

SMARTMESH® IA-510 M2511

2.4 GHz Wireless Mote (H)

About SmartMesh IA-510

Dust Networks' SmartMesh® IA-510 is a WirelessHART®-compliant system that offers industrial automation vendors an industry-leading standards-based system that delivers flexible, secure solutions. The SmartMesh IA-510 system's Intelligent Networking Platform delivers dynamic network optimization and intelligent routing to achieve the carrier-class data reliability, lower latency, and deterministic power management required for the industrial automation market. The SmartMesh IA-510 system consists of the embedded network manager and motes. SmartMesh IA-510 systems are easy for industrial automation vendors to integrate and simple for end users to deploy.

Product Description—M2511

The WirelessHART-compliant M2511 combines Dust Networks' robust Intelligent Networking Platform and industry-leading low-power radio technology in an easy-to-integrate 22-pin module. As part of the SmartMesh IA-510 system, the M2511 provides industrial automation vendors with an embedded wireless system complete with modular radio certifications for easy integration and reuse in developing multiple WirelessHART products.

The M2511 is tailored for use in battery-powered and energy-scavenging wireless devices, and is engineered for applications that demand proven performance and scalability. With Dust Networks' innovative IEEE 802.15.4-compliant design and integrated power amplifier, the M2511 enables a decade of battery life on two AA batteries. Additionally, all motes can function as both battery-powered routers and nodes, enabling a full mesh topology that provides more redundant routes and higher network performance.

The network-ready module integrates all radio circuitry components, including an MMCX-type antenna connector, to eliminate the burden of complex RF design. The international modular certifications, fully engineered RF solution, comprehensive APIs, and complete development documentation for the M2511 mote module offer rapid field device integration, reduced development time, and reduced cost for WirelessHART solutions.

Key Product Features

WirelessHART Compliance

- Interoperable with WirelessHART devices

Superior Reliability

- Robust network reliability in even the most challenging industrial environments
- Every M2511 can act as both an endpoint and a router, increasing network reliability

Easy Integration

- Fully engineered RF—power amplifier, balun, crystals, antenna matching circuitry and antenna connector on module
- Comprehensive APIs deliver rich functionality and flexibility without complex coding

Ultra-low Power Consumption

- Industry-leading radio technology optimized for battery or loop-powered operation
- Ultra-efficient power usage, enabled through SmartMesh Intelligent Network management, delivers over a decade of network operation on two AA batteries

Secure Global Market Solution

- IEEE 802.15.4-certified radio operates on 2.4 GHz global license-free band
- Configurable radio output power—meets RF emission limits for different regions with a single product
- Modular RF certifications for FCC, IC, and CE
- AES-128 bit encryption (certified NIST FIPS-197 compliant)

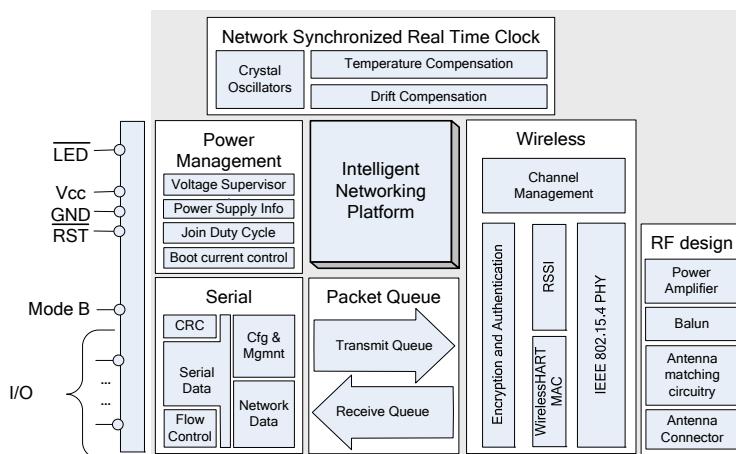


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1.0 Absolute Maximum Ratings

The absolute maximum ratings shown below should not be violated under any circumstances. Permanent damage to the device may be caused by exceeding one or more of these parameters.

Unless otherwise noted, all voltages in Table 1 are made relative to V_{SS} .

Table 1 Absolute Maximum Ratings

Parameter	Min	Typ	Max	Units	Comments
Supply voltage (V_{DD} to V_{SS})	-0.3		3.6	V	
Voltage on any digital I/O pin	-0.3		$V_{DD} + 0.3$ up to 3.6	V	
Input RF level			10	dBm	Input power at antenna connector
Storage temperature range	-40		+85	°C	
Lead temperature			+245	°C	For 10 seconds
VSWR of antenna			3:1		
ESD protection					
Antenna pad			± 3	kV	HBM
All other pads			± 2	kV	HBM
			± 200	V	CDM



Caution! ESD sensitive device. Precaution should be used when handling the device to prevent permanent damage.

2.0 Normal Operating Conditions

Unless otherwise noted, Table 2 assumes V_{DD} is 3.0 V and temperature is 25 °C.

Table 2 Normal Operating Conditions

Parameter	Min	Typ	Max	Units	Comments
Operational supply voltage range (between V_{DD} and V_{SS})	2.75		3.6	V	Including noise and load regulation
Voltage supply noise			150	mV _{p-p}	50 Hz to 2 MHz
Voltage supervisor trip point		2.64		V	Reset trip point
Peak current		6		mA	Searching for network, typically 150 ms on and 2850 ms in doze*
		12		mA	Mote boot, see section 7.0
Power amplifier enabled		18		mA	TX, 5 ms maximum
Power amplifier enabled		24		mA	TX, 5 ms maximum, +85 °C, 3.3 V
Power amplifier disabled		7		mA	TX, 5 ms maximum
Reset		1.25		mA	RST asserted
Operating temperatures	-40		+85	°C	
Maximum allowed temperature ramp during operation			8	°C/min	-40 °C to +85 °C
Operating relative humidity	10		90	% RH	Non-condensing

* The duration of doze time and “on” time is determined by the joinDutyCycle command in the mote serial API. Refer to the *SmartMesh IA-510 Mote Serial API Guide* for details.

Unless otherwise noted, Table 3 assumes V_{DD} is 3.0 V.

Table 3 Current Consumption

Parameter	Min	Typ	Max	Units	Comments
Transmit					
Power amplifier enabled		18		mA	
Power amplifier disabled		7		mA	
Receive		6		mA	

3.0 Electrical Specifications

Table 4 Device Load

Parameter	Min	Typ	Max	Units	Comments
Total capacitance			6	μ F	V_{DD} to V_{SS}
Total inductance			4.9	μ H	V_{DD} to V_{SS}

Unless otherwise noted, V_{DD} is 3.0 V and temperature is -40°C to $+85^{\circ}\text{C}$.

Table 5 Digital I/O Type 1

Digital Signal	Min	Typ	Max	Units	Comments
V_{IL} (low-level input voltage)	-0.3		0.6	V	
V_{IH} (high-level input voltage)	$0.8 \times V_{DD}$		$V_{DD} + 0.3$	V	
V_{OL} (low-level output voltage)			0.4	V	
V_{OH} (high-level output voltage)	2.4			V	
Digital current*					
Output source (single pin)		3.7		mA	25 °C
Output sink (single pin)		2.0		mA	25 °C
Input leakage current		50		nA	25 °C

* This current level guarantees that the output voltage meets V_{OH} and V_{OL} specifications above.

Table 6 Digital I/O Type 2

Digital Signal	Min	Typ	Max	Units	Comments
V_{IL} (low-level input voltage)	-0.3		0.6	V	
V_{IH} (high-level input voltage)	$0.8 \times V_{DD}$		$V_{DD} + 0.3$	V	
V_{OL} (low-level output voltage, multifunction I/O configured as output)	-0.3		0.6	V	$I_{OL} < 0.6 \text{ mA}, 85^{\circ}\text{C}$
V_{OH} (high-level output voltage, multifunction I/O configured as output)	$V_{DD} - 0.6$		V_{DD}	V	$I_{OH} > -0.6 \text{ mA}, 85^{\circ}\text{C}$
Digital current*					
Output source (single pin, multifunction I/O configured as output)		0.4		mA	25 °C
Output sink (single pin, multifunction I/O configured as output)		0.6		mA	25 °C
Input leakage current		50		nA	25 °C

* This current level guarantees that the output voltage meets V_{OH} and V_{OL} specifications above.

