RC11xx(HP)-TM/ RC25xx(HP)-TM

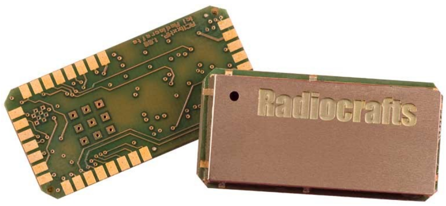
Radiocrafts RF Transceiver Module

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 TinyMesh™ 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
- Building management
- Telemetry stations
- Fleet management
- Asset tracking
- Street lighting control and monitoring



Features

- Embedded TinyMesh™ networking protocol with bidirectional RF data transfer
- Self forming, self healing and self optimizing mesh network
- AES 128 encryption
- Configurable digital I/O, PWM output and analogue input
- Serial Port with software- and hardware- handshake
- RSSI and Network connect LED outputs for simplified field installation
- Clustered Node Detection and Network Congestion Avoidance (CND/NCA™)
- RF Tamper Detection and Alarm, with alarm output and network alarm messaging
- Time-generated, input level-triggered and event-triggered status messages
- Serial Data Streaming support with block counter function
- 256 byte serial data input buffer for MODBUS RTU compatibility
- Locator Function for asset tracking applications
- Network Busy Detection for ad hoc networks with multiple, roaming Gateways
- Multiple Gateway support for redundancy and automatic network load sharing
- Two-wire UART interface for easy RS232/422/485 wire replacement
- Small size (12.7 x 25.4 x 3.3 mm), shielded and optimized for SMD mounting
- No external components
- 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 300 328 (Europe), FCC CFR 47 part 15 (US) and ARIB STD-T66 (Japan)

Quick Reference Data

Parameter	RC1140-TM	RC1170(HP*)-TM RC1171-TM	RC1180(HP*)-TM RC1181-TM	RC1190-TM	RC2500(HP*)-TM	Unit
Frequency bands	433.05-434.79	865.0 – 867.0	868.0 – 870.0	902 – 915	2400 - 2483	MHz
Number of channels	17	15	18 (1 HP channel)	50	83	
Data rate	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 HP Version	10 N/A	10 27	10 27	10 N/A	1 18	dBm
Sensitivity 1.2/ 100 kbit/s HP Version	-110 / -97 N/A	-110 / -97 -109 / -96	-110 / -97 -109 / -96	-110 / -97 N/A	-105 / -89 -108/ -91	dBm
Supply voltage HP Version	2.0 – 3.9 N/A	2.0 – 3.9 2.7 – 3.3	2.0 – 3.9 2.7 – 3.3	2.0 – 3.9 N/A	2.0 - 3.6 2.7 - 3.6	Volt
Current consumption RX / TX HP Version	24 / 35 N/A	24 / 37 24 / 560	24 / 37 24 / 560	24 / 37 N/A	25 / 27 30 / 155	mA
Current consumption SLEEP HP Version	Typ. 0.3 N/A	Typ. 0.3 Typ 3.4	Typ 0.3 Typ 3.4	Typ 0.3 N/A	Typ 0.4 Typ 1.5	uA
Temperature range HP Version	-40 to +85 N/A	-40 to +85 -40 to +85	-40 to +85 -40 to +85	-40 to +85 N/A	-40 to +85 -20 to +85	°C

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.

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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 delivered 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 network device, and no external processor is required for establishing and maintaining the optimum network routing path at all times.

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:

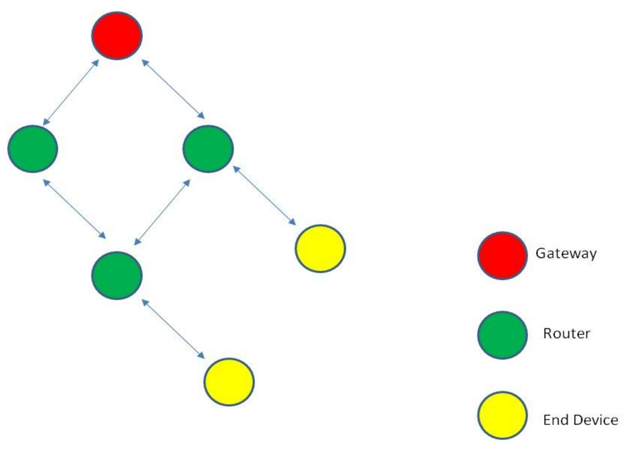
- Optimum network self forming
- Self healing: The path with highest link quality and least number of hops to the recipient is chosen at any time. When optional paths are present, it is indicated with indicative blinks on a LED output. In a changing environment with changing link quality the network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

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

- LBT (listen Before Talk)
- RF packet acknowledge
- Retransmission(s) when required
- AES128 encryption

Network Topology

TinyMesh™ in its simplest topology consists of a single Gateway a Router. Multiple Gateways are allowed within a single network, for redundancy and traffic load sharing. 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

Any TinyMesh™ node may be configured to function as a Gateway, a Router or as an End Node using the 'G', 'R' or 'N' commands in Configuration Mode. A TinyMesh™ network must have at least one Gateway device. The Gateway device initiates the network formation, and is required to keep the network alive. Gateway device provides the connection between the TinyMesh™ Routers and End Devices, and an external host processor or a network interface to a local- or wide area network, such as the Internet.
Router devices are individual, full-functioning devices with serial data UART and Input / Output capabilities, Router devices provide the communication path between individual Router- or End-devices, and the network Gateway

Any Router or Gateway device may be configured as a Locator Device, enabling positioning within the network. Please see later chapter, page 22 for details.

Getting Started

A simple TinyMesh™ network may be formed by configuring at least one module as a Gateway (configure a Gateway via 'G'-command, page 33).
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. The RSSI LED (Red LED on Radiocrafts Demo Board, page 16) 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 16) every time a network invite beacon (HIAM) is transmitted. Routers within acceptable radio range of the Gateway, will detect the invite beacons from the Gateway. If the received signal strength (RSSI) is within predetermined limits of acceptable signal 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 red RSSI Indicator LED now reflects the RSSI level of the established connection, and the yellow Connection indicator starts flashing to indicate successful connection.
All Routers that successfully connect to the network, will immediately start 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 (120 bytes)
- the modem time-out limit is reached (default 20 ms)

Modules will by default use the UART CTS signal to indicate when data may be entered. Routers will hold CTS high when the UART receive buffer is full. After successful connection to a network and delivery of the current contents of the UART buffer, 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 by changing the Serial Port Time Out parameter in Configuration memory. Default setting is 20 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 RF 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.

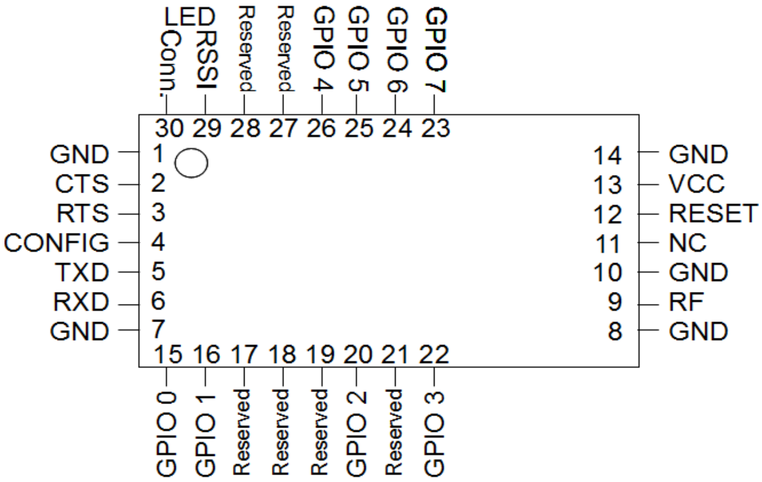
What about the antenna?

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.

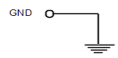
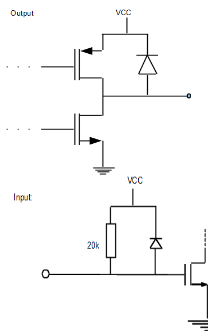
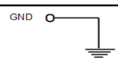
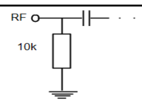
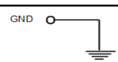
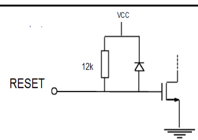
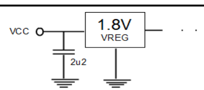
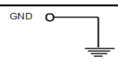
How do I change the RF channel or any other parameter?

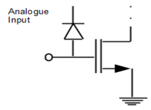
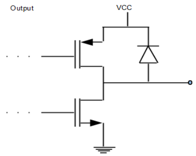
To change configurable parameters, assert the CONFIG pin, and send the command string using the same serial interface as for transmitting data. Configurable parameters are stored in non-volatile memory in the module, please see page 33 and 40 for details.

Pin Assignment



Pin Description

Pin no	Pin name	Pin type	Description	Equivalent circuit
1	GND		System ground	
2	CTS (RXTX)	Output	UART CTS Active Low	
3	RTS	Input	UART RTS	
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	

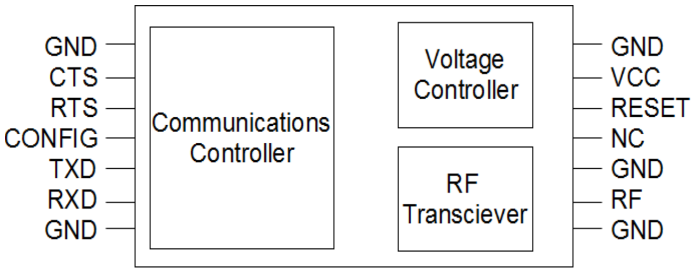
15,16	GPIO 0-GPIO 1	Digital In / out Analogue In	Individually configurable as digital input / output or analogue Input (Internal pull-up disabled)	 Digital Input/ output,Ref pins 2-6
20,22, 26,25, 24	GPIO 2-GPIO 6	Digital In / out	Individually configurable as digital input / output	Ref pins 2-6
23	GPIO 7	Digital In / out PWM out	Configurable as digital input / output or PWM output	Ref pins 2-6
17-19, 21, 27, 28	RESERVED		Test pins or pins reserved for future use. *Do not connect!*	
29	RSSI LED	Output	Direct LED drive output (source). Flash frequency indicates network connection RSSI level	
30	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.

