CEL Z-Plus Series

FREESTAR MODULE

For ZigBee / 802.15.4 Data Transmission

CEL California Eastern Laboratories

LS RESEARCH
Wireless Product Development

About This Manual

This document provides the user with details in setting up and using the FreeStar evaluation kit (Part # FS24-100ST-KIT). The document also provides information and references for software developers to write applications for use with the FreeStar module (Part # FS24-100ST).

This document contains the following chapters:

Chapter 1 – Evaluation Kit Overview

Chapter 2 – Quick Start

Chapter 3 – Interface Module Description

Chapter 4 – FreeStar Evaluation Software

Chapter 5 – FreeStar/Zigbee Ready Module Input/Output

Chapter 6 – FreeStar Application Guide

Appendix A – Open Field Range Test Results

Appendix B – Agency Statements

Related Documents

❏ Host Protocol

❏ EICD

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CHAPTER 1

FreeStar Evaluation Kit Overview

1.1 Description

The evaluation kit provides the end user the ability to quickly become familiar with the FreeStar module. Included in the kit are two FreeStar modules and a quick start guide to demonstrate the communication link between the two modules. Also included is a GUI interface referred to as the FreeStar Evaluation Test Tool (TT) to quickly communicate with the RF modules.

The Evaluation software demonstration is presented in Chapter 4. The important features provided by the evaluation software are:

- Short and Long Addressing

- Configurable Digital and Analog I/O

- Demonstrating a Wireless Link

- Packet Error Rate Statistics.

1.2 Contents

The FreeStar Evaluation Kit Contains:

- ❑ Two RF Modules with Firmware Loaded

- ❑ Two Interface Modules

- ❑ Two RS-232 Interface Cables

- ❑ 4 AA Batteries

- ❑ 1 CD (includes this User's Guide, Host Protocol Document, EICD, and FreeStar Evaluation Tool "Setup.exe" file)

CHAPTER 2

Quick Start

2.1 Board Description

The FreeStar module is a 2.4GHz 802.15.4 data transceiver module based on the Freescale MC13192 Low Power Transceiver device. It provides enhanced range performance with a 100mW* power amplifier. The module also contains the Freescale MC9S08GT60CFD microprocessor and an integrated PCB trace antenna. Power is supplied by the host device through the interface connection in accordance to the operating voltage requirements with a nominal operating voltage of +3.3V. Exact details on the interface connections and messaging are available in the FreeStar Electrical Interface Control Drawing.
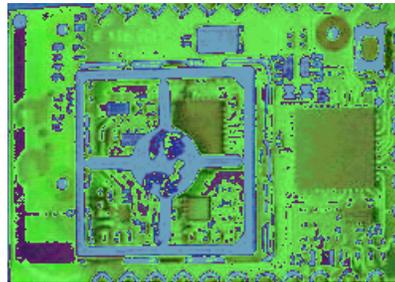

Figure 2-1. Top-Side of RF FreeStar Module
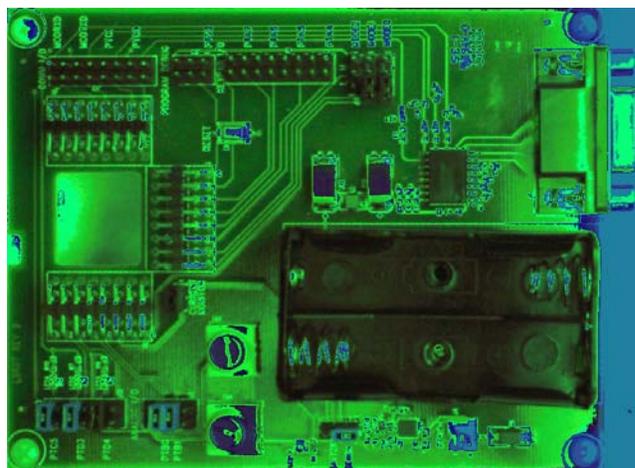
Figure 2-2. Top Side of FreeStar Interface Board

* Operation is Limited to 10mW Maximum for European Union Compliance
  For Australia/ New Zealand Operation, a 100milli-watt EIRP setting may be maintained

2.2 Operational Overview

The quick start demonstration presented in this chapter is referred to as the ping pong test*. The ping pong test allows an end user to easily verify communication between two transceivers and get a feel for the quality of the link via feedback of the flashing LEDs.

Operation involves two boards, with one designated as a master device and the other as a slave device. The master periodically transmits packets to the slave. If the slave receives and verifies the packet, it will flash its LEDs and transmit an acknowledgement to the master. If the master receives and verifies the acknowledgement, it will flash its LEDs.

In normal ping pong mode, LEDs indicate signal strength (two LEDs on indicate high signal strength, one LED indicates low signal strength). If the LEDs do not light, the packet or acknowledgement was not received.

2.2.1 Power Up

Insert batteries into interface boards and verify that battery supply is selected using the jumper as shown in Figure 3-2 chapter 3.

2.2.2 Master/Slave Selection

Master device setup:

1. Press white reset button on Interface Board (See Figure 3-1 location 3) and black button on FreeStar module simultaneously.

2. Release reset button on Interface Module.

3. Wait until green LED is lit, then release button on FreeStar module

Slave device setup:

1. Press white reset button on Interface Board (See Figure 3-1 location 3) and black button on FreeStar module simultaneously.

2. Release reset button on Interface Module

3. Quickly release the button on FreeStar module (Release within 1.5 seconds of performing step 2 above).

2.2.3 Association Mode

In association mode, the red LED will flash rapidly on each board until it has linked with the other device. At this point, the red LED will go out and the green LED will begin to flash rapidly for approximately two seconds. Association mode lasts up to thirty seconds after power up, so the master and slave pair should be powered up at relatively the same time. If the transceivers link, they will enter the ping pong mode after association mode times out. However, if they do not link, they will not communicate and the sequence must be repeated from the point of master/slave selection at power up.

* Demonstration Application Operates at 100mW (This value is Not European Union Compliance)

2.2.4 Ping Pong Mode

In ping pong mode, the master and slave boards will flash one or two LEDs with each packet (slave) or acknowledge (master) received, based on message signal strength. In case there is a lot of other traffic on the default channel, it is possible to change the channel.

2.2.5 Channel Changing
(can only be performed if boards have been associated)

While in the ping pong mode, the current channel can be changed to one of four other unique channels (five channels total). This is accomplished by holding the push button for approximately two seconds, at which point the green LED will be lit steady. Once the push button is released, the current channel option number (one through five) is displayed by a series of flashes on the red LED. Each short push button press will increment the channel option number and display it with a given number of flashes on the red LED. To accept the last selected channel, hold the push button until the green LED goes out (approximately two seconds). After again releasing the button, the device will return to the ping pong mode.

Note that both the master and slave devices must be set to the same channel option number for the pair to communicate, and each board must be individually set to that given channel option number.

FreeStar Interface Module

3.1 Interface Module Overview (See Figure 3 – 1 for Photo)

The interface module provides the user the ability to quickly assess the functions of the FreeStar module such as I/O and the mobility to verify operation of a wireless link in any environment of the user's choosing.

This chapter describes in detail the functions of the FreeStar interface board that can be verified using the FreeStar evaluation software provided in this kit.
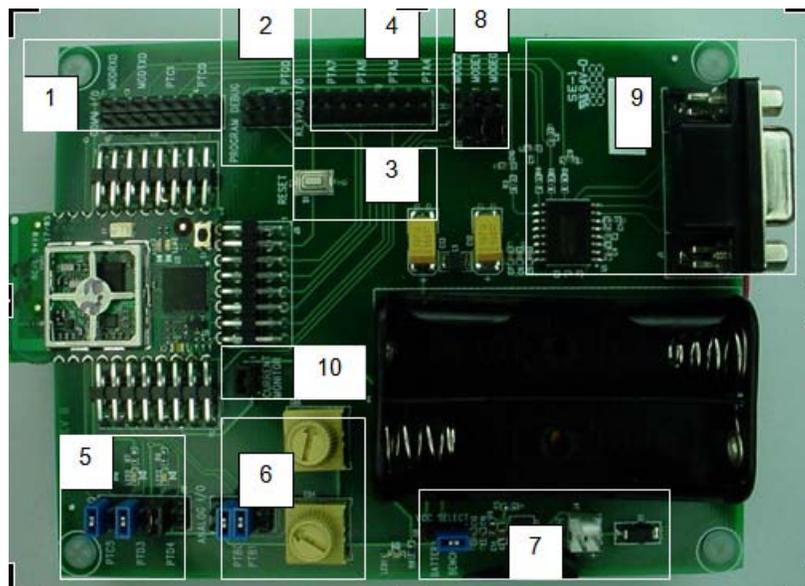
Figure 3-1 Interface Module with FreeStar Module Inserted in Socket

3.1.1 Interface Board Description for Each Location Shown in Figure 3-1

Serial Communications Header (location 1)

- Header that allows the user to monitor the serial TX (MODTXD) and RX (MODTXD) data lines from section 9 as shown in Figure 3-1 above. The header also provides quick access to Port C pins 0 and 1 on the microprocessor.

