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Tinymesh™ RF Transceiver Modules

Product Description

The RC11XX(HP) / RC25XX(HP) / RC17xx(HP)-TM RF Transceiver Modules are compact surface-mounted high performance modules for wireless mesh networking applications. The modules feature a fully embedded Tinymesh™ application and multi-hop protocol stack with automatic network forming and self-healing features. The embedded Tinymesh™ application layer supports a full duplex UART, Analogue- Pulse- and Digital inputs, as well as PWM and Digital outputs. Serial application data entered on the UART port is transported automatically to the desired destination node without further interaction from any external processor. The modules are completely shielded, available as Low Power, High Power and Long Range Ultra Narrow Band versions, and pre-certified for operation in license free bands from 169 MHz to 2.4 GHz.

Typical Applications

- Wireless Sensor Networks
- Automatic Meter Reading
- Alarm- and Security Systems
- Building Management
- Telemetry Stations
- Fleet Management
- Asset Tracking
- Street Light Control and Monitoring

Key Features

- Embedded application layer for I/O control and data collection
- Self-forming, self-healing and self-optimizing bi-directional mesh network stack
- AES 128 encryption
- Selectable Gateway, Router and low power End Device configuration
- Configurable digital I/O, PWM (Dimmer) output and analogue inputs
- Full Duplex Serial Port with handshake, streaming support and 256 byte buffer for easy RS232/422/485 wire replacement and MODBUS RTU compatibility
- Pulse counter with configurable de-bounce time and detection feedback output
- 'Walk-by' mode for low power data logging and metering applications
- RSSI and Network connect LED output control for simplified field installation
- Group-, Broadcast- or Individual addressing modes
- Clustered Node Detection and Network Congestion Avoidance (CND/NCA™)
- RF Jamming Detection and Alarm, with alarm output and network alarm messaging
- Analogue- and Digital level triggered event messages.
- Time-generated and event-triggered status messages
- Locator Function for asset tracking applications
- Network Busy Detection for ad hoc networks with multiple, roaming Gateway Devices
- Multiple Gateway support for redundancy and automatic network load sharing
- Small size (12.7 x 25.4 x 3.3 mm), shielded and optimized for SMD mounting
- No external components
- Wide supply voltage range
- RC1x40/80(HP)-TM conforms with EU R&TTE directive (EN 300 220, EN 301 489, EN 60950)
- RC119x-TM conforms with regulations for operation under FCC CFR 47 part 15
- RC117x(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)
- RC117x-TM and RC117xHP-TM comply to IEEE 802.15.4.g PHY mode 0 encoding when configured for RF Data Rate 8.

Quick Reference Data

Module version LP HP Long Range, UNB-HP Parameter	RC1701HP-TM	RC114x[1]-TM RC1740HP-TM	RC1760HP-TM	RC117x[1]-TM RC117xHP[1]-TM	RC118x-TM[1] RC118xHP-TM[1] RC1780HP-TM	RC119x-TM[1] RC119xHP-TM[1]	RC2500-TM RC2500HP-TM	Unit
Frequency LP HP UNB-HP	 169	433 - 434 424 - 447	 458-468	865 – 867 865 – 867	868 - 870 868 - 870 865 - 870	902– 927 902– 927	2400 - 2483 2400 - 2483	MHz
Channels LP HP UNB-HP	 13	17 173	 239	15 15	18 18 94	50 50	83 83	
Data rate LP HP UNB-HP	 0.3-100	1.2 – 100 0.3-100	 0.3-100	1.2 – 100 1.2 – 100	1.2 – 100 1.2 – 100 0.3 – 100	1.2 – 250 1.2 – 250	1.2 – 100 1.2 - 100	kbit/s
Max TX power LP HP UNB/UNB-HP	 27	11 14/27	 14/27	11 27	11 27 14/27	11 27	1 18	dBm
Sensitivity 1.2/ 100 kbit/s LP HP UNB-HP	 -118 / -102	-110 / -97 -118 / -102	 -118 / -102	-110 / -97 -109 / -96	-110 / -97 -109 / -96 -118 / -102	-110 / -97 -109 / -96	-105 / -89 -108/ -91	dBm
Supply voltage LP HP UNB-HP	 2.8 - 3.6	2.0 – 3.6 2.8 - 3.6	 2.8 - 3.6	2.0 – 3.6 3.0 – 3.3	2.0 – 3.6 3.0 – 3.3 2.8 - 3.6	2.0 – 3.6 3.0 – 3.3	2.0 - 3.6 2.7 - 3.6	Volt
RX/ TX Current LP HP UNB-HP	 31/ 407	24 / 35 31/ 318+63	 31/ 297+72	24 / 37 24 / 560	24 / 37 24 / 560 31/ 297+72	24 / 37 24 / 560	25 / 27 30 / 155	mA
SLEEP Current LP HP UNB-HP	 0.6	0.3 0.6	 0.6	0.3 3.4	0.3 3.4 0.6	0.3 3.4	0.4 1.3	uA
Temp. range LP HP UNB-HP	 -30 to +85	-40 to +85 -30 to +85	 -30 to +85	-40 to +85 -40 to +85	-40 to +85 -40 to +85 -30 to +85	-40 to +85 -40 to +85	-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.