Table 7 Digital I/O Type 3

Digital Signal	Min	Typ	Max	Units	Comments
V_{IL} (low-level input voltage)	-0.3		0.6	V	
V_{IH} (high-level input voltage)	2.0		$V_{DD} + 0.3$	V	
V_{OL} (low-level output voltage)			0.4	V	
V_{OH} (high-level output voltage)	$V_{DD} - 0.2$			V	
Digital current*					
Output source (single pin)		100		μ A	25 °C
Output sink (single pin)		1.6		mA	25 °C
Input leakage current		50		nA	25 °C

* This current level guarantees that the output voltage meets V_{OH} and V_{OL} specifications above.

4.0 Radio

4.1 Detailed Radio Specifications

Table 8 Detailed Radio Specifications

Parameter	Min	Typ	Max	Units	Comments
Operating frequency	2.4000		2.4835	GHz	
Number of channels		15			
Channel separation		5		MHz	
Occupied channel bandwidth		2.7		MHz	At -20 dBc
Frequency Accuracy	-40		+40	ppm	
Modulation					IEEE 802.15.4 DSSS
Raw data rate		250		kbps	
Receiver operating maximum input level		0		dBm	
Receiver sensitivity		-90.5 -88		dBm	At 50% PER, $V_{DD} = 3$ V, 25 °C
Output power, conducted Power amplifier enabled		+5		dBm	At 1% PER, $V_{DD} = 3$ V, 25 °C
Range*					
Power amplifier enabled:					
Indoor [†]		100		m	25 °C, 50% RH, +6 dBi
Outdoor [†]		300		m	omni-directional antenna
Free space		1200		m	

* Actual RF range performance is subject to a number of installation-specific variables including, but not restricted to ambient temperature, relative humidity, presence of active interference sources, line-of-sight obstacles, near-presence of objects (for example, trees, walls, signage, and so on) that may induce multipath fading. As a result, actual performance varies for each instance.

[†] 1 meter above ground.

4.2 Antenna Specifications

A MMCX-compatible male connector is provided on board for the antenna connection. The antenna must meet specifications in Table 9. For a list of FCC-approved antennae, see section 10.1.2.

Table 9 Antenna Specifications

Parameter	Value
Frequency range	2.4 – 2.4835 GHz
Impedance	50 Ω
Maximum VSWR	3:1
Connector	MMCX*

* The M2511 can accommodate the following RF mating connectors:

- MMCX straight connector such as Johnson 135-3402-001, or equivalent
- MMCX right angle connector such as Tyco 1408149-1, or equivalent

When the mote is placed inside an enclosure, the antenna should be mounted such that the radiating portion of the antenna protrudes from the enclosure. The antenna should be connected using a MMCX connector on a coaxial cable. For optimum performance, the antenna should be positioned vertically when installed.

5.0 Pinout

The M2511 has two 11-pin Samtec TW-11-03-G-S-235-150-003 (or equivalent) connectors on the bottom side for handling all of the I/O. The third pin in each of the connectors is not populated, and serves as a key for alignment. The connectors are mounted on opposite edges of the long axis of the M2511.

5.1 M2511 Pinout

The M2511 provides a bidirectional flow-controlled serial interface (see section 8.3 Settable I/O Modes).

Table 10 M2511 Pin Functions

Pin Number	Pin Name	Description	I/O Type	Direction	Pin State in Deep Sleep [†]
1	V _{SS}	Ground	Power	–	–
2	V _{DD}	Power	Power	–	–
3	KEY (no pin)	–	–	–	–
4	RX	UART Rx	2	In	–
5	TX	UART Tx	2	Out	V _{DD}
6	Reserved	No connect	–	–	–
7	MT_RTS	UART active low mote ready to send	2	Out	V _{DD}
8	MT_CTS	UART active low mote clear to send	1	Out	V _{DD}
9	SP_CTS	UART active low serial peripheral clear to send	2	In	–
10	TIME	Falling edge time request	2	In	–
11	Mode_pin_B	Selects between Mode 1 & Mode 3 operation	2	In	–
12	FLASH_P_EN	Active low flash power enable	1	In*	–
13	Reserved	No connect	–	–	–
14	Reserved	No connect	–	–	–
15	Reserved	No connect	–	–	–
16	Reserved	No connect	–	–	–
17	SCK	SPI clock	3	In*	–
18	MOSI	SPI master out slave in serial data	3	In*	–

Pin Number	Pin Name	Description	I/O Type	Direction	Pin State in Deep Sleep [†]
19	MISO	SPI master in slave out serial data	3	Out*	V _{DD} **
20	KEY (no pin)	–	–	–	–
21	SPI_CS	Active low flash chip select	3	In*	–
22	RST	Active low reset	1	In	–

* The direction associated with the flash interface is defined when the device is held in reset and is intended solely for the use of in circuit programming of the device. Following reset, all inputs will become outputs and must not be driven externally.

** Weakly pulled to V_{DD}.

† Deep sleep is the lowest possible power state, with V_{DD} and GND connected. The mote microprocessor and radio are inactive, and the mote must be awakened using the /RST signal (for more information see the lowPowerSleep command in the *IA-510 Mote Serial API Guide*).

The RST input pin is internally pulled up and connecting it is optional. When driven active low, the mote is hardware reset until the signal is de-asserted. Refer to section 7.1 for timing requirements on the RST pin. Note that the mote may also be reset using the mote serial command (see the *SmartMesh IA-510 Mote Serial API Guide*).

The TIME input pin is optional, and must either be driven or pulled up with a 5.1 MΩ resistor. Unless noted otherwise, all signals are active low.

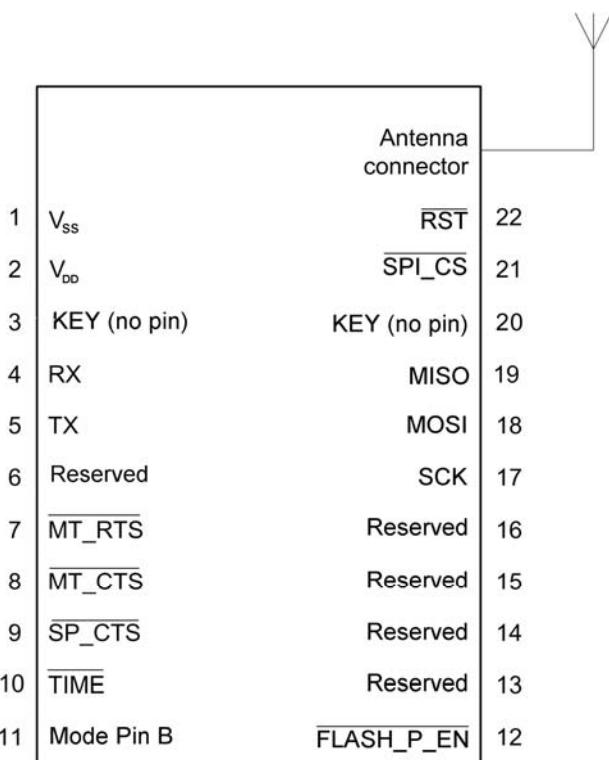


Figure 1 M2511 Package with Pin Labels

6.0 Power Supply Design

The M2511 can be sensitive to instantaneous power supply ramp rates between 20 V/ms and 60 V/ms as the supply ramps through the 200 mV to 2.2 V range. As a result, designs should avoid instantaneous power supply ramp rates that fall within the 20 V/ms to 60 V/ms range.

