RC17xxHP-RC232 Embedded RF Protocol User Manual

Description

The RC232™ Embedded RF Protocol is used in a range of products from Radiocrafts. The protocol and command interface is described in this User Manual.

The RC232™ protocol features described in this document is common to all Radiocrafts modules named RC17xxHP-RC232 and RC17xx-RC232. Device specific data are found in their respective data sheets.

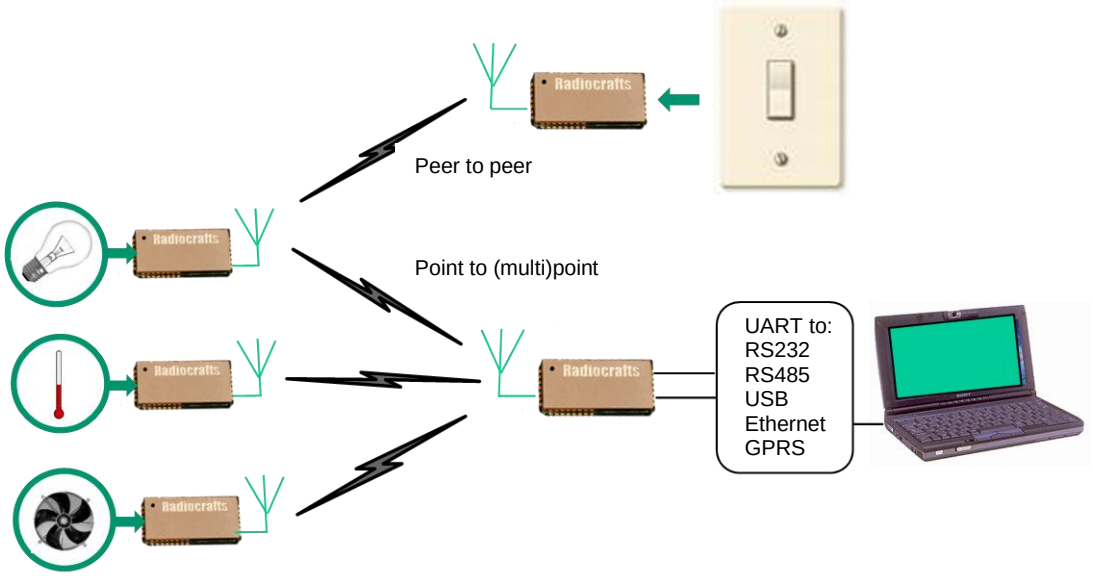


Figure 1: A typical addressed sensor- and actuator application supported by the RC232 protocol

RC232™ Embedded Protocol

The RC232-protocol is an easy-to-use protocol for bidirectional wireless transmission of data packets from a transmitter to a receiver. Data entered on one side is received transparent byte by byte at the other side. The RC232 protocol features:

- Complete MAC layer packet protocol
- Buffered packet transmission mode
- Variable packet length, end character or timeout
- Optional addressing of packets to a unique node, or broadcast to all nodes in a system
- Optional error detection using CRC-16 check sum
- On-the-fly configuration of the radio modem
- 128 byte data buffer
- Power saving schemes
- Easy-to-use UART interface
- RS232/422/485/USB compatible via external level shifter
- Optional UART hardware handshake
- Optional RSSI info on received packets
- Optional Temperature sensor readout
- Optional Voltage sensor readout
- Optional Encryption/Decryption of packets

The RC232™ embedded protocol is compatible with RS232, RS422 and RS485 serial buses. Data is transferred to / from the module using a UART interface, the same as used for RS232, RS422 and RS485, except that it use logic level signals (3 V logic). Most other UART converters, for instance UART-USB, can also be used together with the module.

The UART interface is used both for communication and configuration. A set of easy-to-use hex commands makes it possible to alter the configuration of the module.

Buffered mode communication

This is the most straight-forward and most commonly used mode. A data packet entered on the UART will automatically be transmitted by the module based on one or more of the following triggers:

- Buffer is full. Buffer size is configurable and is named PACKET_LENGTH
- A predefined time after last bit in last byte is received. The time is configurable and is named PACKET_TIMEOUT
- An end character is received. The end character is configurable and is named PACKET_END_CHARACTER

Only ONE of the triggers has to be present for the module to transmit.

