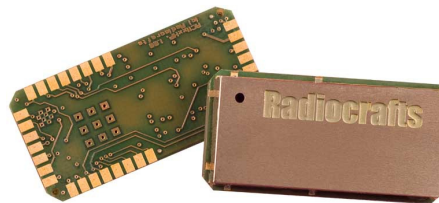

Mesh/Multi-hop RF Transceiver Module

Product Description

The RC11XX(HP)/25XX(HP)-TM RF Transceiver Modules are compact surface-mounted high performance modules for wireless mesh networking applications. The modules feature a fully embedded mesh/multi-hop protocol with automatic network forming and self-healing features. Serial application data is entered on the UART port and transported automatically to the desired destination node without further interaction from any external processor. The modules are completely shielded and pre-certified for operation in world-wide license free bands.

Applications

- Wireless Sensor Networks
- Automatic Meter Reading
- Alarm and security systems
- Telemetry stations
- Fleet management
- Asset tracking
- Street lighting control and monitoring



Features

- Embedded TinyMesh™ networking protocol with bidirectional RF data transfer
- Self forming and self healing network
- Small size (12.7 x 25.4 x 3.3 mm), shielded and optimized for SMD mounting
- Two-wire UART interface for easy RS232/422/485 wire replacement (handshake optional)
- No external components
- Configurable analogue and digital I/O in Packet Mode
- RSSI and network connect LED outputs for easy installation
- IPv4- and IPv6-addressing via standard low-cost external controller running TCP/IP stack
- Wide supply voltage range, 2.0 – 3.9 V
- RC1140/80(HP)-TM conforms with EU R&TTE directive (EN 300 220, EN 301 489, EN 60950)
- RC1190-TM conforms with regulations for operation under FCC CFR 47 part 15
- RC1170(HP)-TM complies with G.S.R.564(E) (G.S.R.168(E)).
- RC2500(HP)-TM complies with EN 300 228 (Europe), FCC CFR 47 part 15 (US) and ARIB STD-T66 (Japan)

Quick Reference Data

Parameter	RC1140-TM	RC1160-TM	RC1170-TM (HP*)	RC1180-TM (HP*)	RC1190-TM	RC2500-TM (HP*)	Unit
Frequency bands	433.05-434.79	868.7 – 869.2	865.0 – 867.0	868.0 – 870.0	902 – 915	2400 - 2483	MHz
Number of channels	17	5	15	18 (3 HP channels)	50	83	
Data rate	1.2 - 100	1.2 – 100	1.2 – 100 (76.8 for HP)	1.2 – 100 (76.8 for HP)	1.2 - 100	1.2 - 100	kbit/s
Max output power	10	10	10	10	-1	1	dBm
HP Version	N/A	N/A	27	27	N/A	18	
Sensitivity 1.2/ 100 kbit/s	-110 / -97	-110 / -97	-110 / -97	-110 / -97	-110 / -97	-105 / -89	dBm
HP Version	N/A	N/A	-109 / -96	-109 / -96	N/A	-108/ -91	
Supply voltage	2.0 – 3.9	2.0 – 3.9	2.0 – 3.9	2.0 – 3.9	2.0 – 3.9	2.0 - 3.6	Volt
HP Version	N/A	N/A	2.7 – 3.3	2.7 – 3.3	N/A	2.7 - 3.6	
Current consumption RX / TX	24 / 35	24 / 37	24 / 37	24 / 37	24 / 37	25 / 27	mA
HP Version	N/A	N/A	24 / 560	24 / 560	N/A	30 / 155	
Current consumption SLEEP	Typ. 0.3	Typ. 0.3	Typ. 0.3	Typ 0.3	Typ 0.3	Typ 0.4	uA
HP Version	N/A	N/A	Typ 3.4	Typ 3.4	N/A	Typ 1.5	
Temperature range	-40 to +85	-40 to +85	-40 to +85	-40 to +85	-40 to +85	-40 to +85	°C
HP Version	N/A	N/A	-40 to +85	-40 to +85	N/A	-20 to +85	

Typical Application Circuit



Please see additional schematic information regarding recommended Reset and Power supply filtering, LED outputs, configurable I/O pins and how to include a firmware upgrade connector later in this document.

TinyMesh™ Embedded Protocol

The TinyMesh™ module family offers a buffered, embedded mesh protocol. All data to be sent is stored in the module before transmitted by the RF circuitry. Likewise, when data is received, data is stored in the module before sent to the host. This allows the internal communication controller to add address information and to do error check of the data. The powerful TinyMesh protocol is fully embedded into each single Device defined in the network and no external processor is required for establishing and maintaining the optimum routing path at all times. The Gateway does not differ from the other nodes in the network, the only action required is to configure one (or more) device(s) to be a Gateway.

TinyMesh™ Conceptual Description

TinyMesh™ is a mesh/multi-hop network protocol which is fully embedded inside a family of Radiocrafts modules with different RF frequency ranges. A network is defined to consist of a number of nodes where a node is one out of three types as described below (End Device availability TBD). The wireless network of nodes may be connected to any type of sensors or actuators. The RF traffic is in a tree-type topology, where data transfer is up or down in the tree structure. The following features are fully contained in the embedded TinyMesh™ application firmware:

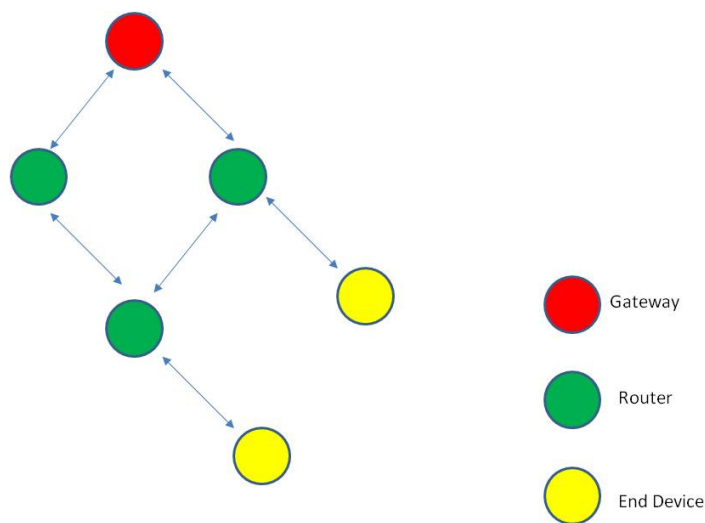
- Optimum network self forming
- Self healing: The path with highest link quality and least number of hops to the recipient is chosen at any time. When optional paths are present, it is indicated with indicative blinks on a LED output. In a changing environment with changing link quality the network dynamically adapts to the optimum route

The features for wireless data transfer between any two nodes in the network are:

- LBT (listen Before Talk)
- Acknowledge
- Retransmission(s) when required
- AES128 encryption (optional)

Network Topology

TinyMesh™ in its simplest topology consists of one Gateway and one Router. There may be several Gateways within one network, they will then share the workload between them but there might be incidental duplicate packages which must be handled at the end-server side. The number of Routers and the number of children of each Router is only limited by the number of addresses, which is 4+4 bytes (4 bytes System ID, 4 bytes Unique ID). The depth of the network (maximum number of hops) is 255.



Typical network topology (End Device TBD availability)

Node Description

A node may be configured to function as Gateway or Router or End Node.

Gateway: Mandatory to form the network and as the name indicates, it takes the bidirectional application data to and from the wide area network (Ethernet, GPRS, PLC or similar) or to a host processor which can be in the shape of a PC.

Router: Must be powered at all times as it takes the bidirectional data from any other device and in real-time either re-transmits and/or enter the application data on its UART.

Any Router or Gateway device may be configured as a locator, enabling positioning within the network. Please see later chapter, page 10 for details.

Getting Started

Form a network by configuring at least one of the modules as Gateway (configure a Gateway via 'G'-command, page 23). Make sure **the Gateway and all Routers have different Unique ID but same System ID**. This is mandatory for successful network self forming. Modules are delivered with default setting 'Router', and with non- identical Unique Ids.

How do I form the network

Power up the nodes in any random sequence. A node in configuration mode will not join the network. The RSSI LED (Red LED on Radiocrafts Demo Board, page 9) will start flashing in a slow pattern, indicating the node is alive and listening, but not connected to the network. The Gateway node starts inviting neighbouring nodes to become members of the network. The Gateway node will flash the TX- Indicator (Red LED on Radiocrafts Demo Board, page 9) every time a network invite is being transmitted. Routers within acceptable radio range of the Gateway will detect the invites from the Gateway. If the received signal strength (RSSI) is within predetermined limits of acceptable strength, the Router node will attempt connecting to the Gateway by sending an invite response. If the Gateway properly accepts the invite response, the Router has successfully joined the network, and signals its new status by changing the LED flash pattern. The RSSI Indicator now reflects the RSSI level of the established connection, and the Connection indicator starts flashing to indicate successful connection

All Routers that successfully connect directly to a Gateway node, will begin inviting new Routers to join the network, forming the next level of connected nodes. New Routers will again start inviting a next level of Routers, automatically propagating the network to encompass all Routers with identical System ID that are within radio range of at least one other Router or Gateway in the same network.

No external processing effort in the terms of a network organizer, controller PC or micro controller is required, each node actively and autonomously participates in the forming of the RF network.

How do I transmit data?

This chapter refers to the most easy-to-use mode, the default mode named "transparent" for transparent, bidirectional data transfer.

Send your data to the RXD pin on the module. Use the UART format with default settings (19200, 8, 1, N, no flow control). Up to 120 payload bytes are buffered in the module. The module will transmit the data when

- the maximum packet length is reached
- the modem time-out limit is reached

Modules use the UART CTS signal to indicate when data may be entered. Routers hold CTS high after power up, while searching for a network connection. After successful connection to a network, CTS will go low, indicating the node is ready to receive data. CTS will remain low until the data buffer is full, or a byte-to-byte time out has occurred. CTS will then go high, indicating no more data may be entered. As soon as the data packet has been successfully transmitted and the data buffer is emptied, CTS will return low, to indicate new data may be entered.

Data may be entered in binary format, any byte value with proper start- and stop bit is accepted. The time-out limit is configurable in-circuit, default setting is 10 ms

How do I receive data?

Any data entered at the Gateway (while CTS is low), will be delivered to all Routers that are connected to the network. Received data with correct check sum will be presented on the TXD pin of all Router(s).

Data entered at any Router node (while CTS is low), will be delivered to the Gateway and presented on the Gateway TXD pin.

What about the antenna?

