875-0077-01 Rev E

ThingMagic Nano Design Guide

For ThingMagic Nano with Firmware Ver. 1.3.2 and later

ThingMagic, A Division of Trimble
1 Merrill Street
Woburn, MA 01801

01 Revision E
April 2016

Revision Table

Date	Version	Description
3/2015	01 Draft 1	Partial Draft for early-access release
4/2015	01 REV A	First Release for prototype units with 1.3.1 firmware
4/2015	01 Rev B	Second release for GA units with version 1.3.2 firmware ◆ Receive sensitivity values updated (RF Characteristics) ◆ Long-term exposure caution updated (ThingMagic Nano Regulatory Information) ◆ Thermal limits explained more fully (ThingMagic Nano Carrier Board) ◆ Minor Editorial Changes ◆ Minor changes following review by Engineering
6/2015	01 Rev C	◆ In the “Hardware Overview” section, the table of pin fumctions erroneously listed pin 39 as both a signal and a ground and omitted ground pin 37. This has been corrected. ◆ The “Host Board Design” section of the “Hardware Integration chapter changed. The “landing pads” outline changed to show heat sink areas. The table that indicated pad sizes and locations incorrectly has been removed and replaced by a reference to the carrier board design files, w hich provide the information in a much more convenient form.
9/2015	01 Rev D	◆ Ambiguity about whether RX and TX pins are inputs or outputs cleared up.
4/2016	01 Rev E	◆ Content added to reinforce that all GPI lines and the RX input line must be low when the module boots up and low when the module shuts down.

Communication Regulation Information

C A U T I O N !

Please contact ThingMagic support - support@thingmagic.com - before beginning the process of getting regulatory approval for a finished product using the ThingMagic Nano.

ThingMagic Nano Regulatory Information

Federal Communication Commission Interference Statement

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. However, there is no guarantee that interference will not occur in a particular installation. 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 of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

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.

FCC Caution: Any changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate this equipment.

W A R N I N G !

Operation of the ThingMagic Nano module requires professional installation to correctly set the TX power for the RF cable and antenna selected.

This transmitter module is authorized to be used in other devices only by OEM integrators under the following conditions:

1. To comply with FCC's RF radiation exposure requirements, the antenna(s) used for this transmitter must be installed such that a minimum separation distance of 21cm is maintained between the radiator (antenna) & user's/nearby people's body at all times and must not be co-located or operating in conjunction with any other antenna or transmitter.
2. The transmitter module must not be co-located with any other antenna or transmitter.

As long as the two conditions above are met, further transmitter testing will not be required. However, the OEM integrator is still responsible for testing their end-product for any additional compliance requirements required with this module installed (for example, digital device emissions, PC peripheral requirements, etc.).

Note

In the event that these conditions can not be met (for certain configurations or co-location with another transmitter), then the FCC authorization is no longer considered valid and the FCC ID can not be used on the final product. In these circumstances, the OEM integrator will be responsible for re-evaluating the end product (including the transmitter) and obtaining a separate FCC authorization.

The OEM integrator has to be aware not to provide information to the end user regarding how to install or remove this RF module in the user manual of the end product.

User Manual Requirement

The user manual for the end product must include the following information in a prominent location;

"To comply with FCC's RF radiation exposure requirements, the antenna(s) used for this transmitter must be installed such that a minimum separation distance of 21 cm is maintained between the radiator (antenna) & user's/nearby people's body at all times and must not be co-located or operating in conjunction with any other antenna or transmitter."

AND

"The transmitting portion of this device carries with it the following two warnings:

"This device complies with Part 15...."

AND

"Any changes or modifications to the transmitting module not expressly approved by ThingMagic Inc. could void the user's authority to operate this equipment" "

End Product Labeling

The final end product must be labeled in a visible area with the following:

"Contains Transmitter Module FCC ID: QV5MERCURY6EN"

or

"*Contains FCC ID: QV5MERCURY6EN."*

Industry Canada

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropic radiated power (e.i.r.p.) is not more than that necessary for successful communication.

This radio transmitter (identify the device by certification number, or model number if Category II) has been approved by Industry Canada to operate with the antenna types listed below with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device

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.

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

This device has been designed to operate with the antennas listed in Authorized Antennas table. Antennas not included in these lists are strictly prohibited for use with this device.

To comply with IC 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 21 cm from all persons and must not be collocated or operating in conjunction with any other antenna or transmitter.

End Product Labeling

The final end product must be labeled in a visible area with the following:

"Contains ThingMagic Inc. ThingMagic Nano (or appropriate model number you're filing with IC) *transmitting module FCC ID: QV5MERCURY6EN (IC: 5407A-MERCURY6EN)"*

Industrie Canada

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante.

Le présent émetteur radio (identifier le dispositif par son numéro de certification ou son numéro de modèle s'il fait partie du matériel de catégorie I) a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés ci-dessous et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur

Le fonctionnement de l' appareil est soumis aux deux conditions suivantes:

1. Cet appareil ne doit pas perturber les communications radio, et
2. cet appareil doit supporter toute perturbation, y compris les perturbations qui pourraient provoquer son dysfonctionnement.

Pour réduire le risque d'interférence aux autres utilisateurs, le type d'antenne et son gain doivent être choisis de façon que la puissance isotrope rayonnée équivalente (PIRE) ne dépasse pas celle nécessaire pour une communication réussie.

L' appareil a été conçu pour fonctionner avec les antennes énumérés dans les tables Antennes Autorisées (Authorized Antennas). Il est strictement interdit de l' utiliser l' appareil avec des antennes qui ne sont pas inclus dans ces listes.

Au but de conformer aux limites d'exposition RF pour la population générale (exposition non-contrôlée), les antennes utilisés doivent être installés à une distance d'au moins 25 cm de toute personne et ne doivent pas être installé en proximité ou utilisé en conjonction avec un autre antenne ou transmetteur.

Marquage sur l’ étiquette du produit complet dans un endroit visible: "Contient ThingMagic transmetteur, FCC ID: QV5MERCURY6EN (IC:5407A-MERCURY6EN)"

Authorized Antennas

This device has been designed to operate with the antennas listed in Authorized Antennas. Antennas not included in this list are strictly prohibited for use with this device.

Contents

Introduction

The ThingMagic® Nano® embedded module is an RFID reader that you can integrate with other systems to create RFID-enabled products.

Applications to control the ThingMagic Nano modules and derivative products can be written using the high level MercuryAPI. The MercuryAPI supports Java, ".NET" and C programming environments. The MercuryAPI Software Development Kit (SDK) contains sample applications and source code to help developers get started demonstrating and developing functionality. For more information on the MercuryAPI see the *MercuryAPI Programmers Guide* and the *MercuryAPI SDK*, available on the ThingMagic website.

This document is intended for hardware designers and software developers. It describes the hardware specifications and firmware functionality of the ThingMagic Nano module and provides guidance on how to incorporate the module within a third-party host system. The document is broken down into the following sections:

- Hardware Overview - Detailed specifications of the ThingMagic Nano hardware. This section should be read in its entirety before designing hardware or attempting to operate the ThingMagic Nano module in hardware other than the ThingMagic Dev Kit.
- Hardware Integration - Describes the ideal attributes of a main board which incorporates the ThingMagic Nano module.
- Firmware Overview - A detailed description of the ThingMagic Nano firmware components including the bootloader and application firmware.
- Communication Protocol - An overview of the low level serial communications protocol used by the ThingMagic Nano.
- Functionality of the ThingMagic Nano - Detailed descriptions of the ThingMagic Nano features and functionality that are supported through the use of the MercuryAPI.
- Appendix A: Error Messages - Lists ThingMagic Nano Error Codes and provides causes and suggested solutions for when they are encountered.
- Appendix B: Getting Started - Dev Kit - Quick Start guide to getting connected to the ThingMagic Nano Developer's Kit and using the Demo Applications included with the MercuryAPI SDK.
- Appendix C: Environmental Considerations - Details about environmental factors that should be considered relating to reader performance and survivability.

Specifications Summary

The table below summarizes the specifications of the ThingMagic Nano module. Many of these specifications are discussed in further detail in the Hardware Overview chapter.

Physical	
Dimensions	**22 mm L x 26 mm W x 3.0 mm H** **(.866 in L x 1.024 in W x 0.118 in H)**
Tag / Transponder Protocols	
RFID Protocol Support	**EPCglobal Gen 2 (ISO 18000-6C) with nominal backscatter rate of 250 kbps**
RF Interface	
Antennas	**Single 50 Ω connection (board-edge)**
RF Power Output	**Separate read and write levels, command-adjustable from 0 dBm to 27 dBm in 0.01 dB steps**

Regulatory	**Pre-configured for the following regions:** **▪ FCC (NA, SA) 917.4-927.2 MHz** **▪ ETSI (EU) 865.6-867.6 MHz** **▪ TRAI (India) 865-867 MHz** **▪ KCC (Korea) 917-923.5 MHz** **▪ MIC (Japan) 916.8 – 923.4 MHz** **▪ ACMA (Australia) 920-926 MHz** **▪ SRRC-MII (P.R.China) 920.1-924.9 MHz** **▪ 'Open' (Customizable channel plan; 859-873 MHz and 915-930 MHz)**
Data/Control Interface	
Physical	**41 board-edge connections providing access to RF, DC power, communication, and GPIO signals**
Control/Data Interfaces	**▪ UART; 3.3V logic levels** **▪ 9.6 to 921.6 kbps data rate** **▪ Enable control**
GPIO Sensors and Indicators	**Four 3.3V bidirectional ports;** **Configurable as input (sensor) or output (indicator)**
API support	**.NET, Java, and Embedded "C" APIs**
Power	

DC Power Required	DC Voltage: 3.3 to 5.5 V for +25 dBm out 3.7 to 5.5 V for +27 dBm out Nominal DC power consumption when reading: 3.6 W@ 5 VDC for +27 dBm out 3.3 W@ 5 VDC for +25 dBm out 1.5 W@ 5 VDC for 0 dBm out
Idle Power Consumption	▪ 0.84 W in ready mode ▪ 0.015 W in sleep mode ▪ 0.00025 W in shutdown mode
Environment	
Certification	▪ FCC 47 CFR Ch. 1 Part 15 ▪ Industrie Canada RSS-21 0 ▪ ETSI EN 302 208 v1.4.1
Operating Temp.	-20C to +60C (case temperature)
Storage Temp.	-40C to +85C
Shock and Vibration	Survives 1 meter drop during handling
Performance	
Boot time	▪ Less than 150 msec for initial boot after firmware download ▪ Less than 30 msec for subsequent boots.
Read/Write Performance	▪ Up to 150 tags/sec to read 96-bit EPC ▪ 80 msec typical for standard write of 96-bit EPC

Hardware Overview

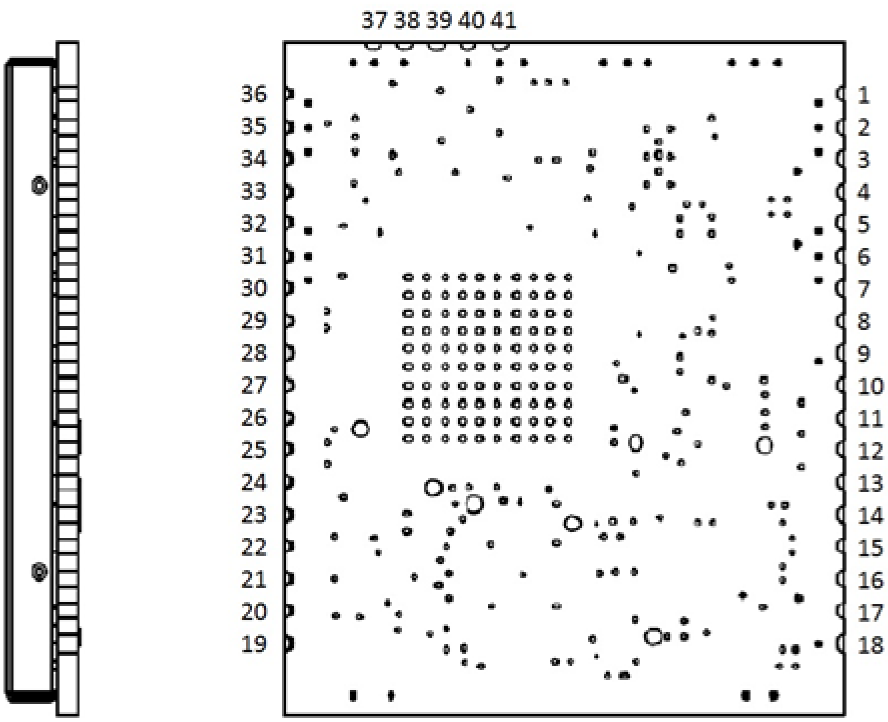
The following section provides detailed specifications of the ThingMagic Nano hardware including:

- Hardware Interfaces
- DC Power Requirements
- RF Characteristics
- Environmental Specifications
- Authorized Antennas
- Physical Dimensions
- Tape-and-Reel Dimensions

Hardware Interfaces

Module Pin-out

Connections are made to the module using 41 edge pads ("vias") that allow the module to be surface mounted to a main board. Here is a bottom view of the module, showing the numerical interfaces of the module:



The document sections that follow explain in detail how these connections are used.

Antenna Connections

The ThingMagic Nano supports one monostatic bidirectional RF antenna through edge vias. See Hardware Integration for antenna edge via locations and layout guidelines.

The maximum RF power that can be delivered to a 50 ohm load from each port is 0.5 Watts, or +27 dBm (regulatory requirements permitting).

Antenna Requirements

The performance of the ThingMagic Nano is affected by antenna quality. Antennas that provide good 50 ohm match at the operating frequency band perform best. Specified performance is achieved with antennas providing 17 dB return loss (VSWR of 1.33) or better across the operating band. Damage to the module will not occur for any return loss of 1 dB or greater. Damage may occur if antennas are disconnected during operation or if the module sees an open or short circuit at its antenna port.

Antenna Detection

C A U T I O N !

Like the Micro module, but unlike the M6e and M5e modules, the ThingMagic Nano does not support automatic antenna detection. When writing applications to control the ThingMagic Nano you must explicitly specify that antenna 1 is to be used. Using the MercuryAPI, this requires creation of a “SimpleReadPlan” object with the list of antennas set and that object set as the active /reader/read/plan. For more information see the *MercuryAPI Programmers Guide* | *Level 2 API* | *Advanced Reading* | *“ReadPlan”* section.

Digital/Power Interfaces

The edge “via” connections provides power, serial communications signals, an enable control, and access to the GPIO lines to the ThingMagic Nano module.

See Hardware Integration for pinout details of both connections and layout guidelines

ThingMagic Nano Digital Connector Signal Definition

Edge Via Pin #	Signal	Signal Direction (In/Out of ThingMagic Nano)	Notes
1-9, 18-19	GND	Signal Return	Must connect all GND pins to ground as they also serve to remove heat from the module
10	Vout	DC Power Output	3.4V DC output. Maximum load 5 mA. Turns off when ENABLE is pulled low. Leave unconnected if not used.
11	ENABLE	Enable/Shut-down	TTL input that turns the module off and reduces its power consumption to nearly zero. Hi=Enable, Low=Shutdown module If left unconnected, module will stay in ENABLE state.
12	GPIO1	Bidirectional GPIO	Each line configurable as input or output interface (by default it is an input with internal pull-down).
13	GPIO2	Bidirectional GPIO	
14	GPIO3	Bidirectional GPIO	
15	GPIO4	Bidirectional GPIO	
16,17	Vin	Power Supply Input	3.3 to 5.5VDC. Pins 16 and 17 are internally connected. Connect the DC power source to both pins to ensure sufficient current carrying capacity.
20	UART_TX	Out	UART Serial output, 3.3V logic
21	UART_RX	In	UART Serial input, 3.3V logic. Must be low when module is powered on or off.
22-28	RFU	Reserved	Reserved for future use - leave unconnected
39	RF	RF Transmit and Receive	Interface to antenna
37-38, 40-41	GND	RF Ground	Must connect all GND pins to ground as they also serve to remove heat from the module

The following table gives the Voltage and Current limits for all communication and control interfaces:

Specification	**Limits**
Input Low-level Voltage	1.0 V max to indicate low state; no lower than 0.3 V below ground to prevent damage
Input High-level Voltage	1.9 V min to indicate high state; 3.7 V max when module is powered up, no more than 0.3 V higher than Vout when module is turned off to prevent damage.
Output Low-level Voltage	0.3 V typ, 0.7 V max
Output High-level Voltage	3.0 V typ, 2.7 V min
Output Low-level Current	10 mA max
Output High-level Current	7 mA max

Control Signal Specification

The module communicates to a host processor via a TTL logic level UART serial port, accessed on the edge “vias”. The TTL logic level UART supports complete functionality. The USB port supports complete functionality except the lowest power operational mode.

TTL Level UART Interface

Only three pins are required for serial communication (TX, RX, and GND). Hardware handshaking is not supported.This is a TTL interface; a level converter is necessary to connect to devices that use a 12V RS232 interface.

The RX line is a 3.3 volt logic CMOS input and is internally pulled up with a resistance value of between 20 and 60 kOhms (40 kOhms nominal). It must be low before the module is turned off and low before the module is turned on. This can be insured if interface drivers are used that are powered by the module itself, as shown in the interface board example.

The connected host processor's receiver must have the capability to receive up to 256 bytes of data at a time without overflowing.

These are the baud rates supported on the interface (bits per second):

- 9600
- 19200
- 38400
- 115200
- 230400
- 460800
- 921600

Note

Upon initial power up, the default baud rate of 115200 will be used. If that baud rate is changed and saved in the application mode, the new saved baud rate will be used the next time the module is powered up. (Check the firmware release notes to confirm that saving of settings is supported.)