Circuit Description

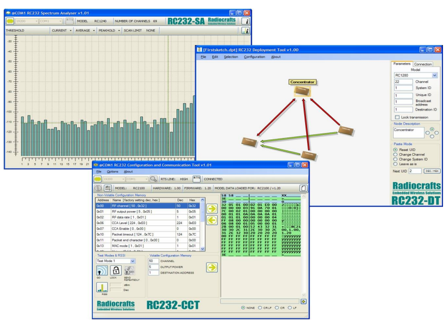
The module contains a communications controller with embedded TinyMesh™ protocol software, a high performance RF transceiver and an internal voltage regulator.
The communications controller handles the radio packet protocol, the UART interface and controls the RF transceiver. Data to be sent by the host 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, RTS 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 loosing data when the default CTS handshake configuration is enabled.
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 33

Block Diagram



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 may be used for both configuration and communication testing. Visit www.radiocrafts.com and Tools for a free download and full documentation.



Transparent Mode Operation

The default, factory setting for TinyMesh™ modules, 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 when when the CTS output is low, or when the Xon character has been received from the UART. RF transmission will automatically be triggered on buffer full or character time-out on the serial port. The connected host MCU should always observe the selected handshake status (CTS or Xon/Xoff) before sending any data, or data may be lost.

Transparent versus Packet Mode Operation

By configuring the Gateway for Packet mode (Page 17), the Gateway may directly control and monitor each Router device. Functions such as analogue and digital input control, PWM output and automatic or event triggered messages are available through Packet Mode operation. Serial data entered and received at the Gateway, will contain extra bytes for addressing, command and control.

Transparent- and Packet Mode Functions

Serial Data Streaming

When streaming serial data from a Router device, or from a Gateway device in Transparent Mode, the data stream will automatically be divided into correctly sized TinyMesh™ RF packets, before data is transmitted in the mesh network. The Serial Data Input Buffer has a capacity of 256 bytes, allowing for instance a complete MODBUS RTU package to be received.
The TinyMesh module will signal a full buffer condition by setting the CTS output high, or by issuing an Xoff character, as configured by the UART Flow Control parameter. The Serial Buffer Full Margin parameter provides for an adjustable margin from the buffer full condition is signalled, until the Serial Data Input Buffer overflows. The default setting of the Serial Buffer Full Margin parameter is 18 (bytes), allowing the host MCU a margin of some additional bytes that may be transmitted before the Serial Data Input Buffer in the module runs full. The default value of 18 bytes has been chosen to optimize packet sizes when streaming data. Most host systems and terminal emulators will be able to respond to the 'CTS off' status within the time needed to transmit two characters. At this point, there will be 240 bytes received in the Serial Data Input Buffer, which is the maximum size of two full TinyMesh RF packets.
The host MCU should stop transmitting data as soon as possible after detecting CTS off, or after receiving the Xoff character. After a time period of a few milliseconds, as determined by the Serial Port Time Out parameter (default 20 ms), the TinyMesh module will start forming new RF packets from the received data, and initiate RF transmission.
If the serial data stream does not stop after the module has signalled the 'buffer full' condition, The TinyMesh™ protocol will prepare the data for RF transmission immediately after a data buffer completely full condition is present (256 bytes). Subsequent data delivered to the UART will then be lost if the data stream continues before the module Serial Data Input Buffer is again available.
After successful transmission of the received data, the module will signal to the external MCU that the Serial Data Input Buffer is again available, by setting the hardware handshake CTS signal low, or by transmitting an Xon character.

Serial Port Handshake

The Gateway and Router serial ports (UARTs), offer several optional handshake settings to support reliable connections to an external host. The different settings are available by changing the UART Flow Control parameter in Configuration Memory (page 40).
The UART Flow Control parameter is a bitmap of optional control mechanisms that may be individually enabled by setting the corresponding bit. The default setting is 0x01, CTS enabled

Bit No	De-fault	Name	Applies to	Function
0	1	CTS	Router and Gateway	The CTS control signal will be low when the module is ready to receive data. The external host should monitor the CTS line before transmitting any data, as the module will discard data received while CTS is high. The Serial Buffer Full Margin parameter in Configuration Memory (58) may be used to set CTS off a number of bytes before the buffer is completely full, thereby allowing the host system time to respond to the CTS off situation. This function is important when for instance using hardware handshake on a system with USB serial ports. The default setting is four (4) bytes.
1	0	RTS	Gateway	The RTS control signal may be used by an external host to signal that the host is ready to receive data. When enabled, the module will observe the RTS line before transmitting any byte. No data will be transmitted while RTS is high. Note: If RTS is enabled, and the host does not set RTS TRUE (Low), a connected Gateway device will not be able to deliver data, and consequently the Gateway will not receive data from the mesh network. The mesh network will disconnect if the Gateway device is not responding.
2	0	RXTX	Router	When RXTX is enabled, the module UART will set CTS low during data

			and Gateway	transmission. The RXTX mode is provided for direction control of RS485 drivers. CTS will be driven LOW immediately before the first startbit is transmitted, and will return HIGH immediately following the last stop bit from the UART.
3	0	Xon/ Xoff	Router and Gateway	When the Xon/ Xoff function is enabled, the module UART will transmit an Xoff character (Value 0x13, ASCII DC3) a settable number of bytes before te buffer runs full. The external host MCU should then halt further data transfer until an Xon (0x11, ASCII DC1) character has been received. An Xon character will be transmitted continuously at 1 second intervals while the module is ready to receive data. The default setting for the Serial Buffer Full Margin parameter in configuration memory is four (4) bytes before buffer is full. The Gateway device will only support Xon/ Xoff when in transparent mode. Please also note that binary data transfer will not work with Xon/ Xoff, as the binary data may contain the Xon / Xoff characters.
4	0	ACK/ NAK	Gateway	When enabled, the Gateway module will answer any received data on the serial port with an Acknowledge or a non-acknowledge message. In this mode, the Gateway will do a format and validity control of received commands before transmitting in the RF mesh network. The first data byte in the event data field will contain the user selected command number. The second data field of the NAK event will indicate why the packet was not accepted.
5	0	Wait For ACK	Gateway	When enabled, the Gateway module will expect an ACK character (0x06, ASCII ACK) response to any packet delivered to the host. If the ACK is not received within the 1 second time frame, the packet will be repeated
6				Reserved
7				Reserved

AES Encryption

Automatic AES encryption is enabled by changing the Security Level parameter in Configuration Memory. When AES encryption is enabled, the payload portion of all RF data packets are encrypted using the 128 bit AES Key no 7.
In Automatic Encryption mode, the Gateway and Router device must share a common AES key, settable by the 'K' Configuration command. See chapter Setting and Changing the AES key, page 35 for details on AES key programming in Configuration Mode.
The encryption key is stored in a secure memory location that will not be displayed with the '0' or 'r' Configuration commands. The key is retained even after an @TM factory reset command.
Encrypted and unencrypted Router nodes may co-exists and will connect to a common network. A Gateway device will be able to receive data from encrypted, as well as unencrypted Router devices, but an unencrypted Router device will not be able to receive and interpret encrypted commands.

Co-Existence with AES Encrypted and unencrypted Devices

Nodes with encryption enabled, may co-exist with unencrypted nodes in a common system. Encrypted data packets are slightly larger than unencrypted packages. AES mode 3 (Compatible mode) is provided for backwards compatibility to field deployed systems where encryption has not been enabled.
In systems with a mixture of encrypted and unencrypted nodes, the following rules will apply:

- Encrypted packets originating from encrypted devices will be transported by unencrypted nodes to their final destination.
- unencrypted packets will be transported by encrypted nodes to their final destination.
- Encrypted nodes will not accept receipt of unencrypted packets (commands or serial out packets)

- unencrypted nodes will not accept receipt of encrypted packets (commands or serial out packets)
- An encrypted Gateway will accept and decrypt messages from encrypted nodes, as well as accept data packets from unencrypted nodes.
- An unencrypted Gateway will only accept messages from unencrypted nodes.

Sleep Mode

A TinyMesh™ module may be set to sleep mode to reduce power consumption by issuing the 'Z' command while the module is in Configuration mode. The module will wake up, go through a full Power On Reset cycle and resume operation when the Configuration pin is driven high.

To enter sleep mode:

1. Set the module to Configuration Mode by pulling the CONFIG input pin 4 low.
2. Observe the module entering Configuration mode by monitoring the '>' prompt character response on the module TXD, Pin 5
3. Issue a 'Z' command to the UART serial port RXD, pin 6

The module is now in sleep mode

To exit sleep mode:

1. Assert a logic high signal to the CONFIG input pin 4, using an active, push-pull output. (All internal pull-up resistors are disabled during sleep mode to reduce excessive power leakage. The CONFIG input must therefore be actively driven to the logic high state.)
2. Observe the module assuming normal operation and connecting to the mesh:

- CTS will be high while the module is going through the reset cycle, then low when the module has made a valid network connection.
- If Xon/Xoff protocol is enabled, (Serial Port Handshake), a single Xoff character will be issued after completed reset cycle. The first Xon character will be issued after successful connection to the mesh.
- The Connection Indicator LED will begin flashing.
- A Reset message, Reset from Sleep or Config Command, will be initiated.
- A Status Message (IMA) will be issued if the IMA On Connect Function is enabled.

RF Tamper Detection and Alarm

The RF Tamper Detection feature is a unique TinyMesh™ function, providing timed logging and alarming of RF conditions that may inhibit radio communication. Radio Frequency interference that may influence RF communication, may be present in form of intended (tampering) disturbance, or un- intended noise from electrical equipment or RF transmitters.

While a tamper situation is present, the module will issue a local RF Tamper Alarm condition by setting a pre-defined GPIO low for the duration of the tamper situation. The local alarm signal may be used by the host MCU to detect, time-stamp and store the tamper situation, and to activate a local alarm if available.

The GPIO alarm output will return high when the tamper situation is no longer present.