Programming Header (location 2)

- Location 2 refers to programming header for programming FreeStar Module. The suggested programmer for the RF Module is the USB HCS08/HCS12 Multilink programmer (Part # USB-ML-12)

Reset Button (location 3)

- Location 3 indicates the white button that provides ability to reset the microprocessor on the FreeStar module.

Port A Header for Access to I/O Pins (location 4)

- Header to provide quick access to Port A pins 4 thru 7 on the microprocessor.

LED Enable/Disable Header (location 5)

- To utilize LED's the jumpers must be connected as shown in Figure 3-1. The jumpers may be removed to externally access Port C pin 5 and Port D pins 3 and 4 for input or output operation.

Analog Input Select Header (location 6)

- Location 6 displays 2 yellow variable analog attenuators. With the jumpers installed as shown in location 6 on the ANALOG I/O header, the onboard attenuators may be utilized to demonstrate the analog capabilities of the FreeStar Module.

- Remove the two jumpers to utilize external analog peripherals.

Power Supply Circuitry (location 7)

- Location 7 encompasses the power supply circuitry. As shown the jumper is set for bench power supply (3.5 – 5VDC). Bench power supply may be connected to the white header (note positive and negative terminals).

- To use battery supply place the jumper as shown in Figure 3-2 below and insert 2 AA batteries in power pack onboard the interface board.
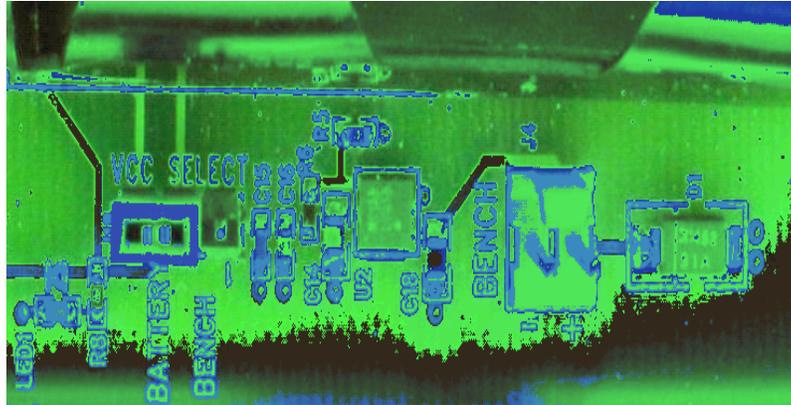
Figure 3-2. Jumper Set for Battery Supply

Mode Select (location 8)

- Leave jumpers uninstalled for normal operation

Serial Interface Circuitry and DB9 connector (location 9)

- Onboard host serial interface for use with supplied evaluation software.

Current Monitor Header (location 10)

- Provides user quick access to monitor current supplied to the RF Module. Useful in determining current used by device when in normal or sleep mode.

- To utilize this feature the user must remove the jumper and attach current monitor between the two header pins.

CHAPTER 4

Software Overview

4.1 Software Description

The FreeStar evaluation software was designed to give the developer an ability to quickly test the features built into the FreeStar module. The evaluation software is described in the following sections. A screen shot of the evaluation software is shown in Figure 4-1. Developers please refer to chapter 5 for information on building custom applications for use on the FreeStar module.
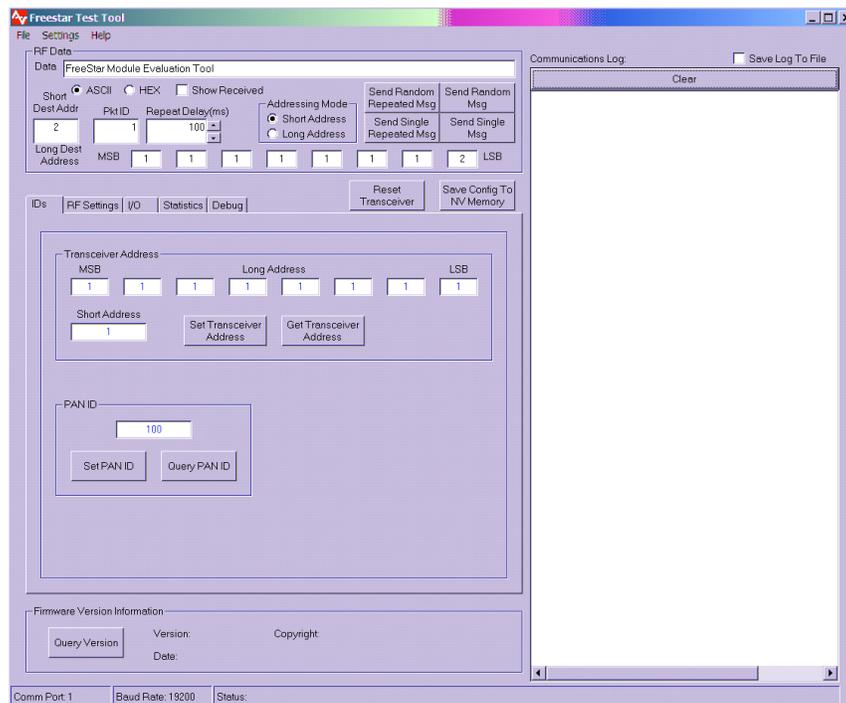

Figure 4-1. Evaluation Software - Main Screen

4.2 Software Setup

Install the Evaluation test tool using the self extracting setup program and execute the FreeStarTT.exe to start the program.

Before communication with the module is possible it is necessary to initialize the serial port.   Pull down the "Settings" menu and click the "Communications" entry. The screen shown in Figure 4-2 will appear.
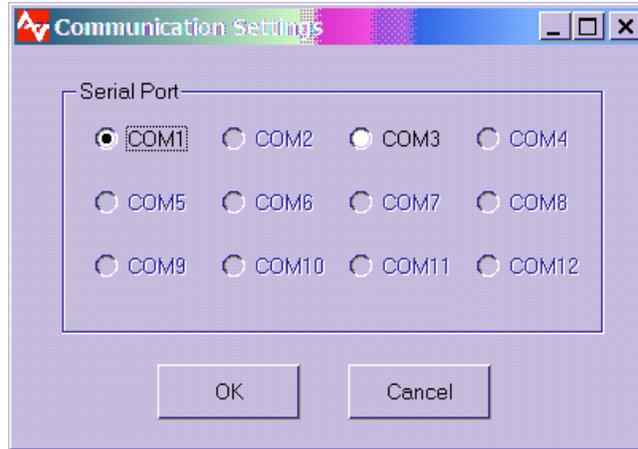
Figure 4–2. Communication Setup Screen under "Settings" Pull Down Menu

Determine serial port in use and select "OK". Next click the "Get Version" button on the bottom of the test tool to verify communication with the device. If the version does not appear verify correct COM port and select "OK" and verify communication successful.

If communication is still unsuccessful with the FreeStar module restart test tool and perform steps outlined above.

4.2.1   Main Section of Test Tool (Upper left portion of the Test Tool as shown in Fig 4-1)

RF Data

- Data - Text box to allow user to transmit desired messages to other modules or view messages from another module.

- Ascii/Hex (Radio Buttons) – Gives user ability to view or enter messages in Hex or Ascii format

- Show Received (Check Box) – If checked the RF Data text box displays received data in selected format.

- Addressing Mode – Selects whether messages are sent to a long or short address.

- Repeat Delay – Allows user to adjust time between sending repeated messages

Reset Transceiver (command button)

- Performs a software reset of the microcontroller.

Save Config to NV Memory (command button)

- Permanently saves configuration settings from ID and RF Settings pages to non volatile memory. This feature allows user to cycle power or reset the module without losing previous saved settings.

4.2.2 Setting Device Identification (See Figure 4-1)

Transceiver Address
- Short Address – Device defaults to using short address unless this field is set to 65,534. If using short address protocol only use values from 0 to 65,533
- Long Address – Eight byte address used for communication between devices if short address is set to 65,534.
- Set Transceiver Address – Sets Long and Short Address*
- Get Transceiver Address – Gets Long and Short Address*

PAN ID (Personal Area Network Identification)
- Set PAN ID – Range 0 to 16383 (14 bit Value)
- Get PAN ID – Returns current PAN ID

4.2.3 RF Settings (See Figure 4-3)

The RF Settings page can be accessed by selecting the *RF settings* tab in the software and is shown in Figure 4-3. The following features are provided in the RF settings page.

- Acknowledgement Settings* – If enabled the destination device will transmit an acknowledgement to the originating device. If disabled the destination device will not send an acknowledgement back to the originating device. Query Acknowledgement settings displays current setting in text box.