General Purpose Input/Output (GPIO)

The four GPIO connections, described in the ThingMagic Nano Digital Connector Signal Definition, may be configured as inputs or outputs using the MercuryAPI. The GPIO pins should connect through 1 kOhm resistors to the module to ensure the input Voltage limits are maintained even if the module is shut off.

Module power consumption can be increased by incorrect GPIO configuration. Similarly, the power consumption of external equipment connected to the GPIOs can also be adversely affected. The following instructions will yield specification compliant operation.

On power up, the ThingMagic Nano module configures its GPIOs as inputs to avoid contention from user equipment that may be driving those lines. The input configuration is a 3.3 volt logic CMOS input and is internally pulled down with a resistance value of between 20 and 60 kOhms (40 kOhms nominal). Lines configured as inputs must be low whenever the module is turned off and low at the time the module is turned on.

GPIOs may be reconfigured individually after power up to become outputs. Lines configured as outputs consume no excess power if the output is left open.

Configuring GPIO Settings

The GPIO lines are configured as inputs or outputs through the MercuryAPI by setting the reader configuration parameters */reader/gpio/inputList* and */reader/gpio/outputList*. The state of the lines can be Get or Set using the *gpiGet()* and *gpoSet()* methods, respectively. See the language specific reference guide for more details.

ENABLE Line

C A U T I O N !

The polarity of the ENABLE line is opposite from the 4-port M6e module.

The ENABLE line (referred to as the SHUTDOWN line in the M6e) must be pulled HIGH or left unconnected in order for the module to be operational. To shut down the module, the line is set LOW or pulled to Ground. Switching from high to low to high is equivalent to performing a power cycle of the module. All internal components of the module are powered down when ENABLE is set LOW.

DC Power Requirements

The module is specified to operate with DC input levels of between 3.3 and 5.5 V. All specifications are maintained as long as the total input current is below 1 A. At 1 A, the internal Voltage regulator's protection circuit allows no more current to be taken in. This 1A current limit will be reached slightly sooner if current is drawn out the Vout line or if the GPIO lines are supplying current to external circuits.

The most obvious impact of this 1A limit is that the module cannot be operated below 3.7 Volts when the RF power output level is set to 27 dBm. This limit is fully explained in the next section.

The module will still operate if the DC input Voltage level falls below 3.3 V, but its specifications are not guaranteed. If the DC input Voltage falls below 3 VDC, a "brown-out" self-protection function in the processor will gracefully turn the module off so that the module will not be in an undeterminate state once the voltage is restored.

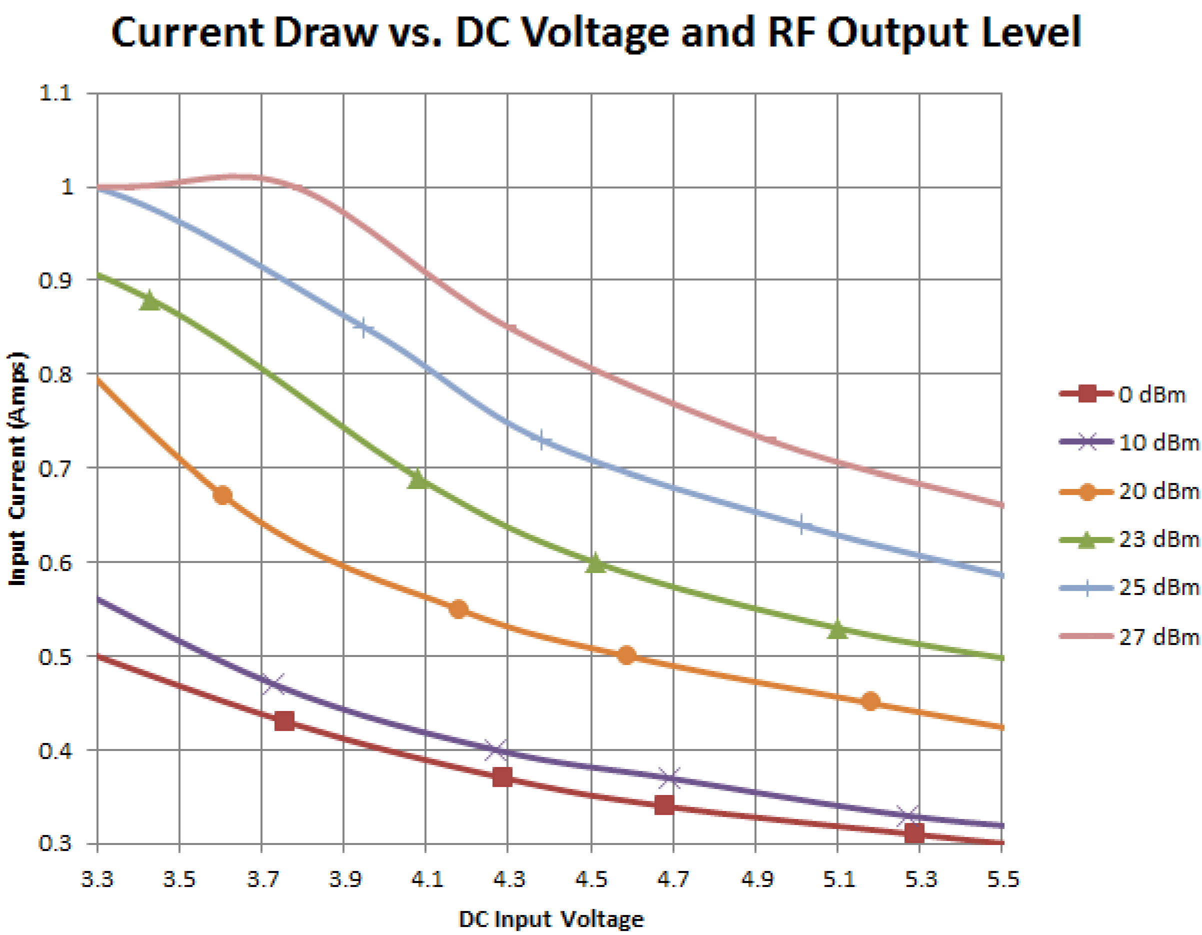
RF Power Output Impact on DC Input Current and Power

The ThingMagic Nano supports separate read and write power level which are command adjustable via the MercuryAPI. The power level limits are:

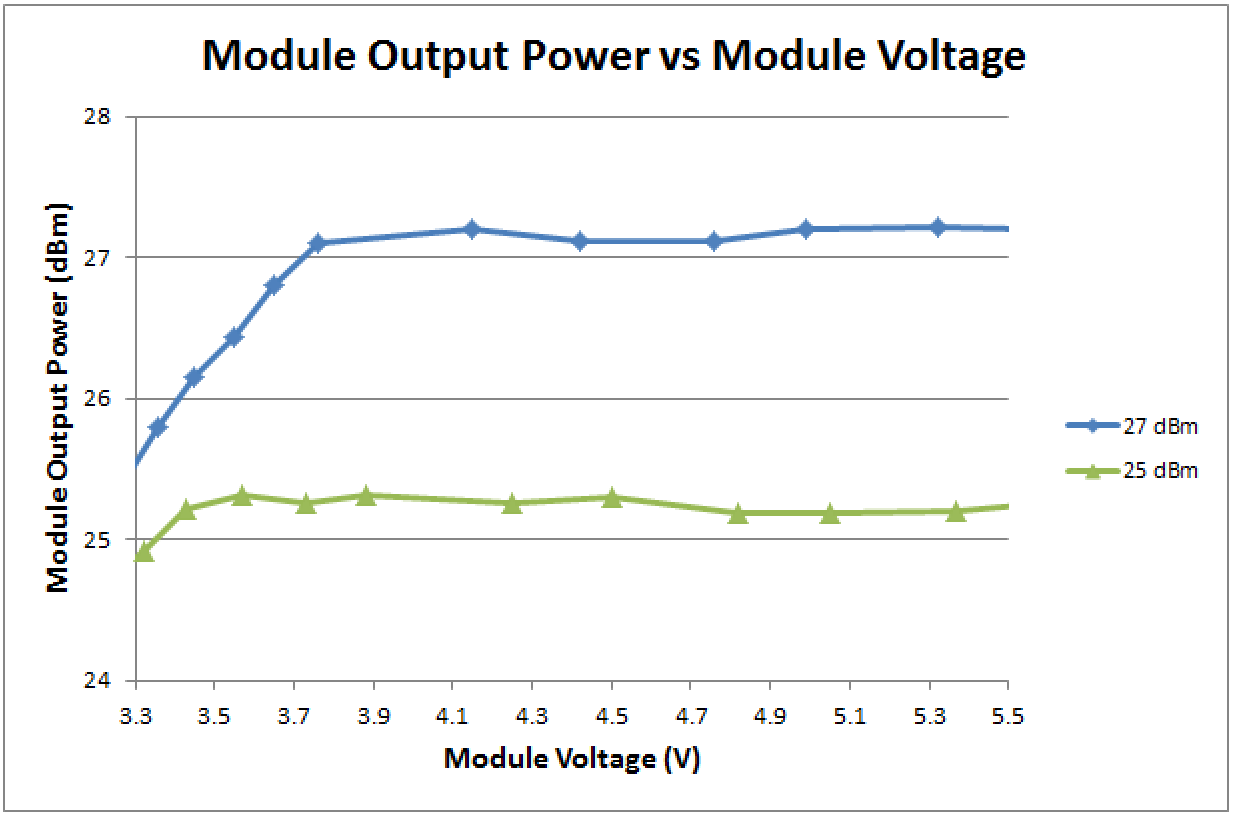
- Minimum RF Power = 0 dBm
- Maximum RF Power = +27 dBm

Note

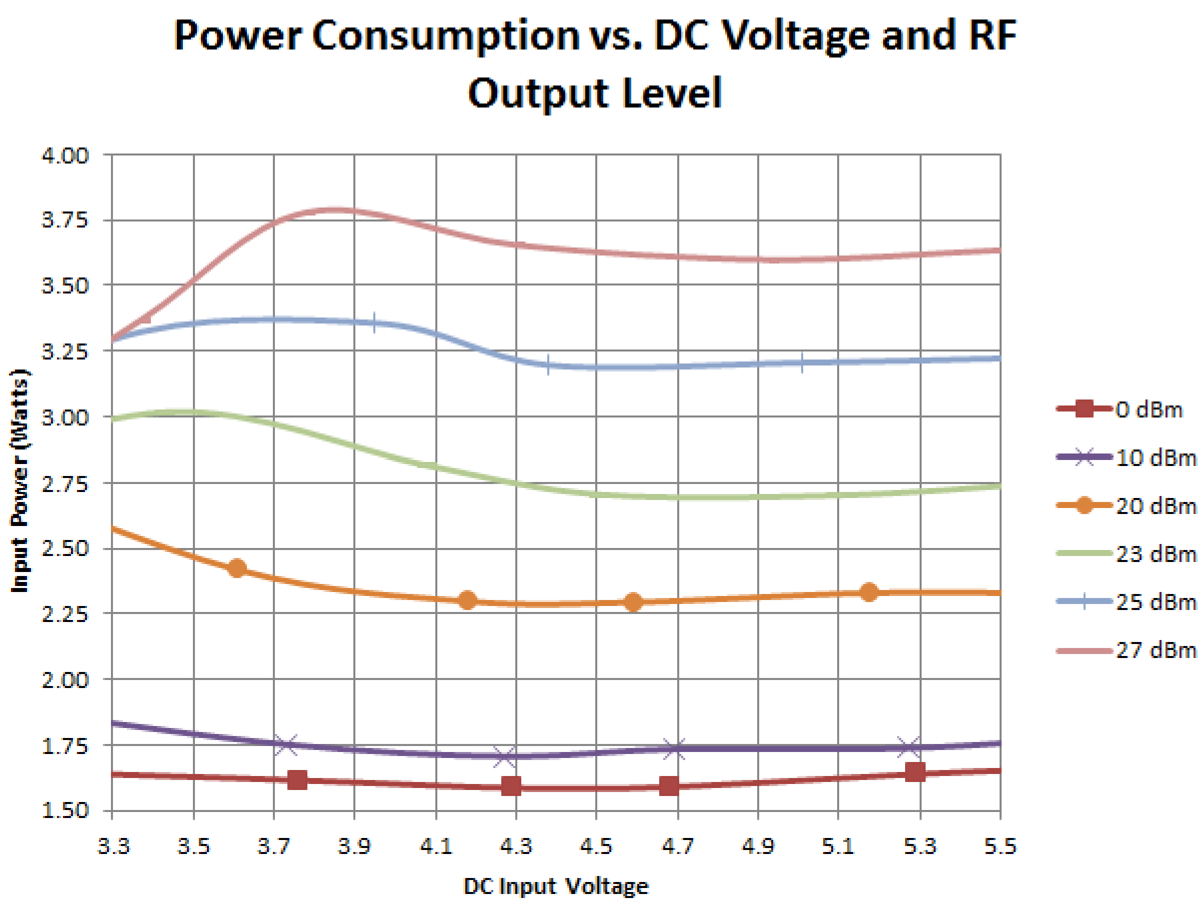
Maximum power may have to be reduced to meet regulatory limits, which specify the combined effect of the module, antenna, cable and enclosure shielding of the integrated product.



As shown in the chart, the current draw when the RF output level is set to +27 dBm reaches the limit of 1A when the DC input voltage is below 3.7 V. Below the 3.7 VDC input level, the RF level will no longer reach 27 dBm, although no error message will be returned. The input Voltage should be maintained above 3.7 Volts if the RF output power setting is above +25 dBm. 3.5 V is adequate for an RF output power level of +26 dBm, and 3.3 V is adequate for an RF output power level of +25 dBm and below. The chart below shows the impact of the input DC Voltage on the RF output level for +25 dBm and +27 dBm RF power levels.



The power drawn by the module is fairly constant, rising slightly as the DC Input Voltage is lowered. Once the 1A input current limit is reached, the input power appears to decrease, but this is because the RF output level is no longer reflecting the desired setting. This chart shows these dependencies:



Note: Power consumption is defined for operation into a 17 dB return loss load (VSWR of 1.33) or better. Power consumption may increase, up to 4 W, during operation into return losses worse than 17 dB and high ambient temperatures. Power consumption will also vary based on which of the Supported Regions is in use.

Power Supply Ripple

The following are the minimum requirements to avoid module damage and to insure performance and regulatory specifications are met. Certain local regulatory specifications may require tighter specifications.

- 3.3 to 5.5 VDC
- Less than 25 mV pk-pk ripple all frequencies,
- Less than 11 mV pk-pk ripple for frequencies less than 100 kHz,
- No spectral spike greater than 5 mV pk-pk in any 1 kHz band.

Idle DC Power Consumption

When not actively transmitting, the ThingMagic Nano module falls back into one of 3 idle states, called “power modes”. There are 5 enumerated idle power modes defined in the API, but the Nano module only supports 3 options, so three of the settings behave identically. Each successive power mode turns off more of the module’s circuits, which have to be restored when a command is executed, imposing a slight delay. The following table gives the power consumption levels and the delay to respond to a command for each. See Idle DC Power Consumption for details.

ThingMagic Nano Power Consumption

Operation	**DC Power Consumed at 5 VDC**	**Time to Respond to a Read Command**
Power Mode = “FULL”	0.85 W	Less than 5 msec
Power Mode = “MINSAVE”, “MEDSAVE”, or “MAXSAVE”	0.04 W	Less than 20 msec
Power Mode = “SLEEP”	0.02 W	Less than 20 msec
ENABLE Line disabled	.00015 W	Module reboots when Enable line brought high

These nominal values should be used to calculate metrics such as battery life. To determine the absolute maximum DC power that would be required under any condition, one must consider temperature, channel of operation, and antenna return loss.

RF Characteristics

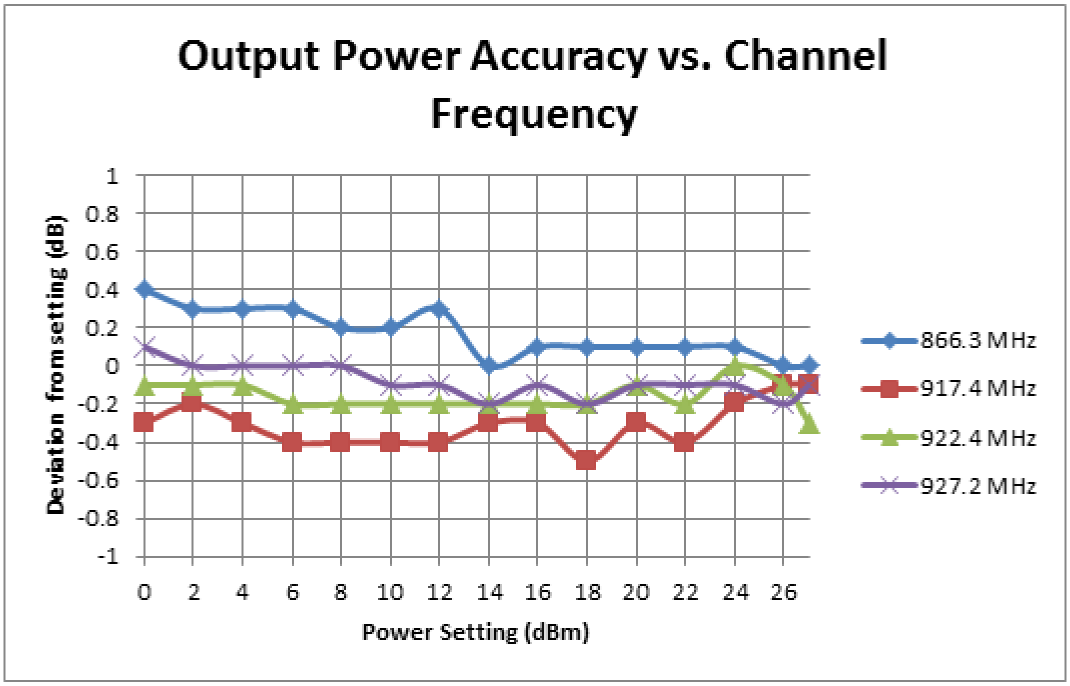
RF Output Power

The output power may be set to a separate value for read and write operations (for many tags, more power is required to write to read). The range of values for both settings is from 0 dBm to +27 dBm, in 0.01 dB increments. (For example, 27 dBm will be configured as “2700” in units of centi-dBm.) The modules are calibrated when they are manufactured in 0.5 dB increments and linear interpolation is used to set values with greater granularity than this.

