Certification Exhibit

FCC ID: HSW-DNT90
IC: 4492A-DNT90

FCC Rule Part: 15.247
IC Radio Standards Specification: RSS-210

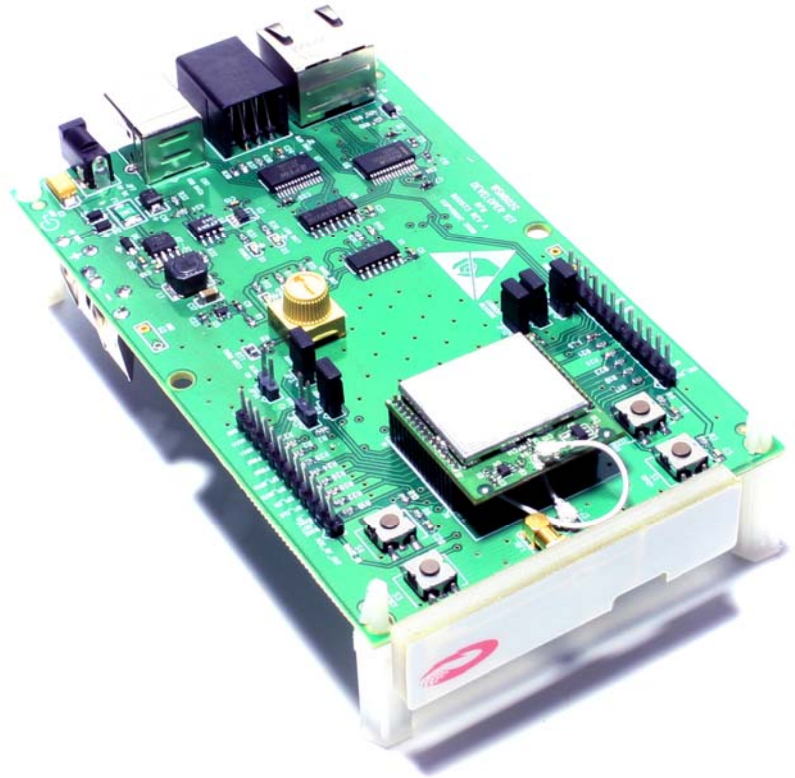
ACS Report Number: 10-0314.W06.11.A

Manufacturer: RFM/Cirronet
Model: DNT90C, DNT90P

Manual

DNT90 Series

900 MHz Spread Spectrum Wireless Transceivers



Integration Guide

Important Regulatory Information

RFM Product FCC ID: HSW-DNT90
IC 4492A-DNT90

Note: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

1) Re-orientate or relocate the receiving antenna,
2) Increase the separation between the equipment and the radiator,
3) Connect the equipment into an outlet on a circuit different from that to which the receiver is connected,
4) Consult the dealer or an experienced radio/TV technician for help.

FCC Antenna Gain Restriction and MPE Statement:

The DNT90 has been designed to operate with any dipole antenna of up to 5.1 dBi of gain, or any Yagi of up to 6.1 dBi gain.

The antenna(s) used for this transmitter must be installed to provide a separation distance of at least 20 cm from all persons and must not be co-located or operating in conjunction with any other antenna or transmitter.

Industry Canada Specific Statements:

The term "IC:" before the radio certification number only signifies that Industry Canada technical specifications were met.

This Class B digital apparatus meets all requirements of the Canadian Interference Causing Equipment Regulations. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Cet appareillage numérique de la classe B répond à toutes les exigences de l'interférence canadienne causant des règlements d'équipement. L'opération est sujette aux deux conditions suivantes: (1) ce dispositif peut ne pas causer l'interférence nocive, et (2) ce dispositif doit accepter n'importe quelle interférence reçue, y compris l'interférence qui peut causer l'opération peu désirée.

IC RSS-210 Detachable Antenna Gain Restriction:

This device has been designed to operate with the antennas listed below, and having a maximum gain of 6.1 dB. Antennas not included in this list or having a gain greater than 6.1 dB are strictly prohibited for use with this device. The required antenna impedance is 50 ohms:

RFM RWA092R Omnidirectional Dipole Antenna, 2 dBi
RFM OMNI095 Omnidirectional Dipole Antenna, 5 dBi
RFM YAGI099 Directional Antenna, 6.1 dBi

To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that permitted for successful communication.

See Section 6.8 of this manual for regulatory notices and labeling requirements. Changes or modifications to a DNT90 not expressly approved by RFM may void the user's authority to operate the module.

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1.0 DNT90 Introduction

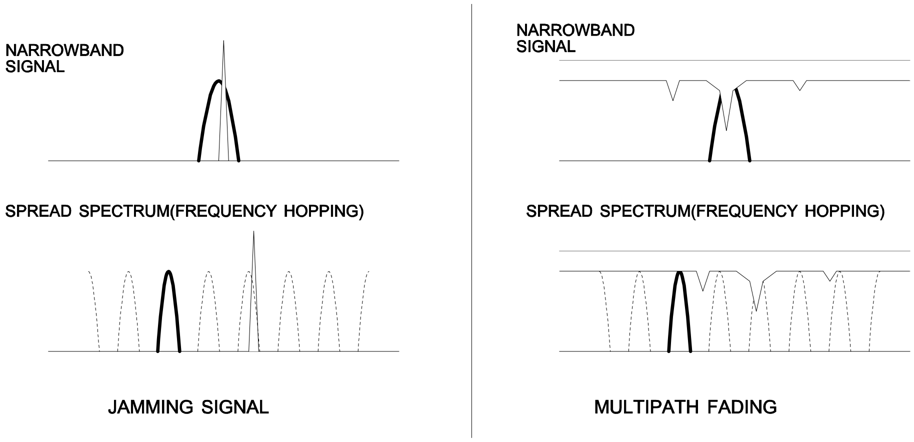
DNT90 transceivers provide highly-reliable wireless connectivity for point-to-point, point-to-multipoint and store-and-forward radio applications. Frequency hopping spread spectrum (FHSS) technology ensures maximum resistance to multipath fading and robustness in the presence of interfering signals, while operation in the 900 MHz ISM band allows license-free use in the US, Canada, South America, Israel, Australia and New Zealand. The DNT90 supports serial data rates for host communications from 1.2 to 230.4 kbps, plus three SPI data rates from 125 to 500 kbps. On-board data buffering plus an error-correcting radio protocol provide smooth data flow and simplify the task of integration with existing applications. Key DNT90 features include:

- Multipath fading resistant frequency hopping technology with up to 52 frequency channels, 902.76 to 927.24 MHz
- Support for point-to-point, point-to-multipoint, and store-and-forward networks
- FCC 15.247 and IC RSS-210 certified for license-free operation
- 5 mile plus range with omnidirectional antennas (antenna height dependent)
- Transparent ARQ protocol with data buffering ensures data integrity
- Analog and Digital I/O simplifies wireless sensing
- Ad Hoc TDMA operating mode supports a large number of remotes with low latency for burst data streaming
- AES encryption provides protection from eavesdropping
- Nonvolatile memory stores DNT90 configuration when powered off
- Selectable +16 or +22 dBm transmit power levels
- Simple interface handles both data and control at up to 230.4 kbps on the serial port or 500 kbps on the SPI port
- Automatic event reporting mode for I/O simplifies application development

1.1 Why Spread Spectrum?

A radio channel can be very hostile, corrupted by noise, path loss and interfering transmissions from other radios. Even in an interference-free environment, radio performance faces serious degradation from a phenomenon known as multipath fading. Multipath fading results when two or more reflected rays of the transmitted signal arrive at the receiving antenna with opposing phases, thereby partially or completely canceling the signal. This problem is particularly prevalent in indoor installations. In the frequency domain, a multipath fade can be described as a frequency-selective notch that shifts in location and intensity over time as reflections change due to motion of the radio or objects within its range. At any given time, multipath fades will typically occupy 1% - 2% of the band. From a probabilistic viewpoint, a conventional radio system faces a 1% - 2% chance of signal impairment at any given time due to multipath fading.

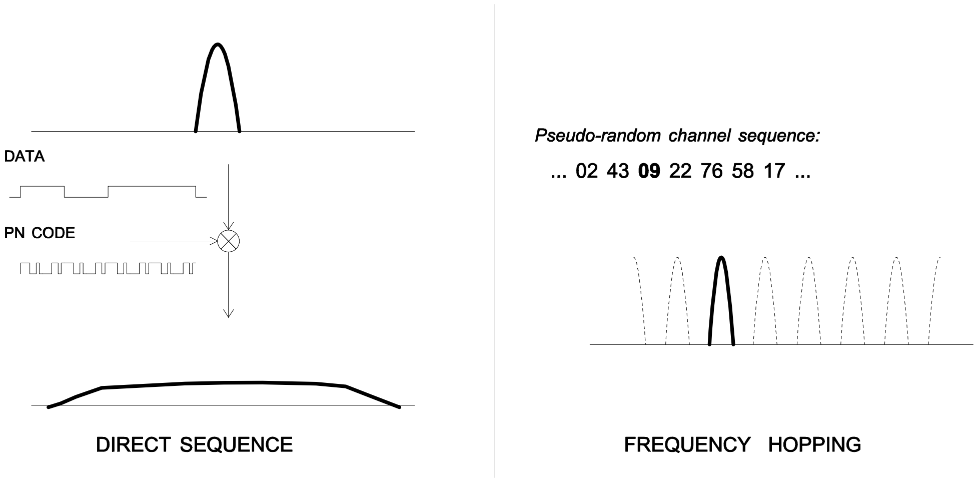
Spread spectrum reduces the vulnerability of a radio system to both multipath fading and jammers by distributing the transmitted signal over a larger region of the frequency band than would otherwise be necessary to send the information. This allows the signal to be reconstructed even though part of it may be lost or corrupted in transmission.


NARROWBAND SIGNAL
SPREAD SPECTRUM(FREQUENCY HOPPING)
JAMMING SIGNAL
NARROWBAND SIGNAL
SPREAD SPECTRUM(FREQUENCY HOPPING)
MULTIPATH FADING

Narrow-band versus spread spectrum transmission
Figure 1.1.1

1.2 Frequency Hopping versus Direct Sequence

The two primary approaches to spread spectrum are direct sequence spread spectrum (DSSS) and frequency hopping spread spectrum (FHSS), either of which can generally be adapted to a given application. Direct sequence spread spectrum is produced by multiplying the transmitted data stream by a much faster, noise-like repeating pattern. The ratio by which this modulating pattern exceeds the bit rate of the base-band data is called the processing gain, and is equal to the amount of rejection the system affords against narrow-band interference from multipath and jammers. Transmitting the data signal as usual, but varying the carrier frequency rapidly according to a pseudo-random pattern over a broad range of channels produces a frequency hopping spectrum system.



Forms of spread spectrum - direct sequence and frequency hopping
Figure 1.1.2

One disadvantage of direct sequence systems is that due to design issues related to broadband transmitters and receivers, they generally employ only a minimal amount of spreading, often no more than the minimum required by the regulating agencies. For this reason, the ability of DSSS systems to overcome fading and in-band jammers is relatively weak. By contrast, FHSS systems are capable of hopping throughout the entire band, statistically reducing the chances that a transmission will be affected by fading or interference. This means that a FHSS system will degrade gracefully as the band gets noisier, while a DSSS system may exhibit uneven coverage or work well until a certain point and then give out completely.

Because it offers greater immunity to interfering signals, FHSS is often the preferred choice for co-located systems. Since direct sequence signals are very wide, they can offer only a few non-overlapping channels, whereas multiple hoppers can interleave, minimizing interference. Frequency hopping systems do carry some disadvantages, in that they require an initial acquisition period during which the receiver must lock on to the moving carrier of the transmitter before any data can be sent, which typically takes several seconds. In summary, frequency hopping systems generally feature greater coverage and channel utilization than comparable direct sequence systems. Of course, other implementation factors such as size, cost, power consumption and ease of implementation must also be considered before a final radio design choice can be made.

2.0 DNT90 System Overview

A DNT90 radio can be configured to operate in one of three modes - *base, remote* or *router*. A *base* controls a DNT90 *system*, and interfaces to an application *host* such as a PC or Internet gateway. A *remote* functions to transmit or receive serial, digital (state) and analog data. A *router* alternates between functioning as a *remote* on one hop and a *network base* on the next hop. When acting as a remote, the router stores messages it receives from its *parent,* and then repeats the messages to its *child* radios when acting as a network base. Likewise, a router will store messages received from its child radios when acting as a base, and repeat them to its parent when acting as a remote. Any message addressed directly to a router is processed by the router rather than being repeated.

2.1 Point-to-Point Systems

A DNT90 *system* contains at least one *network*. The simplest DNT90 topology is a point-to-point system, as shown in Figure 2.1.1. This system consists of a base and one remote forming a single network. Point-to-point systems are often used to replace wired serial connections. Point-to-point systems are also used to transmit switch positions or analog signals from one location to another.

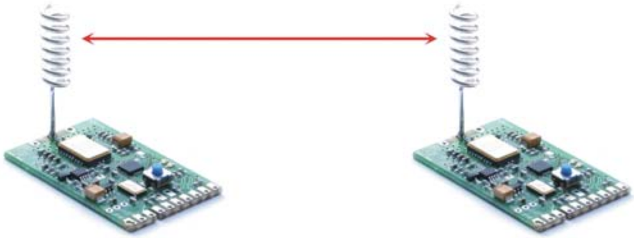


Figure 2.1.1 **[replace with DNT90 graphics]**

2.2 Point-to-Multipoint Systems

Figure 2.2.1 shows the topology of a point-to-multipoint (star) system, which consists of a base and more than one remote in a single network. Point-to-multipoint systems are typically used for data, sensor and alarm systems. While most traffic in a point-to-multipoint system is between the base and the remotes, DNT90 technology also allows for *peer-to-peer* communication from one remote to another.

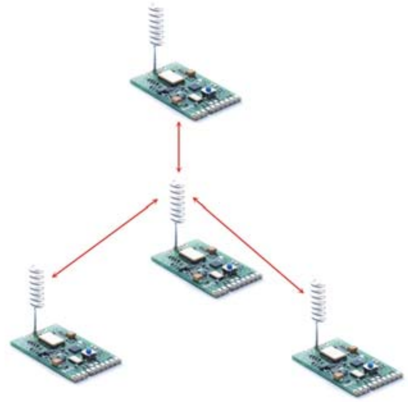


Figure 2.2.1 **[replace with DNT90 graphics]**

2.3 Store-and-Forward Systems

Figure 2.3.1 shows the topology of a *store-and-forward* system, which consists of a base, one or more routers, one or more remotes, and *two or more* networks. Networks in a store-and-forward system form around the base and each router. The base and the routers are referred to as the *parents* of the networks they form. The rest of the radios in each network are referred to as *child* radios. Note that a router can be a child of the base or another router while being the parent of its own network. Each network parent transmits beacons to allow child radios to synchronize with its hopping pattern and join its network. Different frequency hopping patterns are used by the parent radios in a system, minimizing interference between networks.

Store-and-forward systems are used to cover larger areas than is possible with point-to-point or point to-multipoint systems. The trade-off in store-and-forward systems is longer delivery times due to receiving and retransmitting a message several times. Store-and-forward systems are especially useful in applications such as agriculture where data is only collected every hour or so.

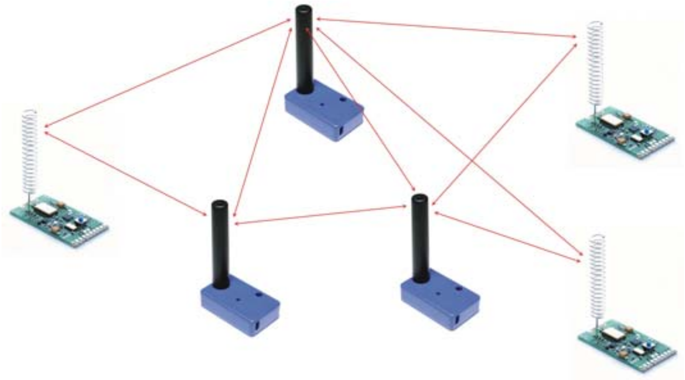


Figure 2.3.1 **[replace with DNT90 graphics]**

2.4 RF Channel Access

The time a DNT90 network stays on each frequency in its hopping pattern is called the hop *duration* or *dwell* time, which can be configured from 8 to 100 ms. Radio communication during each dwell is organized as a time division multiple access (TDMA) *frame*. A DNT90 frame begins with a base-mode *beacon*, followed by 1 to 8 time *slots* used by the network children to transmit to their parent, as shown in Figure 2.4.1. A base-mode beacon can include up to 8 messages addressed to one or more child radios.

DNT90 Communication Frame

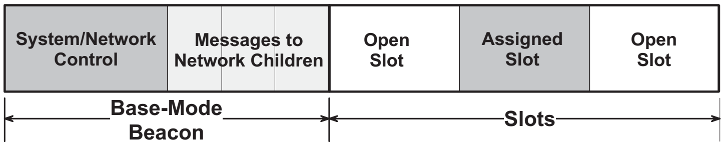


Figure 2.4.1

Each beacon includes the status of all slots - either *registered* (assigned) or *open*. When a child radio has information to transmit to its parent, it randomly selects one of the open slots and transmits all or the first part of its data. If the parent successfully receives the transmission, it includes the child's *MAC* address in the next beacon. This signals the child radio that the slot is temporarily registered to it, allowing the child to efficiently stream any remaining data to the base hop-by-hop until it is all sent.

If a child radio does not see its address in the next beacon following its transmission, it again randomly selects an open slot and retransmit its data. During times when there are no open slots, a child radio keeps its data queued and continues to look for an open slot in each beacon until at least one slot becomes available. The access method the DNT90 uses is referred to as *Ad Hoc TDMA* or *hybrid CSMA/TDMA.*

2.5 DNT90 Addressing

Each DNT90 has a unique *MAC* address. The MAC address can be read or bar-code scanned from the label on top of each radio. A DNT90 radio in any mode (base/router/remote) can be addressed using its MAC address. A DNT90 base can be addressed using either its MAC address or address 0x000000. A DNT90 can send a message to all other DNT90's in its system by using the broadcast address 0xFFFFFF.

The base and all routers (parents) hold a *base-mode network ID*, which is transmitted in every beacon. All routers and remotes hold a *parent network ID* and optionally an *alternate parent network ID* to compare against the *base-mode network IDs* in the beacons they receive. A child router or remote is allowed to join a parent if its *parent network ID* or *alternate parent network ID* matches the parent's *base-mode network ID*, or with any parent when its *parent network ID* is set to 0xFF (wildcard).

In a point-to-point or point-to-multipoint system, the default *base-mode network ID* of 0xFF (wildcard) can be used. In a store-and-forward system, however, the base-mode network IDs of all routers must be set to *different values* between 0x00 to 0x3F. If the *base-mode network ID* of 0x00 is assigned to a router, the base must be assigned an unused base-mode network ID between 0x01 and 0x3F.

Leaving all parent network IDs in a store-and-forward system set to the default value of 0xFF allows networks to automatically form, and self-repair if a parent router fails. Enabling the alternate parent network ID also provides self-repairing message routing.

All DNT90 radios hold a *system ID* that can be used to distinguish systems that physically overlap. In a DNT90 system, the *system ID* must be different from those used by overlapping systems to provide message filtering. Also, using different *base-mode network IDs* for all networks in overlapping systems helps reduce hopping pattern collisions.

The store-and-forward path between the base and any other radio in a system can be determined by reading the radio's *ParentMacAddress* parameter. If this address is not the base, then reading the *ParentMacAddress* parameter of its parent, grandparent, etc., in succession reveals the complete path to the base. Path determination is useful in optimizing and troubleshooting systems during commissioning and maintenance.

2.6 Network Linking and Slot Registration

When first turned on, a DNT90 router or remote rapidly scans all frequency channels in its operating band to acquire synchronization and link to a parent based on a system ID match plus a base-mode network ID to parent network ID/alternate parent network ID match (or by using a wildcard (0xFF) parent network ID).

In addition to the slot status and the MAC addresses of child radios holding slot registrations, each base-mode beacon includes one of a number of *cycled control parameters*. The cycled parameters are collected by child radios, allowing them to register with a parent, and to later follow any control parameter changes. When a router or remote has collected a full set of cycled parameters, it can issue an optional initial heartbeat message and then optional periodic heartbeat messages which allow an application to maintain the status of all routers and remotes in its DNT90 system.

When a router/remote has data to send to its parent, it picks an open slot at random and transmits. It then looks for its MAC address in the next beacon. If its MAC address is present in the beacon, it is temporarily registered to the slot and continues to use it until all current data is sent, or its MAC address drops off the beacon (link lost).

2.7 Transparent and Protocol-formatted Serial Data

A DNT90 remote can directly input and output data bytes and data strings on its serial port. This is referred to as *transparent* serial port operation. In a point-to-point system, the base can also be configured for transparent serial port operation.

In all other cases, serial data must be *protocol* formatted:

- configuration commands and replies
- I/O event messages
- announcement messages including heartbeats

Protocol-formatted messages are discussed in detail in Section 7. Briefly, protocol-formatted messages include a start-of-messages character, message length and message type information, the destination address of the message, and the message payload.

Transparent data is routed using a *remote transparent destination address*. In a remote, this address defaults to the base, 0x000000, and in the base this address defaults to broadcast, 0xFFFFFF. These defaults can be overridden with specific radio addresses. For example, it is possible to set up transparent peer-to-peer routing between two remotes in a point-to-multipoint or store-and-forward system by loading specific MAC addresses in each radio's remote transparent destination address.

3.0 DNT90 Application Interfaces

A DNT90 module provides a variety of application interfaces including a serial port, SPI port, six digital I/O ports (logic state), three 12-bit ADC input ports, and two 12-bit DAC output ports. Each of these interfaces is discussed below.

3.1 Serial Port

The DNT90 serial port is a full-duplex UART interface with hardware flow control on two of the digital I/O pins as a default feature. One digital I/O pin can also be configure as an RS485 enable function. The serial port can be configured with baud rates from 1.2 to 230.4 kbps, with 9.6 kbps the default baud rate. The DNT90 serial port transmits/receives 8-bit data with a choice of even/odd/no parity and 1 or 2 stop bits. The default configuration is no parity and one stop bit. See Section 5.1 for recommendations on configuring the serial port, and Section 7.4.4 for detailed information on serial port configuration parameters.

3.2 SPI Port

The DNT90 serial peripheral interface (SPI) port can operate either as a master or a slave. The port includes the four standard SPI connections - MISO, MOSI, SCLK and /SS, plus three signals used to support SPI slave mode operation - /HOST_RTS, /HOST_CTS and DAV. The serial port and SPI master mode can run simultaneously. Serial port operation is disabled when the SPI port is configure for slave mode. Note that all SPI slave mode messages must be protocol formatted.

DNT90 SPI Master Mode Signaling

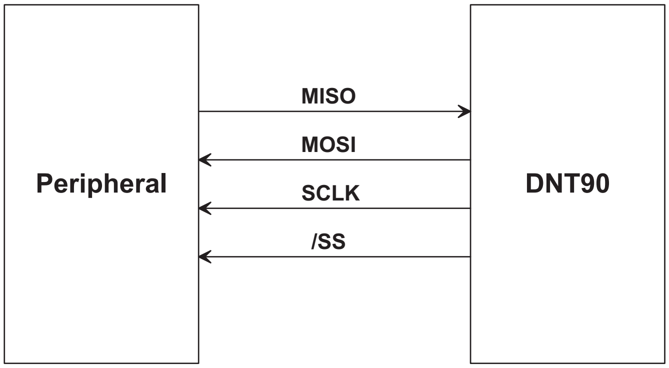


Figure 3.2.1

The DNT90 SPI port can run at three clock rates in master mode - 125, 250 or 500 kbps. There are two message sources available to a DNT90 SPI master, a protocol-formatted *RxData* message, or a stored command. The DNT90 master will clock a message from either source into its slave and return the bytes clocked out as a protocol-formatted *TxData* message. The DNT90 event timer triggers sending the stored command to the DNT90's slave. The stored command can be up to 16 bytes in length. Figure 3.2.1 shows the required SPI master mode-signal connections, and Figure 3.2.2 shows the SPI master-mode timing.

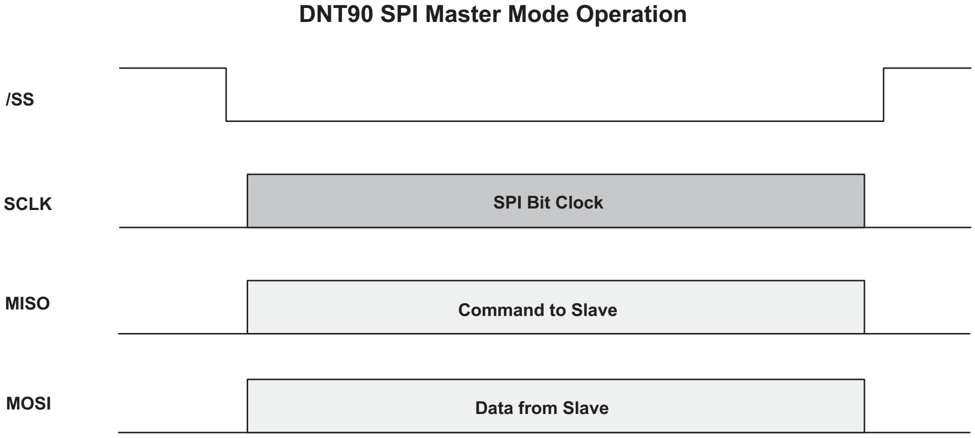


Figure 3.2.2

In SPI slave mode, the host can stream data into DNT90 at up to 250 kbps, provided the host suspends clocking within 10 bytes following a low-to-high transition on /HOST_CTS. The host can clock data into the DNT90 at up to 4 Mbps for data bursts of up to 50 bytes, provided the interval from the end of one burst to the start of the next burst is at least 2 ms, and the host suspends clocking on a low-to-high transition on /HOST_CTS. See Figure 3.2.4

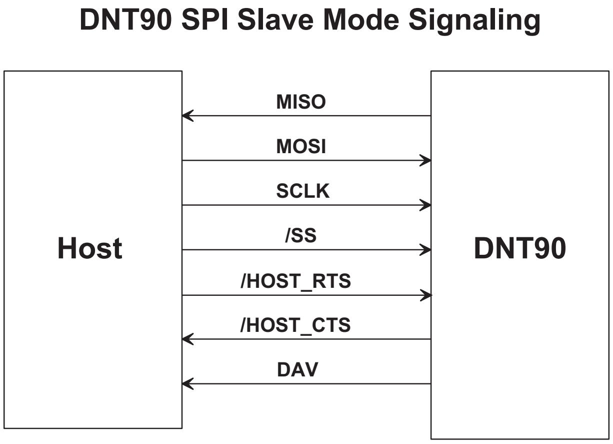


Figure 3.2.3

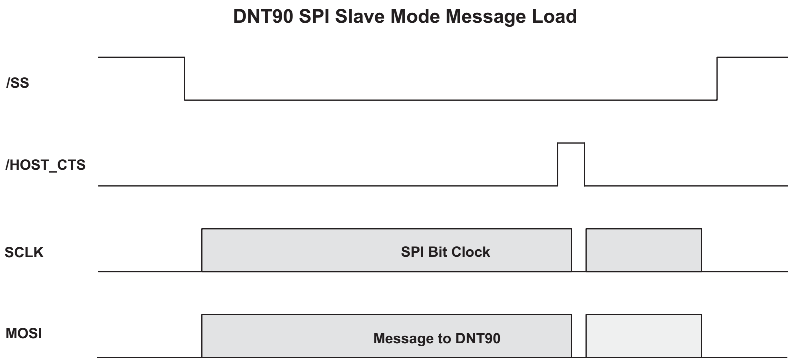


Figure 3.2.4

The host should use the following steps to fetch data from a DNT90 SPI slave, as show in Figure 3.2.5:

1. The host sets the /HOST_RTS signal high to allow the DNT90 to signal data available.
2. The DNT90 sets the data available (DAV) high to signal the host it has data.
3. The host set the /SS signal low to enable SPI operation.
4. The host clocks in one dummy byte (ignore the output byte) and then sets /HOST_RTS low.
5. The host begins to clock out the data, which can include several messages.
6. The host continues to clock out data until a 0x00 byte occurs in the byte stream where a 0xFB start-of-message would be expected.
7. The host has now clocked out all messages and the 0x00 is discarded.
8. The host sets /HOST_RTS and /SS high to allow the DNT90 to signal DAV the next time it has data.

Note that the DAV signal can go low before the last message is clocked out. It is not a reliable indication that the last byte of the message(s) has been clocked out. See Section 5.2 for recommendations on configuring the SPI port, and Section 7.4.4 for detailed information on SPI port configuration parameters.

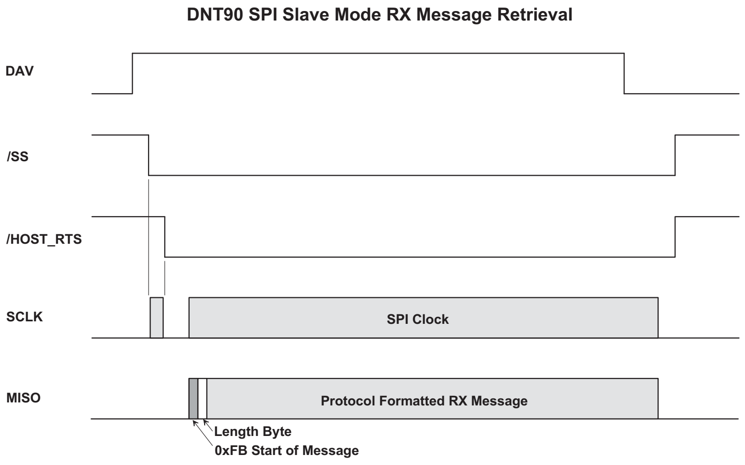

DNT90 SPI Slave Mode RX Message Retrieval
DAV
/SS
/HOST_RTS
SCLK
SPI Clock
MISO
Protocol Formatted RX Message
Length Byte
0xFB Start of Message

Figure 3.2.5

3.3 Digital I/O

The DNT90's six digital (state) I/O ports are labeled GPIO0 through GPIO5. GPIO5 defaults to /HOST_RTS and GPIO4 defaults to /HOST_CTS, providing hardware handshaking for the serial port and SPI slave mode operation. If serial port hardware handshaking is not required and SPI slave mode is not enabled, GPIO4 and GPIO5 can be used for other digital I/O functions. When SPI slave mode is enabled, GPIO5 and GPIO4 *must* be used for /HOST_RTS and /HOST_CTS respectively, and GPIO3 *must* be used to provide the DAV signal (SPI slave mode overrides any other configuration for these ports). Except in SPI slave mode, GPIO0 through GPIO3 and optionally GPIO4 and GPIO5 are available for customer-defined functions:

- The direction of each GPIO pin can be set for both active and sleep modes.
- The initial state (power on) of all GPIO pins configured as outputs can be set.
- The state of all GPIO pins configured as outputs in sleep mode can be set.
- GPIO triggering of I/O event reporting can be configured.
- GPIO level control of sleep hold-off can be configured.

See Section 5.3 for recommendations on configuring the digital I/O, and Sections 7.4.6 and 7.4.7 for detailed information on GPIO parameters.

3.4 Analog I/O

The DNT90's three ADC inputs are labeled ADC0 through ADC2. The ADCs can be disabled if unused to reduce current consumption. ADC measurements are made with 12-bit resolution. There are three options for the ADC full-scale reference:

1. The DNT90 regulated buss voltage divided by 1.6 or about 2.06 V
2. An internal band-gap reference voltage, 1.00 V nominal
3. A voltage supplied to the DNT90's ADC_EXT_REF input pin, 2.70 V maximum. If no connection is made to this pin, a voltage equal to about 1/2 the buss voltage will be present.