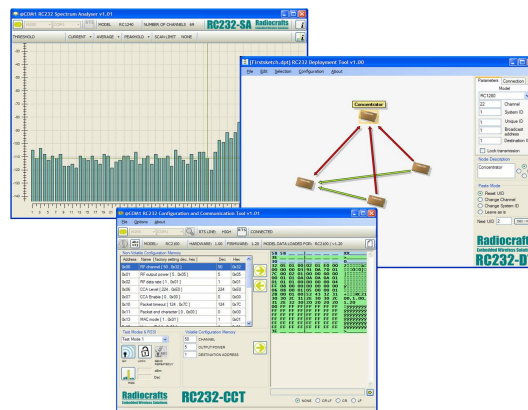
In most cases, a simple quarter wavelength wire or a PCB track will do. Connect a piece of wire to the RF pin with length corresponding to the quarter of a wavelength. For space limited products, contact Radiocrafts and we will recommend the best antenna solution for your application.

How do I change the RF channel or any other parameter?

To change configurable parameters, assert the CONFIG pin, and send the command string using the same serial interface as for transmitting data. Configurable parameters are stored in non-volatile memory in the module, please see page 23 and 25 for details.

RCTools

RCTools is a powerful and easy to use PC suite that helps you during test, development and deployment of the RC11XX(HP)/25XX(HP)-TM. The tool can be used for both configuration and communication. Visit www.radiocrafts.com and Tools for a free download and full documentation.



Transparent mode versus Packet Mode

The default, factory setting is transparent mode, well suited for applications requiring serial data transmission only. In transparent mode, UART data entered at the Gateway, will be received by all Routers in the network and will be made available at their UARTs without any changes. The addressing must be handled by the host MCU application.

UART data transmitted from a Router will only be received by the Gateway, and will be delivered 'transparently', without any changes.

Regardless of device type (Gateway or Router), the serial port UART is ready to receive data only when CTS is true (low). RF transmission will automatically be triggered on buffer full or character time-out on the serial port. The connected host MCU must always verify CTS is true (Low) before sending any character, or data may be lost.

By configuring the Gateway for Packet mode, addressed data is possible as well as individual I/O control and monitoring of each Router. Serial data packets entered and received at the Gateway, will contain extra bytes for command and control.

Packet Mode Operation

When configured for packet mode operation, data may be directed from the Gateway to one specific router or vice versa. Packet mode allows for setting and reading of the GPIO pins on the module, as well as reading the two analogue inputs, and activating the PWM output control for dimmer or speed control applications. Digital inputs may be set to trigger messages on input condition changes.

Routers will acknowledge receipt of commands and data. The Acknowledge packet will be available on the Gateway UART.

Gateway in Packet Mode

All data entered on the Gateway UART in Packet mode must follow strict formatting rules. The following tables describe packet formatting for transmitted and received packages. Please note Data must be entered in one, contiguous string of bytes. Any time gap of more than the configured time out value (default 20ms), will cause the Gateway to treat the entered data as a complete package. If a time-out should occur before the intended end of the packet, the Gateway will not recognize the packet format, and the packet will be discarded (lost).

Router in Packet Mode

Routers behave similarly in Transparent and Packet mode. All packets are always routed to the Gateway. Packet formatting and addressing is handled automatically by the Router firmware, and binary serial data may be entered to the UART without packet formatting and address information. Serial data packets will be transmitted immediately when the UART buffer is full (120 bytes), or after a configurable time gap between characters (Default = 20ms).

To switch between Transparent and Packet Mode operation, only the Gateway configuration needs to be changed.

Transmitting Command and Configuration Packets from Gateway

Commands sent from the Gateway to Routers are used to set or read GPIO pins, to enquire module operating status, or to alter settings in the Configuration Memory of Router modules. All GPIO pins are initially configured as digital inputs with no triggering enabled. The desired GPIO function must be configured by altering the Configuration Memory settings, to enable functions such as analogue input, PWM control, digital output or input trigger functions.

All TinyMesh™ modules may be configured through the UART in Configuration Mode (page 23 and page 25). Router modules may also be configured while operating in a live mesh network by issuing Configuration commands from the Gateway module. Some restrictions

Transmit Serial Data Packet from Gateway

Enter Serial Data Packets to be transmitted to individual Router nodes, using the following packet format. Maximum packet size is 120 bytes. Payload data bytes may be any format (binary data). Please note that the start byte is a calculated value

Byte #	Field	Size	Description
1	Start character	1	Calculated value, total number of bytes, including start character
2	Node Address	4	Configured value of destination router, or use broadcast ID (255 255 255 255) if Serial Data Packet for all units.
6	Packet number	1	User selectable number, returned as part of the Acknowledge packet from the Router on completed command execution
7	Command type	1	17 (0x11) Fixed value
8	Serial data	1..120	Binary data

Example 1, Send text string 'Hello' from Gateway to Router with UID 0 0 1 2 , packet no 6

Decimal notation	Hex Notation
12 0 0 1 2 6 17 72 101 108 108 111	C 0 0 1 2 6 11 48 65 6c 6c 6F

Received Package Formats

Packets received by the Gateway in Packet Mode, will be delivered on the module UART TXD-pin in the following formats (byte 1-34). Packet header is identical for all packet types, while the data contents formatting (starting at data byte # 18) will be formatted differently when receiving serial data.

Byte #	Field name	Size	Description
1	Start character	1	Total number of bytes in the message, including start character
2	System ID	4	System wide ID, must be identical for all devices in a system
6	Origin ID	4	Address of Router that created the message
10	Origin RSSI	1	RSSI from first receiver to originating node, ref. page 22
11	Origin network level	1	'Hop' level, number of vertical hops to reach Gateway
12	Hop counter	1	Number of actual hops from Router to Gateway
13	Message counter	2	Unique number maintained by originating node
15	Latency	2	Time in 10 ms resolution from message creation to delivery
17	Message type	1	Event 2 (0x02) or Serial data in 16 (0x10)

Event type packages (Message type 0x02)

Byte #	Field name	Size	Description
18	Message detail	1	1 (0x01) Digital input change detected 2 (0x02) Analogue 0 Input Trig 3 (0x03) Analogue 1 Input Trig 8 (0x08) Power ON Reset 9 (0x09) Status message (IMA) 16 (0x10) Command Acknowledge 17 (0x11) Command received, but not accepted
19	Message Data	2	If command acknowledge, Message data LSB = User selected Command/ Packet number entered from Gateway
21	Locator ID	4	Address of Locator Router with best received signal strength (RSSI)
25	Module Temp	1	Module temperature, ref. page 22
26	Module voltage	1	Voltage / battery monitor, ref. page 22
27	Digital inputs	1	GPIO 0-7
28	Analogue 0	2	Analogue 0 converter, GPIO 0 (12 bits)
30	Analogue 1	2	Analogue 1 converter, GPIO 1 (12 bits)
32	HW version	2	
34	FW version	2	

Serial data packages (Message type 0x10)

Byte #	Field name	Size	Description
18		1	Always zero
19	Serial data	1..120	Serial data

LED Indicators

Module pins 29 and 30 are designed to directly drive LEDs. The Red LED (D1) of the Radiocrafts Demo Board is connected to module pin 29, and the Yellow LED (D2) is connected to module pin 30. It is suggested that these LED outputs are also implemented in target hardware, as the LED signals may be useful for system deployment and configuration.

Router function: Network Quality Indicators

An LED connected to module pin 29 (Radiocrafts Demo Board Red LED, D1), will function as an RSSI indicator for Router module. The LED will flash with one of the following frequencies/intervals based on RSSI level for the established connection:

1. Fast flash, 2X/ second:
RSSI is excellent, at least -15dBm better than minimum connection level
2. Moderate flash, on for 1 second, off for 1 second:
RSSI is acceptable for reliable communication
3. Very slow (2 seconds ON, 2 seconds off):
RSSI is below the level that will allow connection. No new connections will be established at this low RSSI, but an existing connection may still exist if the Connection LED is flashing

An LED connected to module pin 30 (Radiocrafts Demo Board Yellow LED, D2), will function as a connection indicator. The LED will flash with one of the following patterns:

1. Steady ON
Direct connection to Gateway, and at least one more Gateway available for alternate routing.
2. Rapid flash, 5 times per second
Direct connection to Gateway
3. Fast flash, 2 times per second
Connected to a router, and at least one more router available on same level as an alternate route (redundant connection)
4. Moderate flash, on for one second and off for one second:
Connected to a router, and no alternatives exist on same level.
5. No light:
Disconnected

In general, the higher frequency on the indicators, the lower the packet loss rate will be and the network will be more robust against changing conditions in each hop.

Both outputs from the module may also be monitored by an external processor for other visualization of RSSI level and network connection quality.

Gateway Function: Radio RX /TX Indicator

An LED connected to module pin 29 (Radiocrafts Demo Board Red LED), will flash every time an RF package is transmitted.

An LED connected to module pin 30 (Radiocrafts Demo Board Yellow LED), will flash every time an RF package with valid formatting and valid CRC is received.

Configuration mode indicator

When TinyMesh™ modules enter into Configuration mode, the two LEDs will both be turned ON. On exit from Configuration Mode, the LEDs will resume original function as either RX/TX indicator for Gateways, or Connection Quality indicator for Router modules.

Locator Function

Any Router or Gateway may be set as a 'Locator' by enabling the Locator bit in the configuration memory (page 25). By default, this setting is disabled (0).

When a Router sends an Event type message to the Gateway, the Unique ID (UID) of the Locator device within closest radio range (best RSSI) of the Router, may be found as part of the event message (page 8).

The Locator feature may be utilized in systems designed for asset tracking or other locating functions. Router devices placed in fixed, known locations should be set as Locator devices. Devices that may be portable or with unknown location should have the Locator bit disabled. When a device moves around within the mesh network, it will report the address of the closest Locator device in any event message that is transmitted. An event message may be triggered on a timely basis (HIAM interval in the configuration memory), through a request from the Gateway, or be triggered by a digital- or analogue input level shift.

IMA On Connect Function

A Router may be set to send a status report (IMA message) every time the Router connects to the mesh network. This function may be useful in networks that are normally inactive, and that are temporarily formed by introducing a Gateway unit, e.g. for data collection when using a hand held Gateway. The received IMA messages will contain the addresses of all Routers that are connected to the network. Enable IMA On Connect by changing the default configuration setting (Configuration Address 94, page 25)

Input/ Output Functions

Eight connection pins on the TinyMesh™ module are dedicated for application Input or Output control (GPIO). The Gateway must be configured for Package mode (page 6 and 25) to support the Input / Output functions. Sampled analogue and digital GPIO values may be found in all Event type packages (Message type 0x02) delivered by a Gateway, and outputs may be controlled by commands from the Gateway (Command type 0x03). Event packages may be triggered in multiple ways:

- ▲ By an analogue input signal changing value (Configurable thresholds, hysteresis and trig condition)
- ▲ A digital input changing value (Configurable trig: No / Hi-Lo / Lo-Hi / Both)
- ▲ A timed event (Configurable in 1 minute intervals)
- ▲ By a request command from Gateway

By default, all GPIO pins are configured to function as inputs. Any of the 8 GPIOs may however be changed to function as outputs, and GPIO 0 and 1 may be configured to function as analogue inputs by altering the configuration settings.