Care should be taken in cases where the mote inputs will be driven to logic level high. Refer to the *040-0067 SmartMesh IA-510 Mote Serial API Guide* for information on mote bring-up and power cycling.

7.0 Mote Boot Up

7.1 Power-on Sequence

The M2511 has internal power-on reset circuits that ensure that the mote will properly boot. However, for the power-on reset circuitry to function properly the external power supply must meet the timing shown in Figure 2 and specified in Table 11.

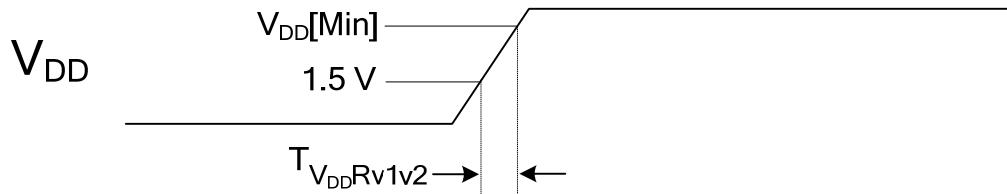


Figure 2 External Power Supply Timing Requirement

The following reset sequence (shown in Figure 3 and specified in Table 11) is required for external power supplies that fail to meet the requirement above.

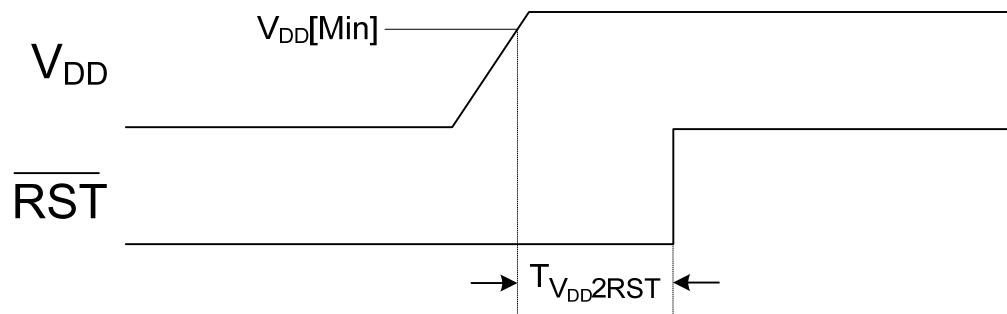


Figure 3 Power-on Sequence

Table 11 Power-on Sequence

Parameter	Min	Typ	Max	Units	Comments
$T_{V_{DD} 2 RST}$	125			μs	
$T_{V_{DD} Rv1 v2}$			1	ms	
RST pulse width	125			μs	Reset timing

7.2 Inrush Current

During power on, the mote can be modeled as a lumped impedance, as shown in Figure 4. With a source impedance (R_{src}) of 1Ω , the inrush current on the mote appears as shown in Figure 5.

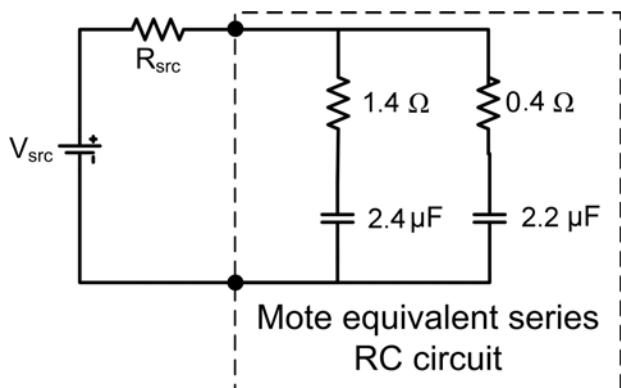


Figure 4 M2511 Equivalent Series RC Circuit

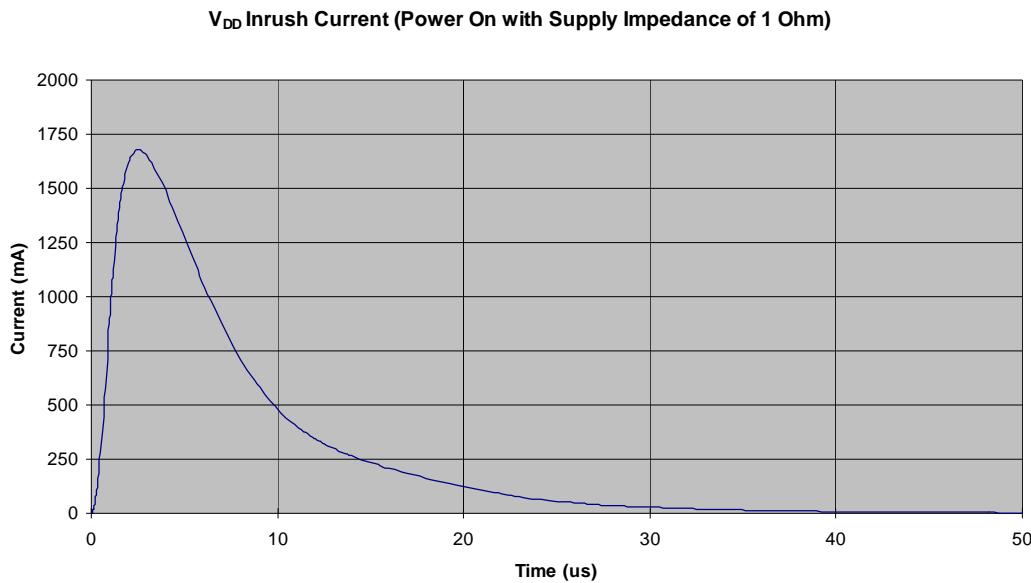


Figure 5 V_{DD} Inrush Current

7.3 Mote Boot Sequence

Following the negation of \overline{RST} the mote completes its boot-up process by loading and decrypting the application image and loading the operating parameters. During the boot-up process, the mote's output signals are not actively driven and the input signals are ignored.

The M2511 supports two mote boot modes: standard boot and low current boot. Standard boot is optimized for quick boot time. Low current boot lowers the average current but at a longer boot time. The mote boot mode is determined by the software executable loaded onto the M2511.

7.3.1 Standard Boot

When the M2511 operates in standard boot, the time between the mote power up and the serial interface availability is defined as t_{boot_delay} and specified in Table 12 below. The peak current during mote boot is specified under Peak Current in Section 2.0 Normal Operating Conditions.

Table 12 Standard Boot Sequence

Parameter	Min	Typ	Max	Units	Comments
t_{boot_delay}			6	s	The time between mote power up and serial interface availability.

7.3.2 Low Current Boot

When operating in low current boot, the M2511 lowers average current consumption by spreading the boot operation over a longer time. This mode is intended to support systems with supplies having a maximum DC current less than the peak current required by the M2511. These systems must store enough charge (Q) to maintain the supply through the M2511's peak current consumption. For additional information, contact your Dust Networks applications engineer.

7.4 Serial Interface Boot Up

7.4.1 M2511 Serial Interface Boot Up

Upon M2511 power up, the MT_CTS line is high (inactive). The M2511 serial interface boots within t_{boot_delay} of the mote powering up (see section 7.3), at which time the M2511 will transmit an HDLC boot event packet. Note that full handshake is in effect and is required to receive this packet.

8.0 Interfaces

8.1 Reset Pin

The /RST input pin is internally pulled up. Connecting it is optional; however, in applications operating in the presence of EMI, /RST should be actively driven high. When driven low, the mote hardware is in reset. Note that the mote may also be reset using the mote reset command (0x08). For requirements on reset timing, see section 7.1.

The M2511 is a highly sophisticated device and Dust Networks recommends doing resets gracefully. If the device is in the network, a disconnect command (0x07) should be issued before the /RST signal is asserted. This will result in the device rebooting and sending the “boot” event.