The following Configurable parameters are used to control the RF Tamper alarm feature:

- Enter the GPIO number (0-7) selected for the local alarm output in the RF Tamper Alarm parameter.
- Configure the selected GPIO as Output by changing the appropriate GPIO Configuration setting.
- Enter the number of minutes of continuous RF interference status to constitute an alarm condition in the RF Tamper Detect parameter.

RF Tamper Detection in Packet Mode Systems

The TinyMesh™ module will create an RF Tamper alarm message that will be transmitted through the mesh as soon as the RF communication is re-established. The RF Tamper message will contain timing information in the Event Message Data bytes MSB and LSB. The Message Data MSB indicating tamper time in minutes, and the LSB indicating time since tamper condition ended in hours.

Clustered Node Detection and Network Congestion Avoidance (CND/NCA™)

The Clustered Node Detection feature, is a unique TinyMesh™ function, provided to prevent RF network congestion in situations where multiple TinyMesh™ devices are located densely together. In for instance energy metering installations, large groups of meters may often be located side-by side, forming clusters of devices ranging from a handful of units, to tens or hundreds of meters in the same location.
In such clustered situations, there is a risk of excessive amounts of radio traffic, causing network congestion and bad connectivity, as the RF bandwidth will be filled with radio packets intended for network maintenance, and there will be very little bandwidth available for data packets containing payload data.
The Clustered Node Detection feature, is controllable through the following, configurable parameters:

Clustered Node RSSI. The default RSSI setting is 60 (-30 dBm). Lower settings will effectively disable this function, as the value will be lower than the RX saturation level for the radio. By increasing the value, the cluster detection function may be adapted to situations with modules using lower TX output power.

Clustered Node Device Limit. The default setting is 10, forcing the clustered node detection function to start reducing unnecessary RF traffic when more than ten devices are located closely together.

Optimizing Polled Systems

Wireless TinyMesh™ networks are well suited for replacement of wired multi-drop systems, offering significantly lower installation- and infrastructure cost. Transparent- as well as Packet mode configurations of TinyMesh™ may satisfy the requirement for an RS485 or similar multi-drop replacement.
Multi-drop systems are often based on a polled communication protocol, with a master device sending individually addressed, or broadcast 'poll' commands, asking for response from the slave devices.
A wireless mesh will generally provide less communication bandwidth as compared to a wired system, and unnecessary communication overhead should be avoided when possible, to increase payload throughput. The TinyMesh™ protocol provides a number of mechanisms that serve to improve data throughput in master-slave systems.
In Transparent Mode systems, the master device should, when possible, use broadcast polling rather than sending individual device poll commands. Successful implementation of broadcast polling requires that the individual device will respond with a data package containing the device address as part of the data payload.
When receiving a command broadcast, all TinyMesh™ devices will simultaneously attempt communicating the command response. The device that first detects a clear RF channel when performing the Listen Before Talk procedure, will immediately start transmission. Other devices will detect that the radio channel is busy, and will retry communication after a random time period. This automatic retry mechanism will ensure that responses from all devices are communicated error free and within an optimum time period.
The TinyMesh™ Packet mode configuration will offer additional means for creating an efficient replacement for a wired, polled system. When implemented in a Packet Mode system, the address field of the response packet may be used to identify the individual device, eliminating the requirement for having device address as part of the data payload.
Individual TinyMesh™ devices may also be set to generate automatic, time generated status reports, and devices may be configured to automatically generate messages on digital- or analogue input status changes, eliminating the need for the master controller poll function. For further information, please reference the later chapter on Automatic Status Reporting.

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.

RSSI Indicator LED

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

1. Very fast flash (Five flashes per second)
   RSSI is better than configured Excellent RSSI Level
2. Fast flash, (Two flashes per second):
   RSSI is good, at least RSSI Change Margin better than RSSI Acceptance level
3. Moderate flash, on for1 second, off for1 second:
   RSSI is acceptable for reliable communication
4. 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

Connection Indicator LED

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 jump level as an alternate route (redundant connection)
4. Moderate flash, on for one second and off for one second:
   Connected to a single router, no alternatives exist on same jump level.
5. No light: Disconnected

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

Radio RX /TX Indicator LED

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.

Packet Mode Operation

When configured for packet mode operation, data may be directed from the Gateway to one specific router or end node device (availability tbd). 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 and analogue inputs may be set to trigger messages on input condition changes.
Routers will acknowledge receipt and acceptance of commands and data. The Acknowledge packet will be available on the Gateway UART.
The Gateway module will provide additional, bi directional ACK / NAK handshake for error free connection to an external host

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

Gateway commands may be 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 33 and page 40), or while operating in a live mesh network by issuing Configuration commands from the Gateway module.
To avoid loosing connection with devices in a live mesh network, the RF channel, RF data rate and module address (UID) may not be changed through Gateway Commands after the System ID has been changed from the factory default (0 0 0 1) setting.
The Command Packet formats for module control, inquiry and configuration, are shown in the table below. The destination TinyMesh™ module will respond to valid commands by transmitting either a *Command Received and Executed* Event (Packet Type 2, Message Detail 16) if the command was accepted and executed, or a *Command Rejected, Not Executed (NAK)* Event (Packet Type 2, Message Detail 11), if the command data or arguments were out of range.
There is no Acknowledge response to broadcast commands.
Please reference Received Package Format, (page 19) for detailed package description.

Byte #	Field	Size	Description	
			Control and Status request	Change Configuration
1	Start character	1	10 (0x0A) Equals length of string	40 (0x28) Equals length of string
2	Node Address	4	Configured value of destination node, or use broadcast ID (255 255 255 255) if command for all units.	
6	Command No.	1	User selectable. This number will be returned as part of the Acknowledge packet from the Router on completed command execution	
7	Packet Type	1	3 (0x03) Fixed value	
8	Command Argument	1	1 (0x01) Set Outputs 2 (0x02) Set PWM 5 (0x05) Set Gateway in Config Mode 16 (0x10) Get CID 17 (0x11) Get Status 18 (0x12) Get DID Status 19 (0x13 Get Configuration 21 (0x15) Force Router Reset 22 (0x16) Get Packet Path	3 (0x03) Set Configuration
9	Data 1	1	Set Outputs: Bitmap for setting GPIO 0..7 Set PWM: 0-100 % duty cycle. For other Command arguments, this byte is don't care.	Data 1..33 (32 bytes) 1st. Byte = address 2nd. Byte= value ….. 32rd. Byte=last address 33rd. Byte=last value Address=00 indicates last valid address.(see example below)
10	Data 2	1	Set Outputs: Bitmap for clearing GPIO 0..7 For other command arguments, this byte is don't care.	

Note: The sequence of the IDs below are UID0-UID4

Example 1, Set GPIO 0, node address 0 0 2 21, user command number 1

Decimal notation	Hex Notation
10 0 0 2 21 1 3 1 1 0	A 0 0 2 15 1 3 1 1 0

Example 2, Set GPIO 1, Clear GPIO 0, address 0 0 2 31, user command number 2

Decimal notation	Hex Notation
10 0 0 2 31 2 3 1 2 1	A 0 0 2 1F 2 3 1 2 1

Example 3, Set PWM 50%, address 0 0 2 3, user command number 7:

Decimal notation	Hex Notation
10 0 0 2 3 7 3 2 50 0	A 0 0 2 3 7 3 2 32 0

Example 4, Get Router status, address 0 0 2 21, user command number 4:

Decimal notation	Hex Notation
10 0 0 2 21 4 3 17 0 0	A 0 0 2 15 4 3 11 0 0

Example 5, Get Router configuration, address 0 0 2 23, user command number 5:

Decimal notation	Hex Notation
10 0 0 2 23 5 3 19 0 0	A 0 0 2 17 5 3 13 0 0

Example 6, Set Router configuration, address 0 0 2 23, Positive edge trig, GPIO1 (Address 25 = 1), no other settings

Decimal notation
40 0 0 2 23 6 3 3 25 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

Hex Notation
28 0 0 2 17 6 3 3 19 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

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 the start byte is a calculated value

Byte #	Field	Size	Description
1	Start Byte	1	Calculated value, total number of bytes, including Start Byte
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	Packet 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. The packet Header is identical for all packet types, while the data payload formatting (starting at data byte # 18) will be formatted differently when receiving serial data and command responses requiring larger amounts of 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
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 Counter	2	Time in 10 ms resolution from message creation to delivery
17	PacketType	1	Event 2 (0x02) or Serial data in 16 (0x10)

General Event Packet Format (Packet 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
			6 (0x06)	RF Tamper Detected
			8 (0x08)	Reset
			9 (0x09)	Status Message (IMA)
			10 (0x0A)	Channel is Busy with Similar System ID
			11 (0x0B)	Channel is Free
			12 (0x0C)	Channel is Jammed
			13 (0x0D)	Other TinyMesh™ System Active on this Channel
			16 (0x10)	Command Received and Executed (ACK)
			17 (0x11)	Command Rejecteded, Not Executed (NAK)
			18 (0x12)	Status Message (CID)
			19 (0x13)	Status Message Next Receiver
19	Message Data MSB	1	**Message Detail**	**Message Data**
			1,2,3,8,9,10,11, 12,13,18,19	0
			6	Tamper condition duration in minutes
			16,17	User selected command number
20	Message Data LSB	1	**Message Detail**	**Message Data**
			1,2,3,9,10,11, 12,13,16,18,19	0
			6 (0x06)	Hours since tamper condition ended
			8 (0x08)	1 (0x01): Power On Reset 2 (0x02): External Reset (RESET input low) 3 (0x03): Reset from Sleep or Config Command 4 (0x04): Forced Reset by command 5 (0x05): Watchdog Reset

Byte #	Field name	Size	Description	
			17 (0x11)	1 (0x01): Bad packet length 2 (0x02): Bad Gateway configuration command 3 (0x03): Bad packet format 16 (0x10): Bad Node config string length 17 (0x11): Bad Node config command 18 (0x12): Bad Node packet format 19 (0x13): Bad Node command
21	Address(ID) Data	4	Message Detail	Message Data
			0 (0x0)- 17 (0x11)	Address of Locator Router with best received signal strength (RSSI)
			18 (0x12)	Gateway Container Address
			19 (0x13)	Address of first receiver in hop path
25	Module Temperature	1	Module Temperature, ref. page 35	
26	Module Voltage	1	Voltage/ Battery Monitor, ref. page 35	
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		

Event Packet Format (Packet Type 0x02), Response to Get Path Command

Byte #	Field name	Size	Description	
18	Message Detail	1	32 (0x20)	Get Path Response
19..23	Message Data	5	Byte number	Content
			1	RSSI first jump
			2..5	First receiver ID
New entries of 5 bytes added per additional jump until packet is full (138 bytes) or last destination reached				
134..138	Message Data	5	Byte number	Content
			1	RSSI Last jump
			2..5	Last receiver ID

Event Packet Format (Packet Type 0x02), Response to Get Configuration Command

Byte #	Field name	Size	Description	
18	Message Detail	1	33 (0x21)	Confiuration Memory Dump
19-138	Message Data	120	Byte number	Content
			1..120	First 120 bytes of configuration memory

Serial Data Packet Format (Packet Type 0x10)

Byte #	Field name	Size	Description
18	Serial data block counter	1	0: Single data block, terminated by UART time-out. 1-255: Block (partition) number in large data streams controlled by CTS or Xon/Xoff handshake
19	Serial data	1..120	Serial data

Practical use of Header Data

The header section is identically formatted for all TinyMesh™ data packets. The header section contains valuable information for network quality analysis and data validation in a host system.