Digital Input

When a GPIO has been configured for input, a separate configuration setting is used to determine if the input signal should be used to trigger an event message. This function may for instance be used to trigger an alarm condition. The configuration settings allow for triggering on digital signals when changing from high to low level, from low to high, or both. The default setting is *no trig*. Digital inputs are pre-configured with a 20k pull-up resistor. With no external signal connected, a digital input will always read as a '1' in the event message.

Input Debouncing.

Digital inputs are protected by a debounce mechanism, to eliminate problems with unstable signals or settling times for micro switches or detectors. The debounce setting is common for all digital inputs, and settable in intervals of 1ms. The default setting is 10ms, meaning that any digital input must deliver a stable input (no change) for at least 10ms, to trigger an event.

Digital Output

Digital outputs are controlled by Gateway commands, using Command Argument 1. Please see separate chapter page 6 for detailed description of the command format. Also note the GPIO must first be enabled as outputs, see pages 23 and 25 for details on module configuration (Default configuration is Input). A command to set or reset a GPIO that has not been configured for Output, will have no effect. The default output value at Reset is configurable. The factory setting is 1 (high).

The 'Data 1' and 'Data 2' bytes in the command message format, page 6, are used to control the output status. The contents of these bytes are 'bit mapped', such that the first bit of the byte controls GPIO 0, and the 7th bit of the byte is used to set GPIO 7. Data 1 is used for setting outputs, while Data 2 is used for clearing outputs. Note that setting a bit in Data 2 (Clear output) will override a bit that has been set in Data 1 (Set Output). By using two separate bits for setting / clearing an output, the external application firmware may be relieved of the task of knowing the previous state of a digital output, because only the single bits selected by the command will be affected.

Example 1: Set GPIO Outputs 5 and 7

Command Data byte 1							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
1	0	1	0	0	0	0	0

Command Data byte 2							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	0	0	0	0	0	0

GPIO Output							
GPIO7	GPIO6	GPIO5	GPIO4	GPIO3	GPIO2	GPIO1	GPIO0
Set	No Change	Set	No Change	No Change	No Change	No Change	No Change

Example 2: Clear GPIO Output 3

Command Data byte 1							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	0	0	0	0	0	0

Command Data byte 2							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	0	0	1	0	0	0

GPIO Output							
GPIO7	GPIO6	GPIO5	GPIO4	GPIO3	GPIO2	GPIO1	GPIO0
No Change	No Change	No Change	No Change	Cleared	No Change	No Change	No Change

Example 3: Command Data Byte 2 settings will override Command Data Byte 1 settings Setting and clearing the same output, results in clearing the output:

Command Data byte 1							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	0	0	0	1	0	0

Command Data byte 2							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	0	0	0	1	0	0

GPIO Output							
GPIO7	GPIO6	GPIO5	GPIO4	GPIO3	GPIO2	GPIO1	GPIO0
No Change	No Change	No Change	No Change	No Change	Cleared	No Change	No Change

GPIO mapping							
GPIO7	GPIO6	GPIO5	GPIO4	GPIO3	GPIO2	GPIO1	GPIO0
Module pin 23	Module pin 24	Module pin 25	Module pin 26	Module pin 22	Module pin 20	Module pin 16	Module pin 15

Digital Output Drive

GPIO 0 - 7, when configured as outputs, are capable of driving 2mA, which is sufficient for driving a transistor or some high efficiency LEDs. When used to drive higher loads, the outputs must be buffered by a transistor or similar, to provide sufficient drive current. The two dedicated LED outputs on module pins 29 and 30 should be limited by an external resistor for a maximum load of 10mA.

PWM Output

GPIO 7 may be configured for PWM output (Pulse Width Modulation), and used for light dimming or motor speed control by setting GPIO 7 Configuration Address 23, value = 3. The PWM output value may now be controlled by sending a PWM command to the module (see page 6 for command description). The default PWM value at Reset is configurable 0 to 100% by setting the Configuration memory address 95. The factory setting is 0.

Analogue Input

The TinyMesh™ module features two independent analogue inputs. The analogue inputs may be individually enabled by changing the default configuration setting of GPIO 0 and 1. The analogue inputs will be sampled at a sampling rate as defined by the Sample Rate configuration setting. The Sample Rate may be set in increments of 0.1 s. The default setting is 10, or one sample per second. Samples are stored in an internal sampling buffer, and the sampling result is calculated as a sliding average of the last 8 samplings. The analogue converter is pre-configured to use an internal 1,25V voltage reference. A positive input voltage between 0 and 1,25V applied to an analogue input pin will be converted to a positive number between 0 and 2047 (0x07FF). Out of range values will be reported as either 0 or 2047. The absolute value of the input signal, may be calculated as:

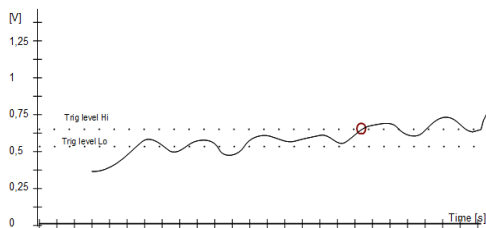
	Value	= Sampled value * 1,25 / 2047 [V]
<i>Example:</i>	Sampled value:	= 0x4CC
	Convert to decimal :	= 1228
	Analogue voltage= 1228*1,25 / 2047	= 0,75 [V]

Please note that negative voltages, or voltages above the module supply voltage may result in permanent damage to the module, please reference the electrical specifications for details.

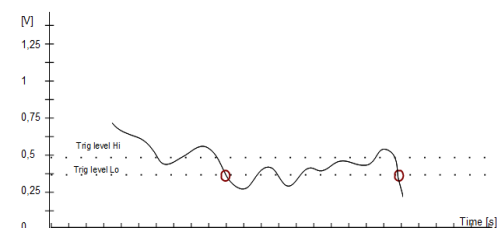
Analogue Triggering

The two analogue inputs may be set to trigger event messages when the measured analogue values exceed or go below defined threshold values. The analogue High and Low settings may be used to create a hysteresis, to avoid multiple messages to be generated if the analogue signal changes very slowly over time, or is following a non-linear curve. This will typically be the situation when analogue inputs are used to sense temperature variations or battery voltage. By setting the Analogue High Trig and the Analogue Low Trig to different values, an event message will be triggered when the sampled analogue signal passes through the hysteresis, from below the low trig value to above the high trig value, or vice versa. Please see below examples for clarification.

Low- to high trigger



High- to low trigger



Setting the Analogue Trigger Level

The analogue high, and the low trigger level threshold values must be entered as two byte values. The maximum trigger level value is 2047, or Hex 0x7FF, entered as High byte = 0x07 and Low byte = 0xFF in the configuration memory.

$$\text{Trigger value} = \text{Analogue trigger voltage} * 2047/1,25$$

Example: Analogue trigger voltage = 0,75[V], Trigger value = $0,75 * 2047 / 1,25 = 1228$

To calculate the proper settings in the configuration memory, the trigger value must be converted to a two-byte value.

Divide the Trigger Value by 256 to find the Trigger High Byte value:

$$1228 / 256 = 4,796 \Rightarrow \text{High byte} = 4$$

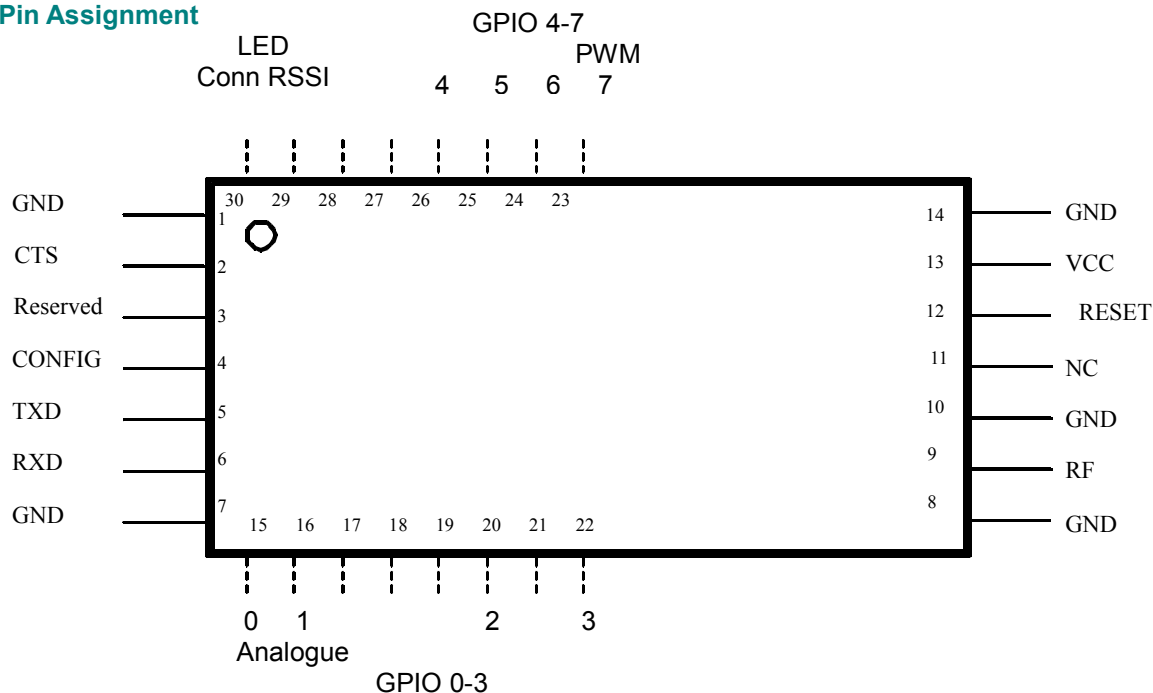
Then calculate the low byte value: $1228 - (4 * 256) = 204$ (Hex 0xCC).

Note: The input impedance of the analogue input pins are in the range of Mohms. Any voltage given to the inputs should rely on external voltage dividing circuitry.

Setting the Analogue Sampling Interval.

