notify Event. The external controller may read the Event Flags parameter to determine the type of condition, and read the appropriate parameters to get further details.

All interrupting conditions must be reset before the Notify Event can be generated again. Multiple interrupt conditions may be set. A Notify Event occurs when the first condition is met and does not occur again until after all interrupting event flags are cleared, even if subsequent interrupt conditions are met. If multiple events occur before the flags are cleared, the appropriate bits are set in the Event Flags parameter, but a Notify Event is not be generated.

The events may be cleared by writing a 0 to the associated event flag bits directly or by reading the associated parameter ItemIDs. Reading the resetting ItemID automatically clears the event flag. Clearing all the event flags resets the Module Interrupt Flag, enabling future Notify Events. The Module Interrupt Flag is set when any of the interrupt flags are set.

The state of the Module Interrupt Flag can be read with the Module Status parameter. This flag should be read to ensure that all events have been serviced. If the Module Interrupt Flag is set after clearing events, a new event has occurred and must also be cleared before another Notify Event can be generated.

By default the Interrupt Mask is set to 0, which disables Notify Events.

Please see the Interrupt Mask and Event Flag parameter descriptions for more information.

> Note: If the Interrupt Mask bit 1 or 2 is non-zero, then floating inputs may cause a series of control line or status line change interrupts. Ensure that all inputs are set to supply or ground and are not floating.

Examples

The CDI can be used for many purposes.

Production Programming

The modules can be configured in production through the CDI rather than needing to manually set the hardware lines.

- Use the Status Line I/O Mask parameter to configure the status lines as either inputs or outputs.
- Use the Latch Mask parameter to set each status line as either latched or momentary.
- Use the Control Source parameter to set the hardware or software control of the inputs.

Dynamically Change Transmitter Output Power

The transmitter output power can be reduced to lower current consumption in instances where signal conditions are good and the full power level is not needed. An external microcontroller can compare the RSSI to a threshold and lower the power when the RSSI is above the threshold. Multiple thresholds can be set to correspond to multiple output power levels.

- Use the RSSI parameter to get the signal strength of the last received packet.
- Use the TX Power Level parameter to adjust the transmitter output power.

Add or Remove Specific Devices

In cases where a module in a system becomes lost or damaged and needs to be replaced, the new module can be programmed with the same address and paired devices as the old unit. This prevents the need for reprogramming all of the other devices in the system.

If a system is planned out, then all devices can be programmed rather than have to manually pair each device in the system with every other device.

The Permissions Mask is also set for each paired device, setting whether or not a specific paired device is authorized to control specific outputs.

- Use the Paired Unit Descriptor command to load addresses and Permissions Masks into the module.

Power Savings

When set as an IU only (all status lines are inputs) the module automatically goes into a low power state until a status line is activated or a command is received on the CMD_DATA_IN line. When configured as an RU (at least one status line is an output and no inputs are activated) the module defaults to receive mode looking for a command message. To conserve power, the receiver can be turned off indefinitely or duty cycling may be enabled. The expense is a longer response time to a command since no packets are received while the receiver is off.

- To turn off the receiver, use the Control Source parameter to set CWord bit 2 to a 0. Set the bit to a 1 to reactivate the receiver.
- Use the Receiver Duty Cycle parameter to set the duty cycle interval.

Output Received Messages

The control messages received by the module can be output by the CDI for further analysis by an external device. This can include logging the address of the IU for recording access attempts and monitoring the status line settings in the received packet instead of monitoring eight hardware lines. All valid messages can be output so that an external device with more memory can perform the address validation. This can expand the system beyond the 40 units that can be paired with each module.

- Use the Message Select parameter to set the type of messages to capture.
- Use the Interrupt Mask parameter to trigger an interrupt when the selected message is received.
- Use the Captured Receive Packet command to read the received packet.

Send Custom Data

Up to two bytes of custom data can be sent with each transmission and acknowledgement. This can include sensor data, battery voltage or additional command or verification data.

- Set Control Source CData1 and CData2 values to specify the custom data sent when an input status line initiates a transmission.
- Use the Transmit Control Data command to directly transmit status and custom data.
- Use the Transmit AWD command to send a custom response with data.
- Use the Message Select parameter to set the type of message to capture.
- Use the Interrupt Mask parameter to trigger an interrupt when the selected message is received.
- Use the Captured Receive Packet ItemID to read the received packet.

Initiate a Transmission with Software

The CDI can be used to initiate transmission of control messages rather than using the hardware status lines.

- Use the Transmit Control Data item to initiate transmission of control messages.

Trigger a Transmission

The CDI can be used to configure the module to send a specific number of control packets when an input is triggered or to send them periodically while the input line is high rather than continuously.

- Use the Trigger Operation item to configure the triggered transmission of control messages.

Control Acknowledgements

The CDI can be used to control the acknowledgements transmitted in response to valid control messages rather than using the hardware ACK_EN line.

- Use the Transmit ACK command to initiate the transmission of acknowledge messages in response to qualified control messages.

- Use the Transmit AWD command to initiate the transmission of acknowledge messages in response to qualified control messages that include two bytes of custom data.

Set Interrupts

The module supports interrupts that trigger a pulse on the CMD_DATA_OUT line. This pulse is interpreted as a break condition by a connected microcontroller. Interrupts can be enabled for several types of events.

- Use the Interrupt Mask parameter to set the events that trigger an interrupt.

- Use the Event Flags parameter to view which event or events triggered the interrupt.

- Use the Module Status parameter to view the master Module Interrupt Flag (SFlag bit 7).

Read the Received Signal Strength

The module records the signal strength of each packet as it is received as well as the ambient RF level. This can be used to assess the link quality as well as the current RF environment.

- Use the RSSI parameter to read out the RSSI of the last valid packet and the current ambient level.

Read Analog Voltages

The module can read analog voltages on up to two lines and transmit the measured values.

- Use the Analog Input Select parameter to configure the analog channels.
- Use the Custom Data Source parameter to configure the module to add the analog values to each transmitted message.
- Use the Analog Input Reading to read the current analog values.
- Use the Transmit IU Packet command to trigger a remote unit to respond with its measured values and the Captured Receive Packet parameter to read the values out of the response.
- Use the Control Source parameter to configure the module to automatically respond to sample requests from an IU.

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