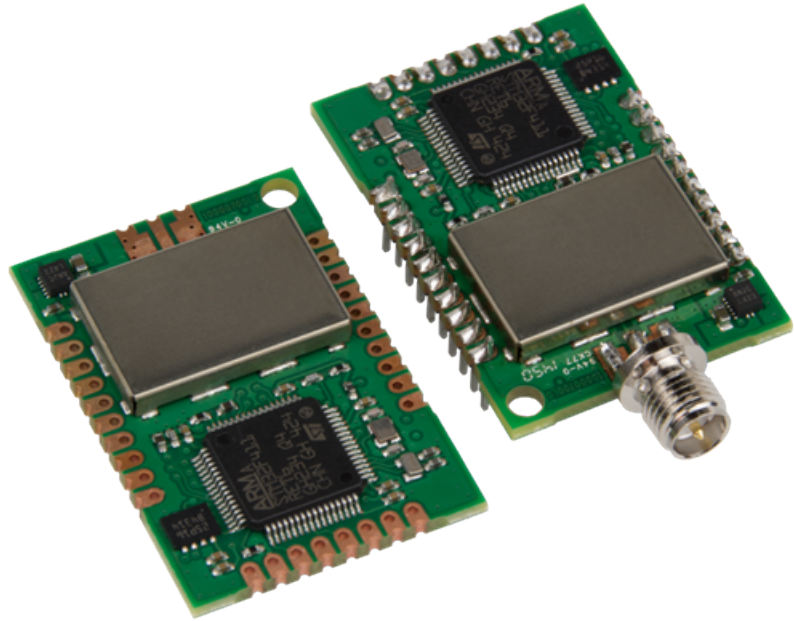
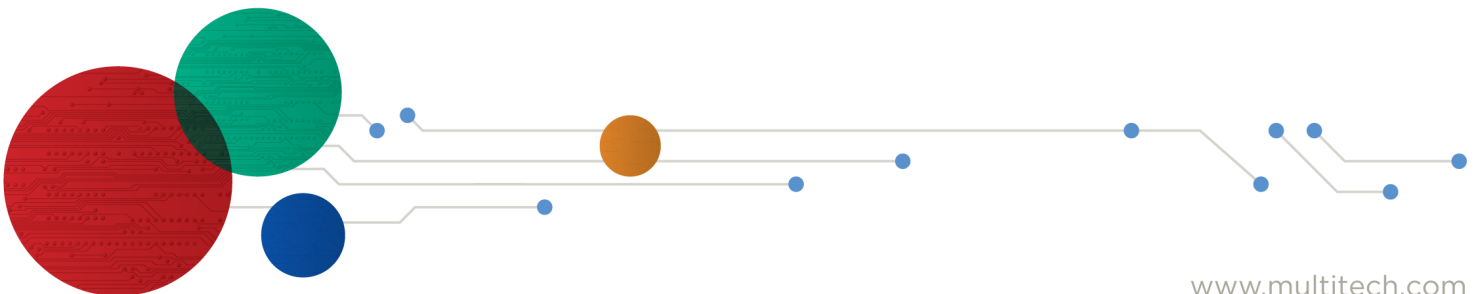




mDot™

---

## MTDOT Developer Guide



## mDot Developer Guide

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

Part Number: S000612, Version 7.1

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| Country                      | By Email                                                             | By Phone                         |
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| U.S., Canada, all others:    | <a href="mailto:support@multitech.com">support@multitech.com</a>     | (800) 972-2439 or (763) 717-5863 |

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# 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 unlicensed ISM bands. 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 4.1

The new release includes the following changes:

- Protected Settings Backup using OTP
- LoRaWAN 1.0.4 Support and Regional Parameters RP2 1.0.3
- FOTA Enhancements
- Changes to Wake Pin
- New and updated AT Commands

### Protected Settings Backup using OTP

To safeguard your configuration, a backup of protected settings (Device ID, Network ID, Network Key, and Gen App Key) can be stored in mDot One-Time-Programmable (OTP) flash.

### LoRaWAN 1.0.4 Support and Regional Parameters RP2 1.0.3

Adds AS923-4, extending support to Israel.

### FOTA Enhancements

#### Available space on mDot flash

When starting a FOTA session, the device will check the flash file system for adequate free space to complete download and upgrade processes.

#### Bootloader update

mDot bootloader “erase” command will only delete the area of flash containing the file system. Configuration data is left untouched. Specifying “erase all” will erase the entire flash storage.

