THINGMAGIC® M7E-TERA USER GUIDE

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www.JADAKtech.com

1. COPYRIGHT INFORMATION

2. TECHNICAL SUPPORT AND CONTACT INFORMATION

Telephone: 315.701.0678 https://www.jadaktech.com

Email: rfid-support@jadaktech.com

3. REVISION HISTORY

Date	Version	Description
March 2023	1.0	First Revision for early-access release.
October 12, 2023	1.1	Updated Mechanical Parameters, Regional Frequency Specs updated
November 17, 2023	1.2	Updated Regional Frequency specs for AU, ID and RU.
December 5, 2023	1.3	Updated DC power requirements, added CB schematics, Added Document #, removed Preliminary watermark.
December 10, 2023	1.4	Updated Module Specifications
December 15, 2023	1.5	Updates to Regulatory support section and CB schematics

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4. Introduction

This document applies to the ThingMagic M7E-TERA embedded module. This is an Ultra High Frequency (UHF) RAIN® Radio Frequency Identification (RFID) reader module that can be integrated with other systems to create RFID-enabled products. This document is for hardware designers and software developers.

For the remainder of this document the ThingMagic M7E-TERA module will be referred to as "the module" or the ThingMagic module.

Applications to control the ThingMagic module can be written using the high level MercuryAPI version 1.37.2 and later. The MercuryAPI supports C, C#/.NET and Java 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 Release notes associated with the release of your module. The Release Notes contain links to Mercury API Programmers Guide and the Mercury API SDK.

4.1 Release Notes

The information in this document is relevant to modules with Firmware Ver 2.1.3 and later. This firmware is not compatible with any other ThingMagic modules.

Module firmware version 2.1.3 has been developed in conjunction with MercuryAPI. The version of Mercury API linked to in the separate Release Notes document must be used. Previous versions of the API will not support all the features of this firmware release.

This document explains how to set up the reader module. If you operate the module with firmware newer than this, refer to the corresponding Firmware Release Notes for operational differences from what is in this User Guide.

Release notes include new features or known issues as well as all changes since this User Guide was last updated. Release notes are downloaded from the same web site where you obtained this document

5. Hardware Overview

5.1 Hardware Interfaces

5.1.1 Module Pin-out

Connections are made to the module using 38 edge pads ("vias") that allow the module to be surface-mounted to a main board. Figure 1 shows a bottom view of the module, showing the numerical pins of the module:

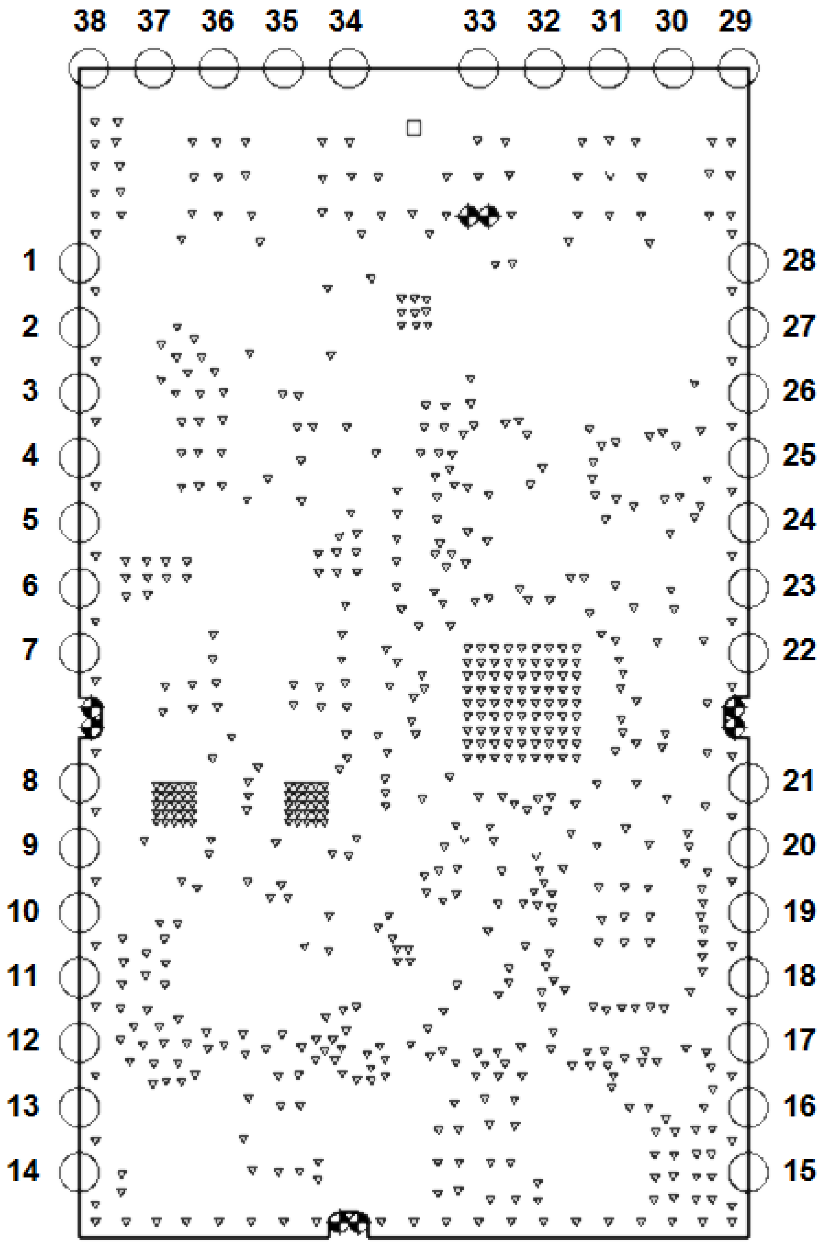


Figure 1: Module Pinout with Drill Drawing Top View

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

Table 1: Module Pinout Definition

Edge Via Pin #	Pin Name	Signal Direction	Notes
1-8	GND		
9	RFU		Reserved for Future Use
10	RUN	Input	Hi=Run, Low=Shutdown Internal pull up to Vin Leave Open for Run
11-12	GND		
13	VIN	Input	3.3 to 5.5 V
14	VIN	Input	3.3 to 5.5 V
15	UART_RX	Input	Serial input, 3V CMOS logic levels
16	UART_TX	Output	Serial output, 3V CMOS logic levels
17	GPIO1	In/Out	User, general purpose I/O
18	GPIO2	In/Out	User, general purpose I/O
19	GPIO3	In/Out	User, general purpose I/O
20	GPIO4	In/Out	User, general purpose I/O
21	GND		
22-25	RFU		Reserved for Future Use
26-29	GND		
30	ANT1	In/Out	860 to 930 MHz RFID bidirectional signal
31	GND		
32	ANT2	In/Out	860 to 930 MHz RFID bidirectional signal
33	GND		
34	GND		

Edge Via Pin #	Pin Name	Signal Direction	Notes
35	ANT3	In/Out	860 to 930 MHz RFID bidirectional signal
36	GND		
37	ANT4	In/Out	860 to 930 MHz RFID bidirectional signal
38	GND	In/Out	

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

5.1.2 Antenna Connections

The module has four antenna ports, and the connection is only through the edge vias of the module.

The maximum RF power that can be delivered to a 50-ohm load from the antenna port of the module is 1.5 Watts, or +31.5 dBm

5.1.2.1 Antenna Requirements

The performance of ThingMagic module is affected by antenna quality. Antennas that provide good 50 ohm match at the operating frequency band perform best. Specified sensitivity 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.**

5.1.2.2 Antenna Detection

Caution: This ThingMagic module does not support automatic antenna detection. When writing applications to control the module, 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 Mercury API Programmers Guide defined in the Release Notes. *Level 2 API* | *Advanced Reading* | *ReadPlan* section.

5.1.3 Voltage and Current Limits

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

Table 2: Voltage and Current Limits

Specification	Limits
Input Low-level Voltage	0.7 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 V3R3 when module is turned off to prevent damage.
Output Low-level Voltage	0.3 V typical, 0.7 V maximum
Output High-level Voltage	3.0 V typical, 2.7 V minimum
Output Low-level Current	10 mA maximum
Output High-level Current	7 mA maximum

5.1.4 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.

5.1.4.1 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 49.9 kOhms to V3R3.

The connected host processor's receiver must have the capability to receive up to 255 bytes of data at a time without overflowing. Flow control is not supported.

5.1.4.2 Supported Baud Rates

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

- 9600
- 19200
- 38400
- 57600
- 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.)

Recommended maximum receiver baud-rate errors for various character sizes are shown in the table below.

Table 3: Receiver Baud Rate Tolerance

Baud rate	Recommended max Rx error	
	Min (-2%)	Max (+2%)
9600	9412	9796
19200	18823	19592
38400	37647	39184
57600	56470	58775
115200	112941	117551
230400	225882	235102
460800	451765	470204
921600	903529	940408

5.1.5 General Purpose Input/Output (GPIO)

The four GPIO connections, 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.

On power up, the 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.

