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M6e-Micro Hardware Guide

For: M6e-Micro (Firmware Ver. 1.1.0 and later)

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ThingMagic
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Revision Table

Date	Version	Description
9/2012	01 Rev1	Revision 1 final release
11/2012	01 RevB	Updated Authorized Antennas list

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Communication Regulation Information

M6e-Micro

EMC	FCC 47 CFR, Part 15 Industrie Canada RSS-210

M6e-Micro Regulatory Information

Federal Communication Commission Interference Statement

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one of the following measures:

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

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

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

W A R N I N G !

Operation of the M6e-Micro 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. The antenna(s) must be installed such that a minimum separation distance of 25cm is maintained between the radiator (antenna) & user's/nearby people's body at all times.

2. The transmitter module must not be co-located with any other antenna or transmitter.

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

Note

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

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

User Manual Requirement

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

"To comply with FCC's RF radiation exposure requirements, the antenna(s) used for this transmitter must be installed such that a minimum separation distance of 25cm is maintained between the radiator (antenna) & user's/nearby people's body at all times and must not be co-located or operating in conjunction with any other antenna or transmitter."

AND

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

> *"This device complies with Part 15...."*
>
> AND
>
> *"Any changes or modifications to the transmitting module not expressly approved by ThingMagic Inc. could void the user's authority to operate this equipment" "*

End Product Labeling

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

"Contains Transmitter Module FCC ID: QV5MERCURY6E-M"

or

"Contains FCC ID: QV5MERCURY6E-M."

Industry Canada

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

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

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

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

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

To comply with IC RF exposure limits for general population/uncontrolled exposure, the antenna(s) used for this transmitter must be installed to provide a separation distance of at least 25 cm from all persons and must not be collocated or operating in conjunction with any other antenna or transmitter.

End Product Labeling

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

"Contains ThingMagic Inc. M6e-Micro (or appropriate model number you're filing with IC) *transmitting module FCC ID: QV5MERCURY6E-M (IC: 5407A-MERCURY6EM)"*

Industrie Canada

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

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

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

1. Cet appareil ne doit pas perturber les communications radio, et

2. cet appareil doit supporter toute perturbation, y compris les perturbations qui pourraient provoquer son dysfonctionnement.

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

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

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

Marquage sur l' étiquette du produit complet dans un endroit visible: "Contient ThingMagic transmetteur, FCC ID: QV5MERCURY6E-M (IC:5407A-MERCURY6EM)"

Authorized Antennas

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

M6e-Micro Introduction

The ThingMagic® M6e-Micro® embedded module is an RFID engines that you can integrate with other systems to create RFID-enabled products.

Applications to control the M6e-Micro modules and derivative products can be written using the high level MercuryAPI. The MercuryAPI supports Java, .NET and C programming environments. The MercuryAPI Software Development Kit (SDK) contains sample applications and source code to help developers get started demoing and developing functionality. For more information on the MercuryAPI see the *MercuryAPI Programmers Guide* and the *MercuryAPI SDK*, available on the ThingMagic website.

This document is for hardware designers and software developers. It describes the hardware specifications and firmware functionality and provides guidance on how to incorporate the M6e-Micro module within a third-party host system. The rest of the document is broken down into the following sections:

- Hardware Overview - This section provides detailed specifications of the M6e-Micro hardware. This section should be read in its entirety before designing hardware or attempting to operate the M6e-Micro module in hardware other than the ThingMagic DevKit.
- Firmware Overview - This section describes provides a detailed description of the M6e-Micro firmware components including the bootloader and application firmware.
- Communication Protocol - This section provides an overview of the low level serial communications protocol used by the M6e-Micro.
- Functionality of the M6e-Micro - This section provides detailed descriptions of the M6e-Micro features and functionality that are supported through the use of the MercuryAPI.
- Appendix A: Error Messages - This appendix lists and provides causes and suggested solutions for M6e-Micro Error Codes.
- Appendix B: Getting Started - Devkit - QuickStart guide to getting connected to the M6e-Micro Developer's Kit and using the Demo Applications included with the MercuryAPI SDK.

Hardware Overview

The following section provides detailed specifications of the M6e-Micro hardware including:

- Hardware Interfaces
- Power Requirements
- Environmental Specifications
- Assembly Information

Hardware Interfaces

Antenna Connections

The M6e-Micro supports two monostatic bidirectional RF antennas through two U.FL connector or edge vias. See Cables and Connectors for more information on antenna connector parts and M6e-Micro Footprint for antenna edge via locations and layout guidelines.

The maximum RF power that can be delivered to a 50 ohm load from each port is 1 Watt, or +30 dBm (regulatory requirements permitting).

Note

The RF ports can only be energized one at a time.

Antenna Requirements

The performance of the M6e-Micro 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 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.

Digital/Power Interfaces

The digital connector provides power, serial communications signals, shutdown and reset signals to the M6e-Micro module, and access to the GPIO lines. These signals are provided through edge vias and the Molex 53748-0208 connector. See Cables and Connectors for more information on parts.

See M6e-Micro Footprint for pinout details of both connections and layout guidelines

M6e-Micro Digital Connector Signal Definition

Edge Via Pin #	Molex 53748-0208 Pin #	Signal	Signal Direction (In/Out of M6e-Micro)	Notes
1-15, 21, 23, 29, 31	5-8	GND	P/S Return	Must connect all GND pins to ground
25, 27	1-4	Vin	P/S Input	3.5 to 5.25VDC. Must connect all Vin supplies.
22	11	GPIO1	Bi-directional	Input 5VDC tolerant, 16mA Source/ Sink
24	13	GPIO2	Bi-directional	
28	15	UART_RX_TTL	In	
26	17	UART_TX_TTL	Out	
18	14	USB_DM	Bi-directional	USB Data (D-) signal
16	12	USB_DP	Bi-directional	USB Data (D+) signal
20	9	USB_5VSENSE	In	Input 5V to tell module to talk on USB
19	19	SHUTDOWN	In	• HIGH or Open Circuit to ENABLE module • LOW or Ground to SHUTDOWN
17	20	RESET	Bi-directional	• HIGH output indicates Boot Loader is running LOW output indicates Application Firmware is running
30	U.FL	Antenna 1	Bi-directional	U.FL connector closest to the Molex connector
32	U.FL	Antenna 2	Bi-directional	U.FL connector closest to the module's edge

Control Signal Specification

The module communicates to a host processor via a TTL logic level UART serial port or via a USB port. Both ports are accessed on the Molex connector or edge vias. The TTL logic level UART supports complete functionality. The USB port supports complete functionality except the lowest power operational mode.