The granularity of the RF output power setting should not be confused with its accuracy. The accuracy of the output level is specified to be +/- 1 dBm for each regional setting.

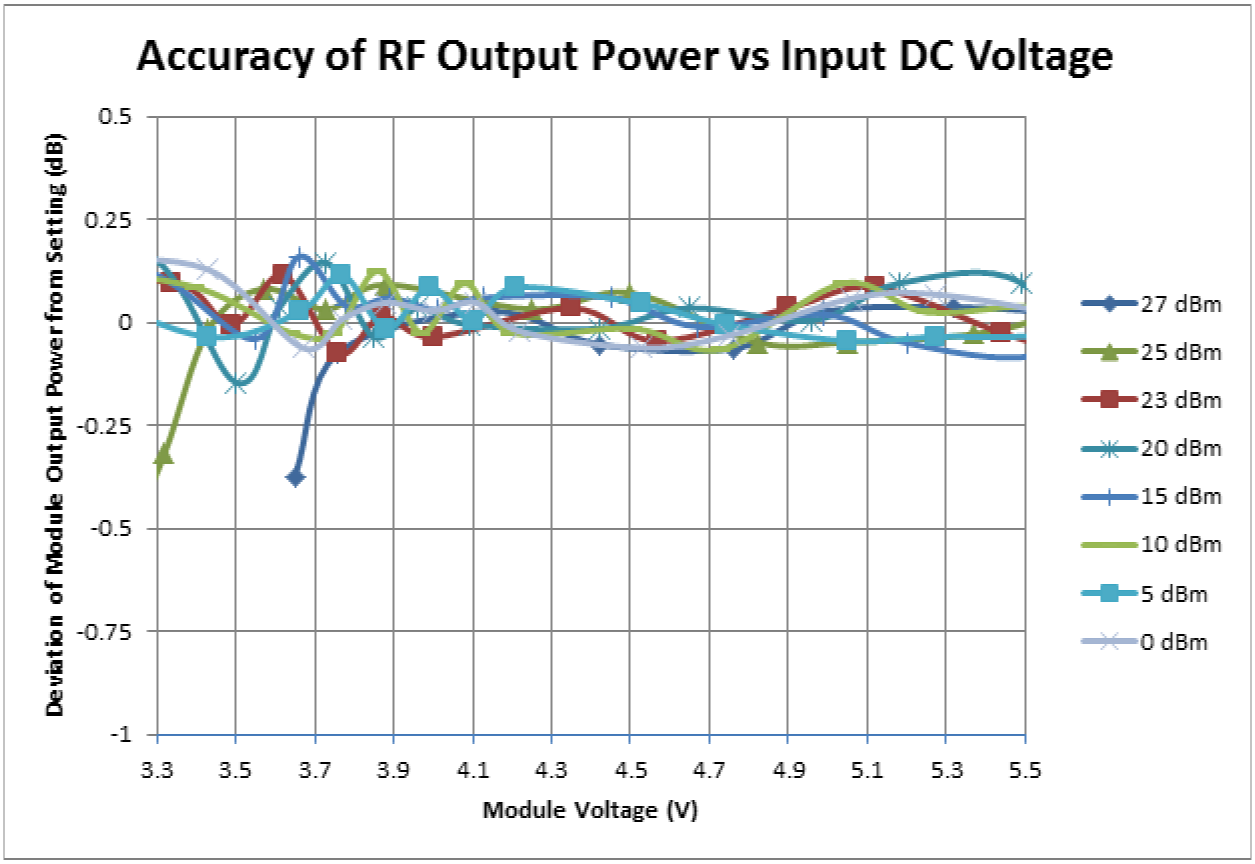
Additional variation may be experienced if the DC input Voltage and temperature changes while the module is operational.

This chart shows the typical transmit output variation over frequency. The typical variation is less than +/-0.5 dBm for all transmit levels, across the entire frequency band.

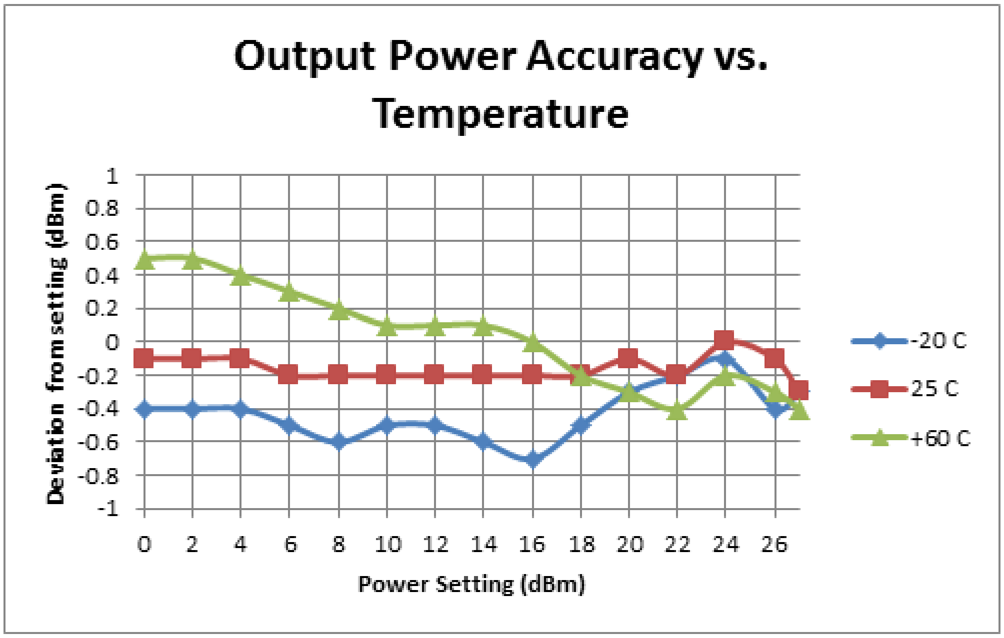


DC Input Voltage also affects the transmit output level accuracy. The typical variation is less than +/- 0.20 dBm except at high RF output levels for low DC input voltages, as has been discussed in the RF Power Output Impact on DC Input Current and Power section.

The following chart shows the accuracy of the RF power setting across all supported input DC voltages. Note that the actual RF output level starts to drop for +27 dBm output level settings at around 3.7 VDC input levels and the RF output level starts to drop for +25 dBm settings at around 3.3 VDC input levels.



The output accuracy over temperature is typically +/- 0.75 dBm, with most variation occurring at lower transmit output power levels.



Receive Sensitivity

The receive sensitivity is influenced by both user-defined settings and by external environmental factors. These factors are:

- Transmit Level
- Gen2 “M” setting
- Region of Operation

Receive sensitivity is strongly influenced by the amount of interference caused by the reader’s own transmit signal. This interference can be reduced by reducing the transmit level. ThingMagic always quotes the receive sensitivity at the highest transmit level (+27 dBm for the Nano), but 1 dB of sensitivity is typically gained for every dB that the transmitter output level is reduced.

The Gen2 “M” setting influences how data is encoded when sent from the tag to the reader. Higher “M” values send data at lower rates and are more noise immune, increasing the module's sensitivity. Lower "M" values send data at higher rates, decreasing the sensitivity somewhat.

The region of operation is also a factor. The Nano has slightly better receive sensitivity in the regions that fall within the range of 865 to 868 MHz than in regions that fall within the range of 917 to 928 MHz.

The following table gives the sensitivity for region and "M" value at a transmit output level of +27 dBm.

Region	"M" Value	Sensitivity
North America and subsets of 917 to 928 MHz band	8	-57 dBm
	4	-55 dBm
	2	-45 dBm
EU and India (865 to 868 MHz	8	-60 dBm
	4	-58 dBm
	2	-49 dBm

Note that sensitivity is strongly affected by the success rate required by the application. The sensitivity values in the table reflect a very high read success rate (greater than 90%). Tags typically will begin to respond sporadically at receive levels that are 5 dB lower than the values shown in this table.

Receiver Adjacent Channel Rejection

The ThingMagic Nano receives signals that are centered at +250 kHz from its own carrier. The width of the receive filter is adjusted to match the "M" value of the signal being sent by the tag. An M value of 2 require the widest filter and an M value of 8 requires the narrowest filter. If operating in an environment where many readers are present, observe the performance of one reader as the other readers are turned on and off. If the performance improves when the other readers are turned off, then the system may be experiencing reader-to-reader interference. This reader-to-reader interference will be minimized by using the highest "M" value that is consistent with the tag read rates required by the application.

Environmental Specifications

Thermal Considerations

The module will operate within its stated specifications over a temperature range o f -20 to +60 degrees C, measured at the ground plane that the ThingMagic Nano module is soldered to.

It may be safely stored in temperatures ranging from -40 degrees C to +85 degrees C.

Thermal Management

Heat-sinking

For high duty cycles, it is essential to use a surface mount configuration where all edge vias are soldered to a carrier or mother board, with a large area of ground plane, that will either radiate heat or conduct the heat to a larger heat-sink. A high density of PCB vias from the top to bottom of the board will efficiently conduct heat to a bottom mount heat-sink. Often the weak link in thermal management design is not the thermal interface from the ThingMagic Nano to the heat-sink, but rather the thermal interface from the heat-sink to the outside world.

Duty Cycle

If overheating occurs it is recommended to first try reducing the duty cycle of operation. This involves modifying the RF On/Off (API parameter settings /reader/read/asyncOnTime and asyncOffTime) values. A good place to start is 50% duty cycle using 250ms/250ms On/Off.

If your performance requirements can be met, a low enough duty cycle can result in no heat sinking required. Or with adequate heat sinking you can run continuously at 100% duty cycle.

Temperature Sensor

The ThingMagic Nano module has an integrated temperature sensor, located near the components which generate the most heat. The temperature can be obtained through the user interface as a status indication. This information is also used by the firmware to prevent transmission when the module is too hot or too cold to operate properly. The temperature limits for allowing transmission are -20 C to +85 C.

Note

The temperature level at which transmission is prevented, +85 C, is higher than the +60 C operating limit for two reasons: (1) The temperature indicated by the on-board sensor will always be higher than ambient temperature, due to heat generated by internal components, and (2) the temperature limit for transmission is chosen to prevent damage to the components, while the +60 C limit for operation is chosen to ensure that all specifications are met.

Electro-Static Discharge (ESD) Specification

The Electro-Static Discharge Immunity specifications for the ThingMagic Nano are as follows:

IEC-61000-4-2 and MIL-883 3015.7 discharges direct to operational antenna port tolerates max 1 KV pulse. It will tolerate a 4 kV air discharge on the I/O and power lines. It is recommended that protective diodes be placed on the I/O lines as shown in the carrier board schematic diagram (see Hardware Integration).

Note

Survival level varies with antenna return loss and antenna characteristics. See ElectroStatic Discharge (ESD) Considerations for methods to increase ESD tolerances.

W A R N I N G !

The ThingMagic Nano antenna port may be susceptible to damage from Electrostatic Discharge (ESD). Equipment failure can result if the antenna or communication ports are subjected to ESD. Standard ESD precautions should be taken during installation and operation to avoid static discharge when handling or making connections to the ThingMagic Nano reader antenna or communication ports. Environmental analysis should also be performed to ensure static is not building up on and around the antennas, possibly causing discharges during operation.

Shock and Vibration

The ThingMagic Nano module is specified to survive a 1 meter drop onto a hard surface. It will also survive the following vibration limits:

- 4.02 Grms random, mounted on a non-resonant hard carrier
- Five shipments by air, MIL-STD-810G METHOD 514.6 ANNEX C, Figure 514.6C-5 General Exposure pg 514.6C-16, and Table 514.6C-VII, General Exposure. 5 minutes each of three axes.

Authorized Antennas

This device has been designed to operate with the antennas listed below, and having a maximum gain of 8.15 dBiL. Antennas not included in this list or having a gain greater than 8.15 dBiL are strictly prohibited for use with this device without regulatory approval. (Circularly polarized antennas can have a circular gain has high as 11.15 dBiC and still maintain a maximum linear gain of 8.15 dBiL.) The required antenna impedance is 50 ohms.

ThingMagic Nano Authorized Antennas

Vendor	**Model**	**Type**	**Polarization**	**Frequency Range**	**Circular Gain (dBiC)**	**Max Linear Gain (dBi)**
MTI Wireless	MT-263020	Patch	Circular	902-928 MHz	11 min	8
Laird	S9025P	Patch	Circular	902-928 MHz	5.5	4.3
Laird	S8658WPL	Patch	Circular	865-960 MHz	8.5	6.0
MTI Wireless	MTI-262013	Patch	Circular	902-928 MHz	7 min, 7.5 max	6.0
MTI Wireless	MTI-242043	Patch	Circular	865-956 MHz	7.5 in EU band, 8.5 in NA band	6.0
Laird	FG9026	Dipole	Linear	902-928 MHz	[Not Applicable]	8.15

Note: Most tags are linearly polarized, so the “max linear gain” value is the best number to use when calculating the maximum read distance between the module and a tag.

FCC Modular Certification Considerations

Trimble has obtained FCC modular certification for the ThingMagic Nano module. This means that the module can be installed in different end-use products by another equipment manufacturer with little or no additional testing or equipment authorization for the transmitter function provided by that specific module. Specifically:

- No additional transmitter-compliance testing is required if the module is operated with one of the antennas listed in the FCC filing
- No additional transmitter-compliance testing is required if the module is operated with the same type of antenna as listed in the FCC filing as long as it has equal or lower gain than the antenna listed. Equivalent antennas must be of the same general type (e.g. dipole, circularly polarized patch, etc.), must be of equal or less gain than an

antenna previously authorized under the same FCC ID, and must have similar in band and out of band characteristics (consult specification sheet for cut-off frequencies).

If the antenna is of a different type or higher gain than those listed in the module's FCC filing, see ThingMagic Nano Authorized Antennas, a *class II permissive change* must be requested from the FCC. Contact us at support@thingmagic.com and we can help you though this process.

The FCC regulations state that a host device using a module that has a modular grant can:

1. Be marketed and sold with the module built inside that does not have to be end-user accessible/replaceable, or

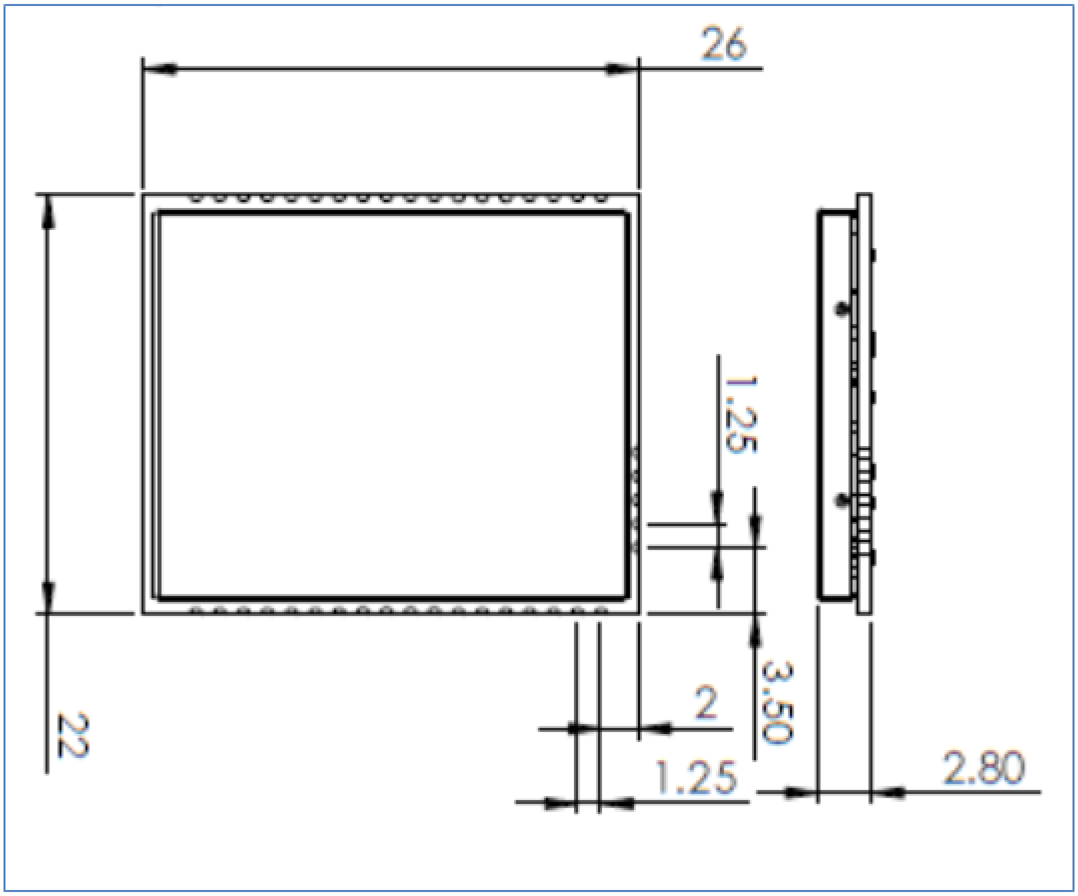
2. Be end-user plug-and- play replaceable.