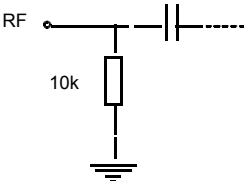
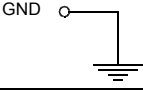
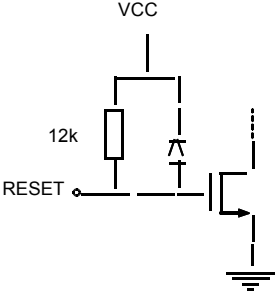
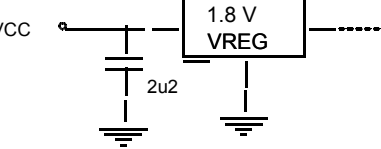
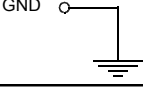
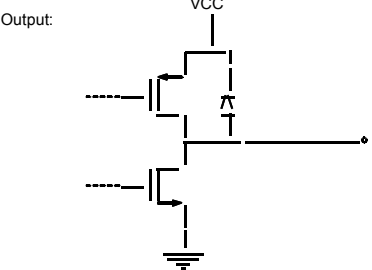
The sampling interval may be set in steps of 0,1 seconds, for values between 1 and 25,5 seconds. The analogue value is then calculated as the average value of the last 8 samples. The sliding average and the sampling interval, may be used as a filter function to eliminate spurious glitches in the sampled voltage. The default sampling interval is set for 1 second.

Pin Assignment



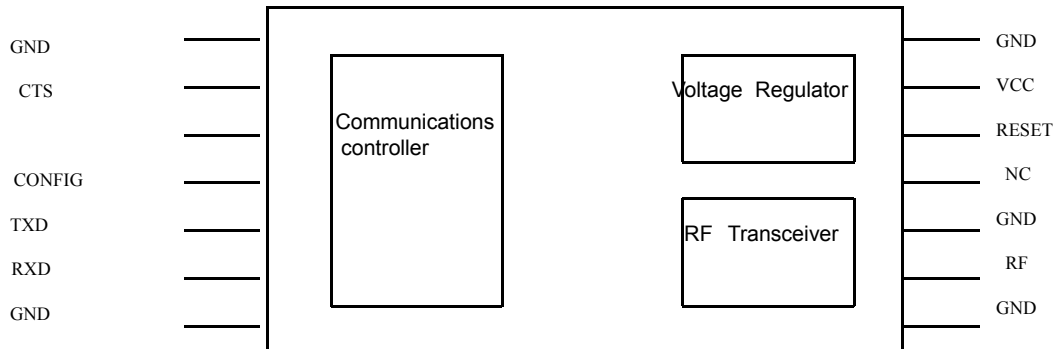
Pin Description

Pin no	Pin name	Pin type	Description	Equivalent circuit
1	GND		System ground	
2	CTS	Output	UART Clear to Send Active Low	
3	Reserved	Input		
4	CONFIG	Input	Configuration Enable. Active low. Should normally be set high. (See Note 2)	
5	TXD	Output	UART TX Data	
6	RXD	Input	UART RX Data. Use external max 8k2 pull-up resistor if connected to an open collector output from a host MCU or other high impedance circuitry like level shifters. (See Note 1)	
7	GND		System ground	
8	GND		System ground	

9	RF		RF I/O connection to antenna	
10	GND		System ground	
11	NC		Not connected	
12	RESET	Input	Main reset (active low). Should normally be left open. Internal 12 k pull-up resistor.	
13	VCC		Supply voltage input. Internally regulated.	
14	GND		System ground	
15,16, 20, 22-26	GPIO 0-GPIO 7 configurable I/O	Input / output	Each pin individually configurable as input / output.	Ref pins 2-6
17-19, 21, 27, 28	RESERVED		Test pins or pins reserved for future use. <i>Do not connect!</i>	
29	RSSI LED	Output	Direct LED drive output (source). Flash frequency indicates network connection RSSI level	
30	Network connection LED	Output	Direct LED drive output (source). Flash frequency indicates network connection redundancy.	

Note 1: For UART communication the TXD and RXD are used for serial data, and CTS for flow control. RXD must be high when not sending data to the module.

Block Diagram



Circuit Description

The module contains a communications controller with embedded TinyMesh™ protocol software, a high performance RF transceiver and an internal voltage regulator.

The communications controller handles the radio packet protocol, the UART interface and controls the RF transceiver. Data to be sent by the host is received at the RXD pin and buffered in the communications controller. The data packet is then assembled with preamble, start-of-frame delimiter (SOF), network routing information and CRC check sum before it is transmitted on RF.

The RF transceiver modulates the data to be transmitted on RF frequency, and demodulates data that are received.

Received data are checked for correct address and CRC by the communication controller. If the address matches the module's own address, and no CRC errors were detected, the data packet is acknowledged before re-transmitted.

The asynchronous UART interface consists of RXD, TXD and CTS. The CTS output will be TRUE LOW when the module is ready to receive data. CTS must be monitored on a **byte-by-byte basis** to avoid losing data.

When the CONFIG pin is asserted, the communications controller interprets data received on the RXD pin as configuration commands. There are commands to change the radio channel, the output power, the RF bit rate etc. Configuration parameters are stored in non-volatile memory. For a full overview of configuration commands, please see Module Configuration, page 23

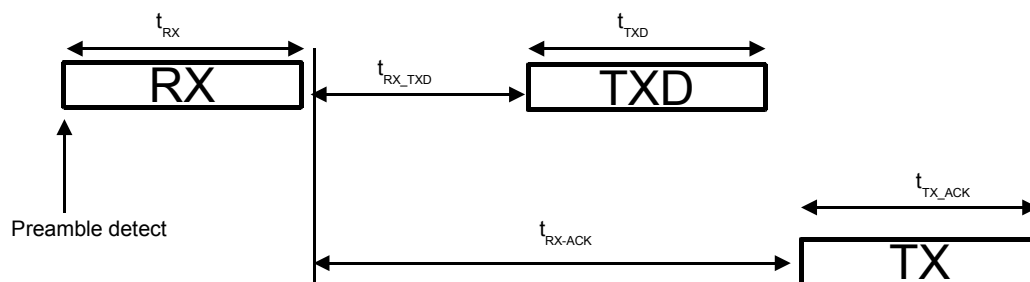
Receive and transmit timing information

The figures and tables below show the timing information for the module when changing between different operating states.

RXD and TXD are processes for receiving or transmitting UART data. The UART operates in full duplex, allowing simultaneous serial transmit and receive between the module and a host processor.

RX and TX are radio states, in which the built in radio transmitter is busy either receiving or transmitting data.

Receive RF packet timing

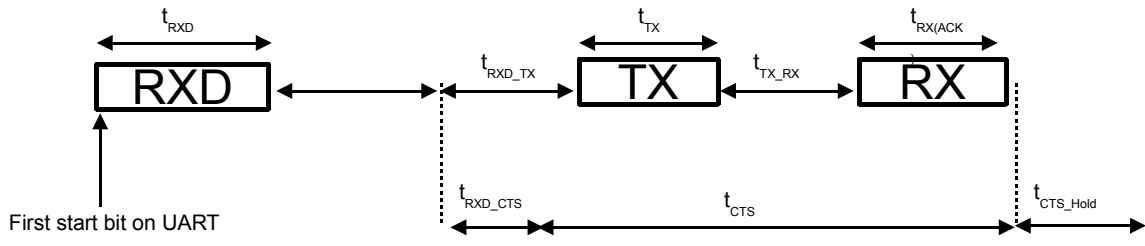


Tiny Mesh RF Receive timing diagram

Symbol	Value	Description / Note
t_{RX}	Serial data: 3.5 – 16ms Event packet: 5.1 ms	Time from preamble detected until package received.
t_{RX_TXD}	Max 1 ms	Time from package fully received until first character sent to UART
t_{TXD}	Min 521 us	Number of bytes x 521 us
t_{RX_ACK}	2 ms - 33 ms	Time from package fully received until Acknowledge message ready to be transmitted, including LBT and random MAC timing
$t_{TX(ACK)}$	3.2 ms	Time to transmit ACK package, including preamble and sync

Note: Timing diagram representative for packet transmission without collision and retry, and no wait for clear channel delay.

UART receive and CTS timing



Tiny Mesh UART receive and CTS timing diagram

Symbol	Value	Description / Note
t_{RXD}	Min 521 us	Number of bytes in message x 521 us
$t_{Packet_Timeout}$	min 0, max 255 ms	Configurable 10-2550 ms. No time out if buffer is filled (120 bytes).
t_{RXD_TX}	2 - 32 ms	Time from serial data received on UART until packet ready to be transmitted, including LBT and random MAC timing
t_{TX}	4.3-16.8 ms	Time to transmit package, including preamble and sync. Transmit time = 4.3ms + number of bytes* 0.104ms
t_{TX_RX}	2 - 32 ms	Time from RF packet transmitted until Acknowledge preamble detected. Time equals t_{RX_ACK} in Receiver RF Packet timing diagram
$t_{RX(ACK)}$	3.2 ms- 16.8 ms	Time to receive and verify Acknowledge packet Router: 3.2 ms, Gateway 4.3-16.8 ms, depending on packet size.
t_{RXD_CTS}	10 us	Time from buffer full or time-out, until CTS high (Off)
t_{CTS}	9.5- 82 ms	Time from CTS Off until Acknowledge received= $t_{RXD_TX} + t_{TX} + t_{TX_RX} + t_{RX(ACK)} - t_{RXD_CTS}$
t_{CTS_Hold}	min 0, max 255 ms	Time from Acknowledge received until CTS released (on) Configurable Gateway parameter, always 0 for Router nodes

Note: Timing diagram representative for packet transmission without collision and retry, and no wait for clear channel delay.