Note

Power Consumption specifications apply to control via the TTL UART.

Note

It is not recommended to use the TTL interface when planning to operate the module in Tag Streaming/Continuous Reading mode. The TTL interface (both the module side and the host side) cannot detect physical disconnections, as can the USB Interface, simplifying reconnection.

TTL Level UART Interface

TTL Level TX

V-Low: Max 0.4 VDC
V-High: 2.1 to 3.3 VDC
8 mA max

TTL Level RX

V-Low: -0.3 to 0.6 VDC
V-High: 2.2 to 5 VDC

A level converter could be necessary to interface to other devices that use standard 12V RS232. Only three pins are required for serial communication (TX, RX, and GND). Hardware handshaking is not supported. The M6e-Micro serial port has an interrupt-driven FIFO that empties into a circular buffer.

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

Baud rates supported:

– 9600
– 19200
– 38400
– 115200
– 230400
– 460800
– 921600

Note

The baudrate in the Boot Loader mode depends on whether the module entered the bootloader mode after a power-up or through an assert or "boot bootloader" user command. Upon power up if the Reset Line is LOW then the default baud rate of 9600 will be used. If the module returns to the bootloader from Application Firmware mode, then the current state and baudrate will be retained.

USB Interface

Supports USB 2.0 full speed device port (12 Megabits per second) using the two USB pins (USB_DM and USB_DP).

General Purpose Input/Output (GPIO)

The two GPIO connections, provided through the M6e-Micro Digital Connector Signal Definition, may be configured as inputs or outputs using the MercuryAPI. The GPIO pins connect through 100 ohm resistors to the high current PA0 and PA1 pins of the AT91SAM7S processor. The processor data sheet can be consulted for additional details.

Pins configured as inputs must not have input voltages that exceed voltage range of -0.3 volts to +5.5 volts. In addition, during reset the input voltages should not exceed 3.3V.

Outputs may source and sink 16 mA. Voltage drop in the internal series 100 ohm resistor will reduce the delivered voltage swing for output loads that draw significant current.

Input Mode

– TTL compatible inputs,
– Logic low < 0.8 V,
– Logic high > 2.0V.
– 5V tolerant

Output Mode

– 3.3 Volt CMOS Logic Output with 100 ohms in series.
– Greater than 1.9 Volts when sourcing 8 mA.
– Greater than 2.9 Volts when sourcing 0.3 mA.
– Less than 1.2 Volts when sinking 8 mA.
– Less than 0.2 Volts when sinking 0.3 mA.

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

On power up, the M6e-Micro module configures its GPIOs as inputs to avoid contention from user equipment that may be driving those lines. The input configuration is as a 3.3 volt logic CMOS input and will have a leakage current not in excess of 400 nA. The input is in an undetermined logic level unless pulled externally to a logic high or low. **Module power consumption for floating inputs is unspecified**. With the GPIOs configured as inputs and individually pulled externally to either high or low logic level, module power consumption is as listed in the M6e-Micro Power Consumption table.

GPIOs may be reconfigured individually after power up to become outputs. This configuration takes effect either at API execution or a few tens of milliseconds after power up if the configuration is stored in nonvolatile memory. The configuration to outputs is defeated if the module is held in the boot loader by Reset Line being held low. Lines configured as outputs consume no excess power if the output is left open. Specified module power consumption is achieved for one or more GPIO lines set as output and left open. Users who are not able to provide external pull ups or pull downs on any given input, and who do not need that GPIO line, may configure it as an output and leave it open to achieve specified module power consumption.

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. Once configured as inputs or outputs the state of the lines can be Get or Set using the gpiGet() and gpoSet() methods, respectively. See the language specific reference guide for more details.

Reset Line

Upon power up the RESET line is configured as an input. The input value will determine whether the Boot Loader (pulled LOW) will wait for user commands or immediately load the Application Firmware (left open) image and enter application mode. After that action is completed, this line is configured as an output line. While the unit continues to be in bootloader the line is driven high.

Once in application mode, the RESET line is driven low. if the module returns to the bootloader mode, either due to an assert or “boot bootloader”, the RESET line will again be driven high.

To minimize power consumption in the application, the RESET line should be either left open or pulled weakly low (10k to ground).

See Note about baud rate applicable when using TTL Level UART Interface.

Shutdown Line

CAUTION!

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

The SHUTDOWN line must be set HIGH or Open Circuit to ENABLE module. In order to shutdown/reset/power cycle the module the line can be 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 are powered down when set low.

Power Requirements

RF Power Output

The M6e-Micro supports separate read and write power level which are command adjustable via the MercuryAPI. Power levels must be between:

- Minimum RF Power = 0 dBm
- Maximum RF Power = +30 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.

Power Supply Ripple

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

- 3.5 to 5.25VDC
- 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 Consumption

The following table defines the power consumption specifications for the M6e-Micro in various states of operation. See Power Management for details.

M6e-Micro Power Consumption

Operation	**RF Transmit Power Setting (dBm)**	**Nominal DC Power[1] (Watts)**
Active Reader (RF On)	+30	5.5
	+27	3.5
	+23	2.5
	+10	2.0
No Tag Reading (M6e idle) Power Mode = FULL	n/a	0.325
No Tag Reading (M6e idle) Power Mode = MINSAVE	n/a	0.06
No Tag Reading (M6e idle) Power Mode = SLEEP	n/a	0.025
Shutdown Line enabled	n/a	0.000025
Note: 1 - Power consumption is defined for TTL UART operation. Power consumption may vary if the USB interface is connected. Note: 2 - Power consumption is defined for operation into a 17dB return loss load or better. Power consumption may increase, up to TBD, during operation into return losses worse than 17dB and high ambient temperatures.		

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

Environmental Specifications

Thermal Considerations

There are two ways of mounting the M6e-Micro, see M6e-Micro Footprint for additional details. One is to solder the board to the motherboard using its side "vias", with the RF shield can facing upward. The other is to use the board-to-board connectors to connect to the motherboard and solder the 4 tabs on the shield to the motherboard as well. The orientation with the side "vias" soldered down is best for wicking heat away from the module.