- Receive All Messages Setting* - If enabled all messages will be received from devices with same PAN ID and RF Channel and will inhibit device from transmitting. This feature is only to be used for diagnostic purposes.

- Set or Query RF Channel* - channels 11 – 26 may be used

- Set or Query Transmitter Power Level* - Ranges from 0 – 31 (31 is max level)**

- Set RF Module Power Mode for Sleep, Idle, or Wakeup.

- Set/Get All Programmable Settings (PAN ID, Txcvr Long Address, Txcvr Short Address, RF Channel, Receive All Setting, RF Acks/Retries, RF Power Level)

* To permanently save select the "Save Config to NV Memory"

**Set to a value of 14 to operate at 10mW Maximum for European Union Compliance.
  For Australia/ New Zealand Operation, a 100milli-watt EIRP setting may be maintained
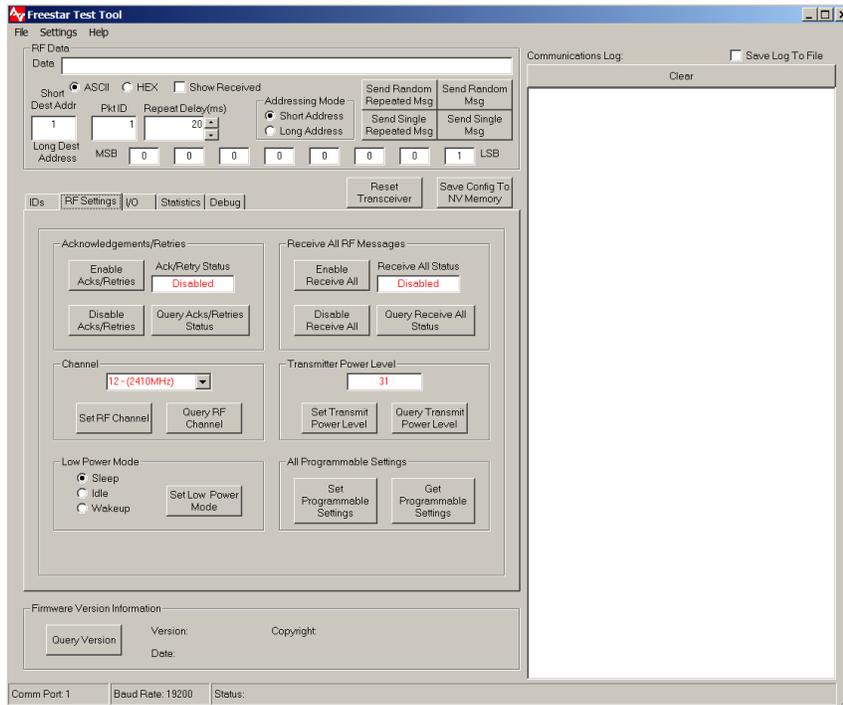
Figure 4–3. RF Settings

4.2.4 I/O Settings (See Figure 4-4)

The I/O page can be selected by clicking the I/O tab in the software. This is shown in Figure 4-4. The I/O page can be used to setup select digital and analog pins for desired operation.
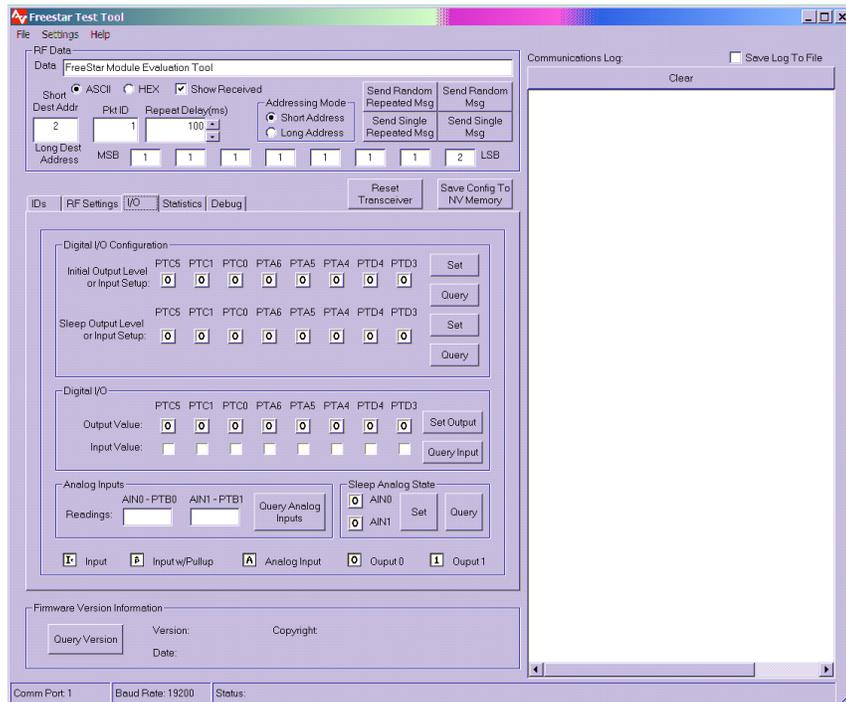
Figure 4–4. I/O Settings

<u>Digital I/O Configuration</u>

- Input Output Level or Input Setup – Gives user ability to set selective Port Pins for Output (0 or 1 Initial Value) or Input (With or Without Internal Pull Up Resistor Enabled)

- Sleep Output Level or Input Setup - gives user the ability to configure Digital I/O as desired for sleep state.

<u>Digital I/O</u>

- Output Value – User can select desired output value for any pin configured as output

- Input Value – Tells user whether the input has a 1 or 0 applied to selective pins configured as input (note pins configured as outputs will register as 0)

<u>Analog Inputs</u>

- Readings – Displays analog input read by the micro

<u>Sleep Analog State</u>

- gives user the ability to configure I/O as desired for sleep state. May be set to Digital Output 1 or 0 or the pins may remain set to analog inputs.

4.2.5 Statistics (See Figure 4-5)

The statistics page can be selected by clicking the *Statistics* tab in the software. This is shown in Figure 4-5. The statistics option can be used to evaluate the wireless link for packet error rates and throughput.
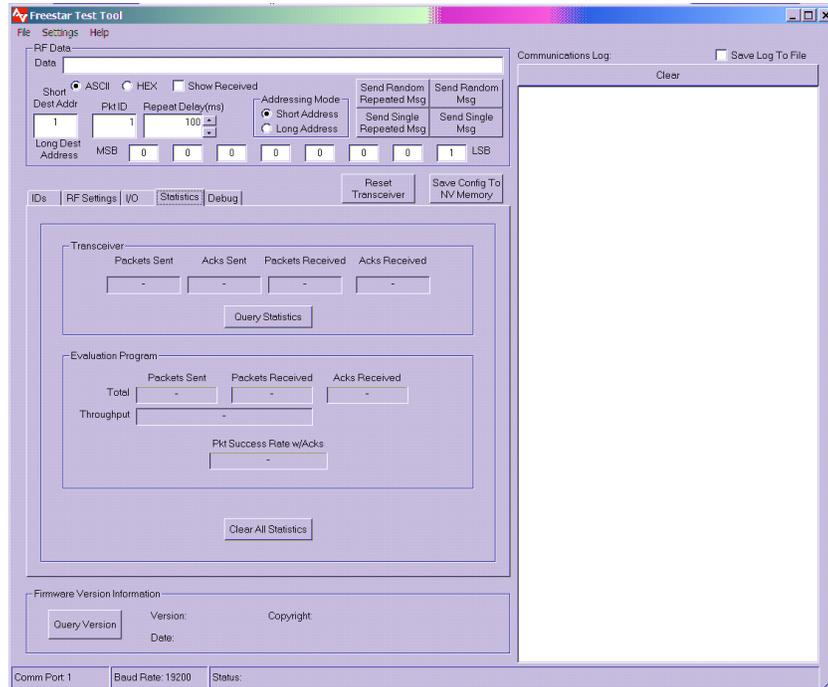
Figure 4-5. Statistics Settings Screen

Transceiver

- **Packets Sent**
  - Number of packets transmitted

- **Acknowledgements (ACK) Sent**
  - Number of acknowledgements sent by receiver.

- **Packets Received**
  - Number of packets received.

- **Acks Received**
  - Number of acknowledgements seen by transmitter.

"Evaluation Program" Statistics

The window toward the bottom the page labeled "Evaluation Program" contains information about the integrity of the link between the host computer and the radio board.