In addition, a host product is required to comply with all applicable FCC equipment authorizations, regulations, requirements and equipment functions not associated with the RFID module portion. For example, compliance must be demonstrated to regulations for other transmitter components within the host product; to requirements for unintentional radiators (Part 15B), and to additional authorization requirements for the non-transmitter functions on the transmitter module (for example, incidental transmissions while in receive mode or radiation due to digital logic functions).

To ensure compliance with all non-transmitter functions the host manufacturer is responsible for ensuring compliance with the module(s) installed and fully operational. For example, if a host was previously authorized as an unintentional radiator under the Declaration of Conformity procedure without a transmitter certified module and a module is added, the host manufacturer is responsible for ensuring that the after the module is installed and operational the host continues to be compliant with Part 15B unintentional radiator requirements. Since this may depend on the details of how the module is integrated with the host, we shall provide guidance to the host manufacturer for compliance with Part 15B requirements.

Physical Dimensions

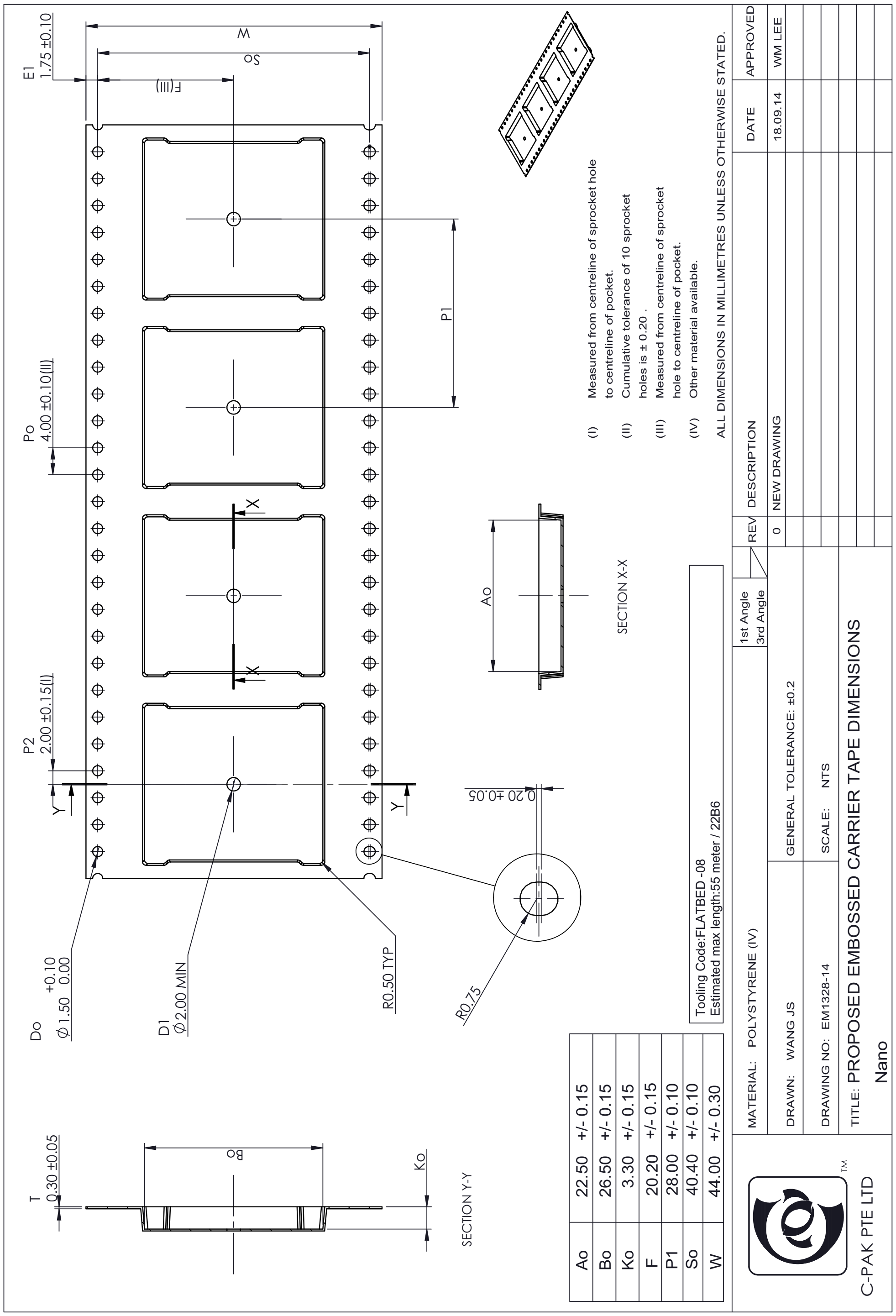
The dimensions of the ThingMagic Nano module are shown in the following diagram and the table below:



Attribute	Value
Width	22 +/-0.2 mm
Length	26 +/-0.2 mm
Height (includes PCB, shield, mask and labels)	3.0 maximum
Mass	3.2 gms

Tape-and-Reel Dimensions

The Nano is delivered in a tape-and-reel package. The reel measures 13 inches by 4 inches. The following drawing gives the dimensions of the tape.

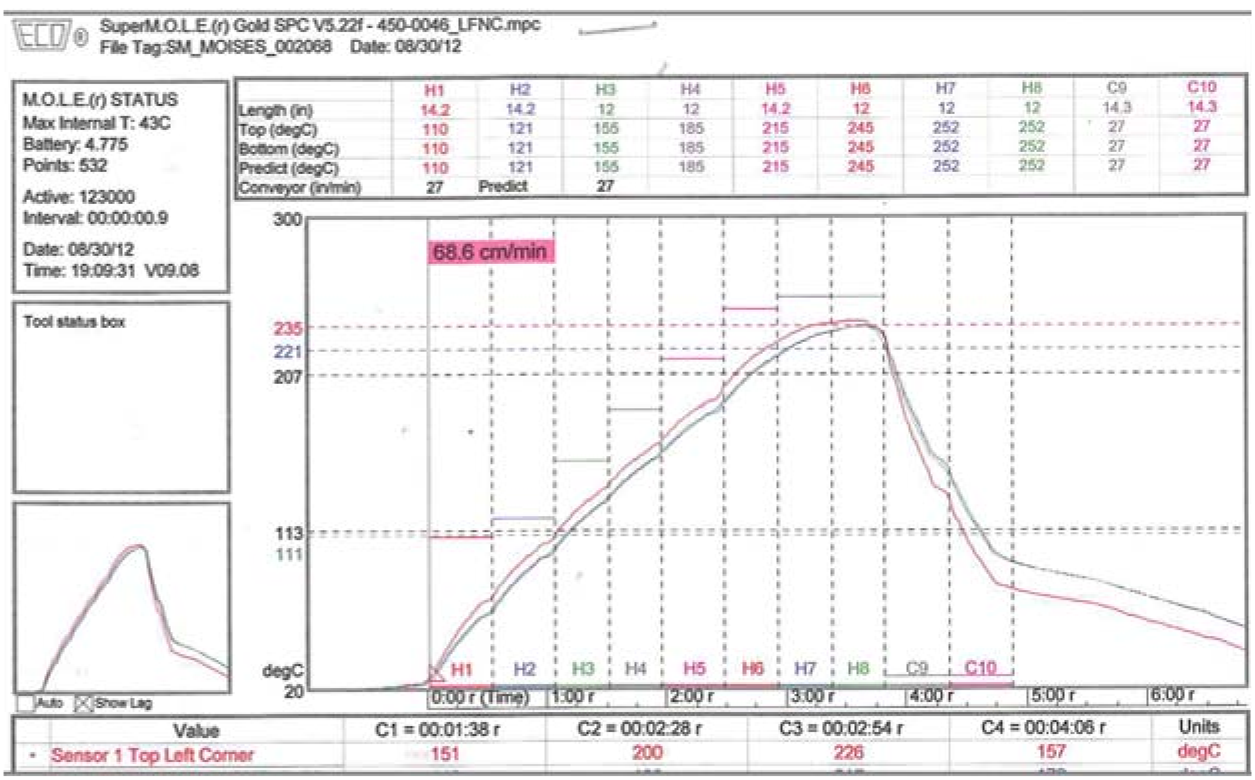

T 0.30 ±0.05
Bo
Ko
SECTION Y-Y
Do ∅1.50 +0.10 0.00
D1 ∅2.00 MIN
R0.50 TYP
R0.75
P2 2.00 ±0.15(I)
Po 4.00 ±0.10(II)
E1 1.75 ±0.10
W
So
F(III)
P1
Y
X
Ao
SECTION X-X
0.20 ±0.05
Ao 22.50 +/- 0.15
Bo 26.50 +/- 0.15
Ko 3.30 +/- 0.15
F 20.20 +/- 0.15
P1 28.00 +/- 0.10
So 40.40 +/- 0.10
W 44.00 +/- 0.30
Tooling Code:FLATBED -08
Estimated max length:55 meter / 22B6
(I) Measured from centreline of sprocket hole to centreline of pocket.
(II) Cumulative tolerance of 10 sprocket holes is ± 0.20 .
(III) Measured from centreline of sprocket hole to centreline of pocket.
(IV) Other material available.
ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE STATED.
1st Angle
3rd Angle
REV DESCRIPTION DATE APPROVED
0 NEW DRAWING 18.09.14 WM LEE
MATERIAL: POLYSTYRENE (IV)
DRAWN: WANG JS
GENERAL TOLERANCE: ±0.2
DRAWING NO: EM1328-14
SCALE: NTS
TITLE: PROPOSED EMBOSSED CARRIER TAPE DIMENSIONS
Nano
C-PAK PTE LTD
THIS DRAWING CONTAINS INFORMATION THAT IS PROPRIETARY TO C-PAK PTE.LTD.

SMT Reflow Profile

Short reflow profiles are recommended for soldering processes. Peak zone temperature should be adjusted high enough to ensure proper wetting and optimized forming of solder joints.

Generally speaking, unnecessary long exposure and exposure to more than 245C should be avoided.

To not overstress the assembly, the complete reflow profile should be as short as possible. An optimization considering all components on the application must be performed. The optimization of a reflow profile is a gradual process. It needs to be performed for every paste, equipment and product combination. The presented profiles are only samples and valid for the used pastes, reflow machines and test application boards. Therefore a "ready to use" reflow profile can not be given.



There must be only be one reflow cycle, maximum.

Hardware Integration

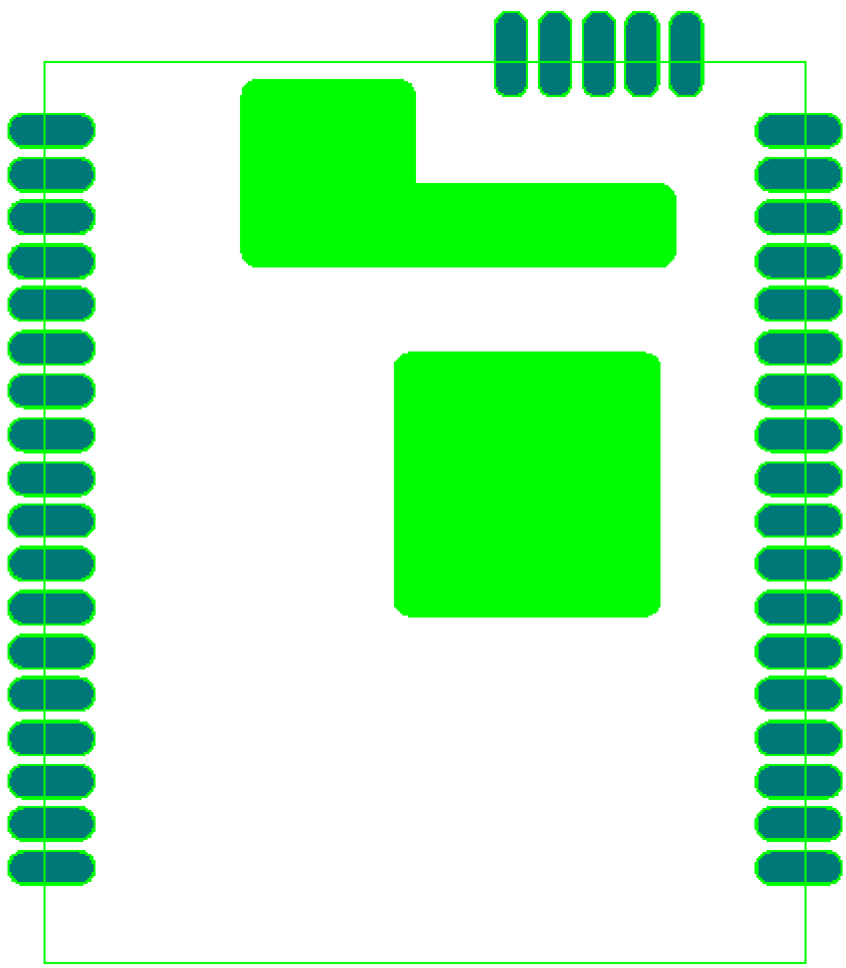
The ThingMagic® Nano® embedded module is an RFID reader that you can integrate with other systems to create RFID-enabled products. This chapter discusses topics relating to this, including requirements for a host board design and characteristics of the Nano Carrier Board that ThingMagic offers for use in Development Kits and for applications where standard connectors are required to interface the module with a host board.

- Host Board Design
- ThingMagic Nano Carrier Board

Host Board Design

Landing Pads

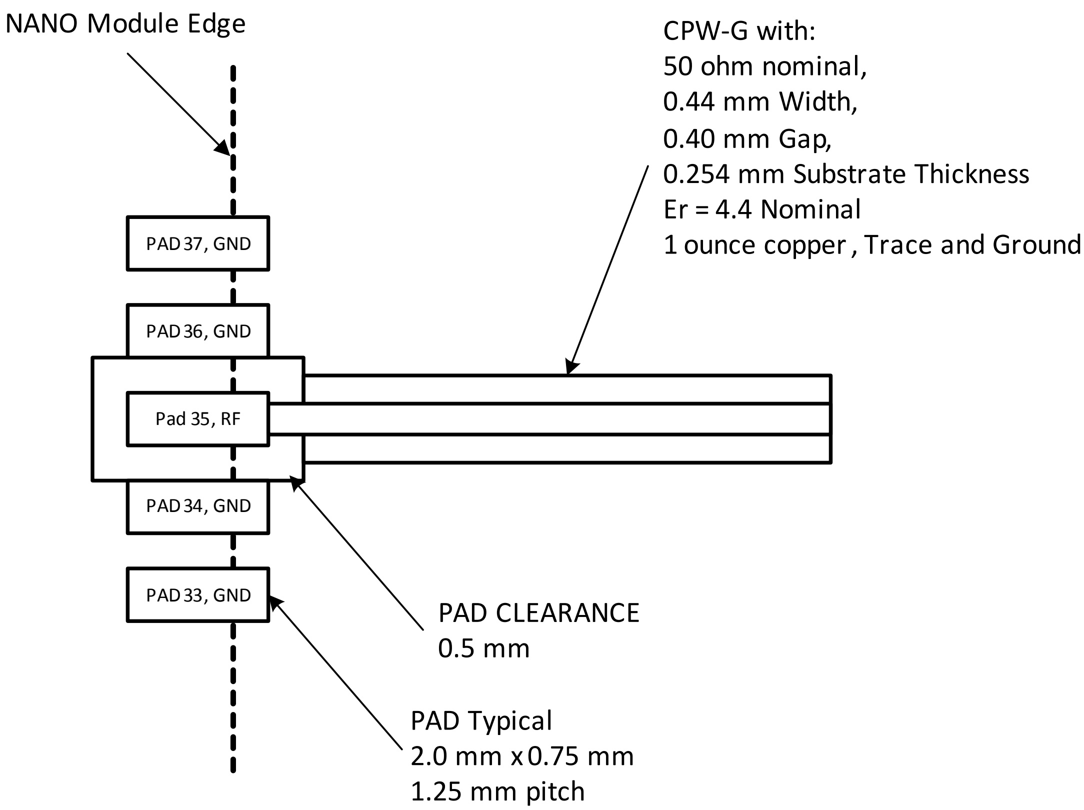
This diagram shows the position and recommended size of the landing pads (in dark green) and the heat-sink areas (in light green):



Hardware design files are available on the Support web site (http://www.thingmagic.com/manuals-firmware) for the “carrier board” that implements this layout.

The ThingMagic Nano module mounts to the host board via the landing pads. These pads are at a pitch of 1.25 mm. The intention is for the ThingMagic Nano module is to use routed-through via connections with 0.7 mm diameter edge vias. The pads of the ThingMagic Nano module underside should align with the copper pads of the footprint, with a pad exposure extending outside the M6e-Nano edge be a nominal 0.5 mm. A 0.5 mm keep-out shall surround any non-ground pad. The module pad positional tolerance shall be not more than +/-0.2 mm to support contact alignment during fixturing.

The circuitry feeding the RF pad of the M6e-Nano shall be optimized for connecting to a coplanar wave guide with ground plane beneath. The CPW-G will have dimensions as shown in the following diagram.



The area beneath the module should be kept clear of traces and copper.

In addition to the design and process recommendations, the following should be considered:

There is the potential for 24MHz harmonics radiating from pins 22 through 28 of the ThingMagic Nano. If emissions testing shows such harmonics, the easiest fix is to put bypass capacitors (typically 39 to 100pf) directly at the offending pins on the carrier board. Note that higher values are not necessarily better. The ideal capacitor value will have series resonance near the most offending frequency. 39pF has been good for around 900 MHz in sample board layouts.