The /RST signal may then be asserted since the device is not in the network.

Refer to the *SmartMesh IA-510 M2510 Integration Guide* for recommendations on how to connect to the /RST pin, including voltage supervision. For detailed information about mote serial commands, refer to the *SmartMesh IA-510 Mote Serial API Guide*.

8.2 Timestamps

The M2511 has the ability to deliver network-wide synchronized timestamps. The M2511 sends a time packet (as described in the *SmartMesh IA-510 Mote Serial API Guide*) through its serial interface when one of the following occurs:

- Mote receives an HDLC request to read time
- The $\overline{\text{TIME}}$ signal is asserted

The $\overline{\text{TIME}}$ pin is optional and has the advantage of being more accurate. The value of the timestamp is taken within approximately 1 ms of receiving a $\overline{\text{TIME}}$ signal activation. If the HDLC request is used, due to packet processing the value of the timestamp may be captured several milliseconds after receipt of the packet. Refer to the *IA-510 Mote Serial API Guide* for more information on timestamps.

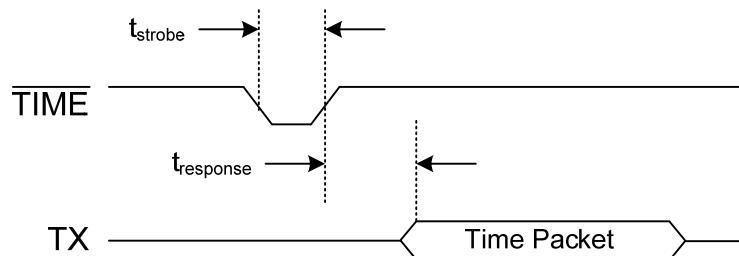


Figure 7 Operation of $\overline{\text{TIME}}$ Pin

Table 14 TIME Timing Values

Variable	Description	Min	Max	Units
t_{strobe}	TIME strobe pulse width	125		μs
t_{response}	Negation of Time strobe to start of time packet		100	ms

8.3 Settable I/O Modes

The M2511 offers a choice of two I/O modes. The functionality of the interface will be determined by the setting of Mode pin B whose pinout is described in section 5.0 Pinout.

Table 15 Mode Pin Settings

Pin	Mode 1	Mode 3
Mode pin B	Externally tied low	Externally tied high

All modes provide a means of transmitting and receiving serial data through the wireless network, as well as a command interface that provides synchronized time stamping, local configuration, and diagnostics.

Mode 1 implements an 8-bit, no parity, 9600 bps baud three, four or five-signal serial interface with bidirectional packet-level flow control operating at 9600 bps. In certain OEM designs, one or two of the serial handshake signals may be optional for reduced pin count, as described in Table 16.

Mode 3 implements an 8-bit, no parity, 115.2 kbps baud five-signal serial interface with bidirectional packet-level flow control and byte-level flow control in the mote-to-microprocessor direction only.

8.3.1 Mode 1: Three/Four/Five-signal Serial Interface (9600 bps)

The M2511 mode 1 provides a three, four, or five-signal serial interface that is optimized for low-powered embedded applications (and in certain designs may provide a low pin count serial solution). The mode 1 serial interface is comprised of the data pins (TX, RX) as well as handshake pins ($\overline{MT_RTS}$, $\overline{MT_CTS}$, $\overline{SP_CTS}$) used for bidirectional flow control. The $\overline{MT_RTS}$ signal is ideal for designs where the microprocessor requires extra time to prepare to receive a packet (for example, the OEM microprocessor sleeps periodically, but requires a wake-up signal prior to receiving a packet). Refer to Table 16 for information on each handshake pin, including details on which pins are optional.

Table 16 Mode 1 Pin Usage

Pin	I/O	Usage
RX	Input	Serial data moving from the microprocessor to the mote.
TX	Output	Serial data moving from the mote to the microprocessor.
$\overline{MT_RTS}$	Output	$\overline{MT_RTS}$ provides a mechanism to wake up the microprocessor in order to receive a packet. This signal is asserted when the mote is ready to send a serial packet. The signal stays low until the $\overline{SP_CTS}$ signal from the microprocessor is detected low by the mote (indicating readiness to receive a packet) or the $t_{MT_RTS \text{ to } SP_CTS}$ timeout defined in Section 8.3.3 expires. If $\overline{MT_RTS}$ times out, it will de-assert $\overline{MT_RTS}$, wait for $t_{MT_RTS \text{ retry}}$ and then re-assert $\overline{MT_RTS}$ to attempt to send the serial packet again (see Figure 11). $\overline{MT_RTS}$ may be ignored by the microprocessor only if $\overline{SP_CTS}$ always stays low.
$\overline{SP_CTS}$	Input	$\overline{SP_CTS}$ provides packet-level flow control for packets transferred from the mote to the microprocessor. When the microprocessor is capable of receiving a packet it should assert the $\overline{SP_CTS}$ signal. $\overline{SP_CTS}$ may be externally tied low (reducing pin count) only if the microprocessor is always ready to receive a serial packet.
$\overline{MT_CTS}$	Output	$\overline{MT_CTS}$ provides packet-level flow control for packets transferred from the microprocessor to the mote that are destined for transfer over the network. Upon reset, following boot the mote will negate $\overline{MT_CTS}$ until the mote establishes a wireless network connection. During operation, the mote will negate $\overline{MT_CTS}$ if the mote does not have sufficient buffering to accept another packet. $\overline{MT_CTS}$ will also remain high if the mote is not part of the network. The microprocessor must check that the $\overline{MT_CTS}$ pin is low before initiating each serial packet for wireless transmission. Note that the mote may receive local serial packets at any time regardless of the $\overline{MT_CTS}$ state. (For a list of local commands, see the <i>SmartMesh IA-510 Mote Serial API Guide</i> .)
TIME	Input	The TIME pin can be used for triggering a timestamp packet. Its usage is optional.

8.3.2 Mode 3: Five-signal Serial Interface (115.2 kbps)

The M2511 mode 3 provides a five-signal serial interface with byte-level flow control on transfers from the mote to the microprocessor. The mode 3 serial interface is comprised of the data pins (TX, RX) as well as handshake pins ($\overline{MT_RTS}$, $\overline{MT_CTS}$, $\overline{SP_CTS}$) used for bidirectional flow control. The $\overline{MT_RTS}$ signal is ideal for designs where the microprocessor requires extra time to prepare to receive a packet (for example, the OEM microprocessor sleeps periodically, but requires a wake-up signal prior to receiving a packet). In order to support 115.2 kbps the microprocessor must include two framing bytes, 0x7E, at the start of each packet sent from the microprocessor to the mote. Refer to Table 17 for information on each handshake pin, including details on which pins are optional.

Table 17 Mode 3 Pin Usage

Pin	I/O	Usage
RX	Input	Serial data moving from the microprocessor to the mote.
TX	Output	Serial data moving from the mote to the microprocessor.
MT_RTS	Output	MT_RTS provides a mechanism to wake up the microprocessor in order to receive a packet. This signal is asserted when the mote is ready to send a serial packet. The signal stays low until the SP_CTS signal from the microprocessor is detected low by the mote (indicating readiness to receive a packet) or the tMT_RTS to SP_CTS timeout defined in Section 8.3.3 expires. If MT_RTS times out, it will de-assert MT_RTS, wait for tMT_RTS retry and then re-assert MT_RTS to attempt to send the serial packet again (see Figure 11).
SP_CTS	Input	SP_CTS provides byte-level flow control for packets transferred from the mote to the microprocessor. When the microprocessor is capable of receiving a packet it should assert the SP_CTS signal. In mode 3 byte-level flow control is achieved by having the microprocessor negate and then reassert the SP_CTS signal following the receipt of each byte. The mote will begin transmission of the next byte after detecting the reassertion of SP_CTS.
MT_CTS	Output	MT_CTS provides packet-level flow control for packets transferred from the microprocessor to the mote that are destined for transfer over the network. Upon reset, following boot the mote will negate MT_CTS until the mote establishes a wireless network connection. During operation, the mote will negate MT_CTS if the mote does not have sufficient buffering to accept another packet. MT_CTS will also remain high if the mote is not part of the network. The microprocessor must check that the MT_CTS pin is low before initiating each serial packet for wireless transmission. Note that the mote may receive local serial packets at any time regardless of the MT_CTS state. For a list of local commands, see the <i>SmartMesh IA-510 Mote Serial API Guide</i> .
TIME	Input	The TIME pin can be used for triggering a timestamp packet. Its usage is optional.