The four byte System ID uniquely identifies the network that originated the message, and may be used as an identifier in host systems that handle multiple TinyMesh™ networks.

The Origin IDis the Unique ID of the device that originated the message, and an important identifier in a host system database.

The Origin RSSI is the RF signal strength of the first link in the hop path for the message, and is an indication of the quality of the first link. A high value, approaching the minimum level for reliable connection indicates poor connection, and may be an indication of poor connectivity with possibility for unreliable connection. An RSSI value above 190 is regarded as potentially too low for stable and reliable connection. The RSSI Acceptance level parameter in Configuration Memory determines the highest allowable link RSSI for establishing a new connection.

Origin Network Level level indicates the network level of the originating device at the time when the message was first dispatched. As an example, if Origin Network Level is 3, it indicates the message will have to hop three times from the originating node, until it reaches the Gateway. As a TinyMesh™ network inherently is a dynamical network that continuously adapts to changing RF conditions, it is possible that the message may require more, or less than the anticipated number of hops before reaching the Gateway. The actual number of hops travelled by the message, is indicated by the Hop Counter value, that will increase by one each the message is passed from one node to another.

The Message Counter is a unique, 16 bit number maintained by the originating node. Every message received by a host system may be uniquely identified by a combination of the System ID, Unique ID and Message Counter.
Note that the Message Counter is reset to zero after 64k messages, or after a device Reset. In practical implementations, it may be assumed that a new numbering sequence starts every time a Reset message is received from the device. Reset messages will be generated after Power On, after a Force Router Reset Command or after execution of a Device Set Configuration Command.

The Latency Counter is a timer that is reset to zero when the message is created, and maintained throughout the transportation chain until the message is delivered from the Gateway device to the external host. The timer is updated at 10ms intervals, and provides a good indicator of the total transportation delay from the message was initiated at the originating node, until delivered at the Gateway. With a time resolution of 10ms and a 16 bit counter, the maximum measurable delay is just over 10 minutes. The timer will stop counting after reaching the maximum value. The message transportation delay is a good indicator of network reliability, and may also be used in time critical implementations, to recreate an accurate time stamp for an event. Typical transportation delays may be expected to be less than 100ms per network hop.

Device and Network Status Interrogation

The TinyMesh™ protocol supports several optional commands for system and device status interrogation. Automatic, time- generated status messages may be generated by setting the IMA Time parameter in Configuration Memory. The time generated messages may be used for data logging purposes, and as a means to keep track of the on-line status of devices. As an example, if the Router nodes are set to report status once every hour, a host system may routinely check that all devices have reported back within the time window, and generate an alert if status messages are missing.

The Get Status, Get DID Status, and Get CID commands all return similarly formatted status messages with a payload portion containing the current status of all input parameters: Analog, Digital, Temperature and Supply Voltage (See message format description , page 20)
The Get Status command returns the Status Message (IMA) event message, and may be activated on an automatic timebase by setting the IMA Time parameter in Configuration Memory.
The Get DID Status command returns a Status Message Next Receiver event message, containing the next receiver ID in the address field. Next Receiver is the preferred receiver of all communication from this node.
The Get CID command is only recognized by Gateway devices, and returns a Status Message (CID) event message, containing the Gateway Container address in the address field.
The Get Configuration command returns a Confiuration Memory Dump event message, a complete listing of the first 120 bytes of Configuration Memory of the adressed module. This command is useful for verification of individual configuration settings in the network.

The Get Packet Path command returns a variable length payload, see Get Path Response event message description for further details. The payload contains the address and RSSI of all network hops from the original node to the Gateway. Note that in extremely large systems, the number of hops may exceed the maximum payload size of the packet. The maximum payload size is 120 bytes, allowing room for 120/ 5 = 24 hops. In such events, the received message will contain all hops from original node until full packet, and a new Get Packet Path may be issued, addressing the last node in the previously received path.
Also note the Get Packet Path command will only return a valid path when executed in unencrypted systems.

Serial Data Block Counter

The TinyMesh™ protocol supports long data frames and streamed data. Byte number 18 of serial data packets, Serial Data Packet Format (Packet Type 0x10), delivered by Gateway devices in packet mode, contains a block counter that is used by the TinyMesh™ network to indicate if the data belongs to a larger stream of serial data, or if the delivered data is a single delivery.
If the block counter is zero (0), the delivered data is a single packet, generated by the router module after detecting a time-out on the serial port, before a 'buffer almost full condition' was signalled through CTS Off or Xoff (See Serial Port Handshake).
If the block counter is 1 or higher, the delivered data is part of a larger stream of data, and the block counter is an indication of the sequence of the received data. The block counter will roll over to 1 after reaching the maximum value of 255, and will automatically be reset to 0 after receiving the last packet of the long data stream.

Locator Function

Any Router or Gateway may be set as a 'Locator' by enabling the Locator bit in the Configuration Memory. By default, this setting is disabled (0).
Every time a Router sends an Event message (General Event Packet Format) to the Gateway, the Unique ID (UID) of the Locator device within closest radio range (best RSSI) of the Router, may be found in the Address(ID) Data field, as part of the event message.
The Locator feature may be utilized in systems designed for asset tracking or other locating functions. Router devices placed in fixed, known locations should then 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 (IMA Time in the Configuration Memory), through a request from the Gateway, or be triggered by a digital- or analogue input level shift.

Network Busy Detection

The Gateway device may be set to monitor and report network activity before starting to build the mesh network. In some applications using ad hoc networks with for instance portable Gateway devices, it may be important for the operation of the systems that only one Gateway device is active at any time.
By enabling the Detect Network Busy parameter, the Gateway device will either monitor and report status before building the network, it may optionally refrain from building the network if competing activity is discovered.

Container Address

The Container address function is intended for host systems operating multiple mesh networks, such as the TinySolution™ platform. For stand alone systems, the System ID is an adequate means for identifying devices belonging to a system. When deploying Internet based host platforms there may however already exist networks that are in operation, with identical System IDs (SID). To be able to uniquely distinguish between co-existing systems with identical SID, the Gateway device may be configured with a unique, four byte Container Address that is allocated by the hosting system, to guarantee uniqueness.

A host system should request the Gateway Container ID by sending a Get CID command to Node Address 00 00 00 00. The Gateway device will respond with a Status Message (CID) event, containing the Container Address in the Address(ID) Data field.
The Container ID is stored in the module Calibration memory and will be retained after an @TM factory reset command. To change the Container ID, the module must be set to Configuration Mode, and the Setting and Changing the Container ID (CID) procedure should be used to change the CID.

IMA On Connect Function

A Router may be set to send a Status Message (IMA) report 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 IMA On Connect configuration setting, page 40.

Automatic Status Reporting

TinyMesh™ networks provide efficient mechanisms for automatic, time generated status reporting, automatic messaging on analogue- or digital input status change and automatic data transmission on serial data (UART) input. Automatic status- and event reports should be considered as an alternate and more efficient system design than traditional status polling. Poll commands from a master will occupy valuable RF bandwidth, limiting the data throughput and responsiveness in a mesh system. In contrast to protocols normally employed in wired multi-drop systems, a TinyMesh™ network allows any device to initiate communication as long as the communication media (the RF channel) is free. The local intelligence embedded in TinyMesh™ devices automatically handles the access to the shared RF channel by employing a principle referenced CSMA (Carrier Sense Multiple Access), eliminating the need for a polling master controller.

The IMA Time parameter in Configuration Memory may be set to trigger automatic status reports on any interval between 1 and 254 minutes.
Please reference Device and Network Status Interrogation chapter, page 21.

Analogue and digital inputs may be set to automatically trigger event messages on pre-determined status changes. Event messages triggered by input status changes will be transmitted immediately, providing a more responsive approach than what may be achieved in a traditional, polled system.
Please reference the chapters Analogue Input Event Triggering and Digital Input for in-depth information on configuring the inputs for automatic event triggering.

All event message packets contain the current value of Digital and Analog inputs, module temperature, module voltage and the address of the closest Locator Device.
Please reference the Received Package Formats chapter, page 19.

Serial data entered on the device UART will automatically trigger a serial data transmission, see Received Package Formats and Serial Data Packet Format (Packet Type 0x10) for details on the packet format.

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 Packet Mode Operation, page 17, to support the Input / Output functions. Sampled analogue and digital GPIO values may be found in all Event type packages, reference Received Package Formats, General Event Packet Format, delivered by a Gateway. Outputs may be controlled by Set Outputs and Set PWM commands from the Gateway. 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 Memory settings.

Digital Input

When a GPIO has been configured for input,e.g. GPIO 0 Configuration, a separate configuration setting GPIO 0 trig, 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, see Pin Description. 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 by changing the Input Debounce Configuration Parameter. 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 the Set Outputs Command. Please see separate chapter page 17 for detailed description of the command format. Also note the GPIO must first be enabled as outputs, see pages 33 and 40 for details on module configuration (Default configuration is Input). A command to set or reset a GPIO that has not been configured for Output (e.g GPIO 0 Configuration), will have no effect. The default output value at Reset is configurable.

