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MULTITECH®

MultiConnect® mDot™

MTDOT Developer Guide

MultiConnect mDot Developer Guide

Models: MTDOT-915-xxx, MTDOT-868-xxx includes also the MTUDK2-ST-MDOT Developer Kit

Part Number: S000612, Version 3.1

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Europe, Middle East, Africa:	support@multitech.co.uk	+(44) 118 959 7774
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Contents

Chapter 1 Product Overview

Overview

The MultiConnect mDot is a programmable, long-range RF module that provides encrypted data connectivity to sensors, industrial equipment, and remote appliances. By using LoRa™ Long Range Spread Spectrum technology, bi-directional data communication can be maintained for distances up to 5 miles/8 km line of sight, deep into buildings, or within noisy environments* using the unlicensed ISM bands in North America, Europe and worldwide. mDot simplifies local connectivity for Internet of Things (IoT) applications.

The mDot features an integrated ARM® Cortex®-M4 processor and mbed™ compatible software library for developers to control, monitor and bring edge intelligence to their Internet of Things (IoT) applications.

*Actual distance depends on conditions, configuration, antennas, desired throughput, and usage frequency. In dense urban environments, a typical range is 1-2 miles.

What's New in Firmware Version 2.0

The new release includes the following changes:

- LoRaWAN 1.01 Enhancements
- AU915 Support
- Class C
- US915 Test Mode

LoRaWan 1.0.1 Enhancement

Join Backoff updated to use the RTC clock to track time since the last join failure.

AU915 Support

AU915 support in this release as defined in LoRaWAN 1.01.

Class C

Allows the device to receive downlink packets from the network server without issuing an uplink first. Before the device can receive packets, it must first join the network via OTA or ABP. The device then listens for packets when idle, which leads to higher current consumption.

Configuration

Join via OTA or ABP as normal.

AT+DC=C
AT&W
AT+SD

Soon after being schedule to the network server, the device receives packets. If the network server requests an ACK, the device automatically sends an empty packet, only when the device is in serial data mode.

Network Server Configuration

After a device has joined via OTA or ABP, you can change from the default Class A setting. In the case of ABP join, the class can be set when you add the device.

lora-query -u <NODE-ADDR> class C

AT Commands Added or Changed in Version 2.0

The following AT Commands were added or modified in this release. Refer to the Dot Series AT Command Reference for details

Command	Function
AT+TXCH	Change, datarate range and current channel mask enabled settings are now shown in channel output.
AT+DC	Change. Class C allowed.
AT+SD	Change, if RX packet requires ACK or data pending bit is set, an empty packet is sent automatically.
AT+CHM	New, enables channel mask.
AT+MAC	New, injects MAC command.

Maintenance Release 1.0.8-1

Firmware release 1.0.8-1 addresses power consumption in sleep mode. For power draw changes, refer to notes and measurements in *Power Measurements*.

What's New in Firmware Version 1.0

The release includes the following changes:

- Separate AT Command Reference Guide document, with expanded details.
- Enhanced support of LoRaWAN 1.0 and 1.0.1 specification.
- Adaptive Data Rate
- Peer to Peer
- EU868 Test Mode
- Enhanced sleep mode
- Preserve session

About Adaptive Data Rate

LoRaWAN provides MAC Commands, LinkADRReq and LinkADRAns to support Adaptive Data Rate (ADR).

ADR allows the network server to change a device's data rate, Tx power, and repetition settings. If ADR is enabled, the network server samples the SNR from each packet and computes a possible data rate based on that sample. The possible data rate for a number of packets is held until the packet threshold is met. Once the threshold is met, a LinkADRAns MAC command is sent to request that the device change data rate.

For the ADR to judge the SNR correctly, set Tx power to maximum. Greater power savings are achieved through Highest Power/Highest Data Rate than with Lowest Power/Lowest Data Rate. Each step in spreading factor/bandwidth (SD/BW) gives about 3 dB increase in link budget.

Once the highest data rate is assigned, the network server looks at adjusting Tx power. If the SNR ratio for the last several packets is 3 dB above the highest data rate threshold, power is lowered.

Related commands

AT+ADR – Enables adaptive data rate

AT+SDR - Shows the current data rate

Peer to Peer Communication

Peer to Peer mode allows mDots to communicate without a network server. Two mDots can be configured with identical network addresses and session keys and default to receive mode. In peer to peer mode, both mDots are in listen mode when not transmitting and, if acknowledgments are enabled, every data packet is acknowledged immediately.

> **Note:** In peer to peer mode, mDots only communicate with each other; mDots cannot make both peer to peer and network connections in the same session.

To use this feature, the following settings must match on each mDot.

Item	Command	Configuration
Network Address	AT+NA	<NET-ADDR>
Network Join Mode	AT+NJM	3
Network Session Key	AT+NSK	<NWK-SK>
Data Session Key	AT+DSK	<DATA-SK>
Transmit Frequency	AT+TXF	**US 915MHz:** Any; 915.5-919.7 is recommended
		EU 868MHz: FIXED at 869.85
Transmit Data Rate	AT+TXDR	**US 915MHz:** DR8-DR13
		EU 868MHz: DR0-DR6
TX/RX Inverted	AT+TXI, AT+RXI	0, 1 Use the AT+TXI setting for both
Require Acknowledgment	AT+ACK	0-8
Save Configuration	AT&W	
Serial Data Mode	AT+SD	

EU 868 Test Mode

This feature allows test mode for EU 868MHz devices as defined by the LoRa Alliance. Test mode is administered at the application level so the mDot must be joined to the network via ABPA or OTAA prior to testing.

Test mode allows you to test the mDot without special commands from the UI. Instead the network server initiates test mode with a special packet (0x01010101) on port 224. Once initiated, the server changes settings on the mDot

through MAC commands and records the packets received from a number of attempts. Duty cycle limits are disabled during test mode.

The libmDot library now includes the test mode implementation, so an application built with libmDot will also have it. The libmDot library generates uplink packets and responds to commands from the network server test application.

Sleep Mode Enhancements

Changes to sleep mode include:

- Sleep mode now allows both Sleep Mode (stop) and Deep sleep (standby). Earlier firmware allowed only Deep sleep.
- Deep sleep has been changed to allow devices to wake on interval, interrupt, or both.
- Allow user to set a wake up pin for sleep mode.