4.2.6 Debug Settings (See Figure 4-6)
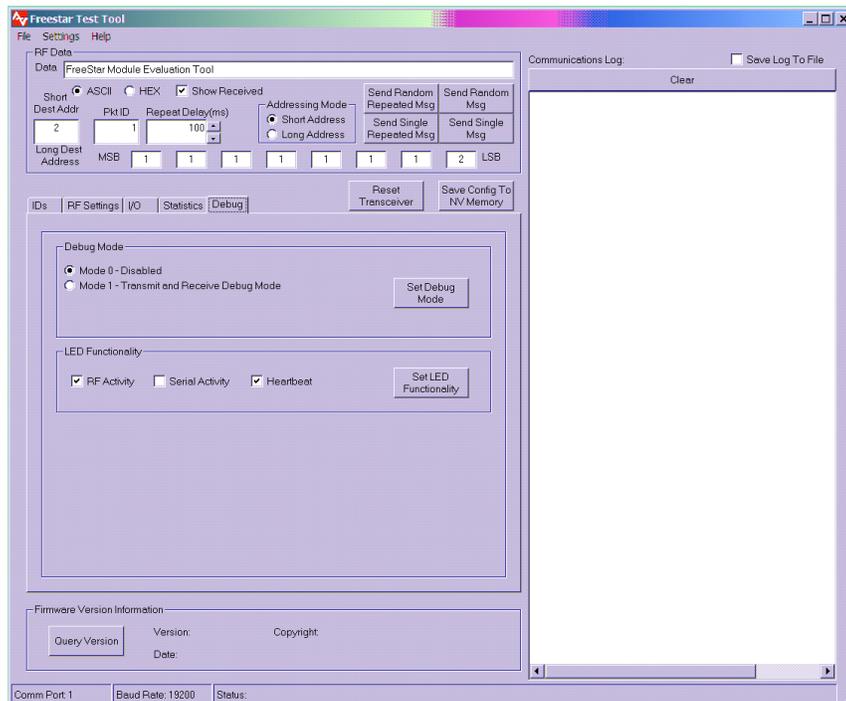
Figure 4-6. Debug Settings Screen

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<u>Debug Mode</u>

- Mode 0 – No debug pulses on pins

- Mode 1 – Refer to Host Protocol Document for Information

LED Functionality (Refer to Host Protocol Document for Information)

Red (LED2) = receive
Green (LED3) = transmit

- RF Activity – LEDs flash when transmitting or receiving device

- Serial Activity – LEDs flash when communicating through the serial port. Received RF messages will flash the transmit LED if the message is transmitted out the host serial port.

Heartbeat – Red LED flashes every two seconds to visually verify to user that device is operating

4.3 Setting Up and testing a Wireless Link

Operational testing of the FreeStar RF module requires at least 2 units in order to establish a link. One unit will be the initiator and the other will be the responder. In order for a link to be established it is necessary to setup the transceivers RF Channel, long or short address and PAN id.

Link testing may be performed in either a single ended or a round trip fashion. This can help to differentiate between real world packet error performance and raw radio performance. If Acknowledgement settings are not used then it is a single-ended test, if Acknowledgements are enabled then it is a round trip test.

4.3.1 Single-ended Test

Single ended performance will require 2 computers, since it will be necessary to read the statistics from each radio. An example setup is outlined below.

Device 1 (Refer to Figures 4-7 and 4-9)

1. Set PAN ID to 100 (IDs Page)

2. Set Short Address to 1 (IDs Page) *Note to use long addressing set short address to 65,534

3. Disable Acknowledgements/Retries (RF Settings Page)

4. Disable Receive All RF Messages (RF Settings Page)

5. Set to RF Channel 23 (RF Settings Page)

6. Set transmitter power setting to 31 (RF Settings Page)*

7. Set Short Destination address to 2 (Located Upper left corner of TT)

8. Select Short Address Radio Button (Upper Section of TT) *Long may be selected if sending to a long address device

9. Select "Save Config To NV Memory" Command Button (Upper Section of TT)

10. Check the Show Received box (Upper Section of Test Tool)

*Set to a value of 14 to operate at 10mW Maximum for European Union Compliance.
 For Australia/ New Zealand Operation, a 100milli-watt EIRP setting may be maintained.

<u>Device 2 (Refer to Figures 4-8 and 4-9)</u>

1. Set PAN ID to 100 (IDs Page)

2. Set short address to 2 (IDs Page) *Note to use long addressing set short address to 65,534

3. Disable Acknowledgements/Retries (RF Settings Page)

4. Disable Receive All RF Messages (RF Settings Page)

5. Set to RF Channel 23 (RF Settings Page)

6. Set transmitter power setting to 31 (RF Settings Page)*

7. Set Short Destination address to 1 (Located Upper left corner of TT)

8. Select Short Address Radio Button (Upper Section of TT) *Long may be selected if sending to a long address device

9. Select "Save Config To NV Memory" Command Button (Upper Section of TT)

10. Check the Show Received box (Upper Section of Test Tool)

* Set to a value of 14 to operate at 10mW Maximum for European Union Compliance. For Australia/ New Zealand Operation, a 100milli-watt EIRP setting may be maintained.
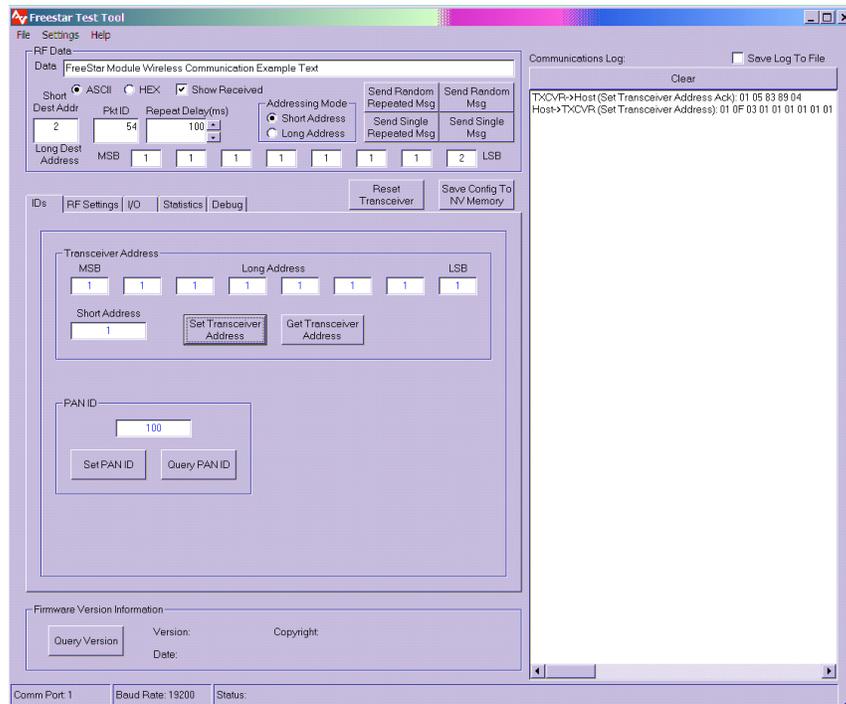

Figure 4-7 ID Settings for Device 1
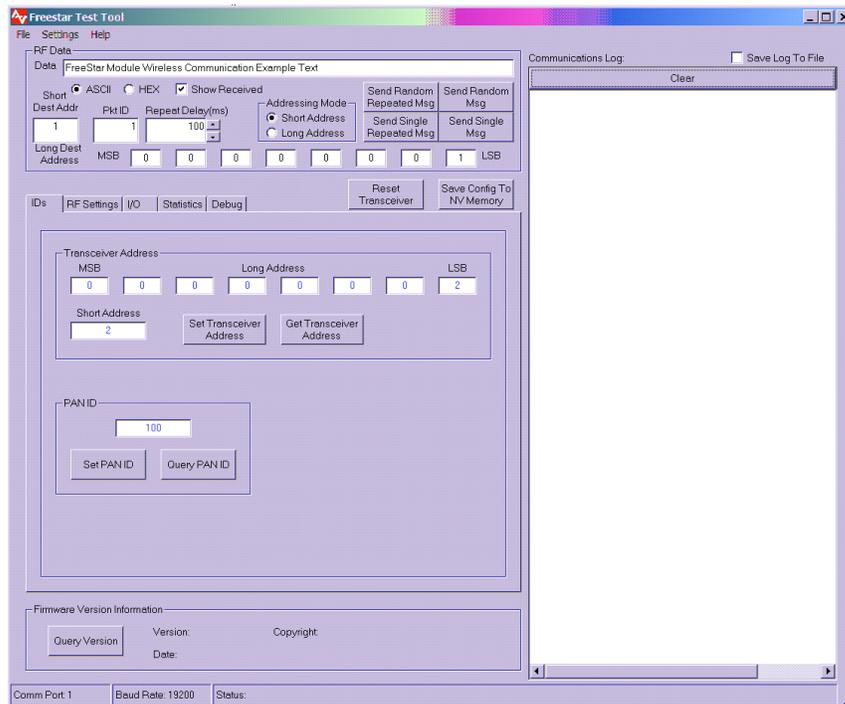
Figure 4-8. ID Settings for Device 2.
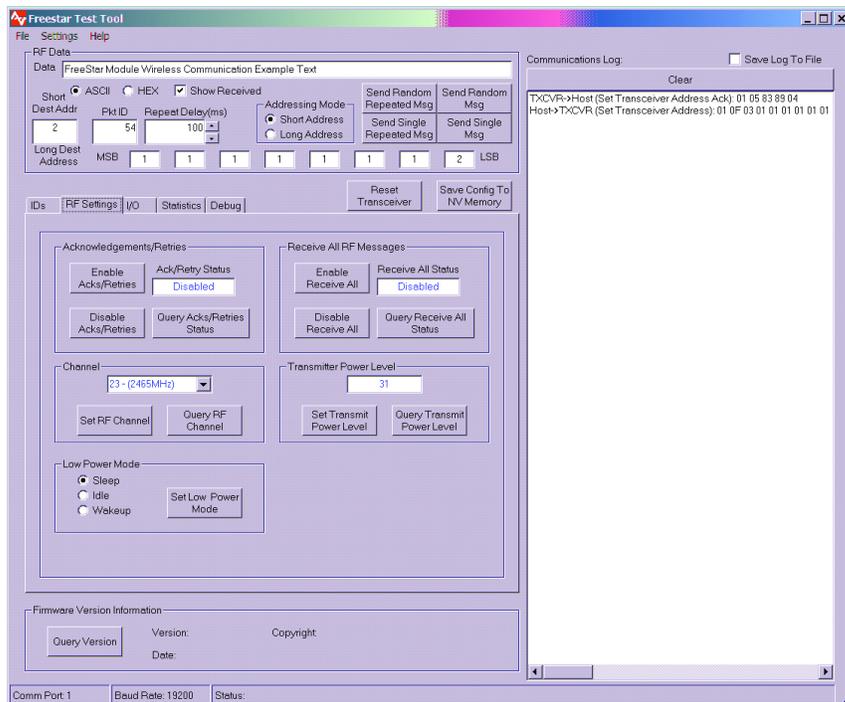
Figure 4-9. RF Settings for Initiating and Receiving Device