Most applications involve the module transmitting periodically to inventory tags in the field. The longer the transmitter is on in relation to its off time (the "duty cycle") the faster the temperature will rise. The module will not transmit if the temperature is at a dangerous level, but will transmit again as soon as the temperature drops – often so quickly it is hardly noticeable. Other factors that affect the time before the module begins to protect itself is the ambient temperature and the power level at which the module is transmitting. These factors are represented in the following table, which give the typical minutes of transmission time before thermal protection is enabled:

Thermal Calculations

Mounting	Ambient Temp (C)	RF Power (dBm)	Duty Cycle %	Time (m) to reach max temperature
Board to board	-40	30	98	>10
Board to board	25	23	98	>10
Board to board	25	30	80	>10
Board to board	25	30	90	7.34
Board to board	25	30	98	5.99
Board to board	60	23	50	>10
board to board	60	23	60	7.59
Board to board	60	23	80	2.24
Board to board	60	23	98	1.46
Board to board	60	30	30	>10
Board to board	60	30	50	4.17

Mounting	Ambient Temp (C)	RF Power (dBm)	Duty Cycle %	Time (m) to reach max temperature
Board to board	60	30	60	1.99
Board to board	60	30	80	1.11
Board to board	60	30	98	0.98
Soldered down	-40	30	98	>10
Soldered down	25	23	50	>10
Soldered down	25	23	60	2.93
Soldered down	25	23	80	2.22
Soldered down	25	23	98	1.24
Soldered down	25	30	40	>10
Soldered down	25	30	50	6.68
Soldered down	25	30	60	2.49
Soldered down	25	30	80	1.5
Soldered down	25	30	98	1.06
Soldered down	60	23	30	5.64
Soldered down	60	23	50	1.13
Soldered down	60	23	60	0.81
Soldered down	60	23	80	0.54
Soldered down	60	23	98	0.29
Soldered down	60	30	15	>10
Soldered down	60	30	30	1.98
Soldered down	60	30	50	0.73
Soldered down	60	30	60	0.56
Soldered down	60	30	80	0.27
Soldered down	60	30	98	0.27

Electro-Static Discharge (ESD) Specification

IEC-61000-4-2 and MIL-883 3015.7 discharges direct to operational antenna port tolerates max 2KV pulse.

Note

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

WARNING!

The M6e-Micro antenna ports 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 M6e-Micro 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.

Authorized Antennas

This device has been designed to operate with the antennas listed below, and having a maximum gain of 6 dBiL. Antennas not included in this list or having a gain greater than 6 dBiL are strictly prohibited for use with this device without regulatory approval. The required antenna impedance is 50 ohms.

M6e-Micro Authorized Antennas

Vendor	Model	Type	Polarization	Linear Gain[1] (dBi)
Laird	S9025P	Patch	Circular	4.3
Laird	S8658WPL	Patch	Circular	6.0
MTI Wireless	MT-262013	Patch	Circular	6.0
MTI Wireless	MT-242043	Patch	Circular	6.0
MTI Wireless	MT-242025	Patch	Circular	5.1
Laird	FG9026	Dipole	Linear	6.0

Note: 1 - These are circularly polarized antennas, but since most tag antennas are linearly polarized, the equivalent linear gain, as provided, of the antenna should be used for all calculations.

Assembly Information

Cables and Connectors

The following are the cables and connectors used in the M6e-Micro Developer's Kit interface board:

Mating Connectors for Flip Mount

Power-I/O: Molex 52991-0208

RF: Lighthorse LTI-IPXSF66GT-X1 or LTI-IPXSF54GT

Digital Interface

The cable assembly used consists of the following parts:

Note

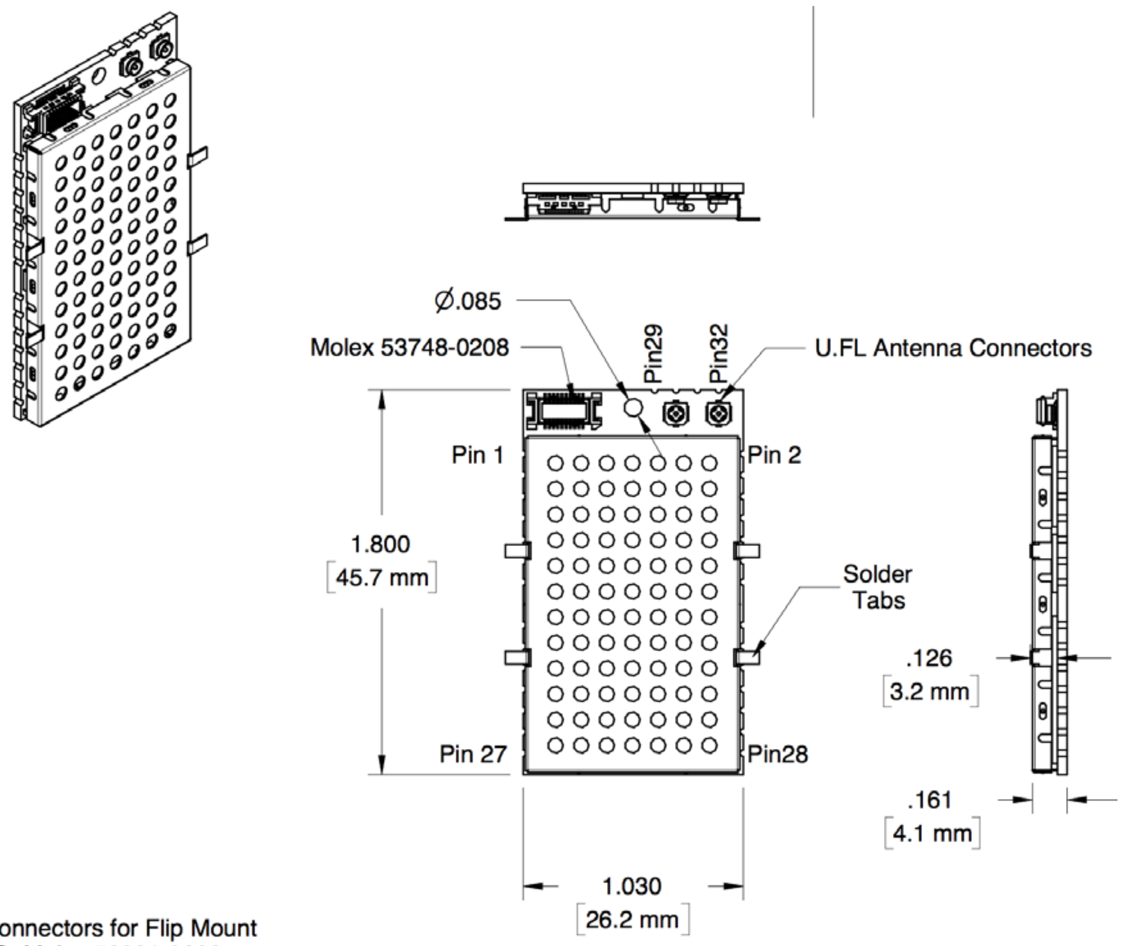
Pin numbers and assignments are shown in the M6e-Micro Digital Connector Signal Definition table.