Related Commands

- Sleep Mode (+SLEEP)
- Wake Mode (+WM)
- Wake Interval (+WI)
- Wake Pin (+WP)

Preserve Session

This feature allows you to preserve an AUTO_OTA LoRa Network session across power cycle or reset. The preserve session feature is applicable only when AT+NJM=2 (AUTO_OTA). However, AT+RS and AT+SS commands can be used with AT+NJM=1 or 0 (OTA or MANUAL) modes as well.

Related Commands

- Preserve Session (+PS)
- Restore Saved Session (+RS)
- Send using restored session (+SEND)
- Save Session (+SS)

AT Commands Added or Changed in Version 1.0

The following AT Commands were added or modified in this release.Refer to the MultiConnect Dot AT Command Reference for details

Command	Function
AT+TXCH	Change allows users to now add channels for EU 868MHz models.
AT+ULC	New, uplink counter
AT+DLC	New, downlink counter
AT+ANT	New, antenna gain
AT+JD	New, join delay
AT+RXD	New, receive delay
AT+TXDR	Change to data rate format

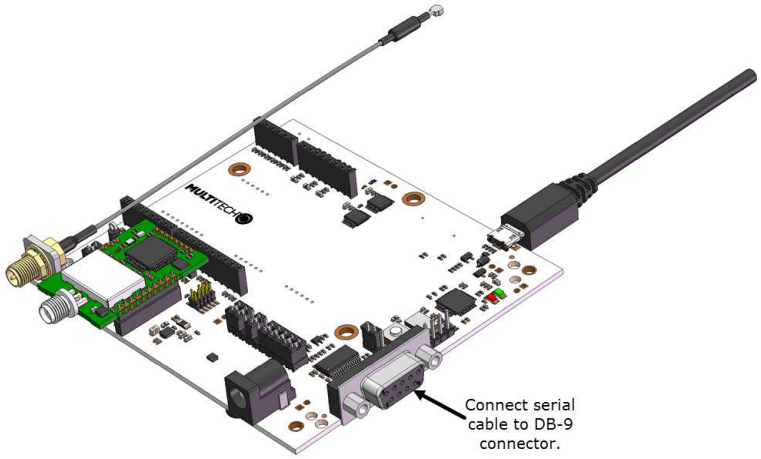
Command	Function
AT+SDR	New, displays the current data rate
AT+SDCE	New, serial data clear on error
AT&K0/3	New, hardware flow control
AT+DC	New, device class
AT+AP	New, application port
AT+SS	New, save network session
AT+RS	New, restore network session
AT+PS	New, preserve session

Getting Started

Getting started depends on what you want to do. By default, mDot ships with firmware that supports AT Commands that use the serial I/O. For AT Commands, refer to the separate *MultiConnect Dots AT Command Reference Guide*.

To send commands to the mDot:

1. Mount the mDot on the developer board. For details, refer to *Chapter 11, Developer Board Installation.*
2. Connect a serial cable into the DB-9 connector.



3. Open communications software, such as HyperTerminal or TeraTerm.
4. Set the following:
   - Baud rate = 115,200
   - Data bits = 8
   - Parity = N
   - Stop bits = 1
   - Flow control = Off

Two serial interfaces are available through the USB interface, one is used to program the mDot and the other is for debug messages. Refer to “mDot Pinout Design Notes” in *Chapter 3, Specifications and Pin Information* for information on which pins are available out of the box.

To develop using mbed, the mDot mbed page includes libraries and test cases. Refer to “mBed Documentation” for details and links.

For help setting up a MultiConnect® Conduit™ to send data to and from an mDot, refer to “Related Documentation.”

Documentation Overview

This manual is one part of mDot documentation. Refer to the *Related Documentation* and *mbed* sections for additional information needed to program your mDot and integrate your application with the MultiConnect Conduit gateway.

This document includes the following sections:

- **mDot device information:** Mechanical drawings, specifications, safety and regulatory information, and other device specific content. Chapters 1-8
- **Universal Developer Kit information:** Using the MTUDK-ST-MDOT Developer Kit, including design considerations, schematics, and installation and operation information. Chapters 9-13

This manual is available at www.multitech.com/support.

Related Documentation

- **DOT Series AT Command Reference:** Includes details on the AT commands available for mDots. This manual is available at www.multitech.com/support
- **MultiTech Developer Site:** Application notes, LoRa information, and documentation for related products such as the MultiConnect Conduit (MTCDT) gateway and the LoRa accessory card (MTAC-LORA) are available on the MultiTech developer site. This site includes information on using the Conduit with mDots. Go to: www.multitech.net
- **Processor Datasheet:** STmicro ARM® Cortex®-M4 processor datasheet is available on the STMicro website: http://www.st.com/web/en/catalog/mmc/FM141/SC1169/SS1577/LN1877/PF260049

mbed Documentation

ARM mbed is a free, open-source platform and operating system for embedded devices using the ARM Cortex-M microcontrollers. The mbed website provides free software libraries, hardware designs, and online tools for rapid prototyping of products. The platform includes a standards-based C/C++ SDK, a microcontroller HDK, and supported development boards, an online compiler and online developer collaboration tools.

Note: To send and receive data, you need a LoRaWAN 1.0 gateway, such as MultiTech's MultiConnect Conduit (MTCDT) with an MTAC-LORA accessory card installed.

Programming the mDot Microcontroller

With the mDot and the MTUDK2-ST-xx developer board, use the ARM mbed ecosystem to program the microcontroller. Compile in the cloud or locally, copy the resulting binary file to the mbed USB drive, and reset the mDot.

Note: To program the mDot, you need an mDot model with programming header, model MTDOT-xx-X1P-SMA.

On the mDot mbed page, MultiTech supplies source code for non-RF portions of the mDot and MTAC-LORA cards. To comply with FCC and ETSI certification, some portions of the software is available only as binary libraries.

MultiTech offers both development and stable release versions of the library.

- Development version: libmDot-dev-mbed5
- Stable release version: libmDot-mbed5

You can use either the mbed online compiler or offline tools.

- Online: Use the mbed-os library in your mbed application
- Offline: Use mbed-cli tools to create, manage, and build your mbed 5.1 application.