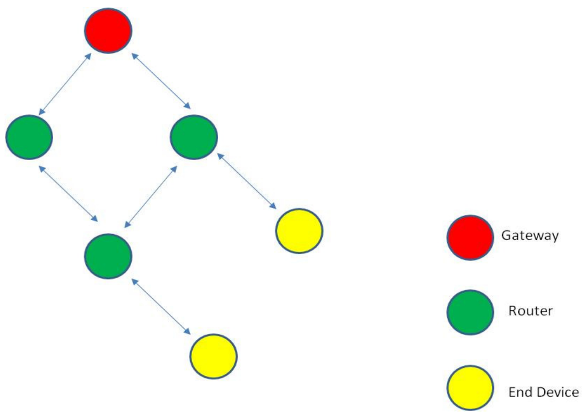
[1] Radiocrafts will deliver RC11x0-TM or RC11x1-TM and RC11x0HP-TM or RC11x1HP-TM depending on availability. The versions performance is identical.

Table of Contents

Tinymesh™ Application and Protocol Stack

The Tinymesh™ Multi-hop Wireless Mesh Network Protocol Stack is a unique set of multi-hop wireless mesh network protocols that enable devices to send messages or transfer data to and from each other. The embedded Application Layer contains an advanced set of configurable I/O handling mechanisms that enable Tinymesh™ devices to be implemented in most application circuits without need for an external MCU.
The Tinymesh™ Stack requires no external processor for establishing and maintaining the optimum network routing path at all times.
Internet applications may connect to Tinymesh™ Wireless Mesh Network through the equally uncomplicated Tinymesh™ Cloud Services.

Tinymesh™ Multi-hop Wireless Mesh Networks may consist of large numbers of Tinymesh™ enabled devices or nodes where a node is one out of three types as described below. The wireless traffic between the Tinymesh™ enabled devices follows a tree-type topology, where data transfer is up or down in the tree structure.



A Tinymesh™ Multi-hop Wireless Mesh Network in its simplest form consists of a single Gateway and a Router. End Devices will not perform packet routing and must connect to a Router or directly to a Gateway. A network may be comprised of thousands of Tinymesh™ enabled devices. There may be several Gateway devices within a network, for redundancy and automatic workload sharing.
The network addressing structure uses four-byte addressing, for a total of 4.3 billion possible unique devices per network. The network tree structure may have a total depth 255 hops.

Tinymesh™ Devices

Any Tinymesh™ enabled device may be configured to function as Gateway, a Router or as an End Device. Single byte configuration commands will set all relevant configuration parameters when changing operating mode.

Gateway Device

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 Devices provide the connection between the Tinymesh™ Routers and End Devices, and an external host processor, or to a local- or wide area network, such as the Internet.
The Tinymesh™ stack supports implementations with multiple Gateways, where additional Gateway devices provide redundancy and data traffic load sharing.
Gateway devices support full Input / Output control capabilities, similar to Routers and End Devices.

Router Device

Router Devices are 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.
Router devices must always be powered, to support routing of packets received from other devices.

End Device

A Tinymesh™END DEVICE will normally be in low power sleep mode for battery operation. End Devices have full input- and output control capabilities, but will not accept messages for re-distribution from other devices.
An End Device will wake up to full power mode by external stimuli, such as a digital input level shift, serial data input, pulse counter activity or by internal clock. Wakeup conditions are selectable through configuration settings. After waking up, the End Device will generate an Event Message or a Serial in Message, depending on the wake-up condition. After delivering the message, the End Device will either return directly to sleep condition, or stay awake for a settable time period, to wait for response commands from a server or application outside the Tinymesh™ network.

Data Integrity

The Tinymesh™ stack uses several mechanisms to ensure safe and reliable data delivery with minimal latency.

- Listen Before Talk in accordance with the harmonized EN 300 220-2 standard, to reduce likelihood of RF traffic collision.
- Link level acknowledge on all packet deliveries for positive confirmation of data reception.
- Packet retransmission on missing acknowledge
- Format, data validity and CRC control on check on packet reception
- AES 128 encryption
- Packet duplicate check
- Housekeeping mechanisms to eliminate stray packets that are either too old or have hopped to many times
- Unique numbering of packets to allow duplicate and sequence control by external applications
- Application level command acknowledge to verify and validate command reception.
- Unique timing mechanisms to handle network congestion

Network Formation

A Tinymesh™ Multi-hop Wireless Mesh Network is self-forming, created by Gateway units starting to invite Routers and End Devices within RF range to join in the network. A Router joins the network after verifying the invitation, and immediately starts inviting new nodes to join. Within seconds of powering up the Gateway, a large network may be created automatically.
Gateway and connected Router devices send periodic beacon packets to indicate presence and availability for connection. Tinymesh™ beacon packets, referenced as HIAM packets, contain information of device address (UID), System Identity (SID), Radio Frequency Channel and device Network Level (Hop Level).
Routers and End Devices receive and evaluate connection alternatives by comparing hop level- and received signal strength of HIAM packets on selectable time intervals (Connect Check Time)

Self-healing

Devices in Tinymesh™ networks continuously evaluate alternate connections by comparing the hop level and signal strength of received HIAM packets. In cases where the primary communication link becomes unresponsive, the device will automatically change to the alternate routing if such routing is available.
If the alternate routing is also unresponsive, the device will enter a state where it searches for new routing possibilities.
Data received by the device, and event data generated by the device will be stored in the internal device buffers until a valid connection has been established.