Examples:

120 bytes serial data entered on Router UART @ 19.2 kbit/s, RF rate=76,8 kbit/s
Time from first start bit enters UART until packet delivered and CTS released (on):

min: $(120 \times 0.521) + 0 + 2 + 16.8 + 2 + 3.2 = 86.5$ ms

max: $(120 \times 0.521) + 0 + 32 + 16.8 + 32 + 3.2 = 146.5$ ms

10 bytes serial data entered on Router UART @ 19.2 kbit/s, RF rate=76,8 kbit/s, packet time-out = 10 ms. Time from first start bit enters UART until packet delivered and CTS released (on):

min: $(10 \times 0.521) + 10 + 2 + 5.3 + 2 + 3.2 = 27.7$ ms

max: $(10 \times 0.521) + 10 + 32 + 5.3 + 32 + 3.2 = 87.7$ ms

10 bytes serial data entered on Gateway UART @ 19.2 kbit/s, RF rate 76,8 kbit/s, packet time-out = 10 ms, CTS_Hold = 10ms. Time from first start bit enters UART until packet delivered and CTS released (on):

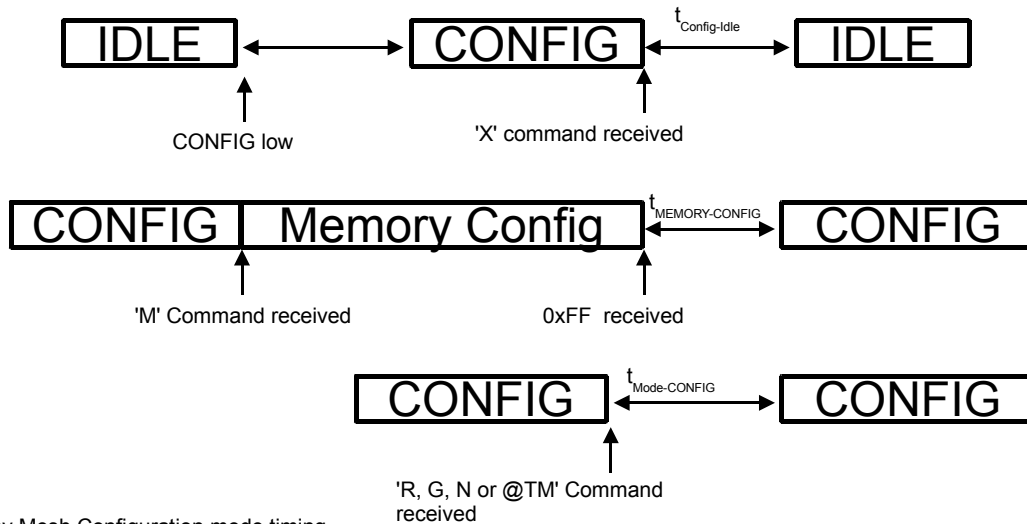
min: $(10 \times 0.521) + 10 + 2 + 5.3 + 2 + 5.3 + 10 = 39.8$ ms

max: $(10 \times 0.521) + 10 + 32 + 5.3 + 32 + 5.3 + 10 = 99.8$ ms

Memory configuration timing

CONFIG is the operating state entered by asserting the CONFIG pin, and is used during parameter configuration over the UART port. MEMORY CONFIG is a 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.



Tiny Mesh Configuration mode timing

Configuration mode timing

Symbol	Value	Description / Note
$t_{\text{RESET-IDLE}}$	3.3 ms	Time from power up reset to module in normal. Idle mode
$t_{\text{CONFIG-PROMPT}}$	1 ms	Time from CONFIG pin is set low until prompt (">")
$t_{\text{MEMORY-CONFIG}}$	24 ms	In this period the internal flash is programmed. <i>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.</i>
$t_{\text{Mode-CONFIG}}$	46 ms	In this period the internal flash is programmed. <i>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.</i>
$t_{\text{Command-Response}}$	10 us	Time from end of command byte to start of response byte received on UART on all commands except R, G, N and memory configuration commands.
$t_{\text{CONFIG-IDLE}}$	1 ms	Time from 'X' command until module in normal operation

RF Frequencies, Output Power Levels and Data Rates

The following table shows the available RF channels and their corresponding frequencies, nominal output power levels and available data rates.

Article Number	RF channel	Output power	Data rate
RC1140-TM	1: 433.100 MHz 2: 433.200 MHz 3: 433.300 MHz 4: 433.400 MHz 5: 433.500 MHz 6: 433.600 MHz 7: 433.700 MHz 8: 433.800 MHz 9: 433.900 MHz 10: 434.000 MHz 11: 434.100 MHz 12: 434.200 MHz 13: 434.300 MHz 14: 434.400 MHz 15: 434.500 MHz 16: 434.600 MHz 17: 434.700 MHz	1: -20 dBm 2: -10 dBm 3: 0 dBm 4: 5 dBm 5: 10 dBm	1: 1.2 kbit/s 2: 4.8 kbit/s 3: 19.0 kbit/s 4: 32.768 kbit/s 5: 76.8 kbit/s 6: 100 kbit/s 7: For future use
RC1160-TM	1: 868.750 MHz 2: 868.850 MHz 3: 868.950 MHz 4: 869.050 MHz 5: 869.150 MHz	1: -20 dBm 2: -10 dBm 3: 0 dBm 4: 5 dBm 5: 10 dBm	1: 1.2 kbit/s 2: 4.8 kbit/s 3: 19.0 kbit/s 4: 32.768 kbit/s 5: 76.8 kbit/s 6: 100 kbit/s 7: For future use
RC1170-TM RC1170HP-TM	1: 865.100 MHz 2: 865.300 MHz 3: 865.500 MHz 4: 865.700 MHz 5: 865.900 MHz 6: 866.100 MHz 7: 866.300 MHz 8: 866.500 MHz 9: 866.700 MHz 10: 866.900 MHz 11: 867.100 MHz 12: 867.300 MHz 13: 867.500 MHz 14: 867.700 MHz 15: 867.900 MHz	RC1170-TM 1: -20 dBm 2: -10 dBm 3: 0 dBm 4: 5 dBm 5: 10 dBm RC1170HP-TM 1: 0 dBm 2: 10 dBm 3: 14 dBm 4: 25 dBm 5: 27 dBm	1: 1.2 kbit/s 2: 4.8 kbit/s 3: 19.0 kbit/s 4: 32.768 kbit/s 5: 76.8 kbit/s 6: 100 kbit/s (N/A for HP version) 7: For future use

Article Number	RF channel	Output power	Data rate
RC1180-TM RC1180HP-TM ^{(*)2}	1: 868.050 MHz 2: 868.150 MHz 3: 868.250 MHz 4: 868.350 MHz 5: 868.450 MHz 6: 868.550 MHz 7: 868.650 MHz 8: 868.750 MHz 9: 868.850 MHz 10: 868.950 MHz 11: 869.050 MHz 12: 869.150 MHz 13: 869.525 MHz (for HP version) 14: 869.750 MHz 15: 869.850 MHz 16: 869.950 MHz 17: 869.475 MHz 18: 869.575 MHz	RC1180-TM 1: -20 dBm 2: -10 dBm 3: 0 dBm 4: 5 dBm 5: 9 dBm RC1180HP-TM 1: 0 dBm 2: 10 dBm 3: 14 dBm 4: 25 dBm 5: 27 dBm	1: 1.2 kbit/s 2: 4.8 kbit/s 3: 19.0 kbit/s 4: 32.768 kbit/s 5: 76.8 kbit/s 6: 100 kbit/s (N/A for HP version) 7: For future use
RC1190-TM	50 channels: 902+nx0.5 MHz for n = [1, 50] default: 4: 904.0 MHz	1: -20 dBm 2: -10 dBm 3: 0 dBm 4: not recommended ^{(*)1} 5: not recommended ^{(*)1}	1: 1.2 kbit/s 2: 4.8 kbit/s 3: 19.0 kbit/s 4: 32.768 kbit/s 5: 76.8 kbit/s 6: 100 kbit/s 7: For future use
RC2500-TM RC2500HP-TM	83 channels: 2399.75+nx1 MHz for n = [1, 83] default: 4: 2403.75 MHz	RC2500-TM 1: -20 dBm 2: -10 dBm 3: -5 dBm 4: -1 dBm 5: 1 dBm RC2500HP-TM 1: -10 dBm 2: 0 dBm 3: 5 dBm 4: 10 dBm 5: 17 dBm	1: 1.2 kbit/s 2: 4.8 kbit/s 3: 19.2 kbit/s 4: 32.768 kbit/s 5: 76.8 kbit/s 6: 100 kbit/s 7: For future use

^{(*)1} Not recommended due to higher output power than the FCC limit.

^{(*)2} Channel 13, 17 and 18 are the only channels to be used with 500mW settings in Europe. For channel 17 and 18, maximum RF speed is 1.2 kbit/s due to limitations in spectrum spread at the 869.4-869.65 MHz band-edges.

RF channel, output power level and data rate may be changed in configuration memory by using the 'M' command in configuration mode. The default factory settings are shown in **bold** in the table above. For more details on changing the RF channel, output power or data rate, refer to the description of the configuration commands, page 23

The use of RF frequencies, maximum allowed RF power and duty-cycles are limited by national regulations. The RC1180(HP)-TM and RC1140-TM are complying with the applicable directives within the European Union when used within these limitations.

RC1190-TM is pending approval under FCC for use in the US and Canada. For more information see section "Regulatory Compliance Information".

RSSI Reading

The module provides a digital Received Signal Strength Indicator (RSSI) through the 'S' command when in Configuration Mode, and included in received messages when the Gateway module is operating in Packet Mode. 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 is used by the TinyMesh™ protocol to indicate fading margin, and as a carrier sense signal to avoid collisions.

The signal strength measure by the S command is the instantaneous value. The RSSI value included in a received package (page 8), is the signal strength at the originating module, when receiving data from the module that has been selected as the first receiver of packets from the originating module i.e. the first jump in the mesh network.

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

$$P = - \text{RSSI} / 2 \text{ [dBm]}$$

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 is also returned in all Event type messages (page 8) while the module is operating in Packet mode

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

$$T = \text{TEMP}(\text{dec}) - 128 \text{ [}^\circ\text{C]} \text{ (Example: TEMP=0x98 equals +24 }^\circ\text{C)}$$

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 voltage level monitoring.

The VCC value is also returned in all Event type messages (page 8) while the module is operating in Packet mode

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

$$V = \text{VCC}(\text{dec}) * 0.030 \text{ [V]} \text{ (Example: VCC=0x68 equals 3.12 V)}$$

Module Configuration and Configuration Mode commands

The configuration of the module may be changed in-circuit from a host MCU during operation, at the time of installation of the equipment, at the manufacturing test, or even as a standalone module.

Router modules may also be configured during normal operation, in an operating mesh network by issuing Configuration commands from the Gateway (page 6). Some restrictions apply. Channel settings and module address may not be changed by Gateway commands, to avoid losing contact with an operating module in a live network.

When configuring the module through the UART interface, the module must first be set to Configuration Mode by asserting the CONFIG pin (set low).

In Configuration Mode, the module will respond to commands by sending a '>' prompt on the TXD pin. This indicates that the module is ready to receive new commands. The CONFIG pin may 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 has been executed, the module responds with the '>' prompt character, indicating it is ready for a new command. New commands must not be entered before the '>' prompt has been received. The time required to execute a command may vary depending on the command (see the Timing Information section). There is no '>' prompt after the 'X' exit command.

Parameter	Command	Argument in hex (decimal)	Note
Signal Strength (RSSI)	'S' – 0x53	Returns one byte indicating the signal strength	See RSSI Reading, page 22
Temperature monitoring	'U' – 0x55	Returns one byte indicating the temperature.	See Temperature Reading, page 22
Battery monitoring	'V' – 0x56	Returns one byte indicating the power supply voltage.	See Power Supply voltage Reading, page 22
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. Parameters changed are stored in non-volatile memory.
Memory Reset	'@TM' – 0x40 0x54 0x4D	No arguments	Restores configuration memory to factory default values.
Exit command	'X' – 0x58	(none)	Exit to normal operation mode. All parameter changes take effect.
Set Router Mode	'R' – 0x52	(none)	Set Router mode and adjust parameters
Set Gateway Mode	'G' – 0x47	(none)	Set Gateway mode and adjust parameters
Set End Node Mode	'N' – 0x4E	(none)	Set End Node mode and parameters (to be released)
Test mode 0	'0' – 0x30	(none)	List all configuration memory parameters
Test mode 1	'1' – 0x31	(none)	TX carrier
Test mode 3	'3' – 0x33	(none)	RX
Test mode 5	'5' – 0x35	Any received character exits Sniffer mode and returns to Test mode 3.	Sniffer mode: Return single byte RSSI for any valid TinyMesh™ package received.