Antennas

The cable assembly used to connect the "external" RP-TNC connectors on the M6e-Micro Devkit to the M6e-Micro MMCX connectors consists of the following parts:

M6e-Micro Mechanical Drawing

M6e-Micro Dimensional Drawing



Mating Connectors for Flip Mount
Power-I/O: Molex 52991-0208
RF: Lighthorse LTI-IPXSF66GT-X1 or LTI-IPXSF54GT

M6e-Micro Footprint

Firmware Overview

The following section provides detailed description of the M6e-Micro firmware components:

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

Boot Loader

The boot loader provides low-level functionality. This program provides the low level hardware support for configuring communication settings, loading Application Firmware and storing and retrieving data to/from flash.

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

Note

Unlike previous ThingMagic modules (M4e and M5e) the M6e-Micro bootloader should effectively be invisible to the user. The M6e-Micro is by default configured to auto-boot into application firmware and for any operations that require the module be in bootloader mode the MercuryAPI will handle the switching automatically.

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.

Programming the M6e-Micro

Applications to control the M6e-Micro module and derivative products 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 the *MercuryAPI Programmers Guide* and the *MercuryAPI SDK*, available on the ThingMagic website.

Upgrading the M6e-Micro

New features developed for the M6e-Micro are made available to existing modules through an Application Firmware upgrade, along with corresponding updates to the MercuryAPI to make use of the new features. Firmware upgrades can be applied using the MercuryAPI to build the functionality into custom applications or using the MercuryAPI SDK demo utilities.

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 boot loader starts the application FW, it first verifies that the image CRC is correct. If this check fails, then the boot loader does not start the application firmware and an error is returned.

Custom On-Reader Applications

The M6e-Micro does not support installing customer applications on the module. All reader configuration and control is performed using the documented MercuryAPI methods in applications running on a host processor.

Communication Protocol

The following section provides an overview of the low level serial communications protocol used by the M6e-Micro.

Serial Communication Protocol

The serial communication between a computer (host) and the M6e-Micro 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 timeout because some commands require more time to execute than others. The host must manage retries, if necessary. The host must keep track of the state of the intended reader if it reissues a command.

Host-to-Reader Communication

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

Header	**Data Length**	**Command**	**Data**	**CRC-16 Checksum**
Hdr	**Len**	**Cmd**	- - - - -	**CRC Hi** **CRC LO**
1 byte	**1 byte**	**1 byte**	**0 to** *250 bytes*	2 bytes

Reader-to-Host Communication

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

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

CCITT CRC-16 Calculation

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

User Programming Interface

The M6e-Micro does not support programming to the serial protocol directly. All user interaction with the M6e-Micro must be performed using the MercuryAPI.

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

Functionality of the M6e-Micro

The following section provides detailed descriptions of the M6e-Micro features and functionality that are supported through the use of the MercuryAPI.

Regulatory Support

Supported Regions

The M6e-Micro has differing levels of support for operation and use under the laws and guidelines of several regions. The regional support is shown in the following table.

Supported Regions

Region	Regulatory Support	Notes
North America (NA)	FCC 47 CFG Ch. 1 Part 15 Industrie Canada RSS-210	

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

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

Protocol Support

The M6e-Micro has the ability to support many different tag protocols. Using the MercuryAPI ReadPlan classes the M6e-Micro can be configured to single or multi-protocol Read operations. The current protocols supported are (some may require a license to enable):

- ISO 18000-6C (Gen2)
- I-PX
- ISO 18000-6B

ISO 18000-6C (Gen2)

Protocol Configuration Options

The M6e-Micro supports multiple ISO-18000-6C profiles including the ability to specify the Link Frequency, encoding schemes, Tari value and modulation scheme. The protocol options are set in the MercuryAPI Reader Configuration Parameters (/reader/gen2/*). The following table shows the supported combinations:

ISO-18000-6C Protocol Options

Backscatter Link Frequency (kHz)	Encoding	Tari (usec)	Modulation Scheme	Notes
250	Miller (M=8)	12.5	PR-ASK	
250	Miller (M=4)	12.5	PR-ASK	
250	Miller (M=2)	12.5	PR-ASK	
250	FM0	12.5	PR-ASK	
250	Miller (M=8)	25	PR-ASK	
250	Miller (M=4)	25	PR-ASK	Default
250	Miller (M=2)	25	PR-ASK	
250	FM0	25	PR-ASK	
250	Miller (M=8)	25	PR-ASK	
640	FM0	6.25	PR-ASK	Not supported in PRC Region

Note

It is important that the `/reader/baudRate` is greater than `/reader/gen2/BLF`, in equivalent frequency units. If its not then the reader could be reading data faster than the transport can handle and send, and the reader's buffer might fill up.

Protocol Specific Functionality

See the *MercuryAPI Programmers Guide* and language specific reference guides for details on supported Gen2 command functionality.

I-PX

Protocol Configuration Options

The M6e-Micro supports multiple I-PX profiles including the ability to specify the Return Link Frequency, encoding and modulation scheme. The two profiles are treated as distinct protocols, the individual parameters are not configurable as with the other protocols. The following table shows the supported combinations:

ISO-18000-6B Protocol Options

Return Link Freq (kHz)	Modulation Scheme	Notes
64	PWM	Protocol ID = TagProtocol.IPX64
256	PWM	Protocol ID = TagProtocol.IPX256

Note

The two link rates are effectively two different protocols and treated as such. I-PX tags are fixed to one of the two frequencies and cannot communicate on the other, unlike ISO 18000-6B/C tags which can operate under multiple profiles.

ISO 18000-6B

Protocol Configuration Options

The M6e-Micro supports multiple ISO-18000-6B profiles including the ability to specify the Return Link Frequency, encoding, Forward Link Rate and modulation scheme. The protocol options are set in the MercuryAPI Reader Configuration Parameters (/reader/iso18000-6b/*). The following table shows the supported combinations:

ISO-18000-6B Protocol Options

Return Link Freq (kHz)	Return Encoding	Forward Link Freq (kHz)	Forward Encoding	Modulation Depth
40	FM0	10	Manchester	11%
40	FM0	10	Manchester	99%
160	FM0	40	Manchester	11%
160	FM0	40	Manchester	99% (default)

Delimiter

ISO18000-6B tags support two delimiter settings on the transmitter. Not all tags support both delimiters, some tags require the delimiter be set to 1, the default is 4.