Note the following:

- PACKET_TIMEOUT= 0 (zero) means “None”, thus is disabling the feature. If this parameter is not used as trigger for transmission one of the other two has to be configured for the transmission to be performed as required. A good practice is to set PACKET_TIMEOUT = 0x02 so the module empties its buffer if an unintentional start bit enters the UART
- If the module transmits based on either full buffer or received end character, the PACKET_TIMEOUT is ignored, thus this configured time does not add to the total time spent for a transmission to take place

Addressing

The module allows addressed point-to-point packet transmissions and broadcast transmissions. Each module has a SYSTEM_ID (one byte) and its own UNIQUE_ID, UID (one byte). The SYSTEM_ID and UNIQUE_ID can be programmed for each module using the configuration interface. The use of addressing can be enabled with ADDRESS_MODE in the configuration memory.

Each module also has a default destination address, DESTINATION_ID, DID. This address will be added to the data packet if addressing is enabled.

All the nodes in one system should have the same SYSTEM_ID. And each node should be set to a different UNIQUE_ID.

To send a packet to a specific node, set the destination address to the specific node's UNIQUE_ID.

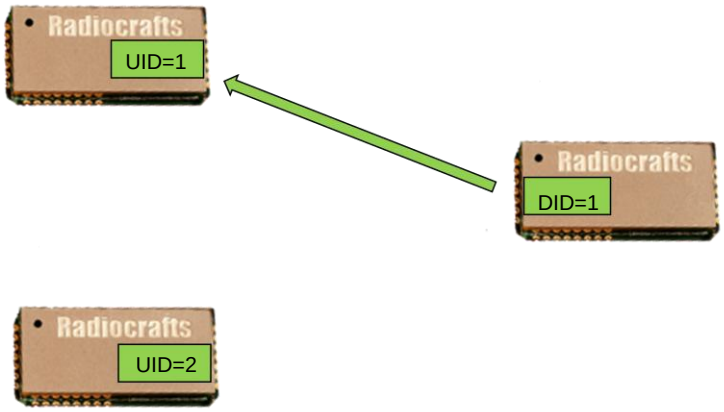


Figure 2: Set DID=UID for an addressed package to arrive at the desired receiver

If a broadcast is to be made, set the destination address to the BROADCAST_ID. By default the BROADCAST_ID is 0xFF (decimal 255), but this can be changed in the configuration. Remember that the BROADCAST_ID cannot be the same as any UNIQUE_ID.

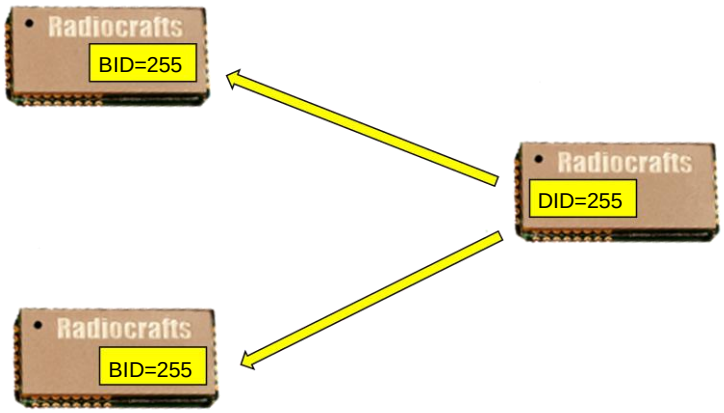


Figure 3: Set DID=BID for a package to arrive at the desired multiple receivers

For addressing to work properly make sure:

- All nodes have addressing enabled (ADDRESS_MODE)
- All nodes within the system have the same SYSTEM_ID

- All nodes within the system have the same BROADCAST_ID
- Each node within the system has one unique UNIQUE_ID

Before transmitting data make sure:

- The DESTINATION_ID is set to the desired receivers UNIQUE_ID
- Or set the DESTINATION_ID to the BROADCAST_ID if the packet is to be received by all nodes

If addressing is disabled (ADDRESS_MODE = 0x00), all receivers may receive any transmission.

CRC Error Detection

The RC232™ protocol has a built in error detection based on a 16 bit CRC. The error detection can be enabled with CRC_MODE in the configuration memory. If a received packet contains an invalid checksum, it will be discarded and not sent to the host.