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 Channel 3, change contents of memory address 0x00 to new value 0x03. 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
'M'	0x4D	>	Wait for '>' prompt
0	0x00		No prompt, module waiting for data
3	0x03		No prompt, module waiting for data
255	0xFF	>	Wait $t_{\text{MEMORY-CONFIG}}$ for '>' prompt
[A new command could be issued here]			
'X'	0x58	(none)	Module returns to IDLE state

Configuration Memory

The table below shows the complete list of configurable parameters stored in non-volatile memory. These values may be changed using the 'M' command while the module is in Configuration Mode (page 23), or through Gateway Commands (page 6). All addresses and arguments must be sent as binary values to the module (not as ASCII representation for hex or decimal).

Parameter	Description	Address	Argument	Factory setting	Comment
Radio and protocol configuration					
RF_CHANNEL	RF channel	0	RC1140: 1-17 RC1160: 1-5 RC1170: 1-12 RC1180: 1-16 RC1190: 1-50 RC2500: 1-83	4	See table page 20 for details. HP (High Power) versions might have reduced number of available channels Not Configurable by Gateway Command
RF_POWER	RF output power	1	1-5	5	See table page 20 for details
RF_DATA_RATE	RF data rate	2	1-6	5	20See table page 20 for details Not Configurable by Gateway Command
Protocol Mode	Packet format selection	3	Transparent:1 Packet: 0	1	See page 6 for details
RSSI Acceptance level	Minimum RSSI to accept network connection	4	160- 210	190	<i>Do not change</i>
RSSI Clear Channel Assessment level	Max RSSI for Clear Channel during Listen Before Talk	5	160- 210	193	<i>Do not change</i>
HIAM time	Time in seconds between network invites	6	1-10	4 (Router)	<i>Do not change.</i> <i>Set by 'G', 'R', 'N' commands</i>
IMA time	Time in minutes between automatic status messages	7	1-255 255= never	255	
Connect Check Time	Time in seconds between network evaluation	8	4-20	4	Must be equal or larger than HIAM time for router modules
Max Jump Level	Highest allowable network jump level	9	1-255	20	
Max Jump Count	Maximum transportation jumps before a packet is eliminated, assumed undeliverable.	10	1-255	30	
Max Packet Latency	Maximum transport time in periods of 2,55s before a packet is eliminated, assumed undeliverable.	11	1-255	5	
RF transmit Retry Limit	Number of unsuccessful RF retries before a Router disconnects and attempts reconnecting to the network.	12	1-100	100	
Serial port Time Out	Time out in periods of 10ms between character inputs on serial port before a packet is transmitted in Transparent mode.	13	1-255	20	
Device Type	1 = Gateway 2 = Router	14	1-3	2	1 = Gateway 2 = Router
Reserved		15			

Parameter	Description	Address	Argument	Factory setting	Comment
GPIO 0 Configuration	Configure GPIO 0/ Module Pin 15	16	0-2,4	1	0 = Output, default High 1 = Input 2 = Analogue in 4 = Output, default Low
GPIO 1 Configuration	Configure GPIO 1/ Module Pin 16	17	0-2,4	1	0 = Output, default High 1 = Input 2 = Analogue in 4 = Output, default Low
GPIO 2 Configuration	Configure GPIO 2/ Module Pin 20	18	0-2,4	1	0 = Output, default High 1 = Input 4 = Output, default Low
GPIO 3 Configuration	Configure GPIO 3/ Module Pin 22	19	0-2,4	1	0 = Output, default High 1 = Input 4 = Output, default Low
GPIO 4 Configuration	Configure GPIO 4/ Module Pin 26	20	0-2,4	1	0 = Output, default High 1 = Input 4 = Output, default Low
GPIO 5 Configuration	Configure GPIO 5/ Module Pin 25	21	0-2,4	1	0 = Output, default High 1 = Input 4 = Output, default Low
GPIO 6 Configuration	Configure GPIO 6/ Module Pin 24	22	0-2,4	1	0 = Output, default High 1 = Input 4 = Output, default Low
GPIO 7 Configuration	Configure GPIO 7/ Module Pin 23	23	0-4	1	0 = Output, default High 1 = Input 3 = PWM output 4 = Output, default Low
GPIO 0 trig	Trigger an event on input level change if port set as input	24	0-3	0	0 = No trig 1 = Rising edge 2 = Falling edge 3 = Both edges
GPIO 1 trig	Trigger an event on input level change if port set as input	25	0-3	0	0 = No trig 1 = Rising edge 2 = Falling edge 3 = Both edges
GPIO 2 trig	Trigger an event on input level change if port set as input	26	0-3	0	0 = No trig 1 = Rising edge 2 = Falling edge 3 = Both edges
GPIO 3 trig	Trigger an event on input level change if port set as input	27	0-3	0	0 = No trig 1 = Rising edge 2 = Falling edge 3 = Both edges
GPIO 4 trig	Trigger an event on input level change if port set as input	28	0-3	0	0 = No trig 1 = Rising edge 2 = Falling edge 3 = Both edges
GPIO 5 trig	Trigger an event on input level change if port set as input	29	0-3	0	0 = No trig 1 = Rising edge 2 = Falling edge 3 = Both edges
GPIO 6 trig	Trigger an event on input level change if port set as input	30	0-3	0	0 = No trig 1 = Rising edge 2 = Falling edge 3 = Both edges
GPIO 7 trig	Trigger an event on input level change if port set as input	31	0-3	0	0 = No trig 1 = Rising edge 2 = Falling edge 3 = Both edges
Input De-bounce	De-bounce time in ms for all inputs	32	0-255	10	
GPIO 0 Analogue High trig High byte	High byte of two byte High Trig level value	33	0-7	7	
GPIO 0 Analogue High trig Low byte	Low byte of two byte High Trig level value	34	0-255	255	

Parameter	Description	Address	Argument	Factory setting	Comment
GPIO 0 Analogue Low trig High byte	High byte of two byte Low Trig level value	35	0-7	0	
GPIO 0 Analogue Low trig Low byte	Low byte of two byte Low Trig level value	36	0-255	0	
GPIO 0 Analogue Sampling Interval	Time between samplings in 100ms increments	37	1-255	10	
GPIO 1 Analogue High trig High byte	High byte of two byte High Trig level value	38	0-7	7	
GPIO 1 Analogue High trig Low byte	Low byte of two byte High Trig level value	39	0-255	255	
GPIO 1 Analogue Low trig High byte	High byte of two byte Low Trig level value	40	0-7	0	
GPIO 1 Analogue Low trig Low byte	Low byte of two byte Low Trig level value	41	0-255	0	
GPIO 1 Analogue Sampling Interval	Time between samplings in 100ms increments	42	1-255	10	
CTS hold time	CTS hold time in 10ms increments	43	1-255	50	Active on Gateway only.
Locator Enable	Enable locator function	44	0-1	0	
UNIQUE_ID0 (UID0)		45	0-255	Unique	UID= UID3:UID2:UID1:UID0
UNIQUE_ID1 (UID1)		46	0-255	Unique	
UNIQUE_ID2 (UID2)		47	0-255	Unique	
UNIQUE_ID3 (UID3)		48	0-255	Unique	
SYSTEM_ID0 (SID0)		49	0-255	1	SID= SID3:SID2:SID1:SID0 Not Configurable by Gateway Command
SYSTEM_ID1 (SID1)		50	0-255	0	
SYSTEM_ID2 (SID2)		51	0-255	0	
SYSTEM_ID3 (SID3)		52	0-255	0	
Data and configuration interface, UART Serial Port					
UART Baud Rate	Baud rate	53	0: Not used 1: 2400 2: 4800 3: 9600 4: 14400 5: 19200 6: 28800 7: 38400 8: 56700 9: 76800 10: 115200 11: 230400	5	BE CAREFUL IF CHANGING AS HOST MAY LOOSE CONTACT WITH MODULE! Does not take effect until module is re-booted / reset.
Reserved		54-59			Do not Change
Module description					
PART_NUMBER		60-68		RCxxxx-TM or RCxxxxHP-TM	Not Configurable by Gateway Command
HW_REV_NO		70-73 or 72-75		x.yz	x, y and z; Any number 0-9 decimal Not Configurable by Gateway Command
FW_REV_NO		75-78 or 77-80		x.yz	x, y and z; Any number 0-9 decimal Not Configurable by Gateway Command
Miscellaneous settings					
Reserved		81-93			Do not Change
IMA On Connect		94	0-1	0	See page 10 for details
PWM default		95	0-100	0	See page 12 for details
Reserved		96-128			Do not Change

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

Antenna Connection

The antenna should be connected to the RF pin. The RF pin is matched to 50 Ohm. If the antenna connector is placed away from the module at the motherboard, the track between the RF pin and the connector should be a 50 Ohm transmission line.

On a two layer board made of FR4 the width of a micro strip transmission line should be 1.8 times the thickness of the board, assuming a dielectric constant of 4.8. The line should be run at the top of the board, and the bottom side should be a ground plane.

Example: For a 1.6 mm thick FR4 board, the width of the trace on the top side should be $1.8 \times 1.6 \text{ mm} = 2.88 \text{ mm}$.

The simplest antenna to use is the quarter wave whip antenna. A quarter wave whip antenna above a ground plane yields 37 Ohm impedance and a matching circuit for 50 Ohm are usually not required.