### Changes to Wake Pin

Ability to set trigger for WAKE pin as rising, falling, or either.

### AT Command Additions and Modifications

**Note:** For AT Command details, refer to [S000643 mDot AT Command Reference Guide](#).

- Changed AT+ERASE=1 so that it only erases the file system for mDot (does not affect the configuration).
- Added AT+ERASE=2 to erase both files and configuration for mDot.
- Changed AT+WP added trigger parameter and mode parameter to set pullup/pulldown.
- Added AT+DUTY set duty cycle maximum or per band.
- Added AT+WOTP write protected settings for mDot to the One-Time Programmable (OTP) memory.

For an archive of release notes, go to Appendix A.

## 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 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](http://www.multitech.com/support).

## Related Documentation

- **mDot AT Command Reference:** Includes details on the AT commands available for mDots. This manual is available at [www.multitech.com/support](http://www.multitech.com/support)
- **MultiTech Developer Site:** Application notes, LoRa information, and documentation for related products such as the Conduit (MTCDDT) 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](http://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 Conduit (MTCDDT) 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-mbed6
- Stable release version: libmDot-mbed6

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 6.0 application.

## General mBed Links

- Explore mbed: <https://os.mbed.com/>
- Getting Started with mbed: <https://os.mbed.com/docs/mbed-os/#gettingstarted>
- mbed Handbook: <https://os.mbed.com/docs/mbed-os>
- mbed online compiler documentation: <https://os.mbed.com/docs/mbed-os/latest/quick-start/online-with-the-online-compiler.html>
- mbed cli documentation: <https://os.mbed.com/docs/mbed-os/latest/quick-start/offline-with-mbed-cli.html>
- mbed workspace tools documentation: <https://os.mbed.com/docs/mbed-os/v6.1/build-tools/index.html>

## 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](http://www.multitech.net)

## Protected Settings Backup

A backup of protected settings (Device ID, Network ID, Network Key, and Gen App Key) can be stored in the mDot's One-Time-Programmable (OTP) flash using AT+WOTP. On startup, the settings are restored if they are invalid (for example, Device ID of 00-00-00-00-00-00-00-00). The device OTP area is divided to allow eight writes of protected settings. The system uses only the latest write to restore settings.

## Configuration Persistence

To safeguard your configuration, the device offers configuration persistence in the form of configuration redundancy and wear leveling.

**Note:** *These features change the configuration storage and make the firmware update a one way process. The configuration is not backward compatible to any version less than 4.0.x. Once a device is flashed with 4.0.x firmware, the configuration is converted to a new format. Any versions earlier than 4.0.x cannot parse this new format.*

## Redundancy

In case of data loss or corruption, your device stores multiple copies of the configuration and can fall back to the last good copy.

## Wear Leveling

Wear leveling writes across the entire flash sector and skips bad sections on write failure. Frequently saved session parameters have more flash space available to extend the expected life of the flash system on your device.

## Differential and Compressed Upgrade Files

Differential and compressed upgrade files can be used to reduce the size of firmware upgrades sent over-the-air (FOTA). Smaller files reduce the time required to deliver an update. Smaller FOTA sessions increase end-device battery life.

### Creating Differential and Compressed Files

To package application firmware binaries for Dot devices with compression or deltas, use the `mtsmultitool` utility. The output is a binary file that can be sent to the bootloader over serial YMODEM or FOTA.

For more details on the utility, see: <https://pypi.org/project/mtsmultitool/>.

The utility requires Python v3.8 installed. To install the utility, open a command prompt and enter: `pip install mtsmultitool`

## Product Build Options

| Product              | Description                                 | Quantity to Order |
|----------------------|---------------------------------------------|-------------------|
| <b>North America</b> |                                             |                   |
| 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          |
| <b>EMEA</b>          |                                             |                   |
| 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          |
| <b>Australia</b>     |                                             |                   |
| 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           |

| Product               | Description                | Quantity to Order |
|-----------------------|----------------------------|-------------------|
| 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          |
| <b>Developer Kits</b> |                            |                   |
| 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 – 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 *mDot AT Command Reference Guide*.

To send commands to the mDot:

1. Mount the mDot on the developer board. For details, refer to [Installing an mDot on the Developer Board](#)
2. Open communications software, such as HyperTerminal or TeraTerm.
3. 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](#) 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 Conduit® to send data to and from an mDot, refer to [Related Documentation](#).