5.1.5.1 *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 programming language-specific reference document included with the Mercury API.

5.1.6 RUN Line

The RUN line must be pulled HIGH or left unconnected 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 RUN is set LOW.

It is recommended that the RUN line be connected to a GPO line of the control processor. This will allow the processor to reset the module into a default state should it become unable to communicate with the processor for any reason. Pulling the RUN line low for 50 milliseconds will reset the module.

5.2 DC Power Requirements

The module is specified to operate with DC input levels of between 3.3V and 5.5V. All specifications are maintained if 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 Volt line or if the GPIO lines are supplying current to external circuits.

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

5.2.1 RF Power Output Impact on DC Input Current and Power

The ThingMagic M7E-TERA module supports separate read and write power levels which are command adjustable via the MercuryAPI. Either power level can be set within the following limits:

- Minimum RF Power = 0 dBm
- Maximum RF Power = +31.5 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.

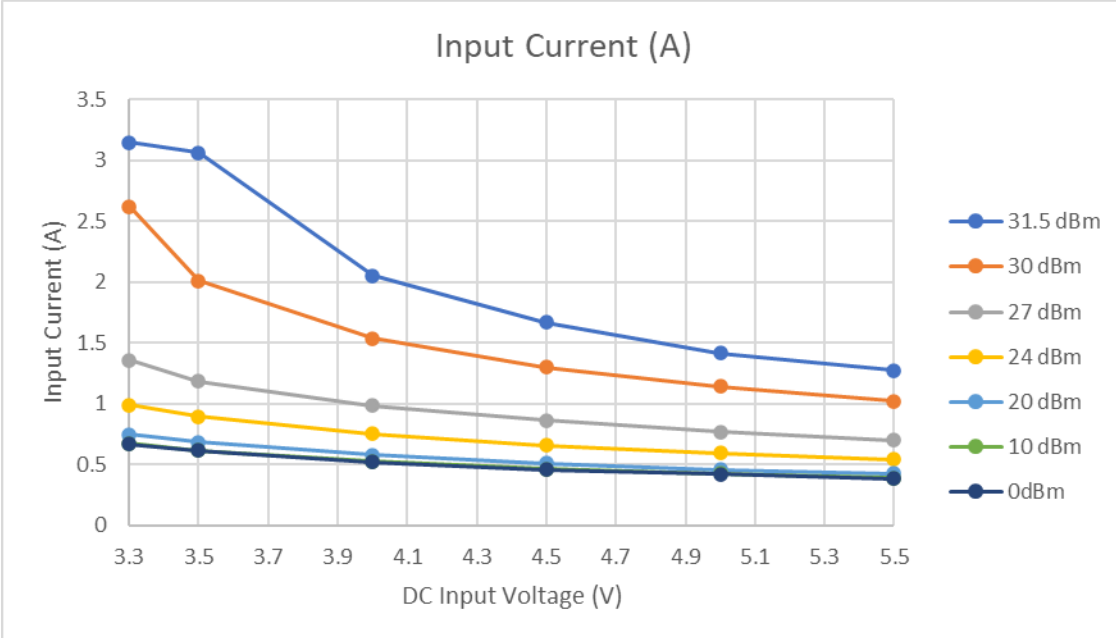


Figure 2: Current Draw vs. DC Voltage and RF Output Level

As shown in the chart in Figure 2 as long as the output power setting is below +25 dBm, the current draw remains below the 1 A limit described in Section 5.2.

The input voltage should be maintained above 3.5V if the RFoutput power setting is above +26dBm and 3.3V 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 +24 dBm, +27 dBm, 30dBm and 31.5dBm RF powerlevels.

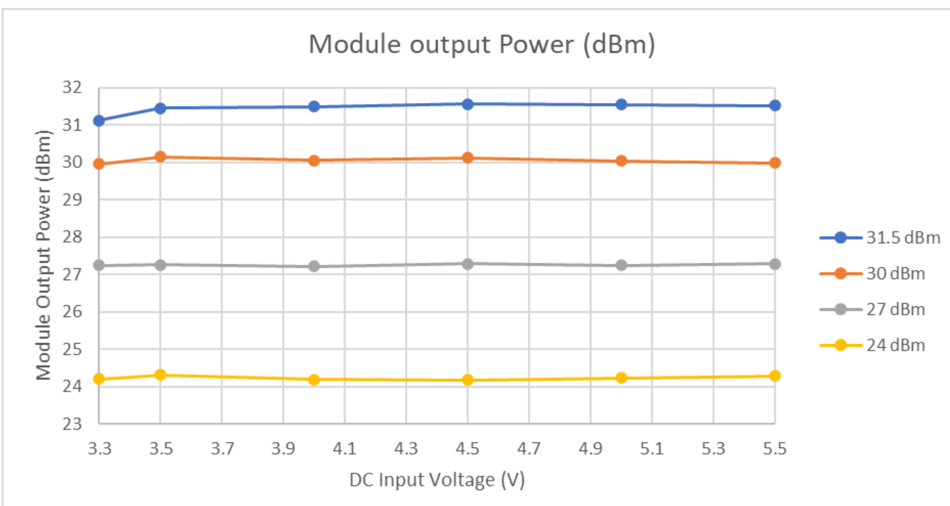


Figure 3: Module Output Power vs. Module Voltage

The power drawn by the module is 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:

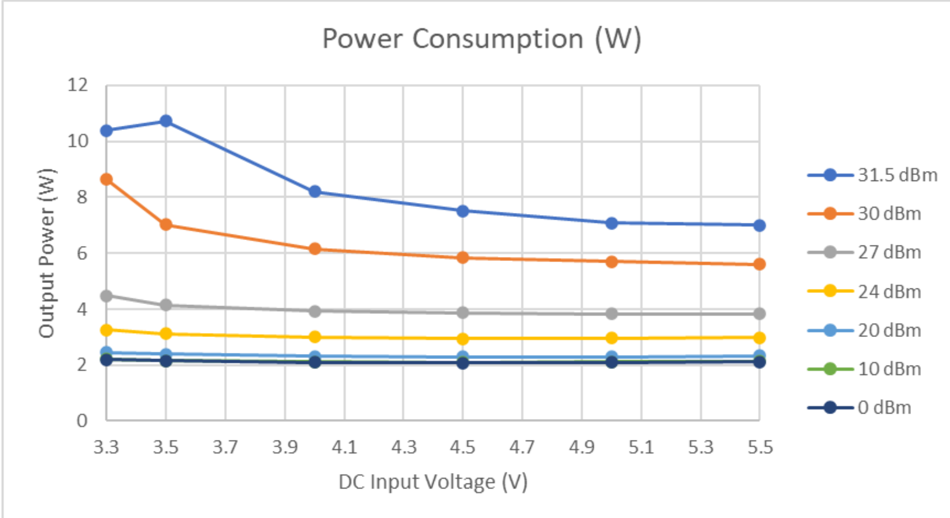


Figure 4: Power Consumption vs DC Voltage and RF Output Level

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 11 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.

5.2.2 Power Supply Ripple

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

- 5 Volt +/- 5%.
- 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.
- Power supply switching frequency equal or greater than 500 kHz.

Caution: Operation in the EU Region (under ETSI regulatory specs) may need tighter ripple specifications to meet ETSI mask requirements.

5.2.3 Idle DC Power Consumption

When not actively transmitting, the module falls back into one of the 3 idle states, called “power modes”. Each successive power mode turns off more of the module’s circuits, which must be restored when any command is executed, imposing a slight delay. The following table gives the power consumption levels and the delay to respond to a tag read command.

5.2.4 Power Consumption

Table 4:Power Modes and Power Consumption

Operation	DC Power Consumed at 5 VDC	Time to Respond to a Read Command
Power Mode = “FULL”	0.780 W	Less than 10 msec.

Power Mode = "MINSAVE"	0.130 W	Less than 30 msec.
Power Mode = "SLEEP"	0.090 W	Less than 40 msec.
RUN Line disabled	0.004 W	Module reboots when RUN 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, consider temperature, channel of operation, and antenna return loss.

5.3 RF Characteristics

5.3.1 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 than read). The range of values for both settings is from 0 dBm to +31.5 dBm, in 0.5 dB increments. For example, 30 dBm will be configured as "3000" 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.

5.3.2 Receiver Adjacent Channel Rejection

The module receives signals that are centered at the link frequency 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 requires 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 still achieves the tag read rates required by the application.

5.4 Environmental Specifications

5.4.1 Thermal Considerations

The module will operate within its stated specifications over a temperature range of -40°C to +60°C, measured at the ground plane that the ThingMagic module is soldered to.

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

5.4.2 Thermal Management

5.4.2.1 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 heatsink. Often the weak link in thermal management design is not the thermal interface from the module to the heat-sink, but rather the thermal interface from the heat-sink to the outside world.

5.4.2.2 Duty Cycle

If overheating occurs, Mercury API returns error code 0x0504 to alert the user. The module protects itself by turning off RF until the temperature falls back within the allowed range. In order to continue operation, try reducing the duty cycle of operation. This involves modifying the RF On/Off (API parameter settings /reader/read/asyncOnTime and asyncOffTime) values. Start with 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. With adequate heat sinking, you can run continuously at 100% duty cycle.