The three ADCs are read each ADC sample interval, which is configurable. High and low measurement thresholds can be set for each ADC input to trigger I/O event reporting messages.

The DNT90's two DAC outputs are labeled DAC0 and DAC1. The DACs can be disabled if unused to reduce current consumption. The DAC settings have 12-bit resolution. There are three options for the DAC full-scale reference:

1. The DNT90 regulated buss voltage, about 3.3 V
2. An internal band-gap reference voltage, 1.00 V nominal
3. A voltage supplied to the DNT90's ADC_EXT_REF input pin, 2.70 V maximum. If no connection is made to this pin, a voltage equal to about 1/2 the buss voltage will be present.

See Section 5.4 for recommendations on configuring the analog I/O, and Sections 7.4.6 and 7.4.7 for detailed information on analog I/O parameters.

3.5 I/O Event Reporting and I/O Binding

The DNT90's I/O event reporting function can generate a protocol-formatted *RxEvent* message when triggered by one of the following I/O events:

- A specific state change of GPIO0, GPIO1, GPIO2 or GPIO3.
- Firing of the periodic event report timer.
- A high or low threshold exceeded on a measurement by ADC0, ADC1 or ADC2.

An I/O report message includes:

- The states of GPIO0 through GPIO5.
- The latest measurements made by ADC0 through ADC2 .
- A set of flags indicating which event(s) triggered the I/O report.
- The settings of DAC0 and DAC1.

The I/O binding function works in conjunction with I/O event reporting. When I/O binding is enabled on a DNT90, data received in an I/O event report it is mapped as follows:

- GPIO2 will output the state of GPIO0 in the last received event report.
- GPIO3 will output the state of GPIO1 in the last received event report.
- DAC0 will output the voltage read by ADC0 in the last received event report.
- DAC1 will output the voltage read by ADC1 in the last received event report.

I/O binding is used to transmit switch positions or analog signals from one location to another. Note that I/O binding cannot be used in a DNT90 when SPI slave mode is enabled. See Section 5.4 for recommendations on configuring I/O event reporting and binding, and Sections 7.4.6 and 7.4.7 for detailed information on I/O reporting and binding parameters.

4.0 DNT90 System Configuration

DNT90 radios feature an extensive set of configuration options that allows them to be adapted to a wide range of applications. Configuration defaults have been carefully selected to minimize the configuration effort for most applications, while providing the ability to individually adjust the configuration of each radio to achieve highly optimized system operation.

4.1 Configuration Parameters

The configuration of a DNT90 is controlled by a set of *parameters* (registers). Parameters that address a particular aspect of operation are grouped into a *bank*. All parameters can be accessed through a module's serial port and over the radio link. Most parameters are read/write. Read-only parameters include fixed values such a MAC addresses, firmware version numbers and parameters that are dynamically adjusted during system operation such as link status. Write-only parameters include security keys and certain action triggers such as reset. Incorrectly configuring certain parameters can disable a module's radio link, but the configuration can always be corrected through the serial port. The organization of the parameter register banks and the details of each parameter are covered in Section 7.4 of this guide. Sections 4.2 through 5.7 discuss which parameters apply to various aspects of configuring a DNT90 system, network or application interface.

4.2 Configuring a Basic Point-to-Point System

A basic DNT90 point-to-point systems is suitable for many serial data applications. The default configuration of a DNT90 is a remote with the serial port configured for transparent operation at 9.6 kbps, 8N1. To configure a basic point-to-point system:

1. Configure one of the modules as a base by setting the *DeviceMode* parameter in Bank 0 to 0x01.

2. Set the *MemorySave* parameter in Bank 0xFF to 0xD2, which will save the *DeviceMode* parameter to EEPROM and reset the module, enabling base operation.

3. All other parameters may be left at their default values.

4.3 Configuring a Custom Point-to-Point or Point-to-Multipoint System

To configure a customized point-to-point system or a point-to-multipoint system, RFM recommends the following configuration sequence:

1. Configure one of the modules as a base by setting the *DeviceMode* parameter in Bank 0 to 0x01.

2. Set the AES security key in all system radios by loading your selected 16-byte string into the *SecurityKey* parameter in Bank 0 (the default is 16 bytes of 0x00).

3. Select the frequency band of operation by setting the *FrequencyBand* parameter in Bank 1 of the base radio as desired (the default is Bank 0).

4. Set the transmitter power level as needed in all radios by setting the *TxPower* parameter in Bank 0 (the default is 40 mW).

5. Configure the system ID in all radios by setting the *SystemID* parameter in Bank 0 (the default OK if there is no chance of overlapping systems).

6. Load the parent network ID in all remotes in the *ParentNetworkID* parameter in Bank 0 as needed (wildcard default is OK for point-to-point and point-to-multipoint systems).

7. Set the *BaseModeNetID* parameter in the base to match the *ParentNetworkID* parameter in the remotes.

8. For a point-to-multipoint system, set the *ProtocolMode* parameter in Bank 4 of the base to 0x01. Set the protocol mode as needed in the base and remote of a point-to-point system, and as needed in the remotes in a point-to-multipoint system. If SPI slave mode will be used, protocol mode must be enabled in all system radios.

9. If using transparent serial mode in the system:

    a. Set the remote transparent destination address in the *RmtTransDestAddr* parameter, Bank 0, in each remote (the base address is the default destination).

    b. Set the transparent point-to-point mode to select either the *RmtTransDestAddr* address (default) or the address of the originator of the last received message as the remote destination address. The parameter that controls this destination address is the *TransPtToPtMode* in Bank 4. Set in all remotes as needed.

    c. Set the timeout for transmission of transparent data in the remotes as needed. The parameter that controls the timeout is the *TxTimeout* in Bank 4 (the default is no timeout).

    d. Set the minimum message length for transmission of transparent data in the remotes as needed. The parameter that controls the length is the *MinPacketLength* in Bank 4 (the default is one byte).

10. Set the maximum number of messages that can be sent in a frame in each system radio. The parameter that controls this number is *MaxDataPackets* in Bank 4 (the default is 8 messages).

11. Load the required base slot size into the *BaseSlotSize* parameter, Bank 1, in the base. The default is 40 bytes. See Section 4.5 below.

12. Configure the number of slots per frame on the base by setting the *NumSlots* parameter (the default is 3 slots). See Section 4.5 below.

13. Set the required hop duration on the base. The *HopDuration* parameter in Bank 0 controls hop duration. The default is 20 ms. See Section 4.5 below.

14. Configure the slot lease on the base by setting the *SlotLease* parameter. The default is 4 hops.

15. Set the heartbeat interval as required in each system radio. The parameter that controls heartbeats is the *HeartBeatIntrvl* in Bank 0. The default is 20 seconds/heartbeat.

16. Enable message ACKs where required by setting the *AckEnable* parameter in Bank 0 to 1. The default is ACKs disabled.

17. Set the message retry limit on the base with the *ArqAttemptLimit* parameter in Bank 1. The default value is 4 retries.

18. Configure the link drop threshold on the base by setting the *LinkDropThreshold* in Bank 1 (the default is 10 hops).

19. Set the point-to-point reply timeout on the base in the *P2PReplyTimeout* parameter in Bank 1. The default is 16 hops.

20. Configure the registration timeout on the base by setting the RegistryTimeout parameter in Bank 1 (the default timeout is 50 hops).

21. Load an optional “friendly description” in each system radio in the *UserTag* parameter, Bank 0.

4.4 Configuring a Store-and-Forward System

The following additional parameters must be set to configure a DNT90 store-and-forward system:

1. Configure the DNT90 radios designated to be routers by setting the *DeviceMode* parameter in Bank 0 to 0x02.

2. Enable store-and-forward operation on *all* system radios by setting the *Store&ForwardEn* parameter in Bank 0 to 0x01.

3. In each router, load a unique base-mode network ID into the *BaseModeNetID* parameter in Bank 0, and into the base if a router is set to 0x00.

4. To configure the system topology manually, set the parent network ID parameter, *ParentNwkID,* and optionally the alternate parent network ID parameter, *AltParentNwkID*, in all routers and remotes. Note that a store-and-forward system topology can be formed either automatically or manually, based on the settings of the *ParentNetworkID* and optionally the *AltParentNwkID* parameters:

   - Setting the *ParentNwkID* parameter to 0xFF in all routers and remotes allows each router and remote to automatically link to a parent, causing the system to form automatically (child routers picking each other as a parent cannot occur). In this case, the *AltParent-NwkID* parameter should be set to 0xFF, which disables it.

- Setting the *ParentNwkID* and optionally the *AltParentNwkID* parameters to specific values in each router and remote allows full manual control of the network topology.

The benefit of automatic system formation is self-healing. If a parent router fails, its child nodes can re-link to any other parent router they can receive. However, automatic topology formation can result in an unnecessary number of hops between routers or remotes and the base.

The benefit of manual system topology formation is to avoid unnecessary extra hops in the system, and to balance the number of children supported by each parent router. If a parent router fails and an active alternate parent network ID has not been assigned, all children downstream from the failure will be off the system until the failed router is repaired or replaced.

4.5 Coordinating Slot Sizes and Hop Duration

The *base slot size* (BSS) is the maximum number of payload bytes the base can transmit during a single hop, when the base is sending *one* message per hop. The maximum BSS is 105 bytes when a DNT90 system is configured for one slot. Adding additional slots reduces the maximum BSS by three bytes per slot**.** The base transmit buffer is set nine bytes larger than the BSS, to a maximum of 114 bytes**.** The base can potentially send more than one message per beacon. Each message in the transmit buffer occupies nine header bytes plus the payload.

For example, the base can send three messages per hop when the BSS is 90 bytes, provided the total payload bytes in the three messages is 72 bytes or less:

slot size	= 90
TX buffer	= 90 + 9 = 99
3 headers	= 3*9 = 27
net for payload	= 99 - 27 = 72

The BSS must be large enough to accommodate all protocol-formatted messages that may be sent over the wireless link, as these messages *must* be sent in a single transmission.

The size of all (child) slots in a hop frame is the same, and is referred to as the *remote slot size* (RSS). The RSS is calculated by all DNT90s in a system. The slot size depends on the current values of the following parameters:

- base slot size
- hop duration
-number of slots in a frame

The user must be able to configure the system so that the RSS will accommodate all protocol-formatted message that may be sent over the wireless link. This is done by setting the appropriate hop duration for the chosen BSS and number of slots. The required hop duration for a specific number of slots, base slot size and remote slot size is calculated as follows:

HD	hop duration in µs
NS	number of slots
BSS	base slot size in bytes
RSS	remote slot size in bytes

HD = NS*(80*RSS + 2440) + 80*BSS + 3280
(round HD up to an even multiple of 500 µs)

Example:

NS = 4
BSS = 96
RSS = 109

HD = 4*(80*109 + 2440) + 80*96 + 3280
HD = 44640 + 7680 + 3280
HD = 55600 round to 56000 µs = 56 ms

Excel® Formatted Equations:

	A	B	C	D	E
1	Slots	BSS	RSS	Hop Duration in µs	Hop Duration in ms, Rounded
2					Up to the next 0.5 ms Step
3	1	20	20	=A3*(80*C3+2440) + 80*B3 + 3280	=0.5*QUOTIENT((D3+499),500)

For transparent serial port operation, the BSS and RSS must be large enough to accommodate all message bytes that can accumulate between transmissions. As discussed above, the number of message bytes is controlled by the *MinPacketLength* parameter setting. The required BSS and RSS for protocol-formatted messages sent over the wireless link are shown in Table 7.3.1. For example, the BSS and RSS size required for a *TxData* protocol-formatted message is three bytes less than the value in the length byte field of the formatted message.

The default BSS is 40 bytes, number of slots is 3 and hop duration is 20 ms. These parameter settings provide a 25 byte RSS. These default settings are suitable for point-to-point and small to medium point-to-multipoint systems operating with protocol-formatted and/or transparent messages. To accommodate all configuration commands, replies, event messages and announce messages, a 20 byte minimum slot size is required.

5.0 DNT90 Application Interface Configuration

DNT90 modules include a comprehensive set of application interfaces and related options that support a wide range of applications including wireless RS232/485 cable replacements, wireless sensor networks, wireless alarm systems and industrial remote control applications. Recommended configuration steps for each application interface are discussed in Sections 5.1 through 5.7 below.

5.1 Configuring the Serial Port

The default serial port configuration is 9.6 kbps, 8-bit data, no parity and 1 stop bit.

1. Configure the serial data rate as required from 1.2 to 230.4 kbps by setting the *SerialRate* parameter in Bank 3.
2. Configure the parity and number of stop bits by setting the *SerialParams* parameter in Bank 3.
3. Enable/disable serial port handshaking as required by setting the *GpioAlt* parameter in Bank 6. Handshaking is enabled by default, and is recommended for data rates 9.6 kbps and higher.

5.2 Configuring the SPI Port

1. Enable either SPI *master mode* or SPI *slave mode* by setting the *SpiMode* parameter in Bank 3. Note that SPI slave mode disables serial port operation.
2. If using SPI master mode:
   a. Select the SPI clock rate by setting the *SpiRateSel* parameter in Bank 3 (default is 125 kbps)

   b. Set the SPI master command string and string length by setting the *SpiMasterCmdStr* and *SpiMasterCmdLen* parameters respectively in Bank 3.
3. Configure the edge trigger direction, bit-sampling edge and bit-order options by setting the *SpiOptions* parameter in Bank 3.

5.3 Configuring Digital I/O

1. GPIO2 through GPIO 5 have configurable alternate functions as discussed in Section 7.4.7. Select either digital (state) functionality or alternate functionality for each of these pins by setting the *GpioAlt* parameter in Bank 6. Note that selecting SPI slave mode overrides the *GpioAlt* parameter setting for GPIO3 though GPIO5.
2. Configure the direction of each GPIO pin as needed by setting the *GpioDir* parameter in Bank 6 (the default is all inputs).
3. Configure the direction of each GPIO pin for sleep mode as needed by setting the *GpioSleepDir* parameter in Bank 6 (the default is all inputs).
4. Set the initial state (power on) of all GPIO pins configured as outputs by setting the *GpioInit* parameter in Bank 6 (the default is all logic low).
5. Set the state of all GPIO pins configured as outputs in sleep mode by setting the *GpioSleepState* parameter in Bank 6 (the default is all logic low).
6. GPIO0 through GPIO3 can trigger I/O event reporting when functioning as digital inputs. Enable event report triggering and optional sleep hold-off for these pins by setting the *GpioEdgeTrigger* parameter in Bank 6.

5.4 Configuring Analog I/O

1. Select the ADC full scale reference by setting the *AdcReference* parameter in Bank 6. This setting applies to all ADC channels. The default is the ADC_EXT_REF input. If ADC operation is not needed, setting this parameter to 0x03 disables ADC operation, reducing current consumption.

2. Configure the ADC measurement interval by setting the *AdcSampleIntvl* parameter. The default is 10 ms, and applies to all ADC channels.

3. Measurements on each ADC input can be compared to high/low threshold values, triggering an I/O event report if the measurements go above/below the respective thresholds. The thresholds for each ADC channel are set by loading the *AdcXThresholdLo* and *AdcXThresholdHi*, where *X* refers to the ADC channel designator, 0 through 2.

4. Select the DAC full scale reference by setting the *DacReference* parameter in Bank 6. This setting applies to both DAC channels. The default is the ADC_EXT_REF input. If DAC operation is not needed, setting this parameter to 0x03 will disable DAC operation, reducing current consumption.

5. Configure the initial (power on) output level for DAC0 and DAC1 by loading the initial settings in the *Dac0Init* and *Dac1Init* parameters respectively.

5.6 Configuring I/O Event Reporting and I/O Binding

1. Select the analog, digital and timing events that will trigger an I/O event report by setting the respective bits in the *IoReportTrigger* parameter in Bank 6. The default is no triggers set.

2. Configure the trigger behavior bits in the *GpioEdgeTrigger* parameter, Bank 6, for each GPIO input selected to generate an I/O event report.

3. For each ADC channel selected to generate an I/O event, set the high and low measurement threshold values. The *AdcThreshold* parameters are in Bank 6 at register offsets 15, 17, 19, 21, 23 and 25.

4. If the periodic timer has been selected to generate an event report, load the required timer report interval into the *IoReportInterval* parameter in Bank 6. The default timer interval is 30 seconds.

5. The *ReportHoldoff* parameter in Bank 6 sets the delay following an event to take ADC readings for the I/O event report. The parameter scaling is in milliseconds, and the default is 0. Set this parameter as required to avoid transient interference with the ADC measurements.

6. If I/O binding operation is desired, set the *IoBindingEnable* parameter in Bank 6 to 0x01. I/O binding is disabled by default.

5.6 Configuring Sleep Mode

Sleep mode can be used in conjunction with I/O reporting to *greatly extend* battery life on DNT90 remotes. At least one I/O report trigger must be enabled to allow sleep mode to be used. Note that the base and routers cannot be configured for sleep mode.

1. Enable sleep mode as desired in each remote by setting the *SleepModeEn* parameter in Bank 0 to 1.

2. Configure the timeout for a remote to attempt to link to its parent when triggered awake. This is done by setting the *WakeLinkTimeout* parameter in Bank 0. The default timeout is 5 seconds.

3. Configure the maximum time a remote in sleep mode will remain awake following linking, receiving an ACK, processing a message addressed to it, or receiving a serial or SPI message by setting the *Wake-ResponseTime* parameter. The default response time is 500 ms. Note that the setting of this parameter is overridden by some *GpioEdgeTrigger* parameter settings.

6.0 DNT90 Hardware

DNT90 Block Diagram

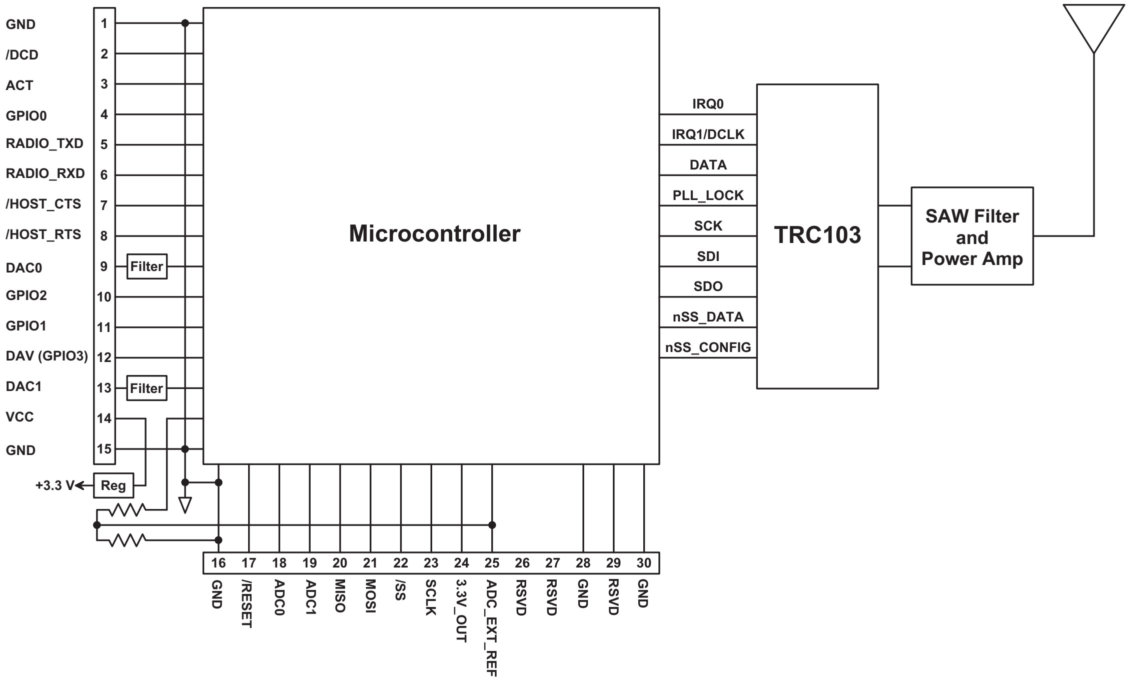


Figure 6.0.1

The major components of the DNT90 include an RFM TRC103 900 MHz FHSS transceiver and a low current 8-bit microcontroller. The DNT90 operates in the 902 to 928 MHz ISM band. There are three selectable hopping patterns providing compatibility with frequency allocations in the US, Canada, South America, Israel, Australia and New Zealand. The DNT90 also has two selectable RF output power levels: +16 dBm (40 mW) and +22 dBm (158 mW).

The DNT90 receiver is protected by a low-loss SAW filter, providing an excellent blend of receiver sensitivity and out-of-band interference rejection that is especially important in outdoor applications.

The DNT90 provides a variety of hardware interfaces. There are two serial ports plus one SPI port. Either the primary serial port or the SPI port can be selected for data communications. The second serial port is dedicated to diagnostics. The primary and diagnostic serial ports support most standard baud rates up to 230.4 kbps. The SPI port supports data rates up to 500 kbps. Also included are three 12-bit ADC inputs, two 12-bit DAC outputs, and six general-purpose digital I/O ports. Two of the digital I/O ports support an optional interrupt-from-sleep mode when configured as inputs. The radio is available in two mounting configurations. The DNT90C is designed for solder reflow mounting. The DNT90P is designed for plug-in connector mounting.

6.1 Specifications

Absolute Maximum Rating	Value	Units
Power Supply Input	-0.5 to +6.5	V
All Input/Output Pins	-0.5 to +3.3	V
Input Power to RFIO Port	0	dBm
Non-operating Ambient Temperature Range	-40 to +85	°C

Table 6.1.1

Operating Characteristic	Sym	Minimum	Typical	Maximum	Units
Operating Frequency Range		902.76		927.24	MHz
Hop Dwell Time		8		100	ms
Number of RF Channels		25		52	
Modulation		FSK			
RF Data Transmission Rate		100			kbps
Receiver Sensitivity, 10^{-5} BER			-100		dBm
Transmitter RF Output Power Levels		40, 158			mW
Optimum Antenna Impedance			50		Ω
RF Connection		U.FL Connector			
Network Topologies		Point-to-Point, Point-to-Multipoint, Store and Forward			
Access Scheme		Hybrid TDMA/CSMA			
Number of Access Slots		1		8	
ADC Input Range		0		2.5	V
ADC Input Resolution				12	bits
ADC Sample Rate			100		Hz
Signal Source Impedance for ADC Reading				10	KΩ
ADC External Reference Voltage Range		1.0		2.7	V
DAC Output Range		0		3.3	V
DAC Output Resolution				12	bits
Primary and Diagnostic Serial Port Baud Rates		1.2, 2.4, 4.8, 9.6, 19.2, 14.4 28.8, 38.4, 57.6, 115.2, 230.4			kbps
Serial Peripheral Interface Data Rate		125	250	500	kbps
Digital I/O:					
Logic Low Input Level		-0.5		0.8	V
Logic High Input Level		2.45		3.3	V
Logic Input Internal Pull-up Resistor			20		KΩ
Power Supply Voltage Range	V_{CC}	+3.3		+5.5	Vdc
Power Supply Voltage Ripple				10	mV_{P-P}
Peak Transmit Mode Current, 158 mW Output				150	mA
Average Operating Receive Current:					
Base, Continuous Data Stream			25		mA
Remote, Linked, No Data			12		mA
Remote, Continuous Data Stream			25		mA
Sleep Current			3	TBD	µA
Operating Temperature Range		-40		85	°C
Operating Relative Humidity Range (non condensing)		10		90	%

Table 6.1.2

6.2 Module Pin Out

Electrical connections to the DNT90C are made through the I/O pads and through the I/O pins on the DNT90P. The hardware I/O functions are detailed in the table below:

Pin	Name	I/O	Description
1	GND	-	Power supply and signal ground. Connect to the host circuit board ground.
2	/DCD (DIAG_TX)	O (O)	This pin's default configuration is a "data carrier detect" output. On a base, this signal is asserted when any valid packet is received, and is cleared if no packets are heard for the configured router/remote registration time-out interval. On a router or remote, this signal is asserted when the radio obtains hopping pattern synchronization, and remains asserted until no beacons are heard for 50 hops. Alternate pin function is the diagnostic serial port output.
3	ACT (DIAG_RX)	O (I)	Data activity output. On a base, this signal blinks when a valid packet is received. On a remote, this signal blinks when a packet is transmitted. On a router, this signal blinks when a valid upstream packet is received or a downstream packet is transmitted. Alternate pin function is the diagnostic serial port input.
4	GPIO0	I/O	Configurable digital I/O port 0. When configured as an input, an internal pull-up resistor can be selected and direct interrupt from sleep can be invoked. When configured as an output, the power-on state is configurable. In sleep mode the pin direction, input pull-up selection or output state are also separately configurable.
5	RADIO_TXD	O	Serial data output from the radio.
6	RADIO_RXD	I	Serial data input to the radio.
7	GPOI4 (/HOST_CTS)	O (I/O)	GPIO4 with the same configuration options as GPIO2. Alternate pin function is UART/SPI flow control output. The module sets this line low when it is ready to accept data from the host on the RADIO_RXD or MOSI input. When the line goes high, the host must stop sending data.
8	GPIO5 (/HOST_RTS)	I (I/O)	GPIO5 with the same configuration options as GPIO2. Alternate pin function is UART/SPI flow control input. The host sets this line low to allow data to flow from the module on the RADIO_TXD pin. When the host sets this line high, the module will stop sending data to the host.
9	DAC0	O	12-bit DAC 0 output with an internal first-order lowpass filter with a 159 Hz 3 dB bandwidth, 10K output resistance. DAC full scale output can be referenced to the voltage at pin 25, the internal 1 V band-gap reference, or the 3.3 V regulated module bus voltage.
10	GPIO2	I/O	Configurable digital I/O port 2. Same configuration options as GPIO0 except interrupt from sleep is only tested at the sleep mode ADC sampling interval.
11	GPIO1	I/O	Configurable digital I/O port 1. Same configuration options as GPIO0.
12	DAV (GPIO3)	O I/O	When SPI slave mode operation is enabled, a logic high on this pin indicates when data is available to be clocked out by the SPI master. Alternate pin function is GPIO3 with the same configuration options as GPIO2.
13	DAC1	O	12-bit DAC 1 output. Same specifications and configuration options as DAC0.
14	VCC	I	Power supply input, +3.3 to +5.5 Vdc.
15	GND	-	Power supply and signal ground. Connect to the host circuit board ground.
16	GND	-	Power supply and signal ground. Connect to the host circuit board ground.
17	/RESET	I	Active low module hardware reset.
18	ADC0	I	12-bit ADC input 0. Full-scale reading can be referenced to Pin 25 for ratiometric measurements. For absolute measurements, the ADC can use either an internal 1 V band-gap reference, the regulated buss voltage divided by 1.6 (about 2.06 V), or an external voltage applied to Pin 25. The ADC full-scale reading is equal to 4095 - calibration offset or nominally 2.5 V when referenced to a 2.7 V input on Pin 27.
19	ADC1	I	12-bit ADC input 1. Same configuration options as ADC0.
20	MISO	I/O	This pin is the SPI master mode input or slave mode output.
21	MOSI	I/O	This pin is the SPI master mode output or slave mode input.
22	/SS	I/O	SPI active low slave select. This pin is an output when the module is operating as a master, and an input when it is operating as a slave.
23	SCLK	I/O	SPI clock signal. This pin is an output when operating as a master, and an input when operating as a slave.

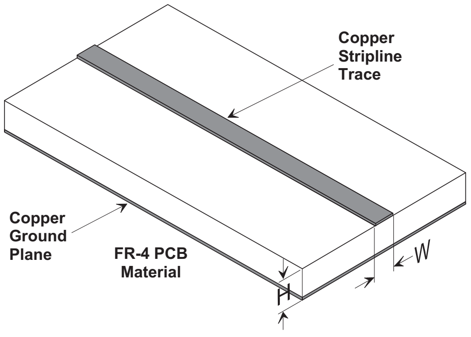
Pin	Name	I/O	Description (continued)
24	ADC2	I	12-bit ADC input 2. Same configuration options as ADC0.
25	ADC_EXT_ REF	I/O	ADC external reference voltage pin. The voltage at this pin can be used by the ADCs as a reference for ratiometric measurements. With no external voltage or load applied, this pin presents a nominal 1.65 V output through a 5 K source resistance. A low impedance external reference voltage in the range of 1.0 to 2.7 V may be applied to this pin as an option.
26	RSVD	-	Reserved pin. Leave unconnected.
27	RSVD	-	Reserved pin. Leave unconnected.
28	GND	-	Connect to the host circuit board ground plane.
29	RSVD	-	Reserved pin. Leave unconnected.
30	GND	-	Connect to the host circuit board ground plane.

Table 6.2.1

6.3 Antenna Connector

A U.FL miniature coaxial connector is provided on both DNT90 configurations for connection to the RFIO port. A short U.FL coaxial cable can be used to connect the RFIO port directly to an antenna. In this case the antenna should be mounted firmly to avoid stressing the U.FL coaxial cable due to antenna mounting flexure. Alternately, a U.FL coaxial jumper cable can be used to connect the DNT90 module to a U.FL connector on the host circuit board. The connection between the host circuit board U.FL connector and the antenna or antenna connector on the host circuit board should be implemented as a 50 ohm stripline. Referring to Figure 6.3.1, the width of this stripline depends on the thickness of the circuit board between the stripline and the groundplane. For FR-4 type circuit board materials (dielectric constant of 4.7), the width of the stripline is equal to 1.75 times the thickness of the circuit board. Note that other circuit board traces should be spaced away from the stripline to prevent signal coupling, as shown in Table 6.3.2. The stripline trace should be kept short to minimize its insertion loss.

Circuit Board Stripline Trace Detail



For 50 ohm impedance W = 1.75 * H

Figure 6.3.1

Trace Separation from	Length of Trace Run
50 ohm Microstrip	Parallel to Microstrip
100 mil	125 mill
150 mil	200 mil
200 mil	290 mil
250 mil	450 mil
300 mil	650 mil

Table 6.3.2

6.4 Power Supply and Input Voltages

DNT90 radio modules can operate from an unregulated DC input (Pad 19) in the range of 3.3 to 5.5 V with a maximum ripple of 5% over the temperature range of -40 to 85 ^{o}C. *Applying AC, reverse DC, or a DC voltage outside the range given above can cause damage and/or create a fire and safety hazard. Further, care must be taken so logic inputs applied to the radio stay within the voltage range of 0 to 3.3 V. Signals applied to the analog inputs must be in the range of 0 to ADC_EXT_REF (Pad/Pin 25). Applying a voltage to a logic or analog input outside of its operating range can damage the DNT90 module.*

6.5 ESD and Transient Protection

The DNT90C and DNT90P circuit boards are electrostatic discharge (ESD) sensitive. ESD precautions must be observed when handling and installing these components. Installations must be protected from electrical transients on the power supply and I/O lines. This is especially important in outdoor installations, and/or where connections are made to sensors with long leads. *Inadequate transient protection can result in damage and/or create a fire and safety hazard.*

6.6 Interfacing to 5 V Logic Systems

All logic signals including the serial ports on the DNT90 are 3.3 V signals. To interface to 5 V signals, the resistor divider network shown in Figure 3.7.1 below must be placed between the 5 V signal outputs and the DNT90 signal inputs. The output voltage swing of the DNT90 3.3 V signals is sufficient to drive 5 V logic inputs.

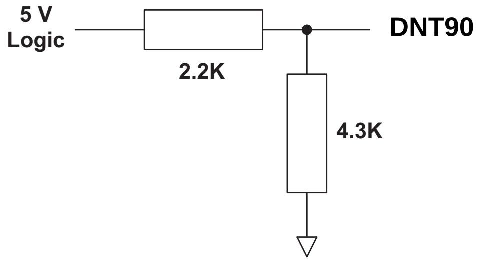


Figure 6.6.1

6.7 Mounting and Enclosures

DNT90C radio modules are mounted by reflow soldering them to a host circuit board. DNT90P modules are mounted by plugging their pins into a set of mating connectors on the host circuit board. Refer to Section 8.3 and/or the DNT90 Data Sheet for DNT90P connector details.