General mBed Links

- Explore mbed: http://developer.mbed.org/explore
- Getting Started with mbed: http://developer.mbed.org/getting-started
- mbed Handbook: http://developer.mbed.org/handbook/Homepage
- mbed online compiler documentation: https://developer.mbed.org/handbook/mbed-Compiler
- mbed cli documentation: https://github.com/ARMmbed/mbed-cli/blob/master/README.md
- mbed workspace tools documentation: https://github.com/ARMmbed/mbed-os/blob/master/docs/BUILDING.md#workspace-tools

mDot Platform

The mDot mbed page includes the mDot library, firmware, and test cases
https://developer.mbed.org/platforms/MTS-mDot-F411

EUI and Networking

All mDots have a factory-programmed Extended Unique Identifier (EUI). This is marked as **Node** on the mDot label.

To connect an mDot to a network, you will need to program it with the network ID for the network you are connecting to as well as the network key and application key. For information on setting up mDots as part of a LoRa network, go to: www.multitech.net

Product Build Options

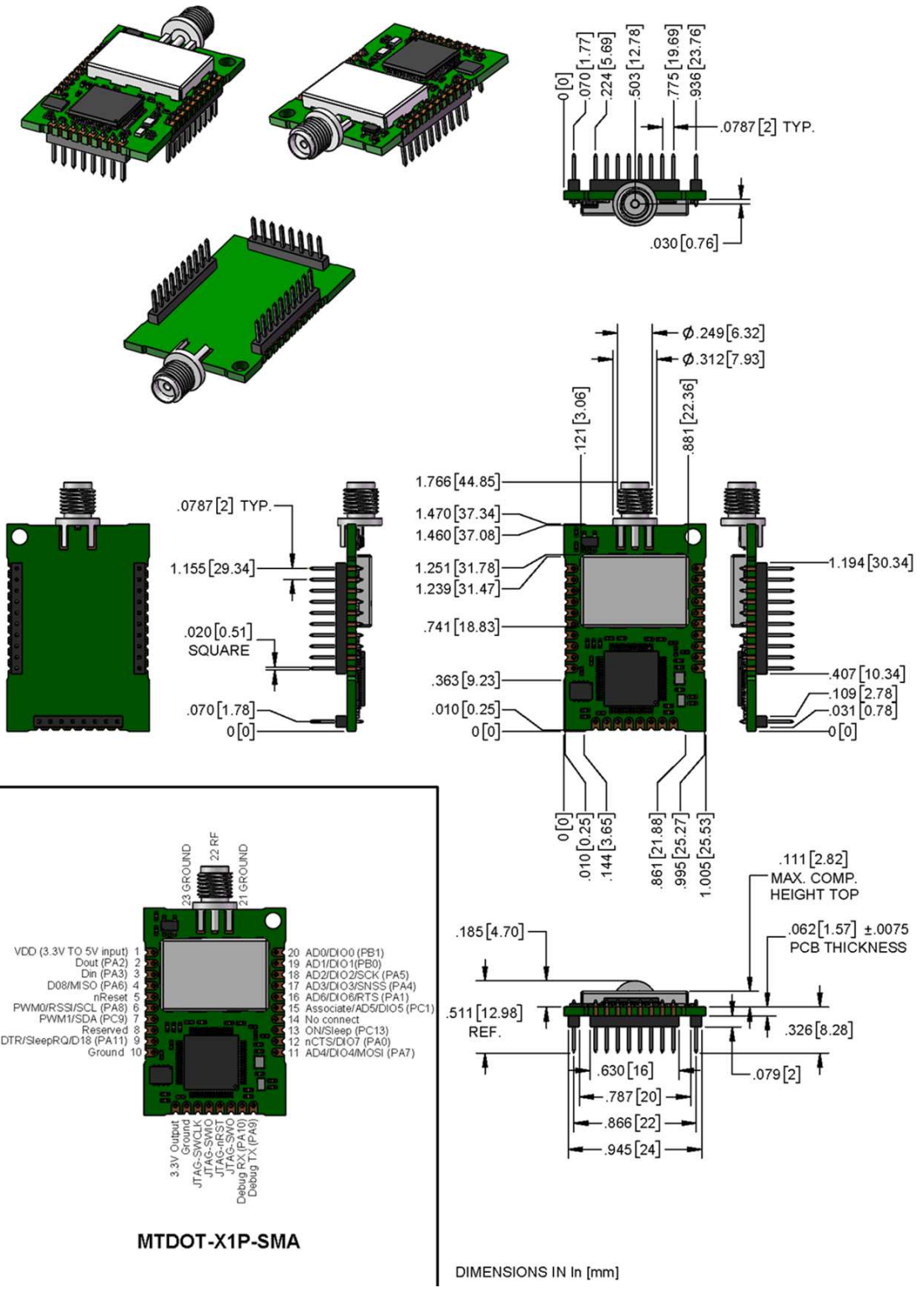
Product	Description	Quanity to Order
North America		
MTDOT-915-X1-SMA	915 MHz LoRa SMA	1 or 50
MTDOT-915-X1P-SMA	915 MHz LoRa SMA with Programming Header	1
MTDOT-915-X1-UFL	915 MHz LoRa U.FL	1 or 50
MTDOT-915-M1-UFL	915 MHz SMT LoRa U.FL	1 or 100
MTDOT-915-M1-TRC	915 MHz SMT LoRa RF Pad	1 or 100
EMEA		
MTDOT-868-X1-SMA	868 MHz LoRa SMA	1 or 50
MTDOT-868-X1P-SMA	868 MHz LoRa SMA with Programming Header	1
MTDOT-868-X1-UFL	868 MHz LoRa U.FL	1 or 50
MTDOT-868-M1-UFL	868 MHz SMT LoRa U.FL	1 or 100
MTDOT-868-M1-TRC	868 MHz SMT LoRa RF Pad	1 or 100
Australia		
MTDOT-915-AU-X1-SMA	AU 915 MHz LoRa SMA	1 or 50
MTDOT-915-AU-X1P-SMA	AU 915 MHz LoRa SMA with Programming Header	1
MTDOT-915-AU-X1-UFL	AU 915 MHz LoRa U.FL	1 or 50
MTDOT-915-AU-M1-UFL	AU 915 MHz SMT LoRa U.FL	1 or 100
MTDOT-915-AU-M1-TRC	AU 915 MHz SMT LoRa RF Pad	1 or 100
Developer Kits		
MTUDK2-ST-MDOT	mDot Developer Kit	1
MTMDK-ST-MDOT	mDot Micro Developer Kit	1