The Data 1 and Data 2 bytes in the command message format, page 17, 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 <u>setting</u> outputs, while Data 2 is used for <u>clearing</u> 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	**Clea-red**	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	**Clea-red**	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 = 3.
The PWM output value may now be controlled by sending a Set PWM command to the module.
The default PWM value at Reset is configurable to any value between 0 to 100% by setting the PWM default parameter in Configuration Memory. The factory setting is 0.
The PWM switching frequency is fixed at 1kHz

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 Configuration and GPIO 1 Configuration. The analogue inputs will be sampled at a sampling rate as defined by the GPIO 0 Analogue Sampling Interval and GPIO 1 Analogue Sampling Interval configuration settings. The Sample Rate may be set in increments of 0.1s. The default setting is 10, or one sample per second. Samples are stored in an 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 analogue voltage value of the input signal, may be calculated as:

Analogue voltage = Measured Value * 1.25 / 2047 [V]

Example:

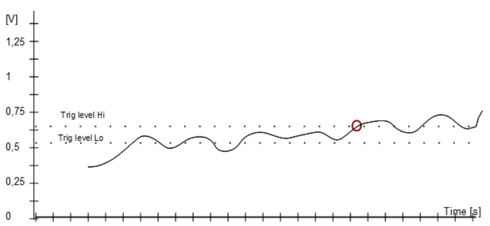
Measured Value:	0x4CC
Convert to decimal :	0x4CC = 1228
Analogue voltage conversion:	1228*1.25 / 2047= 0.75 [V]

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.

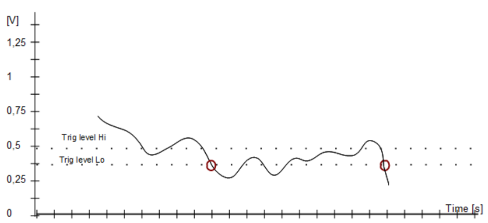
Analogue Input Event Triggering

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 GPIO 0 / GPIO 1 Analogue High, and Analogue Low Trig thresholds 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 in the GPIO 0 or GPIO 1 analogue trigger parameters in Configuration Memory. The maximum trigger level values are 2047, or Hex 0x7FF, entered as High byte = 0x07, and Low byte = 0xFF.

Calculate the Trigger Value as:

Trigger Value = Analogue trigger voltage * 2047/1.25

Example:

Analogue trigger voltage = 0.75[V]

First find the Trigger Value = 0.75* 2047/ 1.25 = 1228

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

1228 / 256 = 4.796 => High Byte = 4

Then calculate the Low Byte value by subtracting the value of the High Byte from the Trigger Value:

1228 – (4 * 256) => Low Byte = 204 (Hex 0xCC).

Note: GPIO 0 and GPIO 1 are both pulled high by an internal 20k resistor when used for digital input or output, see Pin Description. The internal pull-up is disabled when GPIO 0-GPIO 1 are used as analogue inputs, causing the impedance of the analogue inputs to be in the range of several Mohm. Any voltage given to the inputs should rely on external voltage dividing circuitry.

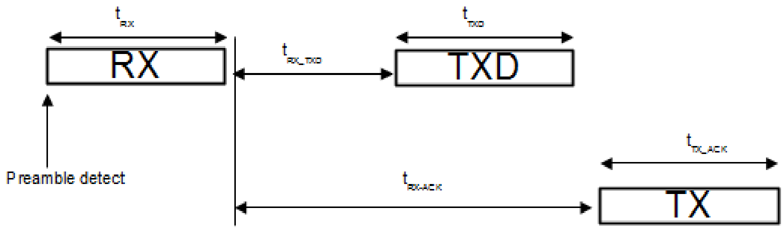
Setting the Analogue Sampling Interval.

The sampling interval may be set in steps of 100ms, by changing the GPIO 0 Analogue Sampling Interval or GPIO 1 Analogue Sampling Interval for values between 1s and 25.5s. The analogue measurement value is calculated as the sliding 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 measured voltage. The default sampling interval is set for 1 second.

Receive and Transmit Timing

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 ether receiving or transmitting data.

Receive RF Packet Timing

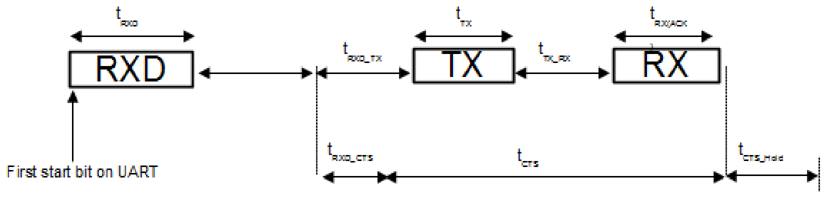


Tiny Mesh RF Receive timing diagram

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
t_{CTS}	9.5- 82 m_s	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 10, max 2550 ms	Time from Acknowledge received until CTS low CTS hold time parameter. Not applicable for Router nodes

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

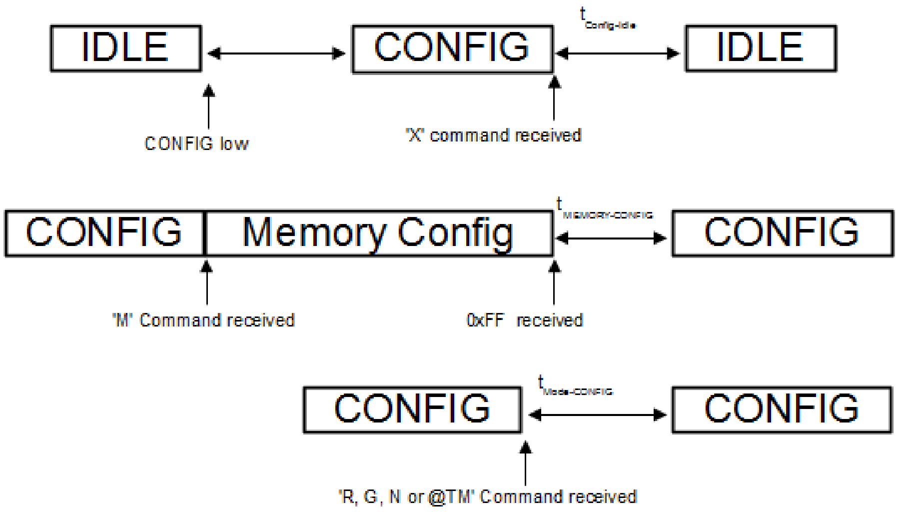
Examples:
120 bytes serial data entered on Router UART @ 19.2 kbit/s, RF rate=76,8 kbit/s
Time from first start bit enters UART until packet delivered and CTS released (on):
min: (120 x 0.521) + 0 + 2 + 16.8 + 2 + 3.2 = 86.5 ms
max: (120 x 0.521) + 0 + 32 + 16.8 + 32 + 3.2 = 146.5 ms

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 x 0.521) + 10 + 2 + 5.3 + 2 + 3.2 = 27.7 ms
max: (10 x 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 x 0.521) + 10 + 2 + 5.3 + 2 + 5.3 + 10 = 39.8 ms
max: (10 x 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.



Configuration Mode Timing

Symbol	Value	Description / Note
$t_{RESET-IDLE}$	3.3 ms	Time from power up reset to module in normal. Idle mode
$t_{CONFIG-PROMPT}$	1 ms	Time from CONFIG pin is set low until prompt (“>”)
$t_{MEMORY-CONFIG}$	24 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.*
$t_{Mode-CONFIG}$	46 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.*
$t_{Command-Response}$	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.
$t_{CONFIG-IDLE}$	1 ms	Time from 'X' command until module in normal operation

RF Frequencies, Output Power 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
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
RC1180-TM **RC1181-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** **RC1181-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: 5 dBm (not recommended (*1)) 5: 9 dBm (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

Article Number	RF channel	Output power	Data rate
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.*

For channels 1, 6, 7, 12, 14 and 16, the maximum RF data rate is 19.2 kbit/s due to limitations in modulation bandwidth at the given sub band-edge.

RF channel, output power level and data rate may be changed in configuration memory by using the Memory Configuration, 'M' command in Configuration Mode, or by using the Set Configuration command for system deployment, while the System ID (SID) is set at the factory default 0 0 0 1 value. 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 33

The use of RF frequencies, maximum allowed RF power and duty-cycles are limited by national regulations. The RC1180(HP)-TM, RC1181-TM and RC1140-TM are complying with the applicable directives within the European Union when used within these limitations.

RC1180-TM and RC1181-TM, channels 5-9 are license free channels within Russia.

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

Module Configuration

Module configuration settings may be changed in-circuit from a host MCU during operation, at the time of installation of the equipment, at the manufacturing test, or as configuration commands through the mesh network.

Configuration Commands

TinyMesh™ modules may be configured during normal operation in an operating mesh network, by using the Set Configuration command. Roters as well as even Gateway devices may be configured using this method.
RF Channel settings, RF Data Rate, Module address (UID) and System ID (SID) may only be changed by Set Configuration commands while the system ID (SID) is still set to the factory default value (0 0 0 1), to avoid loosing contact with an operating module in a live network.
Gateway devices may be forced to the dedicated Configuration Mode by issuing a Set Gateway in Config Mode command over the UART, as an alternate means to asserting the CONFIG input low.

Configuration Mode

TinyMesh™ modules will enter a dedicated Configuration Mode by asserting the CONFIG pin (set low), for direct UART configuration of the module. The Configuration Mode allows a local MCU full control for reconfiguration on the fly, and is highly useful for system development and test.
In Configuration Mode, the module will signal response to commands by sending a '>' prompt on the TXD pin. The prompt 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 34
Temperature Monitoring	'U' – 0x55	Returns single byte indicating the temperature.	See Temperature Reading, page35
Battery Monitoring	'V' – 0x56	Returns single byte indicating the power supply voltage.	See Power Supply voltage Reading, page 35
Memory Read Single Byte	'Y' – 0x59	0x00 – 0x7F Single byte address in the configuration memory.	Return single byte value from the configuration memory.
Memory Configuration	'M' – 0x4D	Pairs of bytes containing address and data. See Example: 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	No arguments	Exit to normal operation mode. All parameter changes take effect.
Set Router Mode	'R' – 0x52	No arguments	Set Router mode and adjust parameters
Set Gateway Mode	'G' – 0x47	No arguments	Set Gateway mode and adjust parameters
Set End Node Mode	'N' – 0x4E	No arguments	Set End Node mode and parameters (to be released)
Set Sleep	'Z' - 0x5A	No arguments	Set module to sleep mode if CONFIG input is low
Set AES Key	'K' - 0x4B	Key index '7' (0x37), 16 bytes key data	Set AES key number Seven Reference Page 35
Set Calibration	'HW'- 0x48	Pairs of bytes containing address	Used to alter calibration defaults.