Self-optimizing

The communication path offering the least number of hops and the highest link quality is always selected as the primary connection for data delivery. A network optimization process runs continuously as a background task in all Tinymesh™ devices.
In changing environments with changing link quality, Tinymesh™ networks dynamically adapt to find optimum routing.

Network Addressing

Tinymesh™ networks utilize a flexible addressing scheme with 4 bytes System address (SID) and 4 bytes for unique device addressing (UID).

The four byte System ID identifies a local network in the same way as a PAN address. All devices in a local mesh must share the same four-byte SID.

Every Gateway, Router, and End Device belonging to a local mesh network must have unique UIDs. Duplicate UIDs will cause network instability, lost packets and connection issues.

A separate 4-byte Network Address is applied to uniquely distinguish local mesh networks sharing a common platform in a cloud- or server controlled environment where local mesh networks may be deployed with similar SID.

The Tinymesh™ Stack supports unique, group and broadcast addressing of individual devices. Routers and End Devices may be assigned to addressing groups, by entering up to eight different single-byte group identifier addresses.

Multiple Gateway Support

Tinymesh™ networks support multiple Gateway devices operating within the same local mesh. In mesh networks with a single Gateway, the Gateway becomes a critical point for system reliability. In a Tinymesh™ network, additional Gateways may be added at any point in time to provide redundancy on the Gateway level.
Adding Gateway devices to a local mesh also improves data throughput and network capacity, as the additional Gateway devices will automatically load share the upstream data traffic from for instance a large data collection or sensor network.

Systems with multiple gateways must be controlled by a common server or cloud platform, such as Tinymesh™ Cloud Services. Data originating from Router- or End Devices will automatically be routed through the mesh to the Gateway device that provides the least number of hops and the best signal strength. If two or more Gateway devices offer the same number of hops and equally good signal strength, for instance if the two Gateway devices are located near to each other, the packet will be delivered to the Gateway device that is currently available. The server platform will use the device UID to identify the packet origin, and the packet number contained in the packet header to verify uniqueness.

Commands (downstream data traffic) in multiple Gateway systems should as a rule be entered to all Gateway devices, to ensure reliable delivery.
Systems where the Gateway devices are located close by each other, offer an exception to this rule. This will be systems where two or more Gateway devices provide redundancy and added throughput, and where the distance between the individual Gateway devices is less than the distance to the closest Router device. A single Gateway may be selected to dispatch commands in such configurations.

Ad Hoc Networks and Hand Held Gateway Devices

Local mesh systems that are created 'ad hoc' by turning on a portable Gateway device such as a portable CMRI used for data collection in automated metering systems will be formed as a web with the portable Gateway in the centre of the mesh network.
Because there is no fixed rule to where a Gateway device is located, or when the mesh is created, there needs to be mechanisms in place to ensure there is only one Gateway device downloading from the mesh at a given time.
A configurable parameter in a Tinymesh™ Gateway device provides a mechanism for the Gateway to detect if a network is already present when the portable Gateway is powered up. Depending on the device configuration, the Gateway device will either refuse connection, provide an alert, or ignore the

presence of the other Gateway that is controlling the mesh.

If a portable Gateway device is configured to ignore the presence of an existing mesh, a portable device may be used to temporarily connect to a device that is already connected to a stationary Gateway device. This function could be used in automatic metering systems with permanently installed data collection units (DCU), for individual interrogation or downloading of data directly to a portable device. The portable device must share the same System ID as the permanent Gateway, and must have unique UID. When turning on the portable device, the portable Gateway will connect to the closest Router devices and act as a secondary gateway in the system.
The portable device may interrogate the connected mesh to detect which Router devices have made connection.
After switching off the portable device, the mesh will automatically reconfigure with the permanent DCU as the preferred Gateway.

Alerts and Device Triggered Events

The application layer in the Tinymesh™ stack supports automatic alerts and triggered events from multiple, configurable sources, eliminating the need for traditional status polling as known from wired multi-drop systems.

- Timer triggered status reporting, with time intervals from seconds to days
- Digital input status change, with configurable de-bounce and edge detection
- Analogue level change, with configurable hysteresis, trigger conditions and sample interval
- Power On detection
- Serial data input
- Radio Frequency Jamming detection

Over the Air Configuration

Gateway, Router, and End devices may be reconfigured at any time, even after system deployment. The flexible format configuration command allows setting of any addressable location in the device configuration memory.
Remote reconfiguration capability is a valuable feature for system maintenance and service. Any configurable function, from changing the de-bounce time for digital input detection, to altering the radio frequency channel may be changed over the air.
A special two-step mechanism protects the most sensitive configuration parameters that may cause a device to lose network connection.