DNT90 enclosures must be made of plastics or other materials with low RF attenuation to avoid compromising antenna performance where antennas are internal to the enclosure. Metal enclosures are not suitable for use with internal antennas as they will block antenna radiation and reception. Outdoor enclosures must be water tight, such as a NEMA 4X enclosure.

6.8 Labeling and Notices

DNT90 FCC Certification - The DNT90 hardware has been certified for operation under FCC Part 15 Rules, Section 15.247. *The antenna(s) used for this transmitter must be installed to provide a separation distance of at least 20 cm from all persons and must not be co-located or operating in conjunction with any other antenna or transmitter.*

DNT90 FCC Notices and Labels - *This device complies with Part 15 of the FCC rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.*

A clearly visible label is required on the outside of the user's (OEM) enclosure stating the following text:

Contains FCC ID: HSW-DNT90
Contains IC: 4492A-DNT90
RFM (Insert Model Designation DNT90C or DNT90P depending on the model used)
This device complies with Part 15 of the FCC Rules. Operation is
subject to the following two conditions: (1) This device may not cause
harmful interference, and (2) this device must accept any interference
received, including interference that may cause undesired operation.

WARNING: This device operates under Part 15 of the FCC rules. Any modification to this device, not expressly authorized by RFM, Inc., may void the user's authority to operate this device.

This apparatus complies with Health Canada's Safety Code 6 / IC RSS 210.

IC RSS-210 Notice - *Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.*

ICES-003

This digital apparatus does not exceed the Class B limits for radio noise emissions from digital apparatus as set out in the radio interference regulations of Industry Canada.

Le present appareil numerique n'emet pas de bruits radioelectriques depassant les limites applicables aux appareils numeriques de Classe B prescrites dans le reglement sur le brouillage radioelectrique edicte par Industrie Canada.

7.0 DNT90 Protocol-formatted Messages

7.1 Protocol Formats

DNT90 modules can work in one of two serial data modes - transparent or protocol. Transparent mode requires no data formatting, but is limited to sending serial data to a single destination. A node that needs to send messages to more than one destination must use protocol formatting. Protocol formatting is also required for configuration commands and replies, and sensor I/O commands, replies and events. All protocol-formatted messages have a common header as shown in Figure 7.1.1:

0	1	2	3 …
SOP	Length	PktType	variable number of arguments …

Figure 7.1.1

The scale above is in bytes.

The *Start-of-Packet* (SOP) character, 0xFB, is used to mark the beginning of a protocol-formatted message and to assure synchronization in the event of a glitch on the serial port at startup.

The *Length* byte is defined as the length of the remainder of the message following the length byte itself, or the length of the entire message - 2.

The *Packet Type* (PktType) byte specifies the type of message. It is a bitfield-oriented specifier, decoded as follows:

Bits 7..5	Reserved for future use
Bit 4	Reply - this bit is set to indicate a message is a reply
Bits 3..0	Type - these bits indicate the message type

As indicated, the lower four bits (3..0) specify a message type. Bit 4 is a modifier indicating that the message is a command or a reply. A reply message has the original command type in bits 3..0, with Bit 4 set to one.

Arguments vary in size and number depending on the type of message and whether it is a message sent from the host, or is a reply or event message from the radio. See Section 7.3 below.

7.2 Message Types

Messages generated on the serial interface by the user are referred to as *host* messages. Messages generated on the serial interface by the radio are referred to as *reply* or *event* messages. Host messages carry commands. For most commands, there is a corresponds reply message. For example, when the host sends a *TxData* command message, the radio will return a *TxDataReply* message to indicate the status of the transmission - whether it succeeded or failed. To assist in interpreting the command-reply data flow, the direction is indicated by the high nibble in the message type. For example, an *EnterProtocolMode* command from the host is a message type 0x00, and the *EnterProtocolModeReply* from the radio is a message type 0x10.

Event messages from a DNT90, such as received data or status announcements make up a third category of messages. Event messages, including *RxData*, *RxEvent* and *Announce* packets are indicated by 0x20 in the high nibble of the type byte**.** If multiple arguments are to be provided, they are to be concatenated in the order shown in Section 7.3 below. Little-Endian byte order is used for all multi-byte arguments except text strings. Little-Endian byte order places the lowest order byte in the left-most byte of the argument and the highest order byte in the right-most byte of the argument.

7.3 Message Format Details

Table 7.3.1 below summarizes the DNT90 protocol-formatted messages:

Com-mand	Reply	Event	Type	Direction	Min Slot Size
0x00	-	-	*EnterProtocolMode*	from Host	N/A
-	0x10	-	*EnterProtocolModeReply*	from Radio	N/A
0x01	-	-	*ExitProtocolMode*	from Host	N/A
0x02	-	-	*DeviceReset*	from Host	N/A
-	0x12	-	*DeviceResetReply*	from Radio	N/A
0x03	-	-	*GetRegister*	from Host	N/A
-	0x13	-	*GetRegisterReply*	from Radio	N/A
0x04	-	-	*SetRegister*	from Host	N/A
-	0x14	-	*SetRegisterReply*	from Radio	N/A
0x05	-	-	*TxData*	from Host	length value -0x03
-	0x15	-	*TxDataReply*	from Radio	0x01
0x06	-	-	*GetRemoteRegister*	from Host	0x03
-	0x16	-	*GetRemoteRegisterReply*	from Radio	0x14
0x07	-	-	*SetRemoteRegister*	from Host	0x13
-	0x17	-	*SetRemoteRegisterReply*	from Radio	0x04
-	-	0x26	*RxData*	from Radio	length value -0x03
-	-	0x27	*Announce/Error*	from Radio	0x07
-	-	0x28	*RxEvent*	from Radio	0x0D

Table 7.3.1

EnterProtocolMode command and reply format details are presented in Tables 7.3.2 and 7.3.3:

Enter Protocol Mode Command		
Byte Offset	**Field**	**Description**
0x00	Start-of-Packet	0xFB = Indicates start of protocol formatted message
0x01	Length	0x07 = Number of bytes in message following this byte
0x02	Packet Type	0x00 = EnterProtocolMode
0x03 - 0x08	Payload	String = “DNTCFG”

Table 7.3.2

Enter Protocol Mode Reply		
Byte Offset	**Field**	**Description**
0x00	Start-of-Packet	0xFB = Indicates start of protocol formatted message
0x01	Length	0x01 = Number of bytes in message following this byte
0x02	Packet Type	0x10 = EnterProtocolModeReply

Table 7.3.3

ExitProtocolMode command format details are shown in Table 7.3.4:

Exit Protocol Mode Command		
Byte Offset	**Field**	**Description**
0x00	Start-of-Packet	0xFB = Indicates start of protocol formatted message
0x01	Length	0x01 = Number of bytes in message following this byte
0x02	Packet Type	0x01 = ExitProtocolMode

Table 7.3.4

DeviceReset command and reply format details are shown in Tables 7.3.5 and 7.3.6:

Device Reset Command		
Byte Offset	**Field**	**Description**
0x00	Start-of-Packet	0xFB = Indicates start of protocol formatted message
0x01	Length	0x02 = Number of bytes in message following this byte
0x02	Packet Type	0x02 = DeviceReset
0x03	Reset Type	0x00 = Normal Device Reset 0x01 = Reset to Serial Bootloader 0x02 = Reset to Over-the-Air Bootloader

Table 7.3.5

Device Reset Reply		
Byte Offset	**Field**	**Description**
0x00	Start-Of-Packet	0xFB = Indicates start of protocol formatted message
0x01	Length	0x01 = Number of bytes in message following this byte
0x02	Packet Type	0x12 = DeviceResetReply

Table 7.3.6

GetRegister command and reply format details are shown in Tables 7.3.7 and 7.3.8:

Get Register Command		
Byte Offset	**Field**	**Description**
0x00	Start-of-Packet	0xFB = Indicates start of protocol formatted message
0x01	Length	0x04 = Number of bytes in message following this byte
0x02	Packet Type	0x03 = GetRegister
0x03	Register Offset	Register offset in its bank
0x04	Register Bank	Register bank number
0x05	Register Size	Register size in bytes

Table 7.3.7

Get Register Reply		
Byte Offset	**Field**	**Description**
0x00	Start-of-Packet	0xFB = Indicates start of protocol formatted message
0x01	Length	0x05 to 0x20 = Number of bytes in message following this byte
0x02	Packet Type	0x03 = Get register reply
0x03	Register Offset	Register offset in its bank
0x04	Register Bank	Register bank number
0x05	Register Size	Register size in bytes
0x0 6 - 0x15	Register Value	Register value, all bytes in the register

Note: an Error message will be returned instead of a Get Register Reply in case of a format error.

Table 7.3.8

SetRegister command and reply format details are shown in Tables 7.3.9 and 7.3.10:

Set Register Command		
Byte Offset	**Field**	**Description**
0x00	Start-of-Packet	0xFB = Indicates start of protocol formatted message
0x01	Length	0x05 to 0x20 = Number of bytes in message following this byte
0x02	Packet Type	0x04 = Set register command
0x03	Register Offset	Register offset in its bank
0x04	Register Bank	Register bank number
0x05	Register Size	Register size in bytes
0x06 - 0x15	Register Value	Register value, all bytes in the register

Table 7.3.9

Set Register Reply		
Byte Offset	**Field**	**Description**
0x00	Start-of-Packet	0xFB = Indicates start of protocol formatted message
0x01	Length	0x01 = Number of bytes in message following this byte
0x02	Packet Type	0x14 = Set register reply

Note: an Error message will be returned instead of a Set Register Reply in case of a format error.

Table 7.3.10

TXData command and reply format details are shown in Tables 7.3.11 and 7.3.12:

TX Data Command		
Byte Offset	**Field**	**Description**
0x00	Start-of-Packet	0xFB = Indicates start of protocol formatted message
0x01	Length	0x07 = Number of bytes in message following this byte
0x02	Packet Type	0x05 = TX data command
0x03 - 0x05	Destination MAC Address	Destination MAC address, in Little Endian byte order
0x06 - 0x72	Tx Data	Up to 109 bytes of data to Base, or 105 bytes from Base

Table 7.3.11

TX Data Reply		
Byte Offset	**Field**	**Description**
0x00	Start-of-Packet	0xFB = Indicates start of protocol formatted message
0x01	Length	0x07 = Number of bytes in message following this byte
0x02	Packet Type	0x15 = TxDataReply
0x03 - 0x05	Destination MAC Address	Destination MAC address, in Little Endian byte order
0x06	Status	0x00 = ACK received from destination 0x01 = no ACK received from destination (NAK) 0x02 = “Device Not Linked” error
0x07	RSSI	Packet RX power in dBm (-128 to 127) or 0x7F if invalid

Table 7.3.12

GetRemoteRegister command and reply details are shown it Tables 7.3.13 and 7.3.14:

Get Remote Register Command		
Byte Offset	**Field**	**Description**
0x00	Start-of-Packet	0xFB = Indicates start of protocol formatted message
0x01	Length	0x07 = Number of bytes in message following this byte
0x02	Packet Type	0x06 = Get Remote Register Command
0x03 - 0x05	Destination MAC Address	Destination MAC address, in Little Endian byte order
0x06	Register Offset	Register offset in its bank
0x07	Register Bank	Register bank number
0x08	Register Size	Register size in bytes

Table 7.3.13

Get Remote Register Reply		
Byte Offset	**Field**	**Description**
0x00	Start-of-Packet	0xFB = Indicates start of protocol formatted message
0x01	Length	0x0A to 0x25 = Number of bytes in message following this byte
0x02	Packet Type	0x16 = Get Remote Register Reply
0x03	Status	Error status (0x00 = No Error, 0xE1 = Invalid Argument)
0x04 - 0x06	Originator MAC Address	Originator’s MAC address, in Little Endian byte order
0x07	RSSI	Packet RX power in dBm (-128 to 127)
0x08	Register Offset*	Register offset in its bank
0x09	Register Bank*	Register bank number
0x0A	Register Size*	Register size in bytes
0x0B - 0x1A	Register Value*	Register value, all bytes in the register

*Bytes eight through the end of the message will not be returned in case of an error

Table 7.3.14

SetRemoteRegister command and reply format details are shown in Tables 7.3.15 and 7.3.16:

Set Remote Register Command		
Byte Offset	**Field**	**Description**
0x00	Start-of-Packet	0xFB = Indicates start of protocol formatted message
0x01	Length	Number of bytes in message following this byte
0x02	Packet Type	0x07 = Set remote register command
0x03 - 0x05	Destination MAC Address	Destination MAC address, in Little Endian byte order
0x06	Register Offset	Register offset in its bank
0x07	Register Bank	Register bank number
0x08	Register Size	Register size in bytes
0x09 - 0x18	Register Value	Register contents

Table 7.3.15

Set Remote Register Reply		
Byte Offset	**Field**	**Description**
0x00	Start-of-Packet	0xFB = Indicates start of protocol formatted message
0x01	Length	0x06 = Number of bytes in message following this byte
0x02	Packet Type	0x17 = Set remote register reply
0x03	Status	Error status: 0x00 = no error, 0xE1 = invalid argument
0x04 - 0x06	Originator MAC Address	Originator's MAC address, in Little Endian byte order
0x07	RSSI	Packet RX power in dBm, -128 to 127

Table 7.3.16

RxData event packet format details are shown in Figure Table 7.3.17:

RX Data Packet		
Byte Offset	**Field**	**Description**
0x00	Start-of-Packet	0xFB = Indicates start of protocol formatted message
0x01	Length	0x00 to 0x6D = Number of bytes in message following this byte
0x02	Packet Type	0x26 = RxData event message
0x03 - 0x05	Originator MAC Address	Originator's MAC address, in Little Endian byte order
0x06	RSSI	Packet RX power in dBm (-128 to 127)
0x07 - 0x73	Rx Data	Up to 105 bytes of data from Base, up to 109 bytes from Router or Remote

Table 7.3.17

Announce/Error message format details are shown in Tables 7.3.18 through 7.3.21:

Startup Announcement or Error Code		
Byte Offset	**Field**	**Description**
0x00	Start-of-Packet	0xFB = Indicates start of protocol formatted message
0x01	Length	0x02 = Number of bytes in message following this byte
0x02	Packet Type	0x27 = Indicates this is an Announce/Error message
0x03	Announce Status	0xA0 = Startup initialization complete 0xE1 = Invalid argument 0xE4 = Register read only error 0xEC = Brownout reset 0xED = Watchdog reset 0xEE = Hardware Error (Crystal or Radio Error)

Table 7.3.18

Join Announcement		
Byte Offset	**Field**	**Description**
0x00	Start-of-Packet	0xFB = Indicates start of protocol formatted message
0x01	Length	0x06 = Number of bytes in message following this byte
0x02	Packet Type	0x27 = Indicates this is an Announce/Error message
0x03	Announce Status	0xA3 = Joined network
0x04	Network ID	ID of network that was joined
0x05 - 0x07	Parent MAC Address	MAC address of parent, in Little Endian byte order

Table 7.3.19

Exit Announcement		
Byte Offset	**Field**	**Description**
0x00	Start-of-Packet	0xFB = Indicates start of protocol formatted message
0x01	Length	0x03 = Number of bytes in message following this byte
0x02	Packet Type	0x27 = Indicates this is an Announce/Error message
0x03	Announce Status	0xA4 = Exited network
0x04	Network ID	ID of network that was exited

Table 7.3.20

Heartbeat Announcement		
Byte Offset	**Field**	**Description**
0x00	Start-of-Packet	0xFB = Indicates start of protocol formatted message
0x01	Length	0x0C = number of bytes in message following this byte
0x02	Packet Type	0x27 = Indicates this is an Announce/Error message
0x03	Announce Status	0xA8 = Heartbeat message
0x04 - 0x06	Device MAC Address	MAC address of originator, in Little Endian byte order
0x07 - 0x09	Parent MAC Address	MAC address of parent, in Little Endian byte order
0x0A	Parent Network ID	Network ID of device’s parent
0x0B	Base Mode Network ID	Network ID if device is a router, otherwise 0xFF
0x0C	Beacon RX Power	Average beacon RX power in dBm, uses 0.0625 “alpha” filter
0x0D	Parent RX Power	RX power of packet as received by device’s parent in dBm

Table 7.3.21

RxEvent message format details are shown in Table 7.3.22:

RX Event Packet		
Byte Offset	**Field**	**Description**
0x00	Start-of-Packet	0xFB = Indicates start of protocol formatted message
0x01	Length	0x12 = number of bytes in message following this byte
0x02	Packet Type	0x28 = RxEvent
0x03 - 0x05	Originator MAC Address	Originator's MAC address, in Little Endian byte order
0x06	RSSI	Packet RX power in dBm (-128 to 127)
0x07	GPIO Readings	Bit Field (GPIO0..GPIO5) indicating GPIO readings
0x08 - 0x09	ADC0 Reading	ADC0 Reading, 0x0000 - 0x0FFF, in Little Endian byte order
0x0A - 0x0B	ADC1 Reading	ADC1 Reading, 0x0000 - 0x0FFF, in Little Endian byte order
0x0C - 0x0D	ADC2 Reading	ADC2 Reading, 0x0000 - 0x0FFF, in Little Endian byte order
0x0E - 0x0F	Event Flags	Bit Field Indicating which events have occurred: Bit 0: GPIO0 Triggered Bit 1: GPIO1 Triggered Bit 2: GPIO2 Triggered Bit 3: GPIO3 Triggered Bit 4: Periodic Report Interval Bit 5: ADC0 Threshold Triggered Bit 6: ADC1 Threshold Triggered Bit 7: ADC2 Threshold Triggered Bits 8-15: Unused (0)
0x10-0x00	DAC0 Setting	DAC0 setting, 0x0000 - 0x0FFF, in Little Endian byte order
0x12 - 0x13	DAC1 Setting	DAC1 setting, 0x0000 - 0x0FFF, in Little Endian byte order

Table 7.3.22

7.4 Configuration Parameter Registers

The configuration parameters in a DNT90 module are stored in a set of variable length *registers*. Most registers are read-write, with a few read-only or write-only. Changes made to the register settings are temporary until a *MemorySave* command is executed. Resetting or power-cycling the module will clear any changes that have not been saved to permanent memory using the *MemorySave* command. DNT90 modules can be configured to start in protocol mode at power-up, in which case the *EnterProtocolMode* command is not required.

7.4.1 Bank 0 - Transceiver Setup

Bank	Location	Name	R/W	Size	Range	Default
0x00	0x00	DeviceMode	*R/W*	0x01	0..2	0
0x00	0x01	HopDuration	*R/W*	0x01	16..200	40 (20 ms)
0x00	0x02	ParentNwkID	*R/W*	0x01	0..63, 255	0xFF
0x00	0x03	SecurityKey	*R/W*	0x10	0..2^128-1	0
0x00	0x13	SleepModeEn	*R/W*	0x01	0..1	0
0x00	0x14	WakeResponseTime	*R/W*	0x02	0..30000	500 (500 ms)
0x00	0x15	WakeLinkTimeout	*R/W*	0x02	0..30000	5000 (5 s)
0x00	0x16	TxPower	*R/W*	0x01	0..1	0
0x00	0x17	UserTag	*R/W*	0x10		“DNT90”
0x00	0x27	RmtTransDestAddr	*R/W*	0x03		0x000000 (Base)
0x00	0x2A	Store&ForwardEn	*R/W*	0x01	0..1	0 (Off)
0x00	0x2B	BaseModeNetID	*R/W*	0x01	1..63255	0xFF
0x00	0x2C	HeartbeatIntrvl	*R/W*	0x02	0..65535	20 (seconds)
0x00	0x2E	SystemID	*R/W*	0x01	0..255	0
0x00	0x2F	AckEnable	*R/W*	0x01	0..1	0
0x00	0x32	AltParentNwkID	*R/W*	0x01	0..63, 255	0xFF (disabled)

Table 7.4.1.1

DeviceMode - this parameter selects the operating mode for the radio:

0x00 = remote (default)
0x01 = base
0x02 = router (store and forward system)

Note that changing this setting does not take effect immediately. It must be followed by a *MemorySave* command and then a hardware reset.

HopDuration - this parameter sets the duration of the hop frame. The duration is set as an 8-bit value, 0.5 ms/count. The valid hop duration range is from 8 to 100 ms. Changing the hop duration must be followed by a *MemorySave* command to allow the change to persist through a reset or power cycle. A *HopDuration* change takes effect immediately. Remotes will re-link following a *HopDuration* parameter change.

ParentNwkID - this parameter specifies the parent (*BaseModeNetID)* that a child radio is allowed to join. The valid range of this parameter is 0x00 to 0x3F, plus 0xFF. Setting the *ParentNwkID* to 0xFF to allow connection to any parent. This parameter is applicable only to remotes and routers. Also see the discussion of *AltParentNwkID* below.

Security Key - this 16-byte parameter sets the 128-bit AES encryption key. To protect the key, it is a write-only parameter for the user. It always reads back as 0x2A.

SleepModeEn - this parameter enables/disables sleep mode. Sleep mode is used in conjunction with the automatic I/O reporting feature to wake up a remote on specific triggers. Sleep mode can only be used with remotes.

WakeResponseTime - this parameter set how long sleep is deferred in a DNT90 remote configured for sleep mode after:

link acquisition
receiving an ACK from the device's parent
receiving a packet that requires processing by the device
after receiving a protocol packet from the device's local host.

WakeLinkTimeout - this parameter sets the maximum length of time that a remote in sleep mode will spend trying to acquire a link to its parent before going back to sleep, from a minimum of 1 ms to 30 s in 1 ms steps. If this value is set to 0, the remote will stay awake and continue trying to link to its base indefinitely.

TxPower - this parameter sets the transmit power level:

0x00 = +16 dBm or 40 mW
0x01 = +22 dBm or 158 mW

UserTag - this parameter is a user definable field intended for use as a location description or other identifying tag such as a "friendly name".

RmtTransDestAddr - this parameter holds the default destination for transparent mode data packets and event packets. This parameter defaults to the base station's address (0x000000) except on a base station, where at startup it will be changed to the broadcast address (0xFFFFFF) if the firmware detects that it is set to 0x000000.

Store&ForwardEn - setting this parameter to 0x01 enables store-and-forward system operation. Store-and-forward operation is disabled by default.

BaseModeNetID - applicable to the base and routers only, this parameter specifies the network ID of a device's own network when acting as parent. A child is allowed to join a network when its *ParentNwkID* parameter matches a parent's *BaseModeNetID*. The valid range of this parameter is 0x00 to 0x3F. A value greater than 0x3F is invalid and will be forced to 0x00 on a base. A router with an invalid *BaseModeNetID* will be forced to operate as a remote.

HeartbeatInterval - When set to 0, all heartbeats are disabled, including the initial heartbeat issued after link acquisition. When set to 0xFFFF, periodic heartbeats are disabled but the initial linkup heartbeat is enabled. If sleep mode is enabled, heartbeats will be generated only if either periodic or ADC sample wakeups are scheduled, since heartbeats can be generated only on wakeup events. Also, the DNT90's real time clock is disabled if neither periodic nor ADC wakeups are scheduled, and heartbeat intervals therefore cannot be tracked. The heartbeat interval is scaled 1 second/count.

SystemID - this parameter holds the ID for a DTN90 system. DNT90 systems that may physically overlap must have different system IDs.

AckEnable - when this parameter is set to 1, the originator will indicate in its transmitted packet that an ACK is expected from the packet's remote destination. Setting this parameter to 0x00 (default) reduces network congestion, but no *TXDataReply* will be sent from the destination to confirm reception.

AltParentNwkID - this parameter specifies an alternate parent (*BaseModeNetID)* that a child radio is allowed to join. This parameter is used to provide more robust message routing when setting the *ParentNwkID* to its 0xFF wildcard value is not appropriate. The valid range of this parameter is 0x00 to 0x3F, plus 0xFF. Rather than specifying wildcard operation, setting the *AltParentNwkID* to 0xFF disables the selection of an alternate parent. This parameter is applicable only to remotes and routers.

7.4.2 Bank 1 - System Settings

Bank 1 holds configuration parameters to be input to the base only. The base passes these parameters to the routers and remotes as needed. The exception is InitFrequencyBand …

Bank	Location	Name	R/W	Size	Range	Default
0x01	0x00	InitFrequencyBand	*R/W*	0x01	0..2, 255	0 (US)
0x01	0x01	NumSlots	*R/W*	0x01	1..8	3
0x01	0x02	BaseSlotSize	*R/W*	0x01	6..105	50
0x01	0x03	SlotLease	*R/W*	0x01	1..255	4 (hops)
0x01	0x04	ArqMode	*R/W*	0x01	0..1	1 (Repeat Broadcasts)
0x01	0x05	ArqAttemptLimit	*R/W*	0x01	1..63	4
0x01	0x06	LinkDropThreshold	*R/W*	0x01	1..255	10 (hops)
0x01	0x07	P2PReplyTimeout	*R/W*	0x01	0..255	100 (hops)
0x01	0x08	RegistryTimeout	*R/W*	0x01	0..255	50 (hops)

Table 7.4.2.1

InitFrequencyBand - this parameter sets the range of frequencies and channel spacing over which the DNT90 system will operate. Three bands are available:

0x00	Band 0: 902.76 to 927.24 MHz, 52 channels, 480 kHz spacing
0x01	Band 1: 902.76 to 926.76 MHz, 26 channels, 960 kHz spacing
0x02	Band 2: 915.72 to 927.74 MHz, 25 channels, 480 kHz spacing

Bands 0, 1 and 2 can be used in North and South America (902 to 928 MHz band), with Band 2 usable in Australia, New Zealand and certain other international locations (915 to 928 MHz band).

NumSlots - this parameter sets the number of slots for child router/remote transmissions on each hop.

BaseSlotSize - this parameter set the maximum number of payload bytes that the base can send on a single hop. The default value is 40 bytes.

SlotLease - this parameter set the number of hops a parent radio will reserve a slot for a child after receiving a message from that child. Small values such as 0x02 are suited to short data bursts, and larger values are generally a better choice when devices send a stream of data across consecutive hops. The minimum value is 1, assuring that a child can receive an ACK on the next hop after it transmits.

BroadcastMode - setting this parameter to 0x01 enables broadcast automatic repeat mode.

ArqAttemptLimit - this sets the maximum number of attempts that will be made to send a message on the RF link. Setting this parameter to the maximum value of 63 is a flag value indicating that there should be no limit to the number of attempts to send each packet (infinite number of attempts). This mode is intended for point-to-point networks in serial data cable replacement applications where absolutely no packets can be lost. Note - if this mode is used in a multipoint network, one remote that has lost link will shut down the entire network if the base is trying to send it data.

LinkDropThreshold - this is the number of consecutive beacons missed by a remote that causes the remote to restart a link acquisition search. Please contact RFM technical support before making changes to the parameter.

P2PReplyTimeout - this parameter sets the reply timeout for peer-to-peer packets sent from one node to another. Because each leg of the journey from one node to another and back may take multiple transmit attempts, the length of time to confirm receipt and issue a *TxDataReply* is subject to more variation than a transmission directly between a base and a remote. The *P2PReplyTimeout* parameter specifies the maximum number of hops or hop pairs that a remote will wait for a reply from its recipient. If a reply returns sooner than the timeout, the remote will send a *TxDataReply* indicating success (ACK) to its host as soon as it is received, and cancels the timeout. If a reply does not come back before the timeout expires, the remote will send a *TxDataReply* to its host indicating failure (NAK). If a reply should come back after the timeout expires the remote will ignore it, as a *TxDataReply* has already been sent. The units of this parameter are in hops for point-to-point and point-to-multipoint operation and in hop pairs for store-and-forward operation.

RegistryTimeout - this parameter sets the number of hops without contact from a child device for which a parent device will preserve the Transaction ID (TID) history for that child. After this timeout, the TID history is reset.

7.4.3 Bank 2 - Status Parameters

Bank	Location	Name	R/W	Size	Range	Default
0x02	0x00	MacAddress	*R*	0x03	0..0xFFFFFF	Fixed value
0x02	0x03	CurrNwkID	*R*	0x01	0..63, 255	As set
0x02	0x04	CurrFreqBand	*R*	0x01	0..2, 255	As set
0x02	0x05	LinkStatus	*R*	0x01	0..5	Current status
0x02	0x06	RemoteSlotSize	*R*	0x01	0..109	As set
0x02	0x07	SlotNumber	*R*	0x01	0..7	As set
0x02	0x08	HardwareVersion	*R*	0x01	0x41..0x5A	0x41 = Rev “A”
0x02	0x09	FirmwareVersion	*R*	0x01	0x00..0xFF	Current FW load
0x02	0x0A	FirmwareBuildNum	*R*	0x02	0..65535	Current FW load
0x02	0x0C	FirmwareBuildDate	*R*	0x03	BCD (“YYMMDD”)	Current FW load
0x02	0x0F	FirmwareBuildTime	*R*	0x03	BCD (“HHMMSS”)	Current FW load
0x02	0x12	RssiIdle	*R*	0x01	-128..127	As set
0x02	0x13	RssiLast	*R*	0x01	-128..127	As set
0x02	0x14	AvgBeaconPower	*R*	0x01	-128..127	As set
0x02	0x15	ParentMacAddress	*R*	0x03	0..0xFFFFFF	As set

Table 7.4.3.1

MacAddress - this parameter holds the radio's unique 24-bit MAC address.

CurrNwkID - this parameter holds the ID of the network the radio is currently assigned to or connected to. A value of 0xFF means the radio is scanning for a network but has not yet joined one.

CurrFreqBand - this parameter holds the frequency band of the network that the radio is currently assigned to or connected to. A value of 0xFF means the radio is scanning for a network at power up but has not yet joined one.

LinkStatus - this parameter holds the link status of a router or remote:

0x00	=	idle
0x01	=	lost link
0x02	=	acquiring link
0x03	=	collecting parameters from the base
0x04	=	registering
0x05	=	registered

RemoteSlotSize - this parameter holds the current remote slot size, defined as the maximum number of message bytes a remote can send on a single hop.

SlotNumber - this parameter holds the current slot number assigned to a router or remote.

HarwareVersion - this parameter holds an identifier indicating the hardware revision (ASCII character). A value of 0x43 is defined for the DNT90 Rev C hardware.

FirmwareVersion - this parameter holds the firmware version of the radio in 2-digit BCD format.

FirmwareBuildNum - this parameter holds the firmware build number, in binary format.

FirmwareBuildDate - this parameter holds the date of firmware build in MM/DD/YY format.

FirmwareBuildTime - this parameter holds the time of the firmware build in HH:MM:SS format.

RssiIdle - this parameter holds the last RSSI measurement made during a time when the RF channel was idle. This parameter is useful for detecting interferers.

RssiLast - this parameter holds the last RSSI measurement made during the receipt of an RF packet with a valid CRC. This parameter is useful for network commissioning and diagnostic purposes.

AvgBeaconPower - Alpha-filtered beacon power received from a device’s parent where alpha = 0.0625.

ParentMacAddress - this parameter holds the MAC address of a DNT90’s parent.