UART Interface

A UART serial bus is used as the interface between the module and the host system for data transmission in the buffered mode and for configuration of the module. Normally no flow control (handshake) is used. Any microcontroller with hardware or software UART or UART converter communicating with the module in its configurable UART speed can be used to communicate with the module.

Optionally the CTS and/or RTS/RXTX can be used for hardware flow control:

CTS pin – Clear to send: The low-asserted CTS pin provides flow control for the module. When CTS is asserted (low), serial data can be sent to the module for RF transmission. If the module is busy, like during RF data transmission or reception, the CTS pin will be de-asserted (high) to stop any data transfer to the module.

RTS pin – Ready to send: When RTS is asserted (low) the host allow data to be sent from the module to the host. The host can stop the module from sending data by de-asserting (high) the RTS signal. Note that if the module has data waiting in the receive buffer, it will not be able to receive or transmit further data until the RTS has been asserted and the data in the buffer is transferred to the host.

RXTX pin – RS485 driver control: RXTX is low when the module can receive data on RXD. RXTX is high when the module is transmitting data on TXD and additionally 5 ms for the module to turn from TXD to IDLE mode (see Timing Information in the module data sheet). The RXTX pin is normally connected to the /RE and DE pins on the RS485 driver circuit.

The configuration of the flow control for the UART interface is done by changing UART_FLOW_CTRL in the non-volatile configuration memory.

Note: The module CTS is set up during the first stop bit sent from to module when the buffer is full, and the host should then halt further character transmissions to prevent character loss. If the host cannot detect the CTS quickly enough during hardware handshake, it should be configured for two stop bits.

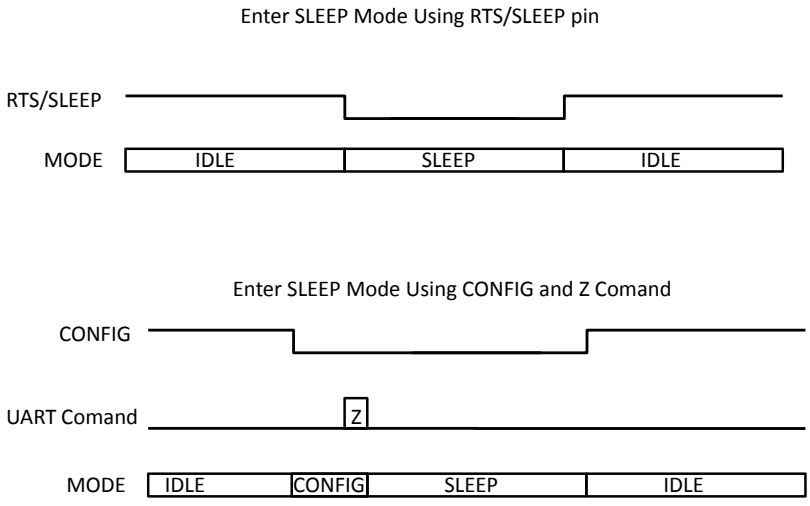
Power Management

The module can be set in SLEEP mode in order to reduce the power consumption.

When the SLEEP pin is not enabled (RF_SLEEP_MODE = 0x00) the module can be set in Sleep mode by activating CONFIG and sending a 'Z' command. The module is woken up when CONFIG is deactivated (goes high). Note: During Sleep the CONFIG pin does not have any internal pull-up, so the CONFIG pin must be driven high in order to wake the module. Any activity on the RXD pin will make the module wake up, but immediately return to Sleep as long as CONFIG is kept low. Such activity on the RXD pin should be avoided in order to reduce current consumption.

When the SLEEP pin is enabled (RF_SLEEP_MODE = 0x02) the module can be set in Sleep mode by activating RTS/SLEEP (asserting low). The module is woken up when RTS/SLEEP is deactivated (goes high). Note: During Sleep the RTS/SLEEP pin does not have any internal pull-up, so the RTS/SLEEP pin must be driven high in order to wake up the module. Any activity on the RXD or CONFIG pins will not make the module wake up. Activity on module pin 16 and 17 can wake the module and must be avoided (do not connect, as previously stated in this document). CONFIG must be high when awakening the module to avoid setting the module directly in configuration mode.