Place the 2 units in physically separate locations and apply power to them. The statistics will clear when power is cycled, but they will need to be cleared manually after each test if power is not cycled.

Connect each individual PC serial port to each of the units and verify the correct destination address is typed in the address field on the top of the test tool. Type a short message into the "*RF Data*" window of the initiating device. The message can be any text or numbers. If no message is entered it will not be possible to transmit.

Set the "Repeat Delay" to 100 msec if it isn't already set. Click the "Send Single *Repeated Msg*" button to start transmission. The radio will send messages repeatedly with 100mSec in between messages until the "*Stop Repeat*" button is clicked.

Allow the test to run for some convenient amount of time and then stop transmission. Go to the "*Statistics*" screen of the initiating device and select the "Query Statistics" command button and record the packets sent in the Transceiver section of the test tool. Next select "Query Statistics" on the receive device and record packets received in the Transceiver section of the Statistics page. Link success is simply the ratio of the "Packets Received" to the "Packets Sent".

This test will give the raw performance of the link in one direction without retries. It is a good indicator of the RF environment in which the radios are being used. High levels of noise or other products operating in the 2.4 GHz band can cause lower packet success rates.

4.3.2 Round Trip Test

To test the ability of the system to retry messages in a noisy environment, it is necessary to use a round trip test where the remote end can acknowledge receipt of packets. Use the setup screen as shown in Figure 4-7 thru 4-9 for each respective device, but **enable** acknowledgements on both devices (Refer to RF Settings Page).

Perform the test in the same manner as the single ended test. Run enough transmissions to get a statistically valid sampling of the radio environment over a reasonable period of time.

Look at the *"Statistics"* screen on the initiating radio to find the total number of packets sent. Link quality is displayed in the Pkt Success Rate w/Acks text box. Total link success is the ratio of "*Acks Received*" to "*Packets Sent*".

FreeStar Module Input/Output

5.1 Overview

There are a total of 10 user input/output pins on the FreeStar module which consist of 8 configurable digital input/outputs and 2 fixed analog inputs.

5.2 Digital Inputs/Outputs

There are 8 configurable digital input/output pins that can be programmed to be either inputs or outputs. In addition if the pins are inputs the internal pullup resistor can either be enabled or disabled. Refer to Table 1 below for a mapping of the digital input and output pins.

Pin Number	Bit Position (MSB to LSB)	Pin Description
0	0b00000001	MC9S08GT60 micro pin PTD3 (pin 23)
1	0b00000010	MC9S08GT60 micro pin PTD4 (pin 24)
2	0b00000100	MC9S08GT60 micro pin PTA4 (pin 39)
3	0b00001000	MC9S08GT60 micro pin PTA5 (pin 40)
4	0b00010000	MC9S08GT60 micro pin PTA6 (pin 41)
5	0b00100000	MC9S08GT60 micro pin PTC0 (pin 2)
6	0b01000000	MC9S08GT60 micro pin PTC1 (pin 3)
7	0b10000000	MC9S08GT60 micro pin PTC5 (pin 7)

Table 1

Using the digital input output pins consists of the following:

- Configuring the pins
    Select direction (input or output), enabling or disabling pullup resistors for pins configured as digital inputs, and setting the initial output value for pins configured as digital outputs. These parameters define the configuration of the pins when a reset occurs. Also the direction and pullup parameters are used to set the state of the pins after exiting sleep mode.

- Configuring the sleep state of the pins
    Select direction (input or output), enabling or disabling pullup resistors for pins configured as digital inputs, and setting the output value for pins configured as digital outputs. Although these parameters are the same as those shown in the "Configuring the pins" item shown above, they are independent and are the state of the pins when the FreeStar module is put into Sleep Mode.

- Reading the state of the pins configured as inputs
    Read the digital value (0 or 1) of the signal applied to the pins configured as inputs.

- Setting the state of the pins configured as outputs
    Set the digital value (0 or 1) for the pins configured as outputs.

CHAPTER 6

FreeStar Application Guide

6.1 Overview

This Chapter describes the essentials for using the host protocol to configure and use a FreeStar module in an application. Please refer to Host Protocol Document for Further Details on messaging.

6.1.1 Host Protocol

The host protocol that is used to communicate with a FreeStar module is a simple binary based protocol. Every message in the protocol consists of a header, a trailer, and potentially some payload information.

The header is made up of a start byte (0x01), a length byte that is the length of the entire message including header and trailer, and a message type that identifies the intention of the message.

The payload varies from message to message but in general includes things such as data to be sent or received, or configuration information.

The trailer is made up of a checksum, which the sum of all of the bytes in the message is starting with the start byte and up through the payload, and an end byte (0x04).

Every message that the host device sends to the FreeStar module has a complimentary acknowledgement message that will get sent back upon successful decoding and processing by the FreeStar module.

6.1.2 Configuration

After power-up or after receiving a "Reset Request" (type 0x18) message, the FreeStar module will read the configurable parameters from the on-board microcontroller's non-volatile memory, and store them in RAM to be used from that point on. Changing a parameter by sending the module a new message does not automatically result in the module saving the parameter to non-volatile memory, but rather just changes the value stored in RAM. This allows a particular host application to change the configurable parameters dynamically without unnecessarily writing to, and shortening the lifetime of, the non-volatile memory. All of the FreeStar module's configurable parameters that are stored in RAM can be saved to non-volatile memory by sending a "Save Configuration Values to Non-Volatile Memory" (type 0x11) message.

Communication Parameters

There are six configuration parameters used to setup the FreeStar module for communications, which are outline below.

1. Set PAN ID – The Personal Area Network (PAN) ID is used to establish networks of transceivers. Only devices with the same PAN ID will communicate with one another.

2. Set Transceiver Address – The Transceiver Address is used to differentiate transceivers within a network. Each transceiver should be configured with a different address. The Transceiver Address consists of both a short two byte and a long eight byte address. Setting the short address to 65,534 (0xFFFE) will cause the FreeStar module to use its long address. To use the short address, the short address should be set to between 0-65,533.

3. Set RF Channel – The RF channel is used to select the channel in the 2.4GHz band that the transceiver will operate on. Communication between transceivers is only possible if the devices are both using the same RF channel. Valid RF channels are from 11 to 26.

4. Enable/Disable Receive All RF Messages – Enabling receive all RF messages allows all messages on the configured PAN ID to be received by the FreeStar module. This intended use of receive all messages is for diagnostics tools so that it is possible to see all messages on a network. Note that when this mode is enabled that it is not possible to transmit RF messages.

5. Enable/Disable RF Acknowledgements and Retries – When RF Acknowledgements and Retries are enabled, the destination transceiver will respond to the received message with an acknowledgement. If the source transceiver does not receive an acknowledgement, it will attempt to re-send the message to the destination transceiver up to 3 more times (3 retries). By using acknowledgments and retries, the likelihood of successfully getting a message from one transceiver to another increases.