The delimiter setting is set using the MercuryAPI Reader Configuration Parameter:

```
/reader/iso180006b/delimiter
```

In addition to setting the delimiter to 1, a `TagFilter` of the class `ISO180006b.Select` must be used in order to read certain ISO18000-6b tags, specifically one of the following options must be used:

- `GROUP_SELECT_EQ`
- `GROUP_SELECT_NE`
- `GROUP_SELECT_GT`
- `GROUP_SELECT_LT`
- `GROUP_UNSELECT_EQ`
- `GROUP_UNSELECT_NE`
- `GROUP_UNSELECT_GT`
- `GROUP_UNSELECT_LT`

Antenna Ports

The M6e-Micro has two monostatic antenna ports. Each port is capable of both transmitting and receiving. The modules also support Using a Multiplexer, allowing up to 8 total logical antenna ports, controlled using two GPIO lines and the internal physical port Antenna1/Antenna2 (A1/A2) switching.

Note

The M6e-Micro does not support bistatic operation.

Using a Multiplexer

Multiplexer switching is controlled through the use of the internal module physical port A1/A2 switch along with the use of one or more of the General Purpose Input/Output (GPIO) lines. In order to enable automatic multiplexer port switching the module must be configured to use *Use GPIO as Antenna Switch* in `/reader/antenna/portSwitchGpos`.

Once the GPIO line(s) usage has been enabled the following control line states are applied when the different Logical Antenna settings are used. The tables below show the mapping that results using GPIO 1 and 2 for multiplexer control (as is used by the ThingMagic 1 to 4 multiplexer) allowing for 8 logical antenna ports.

Note

The Logical Antenna values are static labels indicating the available control line states. The specific physical antenna port they map to depends on the control line to antenna port map of the multiplexer in use. The translation from Logical Antenna label to physical port must be maintained by the control software.

GPIO 1 & 2 Used for Antenna Switching

Logical Antenna Setting	GPIO Output 1 State	GPIO Output 2 State	Active M6e-Micro Physical Port
1	Low	Low	A1
2	Low	Low	A2
3	Low	High	A1
4	Low	High	A2
5	High	Low	A1
6	High	Low	A2
7	High	High	A1
8	High	High	A2

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

ONLY GPIO 1 Used for Antenna Switching

Logical Antenna Setting	GPIO Output 1 State	Active M6e-Micro Physical Port
1	Low	A1
2	Low	A2
5	High	A1
6	High	A2

Note

The “missing” logical antenna settings are still usable when only one GPIO line is used for antenna control and simply results in redundant logical antenna settings. For example, using only GPIO 1, logical setting 1 and 3 both result in GPIO1=Low and M6e-Micro port A1 active.

ONLY GPIO 2 Used for Antenna Switching

Logical Antenna Setting	GPIO Output 2 State	Active M6e-Micro Physical Port
1	Low	A1
2	Low	A2
3	High	A1
4	High	A2

Port Power and Settling Time

The M6e-Micro 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. The order the antennas settings are defined does not affect search order.

Note

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

Tag Handling

When the M6e-Micro performs inventory operations (MercuryAPI Read commands) data is stored in a Tag Buffer until retrieved by the client application, or streamed directly to the client if operating in Tag Streaming/Continuous Reading mode.

Tag Buffer

The M6e-Micro 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 1024 96-bit EPC tags in the TagBuffer at a time. Since the M6e-Micro supports streaming of read results the buffer limit is, typically, not an issue. Each tag entry consists of a variable number of bytes and consists of the following fields:

Tag Buffer Entry

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.
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.

Tag Streaming/Continuous Reading

When reading tags during asynchronous inventory operations (MercuryAPI `Reader.StartReading()`) using an */reader/read/asyncOffTime*=0 the M6e-Micro “streams” the tag results back to the host processor. This means that tags are pushed out of the buffer as soon as they are processed by the M6e-Micro and put into the buffer. The buffer is put into a circular mode that keeps the buffer from filling. This allows for the M6e-Micro 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

It is recommended the USB Interface be used when operating the M6e-Micro in continuous reading mode. When the TTL Level UART Interface is used it is not possible for the module to detect a broken communications interface connection and stop streaming the tag results.

Tag Read Meta Data

In addition to the tag EPC ID resulting from M6e-Micro 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 Meta Data

Meta Data Field	Description
Antenna ID	The antenna on with the tag was 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. When Using a Multiplexer, if appropriately configured, the Antenna ID entry will contain the logical antenna port of the tag read.
Read Count	The number of times the tag was read on [Antenna ID].
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 32 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°)
LQI/RSSI	The receive signal strength of the tag response in dBm.
GPIO Status	The signal status (High or Low) of all GPIO pins when tag was read.

Power Management

The M6e-Micro is designed for power efficiency and offers several different power management modes. The following power management modes affect the power consumption during different periods of M6e-Micro usage and impact performance in different ways. The available power management modes are:

- Power Modes - set in `/reader/powerMode` - Controls the power savings when the M6e-Micro is idle.
- Transmit Modes - set in `/reader/radio/enablePowerSave` - controls power savings while transmitting.

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 is shown in the table under 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 only 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 50 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 100 ms of delay from idle to RF on when initiating an RF operation. **PowerMode.SLEEP is not supported when using the USB interface**. Using the setting PowerMode.MEDSAVE is the same as SLEEP.

Note

See additional latency specifications under Event Response Times.

Transmit Modes

The Transmit Mode setting (set in `/reader/radio/enablePowerSave`) allows the user to trade off RF spectral compliance with the Gen2 DRM Mask for increased power savings while transmitting. The details of the amount of power consumed in each mode is shown in the table under Power Consumption. The behavior of each mode is as follows:

DRM Compliant Mode

This mode maximizes performance in dense reader environments, minimizing interference when used with other M6e-Micro or similar DRM-compliant readers, and is fully compliant with the Gen2 DRM spectral mask.

Power Save Mode (non-DRM Compliant)

This mode reduces the power consumption during RF operations but is not 100% compliant with the DRM spectral mask. This can result increased interference with other readers and reduce overall systems performance.

Performance Characteristics

Event Response Times

The following table provides some metrics on how long common M6e-Micro operations take. An event response time is defined as the maximum time from the end of a command (end of the last bit in the serial stream) or event (e.g. power up) to the response event the command or event causes.