All configuration settings and RAM values are retained during Sleep. The pull-ups on RTS/SLEEP and CONFIG pin are disabled during sleep mode in order to minimise the sleep current consumption. If the module is shut completely off by removing the supply voltage, all configuration settings in non-volatile memory is restored, but values in RAM are overwritten with default settings.



Encryption

The RC232 protocol can encrypt data before transmission, and decrypt at reception. The CRC is used to verify correct decryption, so the 2 byte CRC (CRC_MODE = 2) should be enabled when using encryption.

Also, both the ENCRYPT_FLAG and DECRYPT_FLAG must be set for a successful link.

The encryption method used is AES-128-CTR mode. Using the counter mode means that any packet length can be encrypted without the use of filler bytes. Both the Initialization Vector (Initial Counter Block) and the Encryption Key are fixed. AES uses a symmetric key. That is, the same Encryption Key is used for both encryption and decryption. Also the Initialization Vector must be the same. These are stored as INIT_VECTOR and DEFAULT_KEY, both 16 bytes long.

RSSI Reading

The module provides a digital Received Signal Strength Indicator (RSSI) through the 'S' command, or attached to received messages. The module returns an 8 bit character (one byte) indicating the current input signal strength (followed immediately by a second character which is the prompt ('>') when in command mode). The signal strength can be used as an indication of fading margin, or as a carrier sense signal to avoid collisions.

The signal strength measure by the S command is the instantaneous value. The RSSI value appended to a received message (RSSI_MODE = 1) is the signal strength of that received packet.

The RSSI value increases with increased input signal strength in 0.5 dB steps. Input signal strength is given by (typ.):

P = - RSSI / 2 [dBm]

The dynamic range of the RSSI (P) goes from the Sensitivity level up to typical -30 dBm (RSSI saturation level).

Temperature Reading

The module provides readings of a digital temperature monitoring sensor (TEMP) through the 'U' command. The module returns an 8 bit character (one byte) indicating the current temperature in degrees Celsius (°C) followed immediately by a second character which is the prompt ('>').

The TEMP value increases with increased temperature in 1 °C steps and accuracy of +/- 2 °C.
Temperature is given by:

T = TEMP(dec) – 128 [°C] (example: TEMP=0x98 equals +24 °C)

Power Supply voltage Reading

The module provides readings of an internal power supply voltage monitoring sensor (VCC) through the 'V' command. The module returns an 8 bit character (one byte) indicating the current power supply voltage level followed immediately by a second character which is the prompt ('>'). The command can be useful for battery power monitoring.

The VCC value increases with increased power supply voltage in 30 mV steps. The power supply voltage is given by:

V = VCC(dec)*0.030 [V] (example: VCC=0x68 equals 3.12 V)

Module Configuration

The configuration of the module can be changed in-circuit from the host during operation, at the time of installation of the equipment, at the manufacturing test, or even as a standalone module. The configuration is changed sending commands on the UART interface after the module is set in configuration mode. The configuration mode is entered by asserting the CONFIG pin (set low).

In configuration mode the module will respond by sending a '>' prompt on the TXD pin. This indicates that the module is ready to receive commands. The CONFIG pin can then be de-asserted. Note that the CONFIG pin must be de-asserted *before* the Exit command ('X') is sent to the module in order to return to normal operation.

After a command is executed, the module responds with the '>' prompt character again indicating it is ready for a new command. Do not send a new command before the '>' prompt is received. The time required to execute a command can vary depending on the command (see the Timing Information section). There is no '>' prompt after the 'X' exit command.

The parameters that are set by direct commands (C, P and T) take immediate effect after returning to normal operation (IDLE), but will not be stored in non-volatile memory, and will be lost in case the supply power is turned off or if the module is reset. These parameters are for example the radio channel and output power.

A list of commands is shown in the table below.