6. Set Transmit Power Level – This setting allows for adjusting the transmit power, which affects the overall range. The range varies from 0 to 31. (Set to 31 for 100mW operation or 14 to operate at 10mW Maximum for European Union Compliance. For Australia/ New Zealand Operation, a 100 milli-watt EIRP setting may be maintained.)

Input/Output Parameters

There are three configuration messages used to setup parameters for controlling the user input and output pins, which are outlined below.

1. <u>Set Digital Pin Configuration</u> – This message is used to configure the direction (input or output), whether or not the internal pull-up resistor is enabled for pins configured as inputs, and the initial output value for pins configured as outputs. The initial output value is the default state that output pins will be assigned after power-up or a "Reset Request" command is issued to the module.

2. <u>Set Digital Pin Sleep State</u> – This message defines the state that the digital pins will be put into when the low power sleep mode of operation is requested for the module. Similar to the "Set Digital Pin Configuration" message, the direction of the pin, whether or not the pull-up resistor is enabled for input pins, and the output value for output pins can be configured. Upon exiting sleep mode the pins will be configured back to the state they were in prior to entering sleep mode.

3. <u>Set Analog Pin Sleep State</u> – This message is used to set the state of the two analog input pins when the transceiver is put into the low power sleep mode of operation. It is possible to leave the pin configured as an analog input, or change it to an output either driven low or high. Upon exiting sleep mode the pins will be configured back to be analog inputs.

<u>Diagnostics and Feedback Parameters</u>

There are two configuration parameters used to setup diagnostics and user LED feedback which are outlined below.

1. <u>Set Debug Mode</u> – Setting the debug mode allows the host application to configure what debug information gets displayed on the three mode pins when the mode pins are in their default state. The default state for the mode pins is that none of the external pull-downs are installed. The intent of the debug signals is to allow for monitoring on an oscilloscope how the device is operating.

2. <u>Set LED Functionality</u> – This message is used to configure if any LED feedback information is enabled or not, and if it is enabled what it represents. For modules that are embedded in an enclosure, the LED functionality can altogether be disabled to further reduce power consumption. Several examples of the types of functionality that can be displayed on the LEDs are a heartbeat LED flash to indicate the microcontroller is running or flashes when an RF or serial message is either transmitted or received. Multiple functions can be enabled simultaneously.

Example configuration

The following example will show details of what host protocol messages a host device would send to a FreeStar module to configure all of its programmable settings. After all of the settings have been sent to the transceiver, save configuration parameters message is issued to save the settings to non-volatile memory.

<u>Settings</u>

PAN ID: 100
Transceiver Address: Long Address = 500
                                             (short address needs to be 65,534)

RF Channel: 18
Receive All: Disabled
Acknowledgements and Retries: Enabled
Transmit Power Level: 31 (maximum)

Digital Pin Configuration: All inputs with pull-up resistors
                                             enabled
Digital Pin Sleep State: All inputs with pull-up resistors
                                             enabled
Analog Pin Sleep State: All analog

Debug Mode: Disabled
LED Functionality: Heartbeat and flash on RF activity

Host Messages

1. Set PAN ID
   < 0x01 0x07 0x01 0x64 0x00 0x6D 0x04 >

2. Set Transceiver Address
   < 0x01 0x0F 0x03 0xF4 0x01 0x00 0x00 0x00 0x00 0x00 0x00 0xFE
   0xFF 0x05 0x04>

3. Set RF Channel
   < 0x01 0x06 0x05 0x12 0x1E 0x04 >

4. Disable Receive All RF Messages
   < 0x01 0x06 0x07 0x00 0x0E 0x04 >

5. Enable Acknowledgements and Retries
   < 0x01 0x06 0x09 0x01 0x10 0x04 >

6. Set Transmit Power Level
   < 0x01 0x06 0x0F 0x1F 0x35 0x04 >

7. Set Digital Pin Configuration
   < 0x01 0x08 0x01E 0x00 0xFF 0x00 0x26 0x04 >

8. Set Digital Pin Sleep State
   < 0x01 0x08 0x025 0x00 0xFF 0x00 0x2D 0x04 >

9. Set Analog Pin Sleep State
   < 0x01 0x07 0x23 0x02 0x02 0x2F 0x04 >

10. Disable Debug Mode
    < 0x01 0x06 0x27 0x00 0x2E 0x04 >

11. Enable Heartbeat and Flash On RF Activity LED Functionality
    < 0x01 0x06 0x28 0x05 0x34 0x04 >

12. Save Configuration Parameters To Non-Volatile Memory
    < 0x01 0x05 0x11 0x17 0x04 >

For all of the messages shown above that would get sent from the host application to the FreeStar module, a host level acknowledgement will be sent back when it has been successfully processed. It is recommended that the host application send a message to the module and then wait for an acknowledgement response prior to sending the next message. This will take care of flow control and prevent the host application from overflowing the module.

6.1.3 RF Messaging

Overview

The FreeStar module provides a versatile command set for communications between modules. Depending on the application's requirements, either short or long address modes can be used. Short addressing mode uses a two byte transceiver address, while long addressing mode uses eight byte transceiver addresses. It is also possible to communicate between transceivers using mixed addressing modes, hence a message can be sent from a transceiver with a short address to another transceiver with a long address or vice versa.

There is a single host message that is used to send data from one transceiver to another and two host messages that are generated when a message is received. When in the receive all mode of operation and a message is received by a transceiver, host message type 0xA9 is generated and sent out the serial port to the host. In the default mode of operation (receive all mode disabled) host message type 0x95 is generated and sent out the serial port to the host.

RF host messages consist of a standard header (start, length and type), RF message header, payload, and a standard trailer (checksum and stop). The RF message header contains a Packet ID, a Target/Sender identifier, an Address Mode byte, and the Transceiver Addresses. The Packet ID is used to identify each message and should be incremented for each new packet when sending a message. The Target/Sender byte indicates where the message originated from and is being sent to. Messages either are originated from or sent to either the host or the application. The application is the user application code that is running on the FreeStar module (currently not supported). The host is the host application. The Address Mode byte describes the type of addressing for the particular message. The upper nibble indicates the addressing mode used for the destination of the message, while the lower nibble indicates the mode for the source of the message. A 0 is used to represent a short address, while a 1 represents a long address. Following the Addressing Mode is the destination address and then the source address (for received messages only – types 0x95 and 0xA9).

Short Addressing

In order to use short addressing it is required that the transceiver address be set between 0 and 65,533 (0xFFFD). Setting the short address to 65,534 causes the transceiver module to use the eight byte long address.

Long Addressing

Long addressing mode is configured by setting the short address to 65,534 and then selecting a long address in the range of 0 to 18,446,744,073,709,551,614 (0xFFFFFFFFFFFFFFFE).

Broadcasts

It is possible to broadcast a message to all transceivers configured to the same RF channel and PAN ID.   Messages are broadcast by sending the message to the short destination transceiver address 65,535 (0xFFFF).

Receive All

Receive all mode is used as a diagnostic mode in which a transceiver can listen to and receive all of the messages from any device that is communicating on the same PAN ID and RF channel. Messages with long and short addressing types will be received, and when a message is received it is sent out the host serial port with a message type of 0xA9. In receive all mode it is not possible to transmit messages to other transceivers.

Addressing Modes Summary

The table below gives an overview of the addressing modes that are available in the FreeStar module. The table shows a summary of what happens when messages are sent between two modules (Transceiver A and Transceiver B) using the various addressing modes (short and long), and also broadcasts.

The first column "Host Send Mode" lists what type of message the host would send to the FreeStar module into transceiver A. The "Addressing Mode" columns show what type of address (short or long) each transceiver is configured to use. Upon transceiver A receiving the message from the host device, transceiver A would then send a message over the RF link to transceiver B using the type of address shown in the first column. If transceiver B successfully receives the RF message from transceiver A, then a host message is generated that will be sent from transceiver B to the host connected to transceiver B. The messages that get generated will have the source and destination addresses contained in it which are shown in the table under the "Host Receive Mode" columns. A dash (-) denotes that a message was not received by the transceiver because the destination address for transceiver B was not the same type (short or long) as the destination address type to which the message was sent (shown in the first column). It is assumed that the destination address to whom the message is being sent is the same as that address for which the receiving transceiver is configured to use.

Host Send Mode (Host -> Txcvr A)	Addressing Mode (Txcvr A -> Txcvr B)		Host Receive Mode (Txcvr B -> Host)		Broadcast
	Txcvr A	Txcvr B	Source	Destination	
Short	Short	Short	Short	Short	Ok
Short	Short	Long	- (Note 1)	- (Note 1)	Ok
Short	Long	Short	Long	Short	Ok
Short	Long	Long	- (Note 1)	- (Note 1)	Ok
Long	Short	Short	- (Note 2)	- (Note 2)	-
Long	Short	Long	Short	Long	-
Long	Long	Short	- (Note 2)	- (Note 2)	-
Long	Long	Long	Long	Long	-

Table 2 – Addressing Overview

Note 1: Since a transceiver is setup with both a long and a short address, if long addressing is being used (short address = 65,534) and a message is being sent to the transceiver with a short address of 65,534, a RF acknowledgement will be sent by the MAC.