7.4.4 Bank 3 - Serial and SPI Settings

Bank	Location	Name	R/W	Size	Range	Default
0x03	0x00	SerialRate	*R/W*	0x01	0..10	3 (9600 baud)
0x03	0x01	SerialParams	*R/W*	0x01	0..7	0 (8-N-1)
0x03	0x02	SpiMode	*R/W*	0x01	0..2	0 (SPI Disabled)
0x03	0x03	SpiRateSel	*R/W*	0x01	0..2	0 (125 kHz)
0x03	0x04	SpiOptions	*R/W*	0x01	0..7	0
0x03	0x05	SpiMasterCmdLen	*R/W*	0x01	0..16	0
0x03	0x06	SpiMasterCmdStr	*R/W*	0x10	ASCII	All 0x00 bytes

Table 7.4.4.1

SerialRate - this parameter sets the serial data rate as shown below:

Setting	***Serial rate***
0x00	1.2 kbps
0x01	2.4 kbps
0x02	4.8 kbps
0x03	9.6 kbps
0x04	14.4 kbps
0x05	19.2 kbps
0x06	28.8 kbps
0x07	38.4 kbps
0x08	57.6 kbps
0x09	115.2 kbps
0x0A	230.4 kbps

SerialParams - this parameter sets the serial mode options for parity and stop bits:

Setting	***Mode***
0x00	No parity, 8 data bits, 1 stop bit (default)
0x01	No parity, 8 data bits, 2 stop bits
0x02	Reserved
0x03	Reserved
0x04	Even parity, 8 data bits, 1 stop bit
0x05	Even parity, 8 data bits, 2 stop bits
0x06	Odd parity, 8 data bits, 1 stop bit
0x07	Odd parity, 8 data bits, 2 stop bits

Note that 8-bit data with no parity is capable of carrying 7-bit data with parity for compatibility without loss of generality for legacy applications that may require it.

SpiMode - this parameter sets the SPI operating mode:

Setting	***Mode***
0x00	SPI disabled - serial UART mode (default)
0x01	SPI Slave mode
0x02	SPI Master mode

SpiRateSel - this parameter sets the SPI master mode clock rate:

Setting	***Mode***
0x00	125 kbps
0x01	250 kbps
0x02	500 kbps

SpiOptions - this parameter allows the SPI to be configured with the following options:

Setting	***Option***
0x00	Leading edge rising, sample leading edge, MSBs sent first
0x01	Leading edge rising, sample falling edge, MSBs sent first
0x02	Leading edge falling, sample leading edge, MSBs sent first
0x03	Leading edge falling, sample falling edge, MSBs sent first
0x04	Leading edge rising, sample leading edge, LSBs sent first
0x05	Leading edge rising, sample falling edge, LSBs sent first
0x06	Leading edge falling, sample leading edge, LSBs sent first
0x07	Leading edge falling, sample falling edge, LSBs sent first

SpiMasterCmdLen - this parameter sets the length for the SPI master command string that will be used to interrogate the slave peripheral, when SPI master mode is selected with periodic I/O reporting enabled.

SpiMasterCmdStr - this parameter holds the SPI master command string that is used to interrogate the slave peripheral when SPI master mode is selected and periodic I/O reporting is enabled.

7.4.5 Bank 4 - Host Protocol Settings

Bank	Location	Name	R/W	Size	Range	Default
0x04	0x00	ProtocolMode	*R/W*	0x01	0..1	0 (Transparent)
0x04	0x01	TxTimeout	*R/W*	0x01	0..255	0 (No timeout)
0x04	0x02	MinPacketLength	*R/W*	0x01	0..255	1 (byte)
0x04	0x03	TransPtToPtMode	*R/W*	0x01	0..1	0 (Multipoint)
0x04	0x04	MsgPerHop	*R/W*	0x01	1..8	8

Table 7.4.5.1

ProtocolMode - this parameter selects the host protocol mode. The default is 0x00, which is transparent mode, meaning the radio conveys whatever characters that are sent to it *transparently*, without requiring the host to understand or conform to the DNT90's built-in protocol. This setting is recommended for point-to-point applications for legacy applications such as wire replacements where another serial protocol may already exist. Setting this parameter to 0x01 enables the DNT90 protocol formatting. It is not necessary to define the same protocol mode for all radios in a network. For example, it is frequently useful to configure all the remotes for transparent mode and the base for protocol mode. Note that it is possible for the host to switch the radio from transparent mode to protocol mode and back as required by transmitting an *EnterProtocolMode* command.

TxTimeout - this parameter is the transmit timeout used for determining message boundaries in transparent data mode. Parameter units are in milliseconds. A message boundary is determined whenever a gap between consecutive characters is equal to or greater than the *TxTimeout* value, or the number of bytes reaches the *MinPacketLength*. Either condition will trigger a transmission. The default *TxTimeout* value is 0 ms.

MinPacketLength - sets the minimum message length used for determining packet boundaries in transparent data mode. The default is one byte. A transmission is triggered when either the number of bytes reaches *MinPacketLength* or a gap is detected between consecutive characters greater than *TxTimeout*.

TransPtToPtMode - when this parameter is set to 0x00, the destination address of transparent mode packets will be the configured *RemoteDestAddr*. When set to 0x01, the destination address of transparent mode packets will be the originator of the most recent RX packet processed.

MaxDataPackets - this parameter sets the maximum number of messages a DNT90 can send in each hop frame. The parameter range is 1 to 8 messages.

7.4.6 Bank 5 - I/O Parameters

Bank	Location	Name	R/W	Size	Range In Bits	Default
0x05	0x00	All-IO	*R/W*	0x0D	104	N/A
0x05	0x0D	Gpio0	*R/W*	0x01	1	0
0x05	0x0E	Gpio1	*R/W*	0x01	1	0
0x05	0x0F	Gpio2	*R/W*	0x01	1	0
0x05	0x10	Gpio3	*R/W*	0x01	1	0
0x05	0x11	Gpio4	*R/W*	0x01	1	0
0x05	0x12	Gpio5	*R/W*	0x01	1	0
0x05	0x13	Adc0	*R*	0x02	12	N/A
0x05	0x15	Adc1	*R*	0x02	12	N/A
0x05	0x17	Adc2	*R*	0x02	12	N/A
0x05	0x19	EventFlags	*R*	0x02	16	N/A
0x05	0x1B	Dac0	*R/W*	0x02	12	0
0x05	0x1D	Dac1	*R/W*	0x02	12	0

Table 7.4.6.1

All-IO - this 13-byte parameter packs all the following parameters into a single value. Note that the information in parameters GPIO0 through GPIO5 are compressed into a single byte to save space in the All-IO parameter.

Gpio0 through Gpio5 - if a pin is configured as an output, writing to its corresponding parameter to sets the pin's logic state. If a pin is configured as an input, writing to its corresponding parameter enables or disables the pin's internal pull-up. Reading these registers returns the current level detected on the corresponding pins.

Adc0 through Adc2 - read-only parameters that return the current 12-bit reading for the selected ADC channel (Little-Endian byte order). See the discussion of the *AdcSampleIntvl* parameter below.

EventFlags - used with the automatic I/O reporting feature, this read-only parameter indicates which I/O events have been triggered since the last report:

bits 15..8	Reserved
bit 7	ADC2 high/low threshold excursion
bit 6	ADC1 high/low threshold excursion
bit 5	ADC0 high/low threshold excursion
bit 4	Periodic timer report
bit 2	GPIO2 edge transition
bit 1	GPIO1 edge transition
bit 0	GPIO0 edge transition

Dac0 through Dac1 - sets the DAC outputs. The DAC output voltages are filtered through an integrated low-pass filter to provides an effective DAC resolution of 12 bits. The range of this parameter is 0x0000 to 0x0FFF.

7.4.7 Bank 6 - I/O Settings

Bank	Location	Name	R/W	Size	Range In Bits	Default
0x06	0x00	GpioDir	*R/W*	0x01	6	0x00 (All inputs)
0x06	0x01	GpioInit	*R/W*	0x01	6	0x00 (All zero)
0x06	0x02	GpioAlt	*R/W*	0x01	6	0xC0 (RTS,CTS)
0x06	0x03	GpioEdgeTrigger	*R/W*	0x01	8	0x00
0x06	0x04	GpioSleepMode	*R/W*	0x01	6	0x00 (Off)
0x06	0x05	GpioSleepDir	*R/W*	0x01	6	0x00 (All inputs)
0x06	0x06	GpioSleepState	*R/W*	0x01	6	0x00 (All zero)
0x06	0x07	Dac0Init	*R/W*	0x02	12	0x0000
0x06	0x09	Dac1Init	*R/W*	0x02	12	0x0000
0x06	0x0B	AdcSampleIntvl	*R/W*	0x04	32	10 (ms)
0x06	0x0F	Adc0ThresholdLo	*R/W*	0x02	12	0x0000
0x06	0x11	Adc0ThresholdHi	*R/W*	0x02	12	0x0FFF
0x06	0x13	Adc1ThresholdLo	*R/W*	0x02	12	0x0000
0x06	0x15	Adc1ThresholdHi	*R/W*	0x02	12	0x0FFF
0x06	0x17	Adc2ThresholdLo	*R/W*	0x02	12	0x0000
0x06	0x19	Adc2ThresholdHi	*R/W*	0x02	12	0x0FFF
0x06	0x1B	IoReportTrigger	*R/W*	0x01	8	0x01 (GPIO0)
0x06	0x1C	IoReportInterval	*R/W*	0x04	32	30000 (ms)
0x06	0x20	IoPreDelay	*R/W*	0x01	8	0
0x06	0x21	Reserved	*R/W*	0x01	8	TBD
0x06	0x22	IoBindingEnable	*R/W*	0x01	1	0 (Disabled)
0x06	0x23	DacReference	*R/W*	0x01	2	0 (ADD_Ref_Ext)
0x06	0x24	AdcReference	*R/W*	0x01	2	0 (ADD_Ref_Ext)

Table 7.4.7.1

GpioDir - this parameter is a bitmask that sets whether each GPIO is an input (0) or outputs (1). The default is all inputs.

GpioInit - this parameter is a bitmask that sets the initial value for any GPIOs which are enabled as outputs. For GPIOs enabled as inputs, this sets the initial pull-up setting.

GpioAlt - Specifies which GPIO pins will have their alternate functions enabled: Bit 2 - diversity toggle enable, Bit 3 - RS485 enable, Bit 4 - CTS enable, Bit5 - RTS enable.

Bit	Alternate Function	Default
0	(none)	0
1	(none)	0
2	Diversity Toggle	0
3	RS485 (N/A in SPI Slave mode)	0
4	CTS (N/A in SPI Slave mode)	1
5	RTS (N/A in SPI Slave mode)	1

Table 7.4.7.2

GpioEdgeTrigger - when GPIO triggers are enabled for I/O event reporting, this parameter controls the trigger behavior:

bits 7..6	GPIO3 edge function
bits 5..4	GPIO2 edge function
bits 3..2	GPIO1 edge function
bits 1..0	GPIO0 edge function

The bit values for each GPIO map to the following settings:

Value	GPIO edge behavior
11	Rising edge trigger, neither level keeps remote awake
10	Bidirectional edge trigger, neither level keeps remote awake
01	Rising edge trigger, holding high keeps remote awake
00	Falling edge trigger, holding low keeps remote awake

Table 7.4.7.3

GpioSleepMode - when set to 0x01, this parameter enables setting of GPIOs to the designated direction and state whenever a device is asleep.

GpioSleepDir - when *GpioSleepMode* is enabled, this parameter functions to set the direction of the GPIOs during a device's sleep period. This enables the user to provide alternate configurations during sleep that will help minimize current consumption. Bits 0..5 correspond to GPIO0..GPIO5. Setting a *GpioSleepDir* bit to 1 to specifies an output; 0 specifies an input.

GpioSleepState - when *GpioSleepMode* is enabled, this parameter functions as a bitmask to control the states of the GPIOs, the RADIO_TXD output, and the /HOST_CTS and /DCD outputs during a device's sleep period. This allows the user to set alternate configurations during sleep to minimize current consumption. Bits 0..5 correspond to GPIO0..GPIO5 respectively. Bit 6 sets the state of RADIO_TXD, and bit 7 sets the states of /HOST_CTS and /DCD. A sleep state bit is set to 1 to specify a high output or an internal pull-up on an input, or to 0 to specify a low output or no internal pull-up on an input. Bit 6 must be set low in order to achieve minimum sleep current (high impedance load assumed), and the other bits may need to be set low or high depending on their external loads. When bit 6 is set low, expect a serial "break" condition to occur as the module wakes from sleep. The serial break condition can be eliminated by setting bit 6 high, but sleep current will be increased.

Dac0Init - this parameter sets the initial value for DAC0 at startup.

Dac1Init - this parameter sets the initial value for DAC1 at startup.

AdcSampleIntvl - this parameter sets the interval between the beginning of one ADC read cycle and the beginning of the next ADC read cycle. The three ADC channels are read on each ADC cycle. Each *AdcSampleIntvl* count equals 10 ms. This interval will be the worst-case latency for ADC generated interrupts. This interval is independent of the *IoReportInterval* as the ADCs will be read again on that interval.

Adc0..2ThresholdLo/Hi - these values set the thresholds to trigger an I/O report based on ADC measurements. If I/O reporting is enabled, a single event report containing the contents of the I/O bank is generated when a threshold is crossed. Reporting is "edge-triggered" with respect to threshold boundaries, not "level-triggered"; i.e., if the measurement remains there, additional reports are not triggered until the value crosses the threshold again. Triggers occur whenever one of the following inequalities is satisfied:

ADC*x* < ADC*x*_ThresholdLo
ADC*x* > ADC*x*_ThresholdHi

IoReportTrigger - a trigger event on any enabled trigger source will cause a DNT90 router or remote to send an event message to the base containing the entire current values of the Bank 5.

bit 7	ADC2 high/low thresholds
bit 6	ADC1 high/low thresholds
bit 5	ADC0 high/low thresholds
bit 4	Periodic timer
bit 3	GPIO3 edge
bit 2	GPIO2 edge
bit 1	GPIO1 edge
bit 0	GPIO0 edge

I/O reporting is supported for remotes and routers only, not the base.

IoReportInterval - when periodic timer I/O reporting is enabled, this parameter sets the interval between reports. The parameter scaling is 10 ms/count, and the default report interval is every 30 seconds.

IoPreDelay - this parameter sets the time in milliseconds to delay collection of ADC readings after an event occurs.

IoBindingEnable - this parameter enables I/O binding. Setting this parameter to 0x00 disables I/O binding (I/O mirroring) from a remote device. Setting this parameter 0x01 enables I/O mirroring. When enabled, the data from any received event report is used to drive the device's own outputs. GPIO2 will be set to the event report's GPIO0 reading, GPIO3 will be set to the event report's GPIO1 reading, and DAC0 and DAC1 will be set with the ADC0 and ADC1 readings respectively.

DacReference - this parameter selects the reference voltage for the DACs:

Setting	***Reference***
0x00	ADC_Ref_Ext
0x01	AVVC (analog VCC)
0x02	Internal 1 V reference
0x03	Disable DAC operation

AdcReference - this parameter selects the reference voltage for the ADCs:

Setting	***Reference***
0x00	ADC_Ref_Ext
0x01	Internal VCC divided by 1.6
0x02	Internal 1 V reference
0x03	Disable ADC operation

7.4.8 Bank 0xFF - Special Functions

Bank	Location	Name	R/W	Size	Range	Default
0xFF	0x00	UcReset	*W*	0x01	0..2	N/A
0xFF	0x01	MemorySave	*W*	0x01	0xD0..0xD2	N/A
0xFF	0x04	DiagSerialRate	*R/W*	0x01	0..10	7 (38400 kbps)
0xFF	0x0C	ForceDiscover	*W*	0x03	(See Text)	N/A

Table 7.4.8.1

UcReset - writing a 0 to this parameter initiates a full reset, writing 1 to initiates a reset to the serial bootloader, or writing a 2 to initiates a reset to the OTA bootloader client.

MemorySave - writing 0xD0 to this parameter load default values, writing 0xD1 saves settings to EEPROM, or writing 0xD2 to save settings to EEPROM and resets the module.

DiagSerialRate - this parameter sets the diagnostic port serial data rate as shown below:

Setting	***Serial rate***
0x00	1.2 kbps
0x01	2.4 kbps
0x02	4.8 kbps
0x03	9.6 kbps
0x04	14.4 kbps
0x05	19.2 kbps
0x06	28.8 kbps
0x07	38.4 kbps (default)
0x08	57.6 kbps
0x09	115.2 kbps
0x0A	230.4 kbps

ForceDiscoverRegister - a write to this register, typically using a broadcasted *Set Remote Register* command, will force a heartbeat reply if a device's parent has the specified base-mode network ID (or 0xFF wildcard), and the least significant byte of the device’s MAC address is within a specified min/max range. The payload consists of 3 bytes: NWKID (NN), minimum MAC address (LL), and maximum MAC address (XX). In Little Endian hexadecimal format this would appear as “XXLLNN”.

7.5 Protocol-formatted Message Examples

7.5.1 Data Message

In this example, the ASCII text *"Hello"* is sent from the base to a remote using the *TxData* command. The MAC address of the remote is 0x123456. The protocol formatting for the host message is:

SOP	Length	PktType	Lo MAC	MAC	Hi MAC	"H"	"e"	"l"	"l"	"o"
0xFB	0x09	0x05	0x56	0x34	0x12	0x48	0x65	0x6C	0x6C	0x6F

There are 9 bytes following the length byte, so the length byte is set to 0x09. Note that the 0x123456 network address is entered in Little-Endian byte order, 56 34 12. When an ACK to this message is received from the remote, the base outputs a *TxDataReply* message to its host:

SOP	Length	PktType	Lo MAC	MAC	Hi MAC	Status	RSSI
0xFB	0x07	0x15	0x56	0x34	0x12	0x00	0xB0

The 0x00 *TxStatus* byte value indicates the ACK reception from the remote. The *RSSI* value of the received ACK is 0xB0, indicating a received signal strength of approximately -80 dBm .

The ASCII *"Hello"* message is output at the remote as an 0x26 *RxData* event. The address field contains the originator's address, 0x00 0x00 0x00, which is the base. The *RSSI* value of the received message is 0xB4, indicating a received signal strength of approximately -76 dBm. The data following the RSSI value is the *"Hello"* text.

SOP	Length	PktType	Lo MAC	MAC	Hi MAC	RSSI	"H"	"e"	"l"	"l"	"o"
0xFB	0x0A	0x26	0x00	0x00	0x00	0x35	0x48	0x65	0x6C	0x6C	0x6F

Note that if the remote was in transparent mode, only the *"Hello"* text would be output.

7.5.2 Configuration Messages

In this example, the remote with MAC address 0x123456 is configured by the base (MAC address 0x000000) to generate *RxEvent* messages every 10 seconds. To do this, the *IoReportInterval* in the remote is set to 10 seconds and the *periodic report timer* bit in the *IoReportTrigger* parameter is set ON. The *IoReportInterval* and the *IoReportTrigger* parameters are loaded using *SetRemoteRegister* commands. The command to set the *IoReportInterval* to 10 seconds is:

SOP	Length	PktType	Lo MAC	MAC	Hi MAC	Reg	Bank	Size	Lo Val	Val	Val	Hi Val
0xFB	0x0B	0x07	0x56	0x34	0x12	0x1C	0x06	0x04	0x10	0x27	0x00	0x00

The *IoReportInterval* parameter starts in location 0x1C of Bank 6. The report interval scaling is 1 ms/count, so a 10 second report interval is 10,000 units or 0x00002710 (Little-Endian format 10 27 00 00). The *IoReportInterval* parameter is updated and *SetRemoteRegisterReply* is returned:

SOP	Length	PktType	Status	Lo MAC	MAC	Hi MAC	RSSI
0xFB	0x06	0x17	0x00	0x00	0x00	0x00	0xB2

The command to set the *periodic report timer* bit in *IoReportTrigger* is:

SOP	Length	PktType	Lo Mac	MAC	Hi MAC	Reg	Bank	Size	Val
0xFB	0x08	0x07	0x56	0x34	0x12	0x1B	0x06	0x01	0x10

The *IoReportTrigger* parameter is in location 0x1B of Bank 6. The *periodic report timer* bit in *IoReportTrigger* is located in bit position four (00010000b) or 0x10. The *IoReportTrigger* parameter is updated and *SetRemoteRegisterReply* is returned:

SOP	Length	PktType	Status	Lo MAC	MAC	Hi MAC	RSSI
0xFB	0x06	0x17	0x00	0x00	0x00	0x00	0xB4

7.5.3 Sensor Message

In this example, the base host requests an ADC1 reading from a remote using the *GetRemoteRegister* command, type 0x06. The MAC address of the remote is 0x123456. The current ADC1 measurement parameter is read starting at register location 0x15 and Bank 5. The ADC reading spans two bytes. The protocol formatting for this command is:

SOP	Length	PktType	Lo Mac	MAC	Hi MAC	Reg	Bank	Size
0xFB	0x07	0x06	0x56	0x34	0x12	0x15	0x05	0x02

Note the remote MAC address is entered in Little-Endian byte order, 56 34 12.

The ADC reading is returned in a *GetRemoteRegisterReply* message:

SOP	Length	PktType	Status	Lo MAC	MAC	Hi MAC	RSSI	Reg	Bank	Size	Lo Val	Hi Val
0xFB	0x0B	0x16	0x00	0x00	0x00	0x00	0xB7	0x1C	0x06	0x02	0x7B	0x08

Substantial information is returned in the message. The last two byes of the message give the ADC reading in Little-Endian format, 7B 08. The ADC reading is thus 0x087B (2171). The RSSI value is the byte following the address, 0xB7 (-73 dBm). The *TxStatus* byte to the right of the *GetRemoteRegisterReply* Packet Type is 0x00, showing the packet was acknowledged on the RF channel.

7.5.4 Event Message

The configuration example shown in Section 7.5.2 above causes the remote with MAC address 0x123456 to start sending event messages every 10 seconds as shown in the log below:

```
FB 12 28 56 34 12 B8 00 7A 01 36 01 FF 01 10 00 20 01 40 01
FB 12 28 56 34 12 B0 00 79 01 35 01 C0 01 10 00 20 01 40 01
FB 12 28 56 34 12 A9 00 72 01 35 01 D3 01 10 00 20 01 40 01
FB 12 28 56 34 12 AC 00 75 01 36 01 E7 01 10 00 20 01 40 01
```

The first received message in the above log is constructed as follows:

SOP	Length	PktType	Addr	Addr	Addr	RSSI	Data
0xFB	0x12	0x28	0x56	0x34	0x12	B8	

GPIO	ADC0		ADC1		ADC2		Event Flags		DAC0		DAC1	
0x00	0x7	0x0	0x3	0x0	FF	0x01	0x10	0x00	0x20	0x0	0x4	0x01

	A	1	6	1						1	0	

RxEvent messages are *PktType* 0x28. The message payload consists of the states of GPIO0 through GPIO5, the input voltages measured by ADC0 through ADC2, the event trigger(s), and the DAC output settings. Note the ADC readings, event flags and DAC settings are presented in Little-Endian order. The remote is assumed to be always ON in this example. If the remote is placed in periodic sleep mode (*SleepMode* = 1), a suitable value of the *WakeDuration* parameter should be set to allow the base application to analyze the I/O report and send back a command to the remote as needed.

8.0 DNT90DK Developer’s Kit

Figure 8.0.1 shows the main contents of a DNT90DK Developer’s kit:

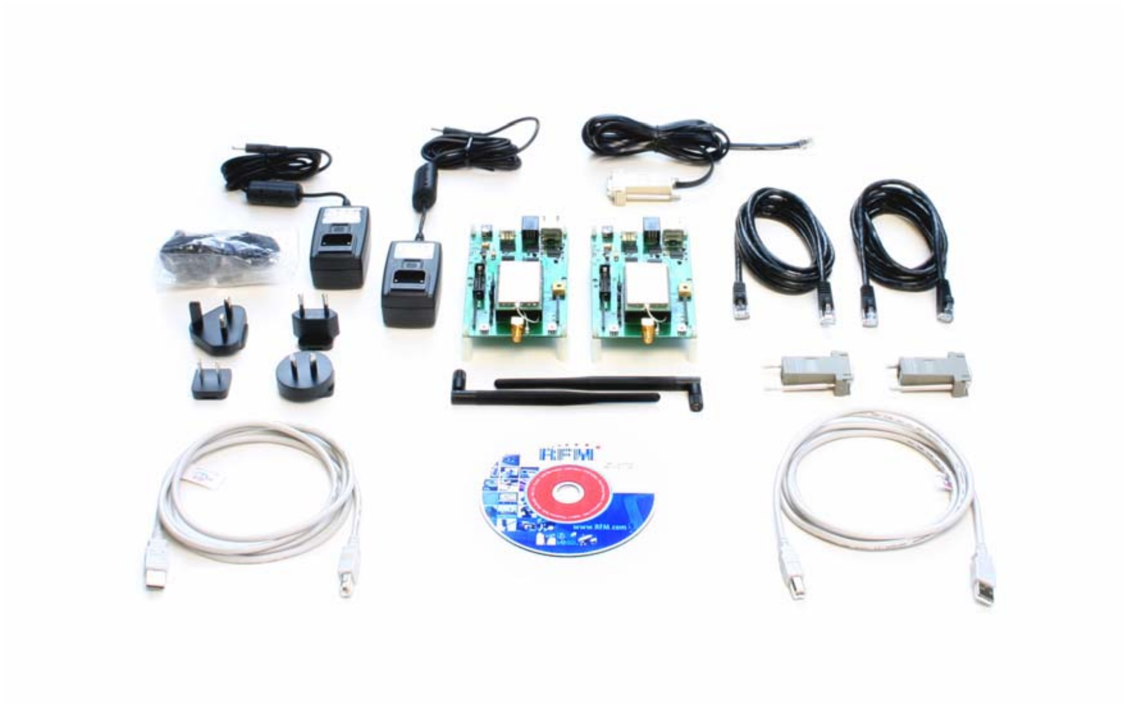


Figure 8.0.1

8.1 DNT90DK Kit Contents

- Two DNT90P radios installed in DNT90 interface boards (labeled Base and Remote)
- Two installed U.FL coaxial jumper cables and two 2 dBi dipole antennas
- Two 9 V wall-plug power suppliers, 120/240 VAC, plus two 9 V batteries (not show above)
- Two RJ-45/DB-9F cable assemblies, one RJ-11/DB-9F cable assembly, two A/B USB cables
- One DNT90DK documentation and software CD

8.2 Additional Items Needed

To operate the kit, the following additional item is needed:

- One PC with Microsoft Windows XP, Vista or Windows 7 operating system. The PC must be equipped with a USB port or a serial port capable of operation at 9.6 kbps.

8.3 Developer’s Kit Default Operating Configuration

The default operating configuration of the DNT90DK developer’s kit is point-to-point with transparent serial data at 9.6 kbps, 8N1. One DNT90P is preconfigured as a base and the other as a remote. Labels on the bottom of the interface boards specify Base or Remote. The defaults can be overridden to test other operating configurations using the DNT utility discussed in Section 8.5. The default RF power setting is +16 dBm (40 mW). The RF power level can be set to +22 dBm (158 mw) as needed for longer range operation.

8.4 Developer's Kit Hardware Assembly

Observe ESD precautions when handling the kit circuit boards. The components that make up a development board are shown in Figure 8.4.1, and are shipped with the DNT90P radios and U.FL coax jumper cables installed in the interface (evaluation) boards. If a DNT90P radio and/or the U.FL jumper cable has been unplugged after receipt, confirm the DNT90P is correctly plugged into its interface board with the radio oriented so that its U.FL connector is next to the U.FL connector on the interface board, as shown in Figure 8.4.2. Also check the radio's alignment in the socket on the interface board. No pins should be hanging out over the ends of the connector. Next, install the dipole antennas.

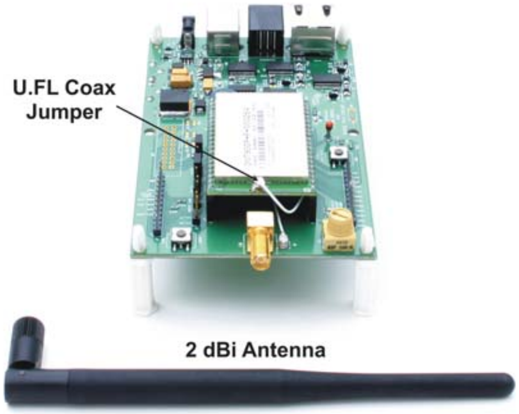


Figure 8.4.1

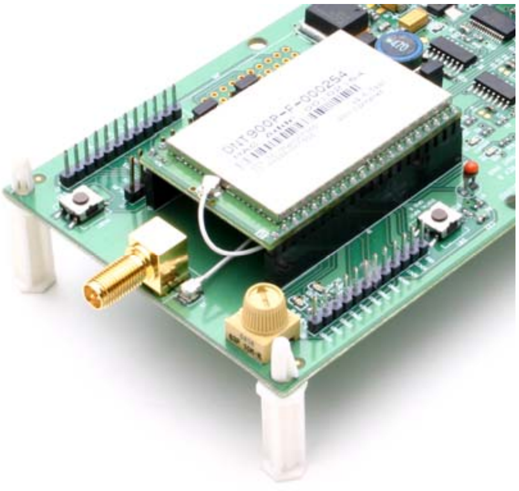


Figure 8.4.2

As shown in Figure 8.4.3, confirm there is a jumper on pins J14. Note - this jumper can be removed and a current meter connected across J14 to measure just the DNT90's current consumption during operation.

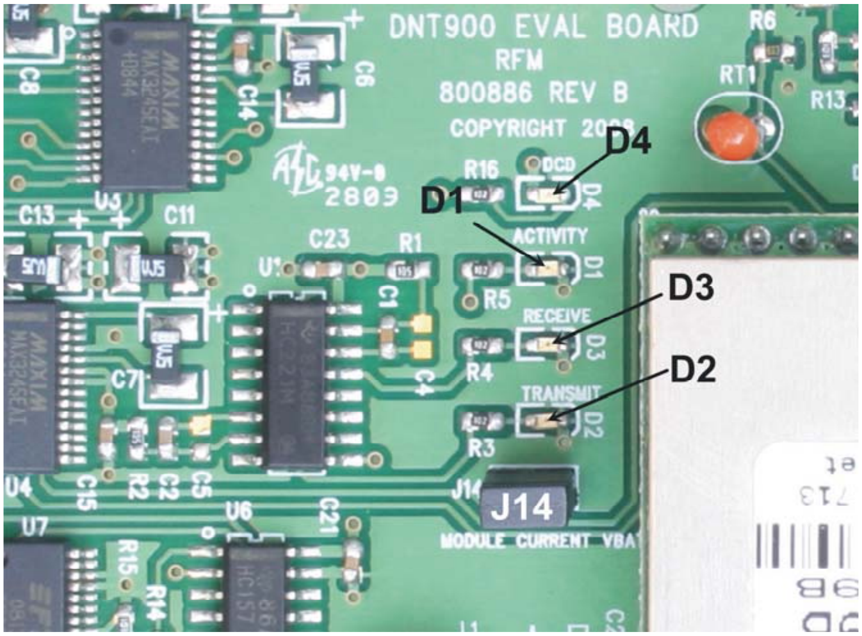


Figure 8.4.3

There are three serial connectors on the interface boards, as shown in Figure 8.4.4. The RJ-45 connector provides a high-speed RS232 interface to the DNT90P's main serial port. The USB connector provides an optional interface to the radio's main serial port. The RJ-11 connector provides a high-speed RS232 interface to the radio's diagnostic port. The DNT Demo utility program runs on the radio's main port.