5.4.2.3 *Temperature Sensor*

The 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 operating Temperature limits for allowing transmission are -40°C to +60°C (case temperature).

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.

5.5 Electro-Static Discharge (ESD) Specification

The Electro-Static Discharge Immunity specifications for the module 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 Section 5.1. Hardware Integration).

The module Carrier Board incorporates extra ESD protection filtering. The user is advised to follow this example for ESD sensitive applications.

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

Warning: The ThingMagic module 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 module 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.

5.6 Shock and Vibration

This module has been designed to survive 1 meter drop during handling. The module has been designed to be installed in host devices which are required to survive 1 meter drops to concrete.

5.7 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 may not be used in some regions without additional regulatory approval. (Circularly polarized antennas can have a circular gain as high as 11.15 dBiC and still maintain a maximum linear gain of 8.15 dBiL.) The required antenna impedance is 50 ohms.

Table 5:Authorized Antennas

Vendor	Model	Type	Polarization	Frequency Range	Max Circular Gain (dBiC)	Max Linear Gain (dBi)
MTI Wireless	MTI-242043	Patch	Circular	865-956 MHz	8.5 in EU band, 9.5 in NA band	6.0
Laird	S8964B	Dipole	Linear	896-960 MHz	[Not Applicable]	6.15

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.

5.8 FCC Modular Certification Considerations

Novanta has obtained FCC modular certification for the ThingMagic M7E-TERA module. This means that the module can be installed in different end-use products by another equipment manufacturer with limited 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.), and must have similar in-band and out-of-band characteristics (consult specification sheet for cutoff frequencies).

If the antenna is of a different type or has higher gain than those listed in the module’s FCC filing, see Authorized Antennas, a *class II permissive change* must be requested from the FCC. Contact us at rfid-support@jadaktech.com for assistance.

A host using a module component 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 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 will provide guidance to the host manufacturer for compliance with Part 15B requirements.

5.9 Physical Dimensions

5.9.1 Module Dimensions

The dimensions of the ThingMagic M7E-TERA module are shown in the following diagram and table:

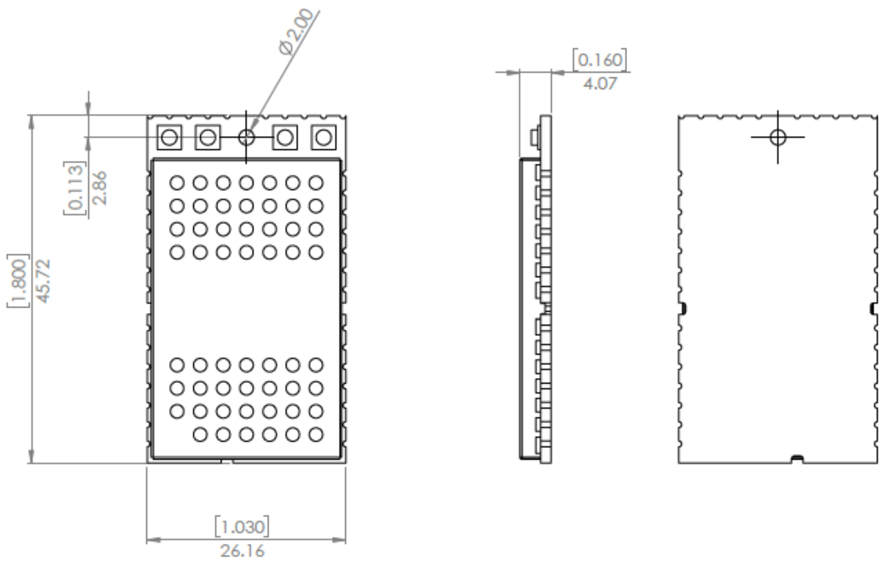


Figure 4: Mechanical Drawing with Module Dimensions

Table 6: Module Dimensions

Attribute	Value
Width	26 +/-0.2 mm
Length	46 +/-0.2 mm
Height (includes PCB, shield, mask and labels)	4.0 maximum
Mass	8 grams

5.9.2 Packaging

Individual modules are packed in separate static bags.

5.10 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.

Unnecessary long exposure and exposure to more than 245°C 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 cannot be given.

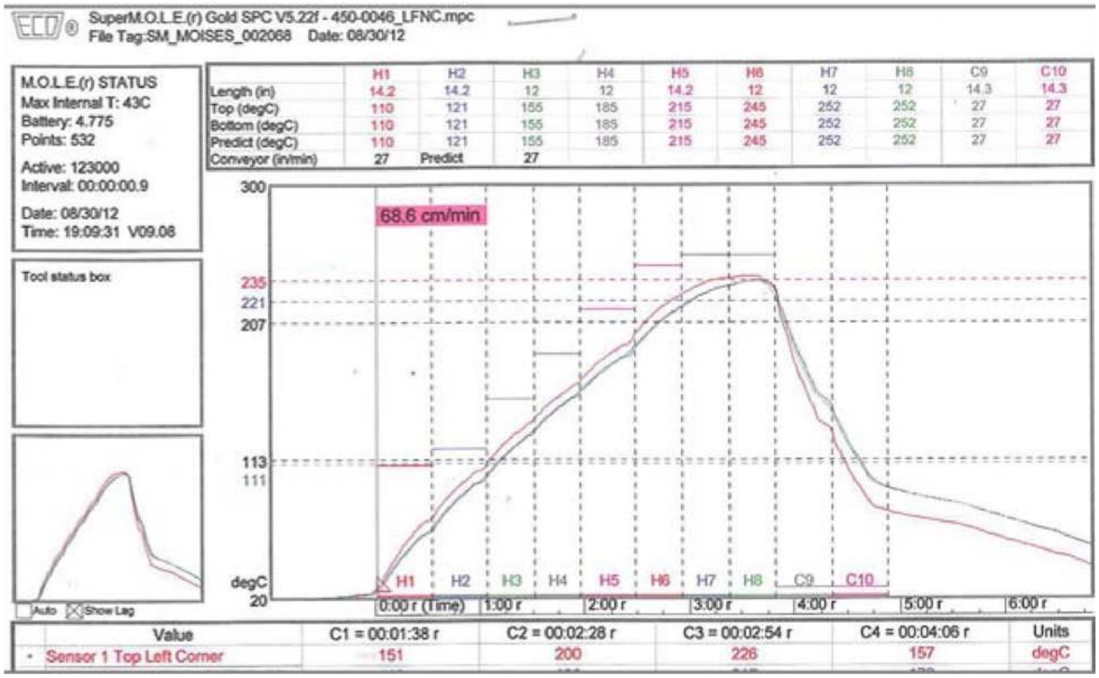


Figure 5: SMT Reflow Profile Plot

There must only be one reflow cycle, maximum.

5.11 Hardware Integration

The module can be integrated with other systems to create RFID-enabled products. This chapter discusses requirements for a host board design and characteristics of the Module Carrier Board offered in the Development Kit and for applications where standard connectors are required to interface the module with a host board.

5.11.1 Landing Pads

The following diagram shows the position and recommended size of the landing pads and the heat-sink areas.