ThingMagic Nano Carrier Board

ThingMagic has created a Carrier Board for the ThingMagic Nano module, as an example of a host board for this module and to create an assembly that is compatible with the standard Development Kit main board. It has the size and dimensions of the M6e module (69 mm x 43 mm), and uses the same connector for power and control (Molex 53261-1571 - 1.25mm pin centers, 1 amp per pin rating. which mates with Molex housing p/n 51021-1500 with crimps p/n 63811-0300).

The pin definitions are the same as for the M6e module, for the functions that are supported by the ThingMagic Nano module, with one exception: The “SHUTDOWN” line of the M6e performs the same function as the ENABLE line in the Nano, but has reversed polarity.

Pin Number	Signal	Signal Direction with respect to Carrier Board	Notes
1,2	GND	Power and Signal Return	Must connect both pins to ground.
3.4	DC Power in	Input	3.3 to 5.5 VDC; must connect both pins to the supply.
5	GPIO1	Bidirectional	Same Specifications as Nano itself.
6	GPIO2	Bidirectional	Same Specifications as Nano itself.
7	GPIO3	Bidirectional	Same Specifications as Nano itself.
8	GPIO4	Bidirectional	Same Specifications as Nano itself.
9	UART RX	Input	
10	UART TX	Output	
11-13	RFU	Not Internally Con-nected	
14	ENABLE	Input	Internally Pulled high, in ENABLE state, if not connected
15	Unused		

The UART RX and UART TX lines are buffered on the Nano Carrier Board. This makes the inputs 5V tolerant and increases the output current driving capability from 10 mA to 15 mA. Diodes are also added on all I/O lines to increase the ESD protection.

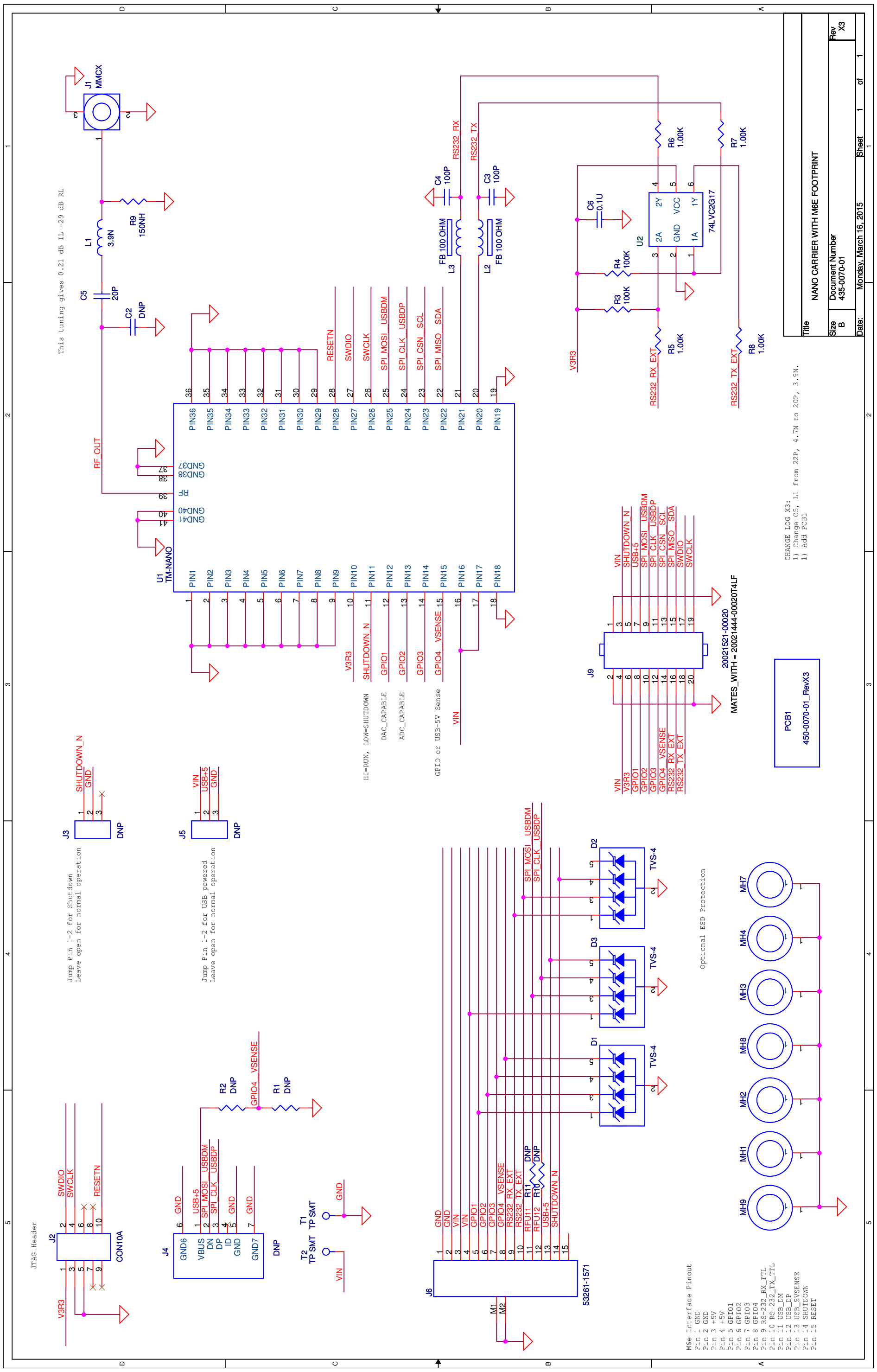
The buffer on the Nano Carrier Board is driven by the Vout pin on the ThingMagic Nano. The current supplied to this buffer will count toward the 1A total current that the

ThingMagic Nano can draw from its power source, potentially requiring slightly higher input voltage levels to achieve the highest RF output levels.

The following page provides a schematic diagram for the Nano Carrier Board. Contact support@thingmagic.com to obtain this in a PDF file.

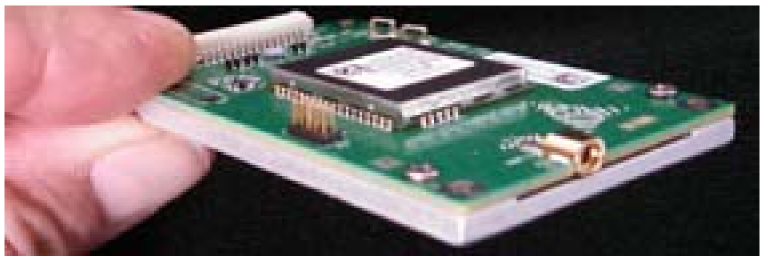
C A U T I O N !

The RX input line and all GPIO lines configured as inputs must be low when the module is turned off and low just before the module is turned on. If input lines are high at the time the module is being powered up, we have seen corruption of memory occur that cannot be remedied except at the factory. The RX input line can be assured to be in a safe state if it is driven by a buffer circuit that is powered by the Nano module as shown in the Nano carrier board design. That way, the input Voltage to the RX pin can never be higher than the DC supply voltage into the Nano module because the buffer is powered by the Nano module.

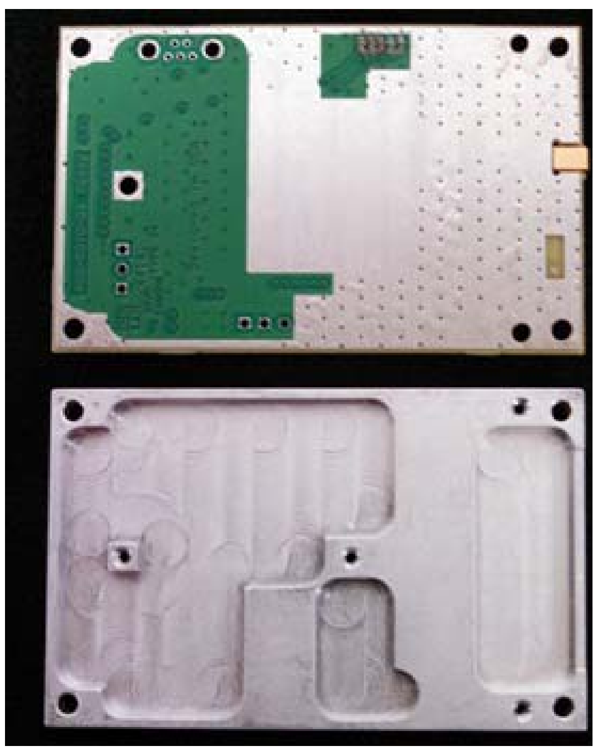

NANO CARRIER WITH M6E FOOTPRINT
Document Number
435-0070-01
Rev
X3
Monday, March 16, 2015
PCB1
450-0070-01_RevX3

Carrier Board Heat Sinking

The ThingMagic Nano can run at full RF power at room temperature on stand-offs in the Dev Kit. If you wish to test the ThingMagic Nano under extreme temperature conditions, you may want to mount it on the heat spreader that is supplied with the Micro modules for the xPRESS Sensor Hub.



Make sure it is assembled as shown in these pictures so no live signals are shorted to ground.



Note

The Xpress Sensor Hub firmware does not support the Thingmagic Nano module at this time.

Firmware Overview

The following section provides detailed description of the ThingMagic Nano firmware components, including:

- Boot Loader
- Application Firmware
- Custom On-Reader Applications

Boot Loader

The boot loader provides module functionality until the module application firmware can start up as well as when the module firmware is in the process of being updated. This program provides the low level hardware support for configuring communication settings, loading Application Firmware and storing data that needs to be remembered across reboots.

When a module is powered up or reset, the boot loader code is automatically loaded and executed.

Note

Unlike the previous generation of ThingMagic modules (M5e and Compact) the ThingMagic Nano bootloader should effectively be invisible to the user. The ThingMagic Nano is configured to auto-boot into application firmware and return transparently to the bootloader for any operations that require the module to be in bootloader mode.

Note

Unlike the M6e and Micro (and Micro-LTE) modules, there is no reset line that can be used to keep the module in bootloader mode when it is initializing. Likewise, the absence of this reset line means that there is no hardware indication that the application software has failed to start and the module has remained in bootloader mode.

Application Firmware

The application firmware contains the tag protocol code along with all the command interpreters to set and get system parameters and perform tag operations. The application firmware is started automatically upon power up.

Programming the ThingMagic Nano

Applications to control the ThingMagic Nano module are written using the high level MercuryAPI. The MercuryAPI supports Java, ".NET" and C programming environments. The MercuryAPI Software Development Kit (SDK) contains sample applications and source code to help developers get started demonstrating and developing functionality. For more information on the MercuryAPI see the *MercuryAPI Programmers Guide* and the *MercuryAPI SDK*, available on the ThingMagic website.

Upgrading the ThingMagic Nano

New features developed for the ThingMagic Nano are made available through an Application Firmware upgrade, released with corresponding updates to the MercuryAPI to make use of the new features. The MercuryAPI SDK contains applications which will upgrade firmware for all ThingMagic readers and modules, as well as source code that allows developers to build this functionality into their custom applications.

Verifying Application Firmware Image

The application firmware has an image level Cyclic Redundancy Check (CRC) embedded in it to protect against corrupted firmware during an upgrade process. If the upgrade is unsuccessful, the CRC will not match the contents in flash. When the bootloader starts the application firmware, it first verifies that the image CRC is correct. If this check fails, then the boot loader does not start the application firmware and an error is returned.

Custom On-Reader Applications

The ThingMagic Nano does not support installing custom applications on the module. All reader configuration and control is performed using the documented MercuryAPI methods in applications running on a host processor.

Communication Protocol

The following section provides an overview of the low level serial communications protocol used by the ThingMagic Nano. Topics include:

- Serial Communication Protocol
- User Programming Interface

Serial Communication Protocol

ThingMagic does not support bypassing the MercuryAPI to send commands to the ThingMagic Nano module directly, but some information about this interface is useful when troubleshooting and debugging applications which interface with the MercuryAPI.

The serial communication between MercuryAPI and the ThingMagic Nano is based on a synchronized command-response/master-slave mechanism. Whenever the host sends a message to the reader, it cannot send another message until after it receives a response. The reader never initiates a communication session; only the host initiates a communication session.

This protocol allows for each command to have its own time-out because some commands require more time to execute than others. MercuryAPI must manage retries, if necessary. MercuryAPI must keep track of the state of the intended reader if it reissues a command.

Host-to-Reader Communication

Host-to-reader communication is packetized according to the following diagram. The reader can only accept one command at a time, and commands are executed serially, so the host waits for a reader-to-host response before issuing another host-to-reader command packet.

Header	Data Length	Command	Data	CRC-16 Checksum

Hdr	Len	Cmd	----------------	CRC Hi / CRC LO

1 byte	1 byte	1 byte	0 to 250 bytes	2 bytes

Reader-to-Host Communication

The following diagram defines the format of the generic Response Packet sent from the reader to the host. The Response Packet is different in format from the Request Packet.

Header	Data Length	Command	Status Word	Data	CRC-16 Checksum
Hdr	Len	Cmd	Status Word	----------------	CRC Hi / CRC LO
1 byte	1 byte	1 byte	2 bytes	0 to 248 bytes	2 bytes

CCITT CRC-16 Calculation

The same CRC calculation is performed on all serial communications between the host and the reader. The CRC is calculated on the Data Length, Command, Status Word, and Data bytes. The header is not included in the CRC.

User Programming Interface

The ThingMagic Nano does not support programming to the serial protocol directly. All user interaction with the ThingMagic Nano must be performed using the MercuryAPI.

The MercuryAPI supports Java, ".NET" and C programming environments. The MercuryAPI Software Development Kit (SDK) contains sample applications and source code to help developers get started demoing and developing functionality. For more information on the MercuryAPI see the *MercuryAPI Programmers Guide* and the *MercuryAPI SDK*, available on the ThingMagic website.

Functionality of the ThingMagic Nano

The following section provides detailed descriptions of the ThingMagic Nano features and functionality that are supported through the MercuryAPI.

Regulatory Support

CAUTION!

Please contact ThingMagic support - support@thingmagic.com - before beginning the process of getting regulatory approval for a finished product using the ThingMagic Nano. We can supply documents, test reports and certifications to the test house, which will greatly accelerate the process.

Supported Regions

The ThingMagic Nano has varied levels of support for operation and use under the laws and guidelines of several regions. The existing regional support and any regulatory constraints are provided in the following table. Additional information on each region is provided in Regional Frequency Specifications.

Region	Regulatory Support	Notes
Narrow Band North America (“NA2”)	FCC 47 CFG Ch. 1 Part 15 Industrie Canada RSS-210	Complies with all FCC regulations but uses a narrow frequency range: 917,400 kHz to 927,200 kHz
European Union (“EU3”)	Revised ETSI EN 302 208 Note: The EU and EU2 regions offered for other modules are for legacy applications using old ETSI regulations. These are not supported in the Nano.	By default EU3 will use four channels. The EU3 region can also be used in a single channel mode. These two modes of operation are defined as: **Single Channel Mode** Set by manually setting the frequency hop table to a single frequency. In this mode the module will occupy the set channel for up to four seconds, after which it will be quiet for 100msec before transmitting on the same channel again. **Multi Channel Mode** Set by default or by manually setting more than one frequency in the hop table. In this mode the module will occupy one of the configured channels for up to four seconds, after which it may switch to another channel and immediately occupy that channel for up to four seconds. It will not return to any channel until that channel has been dormant for 100 msec. This mode allows for more continuous reading.
Korea (KR2)	KCC (2009)	The first frequency channel (917,300kHz) of the KR2 region is derated to a maximum level of +22 dBm to meet the regulatory requirements. All other channels operate up to +27dBm. This has little impact on performance. The reader, by default, automatically switches off channels when no tags are found, often in as little as 40 msec.
India (IN)	Telecom Regulatory Authority of India (TRAI), 2005 regulations	

People's Republic of China (PRC)	SRRC, MII	The PRC specifications defines more channels than are in the Nano's default hop table. This is because the regulations limit channels from 920 to 920.5MHz and from 924.5 to 925.0MHz to transmit levels of 100mW and below. The default hop table uses only the center channels which allow 2W ERP, 1W conducted, power output. If the hop table is modified to use the outer, lower power channels the RF level will be limited to the outer channels limit, 100mW (+20dBm)
Australia (AU)	ACMA LIPD Class Licence Variation 2011 (No. 1)	
New Zealand (NZ)	Radiocommunications Regulations (General User Radio Licence for Short Range Devices) Notice 2011	This region is included for testing purposes. Compliance to New Zealand regulatory requirements has not been confirmed.
Japan (JP)	Japan MIC "36dBm EIRP blanket license radio station with LBT"	Full power operation restricts the channel range from 916.8Mhz to 920.8MHz and all default channels are within this range. Per the regulations, this region supports Listen-before-talk at the required level of -74 dBm.
Open Region	No regulatory compliance enforced	This region allows the module to be manually configured within the full capabilities supported by the hardware, see Regional Frequency Specifications table. The Open region should be used for laboratory testing only as it does not meet any regulatory requirements for any one region.

The region of operation is set using the MercuryAPI. Setting the region of operation configures the regional default settings including:

- Loads the Frequency Hop Table with the appropriate table for the selected region.
- Sets the PLL Frequency Setting to the first entry in the hop table, even if the RF is off.
- Selects the transmit filter, if applicable.