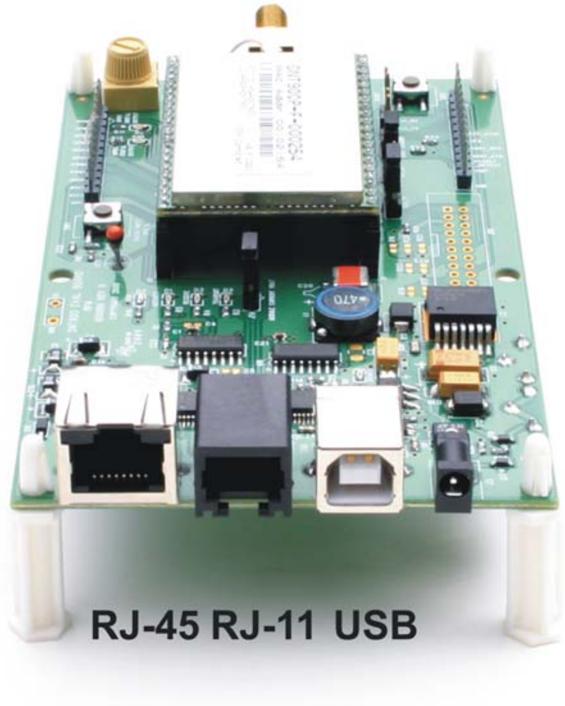


Figure 8.4.4

Many desktop PCs have a built-in serial port capable of operation at 9.6 kbps. The kit can be run satisfactorily at the 9.6 kbps data rate, but not at its fastest throughput. Use the RJ-45 to DB-9F cable assemblies for serial port operation.

Optionally, the kit development boards can be run from USB ports. Plugging in the USB cable automatically switches operation from the RJ-45 connector. The USB interface is based on an FT232RL serial-to-USB converter IC manufactured by FTDI. The FT232RL driver files are located in the i386 and AMD64 folders on the kit CD, and the latest version of the drivers can downloaded from the FTDI website, www.ftdichip.com. The drivers create a virtual COM port on the PC. Power the Base using one of the supplied wall-plug power supplies. Next connect the Base to the PC with a USB cable. The PC will find the new USB hardware and open a driver installation dialog box. Enter the letter of the drive holding the kit CD and click *Continue*. The installation dialog will run *twice* to complete the FT232R driver installation.

8.5 DNT90 Utility Program

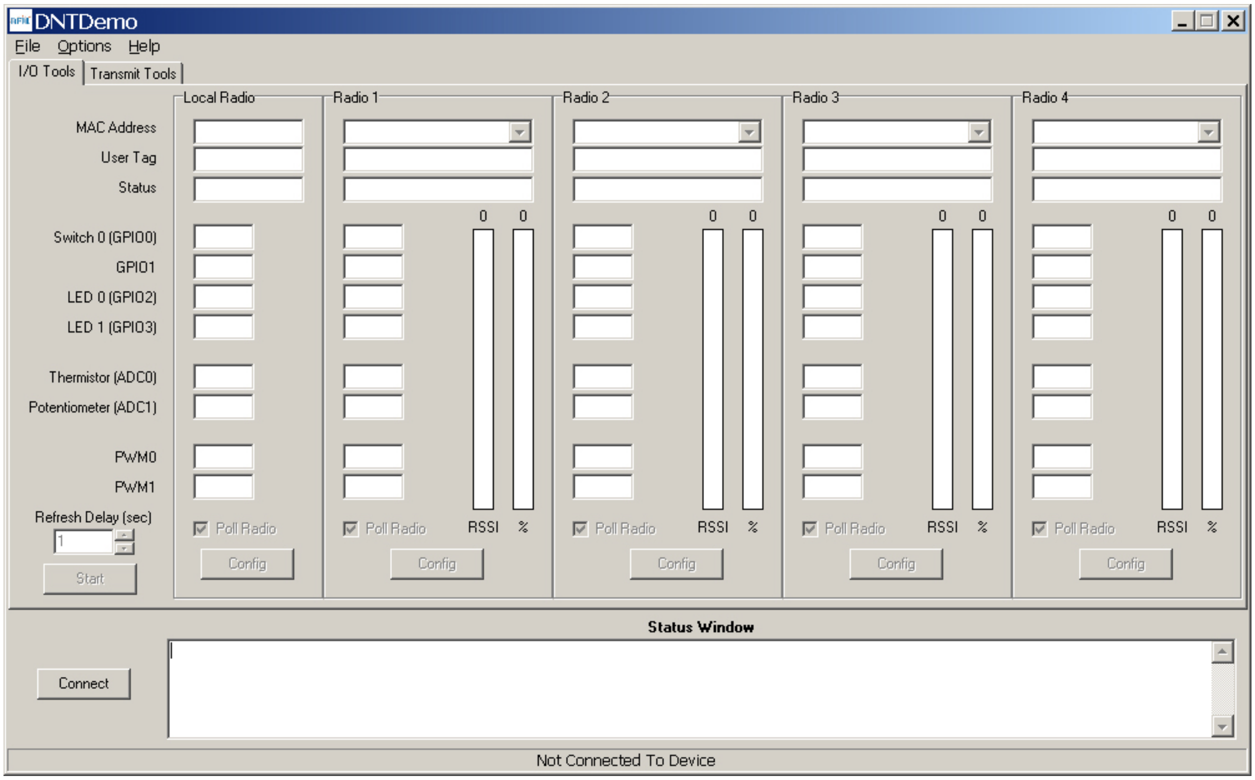
The DNT90 utility program requires only one PC for initial kit operation and sensor applications (ADC, DAC and digital I/O). Two serial/USB ports are required for bidirectional serial communications. Section 8.7 below covers using the DNT Demo utility for initial kit operation and familiarization. Section 8.5.2 covers serial message communication and radio configuration.

8.6 Initial Kit Operation

Create a file folder on the PC and copy the contents of the kit CD into the folder.

The DNT Demo utility program runs on the radio’s main port. The preferred PC interface is a serial port capable of operating at 9.6 kbps or faster. As discussed above, the USB interface can also be used. Connect the Base to the PC and power up the Base and the Remote development boards using the wall-plug power supplies.

The DNT Demo utility program is located in the *PC Programs* folder. The DNT Demo requires no installation and can be simply copied to the PC and run. Start the DNT Demo on the PC. The start-up window is shown in Figure 8.6.1.

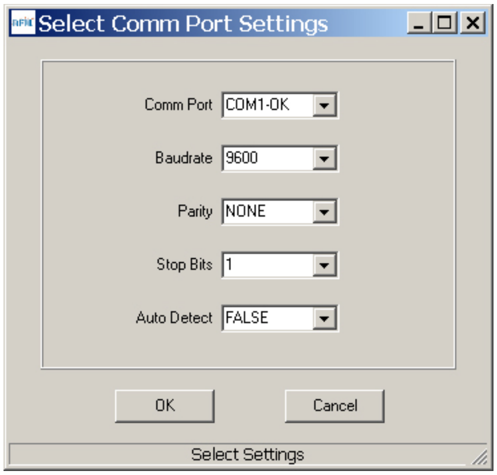


Refresh Delay (sec) 1

Not Connected To Device

Figure 8.6.1

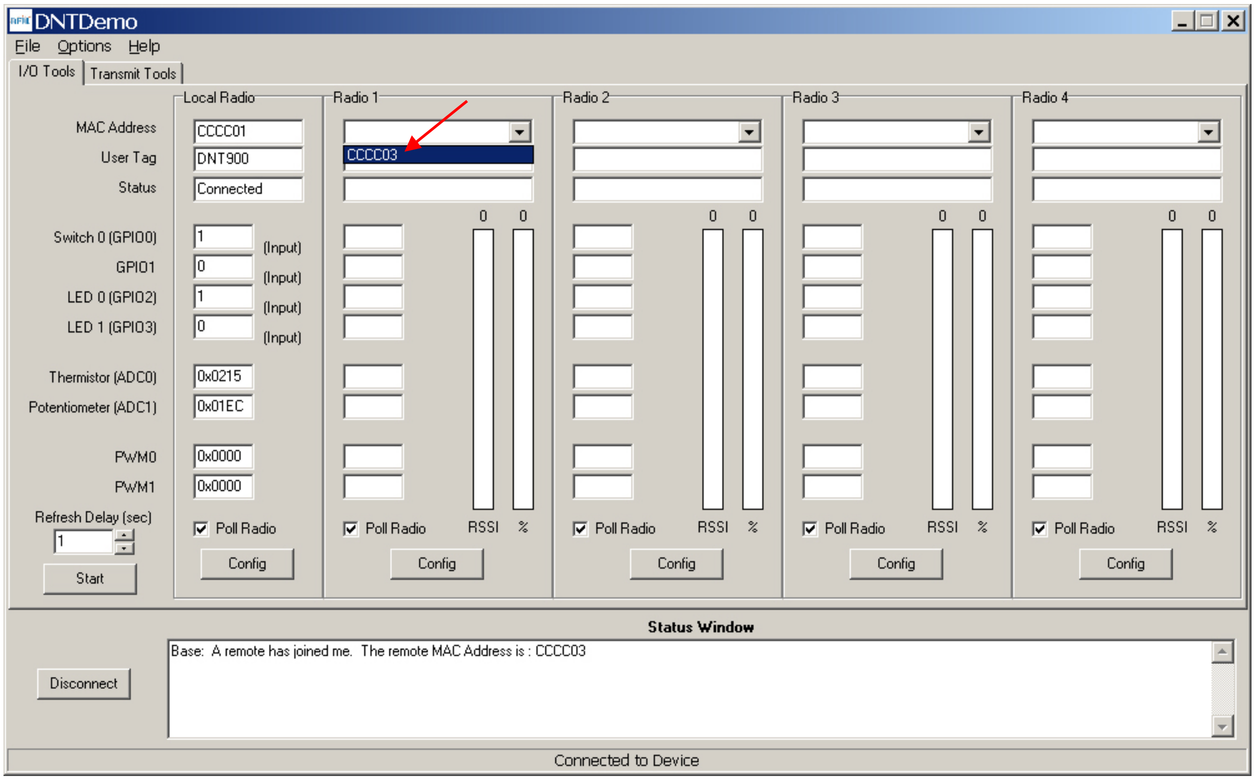
Click on *Connect* to open the *Select Comm Port Settings* dialog box, as shown in Figure 8.6.2. Set the baud rate to 9600 (9.6 kbps). Set the *CommPort* to match the serial port connected to the Base, either the hardware port or the USB virtual serial port. Then click *OK* to activate the serial connection.



Comm Port: COM1-OK
Baudrate: 9600
Parity: NONE
Stop Bits: 1
Auto Detect: FALSE

Figure 8.6.2

At this point the Demo will collect data from the Base, filling in data in the *Local Radio* column on the Demo window as shown in Figure 8.6.3. The *Status Window* should also show that the Remote has joined the Base. Click on the drop-down box at the top of the *Radio 1* column and select the *MAC Address* for the Remote. Next press the *Start* button using the default 1 second *Refresh Delay*.



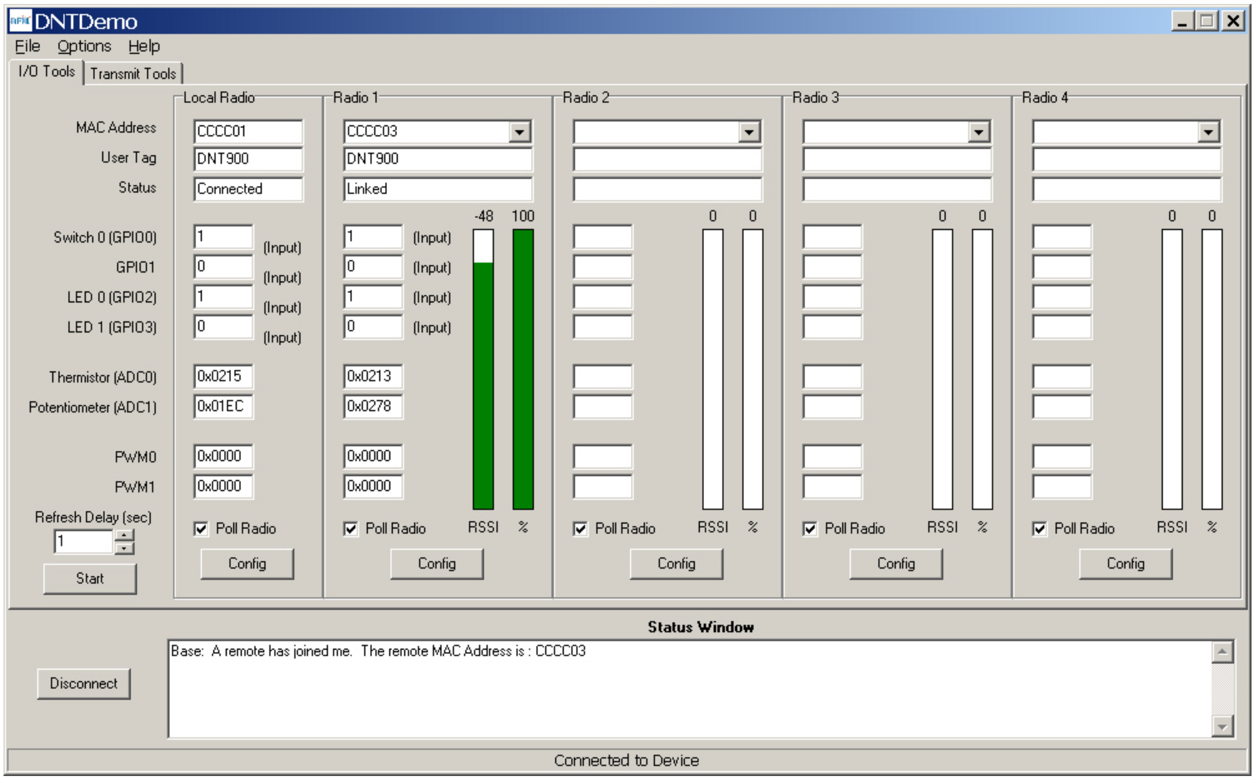
Local Radio:
MAC Address: CCCC01
User Tag: DNT900
Status: Connected
Switch 0 (GPIO0): 1 (Input)
GPIO1: 0 (Input)
LED 0 (GPIO2): 1 (Input)
LED 1 (GPIO3): 0 (Input)
Thermistor (ADC0): 0x0215
Potentiometer (ADC1): 0x01EC
PWM0: 0x0000
PWM1: 0x0000
Refresh Delay (sec): 1
☑ Poll Radio

Radio 1: CCCC03
☑ Poll Radio (Radio 1, Radio 2, Radio 3, Radio 4)

Status Window: Base: A remote has joined me. The remote MAC Address is : CCCC03

Figure 8.6.3

The Demo will display updated data on the Remote in the *Radio 1* column, including bar graphs of *RSSI* signal strength in dBm and percent packet success rate, as shown in Figure 8.6.4. Adjusting the large pot on the Remote can be observed on the *Potentiometer (ADC1)* row.



	Local Radio	Radio 1	Radio 2	Radio 3	Radio 4
MAC Address	CCCC01	CCCC03			
User Tag	DNT900	DNT900			
Status	Connected	Linked			
Switch 0 (GPIO0)	1 (Input)	1 (Input)			
GPIO1	0 (Input)	0 (Input)			
LED 0 (GPIO2)	1 (Input)	1 (Input)			
LED 1 (GPIO3)	0 (Input)	0 (Input)			
Thermistor (ADC0)	0x0215	0x0213			
Potentiometer (ADC1)	0x01EC	0x0278			
PWM0	0x0000	0x0000			
PWM1	0x0000	0x0000			
RSSI		-48	0	0	0
%		100	0	0	0
Poll Radio	☑	☑	☑	☑	☑

Refresh Delay (sec): 1

Status Window

Base: A remote has joined me. The remote MAC Address is : CCCC03

Connected to Device

Figure 8.6.4

To perform serial data loop back testing with the kit, move the two jumpers on the Remote board labeled *Ext_TX* and *Ext_RX* to connect the center and right header pins. This disconnects the module's TX and RX pins from the USB and RS-232C circuits. Use a banana clip or other short jumper to connect together the two pins on the header labeled *Ext_MICRO*. See Figure 8.6.5. Attempting loop back testing by connecting Pins 2 and 3 of the DB9 serial connector can cause erratic behavior due to noise coupling from the serial TX and RX lines into the weakly pulled up flow control lines on the board.

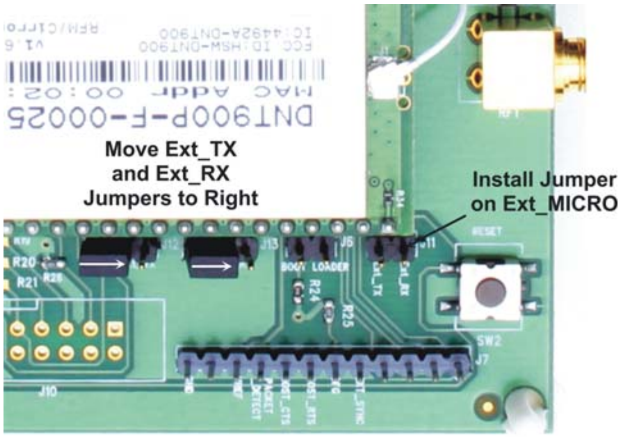


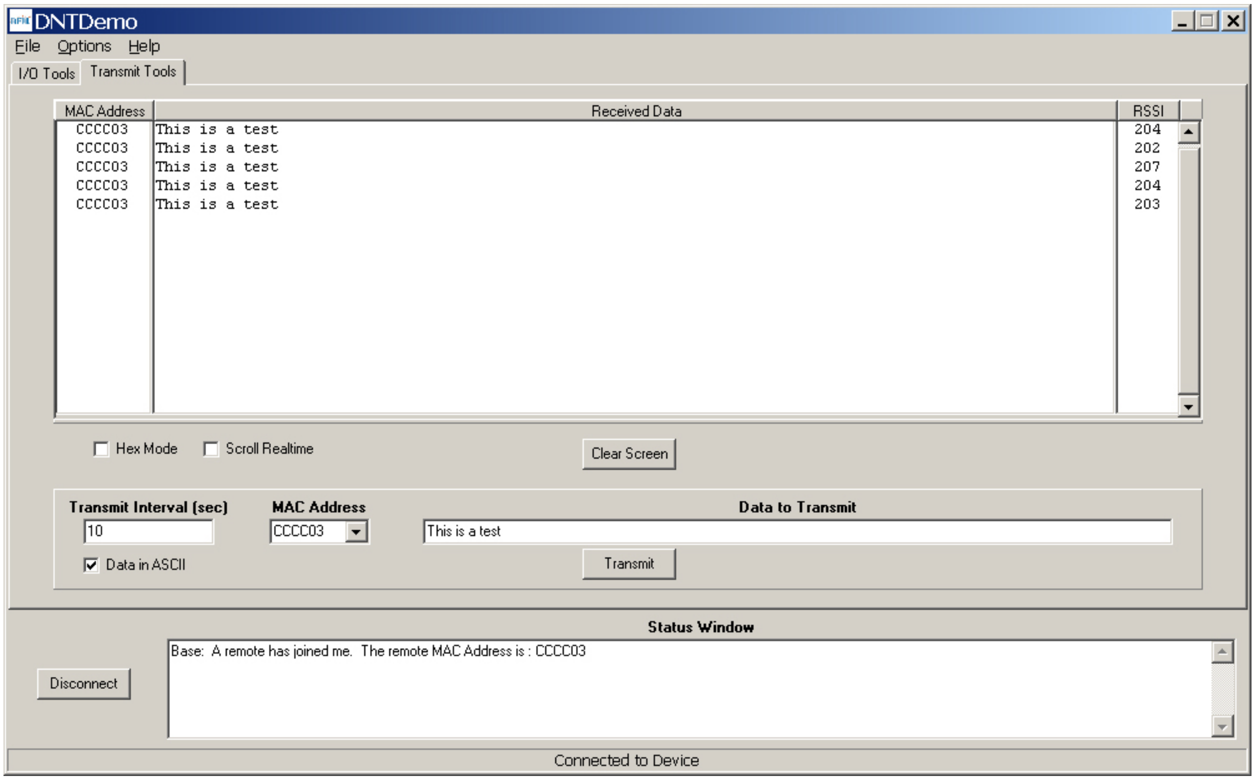
Figure 8.6.5

In order to turn off the DCD LED (D4) on the development board in sleep mode, the *GpioSleepState* parameter in the DNT90P has been set to 0xC0 rather than the factory default value of 0x00. If the DNT90P is reset to its factory defaults, the DCD LED with remain on in sleep mode until the *GpioSleepState* is set to 0xC0. See Section 7.5.7 for additional information on the *GpioSleepState*
parameter.

If any difficulty is encountered in setting up the DNT90DK development kit, contact RFM's module technical support group. The phone number is +1.678.684.2000. Phone support is available from 8:30 AM to 5:30 PM US Eastern Time Zone, Monday through Friday. The E-mail address is tech_sup@rfm.com.

8.6.1 Serial Communication and Radio Configuration

Connect PCs to both the Base and the Remote for serial communication testing. Click the *Stop* button under the *Refresh Delay* label on the *I/O Tools* tab and move to the *Transmit Tools* tab, as shown in Figure 8.6.1.1.



MAC Address	Received Data	RSSI
CCCC03	This is a test	204
CCCC03	This is a test	202
CCCC03	This is a test	207
CCCC03	This is a test	204
CCCC03	This is a test	203

□ Hex Mode □ Scroll Realtime

Transmit Interval (sec): 10

MAC Address: CCCC03

Data to Transmit: This is a test

☑ Data in ASCII

Status Window

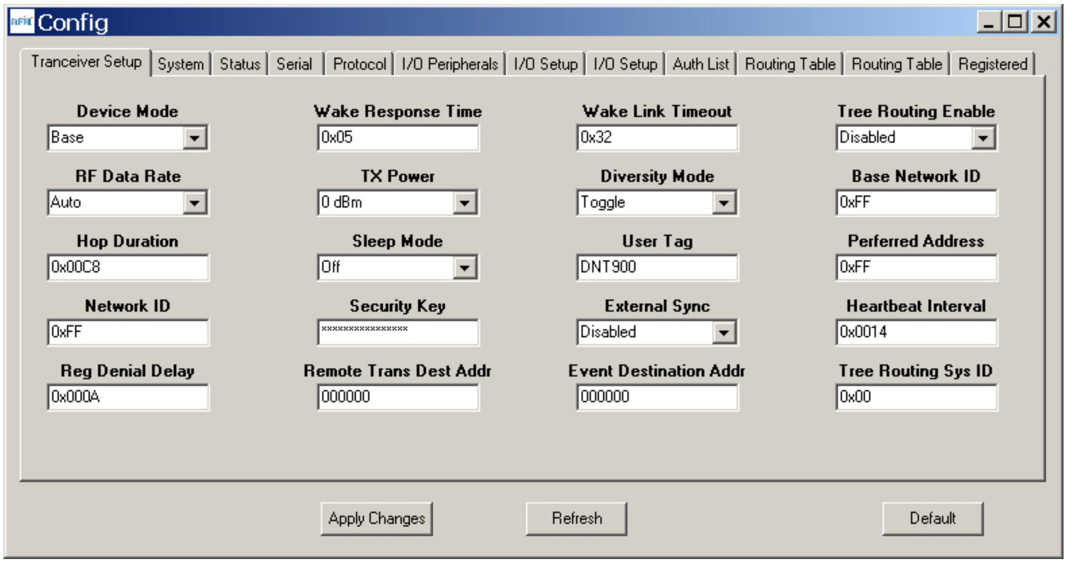
Base: A remote has joined me. The remote MAC Address is : CCCC03

Connected to Device

Figure 8.6.1.1

Pressing the *Transmit* button on this screen sends the message in the *Data to Transmit* text box to the selected *MAC Address*. Note that the *MAC address* a remote usually uses for the base is 0x000000. Data sent to the local radio is displayed in the *Received Data* text box. Received data can be displayed as ASCII (default) or in Hexadecimal format by checking the *Hex Mode* check box. When the *Transmit Interval* is set to zero, *Data to Transmit* is sent once when the *Transmit* button is clicked. When the *Transmit Interval* is set to a positive number, Pressing the *Transmit* button once will cause a transmission each transmit interval (seconds) until the button is pressed again.

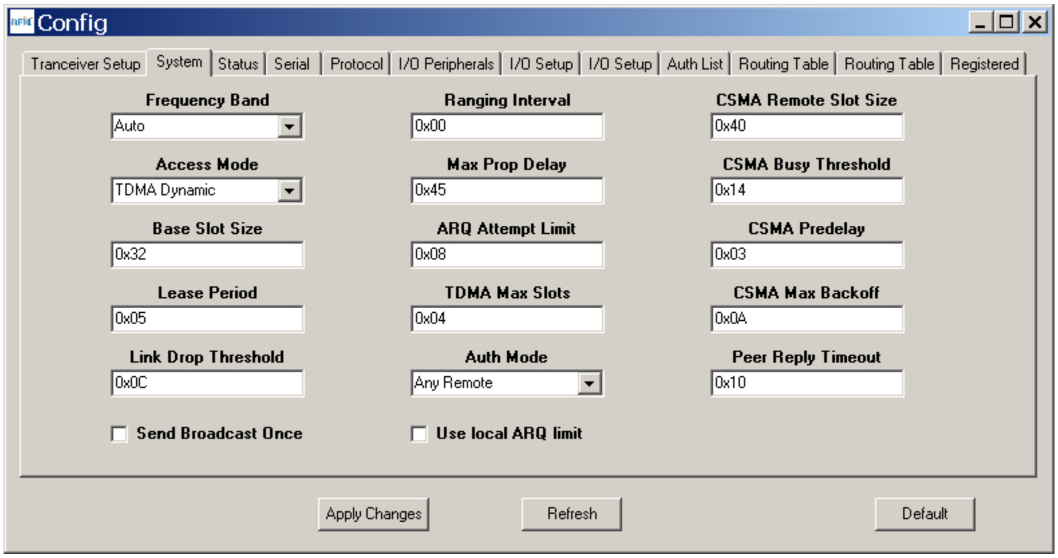
Returning to the *I/O Tools* tab, the multi-tab *Configuration* window for each radio can be accessed by clicking on its *Config* button. The data presented on the first six tabs corresponds to configuration register Banks 0 through 5 as discussed in Section 4.2 above, with the data on the next two tabs corresponding to configuration register Bank 6, the data on the next tab corresponding to Bank 7, the data on the following two tabs corresponding to Bank 8, and the data on the last tab corresponding to Bank 9.



Device Mode	Wake Response Time	Wake Link Timeout	Tree Routing Enable
Base	0x05	0x32	Disabled
RF Data Rate	TX Power	Diversity Mode	Base Network ID
Auto	0 dBm	Toggle	0xFF
Hop Duration	Sleep Mode	User Tag	Perferred Address
0x00C8	Off	DNT900	0xFF
Network ID	Security Key	External Sync	Heartbeat Interval
0xFF	****************	Disabled	0x0014
Reg Denial Delay	Remote Trans Dest Addr	Event Destination Addr	Tree Routing Sys ID
0x000A	000000	000000	0x00

Figure 8.6.1.2

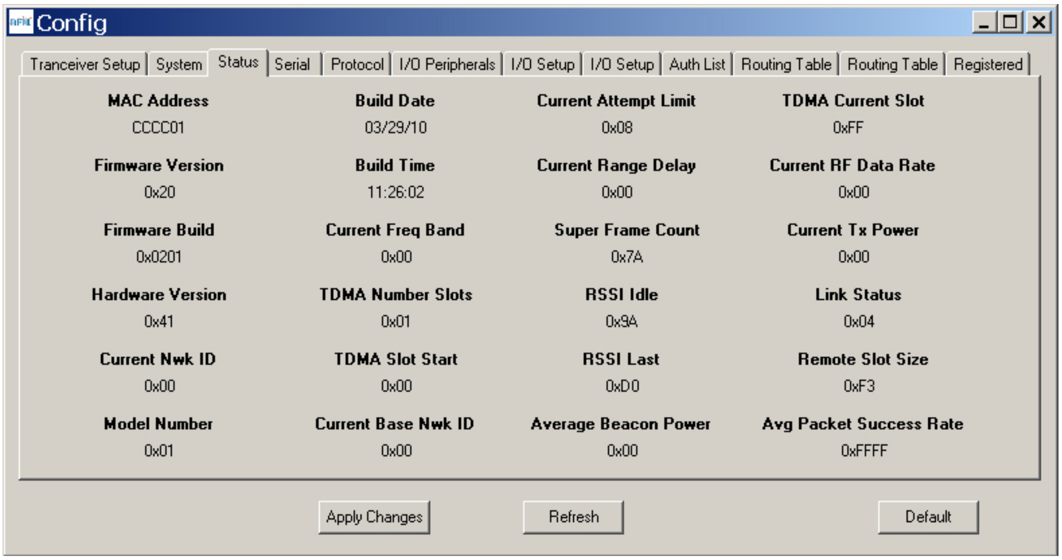
The *Transceiver Setup* Tab is shown in Figure 8.6.1.2 and corresponds to Bank 0. The current values of each Bank 0 parameter are displayed and can be updated by selecting from the drop-down menus or entering data from the keyboard, and then pressing the *Apply Changes* button. Note that data is *displayed and entered in Big-Endian order*. The Demo automatically reorders multi-byte data to and from Little-Endian order when building or interpreting messages.



Frequency Band	Ranging Interval	CSMA Remote Slot Size
Auto	0x00	0x40
Access Mode	Max Prop Delay	CSMA Busy Threshold
TDMA Dynamic	0x45	0x14
Base Slot Size	ARQ Attempt Limit	CSMA Predelay
0x32	0x08	0x03
Lease Period	TDMA Max Slots	CSMA Max Backoff
0x05	0x04	0x0A
Link Drop Threshold	Auth Mode	Peer Reply Timeout
0x0C	Any Remote	0x10
☐ Send Broadcast Once	☐ Use local ARQ limit	

Figure 8.6.1.3

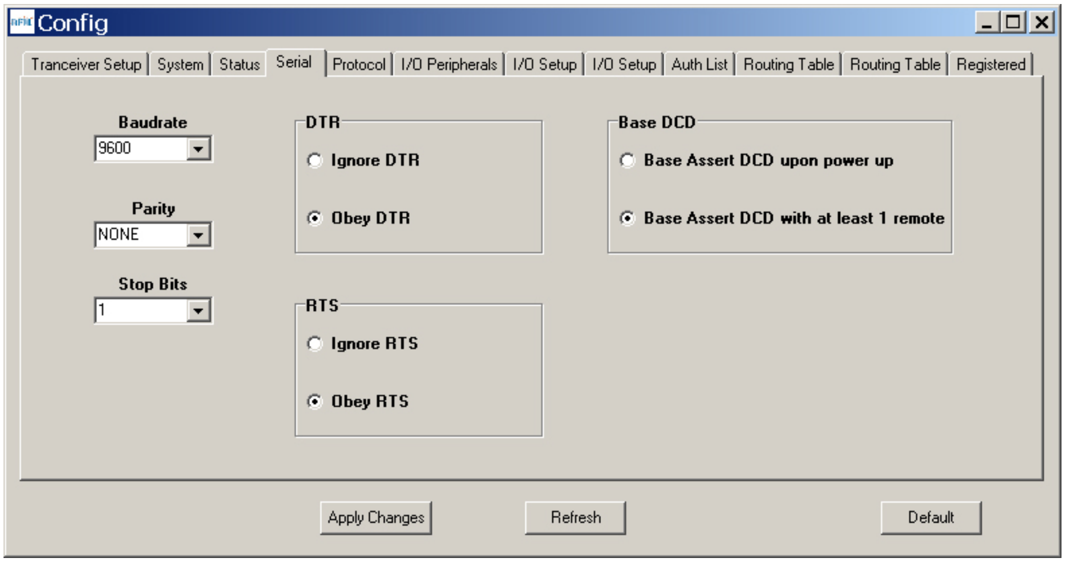
Figure 8.6.1.3 shows the *System* tab contents, corresponding to Bank 1. The current values of each parameter are displayed and can be updated by selecting from the drop-down menus or entering data from the keyboard, and then pressing the *Apply Changes* button. Note that Bank 1 holds configuration parameters for the base only except for *ARQ_Mode,* which applies to both the base and the remotes.