Note:

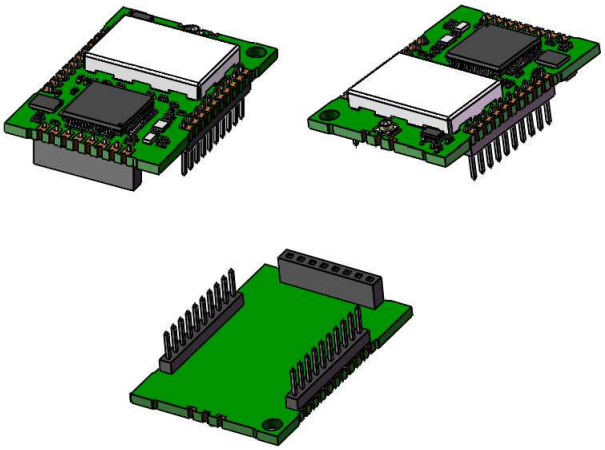
- The complete product code may end in .Rx. For example, MTDOT-915-M1-X1.Rx, where R is revision and x is the revision number.

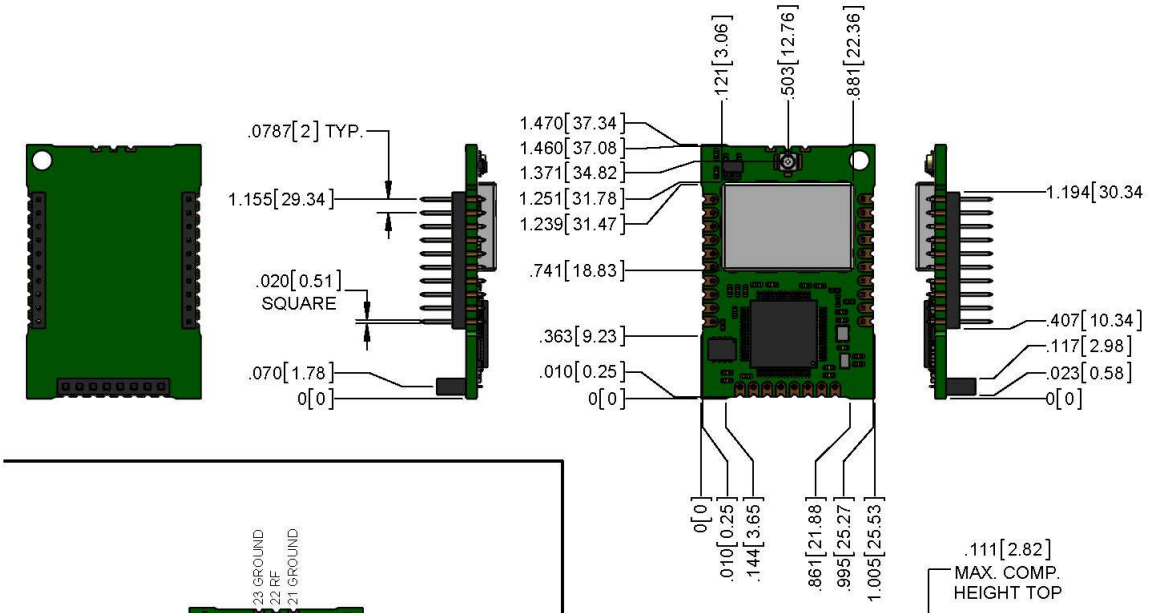
Chapter 2 Mechanical Drawings with Pinouts