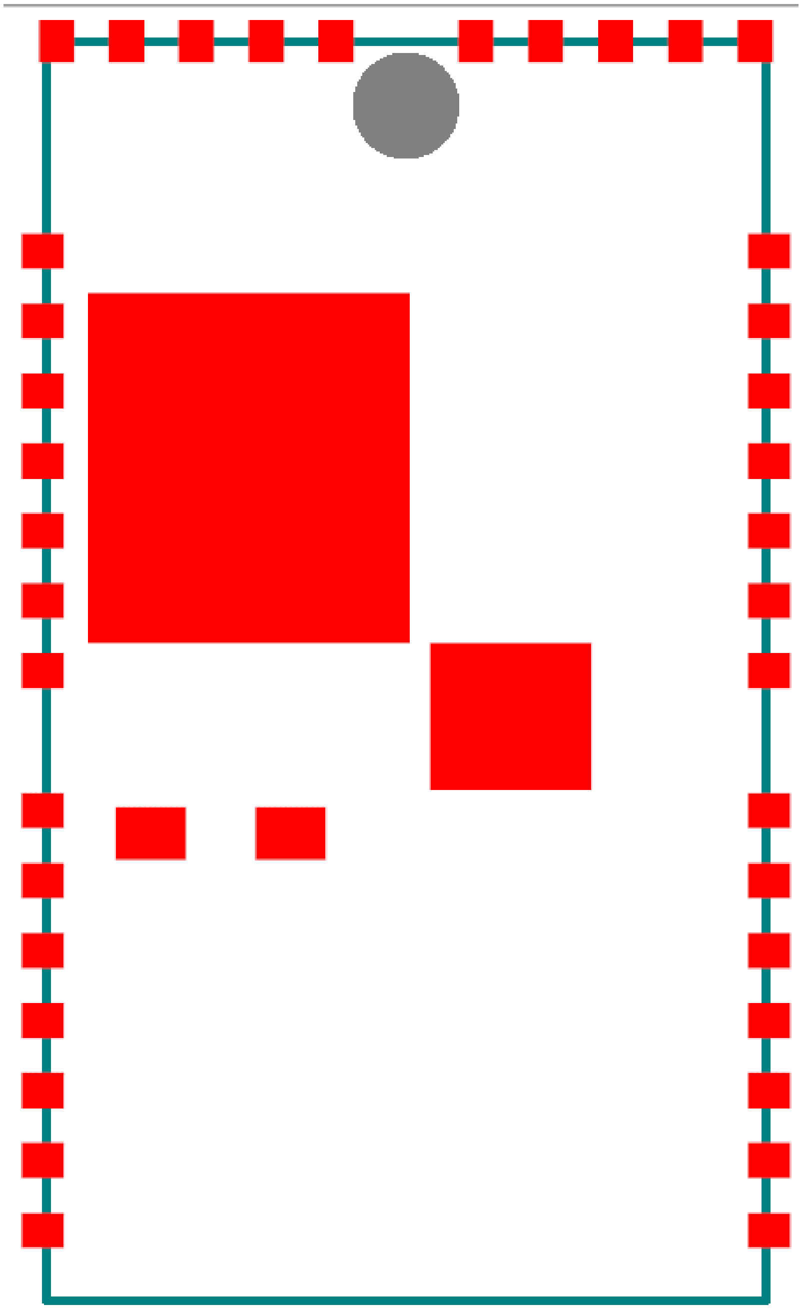


Figure 6: Landing Pads and Heat Sync Areas

Hardware Design Files are available on the web site for the "carrier board" that implements this layout. Links to the Hardware Design Files are found in Release Notes

The 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 The module to use connections with 0.7 mm diameter edge vias. The pads of the The module underside should align with the copper pads of the footprint, with a pad exposure extending outside the module edge by a nominal 0.86 mm. A 0.4 mm keep-out shall be provided between non-ground pads and under the module itself. The RF pad (pin 38) is 0.9 mm in diameter. Clearance on the RF pad is 3.75 mm, between pads and under the module.

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 module shall be optimized for connecting to a coplanar wave guide with ground plane beneath. For pad and trace dimensions, contact JADAK Support.

The area beneath the module should be kept clear of traces and copper with the exception of heat-sinking area.

5.11.2 Module Carrier Board

The module Carrier Board is an example of a host board to create an assembly that is compatible with the standard Development Kit main board. The carrier board uses the same connector for power and control (Molex 532611571 - 1.25mm pin centers, 1 amp per pin rating, which mates with Molex housing p/n 51021-1500 with crimps p/n 63811-0300).

Figure 7: Carrier Board

Table 7: Pinout of 15-pin Connector on Carrier Board

Pin Number	Signal	Signal Direction with respect to Carrier Board	Notes
1,2	GND	Power and Signal Return	Must connect all 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 module.
6	GPIO2	Bidirectional	Same Specifications as module.
7	GPIO3	Bidirectional	Same Specifications as module.
8	GPIO4	Bidirectional	Same Specifications as module.
9	UART RX	Input	
10	UART TX	Output	
11-13	RFU	Not Internally Connected	
14	RUN / SHUTDOWN	Input	Hi=Run, Low=Shutdown Internal pull up to Vin Leave Open for Run
15	RFU	Not Internally Connected	

The UART RX and UART TX lines are buffered in the module. This makes the inputs 5V tolerant.

GPIO lines are not buffered in the module. V3R3 output may be used to power external buffers to protect GPIO inputs.

Caution: The GPIO lines configured as inputs must be low when the module is turned off and low just before the module is turned on. The GPIO lines can be assured to be in a safe state if it is driven by a buffer circuit that is powered by the module as shown in the carrier board design. That way, the input Voltage to the GPIO pins can never be higher than the DC supply voltage into the module because the buffer is powered by the module.

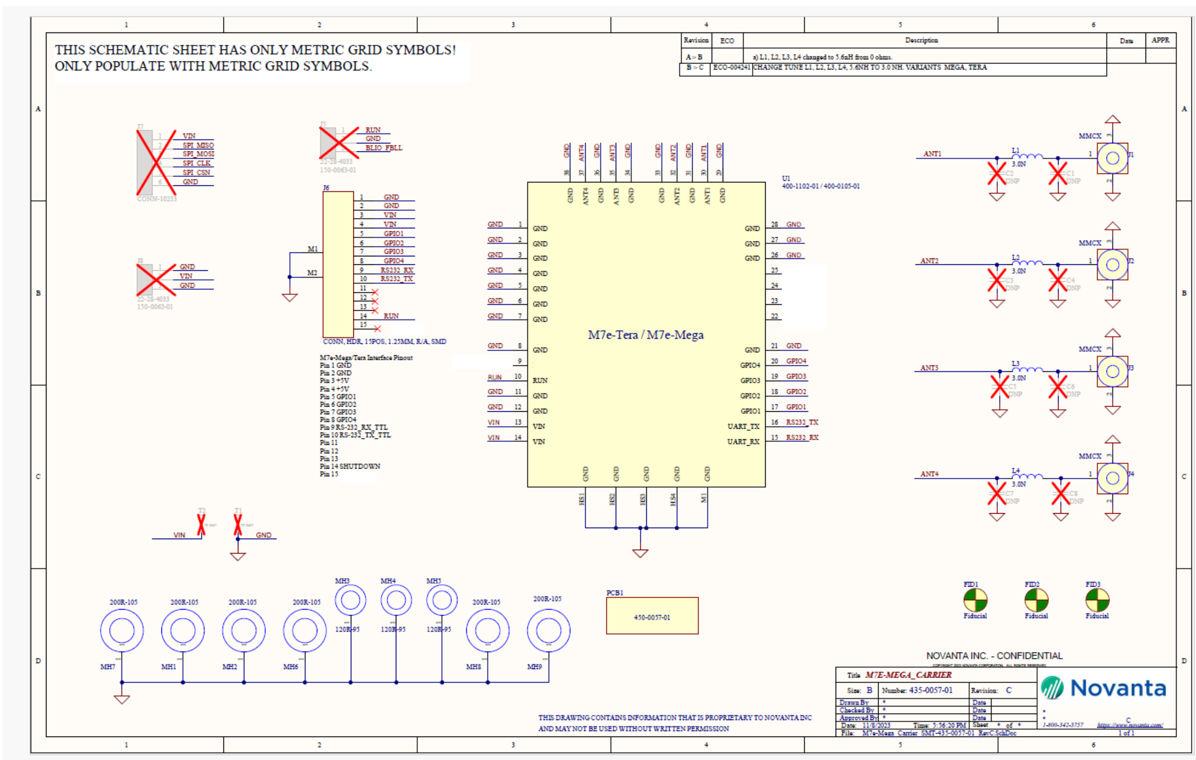


Figure 8:Carrier Board Schematic

5.11.3 Carrier Board Heat Sinking

The module can run at full RF power at room temperature on stand-offs in the Development Kit. If you wish to test the ThingMagic module under extreme temperature conditions, you may want to mount it on the heat spreader that is supplied with the Carrier Board. Make sure it is assembled as shown in these pictures, so no live signals are shorted to ground.

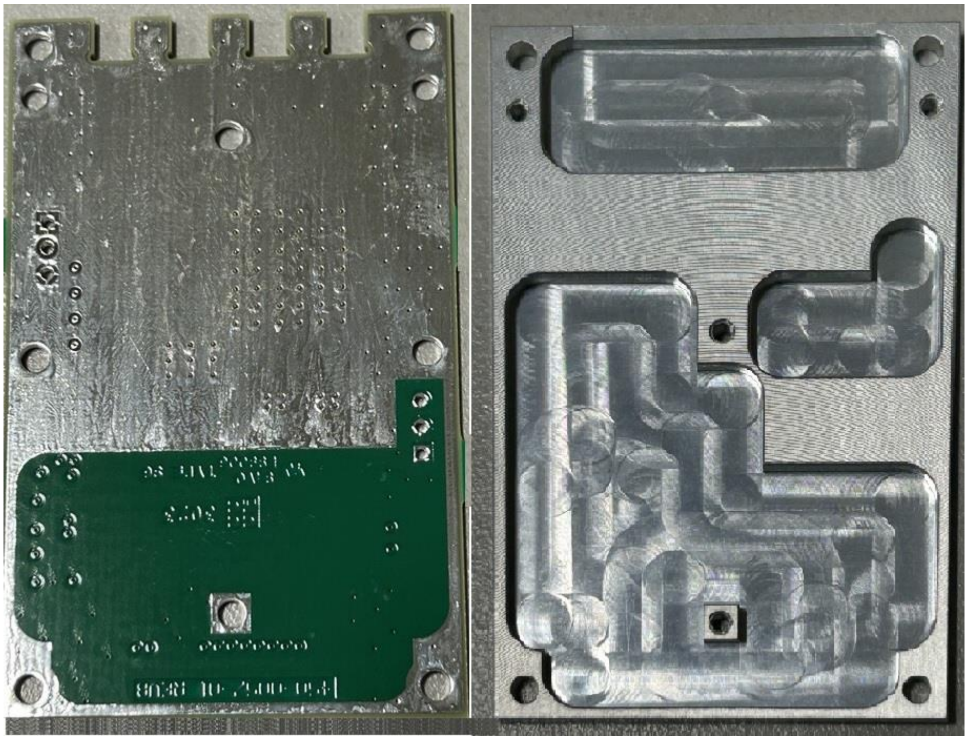


Figure 9: Carrier Board Heat Spreader

6. Firmware Overview

6.1 Bootloader

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 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: The ThingMagic bootloader should effectively be invisible to the user. The ThingMagic module 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.