Parameter	Command	Argument in hex (decimal)	Note
Channel	'C' – 0x43	0x01-0x0C (1-12)	Data is stored in volatile memory only.
Output power	'P' – 0x50	0x01-0x05 (1-5)	Data is stored in volatile memory only.
Signal Strength (RSSI)	'S' – 0x53	Returns one byte indicating the signal strength	See page 6 for details
Destination address	'T' – 0x54	0x00 – 0xFF (0-255)	Data is stored in volatile Memory only.
Temperature monitoring	'U' – 0x55	Returns one byte indicating the temperature.	See page 6 for details
Battery monitoring	'V' – 0x56	Returns one byte indicating the power supply voltage.	See page 6 for details
Memory Read one byte	'Y' – 0x59	0x00 – 0x7F (The argument is the address in the configuration memory.)	Return one byte value from the configuration memory.
Memory configuration	'M' – 0x4D	(Address, Data): see list of parameters below. 0xFF exits memory configuration.	Used to enter memory configuration menu. Parameters changed are stored in non-volatile memory.
Module Reset	'@RR'	No arguments, but CONFIG must be low for this command.	Module reset. Alternative to RESET_N pin low if only UART is connected to host.
Factory Reset	'@RC'	No arguments, but CONFIG must be low for this command.	Resets the configuration memory back to factory default values in the whole non-volatile memory.

Exit command	'X' – 0x58	(none)	Exit to normal operation mode. All changes of parameters take effect.
Sleep mode	'Z' – 0x5A	(none)	CONFIG pin must be asserted while in SLEEP mode. Exit sleep mode by releasing CONFIG pin.
Test mode 0	'0' – 0x30	(none)	List all configuration memory parameters
Test mode 1	'1' – 0x31	(none)	TX carrier
Test mode 2	'2' – 0x32	(none)	TX modulated signal PN9 sequence
Test mode 3	'3' – 0x33	(none)	RX mode
Test Mode 4	'4' – 0x34	(none)	Radio off mode (RX and TX off)

Note: ASCII characters are written as 'X', hexadecimal numbers are written like 0x00, and decimal numbers are written like 10 throughout the text. A table of ASCII characters and their respective hex and decimal values are found in the Appendix.

Commands must be sent as ASCII characters or their corresponding binary value. All arguments must be sent as binary values to the module (not as ASCII representation for hex or decimal). Any invalid command will be ignored and the '>' prompt will be re-sent. The CONFIG line must be de-asserted after the first '>' prompt was received, but before the 'X' command.

To make permanent changes to default values and other parameters, the Memory Configuration command 'M' is used. This command should be followed by pairs of byte being the memory address and the new value to be stored at that address. In order to exit the Memory Configuration mode command 'X' must be sent.

Example:
To select RF channel 3, send the follow sequence after asserting the CONFIG line and the '>' prompt is received:

Command	**Hex**	**Response**	**Comment/Note**
CONFIG asserted		'>'	De-assert CONFIG after '>' prompt
'C'	0x43	'>'	
3	0x03	'>'	Wait for '>' prompt
[A new command could be issued here]			
'X'	0x58	(none)	Module returns to IDLE state

It is important to enter Test mode 3 before exiting the configuration mode ('X') if Test mode 1 or 2 has been used. This will ensure proper operation in normal mode.

Test mode 0 ('0' command) can be used to list all parameters stored in non-volatile memory. This command can be used to verify and check the module configuration.

Configuration Memory

The table below shows the complete list of configurable parameters stored in non-volatile memory. These values can be changed using the 'M' command. All addresses and arguments must be sent as binary values to the module (not as ASCII representation for hex or decimal).