MAC Address	**Build Date**	**Current Attempt Limit**	**TDMA Current Slot**
CCCC01	03/29/10	0x08	0xFF
Firmware Version	**Build Time**	**Current Range Delay**	**Current RF Data Rate**
0x20	11:26:02	0x00	0x00
Firmware Build	**Current Freq Band**	**Super Frame Count**	**Current Tx Power**
0x0201	0x00	0x7A	0x00
Hardware Version	**TDMA Number Slots**	**RSSI Idle**	**Link Status**
0x41	0x01	0x9A	0x04
Current Nwk ID	**TDMA Slot Start**	**RSSI Last**	**Remote Slot Size**
0x00	0x00	0xD0	0xF3
Model Number	**Current Base Nwk ID**	**Average Beacon Power**	**Avg Packet Success Rate**
0x01	0x00	0x00	0xFFFF

Figure 8.6.1.4

Figure 8.6.1.5 shows the *Status* tab contents, corresponding to Bank 2. Note the *Status* tab contains read-only parameters.



Baudrate 9600

Parity NONE

Stop Bits 1

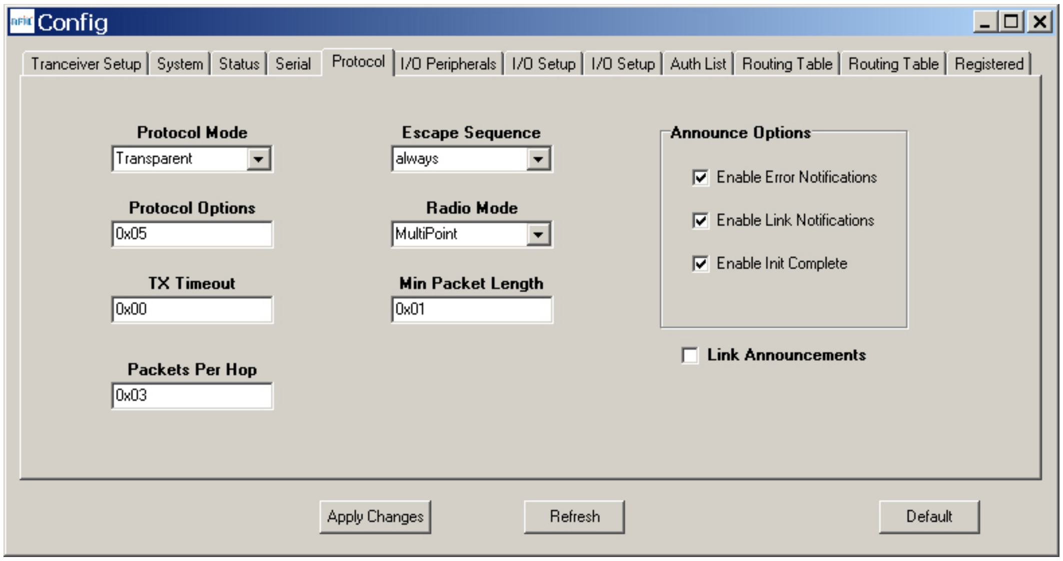
DTR
○ **Ignore DTR**
● **Obey DTR**

RTS
○ **Ignore RTS**
● **Obey RTS**

Base DCD
○ **Base Assert DCD upon power up**
● **Base Assert DCD with at least 1 remote**

Figure 8.6.1.5

Figure 8.6.1.5 shows the *Serial* tab contents corresponding to Bank 3. The values shown are the defaults for serial port operation.



Protocol Mode: Transparent

Escape Sequence: always

Protocol Options: 0x05

Radio Mode: MultiPoint

TX Timeout: 0x00

Min Packet Length: 0x01

Packets Per Hop: 0x03

Announce Options

☑ Enable Error Notifications

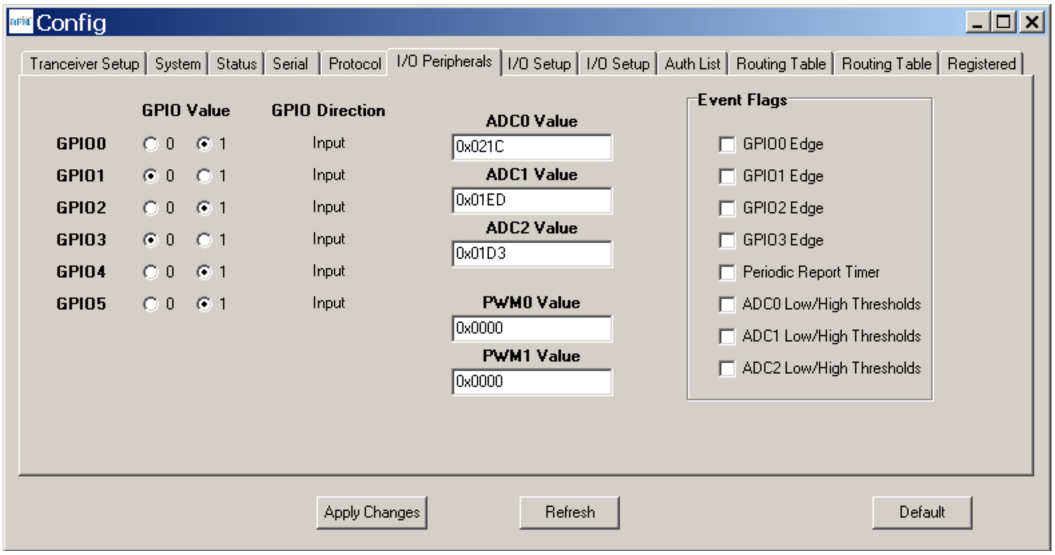
☑ Enable Link Notifications

☑ Enable Init Complete

☐ Link Announcements

Figure 8.6.1.6

Figure 8.6.1.6 shows the *Protocol* tab contents, corresponding to Bank 4. Transparent data serial communication is currently chosen.



	GPIO Value		GPIO Direction
GPIO0	○ 0	● 1	Input
GPIO1	● 0	○ 1	Input
GPIO2	○ 0	● 1	Input
GPIO3	● 0	○ 1	Input
GPIO4	○ 0	● 1	Input
GPIO5	○ 0	● 1	Input

ADC0 Value: 0x021C

ADC1 Value: 0x01ED

ADC2 Value: 0x01D3

PWM0 Value: 0x0000

PWM1 Value: 0x0000

Event Flags

☐ GPIO0 Edge

☐ GPIO1 Edge

☐ GPIO2 Edge

☐ GPIO3 Edge

☐ Periodic Report Timer

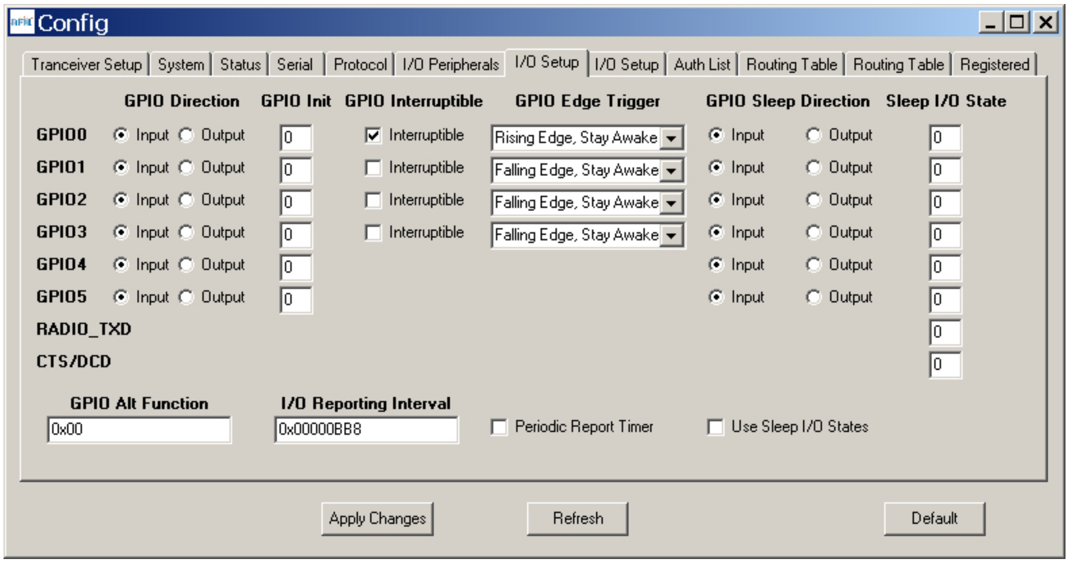
☐ ADC0 Low/High Thresholds

☐ ADC1 Low/High Thresholds

☐ ADC2 Low/High Thresholds

Figure 8.6.1.7

Figure 8.6.1.7 shows the *I/O Peripherals* tab contents, corresponding to Bank 5. GPIO ports 1 and 3 are logic high, GPIO ports 0, 2, 4 and 5 are logic low. The 10-bit ADC input readings and PWM output settings are given in *Big-Endian* byte order. Event flags are presented on the right side of the window.



	GPIO Direction	GPIO Init	GPIO Interruptible	GPIO Edge Trigger	GPIO Sleep Direction	Sleep I/O State
GPIO0	● Input ○ Output	0	☑ Interruptible	Rising Edge, Stay Awake	● Input ○ Output	0
GPIO1	● Input ○ Output	0	☐ Interruptible	Falling Edge, Stay Awake	● Input ○ Output	0
GPIO2	● Input ○ Output	0	☐ Interruptible	Falling Edge, Stay Awake	● Input ○ Output	0
GPIO3	● Input ○ Output	0	☐ Interruptible	Falling Edge, Stay Awake	● Input ○ Output	0
GPIO4	● Input ○ Output	0			● Input ○ Output	0
GPIO5	● Input ○ Output	0			● Input ○ Output	0
RADIO_TXD						0
CTS/DCD						0

GPIO Alt Function: 0x00

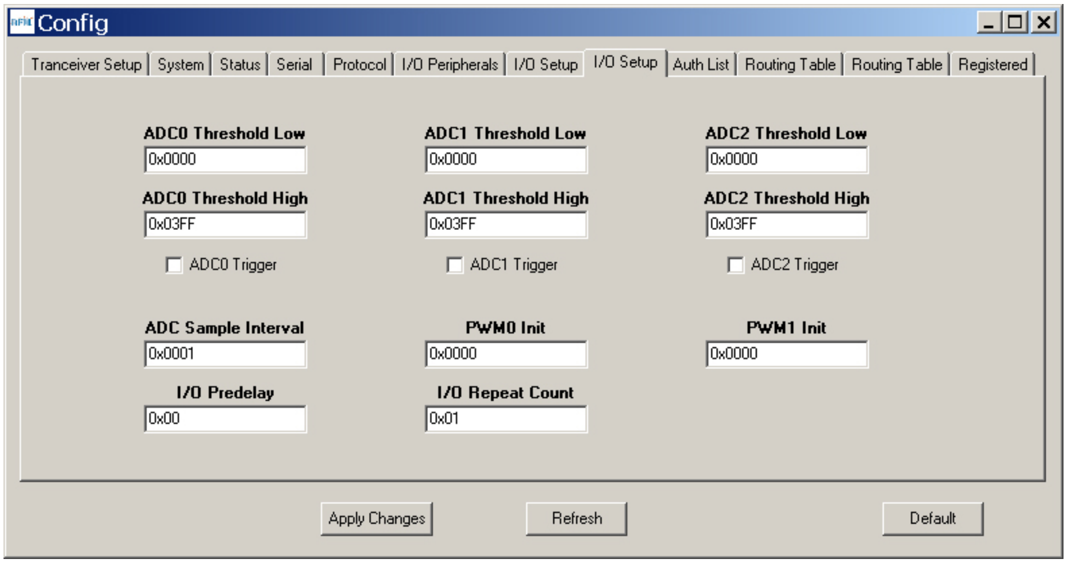
I/O Reporting Interval: 0x00000BB8

☐ Periodic Report Timer

☐ Use Sleep I/O States

Figure 8.6.1.8

Figure 8.6.1.8 shows the first *I/O Setup* tab contents, corresponding to Bank 6 GPIO parameters. This tab allows the direction of the GPIO ports to be set both for active and sleep modes, and in the case of GPIO outputs, the initial power up states and sleep mode states to be set. When GPIO ports 0 - 3 are configured as inputs, event interrupts can be set for them with check boxes. The type of interrupt trigger is selected from the drop-down boxes to the right of the check boxes. GPIO alternate function, periodic I/O reporting, reporting interval and enable/disable sleep I/O states can also be specified under this tab.



ADC0 Threshold Low: 0x0000

ADC1 Threshold Low: 0x0000

ADC2 Threshold Low: 0x0000

ADC0 Threshold High: 0x03FF

ADC1 Threshold High: 0x03FF

ADC2 Threshold High: 0x03FF

☐ ADC0 Trigger

☐ ADC1 Trigger

☐ ADC2 Trigger

ADC Sample Interval: 0x0001

PWM0 Init: 0x0000

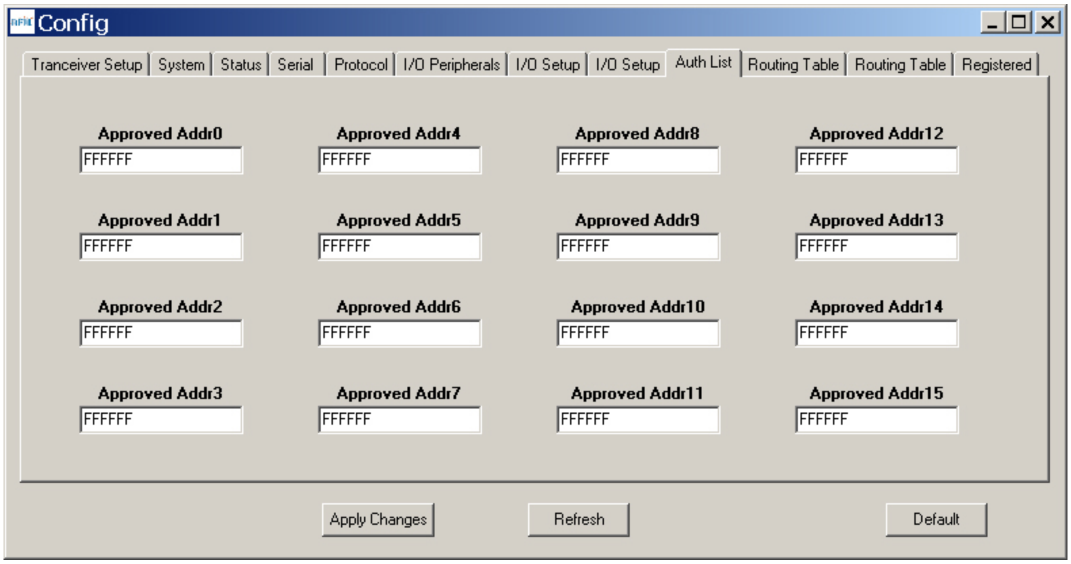
PWM1 Init: 0x0000

I/O Predelay: 0x00

I/O Repeat Count: 0x01

Figure 8.6.1.9

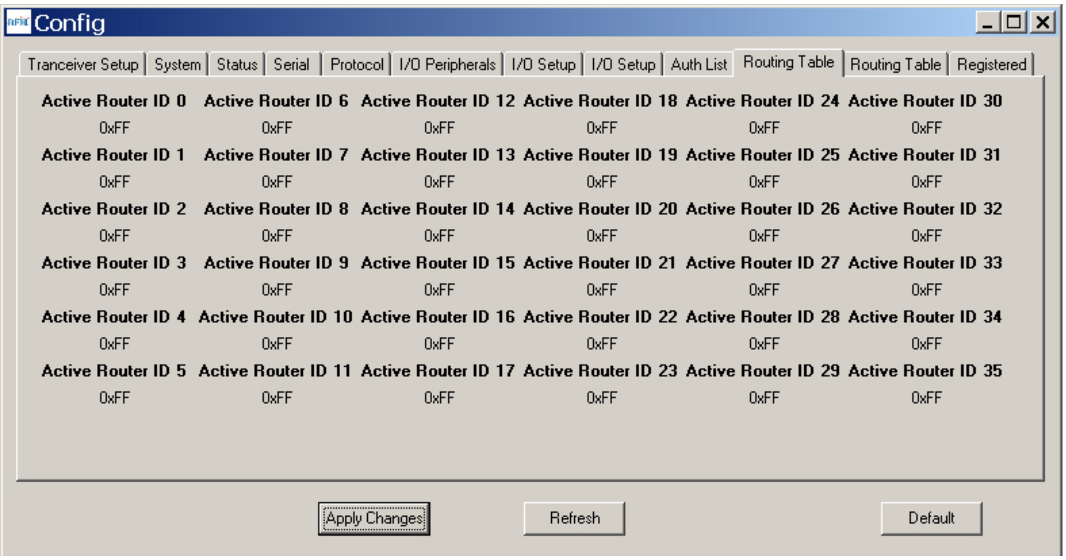
Figure 8.6.1.9 shows the second *I/O Setup* tab contents, corresponding to Bank 6 ADC input and PWM output parameters. The ADC sampling interval, high and low thresholds for event reporting and event reporting triggers on each ADC channel can be set, along with the start-up output values for each PWM (DAC) channel. The event reporting predelay and repeat count parameters can also be set from this tab.



Approved Addr0	Approved Addr4	Approved Addr8	Approved Addr12
FFFFFF	FFFFFF	FFFFFF	FFFFFF
Approved Addr1	Approved Addr5	Approved Addr9	Approved Addr13
FFFFFF	FFFFFF	FFFFFF	FFFFFF
Approved Addr2	Approved Addr6	Approved Addr10	Approved Addr14
FFFFFF	FFFFFF	FFFFFF	FFFFFF
Approved Addr3	Approved Addr7	Approved Addr11	Approved Addr15
FFFFFF	FFFFFF	FFFFFF	FFFFFF

Figure 8.6.1.10

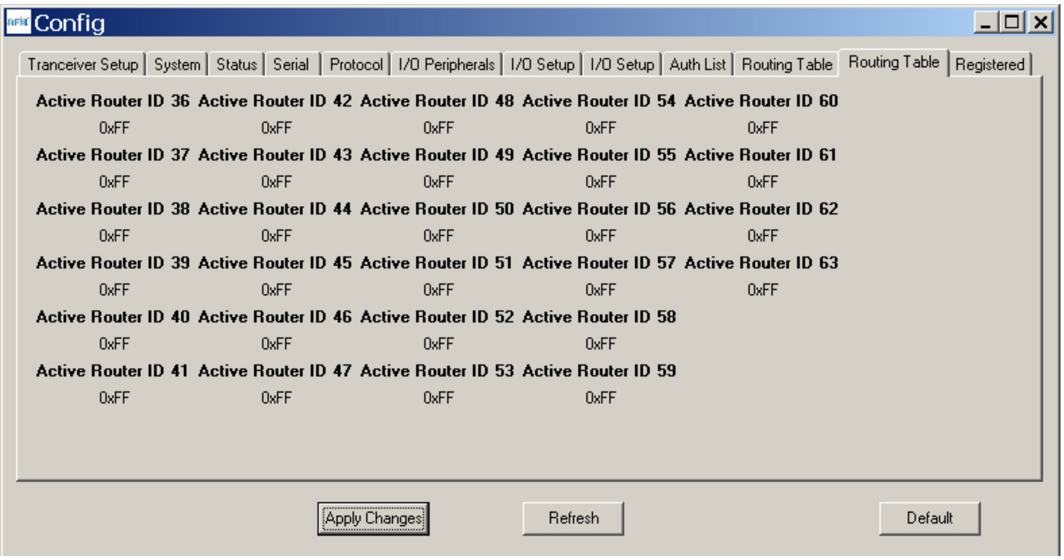
Figure 8.6.1.11 shows the *Auth List* tab, where the MAC addresses of the remotes authorized to join the network in *AuthMode* 1 are input into Bank 7.



Active Router ID 0	Active Router ID 6	Active Router ID 12	Active Router ID 18	Active Router ID 24	Active Router ID 30
0xFF	0xFF	0xFF	0xFF	0xFF	0xFF
Active Router ID 1	Active Router ID 7	Active Router ID 13	Active Router ID 19	Active Router ID 25	Active Router ID 31
0xFF	0xFF	0xFF	0xFF	0xFF	0xFF
Active Router ID 2	Active Router ID 8	Active Router ID 14	Active Router ID 20	Active Router ID 26	Active Router ID 32
0xFF	0xFF	0xFF	0xFF	0xFF	0xFF
Active Router ID 3	Active Router ID 9	Active Router ID 15	Active Router ID 21	Active Router ID 27	Active Router ID 33
0xFF	0xFF	0xFF	0xFF	0xFF	0xFF
Active Router ID 4	Active Router ID 10	Active Router ID 16	Active Router ID 22	Active Router ID 28	Active Router ID 34
0xFF	0xFF	0xFF	0xFF	0xFF	0xFF
Active Router ID 5	Active Router ID 11	Active Router ID 17	Active Router ID 23	Active Router ID 29	Active Router ID 35
0xFF	0xFF	0xFF	0xFF	0xFF	0xFF

Figure 8.6.1.11

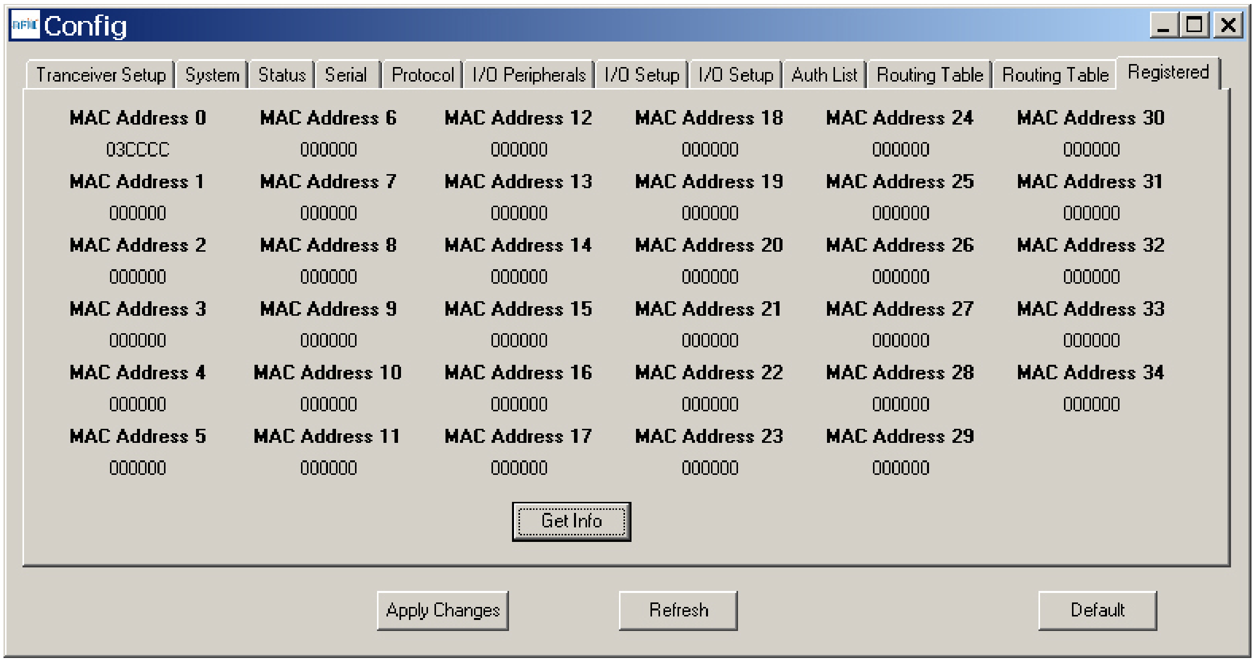
Figure 8.6.1.11 shows the first *Routing Table* tab, which displays part of the contents of Bank 8. This bank contains the store and forward active router ID table, which is maintained by a base for its system. It describes the organization of all active routers in the system. This table is used by the base and the routers to determine which direction to send a packet.



Active Router ID 36	Active Router ID 42	Active Router ID 48	Active Router ID 54	Active Router ID 60
0xFF	0xFF	0xFF	0xFF	0xFF
Active Router ID 37	Active Router ID 43	Active Router ID 49	Active Router ID 55	Active Router ID 61
0xFF	0xFF	0xFF	0xFF	0xFF
Active Router ID 38	Active Router ID 44	Active Router ID 50	Active Router ID 56	Active Router ID 62
0xFF	0xFF	0xFF	0xFF	0xFF
Active Router ID 39	Active Router ID 45	Active Router ID 51	Active Router ID 57	Active Router ID 63
0xFF	0xFF	0xFF	0xFF	0xFF
Active Router ID 40	Active Router ID 46	Active Router ID 52	Active Router ID 58	
0xFF	0xFF	0xFF	0xFF	
Active Router ID 41	Active Router ID 47	Active Router ID 53	Active Router ID 59	
0xFF	0xFF	0xFF	0xFF	

Figure 8.6.1.12

Figure 8.6.1.12 shows the second *Routing Table* tab, which displays the rest of the contents of Bank 8.



MAC Address 0	MAC Address 6	MAC Address 12	MAC Address 18	MAC Address 24	MAC Address 30
03CCCC	000000	000000	000000	000000	000000
MAC Address 1	MAC Address 7	MAC Address 13	MAC Address 19	MAC Address 25	MAC Address 31
000000	000000	000000	000000	000000	000000
MAC Address 2	MAC Address 8	MAC Address 14	MAC Address 20	MAC Address 26	MAC Address 32
000000	000000	000000	000000	000000	000000
MAC Address 3	MAC Address 9	MAC Address 15	MAC Address 21	MAC Address 27	MAC Address 33
000000	000000	000000	000000	000000	000000
MAC Address 4	MAC Address 10	MAC Address 16	MAC Address 22	MAC Address 28	MAC Address 34
000000	000000	000000	000000	000000	000000
MAC Address 5	MAC Address 11	MAC Address 17	MAC Address 23	MAC Address 29	
000000	000000	000000	000000	000000	

Figure 8.6.1.13

Figure 8.6.1.13 shows the *Registered* tab, which displays the first seven parameters in Bank 9. This bank holds the MAC addresses of all radios registered to a base or router. Up to 126 MAC addresses can be registered. Each bank parameter can hold up to five MAC addresses, with each MAC address containing three bytes. Three-byte segments in a parameter not holding a MAC address with hold a null address: 0x000000. In a remote, this bank will contain only null addresses.

8.7 DNT Wizard Program

The DNT Wizard is a complementary program to the DNT90 Utility that emphasizes the details of serial communication between a DNT90 and its host computer. The DNT90 Wizard start-up window is shown in Figure 8.7.1.

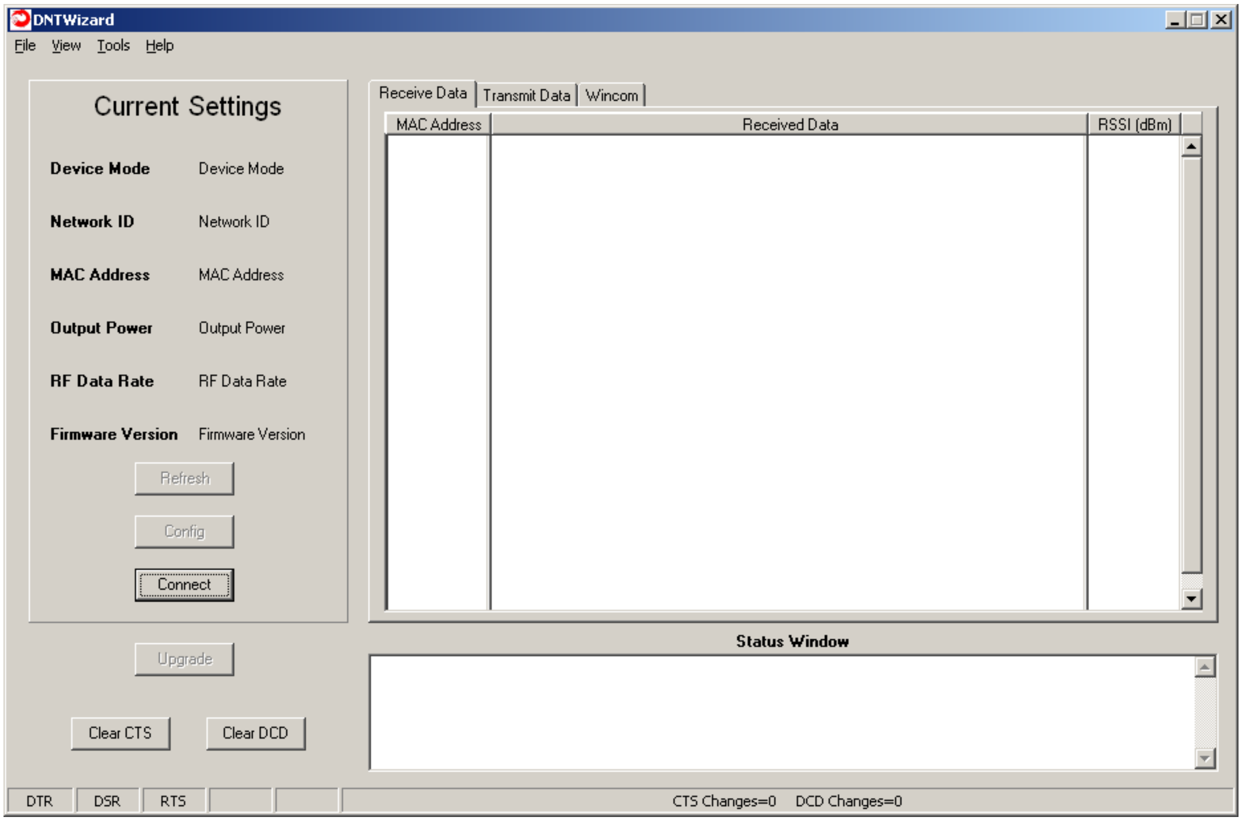


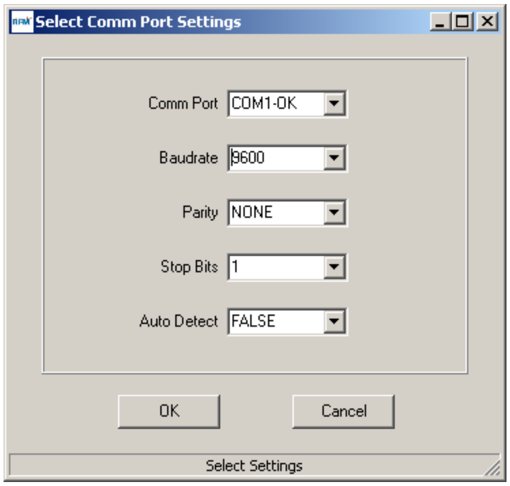
Figure 8.7.1

The DNT Wizard uses three Function keys:

F1 toggles the SLEEP/DTR input to the DNT90 on and off. This allows the DNT90 to be reset.
F2 toggles the RTS input to the DNT90 on and off, providing manual flow control.
F6 toggles test transmissions on and off. The test message is “This is a test”.

The DNT Wizard also includes the ability to log messages to and from the DNT90. This feature is especially useful in confirming the format of protocol command and reply messages. Control of the log file is under the *View* menu. Logging is enabled by default. The log file created is *logfile.dat*, and is in ASCII text format. An example log is shown at the end of this section.

Click on *Connect* to open the *Select Comm Port Settings* dialog box, as shown in Figure 8.7.2. Set the baud rate to 9600 (9.6 kbps). Set the *CommPort* to match the serial port connected to the Base, either the hardware port or the USB virtual serial port. Then click *OK* to activate the serial connection.