8.3.3 UART AC Timing

Table 18 UART Timing Values

Variable	Description	Min	Max	Units
tRX_BAUD	Deviation from baud rate	-2	+2	%
tRX_STOP	Number of stop bits (9600 bps)	1		bit period
tRX_STOP	Number of stop bits (115.2 kbps)	1.5		bit period
tTX_BAUD	Deviation from baud rate	-1	+1	%
tTX_STOP	Number of stop bits	1		bit period
tSP_CTS to MT_RTS	Assertion of SP_CTS to negation of MT_RTS	0	10	ms
tMT_RTS to SP_CTS	Assertion of MT_RTS to assertion of SP_CTS		500	ms
tMT_RTS retry	Time from a MT_RTS timeout to the retry.		500	ms
tSP_CTS to TX	Assertion of SP_CTS to start of byte	0	10	ms
tTX to SP_CTS	Start of byte to negation of SP_CTS	1		bit period
tSP_CTS ack PW	Negation pulse width of SP_CTS	500		ns
tdiag_ack_timeout*	The mote responds to all requests within this time.		125	ms
tinterbyte_timeout	Falling edge of TX to falling edge of SP_CTS (Mode 3 only)		7.1	ms
tinterpacket_delay	The sender of an HDLC packet must wait at least this amount of time before sending another packet	20		ms

* For more information about supported requests and details on when tdiag_ack_timeout applies, refer to the *SmartMesh IA-510 Mote Serial API Guide*.

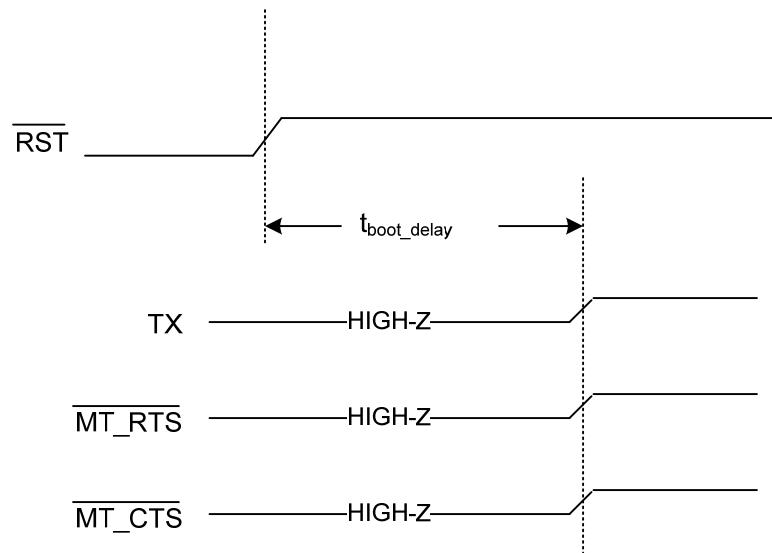


Figure 8 Power-on Sequence (see section 7.1 for value of t_{boot_delay})