Frequency Setting

The modules have a PLL synthesizer that sets the modulation frequency to the desired value. Whenever the frequency is changed, the module must first power off the modulation, change the frequency, and then turn on the modulation again. Since this can take 7 to 10 milliseconds, all passive tags will enter the power-down state during a frequency hop, which affects their behavior, per the EPCglobal Gen2 specification.

The ThingMagic Nano supports commands that allow channels to be removed from the hop table and additional channels to be defined (within limits)

CAUTION!

Use these commands with extreme caution. It is possible to change the module's compliance with the regional channel settings.

Frequency Units

All frequencies in the ThingMagic Nano are expressed in kHz using unsigned 32-bit integers. For instance, a carrier frequency of 918 MHz is expressed as “918000” kHz.

Each region has a defined lower channel limit, minimum separation between channels (“quantization”) and an upper channel limit. The user is allowed to enter any channel frequency, with kHz granularity, as long as it is between the upper and lower channel limits for that region. The actual frequency used by the module is that of the closest permitted channel that matches the specified value, which is based on the lower channel limit plus an integer multiple of the quantization value. Each region has a quantization value based on regulatory specifications. The following table provides the channel setting limits for each region setting.

Regional Frequency Specifications

Region	Frequency Quantization (kHz)	Lowest Channel Limit (kHz)	Highest Channel Limit (kHz)	Number of Channels in Default Hop Table
NA2 (Reduced FCC)	200	917,400 kHz	927,200 kHz	50
EU3 (ETSI)	100	865,600 kHz	867,600 kHz	4
IN (India)	100	865,000 kHz	867,000 kHz	5
KR2 (Korea)	100	917,000 kHz	923,500 kHz	6
PRC	125	920,125 kHz	924,875 kHz	16
AU (Australia)	250	920,000 kHz	926,000 kHz	10
NZ (New Zealand)	250	922,000 kHz	927,000 kHz	11
JP (Japan)	100	916,900 kHz	923,400 kHz	6
Open	100	859,000 kHz 915,000 kHz	873,000 kHz 930,000 kHz	15 16

When manually setting frequencies the module will round down for any value that is not an even multiple of the supported frequency quantization.

For example: In the NA region, setting a frequency of 917,599 kHz results in a setting of 917,400 kHz.

When setting the frequency of the module, any frequencies outside of the valid range for the specified region are rejected.

Frequency Hop Table

The frequency hop table determines the frequencies used by the ThingMagic Nano when transmitting. The hop table characteristics are:

- Contains up to 62 entries.
- Must be within the frequency range for the region currently selected.
- Changes are not stored in flash, thus changes made are not retained after a power cycle, including when the ENABLE line is activated after having been in the shutdown state.
- Individual entries cannot be changed without reloading the entire table.

- Frequencies are used in the order of entries in the table, so if a random order is required, the frequencies must be pre-randomized before entering.

If necessary for a region, the hop table are randomized to create a pseudo-random sequence of frequencies to use. This is done automatically using the default hop tables provided for each region.

Protocol Support

Unlike the M6e and Micro modules, the ThingMagic Nano does not have the ability to support tag protocols other then EPCglobal Gen2 (ISO 18000-6C). Future support for newer versions of the Gen2 protocol, such as ISO 18000-63 (Gen2V2), are possible.

Gen2 (ISO 18000-6C) Protocol

Gen2 Protocol Configuration Options

The ThingMagic Nano supports limited ISO-18000-6C profiles, with only the Backscatter Link Frequency (BLF) and “M” value as configurable options. The protocol options are set in the MercuryAPI Reader Configuration Parameters (/reader/gen2/*). The following table shows the supported combinations:

Backscatter Link Frequency (kHz)	Encoding	Tari (usec)	Modulation Scheme	Notes
250	Miller (M=8)	25	PR-ASK	Up to 85 tags per second read rate
250	Miller (M=4)	25	PR-ASK	Default; Up to 170 tags per second read rate.
250	Miller (M=2)	25	PR-ASK	Up to 240 tags per second read rate.

Note

When continuously reading, it is important that the data transfer rate from the host to the module is faster than the rate at which tag information is being collected by the module. This is assured if the `reader/baudRate` setting is greater than the BLF divided by the “M” value. If it’s not, then the reader could be reading data faster than the host can off-load it, and the reader’s buffer might fill up.

Unsupported Gen2 Functionality

The ThingMagic Nano module firmware can perform some Gen2 functions as a stand-alone command, but cannot do so as part of an embedded TagOps command: Here is the list of supported standard Gen2 functions:

Function	As Embedded TagOPs	As Stand-alone TagOPs
Gen2 Read Data	Yes	Yes
Gen2 Write Tag	No	Yes
Gen2 Write Data	No	Yes
Gen2 Lock Tag	No	Yes
Gen2 Kill Tag	No	Yes
Gen2 Block Write	No	Yes
Gen2 Block Erase	No	Yes
Gen2 Block Perma-lock	No	Yes
Secure Read Data	No	No

Most of the multi-antenna functions are supported because the Nano has the ability to support a 1:4 multiplexer, creating 4 logical ports from its one physical port.

Unsupported Custom Gen2 Functions

The ThingMagic Nano module does not support many of the custom commands which are supported in the other module families. Functionality **NOT** supported includes:

- Higgs 2 FullLoadImage
- Higgs 2 PartialLoadImage
- Higgs 3 FastLoadImage
- Higgs 3 LoadImage
- Higgs 3 BlockReadLock
- NXP G2X and G2i Set/Reset ReadProtect
- NXP G2X and G2i Change EAS and Alarm

- NXP G2X and G2i Calibrate
- NXP G2i ChangeConfig
- Monza 4QT ReadWrite
- AMS/IDS SL900A Sensor Tag Commands

Unsupported Features

- Unlike other ThingMagic modules, the ThingMagic Nano module currently does not support gathering reader statistics independent of the meta data that can be gathered with tag reads. The statistics not supported include:
  - RF On-time
  - Noise Floor,
  - Noise Floor with Transmit On
  - Frequency
  - Temperature
  - Antenna Ports
  - Current Protocol
- The ThingMagic Nano module currently does not support Save and Restore of settings.
- “User Mode”, which is a little-used feature of older modules, is not supported.
- Any commands that involve multiple physical antennas are not supported.
- Antenna detection is not supported (The M6e module supports this, the Nano and Micro modules do not).

Antenna Port

The ThingMagic Nano has one monostatic antenna port. This port is capable of both transmitting and receiving. The module also supports Using a Multiplexer, allowing up to 4 total logical antenna ports, controlled using two GPIO lines.

Note

The ThingMagic Nano does not support bistatic (separate transmit and receive port) operation.

Using a Multiplexer

Multiplexer switching is controlled through the use of one or two of the General Purpose Input/Output (GPIO) lines. In order to enable automatic multiplexer port switching the module must be configured to use *Use GPIO as Antenna Switch* in `/reader/antenna/portSwitchGpos`.

Once the GPIO line(s) usage has been enabled the following control line states are applied when the different Logical Antenna settings are used. The tables below show the mapping that results using GPIO 1 and 2 for multiplexer control (as is used by the ThingMagic 1 to 4 multiplexer) allowing for 4 logical antenna ports.

Note

The Logical Antenna values are static labels that correspond to the control line states. The mapping is shown here:

GPIO 1 & 2 Used for Antenna Switching

GPIO Output 1 State	GPIO Output 2 State	Logical Antenna Setting
Low	Low	**1**
Low	High	**2**
High	Low	**3**
High	High	**4**

If only one GPIO Output line is used for antenna control, the combinations of the available output control line states (the GPIO line in use and the module port) result in a subset of logical antenna settings which can be used.

ONLY GPIO 1 Used for Antenna Switching

GPIO Output 1 State	Logical Antenna Setting
Low	**1**
High	**3**

ONLY GPIO 2 Used for Antenna Switching

GPIO Output 2 State	Logical Antenna Setting
Low	**1**
High	**2**

MercuryAPI allows you to assign your own port numbers to these logical ports so that the port labels are not confusing to the user.

By default, antennas are activated sequentially, from lowest to highest, returning to the lowest whenever a new read command is executed. The user can define a port list if they wish to change this order.

Port Power and Settling Time

The ThingMagic Nano allows the power and settling time for each logical antenna to be set using the reader configuration parameters `/reader/radio/portReadPowerList` and `/reader/antenna/settlingTimeList`, respectively.

Note

Settling time is the time between the control lines switching to the next antenna setting and RF turning on for operations on that port. This allows time for external multiplexer's to fully switch to the new port before a signal is sent, if necessary. Default value is 0.

Tag Handling

When the ThingMagic Nano performs inventory operations (MercuryAPI Read commands) data is stored in a Tag Buffer until retrieved by the client application, or data is streamed directly to the host if operating in Tag Streaming/Continuous Reading mode.

Tag Buffer

The ThingMagic Nano uses a dynamic buffer that depends on EPC length and quantity of data read. As a rule of thumb it can store a maximum of 48 96-bit EPC tags in the Tag Buffer at a time. Since the ThingMagic Nano supports streaming of read results the buffer limit is, typically, not an issue. Each tag entry consists of a variable number of bytes and consists of the following fields:

Total Entry Size	Field	Size	Description
68 bytes (Max EPC Length = 496bits)	EPC Length	2 bytes	Indicates the actual EPC length of the tag read.
	PC Word	2 bytes	Contains the Protocol Control bits for the tag.
	EPC	62 bytes	Contains the tag's EPC value.
	Tag CRC	2 bytes	The tag's CRC.
Additional Tag Read Meta Data			

The Tag buffer acts as a First In First Out (FIFO) — the first Tag found by the reader is the first one to be read out. Duplicate tag reads do not result in additional entries - the tag count is simply incremented, and the meta-data revised if necessary.

Tag Streaming/Continuous Reading

When reading tags during asynchronous inventory operations (MercuryAPI `Reader.StartReading()`) using an */reader/read/asyncOffTime*=0 the ThingMagic Nano “streams” the tag results back to the host processor. This means that tags are pushed out of the buffer as soon as they are put into the buffer by the tag reading process. The buffer is put into a circular mode that keeps the buffer from filling. This allows for the ThingMagic Nano to perform continuous search operations without the need to periodically stop reading and fetch the contents of the buffer. Aside from not seeing “down time” when performing a read operation this behavior is essentially invisible to the user as all tag handling is done by the MercuryAPI.

Note

The TTL Level UART Interface does not support control lines, so it is not possible for the module to detect a broken communications interface connection and stop streaming the tag results. Nor can the host signal that it wishes tag streaming to stop temporarily without stopping the reading of tags.

Tag Read Meta Data

In addition to the tag EPC ID resulting from ThingMagic Nano inventory operation each `TagReadData` (see MercuryAPI for code details) contains meta data about how, where and when the tag was read. The specific meta data available for each tag read is as follows:

Meta Data Field	Description
Antenna ID	The antenna on with the tag was read. When Using a Multiplexer, if appropriately configured, the Antenna ID entry will contain the logical antenna port of the tag read. If the same tag is read on more than one antenna there will be a tag buffer entry for each antenna on which the tag was read.
Read Count	The number of times the same tag was read on the same antenna (and, optionally, with the same embedded data value).
Timestamp	The time the tag was read, relative to the time the command to read was issued, in milliseconds. If the Tag Read Meta Data is not retrieved from the Tag Buffer between read commands there will be no way to distinguish order of tags read with different read command invocations.
Tag Data	When reading an embedded `TagOp` is specified for a `ReadPlan` the TagReadData will contain the first 128 words of data returned for each tag. Note: Tags with the same TagID but different Tag Data can be considered unique and each get a Tag Buffer entry if set in the reader configuration parameter `/reader/tagReadData/uniqueByData`. By default it is not.
Frequency	The frequency on which the tag was read
Tag Phase	Not supported in ThingMagic Nano
LQI/RSSI	The receive signal strength of the tag response in dBm. For duplicate entries, the user can decide if the meta data represents the first time the tag was seen or reflects the meta data for the highest RSSI seen.
GPIO Status	The signal status (High or Low) of all GPIO pins when tag was read.

Power Management

The ThingMagic Nano is designed for power efficiency and offers several power management modes. When transmitting, the power consumption can be minimized by using the lowest RF power level that meets the application requirements, and powering the module with highest DC input Voltage.

A “Power Mode” setting determines the power consumed during periods that the module is not actively transmitting. Power Modes - is set in `/reader/powerMode`.

Power Modes

The Power Mode setting (set in `/reader/powerMode`) allows the user to trade off increased RF operation startup time for additional power savings. Our terminology can be a little confusing. “MINSAVE” refers to the minimum amount of power saving applied, which results in a higher idle power level than “MAXSAVE”.

The details of the amount of power consumed in each mode is shown in the table under Idle DC Power Consumption. The behavior of each mode and impact on RF command latency is as follows:

- **PowerMode.FULL** – In this mode, the unit operates at full power to attain the best performance possible. This mode is intended for use in cases where power consumption is not an issue. This is the default Power Mode at startup.
- **PowerMode.MINSAVE** – This mode may add up to 20 ms of delay from idle to RF-on when initiating an RF operation. It performs more aggressive power savings, such as automatically shutting down the analog section between commands, and then restarting it whenever a tag command is issued. **MEDSAVE** and **MAXSAVE** are the same as **MINSAVE**
- **PowerMode.SLEEP** – This mode essentially shuts down the digital and analog boards, except to power the bare minimum logic required to wake the processor.This mode may add up to 20 ms of delay from idle to RF on when initiating an RF operation. (There is no known disadvantage to using **SLEEP** mode rather than any of the **M**SAVE** modes, since their wake-up times are nearly identical.)

Note

See additional latency specifications under Event Response Times.

Performance Characteristics

Event Response Times

The following table provides information on how long common ThingMagic Nano operations take. An event response time is defined as the maximum time from the end of a command to the beginning of the action the command enables. For example, whenever appropriate, the time represents the delay between the last byte of a read command and the moment when an RF signal is detected at the antenna.

Event Response Times

Start Command/ Event	End Event	Typical Time (msec)	Notes
Power Up	Application Active (with CRC check)	140	This longer power up period should only occur for the first boot with new firmware.
Power Up	Application Active	28	Once the firmware CRC has been verified subsequent power ups do not require the CRC check be performed, saving time.
Tag Read	RF On	8	When in Power Mode = FULL
Tag Read	RF On	20	When in Power Mode = MINSAVE
Tag Read	RF On	20	When in Power Mode = SLEEP

Appendix A: Error Messages

This appendix discusses error messages that you might see in API transport logs or passed up by the API to the host program. Categories of messages include:

- Common Error Messages
- Bootloader Faults
- Flash Faults
- Protocol Faults
- Analog Hardware Abstraction Layer Faults
- Tag ID Buffer Faults
- System Errors

Common Error Messages

The following table lists the common faults discussed in this section.

Fault Message	Code
FAULT_MSG_WRONG_NUMBER_OF_DATA – (100h)	100h
FAULT_INVALID_OPCODE – (101h)	101h
FAULT_UNIMPLEMENTED_OPCODE – 102h	102h
FAULT_MSG_POWER_TOO_HIGH – 103h	103h
FAULT_MSG_INVALID_FREQ_RECEIVED (104h)	104h
FAULT_MSG_INVALID_PARAMETER_VALUE - (105h)	105h
FAULT_MSG_POWER_TOO_LOW - (106h)	106h
FAULT_UNIMPLEMENTED_FEATURE - (109h)	109h
FAULT_INVALID_BAUD_RATE - (10Ah)	10Ah

FAULT_MSG_WRONG_NUMBER_OF_DATA – (100h)

Cause

If the data length in any of the Host-to-module messages is less than or more than the number of arguments in the message, the reader returns this message.

Solution

Make sure the number of arguments matches the data length.

FAULT_INVALID_OPCODE – (101h)

Cause

The opCode received is invalid or not supported in the currently running program (bootloader or main application) or is not supported in the current version of code.

Solution

Check the following:

- Make sure the command is supported in the currently running program.
- Check the documentation for the opCode the host sent and make sure it is correct and supported.
- Check the previous module responses for an assert (0x7F0X) which will reset the module into the bootloader.

FAULT_UNIMPLEMENTED_OPCODE – 102h

Cause

Some of the reserved commands might return this error code.

This does not mean that they always will do this since ThingMagic reserves the right to modify those commands at anytime.

Solution

Check the documentation for the opCode the host sent to the reader and make sure it is supported.

FAULT_MSG_POWER_TOO_HIGH – 103h

Cause

A message was sent to set the read or write power to a level that is higher than the current HW supports.

Solution

Check the HW specifications for the supported powers and insure that the level is not exceeded. For the Nano, this limit is +27 dBm.

FAULT_MSG_INVALID_FREQ_RECEIVED (104h)

Cause

A message was received by the reader to set the frequency outside the supported range

Solution

Make sure the host does not set the frequency outside this range or any other locally supported ranges.

FAULT_MSG_INVALID_PARAMETER_VALUE - (105h)

Cause

The reader received a valid command with an unsupported or invalid value within this command.

For example, currently the module supports one antenna (without a multiplexer). If the module receives a message with an antenna value other than 1, it returns this error.

Solution

Make sure the host sets all the values in a command according to the values published in this document.

FAULT_MSG_POWER_TOO_LOW - (106h)

Cause

A message was received to set the read or write power to a level that is lower than the current HW supports.

Solution

Check the HW specifications for the supported powers and insure that level is not exceeded. The ThingMagic Nano supports powers a low limit of 0 dBm.

FAULT_UNIMPLEMENTED_FEATURE - (109h)

Cause

Attempting to invoke a command not supported on this firmware or hardware.

Solution

Check the command being invoked against the documentation.

FAULT_INVALID_BAUD_RATE - (10Ah)

Cause

When the baud rate is set to a rate that is not specified in the Baud Rate table, this error message is returned.