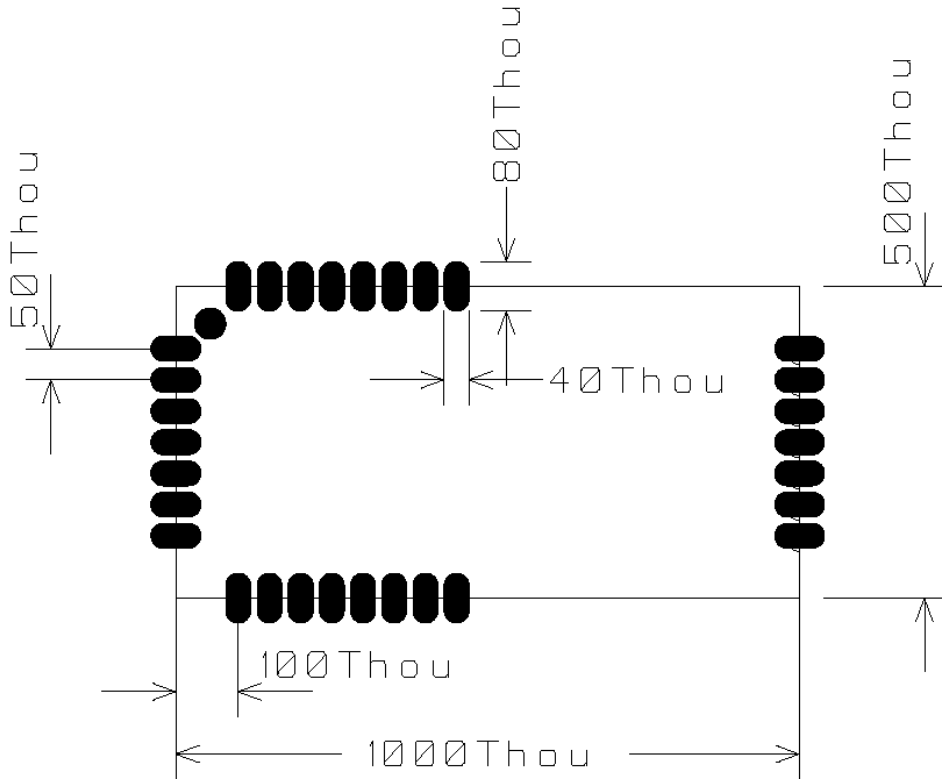
A PCB antenna can be made as a copper track where the ground plane is removed on the back side. The rest of the PCB board should have a ground plane as large as possible, preferably as large as the antenna itself, to make it act as a counterweight to the antenna. If the track is shorter than a quarter of a wavelength, the antenna should be matched to 50 ohms.

The lengths of a quarter wave antenna for different operational frequencies are given in the table below.

Frequency [MHz]	Length [cm]
433	16.4
865-867	8.2
868	8.2
915	7.8
2450	2.9

PCB Layout Recommendations

The recommended layout pads for the module are shown in the figure below. All dimensions are in thousands of an inch (mil). The circle in upper left corner is an orientation mark only, and should not be a part of the copper pattern.



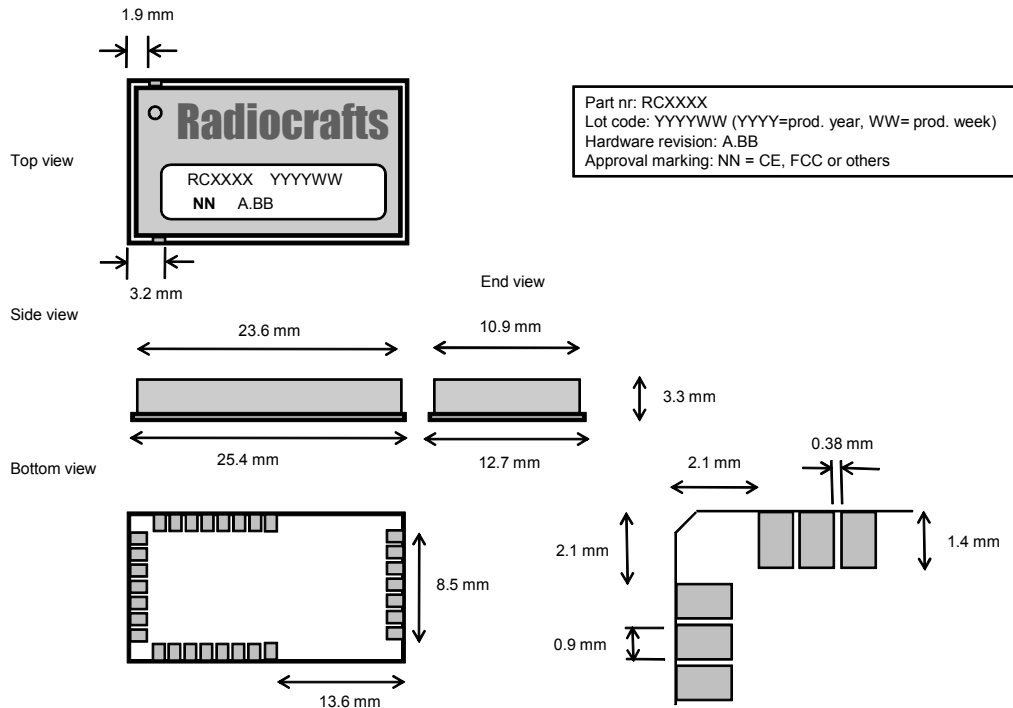
A PCB with two or more layers, and with a **single**, solid ground plane in one of the inner- or bottom layer(s) is recommended. All GND-pins of the module shall be connected to this ground plane with vias with shortest possible routing, one via per GND-pin. It is recommended to avoid multiple GND layers, as it is challenging to achieve sufficiently low impedance between multiple layers.

On the back side of the module there are several test pads. These test pads shall not be connected, and the area underneath the module should be covered with solder resist. If any routing or vias is required under the module, the routing and vias must be covered with solder resist to prevent short circuiting of the test pads. It is recommended that vias are tented.

Reserved pins should be soldered to the pads but the pads must be left floating.

Note that Radiocrafts technical support team is available for schematic and layout review of your design.

Mechanical Drawing



Drawings are not to scale

Mechanical Dimensions

The module size is 12.7 x 25.4 x 3.3 mm.

Carrier Tape and Reel Specification

Carrier tape and reel is in accordance with EIA Specification 481.

Tape width	Component pitch	Hole pitch	Reel diameter	Units per reel
44 mm	16 mm	4 mm	13"	Max 1000

Soldering Profile Recommendation

JEDEC standard IEC/JEDEC J-STD-020B (page 11 and 12), Pb-Free Assembly is recommended.

The standard requires that the heat dissipated in the "surroundings" on the PCB is taken into account. The peak temperature should be adjusted so that it is within the window specified in the standard for the actual motherboard.

Aperture for paste stencil is normally areal-reduced by 20-35%. Nominal stencil thickness of 0.1 -0-12 mm is recommended. Consult your production facility for best experience aperture reduction.

Absolute Maximum Ratings

Parameter	Min	Max	Unit
Supply voltage, VCC	-0.3	3.9	V
Voltage on any pin	-0.3	VCC+0.3V Max 3.9V	V
Input RF level		10	dBm
Storage temperature	-50	150	°C
Operating temperature	-40	85	°C

Caution! ESD sensitive devices.
Precaution should be used when handling the device in order to prevent permanent damage.

Under no circumstances the absolute maximum ratings given above should be violated. Stress exceeding one or more of the limiting values may cause permanent damage to the device.

Electrical Specifications

T=25°C, VCC = 3.0V if nothing else stated.

Parameter	Min	Typ.	Max	Unit	Condition / Note
Operating frequency					
RC1140-TM	433.05		434.79	MHz	
RC1160-TM	868.7		869.2		
RC1170(HP)-TM	865.0		867.0		
RC1180(HP)-TM	868.0		870.0		
RC1190-TM	902.0		928.0		
RC2500(HP)-TM	2400.75		2483.75		
Number of channels					
RC1140-TM		17			
RC1160-TM		5			
RC1170(HP)-TM		15			
RC1180-TM		18			
RC1180HP-TM		3			
RC1190-TM		50			
RC2500(HP)-TM		83			
Input/output impedance		50		Ohm	
Data rate		1.2 4.8 19.0 32.768 76.8 100		kbit/s	
Frequency stability					
RC1140 – RC1190-TM (LP&HP)			+/- 40	ppm	Including 10 years of ageing.
RC2500(HP)-TM			+/- 20		
Frequency stability ageing			1	ppm/year	Starting after 10 years
Transmit power					
RC1140-TM – RC1180-TM	-20		10	dBm	
RC1170HP-TM, RC1180HP-TM	0		27		
RC1190-TM	-20		-1		
RC2500-TM	-15		1		
RC2500HP-TM	-10		18		
RC1140 – RC1190-TM (LP&HP)					
Spurious emission, TX				dBm	
< 1 GHz			-36		
> 1 GHz			-30		
47 – 74 MHz			-54		
87.5 – 118 MHz			-54		
174 – 230 MHz			-54		
470 – 862 MHz			-54		

Parameter	Min	Typ.	Max	Unit	Condition / Note
RC2500(HP)- TM Spurious emission, TX, 1 dBm 30-1000 MHz 1 – 12.75 GHz 1.8 – 1.9 GHz 5.15 – 5.33 GHz			-36 -30 -47 -47	dBm	Complies with EN 300 328, EN 300 440, FCC CFR47 Part 15 and ARIB STD#T66
RC2500(HP)- TM Spurious emission, TX, 10 dBm 30 - 1000 MHz 1 – 12.75 GHz 1.8 – 1.9 GHz 5.15 – 5.33 GHz			-36 -30 -47 -47	dBm	Complies with EN 300 328, EN 300 440, FCC CFR47 Part 15 and ARIB STD#T66
RC2500(HP)- TM Spurious emission, TX, 20 dBm 30 - 1000 MHz 1 – 12.75 GHz 1.8 – 1.9 GHz 5.15 – 5.33 GHz			-36 -30 -47 -47	dBm	FCC CFR47 Part 15 and ARIB STD#T66
Sensitivity RC1140 – RC1190-TM (LP&HP) 1.2 kbit/s 4.8 kbit/s 19.0 kbit/s 32.768 kbit/s 76.8 kbit/s 100 kbit/s RC2500-TM 1.2 kbit/s 4.8 kbit/s 19.0 kbit/s 32.768 kbit/s 76.8 kbit/s 100 kbit/s RC2500HP- TM 1.2 kbit/s 4.8 kbit/s 19.0 kbit/s 32.768 kbit/s 76.8 kbit/s 100 kbit/s		-110 -106 -104 -101 -99 -97 -105 -103 -101 -99 -91 -89 -108 -105 -101 -100 -92 -91		dBm	1% packet error rate, 20 bytes packet length
Adjacent channel rejection RC1140 – 1190-TM RC1170HP-TM, 1180HP-TM		29 27		dB	
Alternate channel selectivity		53		dB	
Image channel rejection		28		dB	
Blocking / Interferer rejection / desensitization RC1140 – RC1190-TM (LP&HP) +/- 1 MHz +/- 2 MHz +/- 5 MHz +/- 10 MHz RC2500(HP) TM Blocking / Interferer rejection / desensitization +/- 10 MHz +/- 20 MHz +/- 50 MHz	30 35 50 60	43 49 68 72 55 60 60		dB	Wanted signal 3 dB above sensitivity level, CW interferer. Minimum numbers corresponds to class 2 receiver requirements in EN300220. Wanted signal 3 dB above sensitivity level, modulated interferer. BER=0.1% Compliant to class 2 receiver requirements in EN 300 440 class 2
Saturation RC1140 – RC1190-TM (LP&HP) RC2500-TM RC2500HP-TM		-14 -10 -20		dBm	