Getting Started

A simple Tinymesh™ network may be formed by configuring at least one module as a Gateway (SET GATEWAY MODE command).

Make sure **the Gateway and all Routers have different Unique ID, but same System ID**. This is mandatory for successful self-forming of the network.
Modules are delivered with default setting 'Router', and with non- identical Unique IDs.

How do I Form a Network?

Power up the nodes in any random sequence.
The Gateway Device starts inviting neighbouring nodes to become members of the network. The Gateway Device will flash the RSSI/ TX LED (Red LED on Demo Board) every time a network invite beacon (HIAM) is transmitted.
The RSSI/ TX LED on nodes configured as Router devices (default configuration) will start flashing in a slow pattern, indicating the node is alive and listening, but not connected to the network.

Router devices 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 Device 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 will signal 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/ RX LED 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 the 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, as 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 Device (while CTS is low), will be delivered to the Gateway and presented on the Gateway TXD pin.

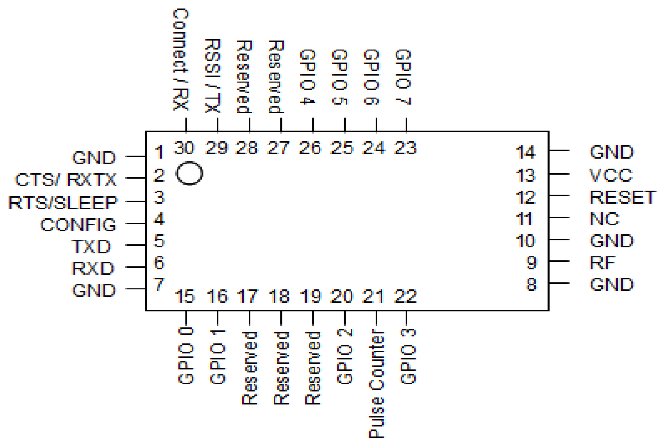
What about the Antenna?

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. When space is limited, contact Radiocrafts for recommendations for the best antenna solution for your application.

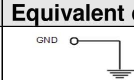
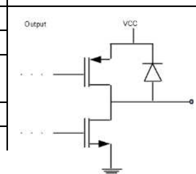
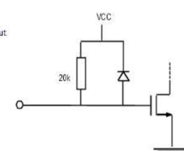
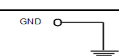
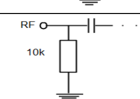
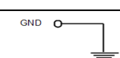
How do I change the RF Channel or any other Parameter?

Configurable parameters such as RF Channel, RF Power or RF Data Rate, are stored in non-volatile memory in the module. There are principally two different ways for changing these parameters. The module must either be entered into CONFIGURATION MODE, for direct input of new parameters on the serial port, or new parameter values may be dispatched to a module in a live mesh network by issuing the SET CONFIGURATION command.
Please see MODULE CONFIGURATION for details.

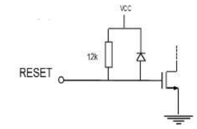
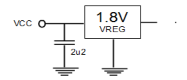
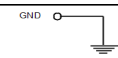
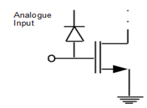
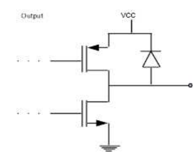
Module Pin Assignment

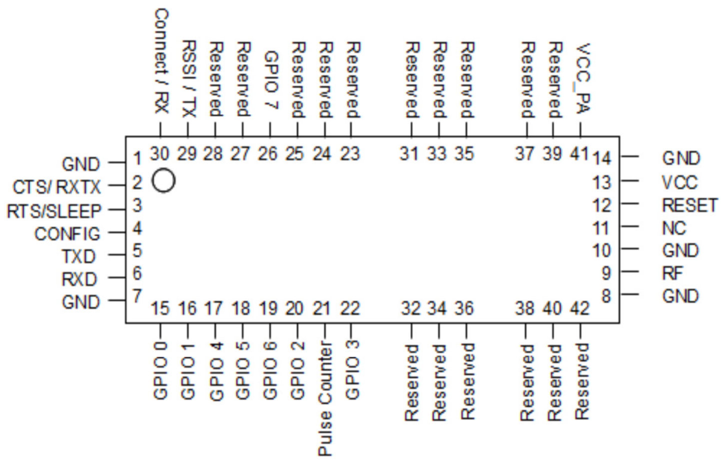


Pin Description, RC11xx(HP)/ RC25xx(HP) Devices

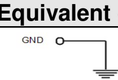
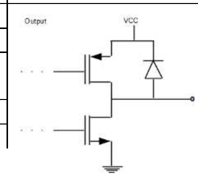
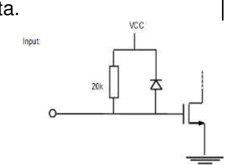
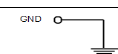
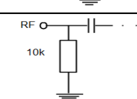
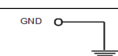
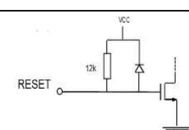
Pin no	Pin name	Pin type	Description	Equivalent circuit
1	GND		System ground	
2	CTS / RXTX	Output	UART CTS or RTX Active Low	
3	RTS / SLEEP	Input	UART RTS or Module Sleep[2]	
4	CONFIG	Input	Configuration Enable. Active low. Should normally be set high[3].	
5	TXD	Output	UART TX Data	
6	RXD	Input	UART 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.*[4] ***Never leave RXD-pin floating***.	
7	GND		System ground	
8	GND		System ground	
9	RF		RF I/O connection to antenna	
10	GND		System ground	
11	NC		Not connected	