Note 2: Since a transceiver is setup with both a long and a short address, if short addressing is being used (short address not equal to 65,534) and a message is being sent to the transceiver with a long address that matches the transceiver's long address, a RF acknowledgement will be sent by the MAC.

6.1.4 Example Messaging

For all of the following examples it is assumed that the PAN ID and RF channel are set to be the same on both FreeStar modules. Also the messages will originate in the host connected to transceiver A and they will be sent to transceiver B. The data contained in the message will be 0x01, 0x02, 0x03. All received messages have a Link Quality Indication (LQI) of 200 (0xC8).

Short To Short Addressing

The following example will show details of communications between two FreeStar modules both configured to use short addressing.

Settings

Transceiver A Address: Short Address = 1
Long Address = Don't care

Transceiver B Address: Short Address = 2
Long Address = Don't care

Packet ID: 10
Target/Sender: Host

Host -> Transceiver A – (Send n RF Data Bytes To Destination Transceiver ID)
< 0x01 0x0D 0x14 0x0A 0x11 0x00 0x02 0x00 0x01 0x02 0x03 0x45 0x04 >

Assuming that Transceiver B receives the message from Transceiver A, then it would send a host message out of its serial port.

Transceiver B -> Host – (Received n RF Data Bytes From Transceiver ID)
< 0x01 0x10 0x95 0x0A 0x11 0xC8 0x00 0x02 0x00 0x01 0x00 0x01 0x02 0x03 0x12 0x04>

Short To Long Addressing

The following example will show details of communications between two FreeStar modules with transceiver A configured to use short addressing and transceiver B configured to use long addressing.

<u>Settings</u>

Transceiver A Address: Short Address = 1
Long Address = Don't care

Transceiver B Address: Short Address = 65,534 (use long address)
Long Address = 2 (0x0000000000000002)

Packet ID: 10

Target/Sender: Host

Host -> Transceiver A – (Send n RF Data Bytes To Destination Transceiver ID)
< 0x01 0x13 0x14 0x0A 0x11 0x10 0x02 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x01 0x02 0x03 0x5B 0x04 >

Assuming that Transceiver B receives the message from Transceiver A, then it would send a host message out of its serial port.

Transceiver B -> Host – (Received n RF Data Bytes From Transceiver ID)
< 0x01 0x16 0x95 0x0A 0x11 0xC8 0x10 0x02 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x01 0x00 0x01 0x02 0x03 0x28 0x04>

Long To Short Addressing

The following example will show details of communications between two FreeStar modules with transceiver A configured to use long addressing and transceiver B configured to use short addressing.

<u>Settings</u>

Transceiver A Address: Short Address = 65,534 (use long address)
Long Address = 1 (0x0000000000000001)

Transceiver B Address: Short Address = 2
Long Address = Don't care

Packet ID: 10
Target/Sender: Host

Host -> Transceiver A – (Send n RF Data Bytes To Destination Transceiver ID)
< 0x01 0x0D 0x14 0x0A 0x11 0x00 0x02 0x00 0x01 0x02 0x03 0x45 0x04 >

Assuming that Transceiver B receives the message from Transceiver A, then it would send a host message out of its serial port.

Transceiver B -> Host – (Received n RF Data Bytes From Transceiver ID)

< 0x01 0x16 0x95 0x0A 0x11 0xC8 0x01 0x02 0x00 0x01 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x01 0x02 0x03 0x19 0x04>

Long To Long Addressing

The following example will show details of communications between two FreeStar modules both configured to use long addressing.

Settings

Transceiver A Address: Short Address = 65,534 (use long address)
Long Address = 1 (0x0000000000000001)

Transceiver B Address: Short Address = 65,534 (use long address)
Long Address = 2 (0x0000000000000002)

Packet ID: 10
Target/Sender: Host
Host -> Transceiver A – (Send n RF Data Bytes To Destination Transceiver ID)
< 0x01 0x13 0x14 0x0A 0x11 0x10 0x02 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x01 0x02 0x03 0x5B 0x04 >

Assuming that Transceiver B receives the message from Transceiver A, then it would send a host message out of its serial port.

Transceiver B -> Host – (Received n RF Data Bytes From Transceiver ID)
< 0x01 0x1C 0x95 0x0A 0x11 0xC8 0x11 0x02 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x01 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x01 0x02 0x03 0x2F 0x04>

6.1.5 Input/Output Usage

There are three host messages used to query and set the inputs and outputs respectively. Below is a more detailed description of each of the messages with examples showing the corresponding host messaging.

1. Query Analog Pin Values – This message is used to read the values of the two analog input signals. The result is returned in a host message that gets sent back from the FreeStar module containing a two byte value (LSB to MSB), for each of the two analog inputs, with the 10 least significant bits representing the voltage applied to the inputs. The input signal voltage is converted to a 1.25v reference.

   Example:

   Analog Input PTB0 = 0.42v (10 bit value => 344 = 0x0158)
   Analog Input PTB1 = 1.07v (10 bit value => 876 = 0x036C)

   Host -> FreeStar Module – (Query Analog Pin Values – Type 0x22)
   < 0x01 0x05 0x22 0x28 0x04 >

   FreeStar Module -> Host – (Respond With Analog Pin Values – Type 0xA2)
   < 0x01 0x09 0xA2 0x58 0x01 0x6C 0x03 0x74 0x04>

2. <u>Query Digital Pin State</u> – This message is used to read the values of the eight potential digital input signals. A bit mask for each digital input/output signal is returned in a host message that gets sent back from the FreeStar module. Only digital pins configured as inputs contain any meaningful information. A zero indicates a low signal is applied to the input, while a one indicates a high signal is applied.

Example:

Digital Pin Configuration – Inputs = PTC1, PTC5, PTD3, and PTD4.
Digital Input PTC1 = 0
Digital Input PTC5 = 1
Digital Input PTD3 = 0
Digital Input PTD4 = 1

Host -> FreeStar Module – (Query Digital Pin State – Type 0x21)
< 0x01 0x05 0x21 0x27 0x04 >

FreeStar Module -> Host – (Respond With Digital Pin State – Type 0xA1)

3. <u>Set Digital Pin State</u> – This message is used to write the values of the eight potential digital output signals. A byte containing a bit mask for each digital input/output signal is sent in a host message to the FreeStar module. Only digital pins configured as outputs contain any meaningful information. A zero indicates a low signal is applied to the output, while a one indicates a high signal is applied.

Example:

Digital Pin Configuration – Outputs = PTA4, PTA5, PTA6, and PTC0.
Digital Output PTA4 = 1
Digital Output PTA5 = 0
Digital Output PTA6 = 0
Digital Output PTC0 = 1

Host -> FreeStar Module – (Set Digital Pin State – Type 0x20)
< 0x01 0x06 0x20 0x24 0x4B 0x04 >

*FreeStar Module -> Host – (Set Digital Pin State Acknowledged– Type 0xA0)*
< 0x01 0x05 0xA0 0xA6 0x04>

Appendix A

Range Test Results

*A.1.1 FreeStar with Inverted F (Trace) Antenna Open Field Range Results at 3.3VDC**

Inverted F (Trace) Antenna
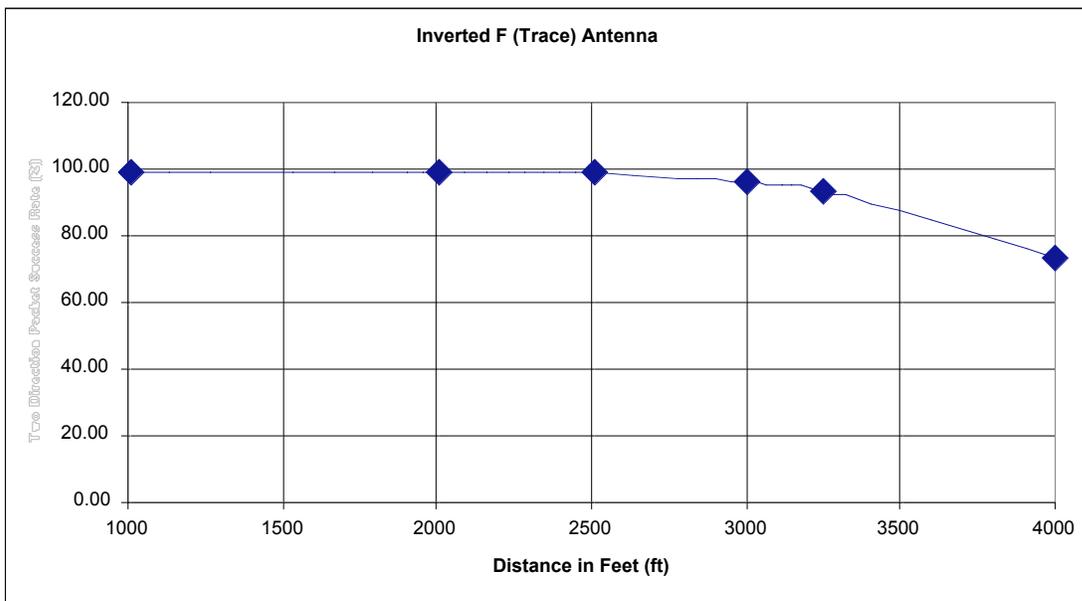
*100mW power level