6.2 Application Firmware

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

6.2.1 Programming the ThingMagic Module

Applications to control the ThingMagic 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 demoing and developing functionality. For more information on the MercuryAPI see links in the most up to date Release Notes.

6.2.2 Upgrading the ThingMagic Module Firmware

New features developed for the ThingMagic module 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.

6.2.3 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.

6.3 Custom On-Reader Applications

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

7. Serial Communication Protocol

ThingMagic does not support bypassing the MercuryAPI to send commands to the ThingMagic module 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 module 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.

7.1 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.

Host-To-Reader Communication

Header	Data Length	Command	Data	CRC-16 Checksum

Hdr	Len	Cmd		- - - - -		CRC Hi I	CRC LO
1 byte	1 byte	1 byte	0 to 250 bytes			2 bytes	

7.2 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.

Reader-To-Host Communication

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

7.3 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.

8. Regulatory Support

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

8.1 Supported Regions

The module 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. Refer to the firmware release notes to determine if additional regions have been added. Additional information on each region is provided in Regional Frequency Specifications.

Table 8: Supported Regions

Region	Regulatory Support	Notes
ISM Band North America (NA1)	FCC 47 CFG Ch. 1 Part 15 Industrial Canada RSS-247	Complies with all FCC regulations

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 M7E-TERA module.	EU3 uses 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 de-rated to a maximum level of +22 dBm to meet the regulatory requirements. All other channels operate up to +31.5dBm. 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 define more channels than are in the module'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 License Variation 2011 (No. 1)	

New Zealand (NZ)	Radiocommunications Regulations (General User Radio License for Short Range Devices) Notice 2011- pending	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 915.8Mhz to 922.2MHz 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.

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 module 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.

8.2 Frequency Units

All frequencies in the ThingMagic module 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 can enter any channel frequency, with kHz granularity, if 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.

Table 9: Regional Frequency Specifications

Region	Frequency Quantization (kHz)	Lowest Channel Limit (kHz)	Highest Channel Limit (kHz)	Number of Channels in Default Hop Table
NA	250	902,750 kHz	927,250 kHz	50
EU3 (ETSI Lower)	100	865,100 kHz	867,500 kHz	4
IN (India)	100	865,100 kHz	866,900 kHz	5
KR2 (Korea)	100	917,300 kHz	920,300 kHz	6
PRC	125	920,125 kHz	924,375 kHz	16
AU (Australia)	250	920,750 kHz	925,250 kHz	10
NZ (New Zealand)	250	922,250 kHz	926,750 kHz	10
JP (Japan)	100	915,800 kHz	920,800 kHz	6
IS (Israel)	250	916,250 kHz	916,250 kHz	1
MY (Malaysia)	250	919,250 kHz	922,750 kHz	8
ID (Indonesia)	125	923,125 kHz	924,875 kHz	8
PH (Philippines)	250	918,250 kHz	919,750 kHz	4
TW (Taiwan)	250	922,250 kHz	927,250 kHz	11
RU (Russia)	100	866,200 kHz	867,600 kHz	8
SG (Singapore)	250	920,250 kHz	924,750 kHz	10
VN (Vietnam)	250	918,750 kHz	922,250 kHz	8
TH (Thailand)	250	920,250 kHz	924,750 kHz	10
HK (Hong Kong)	250	920,250 kHz	924,750 kHz	10
EU4 (ETSI Upper)	100	915,500 kHz	919,900 kHz	4
Open	100	860,000 kHz	930,000 kHz	15

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 915,255 kHz results in a setting of 915,250 kHz.

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

8.2.1 Frequency Hop Table

The frequency hop table determines the frequencies used by the module when transmitting. The hop table is defined when the user selects the region of operation.

8.3 Support for Set/Get Quantization Value and Minimum Frequency

The Open region is intended for testing only. Channel step size (quantization) is set to 100 kHz. This represents how often the channel is nudged back to its desired value, with more frequent nudges creating a more stable channel.

To allow the Open region to be used more flexibly, we permit the setting of the quantization value. 100kHz is the default step value in OPEN region. Other settable values are 50kHz, 125kHz and 250kHz. Error will be returned in other cases (error code number 0x109).

To permit the largest quantization value possible, we also allow setting the minimum frequency value for the Open region. (Smaller quantization values are often driven by the rule that all channels must be an integral multiple of the quantization value above the minimum frequency value.)

Only the Open region supports changing of the quantization value.

8.4 Protocol Support

The module does not have the ability to support tag protocols other than EPCglobal Gen2 (ISO 18000-6C).

Review the latest firmware release notes for updated features and capabilities.

8.5 Gen2 Protocol Configuration Options

The module supports the preconfigured configurations of GEN2/ISO-18000-6C profiles called RF modes with each RF mode corresponding to a unique combination of the Backscatter Link Frequency (BLF), Tari and "M" value as listed in Table 10 below. The RF mode can be set in the MercuryAPI Reader Configuration Parameters (/reader/gen2/*). The following table shows the supported combinations:

Table 10:Gen2 Protocol Supported Combinations

Reader to Tag	**Tag to Reader**			
Tari (usec)	**Backscatter Link Frequency (kHz)**	**Encoding**	**Modulation Scheme**	**Notes**
20	160	Miller (M=8)	PR-ASK	50+ tags per second read rate*
20	250	Miller (M=4)	PR-ASK	Default 190+ tags per second read rate*
20	320	Miller (M=4)	PR-ASK	210+ tags per second read rate*
20	320	Miller (M=2)	PR-ASK	280+ tags per second read rate*
15	320	Miller (M=2)	PR-ASK	300+ tags per second read rate*
7.5	640	Miller (M=2)	PR-ASK	400+ tags per second read rate*
7.5	640	Miller (M=4)	PR-ASK	550+ tags per second read rate*
7.5	640	FM0	PR-ASK	700+ tags per second read rate*

*Based on a population of 100 unique tags

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 not, then the

reader could be reading data faster than the host can off-load it, and the reader's buffer might fill up.

8.6 Supported Gen2 Functionality

The module firmware can perform the Gen2 functions in the following table as standalone commands but cannot do so as part of an embedded TagOps command. The following is the list of supported standard Gen2 functions:

Table 11: Standard Supported GEN2 Functions

Function	As Embedded TagOPs	As Stand-alone TagOPs
Gen2 Read Data	Yes	Yes
Gen2 Write Tag	Yes	Yes
Gen2 Lock Tag	Yes	Yes
Gen2 Kill Tag	Yes	Yes
Gen2 Block Write	Yes	Yes
Gen2 Block Erase	Yes	Yes
Gen2 Block Permalock	Yes	Yes

Most of the multi-antenna functions are supported because the module can support a 1:64 multiplexer from its four physical ports.

8.7 Antenna Port

The ThingMagic M7E-TERA module has four monostatic antenna ports. These ports are capable of both transmitting and receiving.

NOTE: The ThingMagic module does not support bistatic (separate transmit and receive port) operation.

The module also supports using a multiplexer, allowing up to 64 total logical antenna ports, controlled using four GPIO lines.

NOTE: The ThingMagic module does not support bistatic (separate transmit and receive port) operation, even when configured to operate with a multiplexer.

8.7.1 Using a Multiplexer

Multiplexer switching is controlled using the General Purpose Input/Output (GPIO) lines. To enable automatic multiplexer port switching the module must be configured to *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 next section shows the mapping that results using four GPO's for multiplexer control.

8.7.2 GPIO State to Logical Antenna Mapping

The module provides 4 GPIO pins. M7e-Tera uses 2 control lines ANTSW1 and ANTSW2 for antenna switching and multiplexing.   All GPIO pins can be used as PortSwitchGPO control pins. These 4 GPO pins can be used to control up to 64 logical antennas.

Table 12 shows the complete mapping of GPO states to logical antenna numbers.

If any GPO line is unused, assume its state is permanently low and eliminate all row entries corresponding to a high state for that GPO line – those logical antenna numbers will not be used.