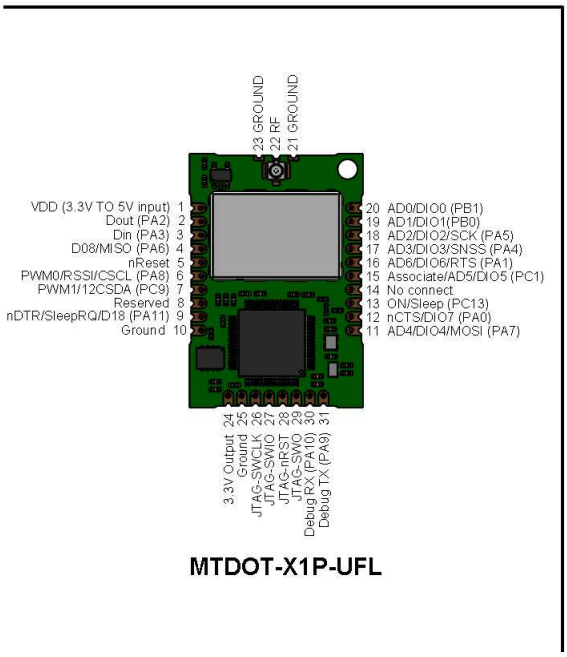
MTDOT-xxx-X1P-SMA



MTDOT-xxx-X1P-U.FL







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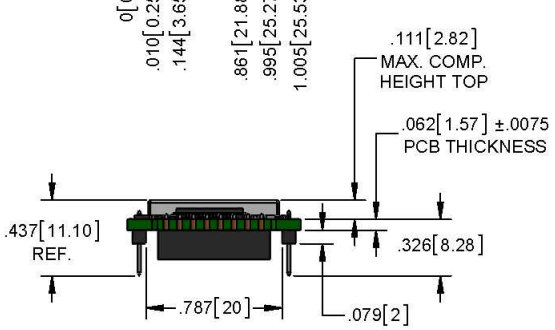
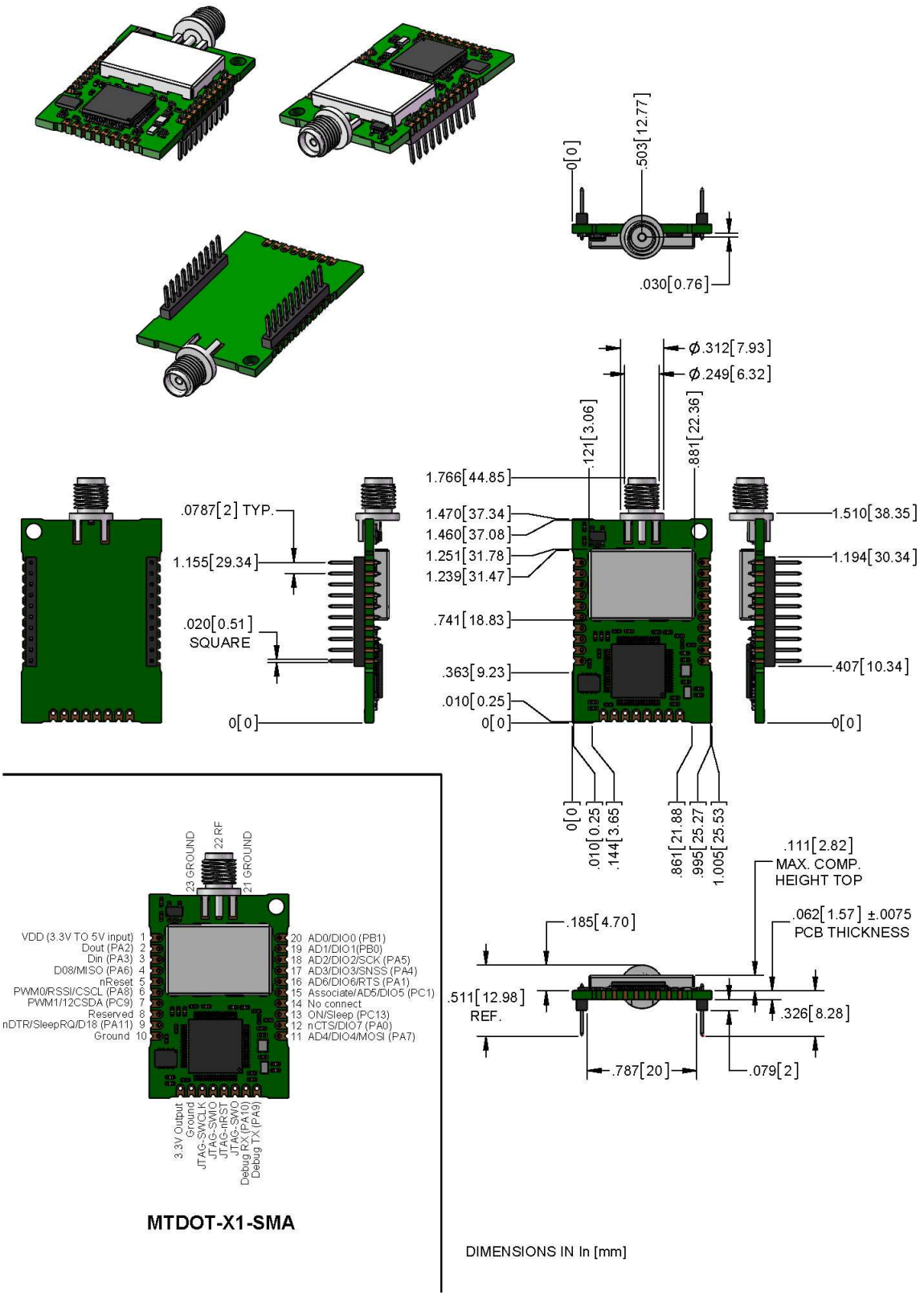


DIMENSIONS IN In [mm]