Event Response Times

Start Command/ Event	End Event	Time (msecs)	Notes
Power Up	Application Active (with CRC check)	1500	This longer power up period should only occur for the first boot with new firmware.
Power Up	Application Active	120	Once the firmware CRC has been verified subsequent power ups do not require the CRC check be performed, saving time.
Tag Read	RF On	20	When in Power Mode = FULL
Tag Read	RF On	50	When in Power Mode = MINSAVE
Tag Read	RF On	120	When in Power Mode = SLEEP
Change to MINSAVE	PowerMode.MINSAVE	5	From Power Mode = FULL
Change to SLEEP	PowerMode.SLEEP	5	From Power Mode = FULL

Save and Restore Configuration

The M6e-Micro supports saving module and protocol configuration parameters to the module flash to provide configuration persistence across boots. Currently the region, baud-rate, and default protocol can be saved across reboots. Future firmware upgrades will support saving other configuration values.

See the *MercuryAPI Programmers Guide* and sample applications for details on saving and restoring reader configuration.

Appendix A: Error Messages

Common Error Messages

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

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

FAULT_MSG_WRONG_NUMBER_OF_DATA – (100h)

Cause

If the data length in any of the Host-to-M5e/M5e-Compact messages is less than or more than the number of arguments in the message, the reader returns this message.

Solution

Make sure the number of arguments matches the data length.

FAULT_INVALID_OPCODE – (101h)

Cause

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

Solution

Check the following:

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

FAULT_UNIMPLEMENTED_OPCODE – 102h

Cause

Some of the reserved commands might return this error code.

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

Solution

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

FAULT_MSG_POWER_TOO_HIGH – 103h

Cause

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

Solution

Check the HW specifications for the supported powers and insure that the level is not exceeded.

The M5e 1 Watt units support power from 5 dBm to 30 dBm.

The M5e-Compact units support power from 10 dBm to 23 dBm.

FAULT_MSG_INVALID_FREQ_RECEIVED (104h)

Cause

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

Solution

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

FAULT_MSG_INVALID_PARAMETER_VALUE - (105h)

Cause

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

For example, currently the module supports four antennas. If the module receives a message with an antenna value other than 1 to 4, it returns this error.

Solution

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

FAULT_MSG_POWER_TOO_LOW - (106h)

Cause

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

Solution

Check the HW specifications for the supported powers and insure that level is not exceeded. The M6e-Micro supports powers between 5 and 30 dBm.

FAULT_UNIMPLEMENTED_FEATURE - (109h)

Cause

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

Solution

Check the command being invoked against the documentation.

FAULT_INVALID_BAUD_RATE - (10Ah)

Cause

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

Solution

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

Bootloader Faults

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

Fault Message	Code
FAULT_BL_INVALID_IMAGE_CRC	200h
FAULT_BL_INVALID_APP_END_ADDR	201h

FAULT_BL_INVALID_IMAGE_CRC – 200h

Cause

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

Solution

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

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

FAULT_BL_INVALID_APP_END_ADDR – 201h

Cause

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

Solution

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

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

Flash Faults

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

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

FAULT_FLASH_BAD_ERASE_PASSWORD – 300h

Cause

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

Solution

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

FAULT_FLASH_BAD_WRITE_PASSWORD – 301h

Cause

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

Solution

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

FAULT_FLASH_UNDEFINED_ERROR – 302h

Cause

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

Solution

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

FAULT_FLASH_ILLEGAL_SECTOR – 303h

Cause

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

Solution

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

FAULT_FLASH_WRITE_TO_NON_ERASED_AREA – 304h

Cause

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

Solution

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

FAULT_FLASH_WRITE_TO_ILLEGAL_SECTOR – 305h

Cause

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

Solution

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

FAULT_FLASH_VERIFY_FAILED – 306h

Cause

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

Solution

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

Protocol Faults

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

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

FAULT_NO_TAGS_FOUND – (400h)

Cause

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

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

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

Solution

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

FAULT_NO_PROTOCOL_DEFINED – 401h

Cause

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

Solution

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

FAULT_INVALID_PROTOCOL_SPECIFIED – 402h

Cause

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

Solution

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

FAULT_WRITE_PASSED_LOCK_FAILED – 403h

Cause

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

Solution

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

FAULT_PROTOCOL_NO_DATA_READ – 404h

Cause

A command was sent but did not succeed.

Solution

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

FAULT_AFE_NOT_ON – 405h

Cause

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

Solution

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

FAULT_PROTOCOL_WRITE_FAILED – 406h

Cause

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

Solution

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

FAULT_NOT_IMPLEMENTED_FOR_THIS_PROTOCOL – 407h

Cause

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

Solution

Check the documentation for the supported commands and protocols.

FAULT_PROTOCOL_INVALID_WRITE_DATA – 408h

Cause

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

Solution

Verify the Tag ID length being written.

FAULT_PROTOCOL_INVALID_ADDRESS – 409h

Cause

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

Solution

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

FAULT_GENERAL_TAG_ERROR – 40Ah

Cause

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

Solution

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

FAULT_DATA_TOO_LARGE – 40Bh

Cause

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

Solution

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

FAULT_PROTOCOL_INVALID_KILL_PASSWORD – 40Ch

Cause

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

Solution

Check the password.

FAULT_PROTOCOL_KILL_FAILED - 40Eh

Cause

Attempt to kill a tag failed for an unknown reason

Solution

Check tag is in RF field and the kill password.

FAULT_PROTOCOL_BIT_DECODING_FAILED - 40Fh

Cause

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

Solution

Check the EPC length being written.

FAULT_PROTOCOL_INVALID_EPC – 410h

Cause

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

Solution

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

FAULT_PROTOCOL_INVALID_NUM_DATA – 411h

Cause

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

Solution

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

FAULT_GEN2 PROTOCOL_OTHER_ERROR - 420h

Cause

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

Solution

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

FAULT_GEN2_PROTOCOL_MEMORY_OVERRUN_BAD_PC - 423h

Cause

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

Solution

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

FAULT_GEN2 PROTOCOL_MEMORY_LOCKED - 424h

Cause

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

Solution

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

FAULT_GEN2 PROTOCOL_INSUFFICIENT_POWER - 42Bh

Cause

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

Solution

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

FAULT_GEN2 PROTOCOL_NON_SPECIFIC_ERROR - 42Fh

Cause

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

Solution

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

FAULT_GEN2 PROTOCOL_UNKNOWN_ERROR - 430h

Cause

This is an error returned by M6e-Micro when no more error information is available about why the operation failed.

Solution

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

Analog Hardware Abstraction Layer Faults

FAULT_AHAL_INVALID_FREQ – 500h

Cause

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

Solution

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

FAULT_AHAL_CHANNEL_OCCUPIED – 501h

Cause

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

Solution

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

FAULT_AHAL_TRANSMITTER_ON – 502h

Cause

Checking antenna status while CW is on is not allowed.