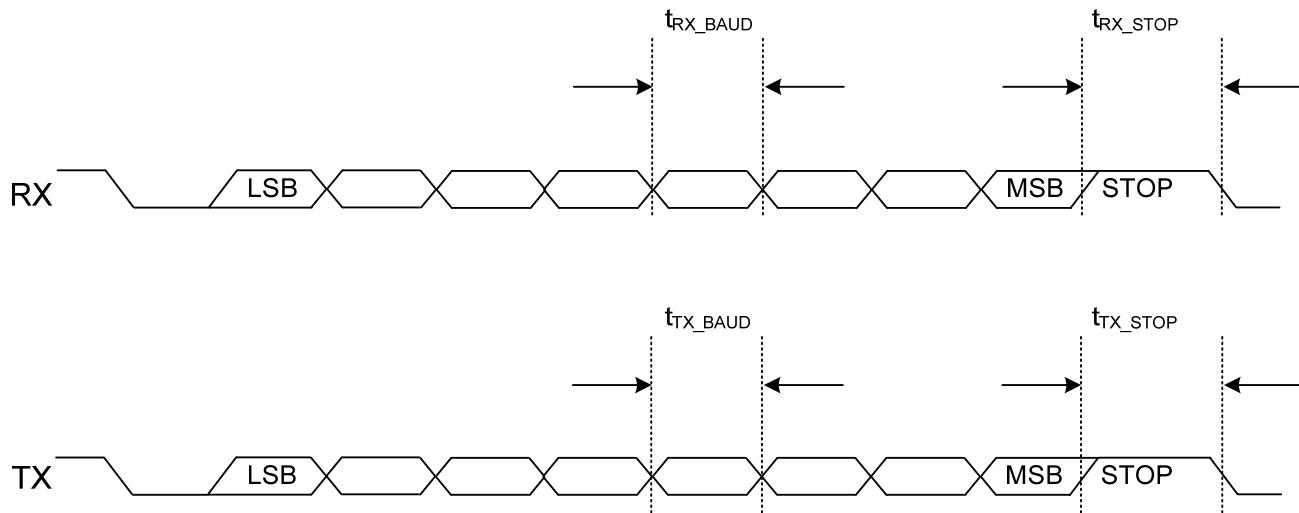


Figure 9 Byte-level Timing

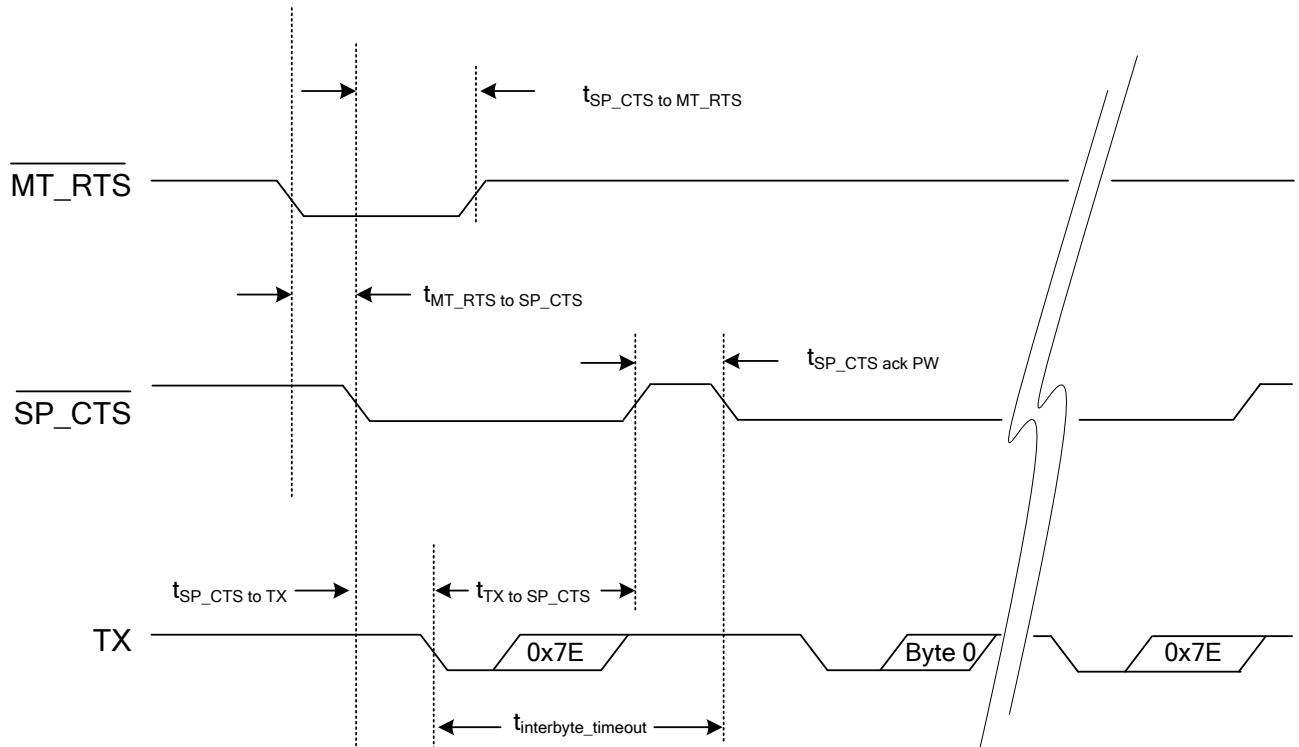


Figure 10 Flow Control Timing

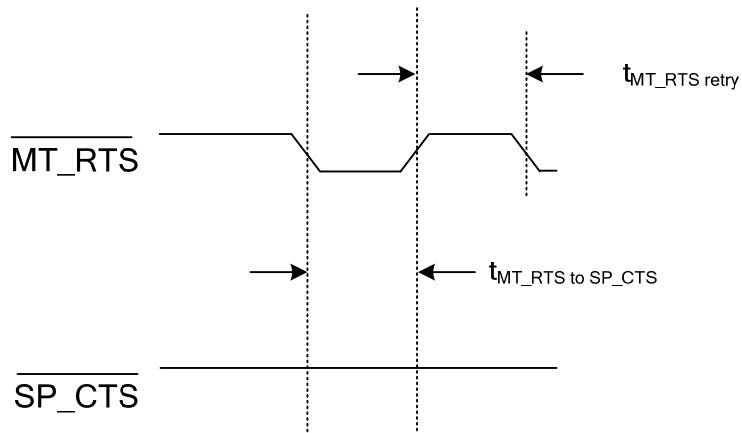


Figure 11 MT_RTS Timeout Behavior

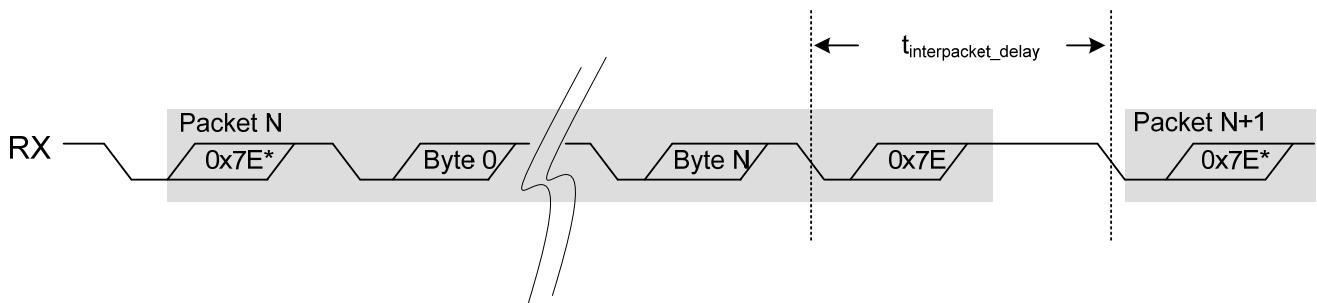


Figure 12 Packet Timing

* For Mode 3 (115.2 kbps) the framing byte, 0x7E, must be repeated at the start of each packet set to the M2511.

8.4 Mote Serial API

The M2511 offers a comprehensive application programming interface (API) that provides full programmatic access to control the mote, monitor its status (such as battery charge and network status), and provide access to the wireless mesh network. Refer to the *SmartMesh IA-510 Mote Serial API Guide* for more information.

8.5 Temperature Sensor

The M2511 has an on-board temperature sensor. The temperature readings are available locally through the mote serial API and through the network at the manager via the XML or serial API. For more information, refer to the *SmartMesh IA-510 Mote Serial API Guide*, *SmartMesh IA-510 Manager Serial API Guide*, or *SmartMesh IA-510 XML API Guide*.

Table 19 Temperature Sensor

Parameter	Min	Typ	Max	Units	Comments
Sensor input range	-40		85	°C	
Accuracy		±7		°C	