MTDOT-xxx-X1-SMA



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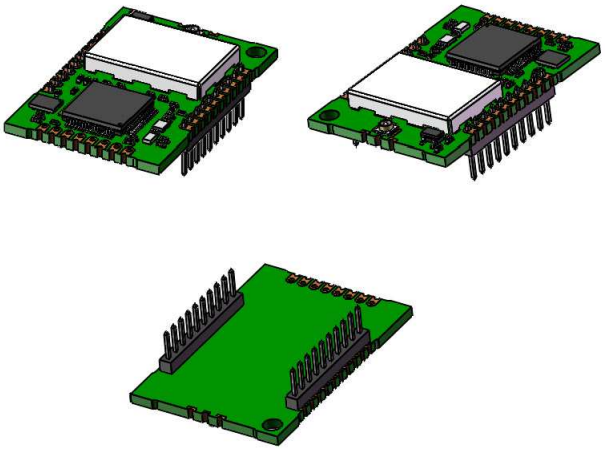
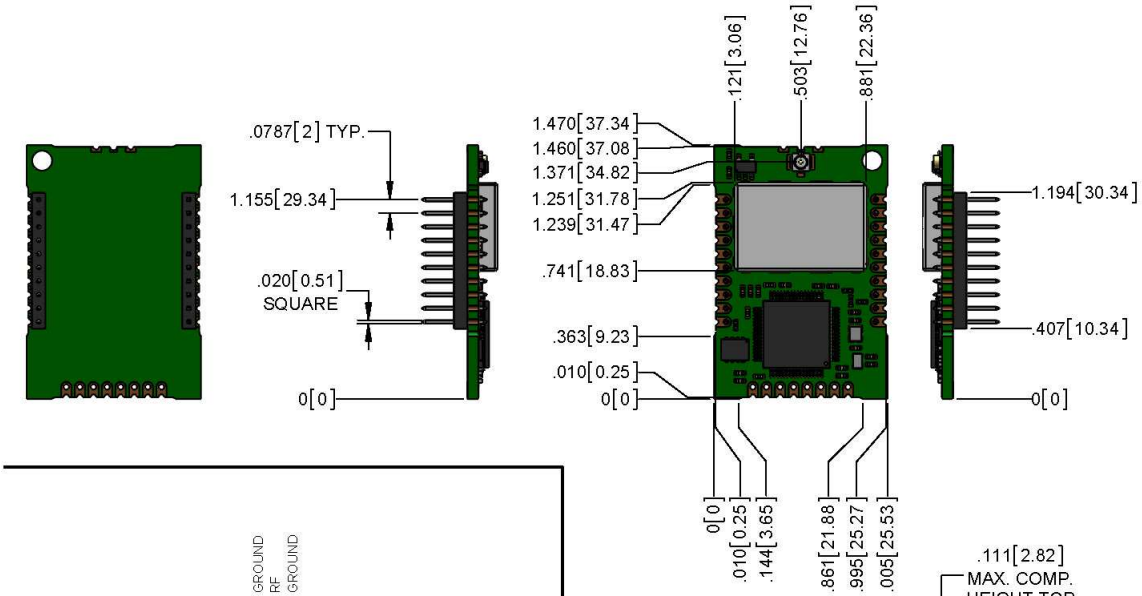
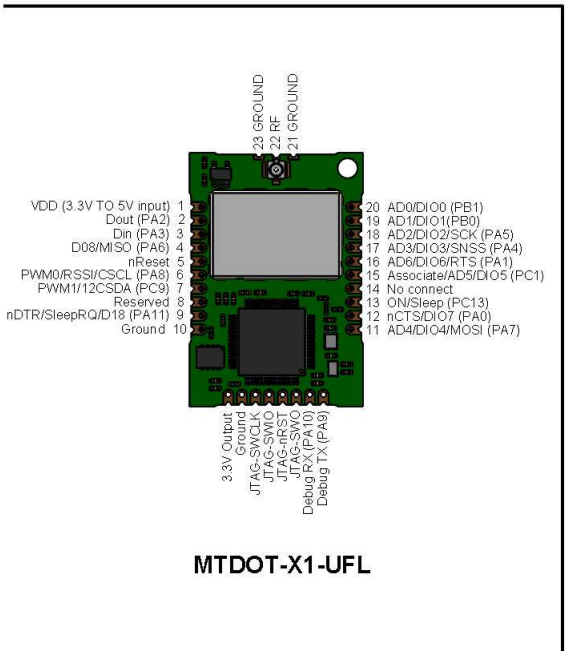
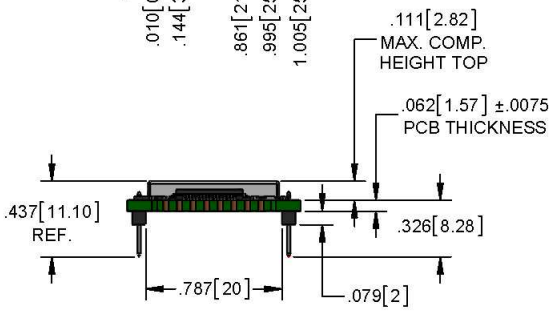