A.1.2 FreeStar with Wire Antenna Open Field Range Results at 3.3VDC*

Wire Antenna Range Results
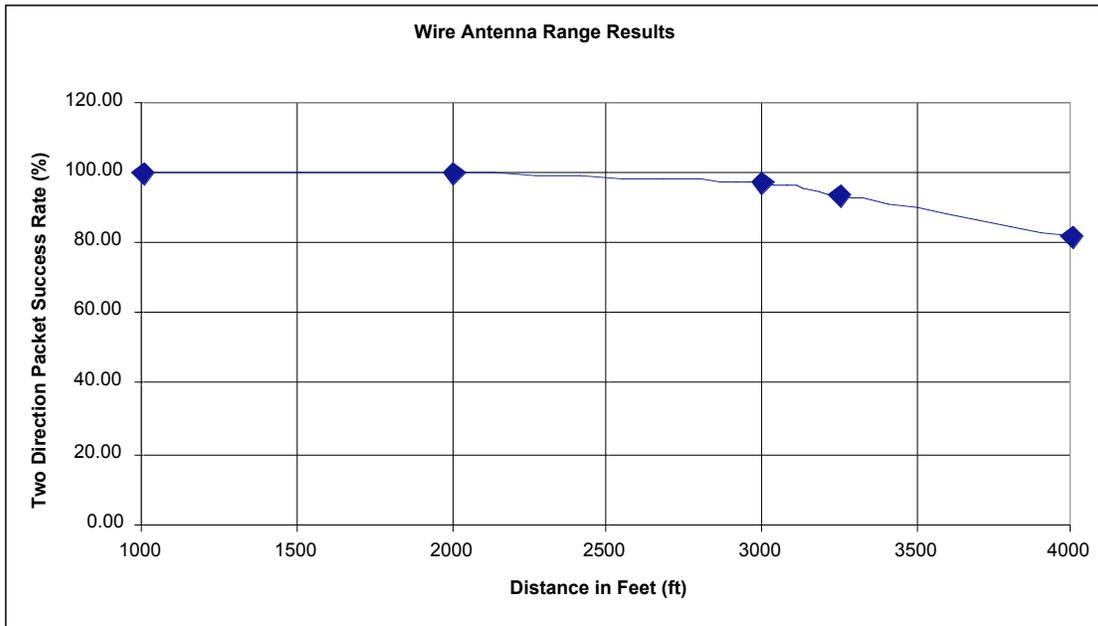
*100mW Power Level

A.1.3 FreeStar with GigaAnt Antenna Open Field Range Results at 3.3VDC*

GigaAnt Range Test Results

*100mW Power Level

Appendix B
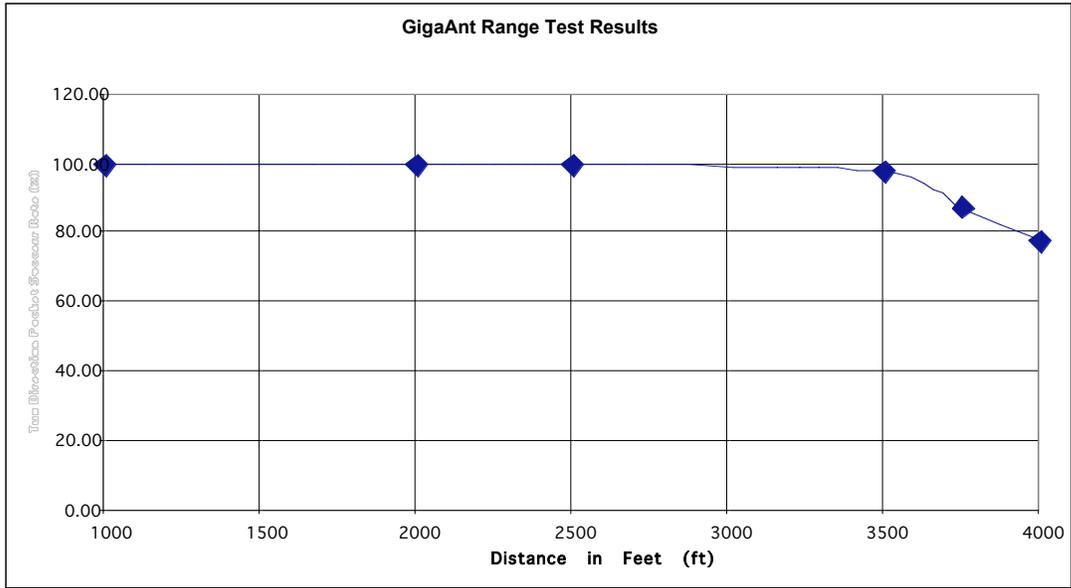
<u>Agency Statements</u>

FCC Statements

Compliance Statement (Part 15.19)
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 (Part 15.21)
Changes or modifications not expressly approved by L.S. Research Inc.
could void the user's authority to operate the equipment.

20 cm Separation Distance
To comply with FCC's RF exposure limits for general population /
uncontrolled exposure, 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.

OEM Responsibility

OEM Responsibility to the FCC Rules and Regulations
The FreeStar Module has been certified per FCC Part 15 rules for integration
into products without further testing or certification. To fulfill the FCC
certification requirements the OEM of the FreeStar Module must ensure that
the information provided on the FreeStar Label is placed on the outside of the
final product.
The FreeStar Module is labeled with its own FCC ID Number. If the FCC ID is
not visible when the module is installed inside another device, then the
outside of the device into which the module is installed must also display a
label referring to the enclosed module. This exterior label can use wording
such as the following:

> "**Contains Transmitter Module FCC ID: TFB-FREESTAR**"

or

> "**Contains FCC ID: TFB-FREESTAR**"

The OEM of the FreeStar Module must only use the approved antenna,
(PCB Trace Antenna) that has been certified with this module.

The OEM of the FreeStar Module must test their final product configuration to
comply with Unintentional Radiator Limits before declaring FCC compliance
per Part 15 of the FCC rules.

Canada Statements

Section 14 of RSS-210
The installer of this radio equipment must ensure that the antenna is located or pointed such that it does not emit RF field in excess of Health Canada limits for the general population.
Consult Safety Code 6, obtainable from Health Canada's website**:**
www.hc-sc.gc.ca/rpb

European Union Compliance Statements

The FreeStar RF module has been tested and certified for use in the European Union.

OEM Responsibility

OEM Responsibility to the European Union Compliance Rules
If the FreeStar module is to be incorporated into a product, the OEM must verify compliance of the final product to the European Harmonized EMC and Low-Voltage / Safety Standards. A Declaration of Conformity must be issued for each of these standards and kept on file as described in Annex II of the R&TTE Directive.

The manufacturer must maintain the user's guide and adhere to the settings described in the manual for maintaining European Union Compliance. If any of the specifications are exceeded in the final product, the OEM is required to make a submission to the notified body for compliance testing.

OEM Labeling Requirements
The 'CE' mark must be placed on the OEM product in a visible location.

CE Labeling Requirements
Note … Propitiate Size must be maintained

The CE mark shall consist of the initials "CE" with the following form:

- If the CE marking is reduced or enlarged, the proportions given in the above graduated drawing must be adhered to.
- The CE mark must be a minimum of 5mm in height
- The CE marking must be affixed visibly, legibly, and indelibly

Since the 2400 – 2483.5 MHz band is not harmonized by a few countries throughout Europe, the Restriction sign must be placed to the right of the 'CE' marking as shown in the picture below.

CE Label Required on OEM Equipment in Non Harmonized Areas

Declarations of Conformity

L.S. Research does not list all standards that must be met for each country. It is the responsibility of the OEM to acquire all information for compliance to a specific country and meeting the guidelines issued by the respective country.

The following websites will assist with understanding of individual restrictions per country.

CEPT ERC 70-03E

Technical Requirements, European restrictions and general requirements: **www.ero.dk/**

R&TTE Directive

Equipment requirements, placement on market: **www.ero.dk/**

Notifications

Since the FreeStar device operates in the 2.4GHz band, a notification must be sent to each country that has restrictions, prior to shipping the product as per Article 6.4 of the R&TTE Directive.