Solution

Do not perform antenna checking when CW is turned on.

FAULT_ANTENNA_NOT_CONNECTED – 503h

Cause

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

Solution

Connect a detectable antenna (antenna must have some DC resistance).

FAULT_TEMPERATURE_EXCEED_LIMITS – 504h

Cause

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

Solution

Take steps to resolve thermal issues with module:

- Reduce duty cycle
- Add heat sink
- Use Power Save Mode (non-DRM Compliant)

FAULT_POOR_RETURN_LOSS – 505h

Cause

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

Solution

Take steps to resolve high return loss on receiver:

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

FAULT_AHAL_INVALID_ANTENA_CONFIG – 507h

Cause

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

Solution

Use the correct antenna setting or change the reader configuration.

Tag ID Buffer Faults

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

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

FAULT_TAG_ID_BUFFER_NOT_ENOUGH_TAGS_AVAILABLE – 600h

Cause

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

Solution

Send a testcase reproducing the behavior to support@thingmagic.com.

FAULT_TAG_ID_BUFFER_FULL – 601h

Cause

The tag id buffer is full.

Solution

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

FAULT_TAG_ID_BUFFER_REPEATED_TAG_ID – 602h

Cause

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

Solution

Send a testcase reproducing the behavior to support@thingmagic.com.

FAULT_TAG_ID_BUFFER_NUM_TAG_TOO_LARGE – 603h

Cause

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

Solution

Send a testcase reproducing the behavior to support@thingmagic.com.

System Errors

FAULT_SYSTEM_UNKNOWN_ERROR – 7F00h

Cause

The error is internal.

Solution

Send a testcase reproducing the behavior to support@thingmagic.com.

FAULT_TM_ASSERT_FAILED – 7F01h

Cause

An unexpected Internal Error has occurred.

Solution

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

Appendix B: Getting Started - Devkit

Devkit Hardware

Included Components

With the devkit, you will receive the following components:

- The M6e-Micro module and power/interface developers board
- One USB cable
- One antenna
- One coax cable
- One 9V power supply
- International power adapter kit
- Sample tags
- One paper insert:
  - *QuickStart Guide* - Details on which documents and software to download to get up and running quickly, along with details on how to register for and contact support.

Setting up the DevKit

When setting up the DevKit, use the following procedures:

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

Connecting the Antenna

ThingMagic supplies one antenna that can read tags from 20' away with most of the provided tags. The antenna is monstatic. Use the following procedure to connect the antenna to the DevKit.

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 DevKit.

Powering up and Connecting to a PC

After connecting the antenna you can power up the DevKit 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 Devkit USB Interfaces options.
2. Plug the power supply into the DevKit's DC power input connector.
3. The LED next to the DC input jack, labeled DS1, should light up. If it doesn't light up check jumper J17 to make sure the jumper is connecting pins 2 and 3
4. Follow the steps based on the Devkit USB Interfaces 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).

W A R N I N G !

While the module is powered up, do not touch components. Doing so may be damaged the devkit and M6e-Micro module.

Devkit USB Interfaces

USB/RS232

The USB interface (connector labeled **`USB/RS232`**) closest to the power plug is to the RS232 interface of the M6e-Micro through an FTDI USB to serial converter. The drivers for it are available at

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

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

Native USB

To use the M6e-Micro native USB interface (connector labeled **`USB`**), if on Windows, a few installation steps are required for Windows to recognize the M6e-Micro and properly configure the communications protocol. In order to use the USB interface with Windows you must have the M6e-Micro.inf file (available for download from rfid.thingmagic.com/devkit). The installation steps are:

1. Plug in the USB cable to the M6e-Micro (devkit) and PC.
2. Windows should report is has “Found New Hardware - Mercury6eUltra” and open the Hardware Installation Wizard.
3. Select the Install from a list or specific location (Advanced) option, click Next.
4. Select Don’t search..., click Next, then Next again.
5. Click Have Disk and navigate to where the m6ultra.inf file is stored and select it, click Open, then OK.
6. “Mercury6eUltra” should now be shown under the Model list. Select it and click Next then Finished.

Note

The M6e-Micro driver file has not been Microsoft certified so compatibility warnings will be displayed. These can be ignored and clicked through.

7. A COM port should now be assigned to the M6e-Micro. 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 Mercury6eUltra (COM#).

Devkit Jumpers

J8

Jumpers to connect M6e-Micro I/O lines to devkit.

J9

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

J10, J11, J13, J15

Jump pins `OUT` to `GPIO#` to connect M6e-Micro GPIO lines to output LEDs. Jumpe pins `IN` to `GPIO#` to connect M6e-Micro GPIO to corresponding input switches `SW[3-6]GPIO#`. Make sure GPIO lines are correspondingly configured as input or outputs (see Configuring GPIO Settings).

J14

Can be used to connect GPIO lines to external circuits. If used jumpers should be removed from J10, J11, J13, J15.

J16

Jump pins 1 and 2 or 2 and 3 to reset devkit 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 DevKit's DC power jack and power brick power.

J19

Jump `SHUTDOWN` to `GND` to enable module. While grounded SHUTDOWN pushbutton (SW2) will break circuit and shutdown the M6e-Micro (see M6e-Micro Digital Connector Signal Definition). AUTO_BOOT controls Reset Line.

Devkit Schematics

Available upon request from support@thingmagic.com.

Demo Application

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

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

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

Notice on Restricted Use of the DevKit

The Mercury6e Developers Kit (DevKit) 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 DevKit 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 DevKit is intended solely for use in future development of devices which may be subject to regional regulatory authorities governing radio emission. This DevKit may not be resold by users for any purpose. Accordingly, operation of the DevKit in the development of future devices is deemed within the discretion of the user and the user shall have all responsibility for any compliance with any regional regulatory authority governing radio emission of such development or use, including without limitation reducing electrical interference to legally acceptable levels. All products developed by user must be approved by the appropriate regional regulatory authority governing radio emission prior to marketing or sale of such products and user bears all responsibility for obtaining the prior appropriate regulatory approval, or approval as needed from any other authority governing radio emission.

Appendix C: Environmental Considerations

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

ElectroStatic Discharge (ESD) Considerations

W A R N I N G !

The M6e-Micro antenna ports 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 M6 reader antenna or communication ports. Environmental analysis should also be performed to ensure static is not building up on and around the antennas, possibly causing discharges during operation.