## Chapter 3 – FOTA (FUOTA) Overview

*This requires mDot firmware Version 3.1 or higher and a Conduit® with AEP (mPower) 1.6 or higher.*

Firmware Over the Air (FOTA) also known as Firmware Upgrade Over the Air (FUOTA) is a way to upgrade Dot end devices using multicast and file fragmentation packages defined in the LoRaWAN specification. FOTA allows the Conduit to update the firmware on many Dots at once using multicast and error correction packets. FOTA is still in its early stages of revision and does have potential problems, which are included in this topic.

Before performing a FOTA update, the device checks the flash file system for adequate free space to complete the download and upgrade processes. If there is not enough free space, user files are deleted until enough space is available.

**Note:** FOTA is enabled by default.

To start the FOTA process, the Conduit sends two setup downlinks to the Dot. First, the Conduit then sends a multicast session setup request to the Dot. The Dot responds with a multicast session setup answer. The Conduit sends a fragmentation setup request. The Dot responds by sending back a fragmentation setup answer. Once setup is complete, the Dot waits until the start of the multicast session. At the start of the session, the Dot switches to class C with the specified data rate and frequency to receive the file fragments sent by the Conduit. After the file fragments are sent, the Conduit starts sending parity fragments. At any point when the Dot is able to reconstruct the firmware file, the CRC is calculated and the CRC message id sent in Class A. This could happen any time after the last fragment is sent to after the last parity is sent.

For details on the FOTA AT Commands, go to *mDot AT Command Reference Guide* (S000643).

### FOTA Stages

A FOTA session has four stages: 1) session setup, 2) fragmentation, 3) parity, and 4) verification.

#### Session Setup

For a multicast session to work with class A devices, a start time must be agreed upon by the network server and each device. This requires the devices to synchronize their time with the server. These critical tasks are done during session setup.

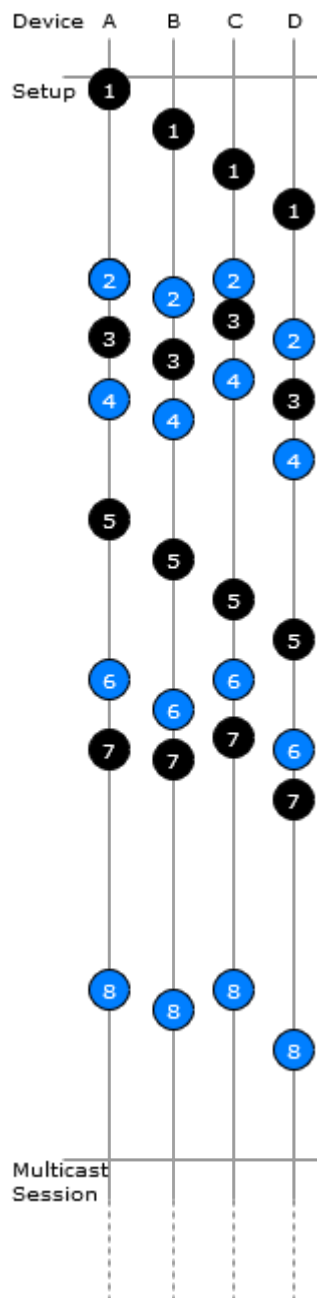
Class A devices must periodically send uplinks to open downlink windows making the time required to complete an operation setup directly tied to the frequency of device uplinks. For each device involved in the operation, some extra time should be added to the total setup time to account for latency in queuing each device's message.

Setup messages are sent up to 3 times. Worst-case timing for operation setup would be  $((3 * \text{device\_uplink\_period} * 2) + (\text{overhead} * \text{number\_of\_devices}))$ .

The included diagram illustrates the events that occur during a best-case setup with no messages missed and well-timed device uplinks. Each device follows these steps:

1. FOTA operation queues Multicast setup message with network server.
2. Device sends an uplink.
3. Multicast setup message is downlinked to the device.
4. Device sends a multicast setup response.
5. FOTA operation queues fragmentation setup message.
6. Device sends an uplink.