Select Comm Port Settings

Comm Port: COM1-OK

Baudrate: 9600

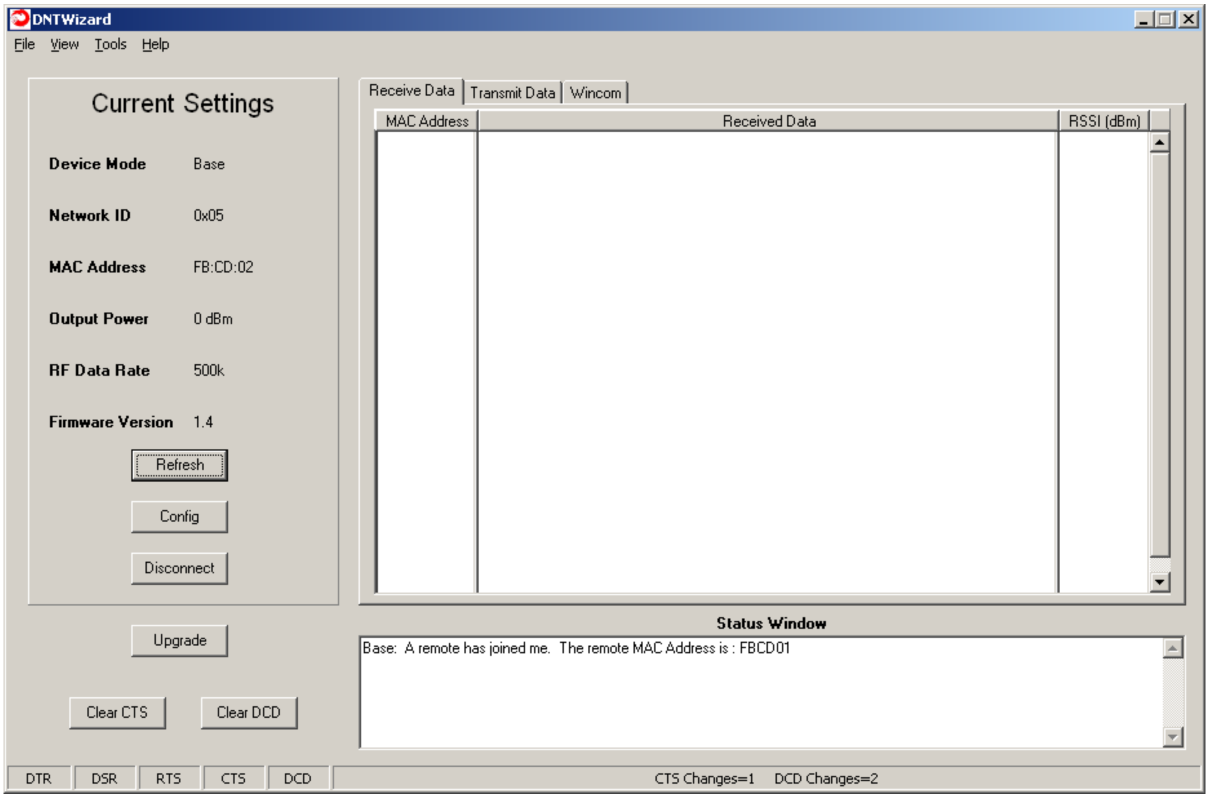
Parity: NONE

Stop Bits: 1

Auto Detect: FALSE

Figure 8.7.2

At this point the Wizard will collect data from the Base, filling in data under *Current Settings* as shown in Figure 8.7.3. The *Status Window* should also show that the Remote has joined the Base.



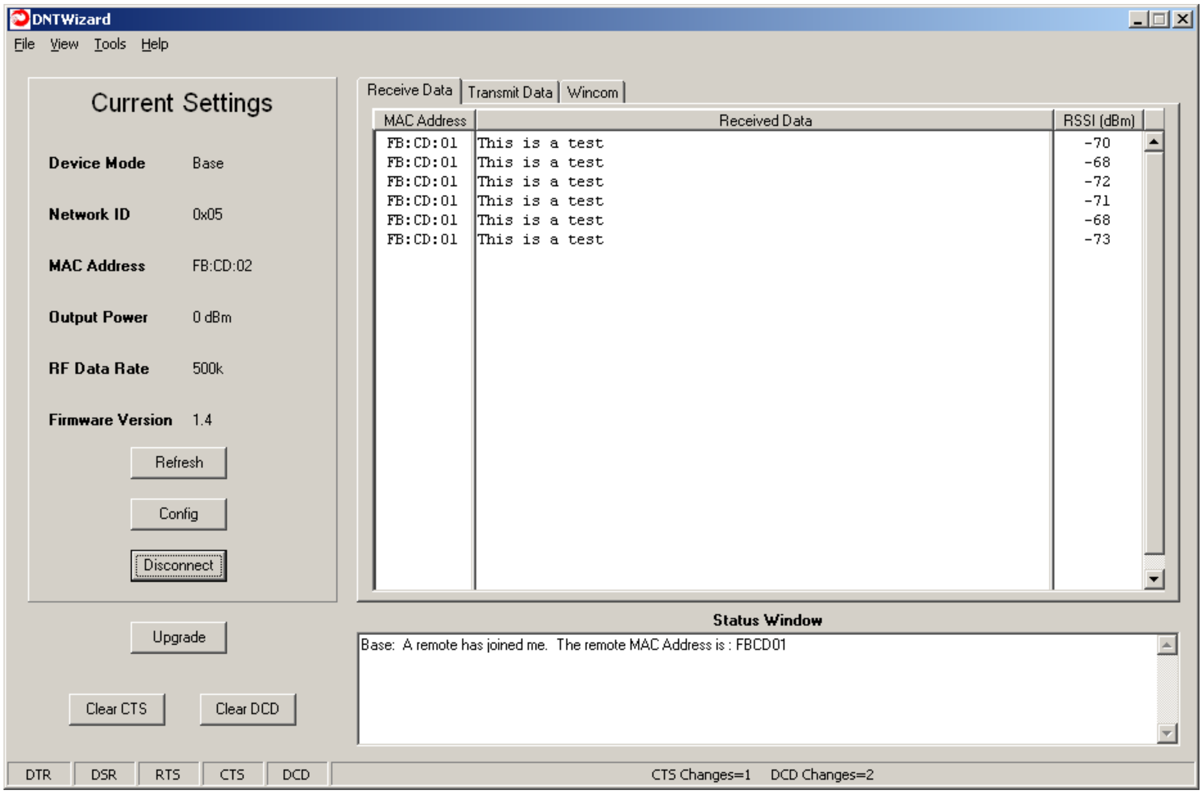
Current Settings

Device Mode	Base
Network ID	0x05
MAC Address	FB:CD:02
Output Power	0 dBm
RF Data Rate	500k
Firmware Version	1.4

Base: A remote has joined me. The remote MAC Address is : FBCD01

Figure 8.7.3

There are three tabs on the DNT Wizard main window: *Receive Data*, *Transmit Data* and *Wincom*.



Current Settings

Device Mode	Base
Network ID	0x05
MAC Address	FB:CD:02
Output Power	0 dBm
RF Data Rate	500k
Firmware Version	1.4

MAC Address	Received Data	RSSI (dBm)
FB:CD:01	This is a test	-70
FB:CD:01	This is a test	-68
FB:CD:01	This is a test	-72
FB:CD:01	This is a test	-71
FB:CD:01	This is a test	-68
FB:CD:01	This is a test	-73

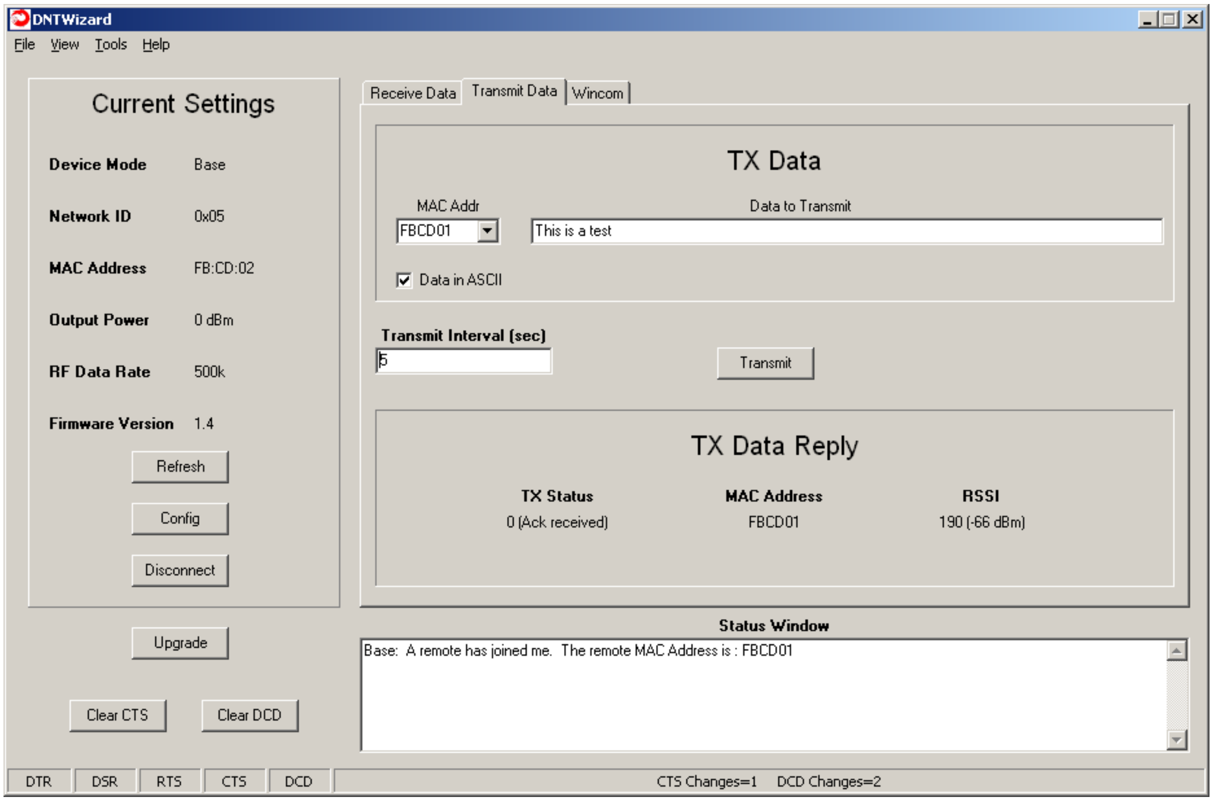
Status Window

```
Base:  A remote has joined me.  The remote MAC Address is : FBCD01
```

CTS Changes=1   DCD Changes=2

Figure 8.7.4

Received messages are displayed in the *Receive Data* tab, along with the MAC address of the sender and the RSSI (signal strength) of the received message in dBm. See Figure 8.7.4.



Current Settings

Device Mode	Base
Network ID	0x05
MAC Address	FB:CD:02
Output Power	0 dBm
RF Data Rate	500k
Firmware Version	1.4

TX Data

MAC Addr: FBCD01

Data to Transmit: This is a test

☑ Data in ASCII

Transmit Interval (sec): 5

TX Data Reply

TX Status	MAC Address	RSSI
0 (Ack received)	FBCD01	190 (-66 dBm)

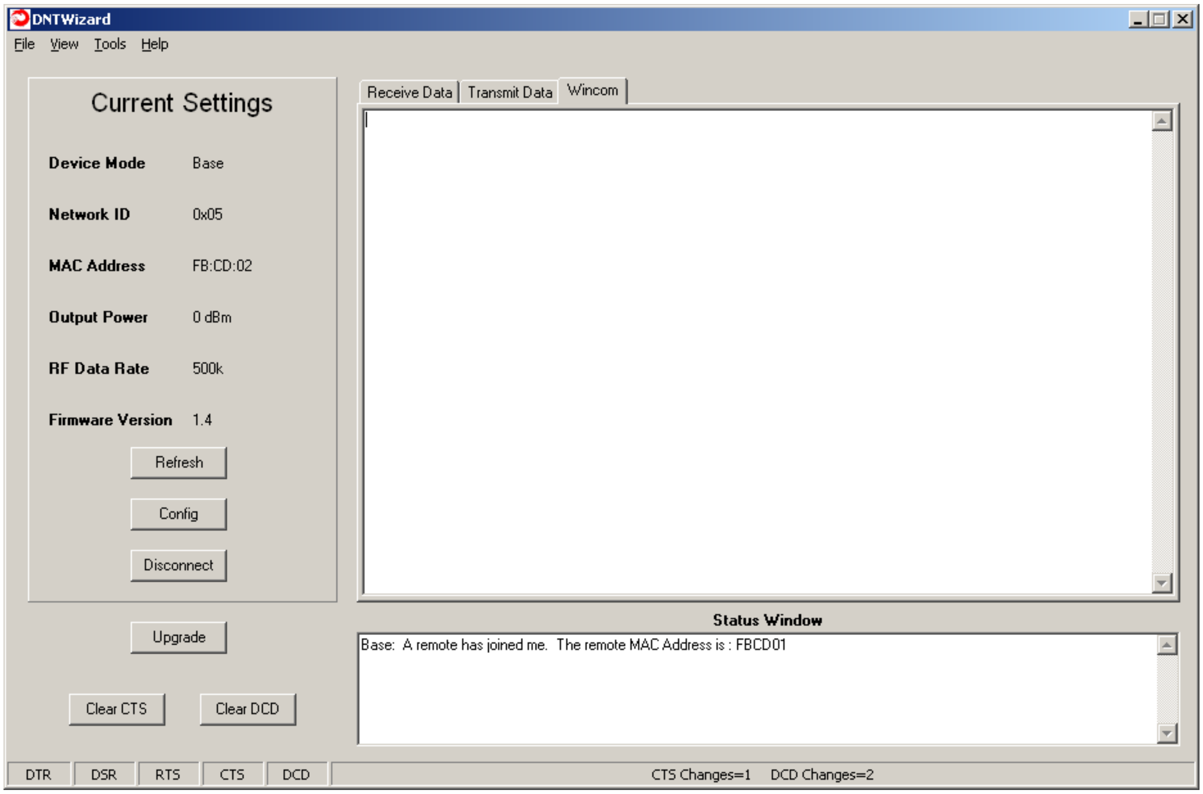
Status Window

Base: A remote has joined me. The remote MAC Address is : FBCD01

CTS Changes=1 DCD Changes=2

Figure 8.7.5

The *Transmit Data* tab is shown in Figure 8.7.5. The message to send is input in the *Data to Transmit* text box. The address to send the message can be chosen or input in the *MAC Addr* drop-down box. Note that the address for the base is always 0x000000. If the *Transmit Interval* is set to 0, the message is sent once each time the *Transmit* button is clicked. When the *Transmit Interval* is set to an integer greater than zero, the message will sent at the beginning of each interval until the *Stop* button (was *Transmit* button) is clicked. The status of each transmission is shown below *TX Data Reply*. Figure 8.7.5 shows that the transmitted message was ACKed, with the received signal strength of the ACK -66 dBm.



Current Settings

Device Mode Base

Network ID 0x05

MAC Address FB:CD:02

Output Power 0 dBm

RF Data Rate 500k

Firmware Version 1.4

Status Window

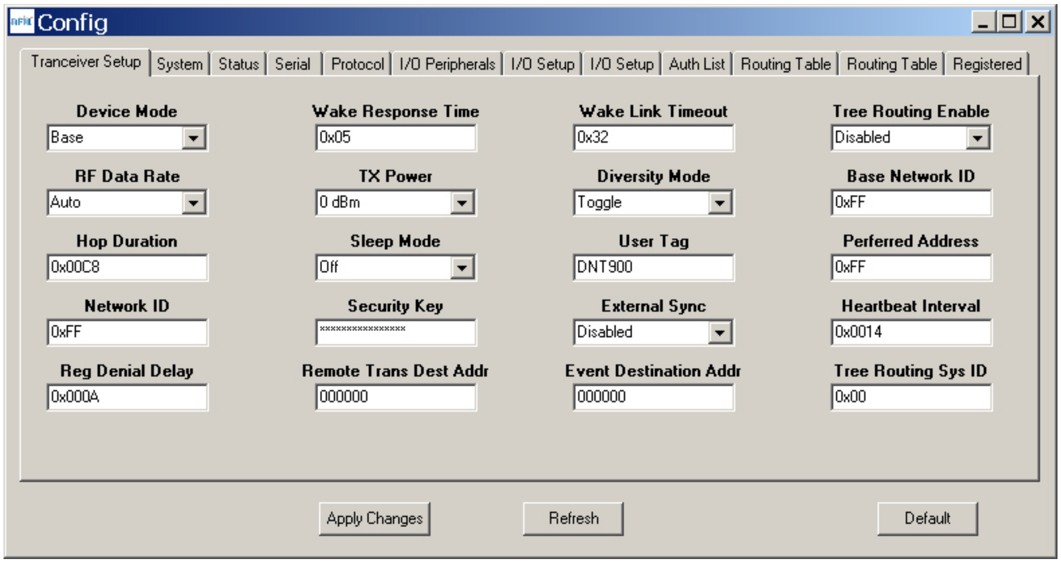
Base: A remote has joined me. The remote MAC Address is : FBCD01

CTS Changes=1 DCD Changes=2

Figure 8.7.6

As shown in Figure 8.7.6, the *Wincom* tab provides the basic functionality of a serial terminal program. Messages typed in are sent, and messages received are appended to the bottom of the on-screen text.

The multi-tab *Configuration* window is accessed by clicking on its *Config* button. The data presented on the first six tabs corresponds to configuration register Banks 0 through 5 as discussed in Section 7.5 above, with the data on the next two tabs corresponding to configuration register Bank 6, the data on the next tab corresponding to Bank 7, the data on the following two tabs corresponding to Bank 8, and the data on the last tab corresponding to Bank 9.

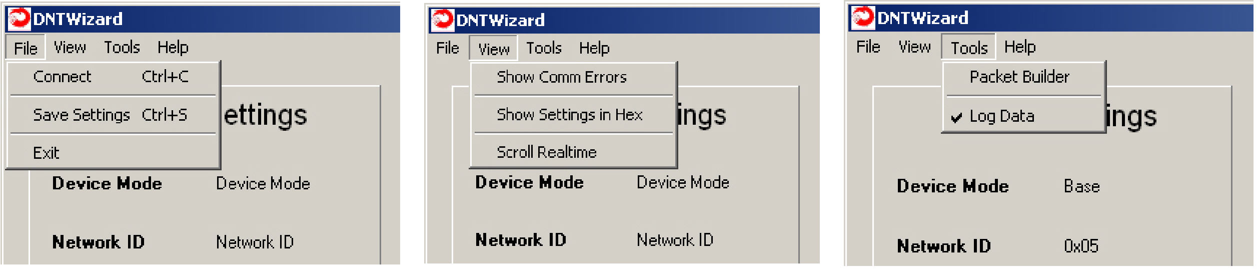


Device Mode	Wake Response Time	Wake Link Timeout	Tree Routing Enable
Base	0x05	0x32	Disabled
RF Data Rate	TX Power	Diversity Mode	Base Network ID
Auto	0 dBm	Toggle	0xFF
Hop Duration	Sleep Mode	User Tag	Perferred Address
0x00C8	Off	DNT900	0xFF
Network ID	Security Key	External Sync	Heartbeat Interval
0xFF	****************	Disabled	0x0014
Reg Denial Delay	Remote Trans Dest Addr	Event Destination Addr	Tree Routing Sys ID
0x000A	000000	000000	0x00

Figure 8.7.7

The *Configuration* window in the DNT Wizard is identical the *Configuration* window in the DNT Demo. See Figures 8.6.1.2 through 8.6.1.13 for *Configuration* window details.

Details of the *File*, *View* and *Tools* menus are shown in Figure 8.7.8.



Device Mode Device Mode

Network ID Network ID

Device Mode Device Mode

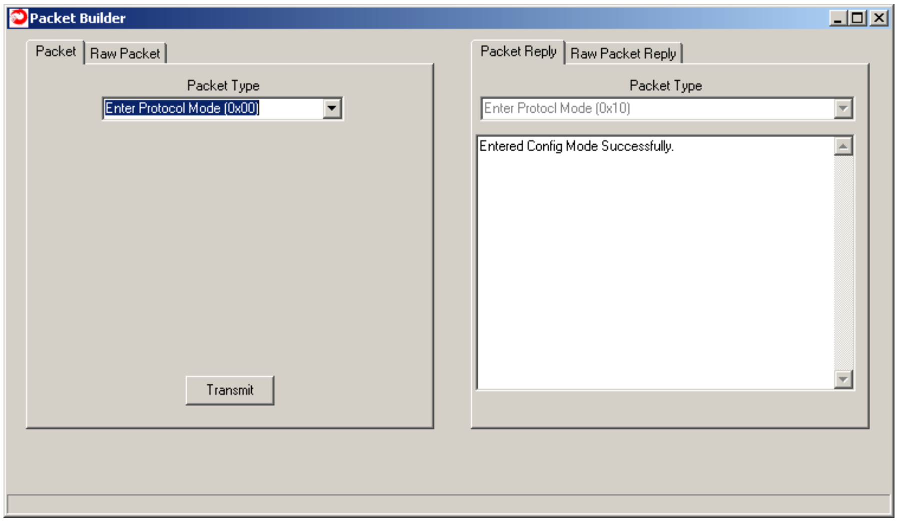
Network ID Network ID

Device Mode Base

Network ID 0x05

Figure 8.7.8

The *Tools* menu contains two very useful items. *Packet Builder* opens the window shown in Figure 8.7.9. On the left, the *Packet Type* drop-down box provides a selection of all packet types used in the DNT90 protocol. On the right, the reply packet types are presented.

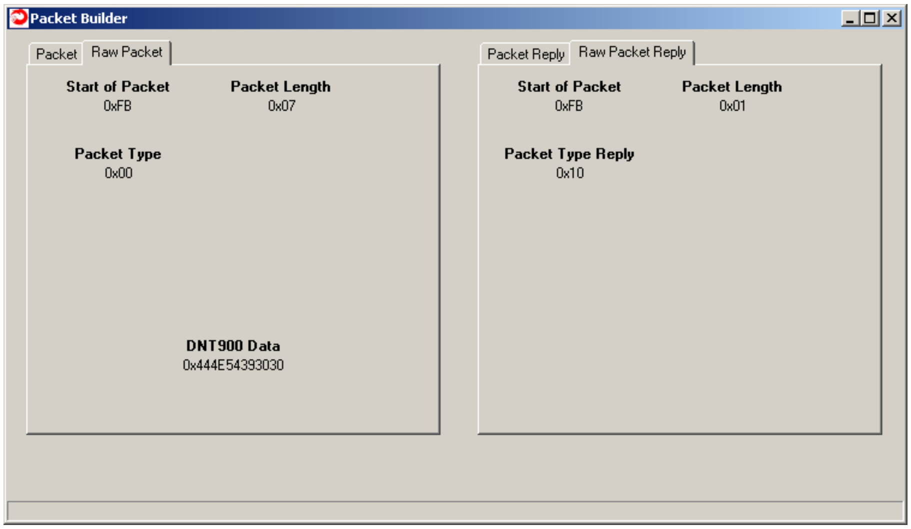


Packet Type: Enter Protocol Mode (0x00)

Packet Type: Enter Protocl Mode (0x10)

Entered Config Mode Successfully.

Figure 8.7.9



Start of Packet 0xFB

Packet Length 0x07

Packet Type 0x00

DNT900 Data 0x444E54393030

Start of Packet 0xFB

Packet Length 0x01

Packet Type Reply 0x10

Figure 8.7.10

Figure 8.7.10 shows the *Raw Packet* and *Raw Packet Reply* tabs. Components of the protocol messages are shown in hexadecimal format.

Log Data controls the log file. Logging is enabled by default. The log file created is *logfile.dat*, and is in ASCII text format. An example log is shown below:

```
New Data----------------------------------------
12/7/2008  |  7:05:39 AM
DNT Wizard Version 0.92
Sent Data : FB 07 00 44 4E 54 35 30 30 (Enter Protocol Mode)
Recv Data : FB 01 10 (Enter Protocol Mode Reply)
Sent Data : FB 04 03 00 00 2C (Get Register)
Recv Data : FB 30 13 00 00 2C 01 FF 68 01 05 2A 2A 2A 2A 2A 2A 2A 2A 2A 2A 2A 2A 2A 2A 2A 2A
00 05 32 00 00 02 02 44 4E 54 39 30 30 00 00 00 00 00 00 00 00 00 (Get Register Reply)
Sent Data : FB 04 03 00 01 0E (Get Register)
Recv Data : FB 12 13 00 01 0E 00 03 D2 05 00 05 08 03 0A 0E 0C 30 14 00 (Get Register Reply)
Sent Data : FB 04 03 00 02 27 (Get Register)
Recv Data : FB 2B 13 00 02 27 02 CD FB 00 05 00 00 04 47 08 00 FF 42 14 49 01 18 00 A9 00 00
05 00 31 31 2F 31 38 2F 30 38 31 36 3A 30 30 3A 35 30 (Get Register Reply)
Sent Data : FB 04 03 00 03 04 (Get Register)
Recv Data : FB 08 13 00 03 04 04 00 00 07 (Get Register Reply)
Sent Data : FB 04 03 00 04 08 (Get Register)
Recv Data : FB 0C 13 00 04 08 00 05 05 01 07 00 02 00 (Get Register Reply)
Sent Data : FB 04 03 00 05 12 (Get Register)
Recv Data : FB 16 13 00 05 12 01 00 00 00 01 01 F5 01 FD 01 DA 01 00 00 00 00 00 00 (Get
Register Reply)
Sent Data : FB 04 03 00 06 1E (Get Register)
Recv Data : FB 22 13 00 06 1E 00 00 00 01 00 00 00 00 00 00 01 00 00 00 FF 03 00 00 FF 03
00 00 FF 03 01 B8 0B 00 00 (Get Register Reply)
Recv Data : FB 07 27 A2 01 CD FB 01 01 (Announce)
Sent Data : FB 12 05 01 CD FB 54 68 69 73 20 69 73 20 61 20 74 65 73 74 (TX Data)
Recv Data : FB 06 15 00 01 CD FB BB (TX Data Reply)
Sent Data : FB 12 05 01 CD FB 54 68 69 73 20 69 73 20 61 20 74 65 73 74 (TX Data)
Recv Data : FB 06 15 00 01 CD FB B6 (TX Data Reply)
Sent Data : FB 12 05 01 CD FB 54 68 69 73 20 69 73 20 61 20 74 65 73 74 (TX Data)
Recv Data : FB 06 15 00 01 CD FB BA (TX Data Reply)
Sent Data : FB 12 05 01 CD FB 54 68 69 73 20 69 73 20 61 20 74 65 73 74 (TX Data)
Recv Data : FB 06 15 00 01 CD FB B8 (TX Data Reply)
Sent Data : FB 12 05 01 CD FB 54 68 69 73 20 69 73 20 61 20 74 65 73 74 (TX Data)
Recv Data : FB 06 15 00 01 CD FB B3 (TX Data Reply)
```

The log file is especially useful in confirming the format of specific protocol commands and replies.

8.8 DNT90 Interface Board Features

The location of LEDs D1 through D4 and jumper pin set J14 are shown in Figure 8.8.1.

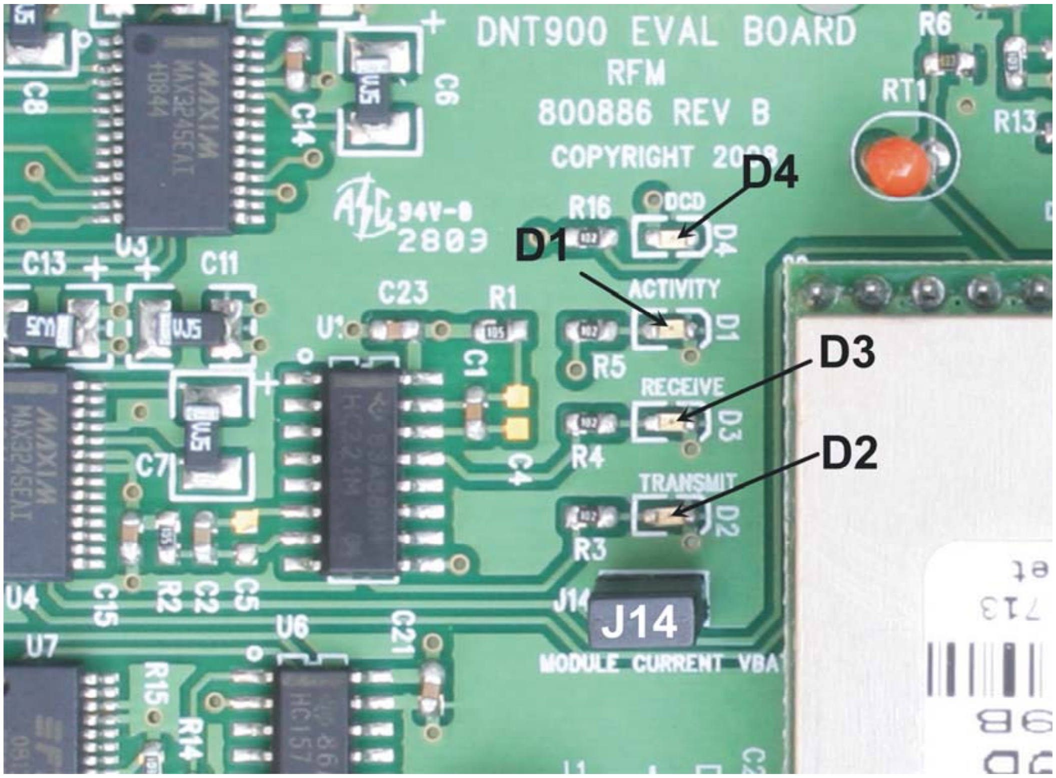


Figure 8.8.1

Amber DCD LED D4 illuminates on a remote to indicate it is registered with the base and can participate in RF communications. DCD LED D4 illuminates on the base when one or more remotes are registered to it, unless the base has been configured to assert DCD on power up. In this case it will be on as long as the dev board is powered. Green Activity LED D1 illuminates when transmitting or receiving RF data. Red Receive LED D3 illuminates when sending received data through the serial port to the PC. Green Transmit LED D2 illuminates when the PC sends data through the serial port to be transmitted. Jumper pin set J14 is provided to allow measurement of the DNT90P current. For normal operation J14 has a shorting plug installed.

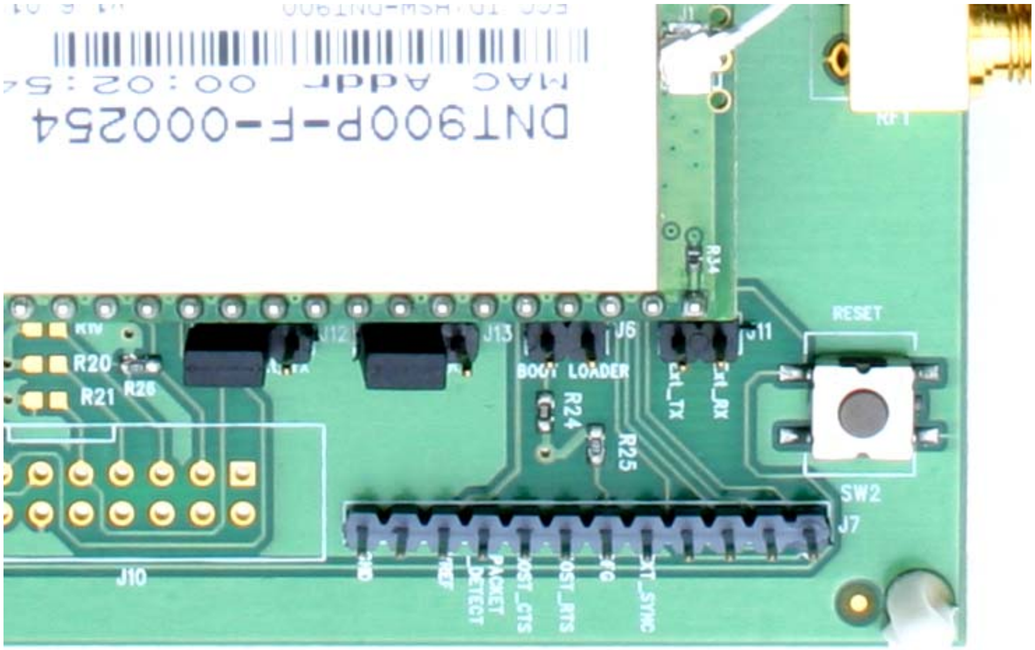


Figure 8.8.2

Figure 8.8.2 shows the connectors to the right of the DNT90P mounting socket. Jumper pin sets J12 and J13 normally have shorting plugs installed as shown in Figure 8.8.2, which connects the DNT90P RADIO_TXD and RADIO_RXD pins to the respective serial data lines on the evaluation board. It is possible to connect directly to RADIO_TXD and RADIO_RXD by moving the jumpers over. In this case, J11-1 is the input for transmitted data and J11-2 is the output for received data. *Note this a 3 V logic interface.* The DNT90 has its own boot loader utility that allows the protocol firmware to be installed with a terminal program that supports YMODEM. Pin strip J7 provides access to various DNT90 pins as shown on the silkscreen. Pressing switch SW2 will reset the DNT90P.