Solution

Check the table of specific baud rates and select a baud rate.

Bootloader Faults

The following table lists the common faults discussed in this section.

Fault Message	Code
FAULT_BL_INVALID_IMAGE_CRC	200h
FAULT_BL_INVALID_APP_END_ADDR	201h

FAULT_BL_INVALID_IMAGE_CRC – 200h

Cause

When the application firmware is loaded the reader checks the image stored in flash and returns this error if the calculated CRC is different than the one stored in flash.

Solution

The exact reason for the corruption could be that the image loaded in flash was corrupted during the transfer or corrupted for some other reason.

To fix this problem, reload the application code in flash.

FAULT_BL_INVALID_APP_END_ADDR – 201h

Cause

When the application firmware is loaded the reader checks the image stored in flash and returns this error if the last word stored in flash does not have the correct address value.

Solution

The exact reason for the corruption could be that the image loaded in flash got corrupted during the transfer or, corrupted for some other reason.

To fix this problem, reload the application code in flash.

Flash Faults

The following table lists the common faults discussed in this section.

Fault Message	Code
FAULT_FLASH_BAD_ERASE_PASSWORD – 300h	300h
FAULT_FLASH_BAD_WRITE_PASSWORD – 301h	301h
FAULT_FLASH_UNDEFINED_ERROR – 302h	302h
FAULT_FLASH_ILLEGAL_SECTOR – 303h	303h
FAULT_FLASH_WRITE_TO_NON_ERASED_AREA – 304h	304h
FAULT_FLASH_WRITE_TO_ILLEGAL_SECTOR – 305h	305h
FAULT_FLASH_VERIFY_FAILED – 306h	306h

FAULT_FLASH_BAD_ERASE_PASSWORD – 300h

Cause

A command was received to erase some part of the flash but the password supplied with the command was incorrect.

Solution

When this occurs make note of the operations you were executing, save FULL error response and send a test case reproducing the behavior to support@thingmagic.com.

FAULT_FLASH_BAD_WRITE_PASSWORD – 301h

Cause

A command was received to write some part of the flash but the password supplied with the command was not correct.

Solution

When this occurs make note of the operations you were executing, save FULL error response and send a test case reproducing the behavior to support@thingmagic.com.

FAULT_FLASH_UNDEFINED_ERROR – 302h

Cause

This is an internal error and it is caused by a software problem in module.

Solution

When this occurs make note of the operations you were executing, save FULL error response and send a test case reproducing the behavior to support@thingmagic.com.

FAULT_FLASH_ILLEGAL_SECTOR – 303h

Cause

An erase or write flash command was received with the sector value and password not matching.

Solution

When this occurs make note of the operations you were executing, save FULL error response and send a test case reproducing the behavior to support@thingmagic.com.

FAULT_FLASH_WRITE_TO_NON_ERASED_AREA – 304h

Cause

The module received a write flash command to an area of flash that was not previously erased.

Solution

When this occurs make note of the operations you were executing, save FULL error response and send a test case reproducing the behavior to support@thingmagic.com.

FAULT_FLASH_WRITE_TO_ILLEGAL_SECTOR – 305h

Cause

The module received a write flash command to write across a sector boundary that is prohibited.

Solution

When this occurs make note of the operations you were executing, save FULL error response and send a test case reproducing the behavior to support@thingmagic.com.

FAULT_FLASH_VERIFY_FAILED – 306h

Cause

The module received a write flash command that was unsuccessful because data being written to flash contained an uneven number of bytes.

Solution

When this occurs make note of the operations you were executing, save FULL error response and send a test case reproducing the behavior to support@thingmagic.com.

Protocol Faults

The following table lists the common faults discussed in this section.

Fault Message	Code
FAULT_NO_TAGS_FOUND – (400h)	400h
FAULT_NO_PROTOCOL_DEFINED – 401h	401h
FAULT_INVALID_PROTOCOL_SPECIFIED – 402h	402h
FAULT_WRITE_PASSED_LOCK_FAILED – 403h	403h
FAULT_PROTOCOL_NO_DATA_READ – 404h	404h
FAULT_AFE_NOT_ON – 405h	405h
FAULT_PROTOCOL_WRITE_FAILED – 406h	406h
FAULT_NOT_IMPLEMENTED_FOR_THIS_PROTOCOL – 407h	407h
FAULT_PROTOCOL_INVALID_WRITE_DATA – 408h	408h
FAULT_PROTOCOL_INVALID_ADDRESS – 409h	409h
FAULT_GENERAL_TAG_ERROR – 40Ah	40Ah
FAULT_DATA_TOO_LARGE – 40Bh	40Bh
FAULT_PROTOCOL_INVALID_KILL_PASSWORD – 40Ch	40Ch
FAULT_PROTOCOL_KILL_FAILED - 40Eh	40Eh
FAULT_PROTOCOL_BIT_DECODING_FAILED - 40Fh	40Fh
FAULT_PROTOCOL_INVALID_EPC – 410h	410h
FAULT_PROTOCOL_INVALID_NUM_DATA – 411h	411h
FAULT_GEN2 PROTOCOL_OTHER_ERROR - 420h	420h
FAULT_GEN2_PROTOCOL_MEMORY_OVERRUN_BAD_PC - 423h	423h
FAULT_GEN2 PROTOCOL_MEMORY_LOCKED - 424h	424h
FAULT_GEN2 PROTOCOL_INSUFFICIENT_POWER - 42Bh	42Bh
FAULT_GEN2 PROTOCOL_NON_SPECIFIC_ERROR - 42Fh	42Fh
FAULT_GEN2 PROTOCOL_UNKNOWN_ERROR - 430h	430h

FAULT_NO_TAGS_FOUND – (400h)

Cause

A command was received (such as like read, write, or lock) but the operation failed. There are many reasons that can cause this error to occur.

Here is a list of possible reasons that could be causing this error:

- No tag in the RF field
- Read/write power too low
- Antenna not connected
- Tag is weak or dead

Solution

Make sure there is a good tag in the field and all parameters are set up correctly. The best way to check this is to try few tags of the same type to rule out a weak tag. If none passed, then it could be SW configuration such as protocol value, antenna, and so forth, or a placement configuration like a tag location.

FAULT_NO_PROTOCOL_DEFINED – 401h

Cause

A command was received to perform a protocol command but no protocol was initially set. The reader powers up with no protocols set.

Solution

A protocol must be set before the reader can begin RF operations.

FAULT_INVALID_PROTOCOL_SPECIFIED – 402h

Cause

The protocol value was set to a protocol that is not supported with the current version of SW.

Solution

This value is invalid or this version of SW does not support the protocol value. Check the documentation for the correct values for the protocols in use and that you are licensed for it.

FAULT_WRITE_PASSED_LOCK_FAILED – 403h

Cause

During a Write Tag Data for ISO18000-6B or UCODE, if the lock fails, this error is returned. The write command passed but the lock did not. This could be a bad tag.

Solution

Try to write a few other tags and make sure that they are placed in the RF field.

FAULT_PROTOCOL_NO_DATA_READ – 404h

Cause

A command was sent but did not succeed.

Solution

The tag used has failed or does not have the correct CRC. Try to read a few other tags to check the HW/SW configuration.

FAULT_AFE_NOT_ON – 405h

Cause

A command was received for an operation, like read or write, but the RF Transmitter was in the off state.

Solution

Make sure the region and tag protocol have been set to supported values.

FAULT_PROTOCOL_WRITE_FAILED – 406h

Cause

An attempt to modify the contents of a tag failed. There are many reasons for failure.

Solution

Check that the tag is good and try another operation on a few more tags.

FAULT_NOT_IMPLEMENTED_FOR_THIS_PROTOCOL – 407h

Cause

A command was received which is not supported by a protocol.

Solution

Check the documentation for the supported commands and protocols.

FAULT_PROTOCOL_INVALID_WRITE_DATA – 408h

Cause

An ID write was attempted with an unsupported/incorrect ID length.

Solution

Verify the Tag ID length being written.

FAULT_PROTOCOL_INVALID_ADDRESS – 409h

Cause

A command was received attempting to access an invalid address in the tag data address space.

Solution

Make sure that the address specified is within the scope of the tag data address space and available for the specific operation. The protocol specifications contain information about the supported addresses.

FAULT_GENERAL_TAG_ERROR – 40Ah

Cause

This error is used by the GEN2 module. This fault can occur if the read, write, lock, or kill command fails. This error can be internal or functional.

Solution

Make a note of the operations you were performing and contact ThingMagic at http://support.thingmagic.com

FAULT_DATA_TOO_LARGE – 40Bh

Cause

A command was received to Read Tag Data with a data value larger than expected or it is not the correct size.

Solution

Check the size of the data value in the message sent to the reader.

FAULT_PROTOCOL_INVALID_KILL_PASSWORD – 40Ch

Cause

An incorrect kill password was received as part of the Kill command.

Solution

Check the password.

FAULT_PROTOCOL_KILL_FAILED - 40Eh

Cause

Attempt to kill a tag failed for an unknown reason

Solution

Check tag is in RF field and the kill password.

FAULT_PROTOCOL_BIT_DECODING_FAILED - 40Fh

Cause

Attempt to operate on a tag with an EPC length greater than the Maximum EPC length setting.

Solution

Check the EPC length being written.

FAULT_PROTOCOL_INVALID_EPC – 410h

Cause

This error is used by the GEN2 module indicating an invalid EPC value has been specified for an operation. This fault can occur if the read, write, lock, or kill command fails.

Solution

Check the EPC value that is being passed in the command resulting in this error.

FAULT_PROTOCOL_INVALID_NUM_DATA – 411h

Cause

This error is used by the GEN2 module indicating invalid data has been specified for an operation. This fault can occur if the read, write, lock, or kill command fails.

Solution

Check the data that is being passed in the command resulting in this error.

FAULT_GEN2 PROTOCOL_OTHER_ERROR - 420h

Cause

This is an error returned by Gen2 tags. Its a catch-all for error not covered by other codes.

Solution

Check the data that is being passed in the command resulting in this error. Try with a different tag.

FAULT_GEN2_PROTOCOL_MEMORY_OVERRUN_BAD_PC - 423h

Cause

This is an error returned by Gen2 tags. The specified memory location does not exist or the PC value is not supported by the Tag.

Solution

Check the data that is being written and where its being written to in the command resulting in this error.

FAULT_GEN2 PROTOCOL_MEMORY_LOCKED - 424h

Cause

This is an error returned by Gen2 tags.The specified memory location is locked and/or permalocked and is either not writable or not readable.

Solution

Check the data that is being written and where its being written to in the command resulting in this error. Check the access password being sent.

FAULT_GEN2 PROTOCOL_INSUFFICIENT_POWER - 42Bh

Cause

This is an error returned by Gen2 tags. The tag has insufficient power to perform the memory-write operation.

Solution

Try moving the tag closer to the antenna. Try with a different tag.

FAULT_GEN2 PROTOCOL_NON_SPECIFIC_ERROR - 42Fh

Cause

This is an error returned by Gen2 tags. The tag does not support error specific codes.

Solution

Check the data that is being written and where its being written to in the command resulting in this error. Try with a different tag.

FAULT_GEN2 PROTOCOL_UNKNOWN_ERROR - 430h

Cause

This is an error returned by ThingMagic Nano when no more error information is available about why the operation failed.

Solution

Check the data that is being written and where its being written to in the command resulting in this error. Try with a different tag.

Analog Hardware Abstraction Layer Faults

FAULT_AHAL_INVALID_FREQ – 500h

Cause

A command was received to set a frequency outside the specified range.

Solution

Check the values you are trying to set and be sure that they fall within the range of the set region of operation.

FAULT_AHAL_CHANNEL_OCCUPIED – 501h

Cause

With LBT enabled an attempt was made to set the frequency to an occupied channel.

Solution

Try a different channel. If supported by the region of operation turn LBT off.

FAULT_AHAL_TRANSMITTER_ON – 502h

Cause

Checking antenna status while CW is on is not allowed.

Solution

Do not perform antenna checking when CW is turned on.

FAULT_ANTENNA_NOT_CONNECTED – 503h

Cause

An attempt was made to transmit on an antenna which did not pass the antenna detection when antenna detection was turned on.

Solution

Connect a detectable antenna. (Antenna must have some DC resistance.) (Does not apply to Micro or ThingMagic Nano as they do not detect antennas.)

FAULT_TEMPERATURE_EXCEED_LIMITS – 504h

Cause

The module has exceeded the maximum or minimum operating temperature and will not allow an RF operation until it is back in range.

Solution

Take steps to resolve thermal issues with module:

- Reduce duty cycle
- Add heat sink

FAULT_POOR_RETURN_LOSS – 505h

Cause

The module has detected a poor return loss and has ended RF operation to avoid module damage.

Solution

Take steps to resolve high return loss on receiver:

- Make sure antenna VSWR is within module specifications
- Make sure antennas are correctly attached before transmitting
- Check environment to ensure no occurrences of high signal reflection back at antennas.

FAULT_AHAL_INVALID_ANTENA_CONFIG – 507h

Cause

An attempt to set an antenna configuration that is not valid.

Solution

Use the correct antenna setting or change the reader configuration.

Tag ID Buffer Faults

The following table lists the common faults discussed in this section.

Fault Message	Code
FAULT_TAG_ID_BUFFER_NOT_ENOUGH_TAGS_AVAILABLE – 600h	600h
FAULT_TAG_ID_BUFFER_FULL – 601h	601h
FAULT_TAG_ID_BUFFER_REPEATED_TAG_ID – 602h	602h
FAULT_TAG_ID_BUFFER_NUM_TAG_TOO_LARGE – 603h	603h

FAULT_TAG_ID_BUFFER_NOT_ENOUGH_TAGS_AVAILABLE – 600h

Cause

A command was received to get a certain number of tag ids from the tag id buffer. The reader contains less tag ids stored in its tag id buffer than the number the host is sending.

Solution

Send a test case reproducing the behavior to support@thingmagic.com.

FAULT_TAG_ID_BUFFER_FULL – 601h

Cause

The tag id buffer is full.

Solution

Make sure the baud rate is set to a higher frequency that the /reader/gen2/BLF frequency. Send a test case reproducing the behavior to support@thingmagic.com.

FAULT_TAG_ID_BUFFER_REPEATED_TAG_ID – 602h

Cause

The module has an internal error. One of the protocols is trying to add an existing TagID to the buffer.

Solution

Send a test case reproducing the behavior to support@thingmagic.com.

FAULT_TAG_ID_BUFFER_NUM_TAG_TOO_LARGE – 603h

Cause

The module received a request to retrieve more tags than is supported by the current version of the software.

Solution

Send a test case reproducing the behavior to support@thingmagic.com.

System Errors

FAULT_SYSTEM_UNKNOWN_ERROR – 7F00h

Cause

The error is internal.

Solution

Send a test case reproducing the behavior to support@thingmagic.com.

FAULT_TM_ASSERT_FAILED – 7F01h

Cause

An unexpected Internal Error has occurred.

Solution

The error will cause the module to switch back to Bootloader mode. When this occurs make note of the operations you were executing, save FULL error response and send a test case reproducing the behavior to support@thingmagic.com.

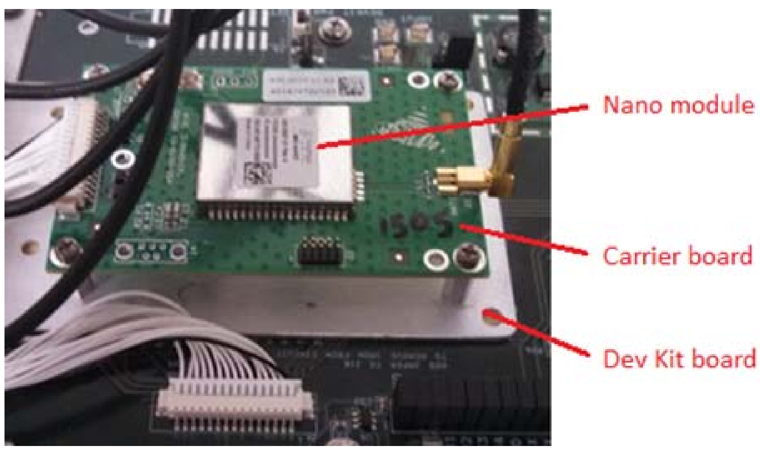
Appendix B: Getting Started - Dev Kit

This appendix provides instructions on the use of the ThingMagic Nano Development Kit:

- Dev Kit Hardware
- Demo Application
- Notice on Restricted Use of the Dev Kit

Dev Kit Hardware

Included Components



With the dev kit, you will receive the following components:

- The ThingMagic Nano module soldered onto carrier board
- Power/interface developers board
- One USB cable
- One antenna
- One coax cable
- One 9V power supply
- International power adapter kit

- Sample tags
- One *QuickStart Guide* - Details on which documents and software to download to get up and running quickly, along with details on how to register for and contact support.

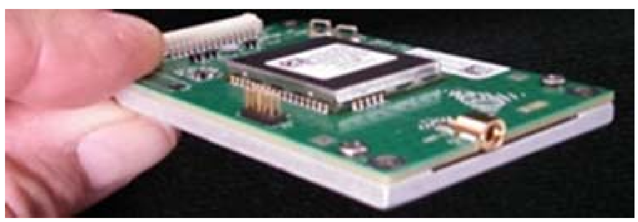
Setting up the Dev Kit

When setting up the Dev Kit, use the following procedures:

- Connecting the Antenna
- Powering up and Connecting to a PC

WARNING!

Never mount the carrier board so that it is resting flat against the metal plate of the Dev Kit main board unless a heat sink has been attached to the bottom of the Carrier Board as shown in this picture:



Connecting the Antenna

ThingMagic supplies one antenna that can read tags from 3 meters away with most of the provided tags. The antenna is monstatic. Use the following procedure to connect the antenna to the Dev Kit.