7. Fragmentation setup is downlinked to the device.
8. Device sends a fragmentation setup response from device.



### Fragmentation

During this stage, the device should only send uplinks as necessary, too many can cause excessive fragment loss. Applications on the device should not perform heavy processing activities during FOTA. Doing so can cause fragments to overlap and excessive fragment loss. The number of fragments required to send a file depends on the Data Rate. The device clears the file system to ensure enough free space to save update firmware and a backup copy of the current firmware saved by the bootloader. User files are removed when the fragmentation session is set up.

### Parity

Multicast messages are unconfirmed meaning some loss of fragments is expected. The device can recover a certain number of fragments though parity.

The mDot can tolerate up to 300 lost fragments.

### Verification

Once a device completes its fragmented file, it calculates a CRC64 and sends a request to the server to verify the CRC. The server sends a response indicating if the CRC matches or not. If the CRC is verified the device reboots and performs the upgrade. If the CRC does not match, the downloaded file is discarded.

## Potential Problems

- If the Dot misses either setup message, the FOTA session will not be successful. The Dot attempts to receive both messages multiple times. If the Dot is unsuccessful, it resets the fragmentation sessions and multicast session.
- If the Dot does not receive a CRC response from the Conduit, it resets the fragmentation and multicast sessions and deletes the fragmentation file.
- The Dot can reset the multicast/fragmentation session at any time using AT+FOTA=2.
- When using AT+SLEEP, make sure to wake up the Dot before a scheduled FOTA session. Using AT+FOTA=3 will return the time in seconds before the FOTA session is scheduled to start.
- If AT+SLEEP is used during the FOTA session, the Dot will miss packets and the session will likely fail.
- The FOTA session sends down packets every 1.5 seconds (assuming no duty cycle) and parity packets every 3 seconds by default. For best results, Multitech recommends users suspend all normal Dot operations until the FOTA session is complete.

## Troubleshooting FOTA

### Troubleshooting FOTA on the Dot

**Problem:** Dot does not receive any file fragments.

#### Troubleshooting:

- The Dot must receive two setup messages for the FOTA session to work, fragmentation setup request and multicast setup request.  
 Verify if the Dot received the fragmentation setup request. This comes down on port 201. When the Dot receives this request, it sends an answer. Check the Dot debug log for *Sending Fragmentation Response*.  
 After sending the fragmentation response, the Dot receives a multicast setup request. Check for this message on port 201. The Dot responds with a multicast setup answer. Check the Dot debug log for *Sending Multicast Response*.
- Make sure the Dot is in Class C at the start of the FOTA session (AT+DC). The Dot must also be awake and will not wake up to start the FOTA/Multicast session. The command AT+FOTA=3 displays the time before a FOTA session starts.
- Make sure the Conduit is sending the fragments by checking the Conduit logs in /var/log/log\_fota\*.

**Problem:** Dot cannot complete the FOTA session.

**Troubleshooting:**

- If the Dot misses too many packets, the FOTA session cannot be completed.
- If the Dot was able to reconstruct the file using parity fragments, it sends a CRC check to the Conduit. Check the Dot debug log for *Sending CRC*. If the Dot does not receive a response or the Conduit responds with CRC not correct, the Dot discards the file.

**Problem:** Dot fails to process parity fragments.

**Troubleshooting:**

- If the Conduit sends parity fragments faster than the Dot can process them, the Dot starts failing to properly receive the fragments. This results in failed MIC checks or wrong address, which is noted in the Dot debug log.
- To correct this, increase the delay between parity fragments on the Conduit.

**Problem:** Dot is unexpected state.

**Troubleshooting:**

- If the Dot is in a bad or unknown state, use ATZ to reset the Dot and clear the multicast and FOTA states. AT+FOTA=2 also resets FOTA and Multicast states.

## Troubleshooting FOTA on the Conduit

**Problem:** FOTA Session not starting.

**Troubleshooting:**

- Verify that there is not a current FOTA session. If there is no current FOTA session and a FOTA session will not start, reboot the Conduit.
- If the Conduit does not receive at least one response from an Dot, the FOTA session will not start. The process will go from SETUP (10%) to TEARDOWN (90%). Check the log (/var/log/log\_fota\*) to make sure the Conduit is receiving the setup answers.

**Problem:** FOTA Session not successful.

**Troubleshooting:**

- For a FOTA Session to be successful, the Dot has to be able to reconstruct the file. If the Dot misses too many packets, the FOTA session will not be successful and the Dot will not send a CRC to the Conduit.
- If the Conduit receives a CRC from an Dot check the FOTA log (/var/log/log\_fota\*) to make sure the CRC matches the Conduit and the CRC correct answer is sent back to the Dot. Check the Dot debug log to verify if the device received the CRC answer.