9.0 Packaging Description

9.1 Mechanical Drawing

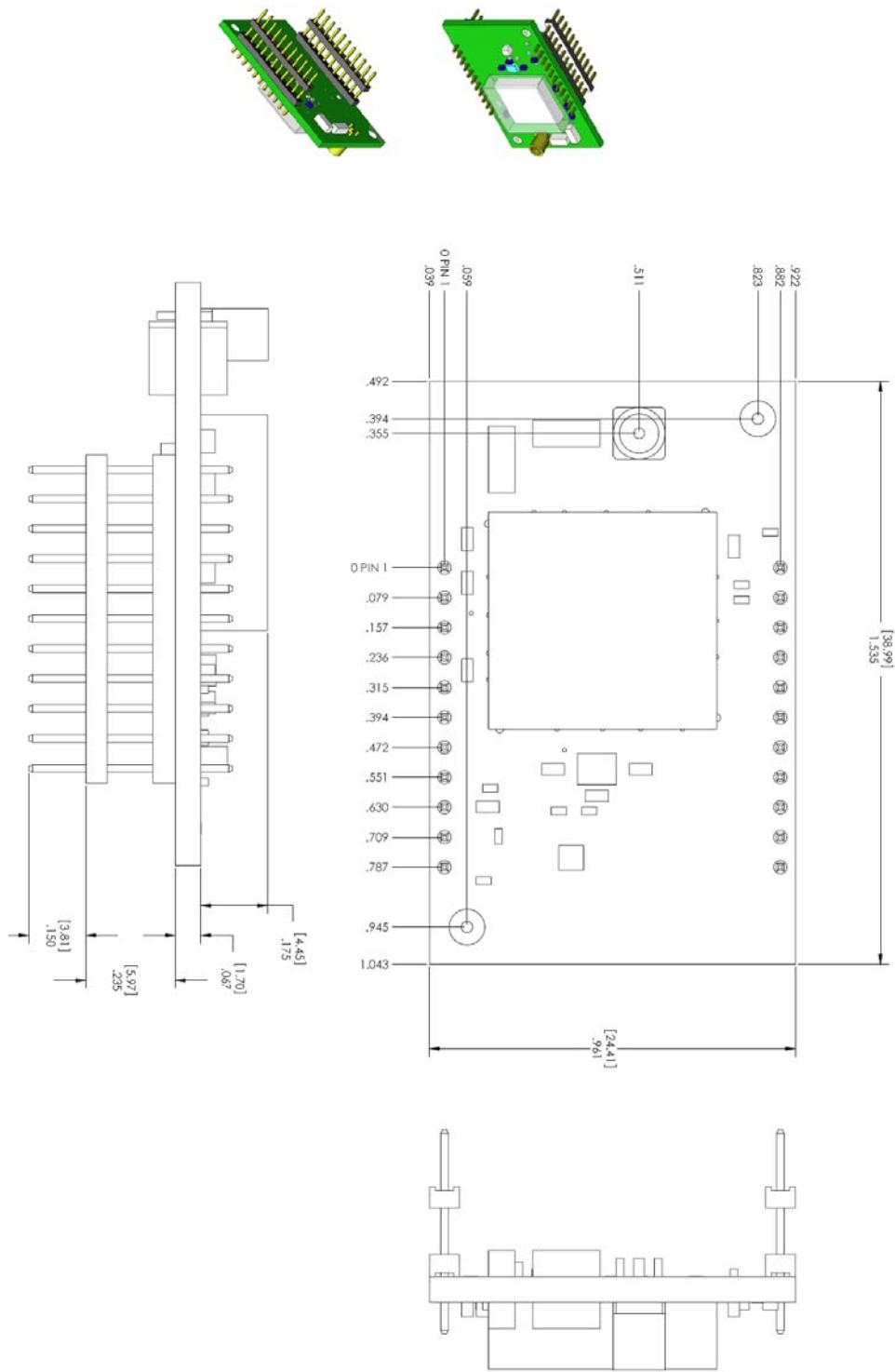


Figure 13 M2511 Mote Mechanical Drawing

RECOMMENDED P.C. BOARD LAYOUT

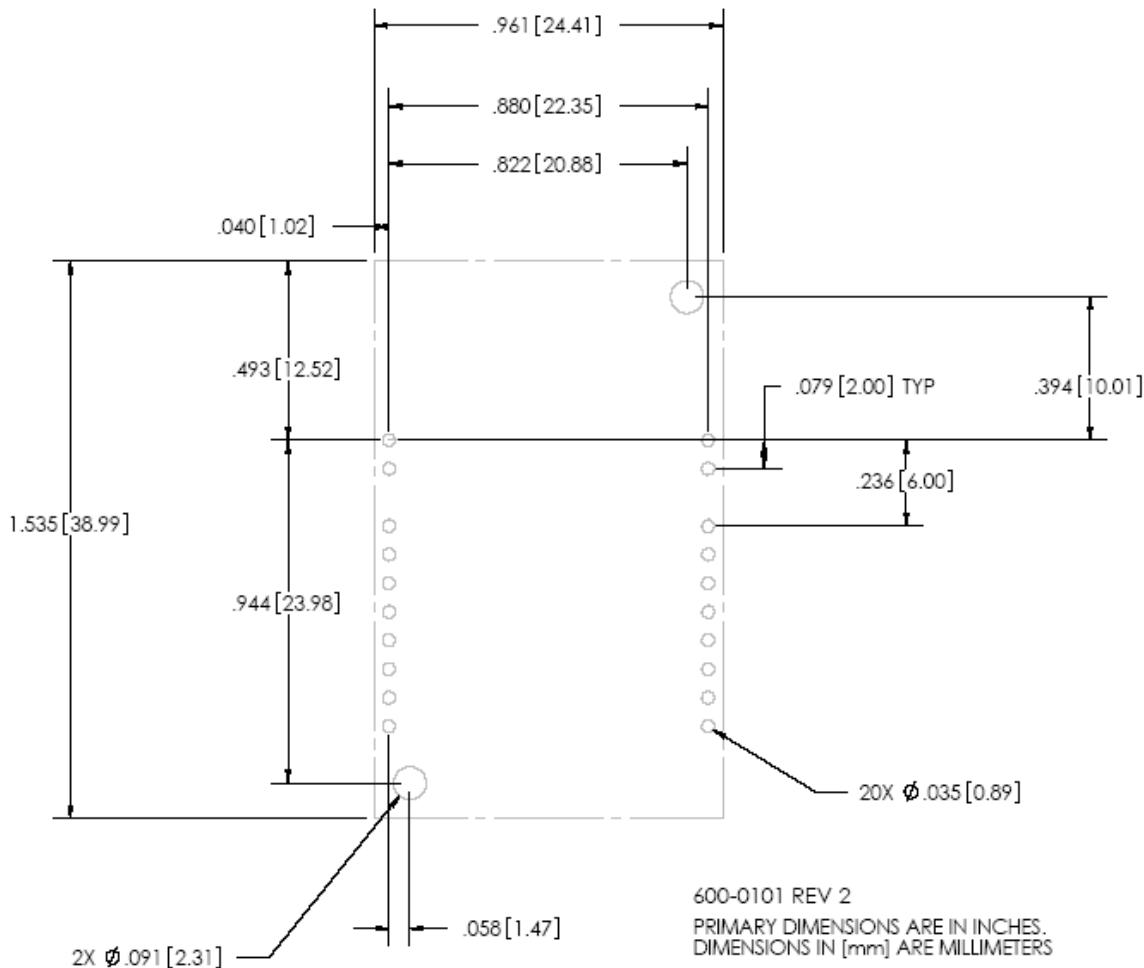


Figure 14 M2511 Mote Footprint

9.2 Soldering Information

The M2511 can be hand soldered with a soldering iron at 230 °C. The soldering iron should be in contact with the pin for 10 seconds or less.

10.0 Regulatory and Standards Compliance

10.1 FCC Compliance

Warning: Changes or modifications to this unit not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

The following paragraph must be included on the product:

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.

If the device is too small to practically support including the preceding label on the product itself, the paragraph shall be placed in a prominent location in the instruction manual or pamphlet supplied to the user or, alternatively, shall be placed on the container in which the device is marketed.

Per FCC Part 15.105, the complete electrical product including the M2511 must include the following information to the user:

- a) For a Class A digital device or peripheral, the instructions furnished the user shall include the following or similar statement, placed in a prominent location in the text of the manual:

NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

- b) For a Class B digital device or peripheral, the instructions furnished the user shall include the following or similar statement, placed in a prominent location in the text of the manual:

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation.

- c) If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:
 - 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.
- d) The provisions of paragraphs (a) and (b) do not apply to digital devices exempted from the technical standards under the provisions of Section 15.103.
- e) For systems incorporating several digital devices, the statement shown in paragraph (a) or (b) needs to be contained only in the instruction manual for the main control unit.
- f) In cases where the manual is provided only in a form other than paper, such as on a computer disk or over the Internet, the information required by this section may be included in the manual in that alternative form, provided the user can reasonably be expected to have the capability to access information in that form.

10.1.1 FCC Testing

The M2511 mote complies with Part 15.247 modular (Intentional Radiator) of the FCC rules and regulations. In order to fulfill FCC certification requirements, products incorporating the M2511 mote must comply with the following:

1. An external label must be provided on the outside of the final product enclosure specifying the FCC identifier as described in 0 below.
2. The antenna must be electrically identical to the FCC-approved antenna specifications for the M2511 as described in 10.1.2, with the exception that the gain may be lower than specified in Table 20.
3. The device integrating the M2511 mote may not cause harmful interference and must accept any interference received, including interference that may cause undesired operation.
4. An unintentional radiator scan must be performed on the device integrating the M2511 mote, per FCC rules and regulations, CFR Title 47, Part 15, Subpart B. See FCC rules for specifics on requirements for declaration of conformity.

10.1.2 FCC-approved Antennae and Installation Requirements

The following are FCC-approved antenna specifications for the M2511.

Table 20 FCC-approved Antenna Specifications for the M2511

Gain	Type	Pattern	Polarization	Frequency	Connector
+2 dBi maximum	Dipole	Omni-directional	Vertical	2.4-2.4835 GHz	Type N Jack
+6 dBi maximum	Dipole	Omni-directional	Vertical	2.4-2.4835 GHz	Type N Jack
+8 dBi maximum	Patch	Directional	Vertical	2.3-2.8 GHz	SMA (female)

Manuals for the completed product must include the following installation instructions:

- 1) FCC rules require professional installation of only the antennas specified in Table 20 with their provided cable assemblies. Installation of antennas not listed in Table 20 will void the user's authority to operate the equipment.
- 2) FCC rules require professional installation such that the general public will not be closer than 20 cm from the radiating aperture of any of the antennas listed in Table 20. End users of these systems must also be informed that RF exposure limits may be exceeded if personnel come closer than 20 cm to the apertures of any of these antennas.
- 3) FCC rules require professional installation such that the antenna is not installed within 20 cm of the radiating aperture of any other antenna.