Table 12: Logical Antenna Mapping

GPO 4	GPO 3	GPO 2	GPO 1	Physical Antenna	Logical Antenna
0	0	0	0	1	1
0	0	0	0	2	2
0	0	0	0	3	3
0	0	0	0	4	4
0	0	0	1	1	5
0	0	0	1	2	6
0	0	0	1	3	7
0	0	0	1	4	8
0	0	1	0	1	9
0	0	1	0	2	10
0	0	1	0	3	11
0	0	1	0	4	12
0	0	1	1	1	13
0	0	1	1	2	14
0	0	1	1	3	15
0	0	1	1	4	16
0	1	0	0	1	17
0	1	0	0	2	18
0	1	0	0	3	19
0	1	0	0	4	20
0	1	0	1	1	21
0	1	0	1	2	22
0	1	0	1	3	23
0	1	0	1	4	24
0	1	1	0	1	25
0	1	1	0	2	26
0	1	1	0	3	27
0	1	1	0	4	28
0	1	1	1	1	29
0	1	1	1	2	30
0	1	1	1	3	31
0	1	1	1	4	32
1	0	0	0	1	33
1	0	0	0	2	34
1	0	0	0	3	35
1	0	0	0	4	36

1	0	0	1	1	37
1	0	0	1	2	38
1	0	0	1	3	39
1	0	0	1	4	40
1	0	1	0	1	41
1	0	1	0	2	42
1	0	1	0	3	43
1	0	1	0	4	44
1	0	1	1	1	45
1	0	1	1	2	46
1	0	1	1	3	47
1	0	1	1	4	48
1	1	0	0	1	49
1	1	0	1	2	50
1	1	0	1	3	51
1	1	0	1	4	52
1	1	0	1	1	53
1	1	0	1	2	54
1	1	0	1	3	55
1	1	0	1	4	56
1	1	1	0	1	57
1	1	1	0	2	58
1	1	1	0	3	59
1	1	1	0	4	60
1	1	1	1	1	61
1	1	1	1	2	62
1	1	1	1	3	63
1	1	1	1	4	64

NOTE: Using an antenna multiplexor will require a Class 2 Permissive Change as trace routes to support antenna multiplexing are not covered under the existing regulatory certificates.

8.7.3 Port Power and Settling Time

The module 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.

8.8 Tag Handling

When the ThingMagic module 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.

8.8.1 Tag Buffer

The ThingMagic module 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 52 96-bit EPC tags in the Tag Buffer at a time. Since the module supports streaming of read results, typically the buffer limit is not an issue. Each tag entry consists of a variable number of bytes and the following fields:

Table 13: Tag Buffer 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.

8.8.2 Tag Streaming/Continuous Reading

When reading tags during asynchronous inventory operations (MercuryAPI Reader.StartReading()) using an */reader/read/asyncOffTime*=0 The module "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 the module 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.

8.8.3 Tag Read Meta Data

In addition to the tag EPC ID resulting from module 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:

Tag Read Metadata

Metadata 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	Average phase of tag response in degrees (0°-180°)
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.
Protocol	The protocol of tag. Only Gen2 is supported.
Gen2 Q	Indicates the Q value used for inventory.
Gen2 Link Frequency	Indicates the back link frequency used for inventory.
Gen2 Target	Indicates the Target value used for inventory.

8.9 Power Management

The module 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.

8.9.1 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.

The details of the amount of power consumed in each mode are 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 30 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.
- **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 30 ms. of delay from idle to RF on when initiating an RF operation.

NOTE: See additional latency specifications under Event Response Times**.**

8.10 Performance Characteristics

8.10.1 Event Response Times

The following table provides information on how long common module 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.

Table 14: Event Response Times

Start Command/ Event	End Event	Typical Time (msecs)	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	4	When in Power Mode = FULL
Tag Read	RF On	30	When in Power Mode = MINSAVE
Tag Read	RF On	35	When in Power Mode = SLEEP

9. Module Specifications

Ordering Information	
Module	M7E-TERA
Module on Carrier Board	M7E-TERA-CB
Development Kit	M7E-TERA-DEVKIT
Physical	
Dimensions	46 mm L x 26 mm W x 4.0 mm H (1.8 in L x 1.0 in W x 0.16 in H)
Tag / Transponder Protocols	
RFID Protocol Support	EPCglobal Gen 2V2 (ISO 18000-63) with DRM
RF Interface	
RF Transceiver	Impinj E710
Antenna Connector	Four 50 Ω connections (board-edge or U.FL)
RF Power Output	Separate read and write levels, command-adjustable from 0 dBm to +31.5 in 0.5 dB steps, accurate to +/-1 dBm
Regulatory	Pre-configured for the following regions: FCC (NA, SA) 902-928MHz; ETSI (EU) 865.6-867.6 MHz; TRAI (India) 865-867 MHz; KCC (Korea) 917- 923.5 MHz; ACMA (Australia) 920-926 MHz; SRRC-MII (P.R. China) 920.1-924.9 MHz; MIC (Japan) 916.8-922.2 MHz; 'Open' (Customizable channel plan; 860-930 MHz)
Data/Control Interface	
Physical	38 board-edge connections providing access to 4 RF ports, DC power, communication, control and GPIO signals
Control/Data Interfaces	UART; 3.3V logic levels from 9.6 to 921.6 kbps
GPIO Sensors and Indicators	Four 3.3V bidirectional ports configurable as input (sensor) ports or output (indicator) ports
API support	C#/.NET, Java, C
Power	
DC Power Required	DC Voltage: 3.3 to 5V DC power consumption when reading: <7.2W @ +31.5 dBm*; <3W @ power levels under +17 dBm
Power Saving Options	Ready: 0.780W Sleep: 0.130W Shutdown: 0.090W
Environment	
Certification	USA (FCC 47 CFR Ch. 1 Part 15); Canada (Industry Canada RSS-247); EU (ETSI EN 302 208 v3.3.1, RED 2014/53/EU); JAPAN (MIC Article 38 Section 24)
Operating Temp.	-40°C to +60°C (case temperature)
Storage Temp.	-40°C to +85°C
Shock and Vibration	Survives 1 meter drop during handling
Performance	
Max Read Rate	Up to 800* tags/second using high-performance settings
Max Tag Read Distance	Over 12 meters (36 feet) with 6 dBi antenna (36 dBm EIRP) *

*Best case with good antenna matching

Specifications subject to change without notice.

10. Compliance and IP Notices

10.1 Communication Regulation Information

Contact rfid-support@jadaktech.com before beginning the process of getting regulatory approval for a finished product using the ThingMagic M7E-TERA.

10.1.1 Federal Communication Commission (FCC) 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.

Warning: Operation of the M7E-TERA 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 Federal Communication Commission's (FCC) 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 always 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

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

The OEM integrator must 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.

10.1.1.1 *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 20 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 Class B 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

AND

“Any changes or modifications to the transmitting module not expressly approved by Novanta could void the user’s authority to operate this equipment”

10.1.1.2 *End Product Labeling*

The final end product must be labeled in a visible area with the following:
“Contains Transmitter Module FCC ID: QV5MERCURY7ET”

or

“Contains FCC ID: QV5MERCURY7ET.”

10.1.2 ISED Canada

Under ISED Canada (IC) regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by ISED Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the Equivalent Isotropically Radiated Power (EIRP) is not more than that necessary for successful communicatiion

This radio transmitter IC ID: *5407A-MERCURY7ET* has been approved by ISED 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 Isotropically Radiated Power (EIRP) is not more than that permitted for successful communication.

This device has been designed to operate with the antennas listed in the 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 29 cm from all persons and must not be colocated or operating in conjunction with any other antenna or transmitter.

10.1.2.1 *End Product Labeling*

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

“Contains ThingMagic M7E-TERA transmitting module IC: 5407A-MERCURY7ET”

10.1.2.2 ISED Canada (French Canadian)

Conformément à la réglementation ISED 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 ISED 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 ISED 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. 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 29 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,

“Contains ThingMagic M7E-TERA transmitting module IC: 5407A-MERCURY7ET"

10.2 Authorized Antennas

This device has been designed to operate with the antennas listed in Authorized Antennas. Antennas not included in this list are permitted under certain circumstances.

10.3 EU Compliance

10.3.1. Declaration of Conformity

European Union Declaration of Conformity for M7E-TERA RFID Reader Module - TBD

10.3.2. EU Authorized Antennas

EU regulations requires that the radiated output of this device not exceed +33 dBm ERP. ERP power is calculated by taking the output level of the module , subtracting any cable losses between the module and the antenna, and adding the antenna gain in dBd units. “dBd” refers to the gain of the antenna with respect to that of a linear dipole antenna. A dipole has gain of 2.15 dBiL, so if the antenna gain is specified in dBiL, you must subtract 2.15 dB to obtain its gain in dBd units. For circularly polarized antennas, you should use the maximum linear gain in any orientation. If this is unknown, it can be calculated using the antenna’s circular gain and axial ratio. If the axial ratio is unknown, the maximum gain can be approximated by subtracting 3 dB from the circular gain if the beam width in both the horizontal and vertical directions are equal.

11. 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.