[2] The internal pull-up is disabled when configured for SLEEP function.
[3] The internal pull-up is disabled when the SET SLEEP MODE (Z-COMMAND) command has been used to enter sleep mode
[4] 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.

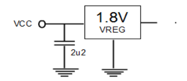
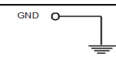
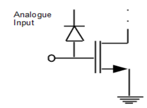
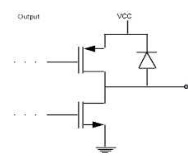
12	RESET	Input	Main reset (active low). Should normally be left open. Internal 12 k pull-up resistor.	
13	VCC		Supply voltage input. Internally regulated.	
14	GND		System ground	
15,16	GPIO 0-GPIO 1	Digital In / out Analogue In	Individually configurable as digital input / output or analogue Input (Internal pull-up disabled)	 Digital Input/ output, Ref pins 2-6
20	GPIO 2-GPIO 6	Digital In / out	Individually configurable as digital input / output	Ref pins 2-6
21	Pulse Counter	Input	Pulse Counter	Ref pins 2-6
22,26, 25,24	GPIO 3-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/ TX LED	Output	Direct LED drive output. Flash pattern given for current sourcing: Flash frequency indicates network connection RSSI level for Routers and End Devices. Flash indicates RF TX activity for Gateway Devices.	
30	Connection/ RX LED	Output	Direct LED drive output. Flash pattern given for current sourcing: Flash frequency indicates network connection redundancy for Routers and End Devices. Flash indicates RF RX (received packets) for Gateway Devices	



Pin Description, RC17xx Devices

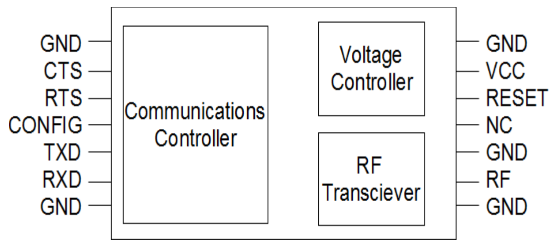
Pin no	Pin name	Pin type	Description	Equivalent circuit
1	GND		System ground	
2	CTS / RXTX	Output	UART CTS or RTX Active Low	
3	RTS / SLEEP	Input	UART RTS or Module Sleep[5]	
4	CONFIG	Input	Configuration Enable. Active low. Should normally be set high[6].	
5	TXD	Output	UART TX Data	
6	RXD	Input	UART 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.[7]* ***Never leave RXD-pin floating***.	
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.	

[5] The internal pull-up is disabled when configured for SLEEP function.
[6] The internal pull-up is disabled when the SET SLEEP MODE (Z-COMMAND) command has been used to enter sleep mode
[7] 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.

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
17, 18,19, 20,22, 26	GPIO 2-GPIO 7,	Digital In / out	Individually configurable as digital input / output	Ref pins 2-6
21	Pulse Counter	Digital Input	Pulse Counter	Ref pins 2-6
29	RSSI/ TX LED	Output	Direct LED drive output. Flash pattern given for current sourcing: Flash frequency indicates network connection RSSI level for Routers and End Devices Flash indicates RF TX activity for Gateway Devices	
30	Connection/ RX LED	Output	Direct LED drive output (source). Flash pattern given for current sourcing: Flash frequency indicates network connection redundancy for Routers and End Devices. Flash indicates RF RX (received packets) for Gateway Devices	
41	VCC_PA	Supply voltage input for Power Amplifier stage	Connect to 5V or VCC for RC17x0HP, and leave open for RC17xx. When VCC_PA is connected to VCC (3.3V) for RC17x0HP, the max output power is limited to +24 dBm. For RC1701HP, the VCC_PA has the same voltage range as VCC, and supports +27 dBm at 3.3 V.	
23,24, 25,27, 28,31, 32,33, 34,35, 36,37, 38,39, 40,42	RESERVED		Test pins or pins reserved for future use. *Do not connect!*	

Circuit Description

The Tinymesh™ module contains a communications controller with embedded Tinymesh™ protocol stack firmware, 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 losing data when the default CTS handshake configuration is enabled.
When the CONFIG pin is pulled low, 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 Data Rate etc. Configuration parameters are stored in non-volatile memory. For a full overview of configuration commands, please see MODULE CONFIGURATION



Selecting the Right Module for Your Application

Radiocrafts modules with embedded Tinymesh™ Protocol Stack are available for all the international license free frequency bands, in two different selections of output power, and as high performance, long range Ultra Narrow Band version. As new members are added to the Radiocrafts family of modules, the Tinymesh™ Stack will be introduced on the new platforms.
All Radiocrafts modules are fully tested and footprint-compatible, allowing equipment manufacturers to use the same electronics design for several markets and varying applications.
The inherent capability to select and configure communications parameters in the protocol stack provides an unsurpassed level of flexibility in adapting the design to the application requirements.
The right module for your application may be selected from a decision matrix weighting the importance of radio range coverage, RF compliance requirements, customer requirements, hardware cost and available power supply limitations.