Memory	0x57	and data. See Feil: Fant ikke kilden til referansen below. 0xFF exits memory configuration.	Reference page
List Calibration Memory	'r' - 0x72	No arguments	List all calibration memory parameters
List Configuration memory (Test Mode 0)	'0' – 0x30	No arguments	List all configuration memory parameters
Test Mode 1	'1' – 0x31	No arguments	TX carrier ON
Test Mode 3	'3' – 0x33	No arguments	RX mode
Sniffer Mode 1 (Test Mode 5)	'5' – 0x35	Any received character exits Sniffer mode1 and returns to Test mode 3.	Sniffer mode 1: Return single byte RSSI for any valid TinyMesh™ package received.
Sniffer Mode 2 (Test Mode 6)	'6' - 0x36	Any received character exits Sniffer mode 2 and returns to Test mode 3.	Sniffer Mode 2: Return RSSI and key packet information 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 input 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.

Set Configuration Memory Command

Configuration parameters in non-volatile Configuration Memory may be changed using the 'M' command

Example:
To select Channel 3, change contents of memory address 0x00 to new value 0x03.

Command	Hex	Response	Comment
Enter Configuration Mode		'>'	By Asserting and releasing the CONFIG input, or By issuing the Set Gateway in Config Mode command to a Gateway node
'M'	0x4D	'>'	Wait for '>' prompt
0	0x00	No response	Address byte received, waiting for Data byte
3	0x03	No response	Data byte received, module waiting for next address or 255 (0xFF) to terminate Memory Configuration
255	0xFF	'>'	Wait $t_{MEMORY\text{-}CONFIG}$ for '>' prompt
New command			The Module remains in Configuration Mode until 'X' command received
'X'	0x58	No response	The TinyMesh™ protocol runs through a full Power On Reset Cycle, to ensure all configuration changes are applied.

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 measured by the S command, is the instantaneous value. The RSSI value included in a received package (page 19), 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 = - 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 is also returned in all Event type messages (page 19) 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 = 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 voltage level monitoring.
The VCC value is also returned in all Event type messages (page 19) 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 = VCC(dec)*0.030 [V] (*Example*: VCC=0x68 equals 3.12 [V])

Setting and Changing the AES key

The default AES key 'TinyMeshAESKey#7' has been pre-loaded to all modules shipped from factory. Initial testing of encrypted communication may be performed using the default key, but systems should not be deployed until the default key has been replaced by a new, secret 16-byte key.
AES keys are stored in a dedicated part of flash memory that is not readable by the '0' and 'r' Configuration Mode commands. After entering a new AES key, there is no way for reading the key back. If there is uncertainty as to what key has been entered in a module, the only way to make sure, is to reprogram the key. The key storage part of flash is also retained during an '@TM' factory reset of flash memory, and may not be changed using the 'M' or 'HW' commands.
The AES Key may only be changed using the 'K' command while the module is in Configuration Mode. The following steps should be used to program a new 16 byte key with value 'A B C D E F G H I J K L M N O P':

Command	Hex	Response	Comment
Enter Configuration		'>'	By Asserting and releasing the CONFIG input, or

Mode			By issuing the Set Gateway in Config Mode command to a Gateway node
'K7'	0x4B 0x37	'>'	Wait for '>' prompt
'A B C D E F G H I J K L M N O P'		'>'	*Note there is a 10 second maximum time-out between characters*
'X'	0x58	No response	The TinyMesh™ protocol runs through a full Power On Reset Cycle, to ensure all configuration changes are applied.

Change Calibration Memory Command

Configuration parameters in non-volatile Calibration Memory may be changed using the 'HW' command

Calibrating the Temperature Sensor

The internal temperature sensor may require calibration to show correct value. The Temp Offset parameter in Calibration Memory is used for temperature calibration in steps of 0.25 degree Celsius.
To calibrate the temperature sensor, locate the TinyMesh™ in a temperature controlled environment, enter Configuration Mode and make sure the module is given sufficient time to adapt to the environmental temperature.
Read back the current value of the temperature sensor using the 'U' command (Page 35)
Calculate the actual temperature using the formula on Page 35 and find the offset as the difference between actual room temperature and the sensor reading.
Multiply the found difference by 4 and subtract the Temp Offset, if the sensor is showing too high value, or add the Temp Offset if the sensor is showing too low temperature.
Verify the sensor calibration by repeat readings using the 'U' command

Example1:
To calculate a new temperature offset
Room temperature: 24 [°C]
Module reading (U- command): 0x9A = decimal 154

1) Convert module reading to temperature in °C: 154-128 = 26 [°C]
2) Calculate the temperature error reading: 24 – 26= -2 [°C]
3) Calculate the compensation offset: -2 * 4 = -8
4) Calculate the new Temp Offset value: Temp Offset= TempOffset -8

If Temp Offset is currently set at the factory default 128, the new Temp Offset will be 120

Command	**Hex**	**Response**	**Comment**
Enter Configuration Mode		'>'	By Asserting and releasing the CONFIG input, or By issuing the Set Gateway in Config Mode command to a Gateway node
'HW'	0x48 0x57	'>'	Wait for '>' prompt
0	0x00	No response	Address byte received, waiting for Data byte
120	0x03	No response	Data byte received, module waiting for next address, or 255 (0xFF) to terminate Memory Configuration
255	0xFF	'>'	Wait $t_{MEMORY-CONFIG}$ for '>' prompt
New command			The Module remains in Configuration Mode until 'X' command received
'X'	0x58	No response	The TinyMesh™ protocol runs through a full Power On Reset Cycle, to ensure all configuration changes are applied.

Setting and Changing the Container ID (CID)

The TinyMesh™ Container ID, is an additional level of network addressing that may be deployed to distinguish between multiple TinyMesh™ networks sharing a common platform or server, such as the TinySolution™ cloud service.

The Container ID needs only be entered in the Gateway device(s), and has no effect on the internal addressing in the individual TinyMesh™ networks. By entering unique CIDs in the Gateway devices, different local networks having identical System ID, may still be differentiated on a larger platform, as the CID will serve as an additional level of systems identification that provides differentiation between messages originating from different systems with identical System ID.

The Container ID is stored in the Calibration part of Flash memory. This part of flash is retained even after an '@TM' factory reset, and may only be changed using 'HW' command from Configuration Mode. The 'r' command may be used to read back and verify the contents the Calibration Memory. The following steps should be used to program a new CID with value 4 3 2 1.

Command	Hex	Response	Comment
Enter Configuration Mode		'>'	By Asserting and releasing the CONFIG input, or By using the Set Gateway in Config Mode command to a Gateway node
'HW'	0x48 0x57	'>'	Wait for '>' prompt
23 1 24 2 25 3 26 4 or Hex: 0x17 0x01 0x18 0x02 0x19 0x03 0x1A 0x04		No response	Four pairs of address and data received, module waiting for next address or 255 (0xFF) to terminate the command
255	0xFF	'>'	Wait $t_{MEMORY-CONFIG}$ for '>' prompt
'r'	0x72	Calibration Memory	Read back the Calibration Memory contents to verify correct settings
'X'	0x58	No response	The TinyMesh™ protocol runs through a full Power On Reset Cycle, to ensure all configuration changes are applied.

Setting and Changing the Fixed Destination ID (FDID)

A TinyMesh™ device may be forced to assume a permanent network connection by setting the Fixed Destination ID (FDID) to a value different from the default 0:0:0:0 setting. A Fixed Destination ID may be useful in systems using sleeping devices, where the device should spend as little time as possible making a network connection after wakeup.

Please note that a device that has been set with Fixed Destination ID will skip the normal procedure of saerching for the best available network connection, and iwill not support Self forming, Self healing and Self optimizing

The Fixed Destination ID is stored in the Calibration part of Flash memory. This part of flash is retained even after an '@TM' factory reset, and may only be changed using 'HW' command from Configuration Mode. The 'r' command may be used to read back and verify the contents the Calibration Memory. The following steps should be used to program a new FDID with value 4 3 2 1.

Command	Hex	Response	Comment
Enter Configuration Mode		'>'	By Asserting and releasing the CONFIG input, or By using the Set Gateway in Config Mode command to a Gateway node
'HW'	0x48 0x57	'>'	Wait for '>' prompt
27 1 28 2 29 3 30 4 or Hex:		No response	Four pairs of address and data received, module waiting for next address or 255 (0xFF) to terminate the command

0x1B 0x01 0x1C 0x02 0x1D 0x03 0x1E 0x04			
255	0xFF	'>'	Wait $t_{MEMORY-CONFIG}$ for '>' prompt
'r'	0x72	Calibration Memory	Read back the Calibration Memory contents to verify correct settings
'X'	0x58	No response	The TinyMesh™ protocol runs through a full Power On Reset Cycle, to ensure all configuration changes are applied.

Sniffer Mode 1

When set to Sniffer Mode 1, the module will output the single byte, received RSSI level for any received and correctly formatted TinyMesh packet. Only packets with matching System ID (SID) will be accepted by the Sniffer function.

Sniffer Mode 2

When set to Sniffer Mode 1, the module will output the received RSSI level for any received and correctly formatted TinyMesh packet, followed by a limited set of decriptive data derived from the received packet. Only packets with matching System ID (SID) will be accepted by the Sniffer function.