Parameter	Description	Address Hex	Argument (dec)	Factory setting hex (dec)	Comment
Radio configuration					
RF_CHANNEL	Default RF channel	0x00	RC1701: 1-10 RC1740: 1-93 RC1760: 1-239 RC1780: 1-84	0x01 (1) 0x01 (1) 0x01 (1) 0x3D (61)	See data sheet for details.
RF_POWER	Default RF output power	0x01	1-5	0x05 (5)	See data sheet for details.
RF_DATA_RATE	Default RF data rate	0x02	1-15	0x04 (4)	See data sheet for details.
SLEEP_MODE	Sleep Mode	0x04	0: SLEEP pin disabled 1: reserved 2: SLEEP pin enabled	0x00 (0)	When enabled, the module will enter sleep mode by asserting sleep pin low. Do not use in combination with enabled UART flow control.
RSSI_MODE	Append RSSI	0x05	0-1	0x00 (0)	0: No RSSI append No 1: RSSI append
Radio packet configuration					
PACKET_ LENGTH_L	Packet Length	0x0F	1-200	0x80	Preamble (header) length, apply for S mode only
PACKET_TIMEOUT	Time before modem time-out and transmitting the buffer	0x10	0x00-0xFE (0-254) 0x00 (0): None 0x01 (1): 32 ms 0x02 (2): 48 ms 0x03 (3): 64 ms 0x7C (124): 2 s 0xF9 (249): 4 s	0x7C (124)	None means packet timeout is disabled (not 0 s). Timeout value is (PACKET_TIMOEOUT x 16 ms) + 0/16 ms min/max 0xFE (254) is max, giving 4.080 sec. Default is 2 s = 0x7C (124)
PACKET_END_ CHARACTER		0x11	0x00: Off 0x01-0xFF: On	0x00	0: No end character 1-255: Use value as end character
Medium access, addressing and network management					
ADDRESS_MODE		0x14	0, 2, 8	0x02 (2)	0: No addressing 2: 1 byte addressing 8: For future use Using addressing adds the SID and DID bytes to the radio packet.
CRC_MODE		0x15		0x02 (2)	0: None 2: CRC16
UNIQUE_ID1 (UID1)		0x19	0-255	0x01 (1)	ADDRESS_MODE=0 No addressing ADDRESS_MODE=2 UID=UID1 SID=SID1 DID=DID1 BID=BID
SYSTEM_ID1 (SID1)		0x1A	0-255	0x01 (0)	
DESTINATION_ID1 (DID1)		0x21	0-255	0x01 (1)	
BROADCAST_ ADDRESS		0x28	0-255	0xFF (255)	
HP_TEMP_COMP		0x29	0-1	0x00 (0)	High Power Temperature compensation. 1: enable 0: disable (default) Stabilize output power and current draw over

					temperature.
Data and configuration interface, UART Serial Port					
UART_BAUD_RATE	Baud rate	0x30	0x00: Not used 0x01: 2400 0x02: 4800 0x03: 9600 0x04. 14400 0x05: 19200 0x06: 28800 0x07: 38400 0x08: 56700 0x09: 76800 0x0A: 115200 0x0B: 230400	0x05 (5)	BE CAREFUL IFCHANGING AS HOST MAY LOOSE CONTACT WITH MODULE! Does not take effect until module is re-booted / reset.
UART_FLOW_CTRL	UART flow control	0x35	0: None 1:CTS only 3:CTS/RTS 4:RXTX(RS485)	0x00 (0)	
ENCRYPT_FLAG		0x3E	0: Disabled 1: Enabled	0	Encryption, enabled when set
DECRYPT_FLAG		0x3F	0: Disabled 1: Enabled	0	Decryption, enabled when set
DEFAULT_KEY		0x40-0x4F		All 0xFF	
INIT_VECTOR		0x50-0x5F		All 0x00	
PART_NUMBER		0x89-0x96		RCxxxx-RC232	
HW_REV_NO		0x98-0x9B		x.yz	x, y and z; Any number 0d-9d
FW_REV_NO		0x9D-0xA0		x.yz	x, y and z; Any number 0d-9d
SERIAL_NUMBER		0x78-0x7F		All 0x00	8 bytes reserved for serial number for traceability. Is programmed by Radiocrafts during test.

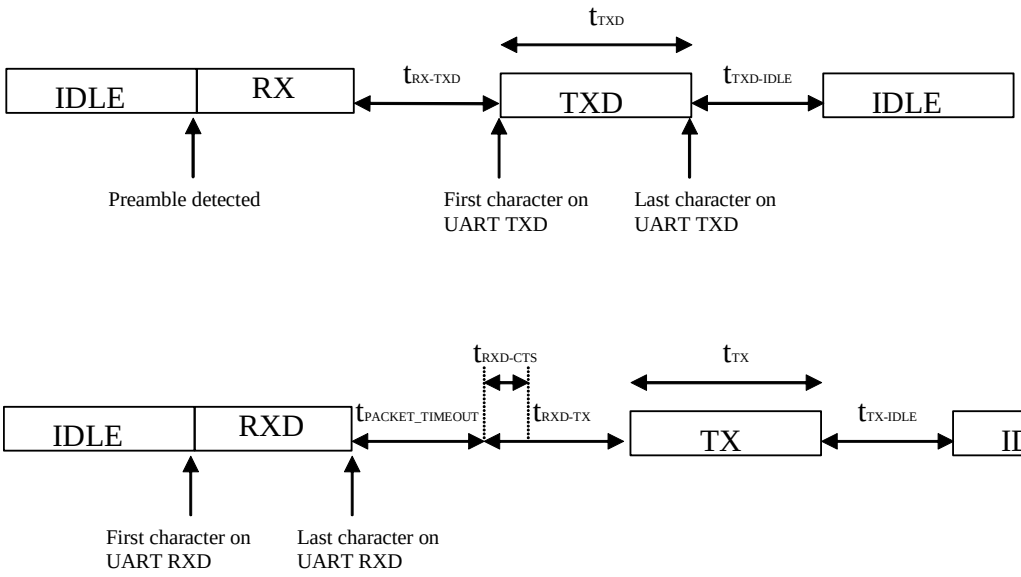
Note: *Address location not listed should not be changed from the default value.*