ESD Damage Overview

In M6e-Micro-based reader installations where readers have failed without known cause, based on anecdotal information ESD has been found to be the most common cause. Failures due to ESD tend to be in the M6e-Micro power amplifier section (PA). PA failures typically manifest themselves at the software interface in the following ways:

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

has returned to the bootloader to prevent any further damage. This jump to boot loader caused by power amp damage occurs at the start of any read tag commands.

Ultimately determining that ESD is the root cause of failures is difficult because it relies on negative result experiments, i.e. it is the lack of failure after a configuration change, rather than a positive flag wave that says “I’m ESD”. Such flag waves are sometimes, but only sometimes, available at the unpackaged transistor level under high power microscopy. The remoteness of microscopic examination from the installed field failures is indicative of the high cost of using such analysis methods for chasing down ESD issues. Therefore most ESD issue resolutions will be using the negative result experiments to determine success.

ESD discharges come with a range of values, and like many things in life there is the “matter of degree”. For many installations, the M6e-Micro has been successfully deployed and operates happily. For these, there is no failure issue, ESD or otherwise. For a different installation that with bare M6e-Micro, has a failure problem from ESD, there will be some distribution of ESD intensities occurring. Without knowledge of a limit in the statistics of those intensities, there may always be the bigger zap waiting in the wings. For the bare M6e-Micro equipped with the mitigation methods described below, there will always be the rouge ESD discharge that exceeds any given mitigation, and results in failure. Fortunately, many installations will have some upper bound on the value of ESD events given the geometry of that installation.

Several sequential steps are recommended for a) determining the ESD is the likely cause of a given group of failures, and b) enhancing the M6e-Micro’s environment to eliminate ESD failures. The steps vary depending on the required M6e-Micro output power in any given application.

Identifying ESD as the Cause of Damaged Readers

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

- Return failed units for analysis. Analysis should be able to say if it is the power amplifier that has in fact failed, but won’t be able to definitively identify that the cause is ESD. However, ESD is one of the more common causes of PA failure.
- Measure ambient static levels with static meter. *AlphaLabs SVM2* is such a meter, but there are others. You may be surprised at the static potentials floating detected. However, high static doesn’t necessarily mean discharges, but should be considered cause for further investigation. High levels that keep changing are highly indicative of discharges.
- Touch some things around the antenna, and operating area. If you feel static discharges, that qualitatively says quite a bit about what is in front of the antenna.

What actually gets to the M6e-Micro is also strongly influenced by the antenna installation, cabling, and grounding discussed above.

- Use the mean operating time statistic before and after one or more of the changes listed below to quantitatively determine if the change has resulted in an improvement. Be sure to restart your statistics after the change.

Common Installation Best Practices

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

- Insure that M6e-Micro, M6e-Micro enclosing housing (e.g. Vega reader housing), and antenna ground connection are all grounded to a common low impedance ground.
- Verify R-TNC knurled threaded nuts are tight and stay tight. Don't use a thread locking compound that would compromise the grounding connection of the thread to thread mate. If there is any indication that field vibration might cause the R-TNC to loosen, apply RTV or other adhesive externally.
- Use antenna cables with double shield outer conductors, or even full metallic shield semirigid cables. ThingMagic specified cables are double shielded and adequate for most applications. ESD discharge currents flowing ostensibly on the outer surface of a single shield coaxial cable have been seen to couple to the inside of coaxial cables, causing ESD failure. Avoid RG-58. Prefer RG-223.
- Minimize ground loops in coaxial cable runs to antennas. Having the M6e-Micro and antenna both tied to ground (per item 1) leads to the possibility of ground currents flowing along antenna cables. The tendency of these currents to flow is related to the area of the conceptual surface marked out by the antenna cable and the nearest continuous ground surface. When this conceptual surface has minimum area, these ground loop current are minimized. Routing antenna cables against grounded metallic chassis parts helps minimize ground loop currents.
- Keep the antenna radome in place. It provides significant ESD protection for the metallic parts of the antenna, and protects the antenna from performance changes due to environmental accumulation.
- Keep careful track of serial numbers, operating life times, numbers of units operating. You need this information to know that your mean operating life time is. Only with this number will you be able to know if you have a failure problem in the first place, ESD or otherwise. And then after any given change, whether things have improvement or not. Or if the failures are confined to one instantiation, or distributed across your population.

Raising the ESD Threshold

For applications where full M6e-Micro power is needed for maximum tag read range and ESD is suspected the following components are recommended additions to the installation to raise the level of ESD the reader can tolerate:

- Select or change to an antenna with all radiating elements grounded for DC. The MTI MT-262031-T(L,R)H-A is such an antenna. The Laird IF900-SF00 and CAF95956 are not such antennas. The grounding of the antenna elements dissipates static charge leakage, and provides a high pass characteristic that attenuates discharge events. (This also makes the antenna compatible with the M6e-Micro antenna detect methods.)
- Install a Minicircuits SHP600+ high pass filter in the cable run at the M6e-Micro (or Vega or other finished reader) end. This additional component will reduce transmit power by 0.4 dB which may affect read range in some critical applications. However the filter will significantly attenuate discharges and improve the M6e-Micro ESD survival level.

Note

The SHP600+ is not rated for the full +31.5 dBm output of the M6e-Micro reader at +85 degree C. Operation at reduced temperature has been anecdotally observed to be OK, but has not been fully qualified by ThingMagic.

- 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 M6e-Micro ESD survival level. * Not yet productized. Needs DC power, contact support@thingmagic.com for details.

Further ESD Protection for Reduced RF Power Applications

In addition to the protective measures recommended above, for applications where reduced M6e-Micro RF power is acceptable and ESD is suspected the following protective measures can also be applied:

- Install a one watt attenuator with a decibel value of +30 dBm minus the dBm value needed for tag power up. Then run the reader at +30 dBm instead of reduced transmit power. This will attenuate inbound ESD pulses by the installed decibel value, while keeping the tag operation generally unchanged. Attenuators of 6 dB have been shown to not adversely effect read sensitivity. Position the attenuator as close to the M6e-Micro as feasible.
- As described above add the SHP600 filter immediately adjacent to the attenuator, on the antenna side.

- Add Diode Clamp, if required, adjacent to the SHP600, on the antenna side.

Variables Affecting Performance

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

- Environmental
- Tag Considerations
- Multiple Readers

Environmental

Reader performance may be affected by the following environmental conditions:

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

Tag Considerations

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

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

- Tag Orientation: Reader performance is affected by the orientation of the tag in the antenna field. The ThingMagic antenna is circularly polarized, so it reads face-to but not edge-to.
- Tag Model: Many tag models are available. Each model has its own performance characteristics.

Multiple Readers

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

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

Note

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