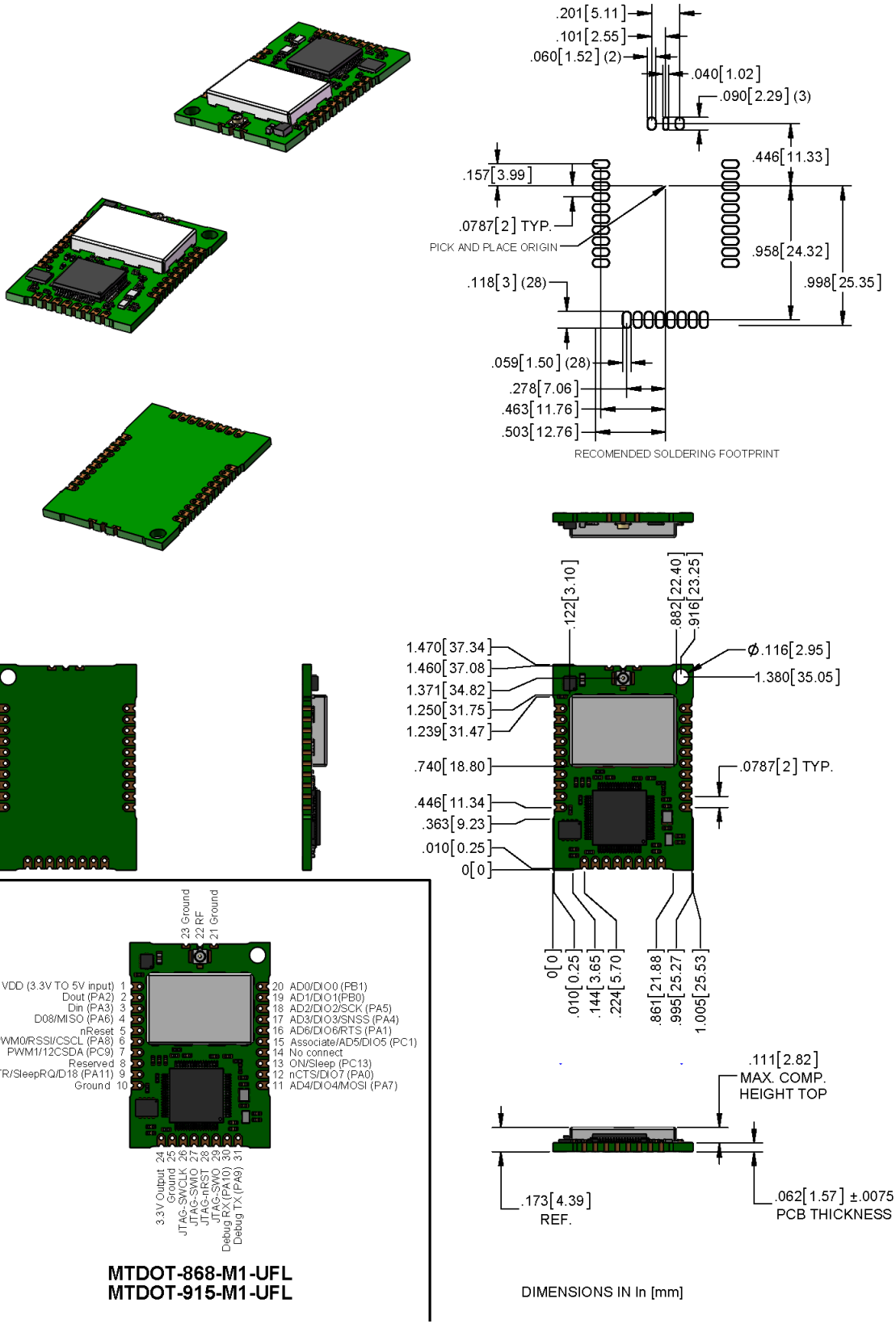


MTDOT-X1-UFL

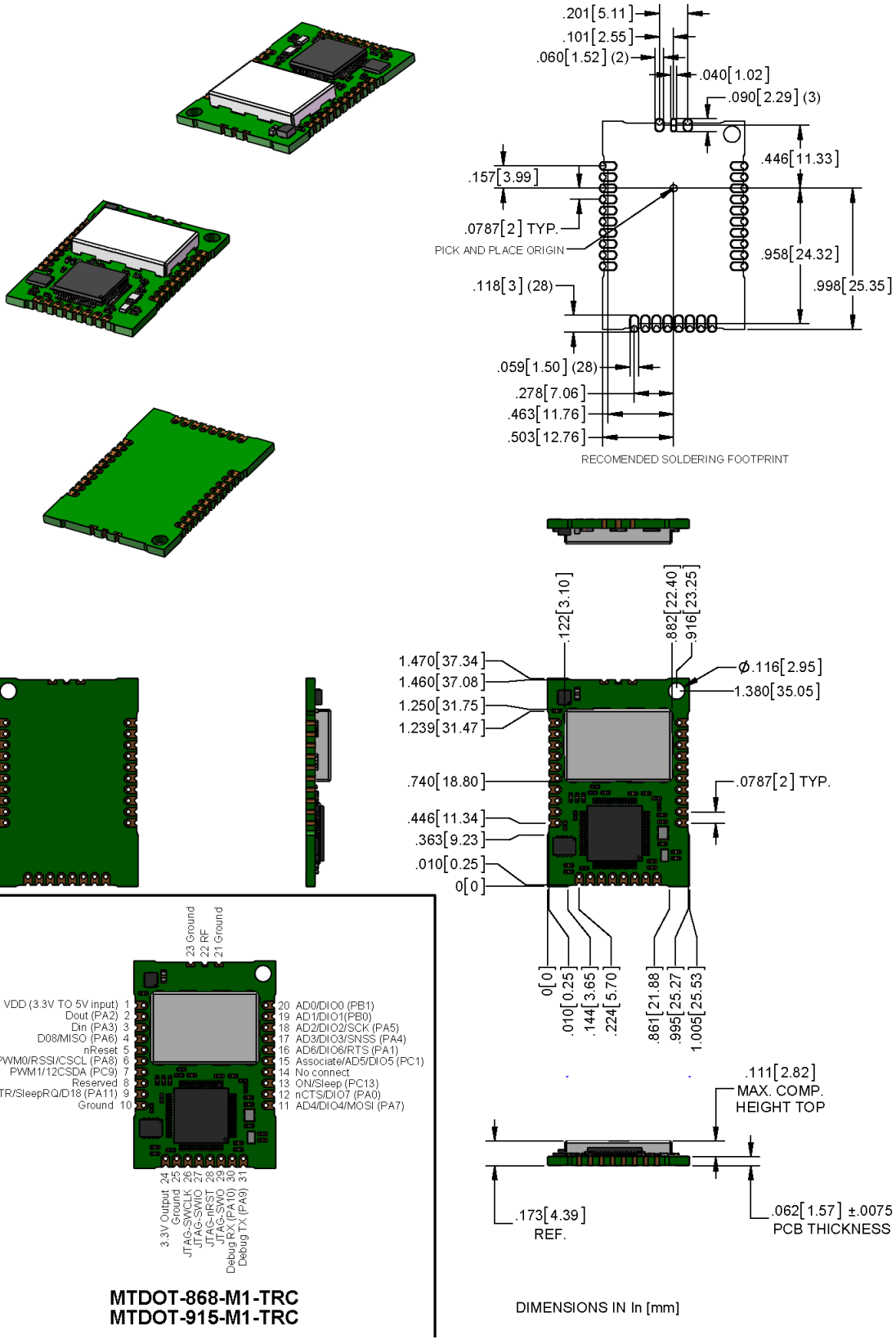


DIMENSIONS IN In [mm]

MTDOT-xxx-M1-UFL



MTDOT-xxx-M1-TRC



Chapter 3 Specifications and Pin Information

MTDOT Specifications

Category	Description
General	
Compatibility	LoRaWAN 1.0.1 specifications
Interfaces	Note that pin functions are multiplexed.
	Up to 21 digital I/O
	Up to 11 analog inputs
	SPI
	I2C
	UART (RX, TX, RTS, CTS)
CPU Performance	
CPU	STM32
Max Clock	96 MHz
Flash Memory	512 KB (400 KB available)
RAM	128 KB
Radio Frequency	
ISM Bands	EU 863 MHz - 868 MHz, NAM 902 MHz - 928 MHz, AU 915 MHz -928 MHz
Physical Description	
Weight[1]	0.2 oz. (5g)
Dimensions	Refer to Mechanical Drawings for Dimensions.
RF Connectors	
SMA Models	SMA
UFL Models	U.FL
Trace Models	Trace Connection
Environment	
Operating Temperature	-40° C to +85° C
Storage Temperature	-40° C to +85° C
Humidity	20%-90% RH, non-condensing
Power Requirements	
Operating Voltage	3.3 V to 5 V (See Important note regarding voltage)

Category	Description
Certifications and Compliance	
EMC Compliance	EN 300 220-2 V2.4.1:2012
	EN 301 489-03 V1.6.1:2013
Radio Compliance	FCC 15.247:2015
	FCC 15.109:2015
	FCC 15.107:2015
	RSS 247:2015
	ICES-003:2012
	CISPR 22:2008
	EN 300 220-2 V2.4.1:2012
Safety Compliance	UL 60950-1 2nd ED
	cUL 60950-1 2nd ED
	IEC 60950-1 2nd ED AM1 + AM2
	AS/NZS 60950.1

[1]Weight is for the MTDOT-xxx-X1P-SMA, which is the heaviest model.

Important:

The MTDOT requires 3.3 V minimum power to maintain certification and to help protect the SPI Flash file system. The onboard LDO regulator output is 3 V derived from the 3.3 V to 5 V (+-5%) input voltage. Starting with firmware version 2.0.16, SPI flash access is prevented if the onboard LDO regulator output drops below 3 V. This code change protects the SPI file system from corruption that could occur from power drop or loss.