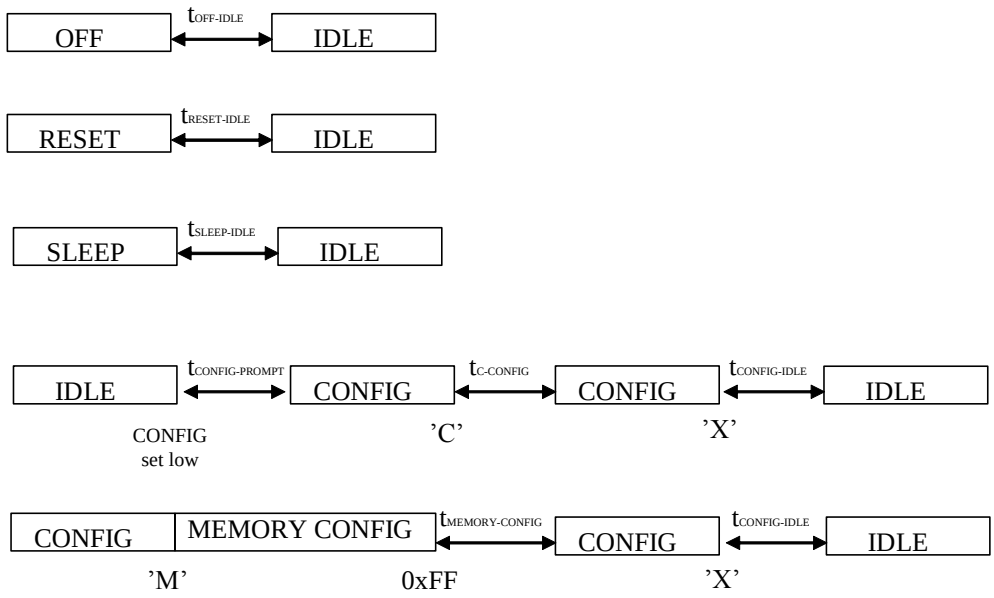
Timing Information

The figure and table below shows the timing information for the module when changing between different operating states in the embedded RC232 protocol.

The IDLE state is the normal state where the module search for preamble on the air and wait for a character to be received on the UART. RXD is the state when receiving characters from the host filling up the internal buffer. TX state is when the data is transmitted on the air. RX state is when data is received from the air after preamble detection. TXD is the state where the received data is sent to the host on the UART.

CONFIG is the state entered by asserting the CONFIG pin and used during parameter configuration, while MEMORY CONFIG is the sub-state entered by the 'M' command where the configuration memory is being programmed. Note the limitation on maximum number of write cycles using the 'M' command, see Electrical Specifications.