Note: High- and Low power modules should not be mixed in the same network, unless the output power settings for all modules are limited to the same dBm level.
Transmission from the higher powered module may be received by the lower powered module, while the high powered module will not be able to detect transmission from the low power device.

End Devices or Router Devices configured to transmit in FIXED DESTINATION AND "Walk By" Mode *represent an exception to the rule, as these devices will transmit without expecting a response (ACK) and hence will not require a balanced connection link.*

Indicative Module Selection Guide

Lower RF frequency	Higher RF frequency

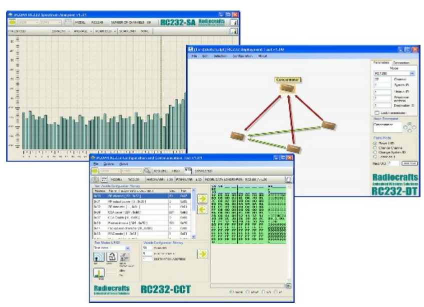
Lower RF frequency	Higher RF frequency
Improved communication range	Shorter and less space demanding antenna
Theoretical Range is approximately inversely proportional to RF frequency. (Double frequency = half range)	2.4 GHz is license free band in many countries and regions.
Lower dependency on direct Line of Sight between devices	

Low Power (standard) Module	High Power (HP) Module
Low Transmit power, simplified power supply design.	Better range, theoretical range improvement approximately double range per+6 dB increase in output power.
Best price performance	

Long Range Ultra Narrow Band (RC17xx)	Wide Band (RC11xx/ RC25xx)
High performance, high selectivity radio Excellent long range and performance	Good performance, good range Best price

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



Transparent Mode Operation

The default, factory setting for Tinymesh™ Gateway 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 output by the Router module UARTs without any changes. The addressing must be handled by the host MCU application.
Data input to a Router or End Device UART will be transported 'transparently' to the network Gateway Device and delivered unchanged by the Gateway Device UART.
Regardless of device type (Gateway or Router), the serial port UART is ready to receive data when the CTS output is low, or when the Xon character has been received from the UART. RF transmission will automatically be triggered on serial 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, to avoid losing data.

Transparent- Versus Packet- Mode Operation

When configured for PACKET MODE OPERATION, the Gateway Device may be used for controlling Inputs- and Outputs in individual Routers and End- Devices.
Analogue and digital input monitoring, digital and PWM output control, and timed or event triggered messages are available through Packet Mode operation.
Gateway Commands may be addressed to individual devices, to groups of devices, or may be broadcast to all devices within a network.
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 e.g. a complete MODBUS RTU packet 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 bytes. 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, 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 stack will prepare the data for RF transmission immediately after a data buffer completely full condition is present (256 bytes).

Note: 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 controller. The different settings are available by changing the UART FLOW CONTROL parameter in CONFIGURATION MEMORY.
The UART FLOW CONTROL parameter is a bitmap of control mechanisms that may be individually enabled by setting the corresponding bit. To combine settings, add the values in the 'Bit Value' column and enter the sum value into the UART FLOW CONTROL parameter in CONFIGURATION MEMORY.

Bit No	Bit Val-ue	De-fault	Name	Applies to	Function
0	1	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 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.
1	2	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.*
2	4	0	RXTX	Router and	The RXTX mode is provided for direction control of RS485 drivers. When RXTX is enabled, the module UART will set CTS HIGH during data

Bit No	Bit Val-ue	De-fault	Name	Applies to	Function
				Gateway	transmission. CTS will be driven high immediately before the first start-bit is transmitted, and will return low immediately following the last stop bit from the UART.
3	8	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 (SERIAL BUFFER FULL MARGIN) before the 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 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	16	0	ACK/ NAK	Gateway	When enabled, the Gateway Device will answer any received data on the serial port with a COMMAND RECEIVED AND EXECUTED or a COMMAND REJECTED, NOT EXECUTED message. In this mode, the Gateway will do a format- and validity control of received commands before transmitting in the RF mesh network. The MESSAGE DATA MSB will contain the user selected Command Number. If the packet is not accepted by the Gateway Device, the MESSAGE DATA LSB in the returned COMMAND REJECTED, NOT EXECUTED message will indicate why the packet was not accepted.
5	32	0	Wait For ACK	Gateway	When enabled, the Gateway Device will expect an ACK character (0x06, ASCII ACK) response to any packet delivered to the host. If the ACK is not received within a 1second time frame, the packet will be repeated until a valid response has been received.
6	64				Reserved
7	128				Reserved