10.1.3 OEM Labeling Requirements

The Original Equipment Manufacturer (OEM) must ensure that FCC labeling requirements are met. The outside of the final product enclosure must have a label with the following (or similar) text specifying the FCC identifier. The FCC ID and certification code must be in Latin letters and Arabic numbers and visible without magnification.

Contains transmitter module FCC ID: *Y95-M2511*

Or

Contains FCC ID: *Y95-M2511*

10.2 Industry Canada

The Language in Sections 10.2.1 and 10.2.3 must be included all OEM users manuals for all OEM equipment that incorporate the M2511.

10.2.1 IC Compliance

This device complies with Industry Canada licence-exempt RSS standard(s). 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.

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes : (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

10.2.2 IC Testing

The M2511 is certified for modular Industry Canada (IC) RSS-210 approval. The OEM is responsible for its product to comply with IC ICES-003 and FCC Part 15, Sub. B - Unintentional Radiators. The requirements of ICES-003 are equivalent to FCC Part 15 Sub. B and Industry Canada accepts FCC test reports or CISPR 22 test reports for compliance with ICES-003.

10.2.3 IC-approved Antennae

The M2511 is designed to operate with antennas meeting the specifications shown in Table 21. Antennas not meeting these specifications are strictly prohibited for use with the M2511. The required antenna impedance is 50 Ohms. 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.

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 IC: 4720A-M2511 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.

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 IC: 4720A-M2511 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.

Table 21 IC-approved Antenna Specifications for the M2511

Gain	Type	Pattern	Polarization	Frequency	Connector
+2 dBi maximum	Dipole	Omni-directional	Vertical	2.4-2.4835 GHz	Type N Jack
+6 dBi maximum	Dipole	Omni-directional	Vertical	2.4-2.4835 GHz	Type N Jack
+8 dBi maximum	Patch	Directional	Vertical	2.3-2.8 GHz	SMA (female)

10.2.4 OEM Labeling Requirements

The Original Equipment Manufacturer (OEM) must ensure that IC labeling requirements are met. The outside of the final product enclosure must have a label with the following (or similar) text specifying the IC identifier. The IC ID and certification code must be in Latin letters and Arabic numbers and visible without magnification

Contains IC: 4720A-M2511

10.3 CE Compliance

10.3.1 Declaration of Conformity

We, Dust Networks, of 30695 Huntwood Ave, Hayward, CA 94544 USA, declare under our sole responsibility that our product, SmartMesh IA-510 M2511, and in combination with our accessories, to which this declaration relates is in conformity with the appropriate standards ETSI EN 300 328, ETSI EN 301 489-17 and EN 60950, following the provisions of Radio Equipment and Telecommunication Terminal Equipment Directive 99/5/EC with requirements covering EMC Directive 2004/108/EC, and Low Voltage Directive 2006/95/EC.

10.3.2 European Compliance

If the M2511 mote is incorporated into a product, the manufacturer must ensure compliance of the final product to the European harmonized EMC and low-voltage/safety standards. A Declaration of Conformity must be issued for each of these standards and kept on file as described in Annex II of the R&TTE Directive. Furthermore, the manufacturer must maintain a copy of this M2511 user documentation and ensure the final product does not exceed the specified power ratings, antenna specifications, and/or installation requirements as specified in the user manual. If any of these specifications are exceeded in the final product, a submission must be made to a notified body for compliance testing to all required standards.

10.3.3 OEM Labeling Requirements

The 'CE' marking must be affixed to a visible location on the OEM product. The CE mark shall consist of the initials "CE" taking the following form:

- If the CE marking is reduced or enlarged, the proportions given in the drawing below must be respected.
- The CE marking must have a height of at least 5 mm except where this is not possible on account of the nature of the apparatus.
- The CE marking must be affixed visibly, legibly, and indelibly.



Figure 15 CE Label Requirements

10.3.4 Restrictions

Norway prohibits operation near Ny-Alesund in Svalbard. More information can be found at the Norway Posts and Telecommunications site (www.npt.no).

10.4 Compliance to Restriction of Hazardous Substances (RoHS)

Restriction of Hazardous Substances (RoHS) is a directive that places maximum concentration limits on the use of cadmium (Cd), lead (Pb), hexavalent chromium(Cr+6), mercury (Hg), Polybrominated Biphenyl(PBB) and Polybrominated Diphenyl Ethers (PBDE). Dust Networks is committed to meeting the requirements of the European Community directive 2002/95/EC.

This product has been specifically designed to utilize RoHS compliant materials and to eliminate, or reduce, the use of restricted materials to comply with 2002/95/EC.

The Dust Networks RoHS compliant design features include:

- RoHS compliant solder for solder joints
- RoHS compliant base metal alloys
- RoHS compliant precious metal plating
- RoHS compliant cable assemblies and connector choices

10.5 Industrial Environment Operation

The M2511 is designed to meet the specifications of a harsh industrial environments which includes:

- **Shock and Vibration**—The M2511 complies with high vibration pipeline testing, as specified in IEC 60770-1.

- **Temperature Extremes**—The M2511 is designed for industrial storage and operational temperature range of -40°C to $+85^{\circ}\text{C}$.

10.6 Encryption Cipher

The M2511's 128-bit Advanced Encryption Standard (AES) cipher has been certified compliant to the United States National Institute of Standards and Technology (NIST) FIPS-197 (NIST certificate number, AES: 1437). To view the FIPS-197 validation list, go to: <http://csrc.nist.gov/groups/STM/cavp/documents/aes/aesval.html>

11.0 Related Documentation

- *SmartMesh IA-510 M2510 Integration Guide*
- *SmartMesh IA-510 Mote Serial API Guide*

12.0 Ordering Information

This section explains Dust Networks' order code format. The product order code specifies the model number, software code, production status, and any special instructions for the product. Table 22 describes the order code options. *Note that not all options are valid for every product.* Please contact your Dust Networks Sales Representative for specific product order code information.

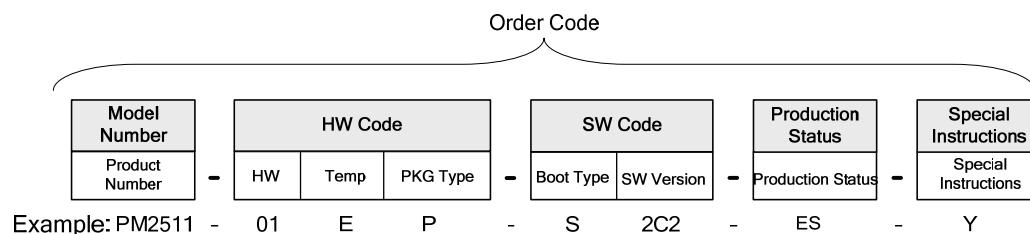


Table 22 Order Code Descriptions

Code Type	Description
Product Number	Product number
HW	Hardware revision
Temp	Temperature: C = Commercial E = Extended industrial H = High temperature industrial Z = Software only order
PKG Type	Package type: Q = QFN L = LGA P = PCA E = Packaged products K = Development or evaluation kit Z = Software only order
Boot Type	Boot type: S = Standard boot L = Low-current boot Z = Hardware only order
SW Version	Software version
Production Status	ES = Engineering sample Empty = Production
Special Instructions	Y = Special instructions Empty = No special instructions

Contact Information:

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Last Revised: March 18, 2011

Document Status	Product Status	Definition
Advanced Information	Planned or under development	This datasheet contains the design specifications for product development. Dust Networks reserves the right to change specifications in any manner without notice.
Preliminary	Engineering samples and pre-production prototypes	This datasheet contains preliminary data; supplementary data will be published at a later time. Dust Networks reserves the right to make changes at any time without notice in order to improve design and supply the best possible product. The product is not fully qualified at this point.
No Identification Noted	Full production	This datasheet contains the final specifications. Dust Networks reserves the right to make changes at any time without notice in order to improve design and supply the best possible product.
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