Symbol	Value	Description / Note
t_{RX-TXD}	180 us	Time from last byte is received from the air until first character is sent on the UART
t_{TXD}	Min 590 us	t_{TXD} = # bytes received x 590 us/char (10 bits at 19.2 kBd + 70 us delay per character)
$t_{TXD-IDLE}$	900 us	Time from last character is sent on the UART until module is in IDLE mode (ready for RXD and RX)
$T_{RXD-CTS}$	20 us	Time from last character is received by the UART (including any timeout) until CTS is activated
t_{RXD-TX}	960 us	Time from last character is received by the UART (including any timeout) until the module sends the first byte on the air.
$T_{TX-IDLE}$	960 us	Time from last character is sent on the air until module is in IDLE mode (ready for RXD and RX)
$t_{OFF-IDLE}$	3.2 ms	
$t_{RESET-IDLE}$	3.0 ms	
$t_{SLEEP-IDLE}$	1.28 ms	
$t_{CONFIG-PROMPT}$	590 us	Time from CONFIG pin is set low until prompt (“>”)
$t_{C\#-CONFIG}$	1.1 ms	Delay after channel-byte is sent until prompt (“>”). (For other commands like ’M’, ’T’ there is no delay but immediate prompt)
$t_{MEMORY-CONFIG}$	62 ms	In this period the internal flash is programmed. *Do not reset, turn the module off, or allow any power supply dips in this period as it may cause permanent error in the Flash configuration memory. After 0xFF the host should wait for the ‘>’ prompt before any further action is done to ensure correct re-configuration.*
$T_{CONFIG-IDLE}$	1.42 ms	
t_{TX}	Min 12 ms	t_{TX} = # bytes to send x 1.67 ms/byte (at 4.8 kbit/s) + 2 bytes preamble, sync + 2 bytes address + 2 bytes CRC
T_{RSSI}	20 ms	Time from end of S command to start of RSSI byte received on UART

Please see RC17xxHP-RC232 for details about the RC232 protocol.

Appendix: ASCII Table

HEX	DEC	CHR	CTRL
0	0	NUL	^@
1	1	SOH	^A
2	2	STX	^B
3	3	ETX	^C
4	4	EOT	^D
5	5	ENQ	^E
6	6	ACK	^F
7	7	BEL	^G
8	8	BS	^H
9	9	HT	^I
0A	10	LF	^J
0B	11	VT	^K
0C	12	FF	^L
0D	13	CR	^M
0E	14	SO	^N
0F	15	SI	^O
10	16	DLE	^P
11	17	DC1	^Q
12	18	DC2	^R
13	19	DC3	^S
14	20	DC4	^T
15	21	NAK	^U
16	22	SYN	^V
17	23	ETB	^W
18	24	CAN	^X
19	25	EM	^Y
1A	26	SUB	^Z
1B	27	ESC	
1C	28	FS	
1D	29	GS	
1E	30	RS	
1F	31	US	
20	32	SP	
21	33	!	
22	34	"	
23	35	#	
24	36	$	
25	37	%	
26	38	&	
27	39	'	
28	40	(	
29	41	)	
2A	42	*	
2B	43	+	
2C	44	,	
2D	45	–	
2E	46	.	
2F	47	/	
30	48	0	
31	49	1	
32	50	2	
33	51	3	
34	52	4	
35	53	5	
36	54	6	
37	55	7	
38	56	8	
39	57	9	
3A	58	:	
3B	59	;	
3C	60	<	
3D	61	=	
3E	62	>	
3F	63	?	

HEX	DEC	CHR
40	64	@
41	65	A
42	66	B
43	67	C
44	68	D
45	69	E
46	70	F
47	71	G
48	72	H
49	73	I
4A	74	J
4B	75	K
4C	76	L
4D	77	M
4E	78	N
4F	79	O
50	80	P
51	81	Q
52	82	R
53	83	S
54	84	T
55	85	U
56	86	V
57	87	W
58	88	X
59	89	Y
5A	90	Z
5B	91	[
5C	92	\
5D	93	]
5E	94	^
5F	95	_
60	96	`
61	97	a
62	98	b
63	99	c
64	100	d
65	101	e
66	102	f
67	103	g
68	104	h
69	105	i
6A	106	j
6B	107	k
6C	108	l
6D	109	m
6E	110	n
6F	111	o
70	112	p
71	113	q
72	114	r
73	115	s
74	116	t
75	117	u
76	118	v
77	119	w
78	120	x
79	121	y
7A	122	z
7B	123	{
7C	124	|
7D	125	}
7E	126	~
7F	127	DEL

Document Revision History

Document Revision	Changes
1.0	First release

Disclaimer

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This Radiocrafts product is not designed for use in life support appliances, devices, or other systems where malfunction can reasonably be expected to result in significant personal injury to the user, or as a critical component in any life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness. Radiocrafts AS customers using or selling these products for use in such applications do so at their own risk and agree to fully indemnify Radiocrafts AS for any damages resulting from any improper use or sale.

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