AES Encryption

Changing the SECURITY LEVEL parameter in CONFIGURATION MEMORY will enable automatic AES data encryption. When AES encryption is enabled, the payload portion of all RF data packets are encrypted using the 128 bit AES encryption algorithm.
The Gateway and Router Device must share a common AES key, settable by the SETTING AND CHANGING THE AES KEY (K7- COMMAND).
The encryption key is stored in a hidden and secure memory location.
The AES key is retained even after an @TM factory reset command.
Encrypted and unencrypted Router Devices may co-exist 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 Un-Encrypted Devices

Nodes with encryption enabled, may co-exist with unencrypted nodes in a common system. Encrypted data packets are slightly larger than unencrypted packets. SECURITY LEVEL 2 (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 will be transported by unencrypted nodes to their final destination.
- Un-encrypted 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)
- Un-encrypted 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 un-encrypted Gateway will only accept messages from un-encrypted nodes.

Sleep Mode

A Tinymesh™ Device may be set to sleep mode to reduce power consumption.

Note: When asleep, a Router Device will not provide network routing for other devices, and a Sleeping Gateway device will not issue HIAM beacons.
Tinymesh™ networks will disconnect if no Gateway Device is active.
These conditions must be considered when designing a network with sleeping devices.

Sleep mode may be entered either by issuing the SET SLEEP MODE command while the module is in CONFIGURATION MODE, or by pulling the RTS / SLEEP pin low, after activating the SLEEP function through proper configuration setting (SLEEP OR RTS).

The sleeping Device will wake up, go through a full Power-On Reset cycle and resume operation when:

- The Configuration pin is driven high, if SET SLEEP MODE-command was used for entering sleep mode.
- When driving the RTS / SLEEP pin high, if the RTS / SLEEP pin was used to enter sleep mode.

To enter/ exit sleep mode using the RTS / SLEEP pin input:

1. Activate the RTS / SLEEP pin by setting SLEEP OR RTS configuration= 1.
2. Pull the RTS/SLEEP input low to enter sleep mode
3. Drive the RTS/SLEEP input high to exit sleep mode.

Note: The internal RTS/ SLEEP and CONFIG input pull-up resistors are disabled during sleep mode to reduce excessive power leakage. The CONFIG and SLEEP inputs must therefore be actively driven to the logic high state to exit sleep mode.

On exiting sleep mode, the Router Device will assume normal operation and connection to the mesh:

- CTS will be high while the module is going through the Reset cycle, and then go low when the module has made a valid network connection.
- If XON/XOFF protocol is enabled, (UART FLOW CONTROL), 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 start flashing.
- A DEVICE RESET message will be issued.
- A STATUS MESSAGE (IMA) will be issued if IMA ON CONNECT is enabled.

RF Jamming Detection and Alarm

The RF Jamming 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 connectivity may be present in form of intended (jamming) disturbance, or unintended noise from electrical equipment or RF transmitters.

The following Configurable parameters control the RF Jamming alarm feature:

- The RF JAMMING DETECT parameter sets the number of minutes of RF jamming that constitutes an alarm condition. The default value is 0 = off.
- The RF JAMMING ALARM PORT parameter selects the GPIO number (0-7) for local alarm output.
- The GPIO parameter sets the selected GPIO function as active low or active high output.

RF Jamming Detection in Packet Mode Systems

When RF Jamming Detection has been enabled by setting the RF JAMMING DETECT parameter, the Tinymesh™ module will create an RF JAMMING DETECTED message that will be transmitted through the mesh as soon as RF communication is re-established. The RF JAMMING DETECTED message MESSAGE DATA MSB will indicate the duration of the jamming situation in minutes, and the MESSAGE DATA LSB will indicate the time since the jamming 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 often use a polled communication protocol, with a master device sending individually addressed, or broadcast 'poll' commands, asking for response from 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 stack provides a number of mechanisms that serve to improve data throughput in master-slave systems.

In systems configured for TRANSPARENT MODE OPERATION, it is advisable that the master (Gateway) performs broadcast polling rather than sending individual device poll commands.

Note: Successful implementation of broadcast polling requires that the networked devices will respond with data packets containing the device address as part of the data payload.

When receiving a command broadcast, the networked devices will attempt communicating the command response more or less simultaneously after executing the received command. The Tinymesh™ Router 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 to the master (Gateway) Device error free and within an optimum time period.

Tinymesh™ Packet mode configuration provides additional means for creating efficient replacements for wired, polled systems. In Tinymesh™ wireless networks configured for PACKET MODE OPERATION, the ORIGIN ID 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 RSSI/ TX LED and CONNECTION/ RX LED are designed to directly drive LEDs. The Red LED (D1) of the Radiocrafts Demo Board is connected to module pin RSSI/ TX LED, and the Yellow LED (D2) is connected to module pin CONNECTION/ RX LED.
We recommend that these LED outputs are also implemented in target hardware. The LED signals will be useful for system deployment and configuration.

Flash patterns as documented in the data sheet assume the outputs to be sourcing power to the LEDs. This is the recommended configuration, that will also work for low power, battery operated devices while in sleep mode.
If using the outputs as power sinks, the LED flash patterns will be inverted, and connected LEDs will leak power while the module is in sleep mode.