Parameter	Min	Typ.	Max	Unit	Condition / Note
Spurious emission, RX 30 – 1000 MHz 1 – 12.75 GHz			-57 -47	dBm	Complies with EN 300 328, EN 300 440, FCC CFR47 Part 15, and ARIB STD#T66
Supply voltage RC1140 – RC1190-TM RC1170HP-TM, RC1180HP-TM RC2500-TM RC2500HP-TM	2.0 2.7 2.0 2.7		3.9 3.3 3.6 3.6	V	
Current consumption, RX/IDLE RC1140 – RC1190-TM (LP&HP) RC2500-TM RC2500HP-TM		24 25 40		mA	Apply over entire supply voltage range
Current consumption, TX RC1140-TM -20 dBm -10 dBm 0 dBm 5 dBm 9 dBm RC1160- RC1190-TM -20 dBm -10 dBm 0 dBm 5 dBm 9 dBm RC2500-TM 1 dBm RC1170HP- RC1180HP-TM 0 dBm 10 dBm 14 dBm 25 dBm 27 dBm RC2500HP-TM -10 dBm 0 dBm 5 dBm 10 dBm 18 dBm		18 20 22 25 35 16 17 22 30 37 27 20 60 80 530 560 80 80 80 80 155		mA	Apply over entire supply voltage range
Current consumption, SLEEP RC1140- RC1190-TM RC1170HP-TM, RC1180HP-TM RC2500-TM RC2500HP-TM		0.3 3.4 0.4 1.3	1.0 10.0 1.0 2.0	uA	
Digital I/O Input logic level, low Input logic level, high Output logic level, low (1µA) Output logic level, high(-1µA)	70 % 0		30 % VCC	V	Of VCC Of VCC
SET pin Input logic level, low Input logic level, high	70 %		30 %	V	Minimum 250 ns pulse width
UART Baud Rate tolerance		+/- 2		%	UART receiver and transmitter
Configuration memory write cycles	1000				The guaranteed number of write cycles using the 'M' command is limited

Regulatory Compliance Information

The use of RF frequencies and maximum allowed RF power is limited by national regulations. The RC1140-TM and RC1180(HP)-TM has been designed to comply with the R&TTE directive 1999/5/EC. According to R&TTE directives, it is the responsibility of Radiocrafts'

customers (i.e. RC11XX-TM end user) to check that the host product (i.e. final product) is compliant with R&TTE essential requirements. The use of a CE marked radio module can avoid re-certification of the final product, provided that the end user respects the recommendations given by Radiocrafts. A Declaration of Conformity is available from Radiocrafts on request.

The RC1190-TM has been tested towards FCC regulations for license free operation under part 15. However, a final approval is required by FCC for the end product.

The RC1170-TM and RC1170HP-TM have been tested towards G.S.R.564(E) and G.S.R.168(E) for license free use in India. The Gazettes are available from Radiocrafts on request.

The RC2500(HP)-TM has been designed to comply with the R&TTE directive 1999/5/EC in Europe, FCC regulation and ARIB regulation. But in order to comply with the different standards, the output power should be configured as commented below.

R&TTE directive (EU)

According to R&TTE directives, it is the responsibility of Radiocrafts customers to check that the host product (i.e. final product) is compliant with R&TTE essential requirements. The use of a CE marked radio module can avoid re#certification of the final product, provided that the end user respects the recommendations established by Radiocrafts. A Declaration of Conformity is available from Radiocrafts on request.

In terms of R&TTE the RC2500HP is a narrowband radio and must comply with EN 300 328 on those premises. This implies that the radiated power must be lower than 10 dBm, **and hence only power level setting 4 and lower can be used for compliance to EN 300 328.**

FCC Compliance (US, Canada)

The RC2500(HP)-TM has been tested towards FCC regulations for license free operation under part 15. However, a final approval is required by FCC for the end product.

Output power is limited to EIRP of -1.25dBm for compliance to part 15, §249. This corresponds to power level 4 in RC2500-TM

The maximum power density must be < 8dBm/3kHz. At full output power for RC2500HP-TM (setting 5), the spreading 6 dB bandwidth (BW) of the signal must be larger than 500 kHz. The the required BW may be achieved by using the highest data rates 250 kbit/s and 500 kbit/s.

WPC Compliance (India)

License based operation in India is bases on case by case grant and the basis is normally a compliance to R&TTE directive(CE) or FCC.

ARIB Compliance

The RC2500(HP) has been designed to comply with the requirements given by the Japanese ARIB STD#T66 for low power (short range) devices in the 2.4GHz range. However, it has not been assessed for conformity with the appropriate regulations. Users must assess and verify that their final product meets the appropriate specifications and to perform the required procedures for regulatory compliance.

The relevant regulations are subject to change. Radiocrafts AS do not take responsibility for the validity and accuracy of the understanding of the regulations referred above. Radiocrafts only guarantee that this product meets the specifications in this document. Radiocrafts is exempt from any responsibilities related to regulatory compliance.

Power Supply

Noisy external circuitry may under certain scenarios affect the TX signal, and precaution should be taken for EU R&TTE conformity. Example of circuits that may generate noise on the transmitted spectrum may be DC/DC converters and some level converters like RS232 and RS485. To increase spectrum margin it is important to add an EMI filter bead on the VCC pin of the module. Alternatively the RC11XX/(HP)25XX(HP)-TM may be powered from a separate voltage regulator. This will ensure that potential switching noise is filtered out from the power supply to the module. A block diagram of a typical PC serial port interface is illustrated below.

Suggested part numbers:

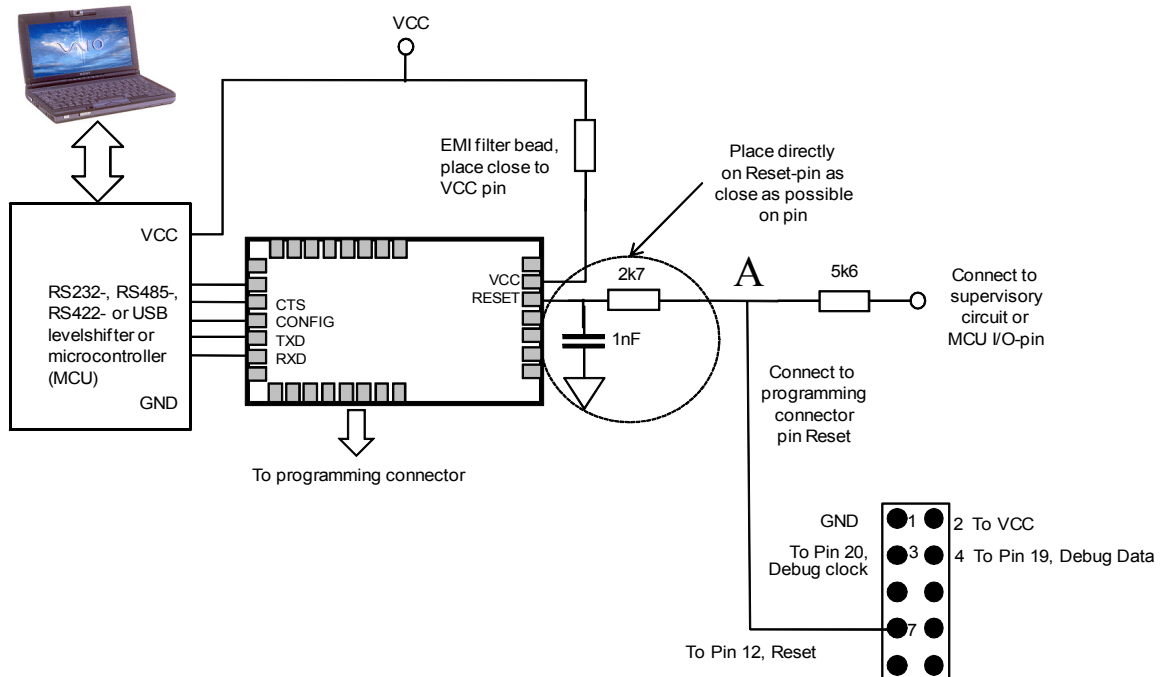
Component	Manufacturer	Part number
EMI filter bead	Murata	BLM11A102S, ordering code BLM18xx102xN1D For High Power versions of modules use BLM18SG331TN1

Programming Interface

For future firmware updates and possible custom variants it is recommended to include a 2x5 pins programming connector to the modules programming pins. The connector should be a 2.54 mm pitch pin-row (same pitch in both directions), SMD or through-hole version, with the connections shown below.

Reset Connection

To minimize effect of noise on the Reset-line, the Reset pin on the module (pin 12) must be connected to external circuitry via an RC-network. It is recommended to connect Reset to either a supervisory circuit or micro controller I/O-pin. If the Reset is driven by a push-pull output, an additional series resistor of 5k6 shall be inserted as shown in the figure, to allow an external programmer used for firmware upgrade to assert Reset low. In noisy surroundings and where Reset is not driven by a push-pull output, it is recommended that the connection 'A' below is pulled to VCC via one or more resistors where the equivalent pull-up resistor is close to 5k6



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
1.01	Packet mode description added
1.02	Gateway packet mode received package description adjusted
1.03	Gateway LED description, Configuration memory address spec, misc text adjustments
1.04	1160, 2500 and HP versions added, timing info added, specs updated
1.1	Correction of some misprints (frequencies and article numbers)
1.15	Added Locator-function information. Added Test Mode 3 and 5. Added I/O control and analogue sampling section Changed all I/O naming references to GPIO
1.16	Added PWM, IMA On Connect description, Added Output config description, Added Config Commands, minor text changes
1.17	Corrected Received Packet Format, Serial data packages, byte 18. Adjusted default values. Minor text changes/ corrections
1.18	Added specification for GPIO output drive. Adjusted text for PCB layout.
1.19	Corrected some configuration-memory default settings. Updated information on End Devices. Corrected default channel for RC1180HP-TM.

Product Status and Definitions

Current Status	Data Sheet Identification	Product Status	Definition
	Advance Information	Planned or under development	This data sheet contains the design specifications for product development. Specifications may change in any manner without notice.
X	Preliminary	Engineering Samples and First Production	This data sheet contains preliminary data, and supplementary data will be published at a later date. Radiocrafts reserves the right to make changes at any time without notice in order to improve design and supply the best possible product.
	No Identification Noted	Full Production	This data sheet contains final specifications. Radiocrafts reserves the right to make changes at any time without notice in order to improve design and supply the best possible product.
	Obsolete	Not in Production	This data sheet contains specifications on a product that has been discontinued by Radiocrafts. The data sheet is printed for reference information only.

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