11.1 Common Error Messages

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

Table 15: Common Fault Errors

Message	Code	Cause	Solution
FAULT_MSG_WRONG_NUMBER_OF_DATA	100h	If the data length in any of the messages is less than or more than the number of arguments in the message, the reader returns this message.	Make sure the number of arguments matches the data length.
FAULT_INVALID_OPCODE	101h	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.	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	Some of the reserved commands might return this error code. This does not mean that they always will do this since JADAK reserves the right to modify those commands at any time.	Check the documentation for the opCode the host sent to the reader and make sure it is supported.
FAULT_MSG_POWER_TOO_HIGH	103h	A message was sent to set the read or write power to a level that is higher than the current hardware supports.	Check the hardware specifications for the supported powers and ensure that the level is not exceeded. For M7E-TERA, this limit is +31.5 dBm.
FAULT_MSG_INVALID_FREQ_RECEIVED	104h	A message was received by the reader to set the frequency outside the supported range.	Make sure the host does not set the frequency outside this range or any other locally supported ranges.

Message	Code	Cause	Solution
FAULT_MSG_INVALID_PARAMETER_VALUE	105h	The reader received a valid command with an unsupported or invalid value within this command. For example, currently the module supports one antenna. If the module receives a message with an antenna value other than 1, it returns this error.	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	A message was received to set the read or write power to a level that is lower than the current hardware supports.	Check the hardware specifications for the supported powers and ensure that level is not exceeded. The ThingMagic module supports a low limit of 0 dBm.
FAULT_UNIMPLEMENTED_FEATURE	109h	Attempting to invoke a command not supported on this firmware or hardware.	Check the command being invoked against the documentation.
FAULT_INVALID_BAUD_RATE	10Ah	When the baud rate is set to a rate that is not specified in the Baud Rate table, this error message is returned.	Check the table of specific baud rates and select a baud rate.
FAULT_INVALID_REGION	10Bh	Attempting to set a region not supported on this firmware or hardware.	Check the documentation for supported regions.
FAULT_INVALID_LICENSE_KEY	10Ch	Attempting to set a license key not supported on this firmware or hardware.	Send a test case reproducing the behavior to rfid-support@jadaktech.com.

Table 16: Bootloader Fault Errors

Message	Code	Cause	Solution
FAULT_BL_INVALID_IMAGE_CRC	200h	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.	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	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.	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 Fault Errors

Message	Code	Cause	Solution
FAULT_FLASH_BAD_ERASE_PASSWORD	300h	A command was received to erase some part of the flash but the password supplied with the command was incorrect.	When this occurs make note of the operations you were executing, save FULL error response and send a test case reproducing the behavior to rfid-support@jadaktech.com.
FAULT_FLASH_BAD_WRITE_PASSWORD	301h	A command was received to write some part of the flash but the password supplied with the command was not correct.	
FAULT_FLASH_UNDEFINED_ERROR	302h	This is an internal error and it is caused by a software problem in module.	
FAULT_FLASH_ILLEGAL_SECTOR	303h	An erase or write flash command was received with the sector value and password not matching.	
FAULT_FLASH_WRITE_TO_NON_ERASED_AREA	304h	The module received a write flash command to an area of flash that was not previously erased.	
FAULT_FLASH_WRITE_TO_ILLEGAL_SECTOR	305h	The module received a write flash command to write across a sector boundary that is prohibited.	
FAULT_FLASH_VERIFY_FAILED	306h	The module received a write flash command that was unsuccessful because data being written to flash contained an uneven number of bytes.	
FAULT_FLASH_PERIPH_UPGRADE_BAD_CRC	307h	The command received is invalid or not supported in the currently running program of the peripheral (bootloader or main application).	

Protocol Fault Errors

Table 17: Protocol Fault Errors

Message	Code	Cause	Solution
FAULT_NO_TAGS_FOUND	400h	A command was received (such as read, write, or lock) but the operation failed. There are many reasons that can cause this error to occur, including: • No tag in the RF field • Read/write power too low • Antenna not connected • Tag is weak or dead	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 tags of the same type to rule out a weak tag. If none passed, then it could be software configuration such as protocol value, antenna, and so forth, or a placement configuration like a tag location.

Protocol Fault Errors (Continued)

Message	Code	Cause	Solution
FAULT_NO_PROTOCOL_DEFINED	401h	A command was received to perform a protocol command but no protocol was initially set. The reader powers up with no protocols set.	A protocol must be set before the reader can begin RF operations.
FAULT_INVALID_PROTOCOL_SPECIFIED	402h	The protocol value was set to a protocol that is not supported with the current version of software.	This value is invalid or this version of software 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	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.	Try to write a few other tags and make sure that they are placed in the RF field.
FAULT_PROTOCOL_NO_DATA_READ	404h	A command was sent but did not succeed.	The tag used has failed or does not have the correct CRC. Try to read a few other tags to check the hardware/ software configuration.
FAULT_AFE_NOT_ON	405h	A command was received for an operation, like read or write, but the RF transmitter was in the off state.	Make sure the region and tag protocol have been set to supported values.
FAULT_PROTOCOL_WRITE_FAILED	406h	An attempt to modify the contents of a tag failed. There are many reasons for failure.	Check that the tag is good and try another operation on a few more tags.
FAULT_NOT_IMPLEMENTED_FOR_THIS_P ROTOCOL	407h	A command was received which is not supported by a protocol.	Check the documentation for the supported commands and protocols.
FAULT_PROTOCOL_INVALID_WRITE_DAT A	408h	An ID write was attempted with an unsupported/incorrect ID length.	Verify the Tag ID length being written.
FAULT_PROTOCOL_INVALID_ADDRESS	409h	A command was received attempting to access an invalid address in the tag data address space.	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	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.	Make a note of the operations you were performing and contact rfid-support@jadaktech.com.

Protocol Fault Errors (Continued)

Message	Code	Cause	Solution
FAULT_DATA_TOO_LARGE	40Bh	A command was received to Read Tag Data with a data value larger than expected or it is not the correct size.	Check the size of the data value in the message sent to the reader.
FAULT_PROTOCOL_INVALID_KILL_PASSWORD	40Ch	An incorrect kill password was received as part of the Kill command.	Check the password.
FAULT_PROTOCOL_KILL_FAILED	40Eh	Attempt to kill a tag failed for an unknown reason.	Check tag is in RF field and the kill password.
FAULT_PROTOCOL_BIT_DECODING_FAILED	40Fh	Attempt to operate on a tag with an EPC length greater than the Maximum EPC length setting.	Check the EPC length being written.
FAULT_PROTOCOL_INVALID_EPC	410h	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.	Check the EPC value that is being passed in the command resulting in this error.
FAULT_PROTOCOL_INVALID_NUM_DATA	411h	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.	Check the data that is being passed in the command resulting in this error.
FAULT_GEN2 PROTOCOL_OTHER_ERROR	420h	This is an error returned by Gen2 tags. It is a catch-all for error not covered by other codes.	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	This is an error returned by Gen2 tags. The specific memory location does not exist or the PC value is not supported by the tag.	Check the data that is being written and where it is being written to in the command resulting in this error.
FAULT_GEN2 PROTOCOL_MEMORY_LOCKED	424h	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.	Check the data that is being written and where it is being written to in the command resulting in this error. Check the access password being sent.
FAULT_GEN2 PROTOCOL_INSUFFICIENT_POWER	42Bh	This is an error returned by Gen2 tags. The tag has insufficient power to perform the memory-write operation.	Try moving the tag closer to the antenna. Try with a different tag.
FAULT_GEN2 PROTOCOL_NON_SPECIFIC_ERROR	42Fh	This is an error returned by Gen2 tags. The tag does not support error specific codes.	Check the data that is being written and where it is being written to in the command resulting in this error. Try with a different tag.

Protocol Fault Errors (Continued)

Message	Code	Cause	Solution
FAULT_GEN2 PROTOCOL_UNKNOWN_ERROR	430h	This is an error returned by ThingMagic module when no more error information is available about why the operation failed.	Check the data that is being written and where it is being written to in the command resulting in this error. Try with a different tag.

Table 18: Analog Hardware Abstraction Layer Fault Errors

Message	Code	Cause	Solution
FAULT_AHAL_INVALID_FREQ	500h	A command was received to set a frequency outside the specified range.	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	With LBT enabled an attempt was made to set the frequency to an occupied channel.	Try a different channel. If supported by the region of operation turn LBT off.
FAULT_AHAL_TRANSMITTER_ON	502h	Checking antenna status while CW is on is not allowed.	Do not perform antenna checking when CW is turned on.
FAULT_ANTENNA_NOT_CONNECTED	503h	An attempt was made to transmit on an antenna which did not pass the antenna detection when antenna detection was turned on.	Connect a detectable antenna (antenna must have some DC resistance). (Does not apply to ThingMagic M7E-TERA; it does not detect antennas.)
FAULT_TEMPERATURE_EXCEED_LIMITS	504h	The module has exceeded the maximum or minimum operating temperature and will not allow an RF operation until it is back in range.	Take steps to resolve thermal issues with module: • Reduce duty cycle • Add heat sink
FAULT_POOR_RETURN_LOSS	505h	The module has detected a poor return loss and has ended RF operation to avoid module damage.	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	An attempt to set an antenna configuration that is not valid.	Use the correct antenna setting or change the reader configuration.