Sniffer 2 data output format:

|RSSI|Packet Size|Destination ID|Source ID|Origin Jump Level|Packet Type|Message Counter*

*Sniffer output is 12 or 14 bytes per packet. There is no Message Counter if packet is ACK or Beacon

Sniffer Mode 2 format details

RSSI	Signal Strength of packet as received by Sniffer Device		
Packet Length	Total length of packet, including header and payload data. Length will vary with Packet Type (see below)		
Destination ID	Next receiver of this packet. (Final detination is always Gateway device)		
Source ID	Last transmitter of this packet. (Not device that created the packet)		
Origin Jump Level	Jump level of device that created this packet		
Packet Type	Packet Type	Packet Length	Description
	0x02	0x2D	Event Message, ref. Received Package Formats
		0x95	Response to Response to Get Configuration Command
		Variable	Respose to Response to Get Path Command and Encrypted packets
	0x03	0x1F	Control and Status Request Command, ref. Transmitting Command and Configuration Packets from Gateway
		0x3D	Change Configuration Command, ref. Transmitting Command and Configuration Packets from Gateway
	0x04	Variable	Encrypted Commad
	0x0A	0x11	Acknowledge (Link level)
	0x0B	0x11	Beacon (Network Invite)
	0x0C	0x11	Beacon from Locator Device, ref. Locator Function
	0x0E	0x11	Connection Request

	0x10	0x1E to 0x95	Serial data to Gateway, ref. Received Package Formats.
	0x11	0x1E to 0x95	Serial data from Gateway, ref. Transmit Serial Data Packet from Gateway
	0xFF		Unknown Packet Type
Message Counter	Sequential counter maintained by originating device. Not appliccable for 0x0A,0x0B,0x0C and 0x0E packets		

Note:
While processing serial port data, the module will not be able to receive new RF data packets.
To avoid loosing data, the transfer speed should be set to the highest acceptale data rate.
The TinyMesh module will support data rates up to 230 400 by setting the UART Baud Rate parameter in Configuration Memory.

Configuration Memory

The table below shows the complete list of configurable parameters stored in non-volatile Configuration memory. These values may be changed using the 'M' command while the module is in Configuration Mode (page 33), or through Gateway Commands (page 17). 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 RC1170: 1-12 RC1171: 1-12 RC1180: 1-16 RC1181: 1-16 RC1190: 1-50 RC2500: 1-83	4	See table page 31 for details. HP (High Power) versions might have reduced number of available channels
RF POWER	RF output power	1	01/05/13	5	See table page 31 for details
RF DATA RATE	RF data rate	2	1-6	5	See table page 31 for details
Protocol Mode	Packet format selection	3	Transparent:1 Packet: 0	1	See page 11 for details
RSSI Acceptance level	Minimum RSSI to accept network connection	4	160- 210	193	*Do not change*
RSSI Clear Channel Assessment level	Max RSSI for Clear Channel during Listen Before Talk	5	100- 210	110	*Do not change*
HIAM Time	Time in seconds between network invites	6	1-10	1 (Router) 1 (Gateway)	*Do not change.* *Set by 'G', 'R', 'N' commands*
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	6	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 number of transportation jumps before a packet is eliminated, assumed undeliverable.	10	1-255	30	
Max Packet Latency	Maximum transport time in periods of 25s 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	1-255	50	
Serial Port Time Out	Time out in periods of 1ms between character inputs on serial port, before a packet is transmitted in Transparent mode.	13	1-255	20	An additional 2ms is automatically added. Actual timing for setting 20 is 22 ms
Device Type	1 = Gateway 2 = Router	14	1-3	2	*Set by 'G', 'R', 'N' commands*
Excellent RSSI Level		15	-	150	Do not Change
GPIO 0 Configuration	Configure GPIO 0/ Module Pin 15	16	0,1,2,4	1	0 = Output, default High 1 = Input 2 = Analogue in 4 = Output, default Low
GPIO 1 Configuration	Configure GPIO 1/ Module Pin 16	17	0,1,2,4	1	0 = Output, default High 1 = Input 2 = Analogue in 4 = Output, default Low
GPIO 2 Configuration	Configure GPIO 2/ Module Pin 20	18	0,1,4	1	0 =Output, default High 1 = Input 4 = Output, default Low

Parameter	Description	Address	Argument	Factory setting	Comment
GPIO 3 Configuration	Configure GPIO 3/ Module Pin 22	19	0,1,4	1	0 = Output, default High 1 = Input 4 = Output, default Low
GPIO 4 Configuration	Configure GPIO 4/ Module Pin 26	20	0,1,4	1	0 = Output, default High 1 = Input 4 = Output, default Low
GPIO 5 Configuration	Configure GPIO 5/ Module Pin 25	21	0,1,4	1	0 = Output, default High 1 = Input 4 = Output, default Low
GPIO 6 Configuration	Configure GPIO 6/ Module Pin 24	22	0,1,4	1	0 = Output, default High 1 = Input 4 = Output, default Low
GPIO 7 Configuration	Configure GPIO 7/ Module Pin 23	23	0,1,3,4	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 hallport 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	
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	6 (60 ms)	Active on Gateway only.
Locator_Enable	Enable locator function	44	0 or 1	0	

Parameter	Description	Address	Argument	Factory setting	Comment
UNIQUE_ID0 (UID0)		45	0-255	Unique	UID= UID3:UID2:UID1:UID0 SID= SID3:SID2:SID1:SID0
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	
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	1: 2 400 2: 4 800 3: 9 600 4. 14 400 5: 19 200 6: 28 800 7: 38 400 8: 56 700 9: 76 800 10: 115 200 11: 230 400	5	BE CAREFUL IFCHANGING, AS HOST MAY LOOSE CONTACT WITH MODULE!
UART Bits		54	8 or 9	8	UART word size
UART Parity		55	0 or 1	0	Odd/ Even parity
UART Stop Bits		56	1 or 2	1	Number of stop bits
Reserved		57			Do not change
UART Flow Control	Select UART handshake	58	1: CTS 2: RTS 4: RXTX 8: Xon/Xoff 16: ACK/NAK 32:Wait for ACK	1 (0x01)= CTS enabled	Reference chapter Serial Port Handshake, page 12
Serial Buffer Full Margin		59	0-100	18	Number of bytes left in Serial Buffer when CTS goes false and /or Xoff transmitted
Module description					
PART Number		60-70		RCxxxx-TM or RCxxxxHP-TM	**Not Configurable**
HW Revision		70-73 or 72-75		x.yz	x, y and z; Any number 0-9 decimal **Not Configurable**
FW Revision		75-78 or 77-80		x.yz	x, y and z; Any number 0-9 decimal **Not Configurable**
Miscellaneous settings					
Security Level	Select encryption mode	81	0: Off 1: On 2: Compatible	0	Select Security Level. Mode 2 will reduce packet size to be compatible with unencrypted systems
Reserved		82-90			
HIACK Enable	Enable command acknowledge from destination node	91	0: Off 1: On	1	Applicable in packet mode only. Broadcast commands will not generate HIACK
Reserved		92-93			
IMA On Connect		94	0-1	0	See page 23 for details
PWM default		95	0-100	0	See page 25 for details
Reserved		96			Do not Change
Reserved		97			
RSSI Change Margin	Minimum difference in RSSI to justify automatic change of network connection	98	0-255	12	Do not Change
Clustered Node Device Limit	Minimum number of densely located nodes to form a node cluster	99	10-100	10	Closely located nodes are forced to act as a single node by reducing network Beacon (HIAM) activity
Clustered Node RSSI	RSSI level to form a node cluster	100	40-100	60	
Detect Network Busy	Gateway action when network activity detected after Reset.	101	0: Ignore 1: Halt+Warn 2: Warn	0	Applicable in Packet mode only

Parameter	Description	Address	Argument	Factory setting	Comment
RF Tamper Detect	RF Tamper Detection Time	102	0-100	0 = Off	Minimum time in minutes of continuous radio jamming on all radio channels before an RF Tamper alarm is generated
RF Tamper Alarm	GPIO port used for RF Tamper alarm output	103	0-7	3	The selected GPIO will go LOW on alarm status, and will remain LOW for as long as alarm status is present. Note: Selected GPIO must be configured for High Output
Reserved		104-120			
Accept New Command Time Out	Minimum time before new command accepted (10 ms)	121	0-255	10	Do Not Change
Command Retry	Retiries if no response to command transmit	122	0-127	3	Do not Change Gateway device uses double setting value.
MAC RndTime2Mask	Radio State 1 max delay mask. Repeat TX	123	0x7F, 0x3F, 0x1F, 0x0F, 0x07,0x03	0x7F	Do not Change
MAC RndTime1Mask	Radio State 1 max delay mask. First TX	124	0x7F, 0x3F, 0x1F, 0x0F, 0x07,0x03	0x0F	Do not Change
Reserved		125			
Firsttime	Flag to force backup storage of config memory at Reset	126		0x55	Do not Change If = 0x55 at Reset, copy Config memory to backup
Reserved		127			

Calibration Memory

The table below shows the complete list of parameters stored in non-volatile Calibration memory. These values may be changed using the 'HW' command while the module is in Configuration Mode (page 33). 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					
Temp Offset	Offset added to TEMP	0	0-255	128	Temperature offset in 0.25 degree (C) increments. Increase for positive adjustment, decrease for negative adjustment of TEMP value
RFPower5		1	0-255		Factory set, do not change
FREQOFF		2	0-255		Factory set, do not change
ADC	Analogue converter Zero calibration	3, 4	0-0xFFFF		Automatically calibrated at first Power On
Pulse Counter Index	Pointer to Pulse Counter Save	5, 6	0-255	2	Do not change
Pulse Counter Save	Pulse Counter Save Memory	7..22	0-255	16	Do not change
Container ID	CID 0	24	0-255	0	Unique identifier for host network and TinySolution™ CID= CID3:CID2:CID1:CID0
	CID 1	25	0-255	0	
	CID 2	26	0-255	0	
	CID 3	26	0-255	0	
Fixed Destination ID	FDID 0	27	0-255	0	Permanent Router or End Device connection address.
	FDID 1	28	0-255	0	
	FDID 2	29	0-255	0	

Parameter	Description	Address	Argument	Factory setting	Comment
	FDID 3	30	0-255	0	
S4 TimeOut	Additional delay in RF State 4	31	0-255	4	Do not Change
Dispatch Delay	Additional delay for Dispatch Timer	32	0-255	0	Do not Change
S4 Command Wait	Additional command response wait time in RF State 4	33	0-255	5	Do not Change

Note: Address locations not listed, should not be changed from their default values

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 x 1.6 mm = 2.88 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.