1. Connect one end of the coax cable to the antenna.
2. Connect the other end of the cable to the antenna port 1 connector on the Dev Kit.

Powering up and Connecting to a PC

After connecting the antenna you can power up the Dev Kit and establish a host connection.

1. Connect the USB cable (use only the black connector) from a PC to the developer's kit. There are two Dev Kit USB Interface options. Use the interface that is labeled

"USB/RS232". The one labeled "USB" is not supported by the ThingMagic Nano module.

2. Plug the power supply into the Dev Kit's DC power input connector.
3. The LED next to the DC input jack, labeled DS1, should light up. If it doesn't light up check jumper J17 to make sure the jumper is connecting pins 2 and 3
4. Follow the steps based on the Dev Kit USB Interface used and make note of the COM port or /dev device file, as appropriate for your operating system the USB interface is assigned.
5. To start reading tags start the Demo Application (Universal Reader Assistant).

WARNING!

While the module is powered up, do not touch components. Doing so may be damage the dev kit and ThingMagic Nano module.

Dev Kit USB Interface

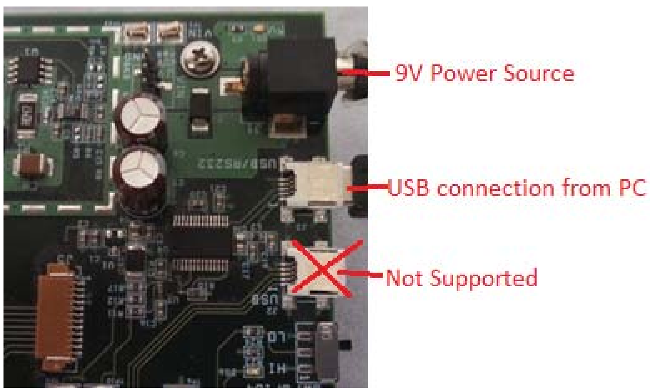
USB/RS232

The USB interface (connector labeled **`USB/RS232`**) closest to the power plug is to the RS232 interface of the ThingMagic Nano through an FTDI USB to serial converter. The drivers for it are available at

http://www.ftdichip.com/Drivers/VCP.htm

Please follow the instructions in the installation guide appropriate for your operating system.

The ThingMagic Nano does not support a USB port directly, so the “USB” port on the Dev Kit is inoperable.



A COM port should now be assigned to the ThingMagic Nano. If you aren’t sure what COM port is assigned you can find it using the Windows Device Manager:

a. Open the Device Manager (located in Control Panel | System).

b. Select the Hardware tab and click Device Manager.

c. Select View | Devices by Type | Ports (COM & LPT) The device appears as USB Serial Port (COM#).

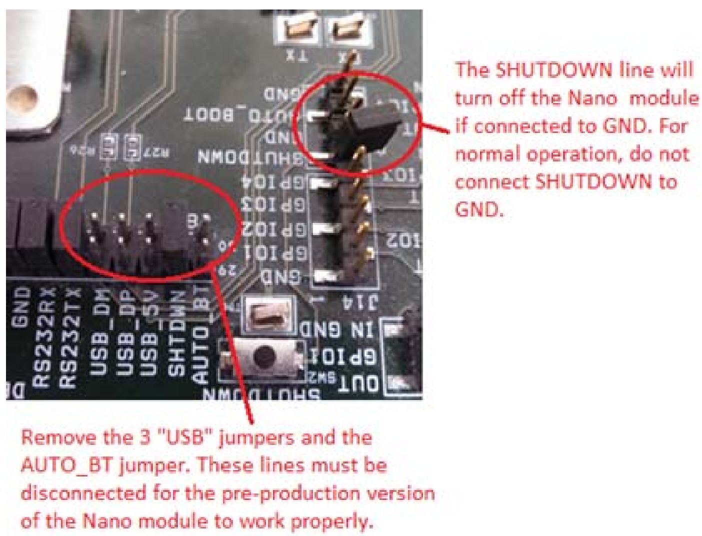
Dev kit Jumpers

J8

Jumpers to connect ThingMagic Nano I/O lines to dev kit. For added safety, you should remove all 3 jumpers for USB connections and the AUTO_BT connection to the module. These lines are not supported, but are connected to the ThingMagic Nano module for test purposes, so should be left unconnected for all applications.

J19

The jumper at J19 that connects SHUTDOWN to ground must be REMOVED. With this jumper removed, the module is always operational. The AUTO_BOOT switch has no affect on the ThingMagic Nano. To put the ThingMagic Nano into shutdown mode, reinstall the jumper at J19 between SHUTDOWN and GND. See ThingMagic Nano Digital Connector Signal Definition for details on the ENABLE Line.



J9

Header for alternate power supply. Make sure DC plug (J1) is not connected if using J9.

J10, J11

Jump pins `OUT` to `GPIO#` to connect ThingMagic Nano GPIO lines to output LEDs. Jump pins `IN` to `GPIO#` to connect ThingMagic Nano GPIO to corresponding input switches.

Make sure GPIO lines are correspondingly configured as input or outputs (see Configuring GPIO Settings).

J13, J15

Not used.

J14

Can be used to connect GPIO lines to external circuits. If used jumpers should be removed from J10, J11.

J16

Jump pins 1 and 2 or 2 and 3 to reset dev kit power supply. Same as using switch SW1 except allows for control by external circuit.

J17

Jump pins 1 and 2 to use the `5V INPUT` and `GND` inputs to provide power. Jump pins 2 and 3 to use the Dev Kit's DC power jack and power brick power.

Dev Kit Schematics

Available upon request from support@thingmagic.com.

Demo Application

A demo application which supports multi-protocol reading and writing is provided in the MercuryAPI SDK package. The executable for this example is included in the MercuryAPI SDK package under /cs/samples/exe/Universal-Reader-Assistant.exe and is also available for direct download from rfid.thingmagic.com/dev kit.

Note: The Universal Reader Assistant included in the MercuryAPI SDK may be an older revision than the one available for standalone download.

See the *Readme.txt* in */cs/samples/Universal-Reader-Assistant/Universal-Reader-Assistant* for usage details.

See the *MercuryAPI Programming Guide* for details on using the MercuryAPI.

Notice on Restricted Use of the Dev Kit

The Mercury6e Developers Kit (Dev Kit) is intended for use solely by professional engineers for the purpose of evaluating the feasibility of applications.

The user's evaluation must be limited to use within a laboratory setting. This Dev Kit has not been certified for use by the FCC in accordance with Part 15 of the FCC regulations, ETSI, KCC or any other regulatory bodies and may not be sold or given for public use.

Distribution and sale of the Dev Kit is intended solely for use in future development of devices which may be subject to regional regulatory authorities governing radio emission. This Dev Kit may not be resold by users for any purpose. Accordingly, operation of the Dev Kit in the development of future devices is deemed within the discretion of the user and the user shall have all responsibility for any compliance with any regional regulatory authority governing radio emission of such development or use, including without limitation reducing electrical interference to legally acceptable levels. All products developed by user must be approved by the appropriate regional regulatory authority governing radio emission prior to marketing or sale of such products and user bears all responsibility for obtaining the prior appropriate regulatory approval, or approval as needed from any other authority governing radio emission.

Appendix C: Environmental Considerations

This Appendix details environmental factors that should be considered relating to reader performance and survivability. Topics include:

ElectroStatic Discharge (ESD) Considerations

WARNING!

The ThingMagic Nano antenna port may be susceptible to damage from Electrostatic Discharge (ESD). Equipment failure can result if the antenna or communication ports are subjected to ESD. Standard ESD precautions should be taken during installation to avoid static discharge when handling or making connections to the ThingMagic Nano reader antenna or communication ports. Environmental analysis should also be performed to ensure static is not building up on and around the antennas, possibly causing discharges during operation.

ESD Damage Overview

In ThingMagic Nano-based reader installations where readers have failed without a known destructive event, ESD has been found to be the most common cause. Failures due to ESD tend to be in the ThingMagic Nano power amplifier section (PA). PA failures typically manifest themselves at the software interface in the following ways:

- RF operations (read, write, etc.) respond with **Assert - 7F01** - indicating a a fatal error. This is typically due to the module not being able to reach the target power level due to PA damage.
- RF operations (read, write, etc.) respond with **No Antenna Connected/Detected** even when a known good antenna is attached.
- Unexpected **Invalid Command errors**, indicating command not supported, when that command had worked just fine shortly before. The reason a command becomes suddenly not supported is that the reader, in the course of its self protection routines, has returned to the bootloader to prevent any further damage. This jump to boot loader caused by power amp damage occurs at the start of any read tag commands.

Ultimately determining that ESD is the root cause of failures is difficult because confirmation is only possible if the failed components are isolated, taken apart, and examined under high power microscopy. Often, concluding that ESD was the cause of a failure is inferred if conditions that could produce ESD are present, anti-ESD precautions have not been taken, and other possible causes are eliminated.

ESD discharges come with a range of values, and like many things in life there is the “matter of degree”. For many installations, the ThingMagic Nano has been successfully deployed and operates happily. For these, there is no failure issue, ESD or otherwise. For a different installation that with bare ThingMagic Nano, has a failure problem from ESD, there will be some distribution of ESD intensities occurring. Without knowledge of a limit in the statistics of those intensities, there may always be the bigger zap waiting in the wings. For the bare ThingMagic Nano equipped with the mitigation methods described below, there will always be the rouge ESD discharge that exceeds any given mitigation, and results in failure. Fortunately, many installations will have some upper bound on the value of ESD events given the geometry of that installation.

Several sequential steps are recommended for a) determining the ESD is the likely cause of a given group of failures, and b) enhancing the ThingMagic Nano's environment to eliminate ESD failures. The steps vary depending on the required ThingMagic Nano output power in any given application.

Identifying ESD as the Cause of Damaged Readers

The following are some suggested methods to determine if ESD is a cause of reader failures, i.e. ESD diagnostics. Please remember- some of these suggestions have the negative result experiment problem.

- Return failed units for analysis. Analysis should be able to say if it is the power amplifier that has in fact failed, but won't be able to definitively identify that the cause is ESD. However, ESD is one of the more common causes of PA failure.
- Measure ambient static levels with static meter. *AlphaLabs SVM2* is such a meter, but there are others. You may be surprised at the static potentials floating detected. However, high static doesn't necessarily mean discharges, but should be considered cause for further investigation. High levels that keep changing are highly indicative of discharges.
- Touch some things around the antenna, and operating area. If you feel static discharges, that qualitatively says quite a bit about what is in front of the antenna. What actually gets to the ThingMagic Nano is also strongly influenced by the antenna installation, cabling, and grounding discussed above.
- Use the mean operating time statistic before and after one or more of the changes listed below to quantitatively determine if the change has resulted in an improvement. Be sure to restart your statistics after the change.

Common Installation Best Practices

The following are common installation best practices which will ensure the readers isn't being unnecessarily exposed to ESD in even low risk environments. These should be applied to all installations, full power or partial power, ESD or not:

- Insure that ThingMagic Nano, reader housing, and antenna ground connection are all grounded to a common low impedance ground.

- Verify R-TNC knurled threaded nuts are tight and stay tight. Don't use a thread locking compound that would compromise the grounding connection of the thread to thread mate. If there is any indication that field vibration might cause the R-TNC to loosen, apply RTV or other adhesive externally.
- Use antenna cables with double-shield outer conductors, or even full metallic shield semi-rigid cables. ThingMagic specified cables are double shielded and adequate for most applications. ESD discharge currents flowing on the outer surface of a single shield coaxial cable have been seen to couple to the inside of coaxial cables, causing ESD failure. Avoid RG-58. Prefer RG-223.
- Minimize ground loops in coaxial cable runs to antennas. Having the ThingMagic Nano and antenna both tied to ground (per item 1) leads to the possibility of ground currents flowing along antenna cables. The tendency of these currents to flow is related to the area of the conceptual surface marked out by the antenna cable and the nearest continuous ground surface. When this conceptual surface has minimum area, these ground loop current are minimized. Routing antenna cables against grounded metallic chassis parts helps minimize ground loop currents.
- Keep the antenna radome in place. It provides significant ESD protection for the metallic parts of the antenna, and protects the antenna from performance changes due to environmental accumulation.
- Keep careful track of serial numbers, operating life times, numbers of units operating. You need this information to know that your mean operating life time is. Only with this number will you be able to know if you have a failure problem in the first place, ESD or otherwise. And then after any given change, whether things have improvement or not. Or if the failures are confined to one instantiation, or distributed across your population.

Raising the ESD Threshold

For applications where full ThingMagic Nano power is needed for maximum tag read range and ESD is suspected the following components are recommended additions to the installation to raise the level of ESD the reader can tolerate:

- Select or change to an antenna with all radiating elements grounded for DC. The MTI MT-262031-T(L,R)H-A is such an antenna. The Laird IF900-SF00 and CAF95956 are not such antennas. The grounding of the antenna elements dissipates static charge leakage, and provides a high pass characteristic that attenuates discharge events. (This also makes the antenna compatible with the ThingMagic Nano antenna detect methods.)
- Install a Minicircuits SHP600+ high pass filter in the cable run at the ThingMagic Nano (or Vega or other finished reader) end. This additional component will reduce transmit power by 0.4 dB which may affect read range in some critical applications. However the filter will significantly attenuate discharges and improve the ThingMagic Nano ESD survival level.

Note

The SHP600+ is rated for the full +27dBm (0.5 W) output of the ThingMagic Nano reader. Care must be taken if it is operated at higher RF input levels at high temperatures.

- 90 V Lightning Arrestors, such as the Terrawave Solutions Model TW-LP-RPTNC-P-BHJ have been shown to be effective in suppressing ESD. This model contains a gas discharge tube which must be replaced periodically.
- Install a Diode Clamp* circuit immediately outboard from the SHP600 filter. This will reduce transmit power by an additional 0.4 dB, but in combination with the SHP600 will further improve the ThingMagic Nano ESD survival level. (Needs DC power, contact support@thingmagic.com for availability.)

Further ESD Protection for Reduced RF Power Applications

In addition to the protective measures recommended above, for applications where reduced ThingMagic Nano RF power is acceptable and ESD is suspected the following protective measures can also be applied:

- Install a half watt attenuator with a decibel value of +27 dBm minus the dBm value needed for tag power up. Then run the reader at +27 dBm instead of reduced transmit power. This will attenuate inbound ESD pulses by the installed decibel value, while keeping the tag operation generally unchanged. Note that the receive sensitivity will be reduced by this same amount. Position the attenuator as close to the ThingMagic Nano as feasible.
- As described above add the SHP600 filter immediately adjacent to the attenuator, on the antenna side.
- Add Diode Clamp, if required, adjacent to the SHP600, on the antenna side.

Variables Affecting Performance

Reader performance may be affected by the following variables, depending on the site where your Reader is being deployed:

- Environmental
- Tag Considerations
- Multiple Readers

Environmental

Reader performance may be affected by the following environmental conditions:

- Metal surfaces such as desks, filing cabinets, bookshelves, and wastebaskets may enhance or degrade Reader performance.
- Antennas should be mounted far away from metal surfaces that may adversely affect the system performance.
- Devices that operate at 900 MHz, such as cordless phones and wireless LANs, can degrade Reader performance. The Reader may also adversely affect the performance of these 900 MHz devices.
- Moving machinery can interfere the Reader performance. Test Reader performance with moving machinery turned off.
- Fluorescent lighting fixtures are a source of strong electromagnetic interference and if possible should be replaced. If fluorescent lights cannot be replaced, then keep the Reader cables and antennas away from them.
- Coaxial cables leading from the Reader to antennas can be a strong source of electromagnetic radiation. These cables should be laid flat and not coiled up.

Tag Considerations

There are several variables associated with tags that can affect Reader performance:

- Application Surface: Some materials, including metal and moisture, interfere with tag performance. Tags applied to items made from or containing these materials may not perform as expected.

- Tag Orientation: Most tags have folded dipole antennas. They read well when facing the antenna and when their long edge is oriented toward the antenna, but very poorly when their short edge is oriented toward the antenna.
- Tag Model: Many tag models are available. Each model has its own performance characteristics.

Antenna Considerations

- Use a circularly polarized antenna. Linear antennas can only be used if the tag orientation to the antenna is consistent, or if not always in the ideal orientation, the antenna or tag can be rotated for best reading.
- Use an antenna whose design naturally presents a short to DC. This will help eliminate ESD issues.
- Use an antenna with a return loss of 17 dB or greater (1.33 VSWR) in the transmission band of the region the module is using.
- Use an outdoor-rated antenna if there is a chance that water or dust could get into the antenna and change its RF characteristics.
- Ensure that the antenna is mounted such that personnel do not stand in the radiation beam of the antenna unless they are more than 21 cm away from the face of the antenna (to adhere to FCC limits for long term exposure). If the application calls for personnel to work in the antenna beam and they will be less than 21 cm from the face of the antenna, the Nano power should be reduced or a lower gain antenna must be used (21 cm assumes a 27 dBm power level into an 8.15 dBi antenna).

Multiple Readers

The Reader adversely affect performance of 900 MHz devices. These devices also may degrade performance of the Reader.

- Antennas on other Readers operating in close proximity may interfere with one another, thus degrading performance of the Readers.
- Interference from other antennas may be eliminated or reduced by using either one or both of the following strategies:
  - Affected antennas may be synchronized by a separate user application using a time-multiplexing strategy.
  - Antenna power can be reduced by reconfiguring the RF Transmit Power setting for the Reader.

Note

Performance tests conducted under typical operating conditions at your site are recommended to help you optimize system performance.