Table 19: Tag ID Buffer Fault Errors

Message	Code	Cause	Solution
FAULT_TAG_ID_BUFFER_NOT_ENOUGH_ TAGS_AVAILABLE	600h	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.	Send a test case reproducing the behavior to rfid-support@jadaktech.com.
FAULT_TAG_ID_BUFFER_FULL	601h	The tag id buffer is full.	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 rfid-support@jadaktech.com.
FAULT_TAG_ID_BUFFER_REPEATED_TAG _ID	602h	The module has an internal error. One of the protocols is trying to add an existing TagID to the buffer.	Send a test case reproducing the behavior to rfid-support@jadaktech.com.
FAULT_TAG_ID_BUFFER_NUM_TAG_TOO _LARGE	603h	The module received a request to retrieve more tags than is supported by the current version of the software.	Send a test case reproducing the behavior to rfid-support@jadaktech.com.

Table 20: System Fault Errors

Message	Code	Cause	Solution
FAULT_SYSTEM_UNKNOWN_ERROR	7F00h	The error is internal.	Send a test case reproducing the behavior to rfid-support@jadaktech.com.
FAULT_TM_ASSERT_FAILED	7F01h	An unexpected internal error has occurred.	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 rfid-support@jadaktech.com.

12. Appendix B: Dev Kit

12.1 Dev Kit Hardware

Components included in the kit:

- ThingMagic M7E-TERA module soldered onto a carrier board
- Power/interface developer's board
- One USB cable
- One antenna
- One coax cable
- One 9V power supply
- International power adapter kit
- Sample tags
- The most up to date Release Notes that details which documents and software to download to get up and running quickly, along with details on how to register for and contact support.

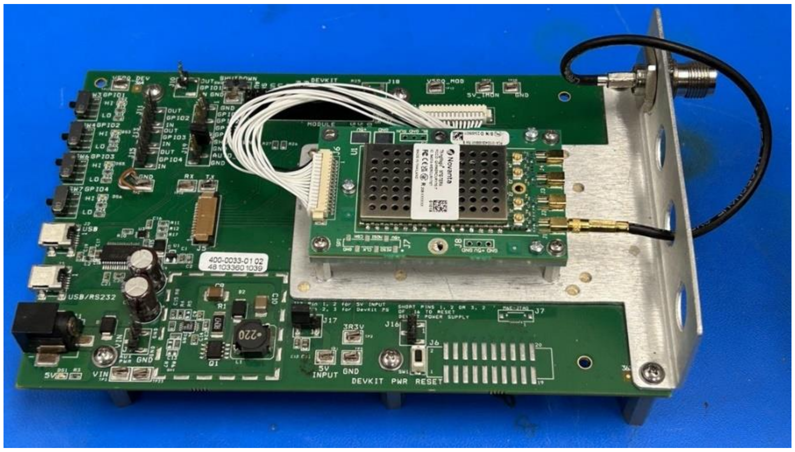


Figure 10: Carrier Board on Dev Kit Board

12.2 Setting Up the Development Kit

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

12.2.1 Connecting the Antenna

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

12.2.2 Powering Up and Connecting to a PC

After connecting the antenna you can power up the Development (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 Development Kit USB Interfaces options. Use the interface that is labeled "USB/RS232." The one labeled "USB" is not supported by this ThingMagic module.

2. Plug the power supply into the Development 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 theDev Kit USB Interface USB/RS232 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).

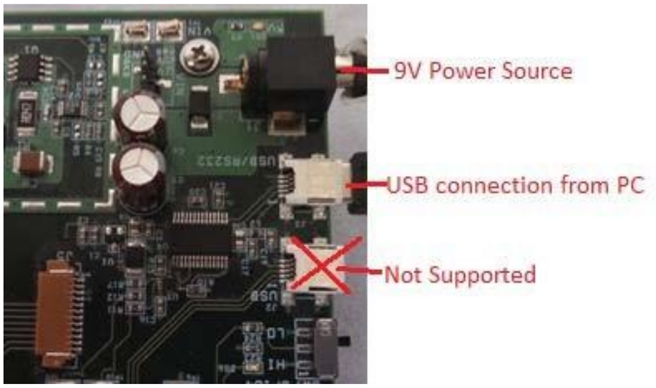
Caution: While the module is powered up, do not touch components. Doing so may damage the Dev Kit and ThingMagic module.

12.2.3 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 module through an FTDI USB to serial converter. The drivers for it are available at http://www.ftdichip.com/Drivers/VCP.htm.

Follow the instructions in the installation guide appropriate for your operating system.

This ThingMagic module does not support a USB port directly, so the "USB" port on the Development Kit is inoperable.



A COM port should now be assigned to the ThingMagic module. 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#).

12.3 Development Kit Jumpers

J8

Jumpers to connect ThingMagic module I/O lines to development 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 module for test purposes, so should be left unconnected for all applications.

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 module GPIO lines to output LEDs. Jump pins IN to GPIO# to connect ThingMagic modiule 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 development 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 Development Kit's DC power jack and power brick power.

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 effect on the ThingMagic module. To put the ThingMagic module into shutdown mode, reinstall the jumper at J19 between SHUTDOWN and GND.

12.4 Development Kit Schematics

Available upon request from rfid-support@jadaktech.com.

12.5 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/URAx64.exe and is also available for direct download from the website.

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

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

See the MercuryAPI Programmers Guide available on the JADAK website for details on using the MercuryAPI.

12.6 Notice on Restricted Use of the Development Kit

The 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.

13. Appendix C: Environmental Considerations

This appendix details environmental factors that should be considered relating to reader performance and survivability.

ElectroStatic Discharge (ESD) Considerations

Warning: The ThingMagic module 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 module 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.

13.1 ESD Damage Overview

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

- RF operations (read, write, etc.) respond with **Assert - 7F01** - indicating 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 previously. A command may become unsupported when the reader, during 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.

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. For many installations, the ThingMagic module has been successfully deployed and operating. For a different installation with this ThingMagic module, a failure problem from ESD may result in some distribution of ESD intensities occurring. Without knowledge of a limit in the statistics of those intensities, there may be the bigger charge in the future, For the bare ThingMagic module equipped with the mitigation methods described below, there will be the rogue ESD discharge that exceeds any given mitigation, and results in failure. Fortunately, many installations have some upper bound on the value of ESD events given the geometry of that installation.

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

13.1.1 Identifying ESD as the Cause of Damaged Readers

The following are some suggested methods to determine if ESD has caused reader failures, i.e., ESD diagnostics. Some of these suggestions have the negative result experiment issue.

- Return failed units for analysis.

Analysis should determine if it is the power amplifier that has 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, for example, *AlphaLabs SVM2*. High static doesn't 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 is an indication of what is in front of the antenna. What gets to the ThingMagic modules are 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.

13.1.2 Common Installation Best Practices

The following are common installation best practices to ensure the reader 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:

- Ensure that ThingMagic module, reader housing, and antenna ground connection are all grounded to a common low impedance ground.
- Verify R-TNC knurled threaded nuts are 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 full metallic shield semi rigid cables. JADAK 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 coupled to the inside of coaxial cables, causing ESD failure. Avoid RG-58. RG-223 is preferred.
- Minimize ground loops in coaxial cable runs to antennas. Tying both the ThingMagic module and antenna 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 currents 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 antenna's metallic parts and protects the antenna from performance changes due to environmental accumulation.
- Keep careful track of serial numbers, operating lifetimes, and numbers of units operating in order to determine the mean operating lifetime. This number indicates if you have a failure problem, ESD or otherwise. After any given change, it also indicates whether things have improved and if the failures are confined to one instantiation or distributed across your population.

13.1.3 Raising the ESD Threshold

For applications where full ThingMagic modiule 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 recommended. The Laird IF900-SF00 and CAF95956 are not recommended. 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 module antenna detect methods.)
- Install a Minicircuit SHP600+ high pass filter in the cable run at the ThingMagic module 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 module ESD survival level.

- 90 V lightning arrestors, such as the Terrawave Solutions Model TW-LP-RPTNC-PBHJ 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 module ESD survival level. Contact rfid-support@jadaktech.com for details.

13.1.4 Further ESD Protection for Reduced RF Power Applications

In addition to the protective measures recommended above, for applications where reduced ThingMagic module 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 , minus the dBm value needed for tag power up. Then run the reader atinstead 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 module as feasible.
- As described above, add the SHP600 filter immediately adjacent to the attenuator, on the antenna side.
- If required, add Diode Clamp adjacent to the SHP600, on the antenna side.

13.2 Variables Affecting Performance

13.2.1 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 with 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, 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.

13.2.2 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 with its own performance characteristics.

13.2.3 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 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 20 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 20 cm from the face of the antenna, module power should be reduced, or a lower gain antenna must be used (20 cm assumes a 27 dBm power level into an 8.15 dBi antenna).

13.2.4 Multiple Readers

- The reader adversely affects 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 optimize system performance.