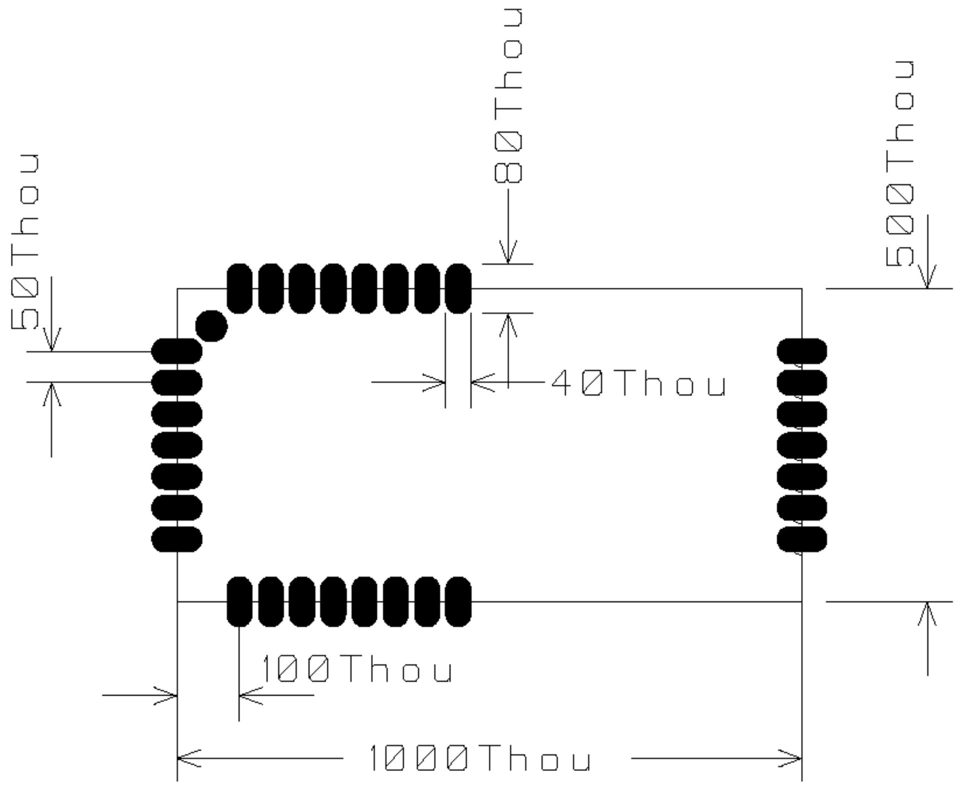
A PCB antenna can be made as a copper track where the ground plane is removed on the back side. The rest of the PCB board should have a ground plane as large as possible, preferably as large as the antenna itself, to make it act as a counterweight to the antenna. If the track is shorter than a quarter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



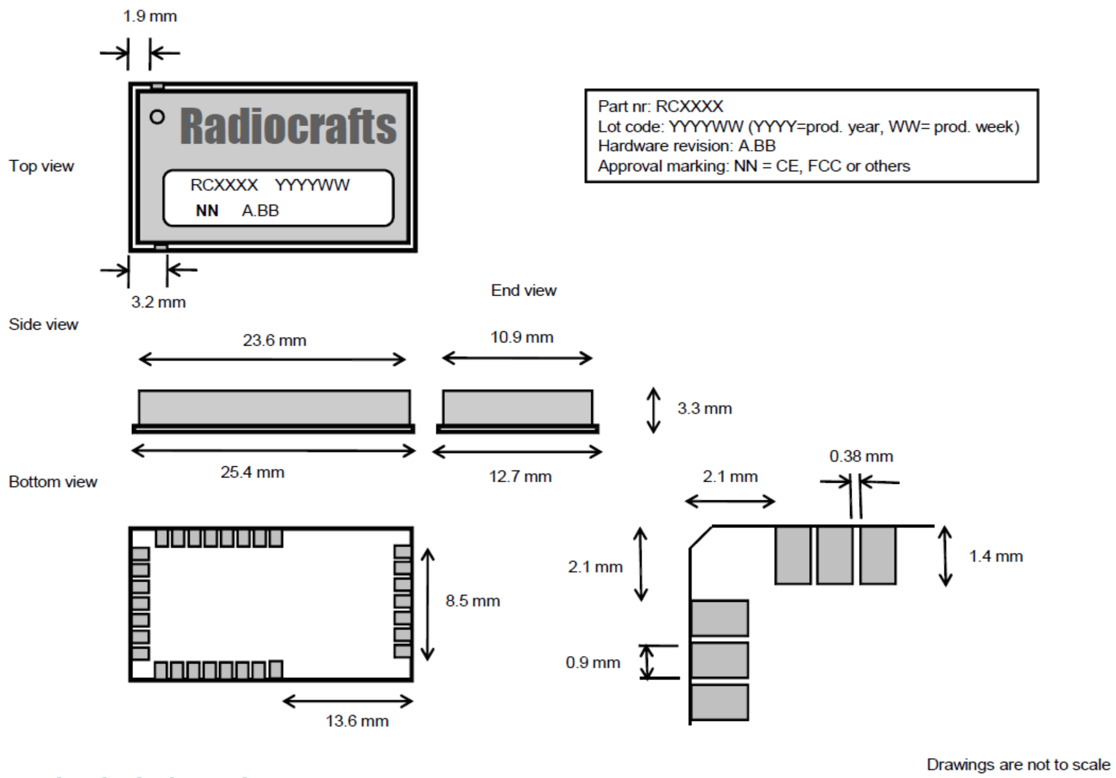
A PCB with two or more layers, and with a **single,** solid ground plane in one of the inner- or bottom layer(s) is recommended. All GND-pins of the module shall be connected to this ground plane with vias with shortest possible routing, one via per GND-pin.
It is recommended to avoid multiple GND layers,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



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 devises. 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 RC1170(HP)-TM,RC1171-TM RC1180(HP)-TM,RC1181-TM RC1190-TM RC2500(HP)-TM	 433.05 865.0 868.0 902.0 2400.75		 434.79 867.0 870.0 928.0 2483.75	 MHz	
Number of channels RC1140-TM RC1170(HP)-TM, RC1171-TM RC1180-TM, RC1181-TM RC1180HP-TM RC1190-TM RC2500(HP)-TM		 17 15 18 3 50 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) RC2500(HP)-TM			 +/- 40 +/- 20	 ppm	 Including 10 years of ageing.
Frequency stability ageing			1	ppm/year	Starting after 10 years
Transmit power RC1140-TM – RC1181-TM RC1170HP-TM,RC1180HP-TM RC1190-TM RC2500-TM RC2500HP-TM	 -20 0 -20 -15 -10		 10 27 -1 1 18	 dBm	
RC1140–RC1190-TM (LP&HP) Spurious emission, TX < 1 GHz > 1 GHz 47 – 74 MHz 87.5 – 118 MHz 174 – 230 MHz 470 – 862 MHz			 -36 -30 -54 -54 -54 -54	 dBm	
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

Parameter	Min	Typ.	Max	Unit	Condition / Note
RC2500(HP)- TM Spurious emissn,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 emissn,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	
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	

Parameter	Min	Typ.	Max	Unit	Condition / Note
Current consumptn, 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 RC1170- 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
PWM switching frequency		1		kHz	Applies to GPIO 7 when configured for PWM

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, RC1171-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 may 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 form 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

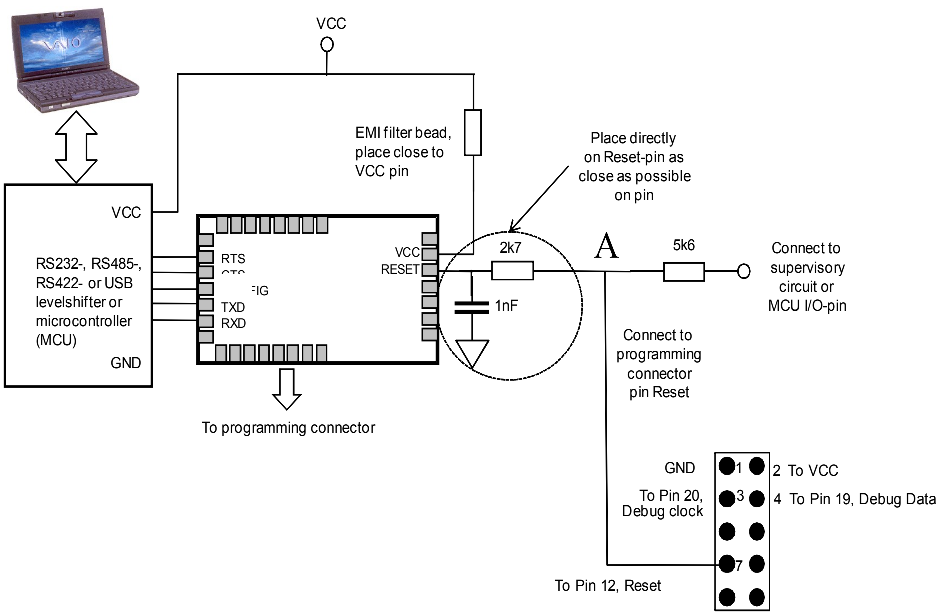
Component	Manufacturer	Part number
EMI filter bead	Murata	BLM11A102S, ordering code BLM18xx102xN1D For High Power versions of modules use BLM18SG331TN1

Programming Interface

For future firmware updates and possible custom variants it is recommended to include a 2x5 pins
programming connector to the module 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.
1.35	Major additions, new features
1.35 a	Added PWM frequency specification
1.36	Added 256 bytes serial input buffer capacity feature Changed various default configuration settings
1.36a	Minor changes, default values
1.38	RC1160-TM version included in RC 1180-TM, RC1181-TM RC 1181-TM / RC1171-TM added New configuration- and calibration parameters added, defaults adjusted

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.
	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.
X	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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As far as possible, major changes of product specifications and functionality, will be stated in product specific Errata Notes published at the Radiocrafts website. Customers are encouraged to check regularly for the most recent updates on products and support tools.

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Life Support Policy

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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