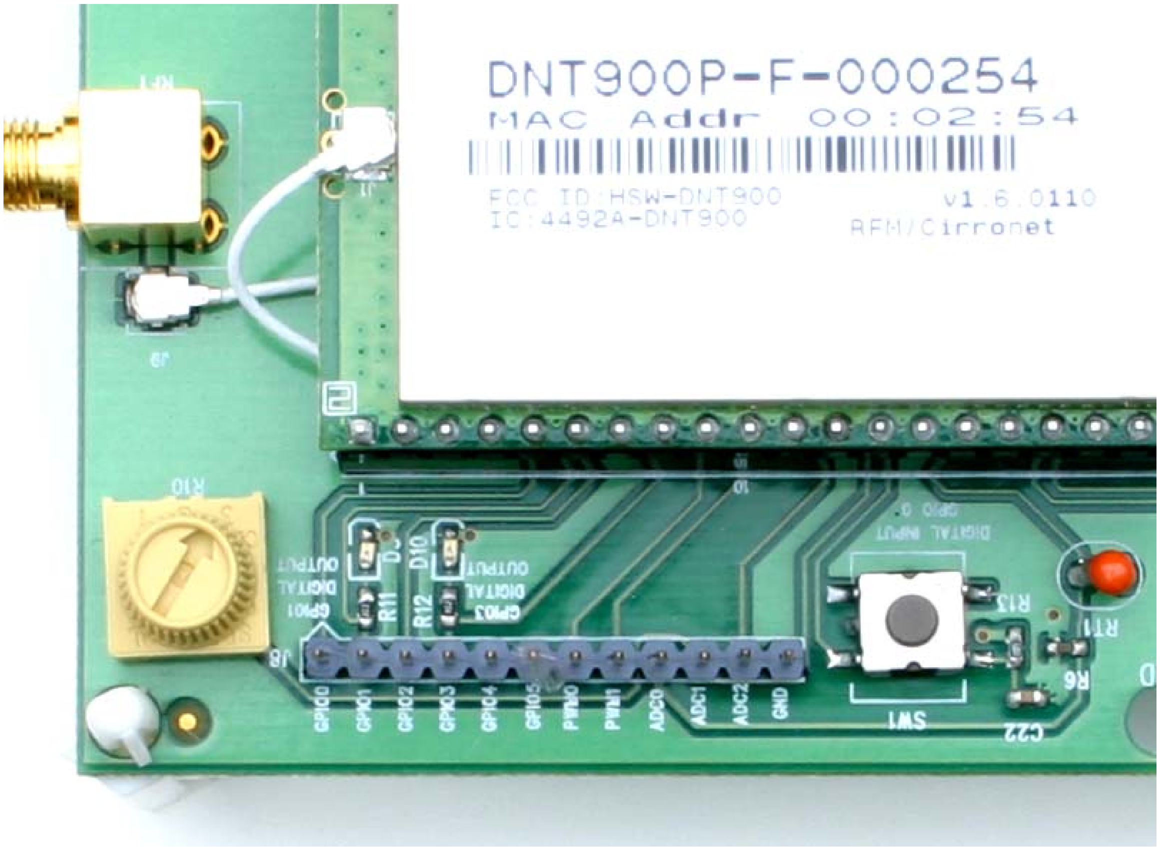


Figure 8.8.3

Figure 8.8.3 shows the connectors to the left of the DNT90P mounting socket. Pressing switch SW1 switches GPIO0 from logic high to logic low. Pin strip J8 provides access to various DNT90 pins as shown on the silkscreen. The wiper of pot R10 drives the input of ADC1. Clockwise rotation of the pot wiper increases the voltage. Thermistor RT1 is part of a voltage divider that drives ADC0. LED D5 illuminates when GPIO1 is set as a logic high output. LED D10 illuminates when GPIO3 is set as a logic high. The DNT90P interface board includes a 5 V regulator to regulate the input from the 9 V wall-plug power supply. Note: do not attempt to use the 9 V wall-plug power supply to power the DNT90P directly. The maximum allowed voltage input to the DNT90P is 5.5 V.

9.0 Troubleshooting

DNT90 not responding - make sure SLEEP/DTR is not asserted (logic low) to bring the radio out of sleep mode.

Can not enter protocol mode - make sure the host data rate is correct. The DNT90 defaults to 9.6 kbps. If using the *EnterProtocolMode* command, send the complete protocol format for this command.

A remote never detects carrier (DCD) - check that the base is running, and that the remote's SystemNwk-ID is the same as the base, and that the *ParentNwkID* parameter is the same as the base, or is set to 0xFF. Also make sure that the security keys are the same.

Carrier is detected, but no data appears to be received - make sure that /HOST_RTS is asserted to enable receive character flow.

Range is extremely limited - this is usually a sign of a poor antenna connection or the wrong antenna. Check that the antenna is firmly connected. If possible, remove any obstructions near the antenna.

9.1 Diagnostic Port Commands

FSTAT <option> - enables a frequency-ordered channel activity status log.

Available options are:

0 - off
1 - on

For either a base or remote, FSTAT shows the DataTx (data packet transmitted), AckRx (ACK received) and RegRx (registration or renewal request or reply received) activity status on each frequency with ASCII characters as follows:

'.' (0x2E) - no activity
'1' (0x31) - DataTx activity only
'2' (0x32) - AckRx activity only
'3' (0x33) - DataTx and AckRx activity
'4' (0x34) - RegRx activity only
'5' (0x35) - DataTx and RegRx activity
'6' (0x36) - AckRx and RegRx activity
'7' (0x37) - DataTx, AckRx and RegRx activity

A sample FSTAT output for 50 channel operation is shown below. The status data is order from the lowest operating frequency on the left to the highest operating frequency on the right. An ASCII CR-LF terminates each line. On most frequencies, DataTx and AckRx occur on the same frequency (‘3’). Occasionally there is DataTx, AckRx and RegRx activity (‘7’), DataTx only activity (‘1’), or no activity (‘.’).

```
33333333333333333333333333133333333333333333333333
33333333333333333333333333333333333333333333333333
33333333333333333333373333133333333333333333333333
33333333333333333333333333333333333333333333333333
33313333333233333333333333333333.33333333333333333
```

INSTR <option>

Available options are:

0 - off
1 - on

For either a base or a remote, INSTR streams instrumentation packets including a time stamp and seven data values. The time stamp is a string of four characters. The first three characters are ASCII representations of hexadecimal numbers. The fourth character is a ‘>’ character. Each time stamp count is 100 µs. The time stamp rolls over to 0x000 after count 0xCE5. The content of the seven data values are detailed below. ASCII representations of the hexadecimal value of each byte are output, separated by space characters:

Byte 0: current channel, 0 to 49; frequency is 902.75 MHz + current channel * 0.5 MHz
Byte 1: same data as FSTAT 1, except no activity is 0x30
Byte 2: RSSI_Last, RSSI of last RF packet received in dBm, 8-bit signed value
Byte 3: RSSI_Idle, most recent RSSI value on a channel with no expected activity
Byte 4: Range delay estimate, remote only, 3.1 µs/tick
Byte 5: Status bits 1
    b7.. b4 - reserved
    b3 - inbound data RF flow control, 1 = device has disabled RF flow
    b2 - outbound data RF flow control, 1 = base has disabled RF flow
    b1 - /HOST_CTS, status of CTS line, 1 = hold
    b0 - /DCD, link LED on; on a remote indicates registration with base, on the base it indicates at least on remote is registered (default)
Byte 6: Status bits 0
    b7 - CSMA channel busy
    b6 - Parser/CRC error
    b5 - valid RF packet received (any type)
    b4 - DataRx, data packet received
    b3 - RegTx, registration or renewal request or reply transmitted
    b2 - RegRx, registration or renewal request or reply received
    b1 - AckRx, ACK received
    b0 - DataTx, data packet transmitted

A sample INSTR output is shown below.

```
896> 26 01 DA 98 00 01 01
940> 0A 03 DA 9C 00 01 23
9E2> 1D 03 DA 99 00 03 23
A8A> 30 01 D6 9F 00 03 21
B36> 11 03 D6 99 00 03 23
```

Looking a the first line in detail:

```
        896> 26 01 DA 98 00 01 01
```

The time stamp is 0x896>
Byte 0, 0x26, indicates the channel of operation is 38 (decimal)
Byte 1, 0x01, is the same status data as FSTAT data above. In this case, DataTx activity only.
Byte 2, 0xDA, is the last RSSI value, -38 dBm
Byte 3, 0x98, is the RSSI idle value, -100 dBm
Byte 4, 0x00, is the range delay estimate (remote only). The remote is very close to the base.
Byte 5, 0x01, provides the serial port status - /HOST_CTS is high
Byte 6, 0x01, provides the communication status - DataTx active only. Note that this byte provides additional status bytes compared to byte index 1.

10.0 Appendices

10.1 Ordering Information

DNT90C: transceiver module for solder-pad mounting
DNT90P: transceiver module for pin-socket mounting

10.2 Technical Support

For DNT90 technical support call RFM at (678) 684-2000 between the hours of 8:30 AM and 5:30 PM Eastern Time

10.3 DNT90 Mechanical Specifications

DNT90C Outline and Mounting Dimensions

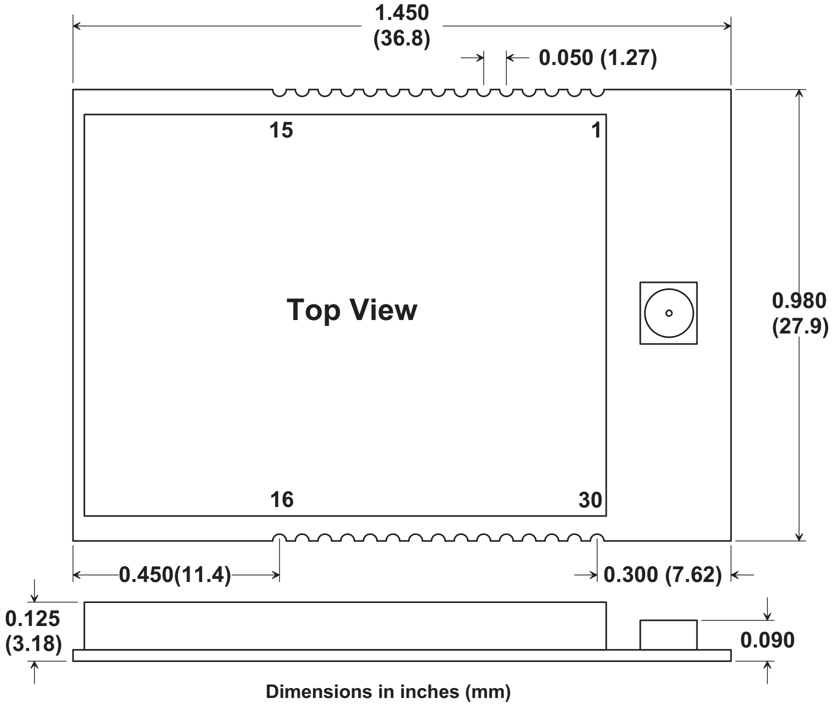


Figure 10.3.1

DNT90C Solder Pad Dimensions

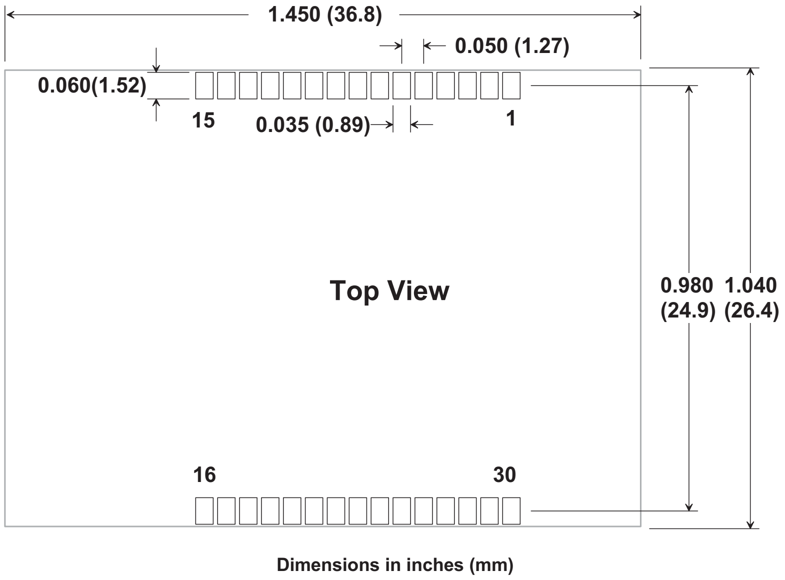
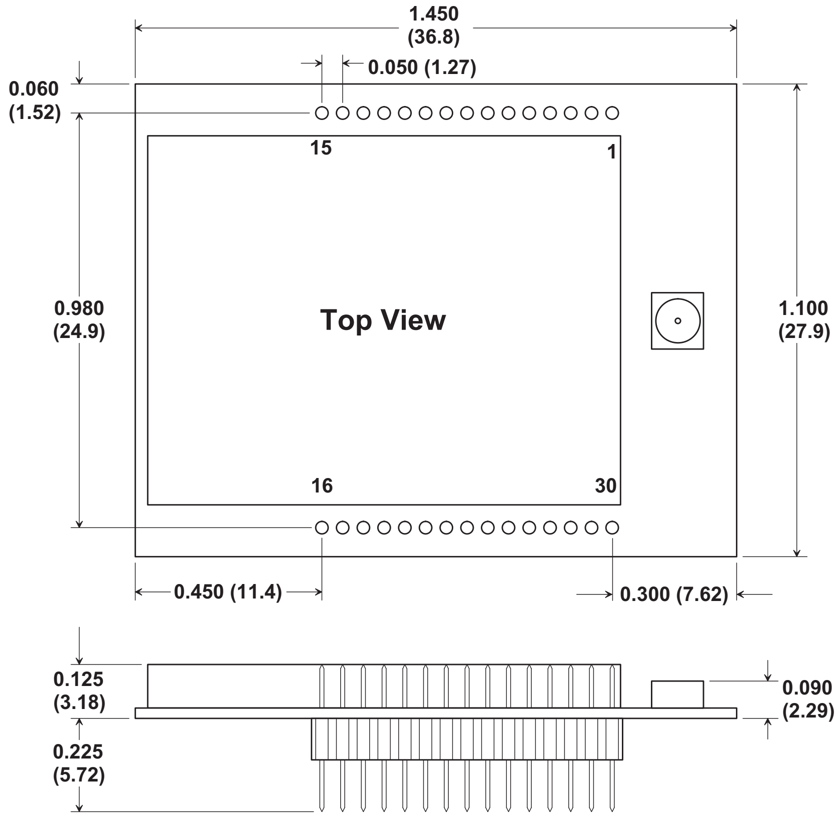


Figure 10.3.2

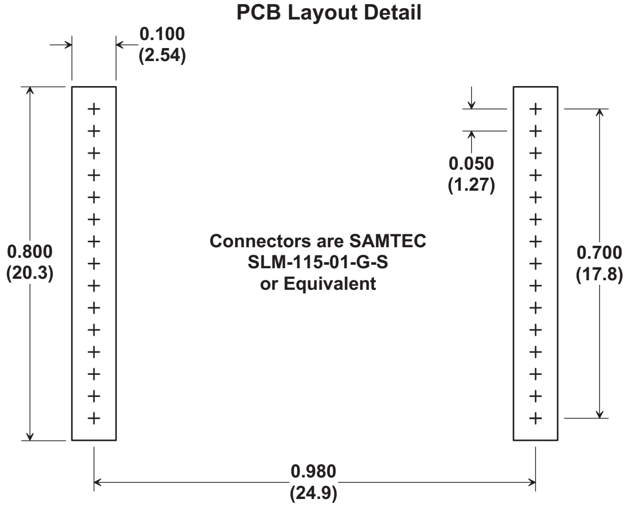
DNT90P Outline and Mounting Dimensions



Dimensions in inches (mm)

Figure 10.3.3

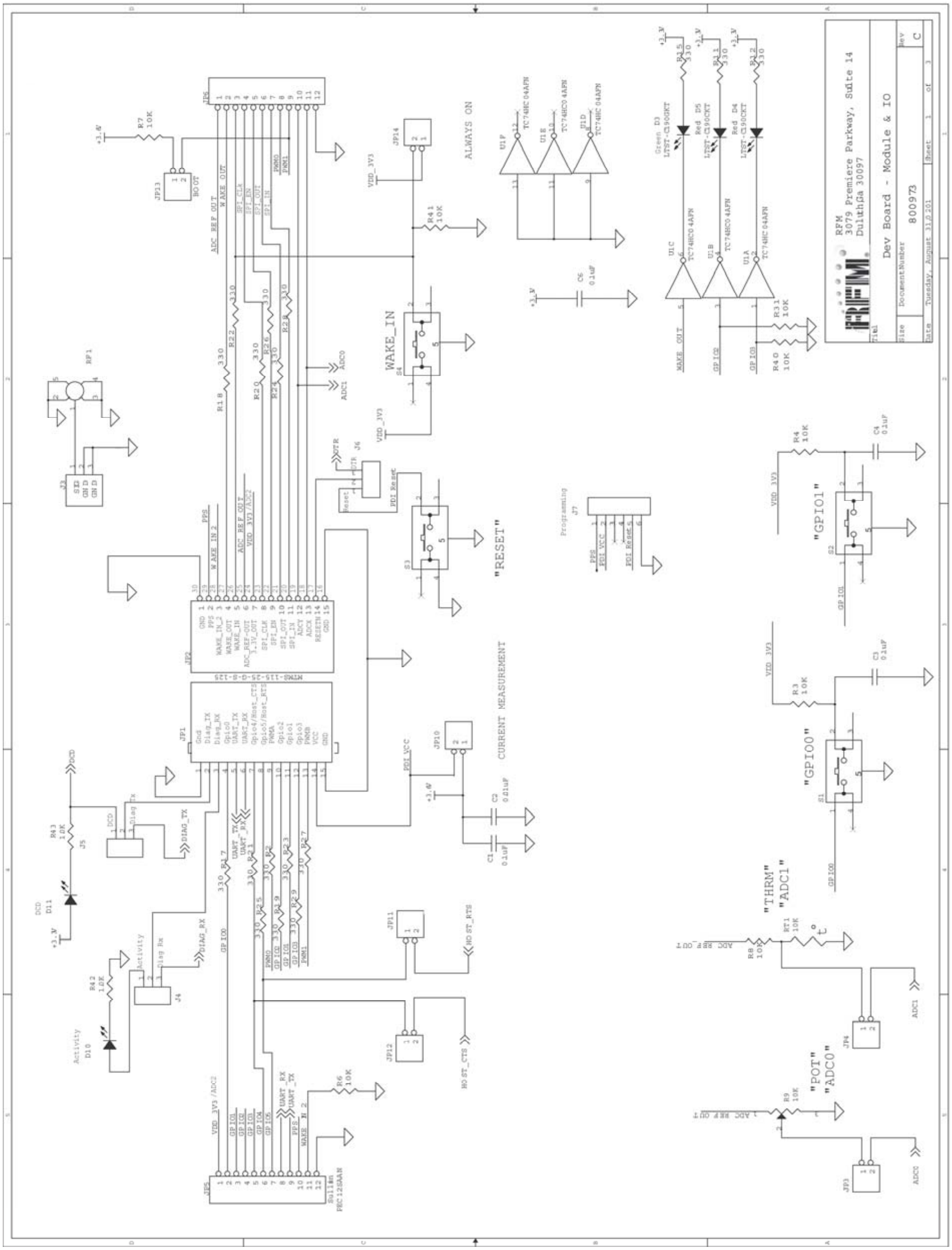
DNT90P Interface Connector
PCB Layout Detail

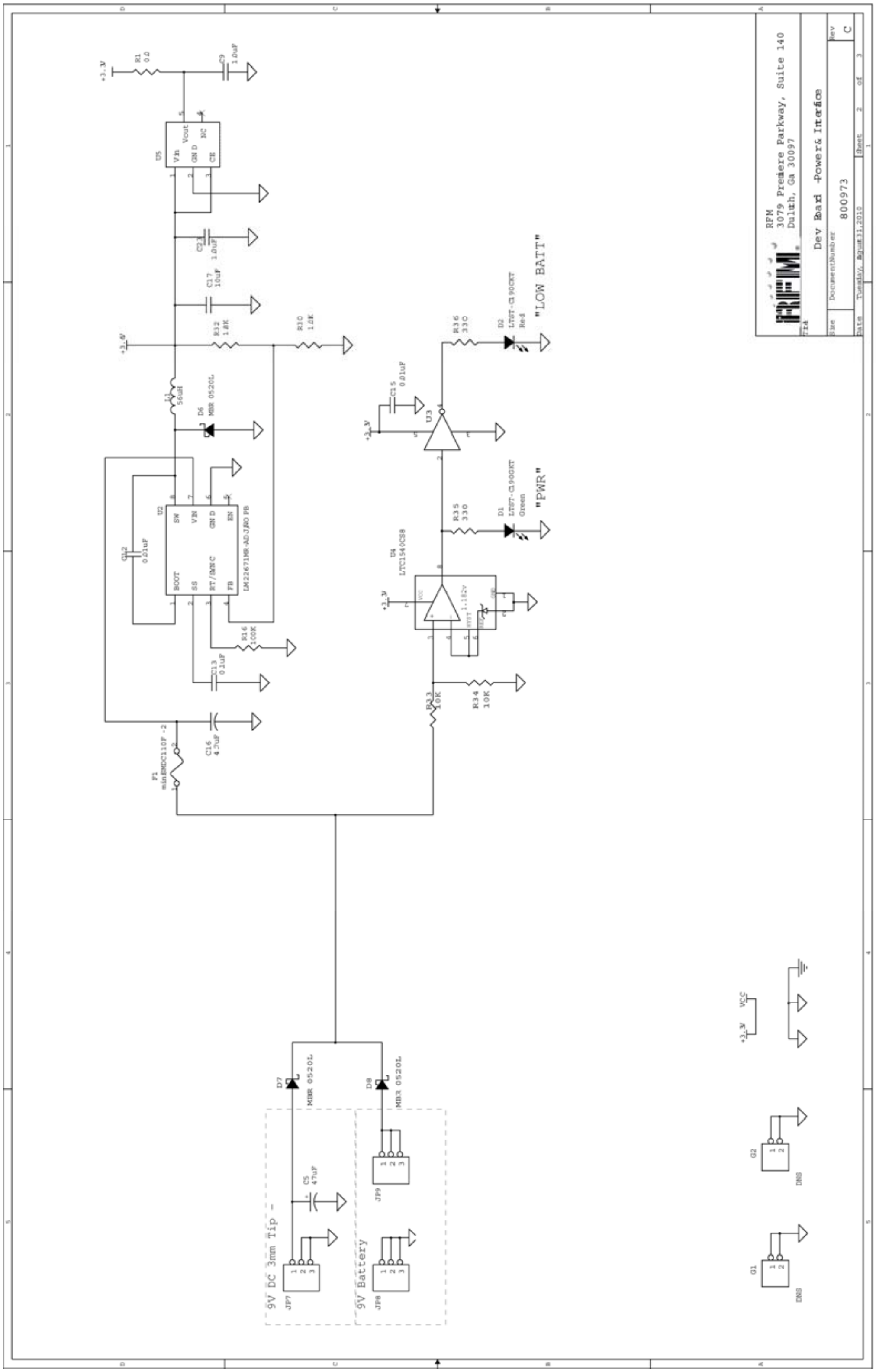


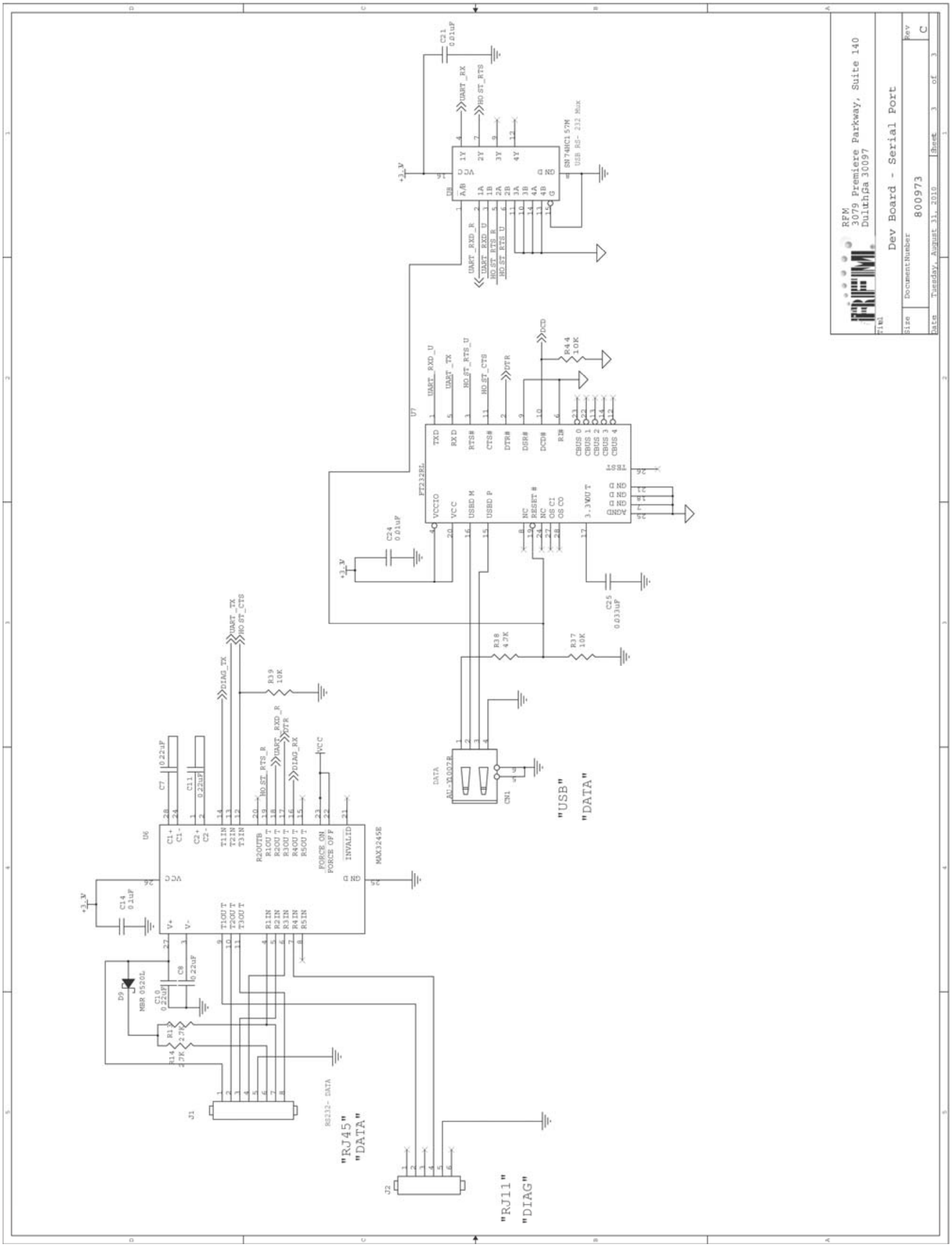
Dimensions are in inches (mm)

Figure 10.3.4

10.4 DNT90 Development Board Schematic




RFM
3079 Premiere Parkway, Suite 140
Duluth, Ga 30097
Title
Dev Board - Power & Interface
Size
Document Number
800973
Rev
C
Date
Tuesday, August 31, 2010
Sheet 2 of 3
+3.3V
R1
0.0
C9
1.0uF
U5
Vin
Vout
GND
NC
CE
C21
1.0uF
C17
10uF
R32
18K
R30
10K
L1
56uH
D6
MBR 0520L
U2
BOOT
SS
RT/SYNC
FB
SW
VIN
GND
EN
LM22671MR-ADJ/NOPB
C12
0.01uF
R16
100K
C13
0.1uF
C16
4.7uF
F1
miniSMDC110F-2
R36
330
D2
LTST-C190CKT
Red
"LOW BATT"
C15
0.01uF
U3
R35
330
D1
LTST-C190GKT
Green
"PWR"
U4
LTC1540CS8
VCC
1.182V
HYST
REF
GND
R33
10K
R34
10K
D7
MBR 0520L
D8
MBR 0520L
C5
47uF
JP7
9V DC 3mm Tip -
JP9
JP8
9V Battery
VCC
G1
G2
DNS


RFM
3079 Premiere Parkway, Suite 140
Duluth, Ga 30097
Title
Dev Board - Serial Port
Size
Document Number
800973
Rev
C
Date
Tuesday, August 31, 2010
Sheet 3 of 3
U8
SN74HC157M
USB RS-232 Mux
UART_RX
HOST_RTS
UART_RXD_R
UART_RXD_U
HOST_RTS_R
HOST_RTS_U
C21
0.01uF
+3_V
U7
FT232RL
UART_RXD_U
UART_TX
HOST_RTS_U
HOST_CTS
DTR
DCD
R44
10K
C24
0.01uF
C25
0.033uF
R38
4.7K
R37
10K
CN1
AU-Y1007R
DATA
"USB"
"DATA"
U6
MAX3245E
C7
0.22uF
C11
0.22uF
C14
0.1uF
C8
0.22uF
C10
0.22uF
D9
MBR 0520L
R13
2.7K
R14
2.7K
R39
10K
DIAG_TX
UART_TX
HOST_CTS
HOST_RTS_R
UART_RXD_R
DTR
DIAG_RX
VCC
J1
RS232- DATA
"RJ45"
"DATA"
J2
"RJ11"
"DIAG"

11.0 Warranty

Seller warrants solely to Buyer that the goods delivered hereunder shall be free from defects in materials and workmanship, when given normal, proper and intended usage, for twelve (12) months from the date of delivery to Buyer. Seller agrees to repair or replace at its option and without cost to Buyer all defective goods sold hereunder, provided that Buyer has given Seller written notice of such warranty claim within such warranty period. All goods returned to Seller for repair or replacement must be sent freight prepaid to Seller's plant, provided that Buyer first obtain from Seller a Return Goods Authorization before any such return. Seller shall have no obligation to make repairs or replacements which are required by normal wear and tear, or which result, in whole or in part, from catastrophe, fault or negligence of Buyer, or from improper or unauthorized use of the goods, or use of the goods in a manner for which they are not designed, or by causes external to the goods such as, but not limited to, power failure. No suit or action shall be brought against Seller more than twelve (12) months after the related cause of action has occurred. Buyer has not relied and shall not rely on any oral representation regarding the goods sold hereunder, and any oral representation shall not bind Seller and shall not be a part of any warranty.

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