LED Indicator Time-Out

In many applications, the LED indicators will be useful during installation or for field service purposes. After installation, the indicators may in some applications no longer be desirable. For battery operated End-Devices the indicators will represent an undesired power consumption.
The configurable INDICATORS ON[8] parameter determines the time the indicator outputs are active after a power-up reset. By default, this parameter is set to 255 = permanently ON for Gateway and Router Devices. For End Devices, the parameter will automatically be set to default value 1 for a one-minute time-out, when using the 'N' - SET END DEVICE MODE configuration command to change between operational modes.
Setting the INDICATORS ON to 0 will permanently disable the indicator function.

Pulse Counter Feedback Indicator

Any GPIO may be configured as a feedback output for the pulse counter mode. Please see

PULSE COUNT Verification for details on the Pulse Counter Feedback function.
The duration of the pulse counter feedback is also controlled by the INDICATORS ON parameter, which will optionally disable this output after a pre-set time-out.

RSSI Indicator LED

When configured as a Router or End Device, an LED connected to module pin RSSI/ TX LED (Radiocrafts Demo Board Red LED, D1), will function as an RSSI indicator for Tinymesh™ Router or End Device 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 CONNECTION CHANGE MARGIN better than RSSI ACCEPTANCE LEVEL
3. Moderate flash, on for 1 second, off for 1 second:
   RSSI is acceptable for reliable communication
4. Very slow (2 seconds ON, 2 seconds off):
   RSSI is below the RSSI ACCEPTANCE LEVEL that will allow new connection. No new connections will be established at this low RSSI, but existing connection may still exist if the Connection LED is still flashing

Connection Indicator LED

When configured as a Router or End Device an LED connected to module pin CONNECTION/ RX LED (Radiocrafts Demo Board Yellow LED, D2), will function as a connection indicator. The LED will flash with one of the following patterns:

8 Available from Tinymesh™ firmware release 1.40

1. Steady ON:
   The device has established direct connection to a Gateway Device, and at least one more Gateway Device is available for alternate routing.
2. Rapid flash, 5 times per second:
   The device has established direct connection to a single Gateway Device.
3. Fast flash, 2 times per second:
   The device has established connection to a Router Device, and at least one more Router Device is available on the same jump level, as an alternate route (redundant connection)
4. Moderate flash, ON for one second and OFF for one second:
   The device has established connection to a single Router Device, and no alternatives exist on the same jump level.
5. No light: The device is disconnected
6. The Connection LED is flashing in sync with the RSSI Indicator LED immediately from module Reset / Power up: The Device is configured with a FIXED DESTINATION ID

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

The device connection status may be included in the data field of STATUS MESSAGE (IMA) messages[10].

Radio RX /TX Indicator LED

When configured as a Gateway Device, an LED connected to module pin RSSI/ TX LED (Radiocrafts Demo Board Red LED), will flash every time an RF packet is transmitted. An LED connected to module pin CONNECTION/ RX LED (Radiocrafts Demo Board Yellow LED), will flash every time an RF packet 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 Gateway Devices, or Connection Quality indicators for Router Devices.

Packet Mode Operation

When configured for packet mode operation, serial data and command packets may be broadcast to all devices, addressed to a group of devices, or addressed to a specific Router or End Device. 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 Device 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 packets. Please note data must be entered in one, contiguous string of bytes.

Note: Any time gap of more than the configured SERIAL PORT TIME OUT value will cause the Gateway to treat the entered data as a complete packet. 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

Router Devices behave similarly in Transparent and Packet mode. All packets will always be routed to the Gateway Device. Packet formatting and addressing is handled automatically by the Router firmware, and binary serial data may be entered to the Router UART without packet formatting and address information. Serial data packets will be transmitted immediately when the UART buffer is full (256 bytes), or after a configurable SERIAL PORT TIME OUT time gap between characters.

Note: 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 transmit serial data, to set or read GPIO pins, to enquire module operating status, or to alter settings in the Configuration Memory of Router Devices.
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.
Tinymesh™ modules may be configured through the UART in Configuration Mode (CONFIGURATION COMMANDS), or while operating in a live mesh network by issuing SET CONFIGURATION commands from the Gateway Device.

Note: To avoid losing connection with devices in a live mesh network, the RF CHANNEL, RF DATA RATE, UNIQUE_ID and SYSTEM_ID may only be changed through Gateway Commands before the SYSTEM_ID has been changed from the factory default setting.

The Command Packet formats for module control, inquiry and configuration, are shown in the COMMAND PACKET FORMAT table.

Group and Broadcast Addressing

Commands may be broadcast to all devices in a network by selecting '255 255 255 255' as the NODE ADDRESS .
Router and End Devices may also be assigned to addressing groups, by entering up to eight different single-byte group identifier addresses in the configurable module GROUP TABLE. The most significant byte of the UNIQUE_ID in the command NODE ADDRESS is interpreted as a group identifier by the receiving device.
The addressing structure for group commands is '255 255 255 nnn', where the 'nnn' byte represents the