Category	Description	
Transmission[2]		
	North America/Australia	**EMEA**
Max Transmitter Power Output (TPO)	19 dBm	14 dBm
Maximum Receive Sensitivity	-137 dBm	-137 dBm
Link Budget[3]	147 dB Point-to-Point	147 dB Point-to-Point
Max Effective Isotropic Radiated Power (EiRP)	22 dBm	10 dBm

Category	Description	
Receive Sensitivity		
Spreading Factor	**North America/Australia Typical Sensitivity**[4]	**EMEA Typical Sensitivity**[5]
6	-111 dBm	-121 dBm
7	-116 dBm	-124 dBm
8	-119 dBm	-127 dBm
9	-122 dBm	-130 dBm
10	-125 dBm	-133 dBm
11	Not Applicable	-135 dBm
12	Not Applicable	-137 dBm

[2]Using the Pulse Electronics W1063 antenna, described in the *Chapter 4, Antennas.*

[3]Greater link budget is possible with higher gain antenna.

[4]RFS_L500: RF sensitivity, Long-Range Mode, highest LNA gain, LNA boost, 500 kHz bandwidth using split Rx/Tx path.

[5]RFS_L125: RF sensitivity, Long-Range Mode, highest LNA gain, LNA boost, 125 kHz bandwidth using split Rx/Tx path.

[2]Using the Pulse Electronics W1063 antenna, described in the *Chapter 4, Antennas.*

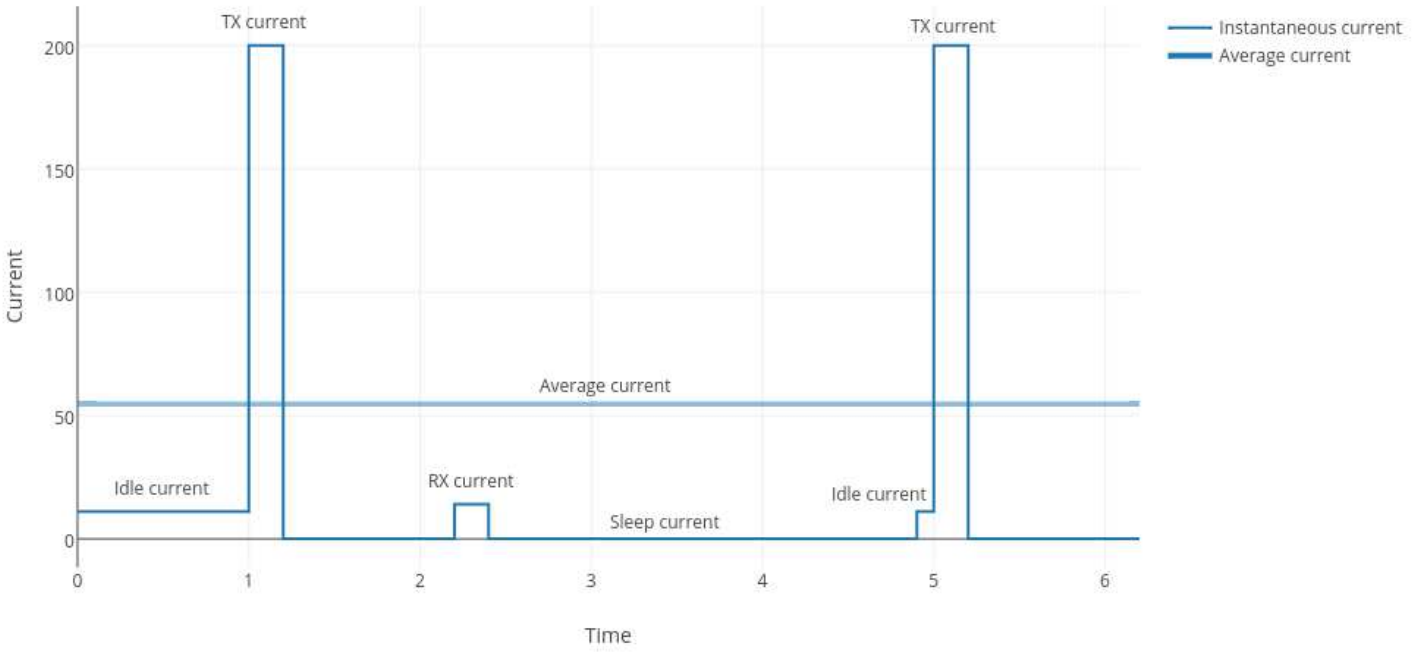
[3]Greater link budget is possible with higher gain antenna.

[4]RFS_L500: RF sensitivity, Long-Range Mode, highest LNA gain, LNA boost, 500 kHz bandwidth using split Rx/Tx path.

[5]RFS_L125: RF sensitivity, Long-Range Mode, highest LNA gain, LNA boost, 125 kHz bandwidth using split Rx/Tx path.

Battery Draw Down

mDot battery life depends on many variables, including transmit power, data rate, sleep usage, and duty cycle. The following figure represents the current consumption in one possible application.



Use the current consumption values from the following Electrical Characteristics table when calculating average power consumption.

Electrical Characteristics

Note:

- All measurements taken at VDD = 3.3 V and 25 degrees Celsius ambient temperature unless otherwise specified.
- Refer to the ST Micro STM32F411RE datasheet for more detailed processor IO characteristics.
- The STM32F411RE and other onboard ICs are powered by an internal 3.0V voltage regulator.

Signal	Description	Conditions	Min	Typical	Max	Units
VCC	Operating Voltage		3.3	--	5	V
Vin Low	IO input low level		--	--	0.9	V
Vin High	IO input high level		2.1	--	--	V
Vout Low	IO output low level	Pin current = 8mA	--	--	0.4	V
Vout High	IO output high level	3.3V < VDD < 5V	2.4	--	--	V
Vout Low	IO output low level	Pin current = 20mA	--	--	1.3	V
Vout High	IO output high level	3.3V < VDD < 5V	1.7	--	--	V
ICC		Idle mode (no TX, no RX), processor active	--	32	--	mA
		TX, TXP=2	--	34	--	mA
		TX, TXP=11	--	73	--	mA
		TX, TXP=20	--	130	--	mA
		Maximum supply current. Transmitting at TXP=20, all peripherals active, no load on IO pins. VDD = 3.3V. 25 degC ambient temperature.	--	--	250	mA
		Sleep mode	--	40	--	uA
		Deep sleep mode	--	40	--	uA
		RX	--	43	--	mA