**Problem:** Stop FOTA Session / FOTA Session won't start (FOTA in progress) / Stop Multicast Session

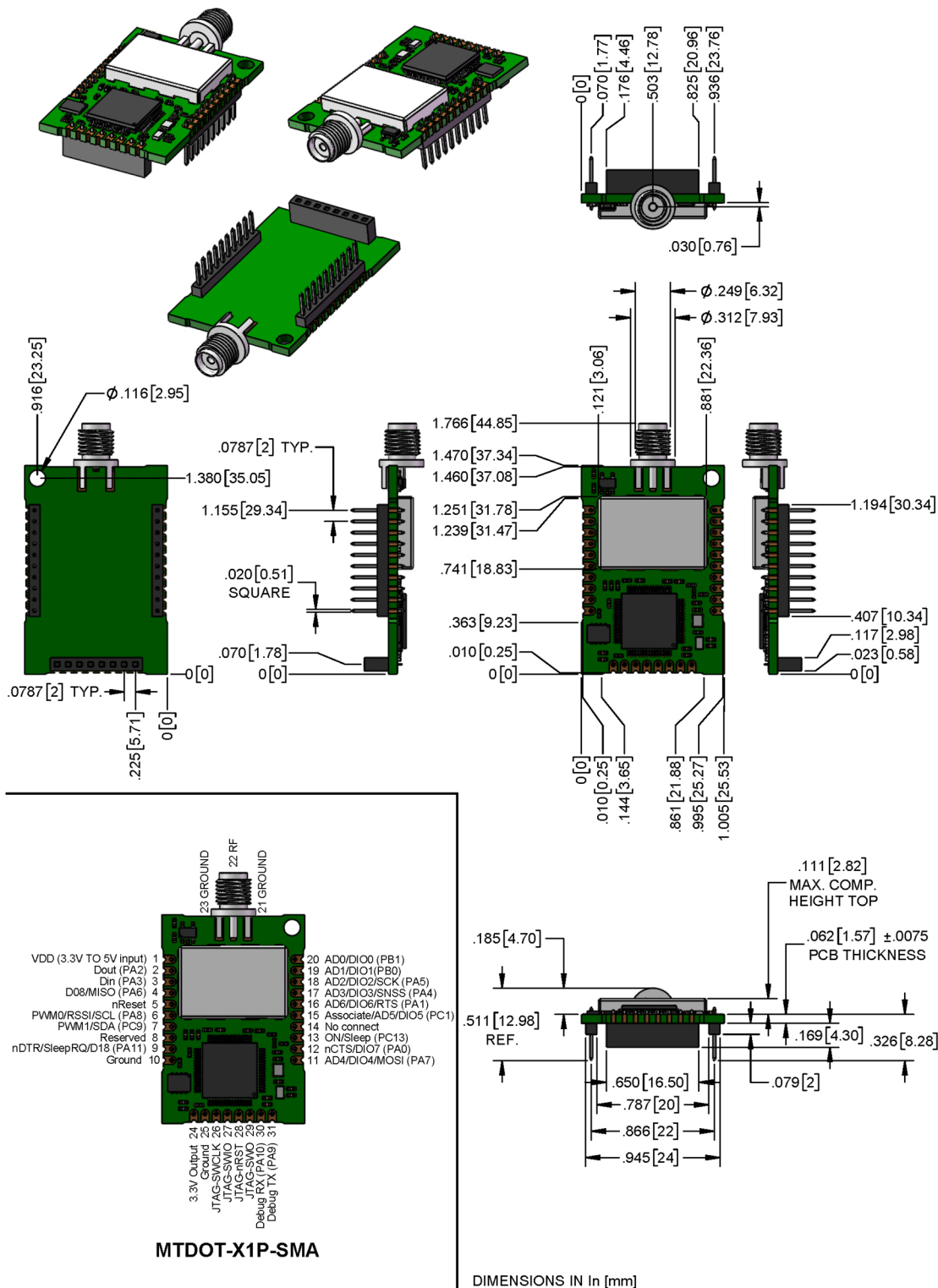
**Troubleshooting:**

- To end a FOTA session that is in progress, send 'ps -A | grep fota'. Find the PID associated with lora-fota (not lora-fota-demo). Then send 'kill (pid of lora-fota)'.

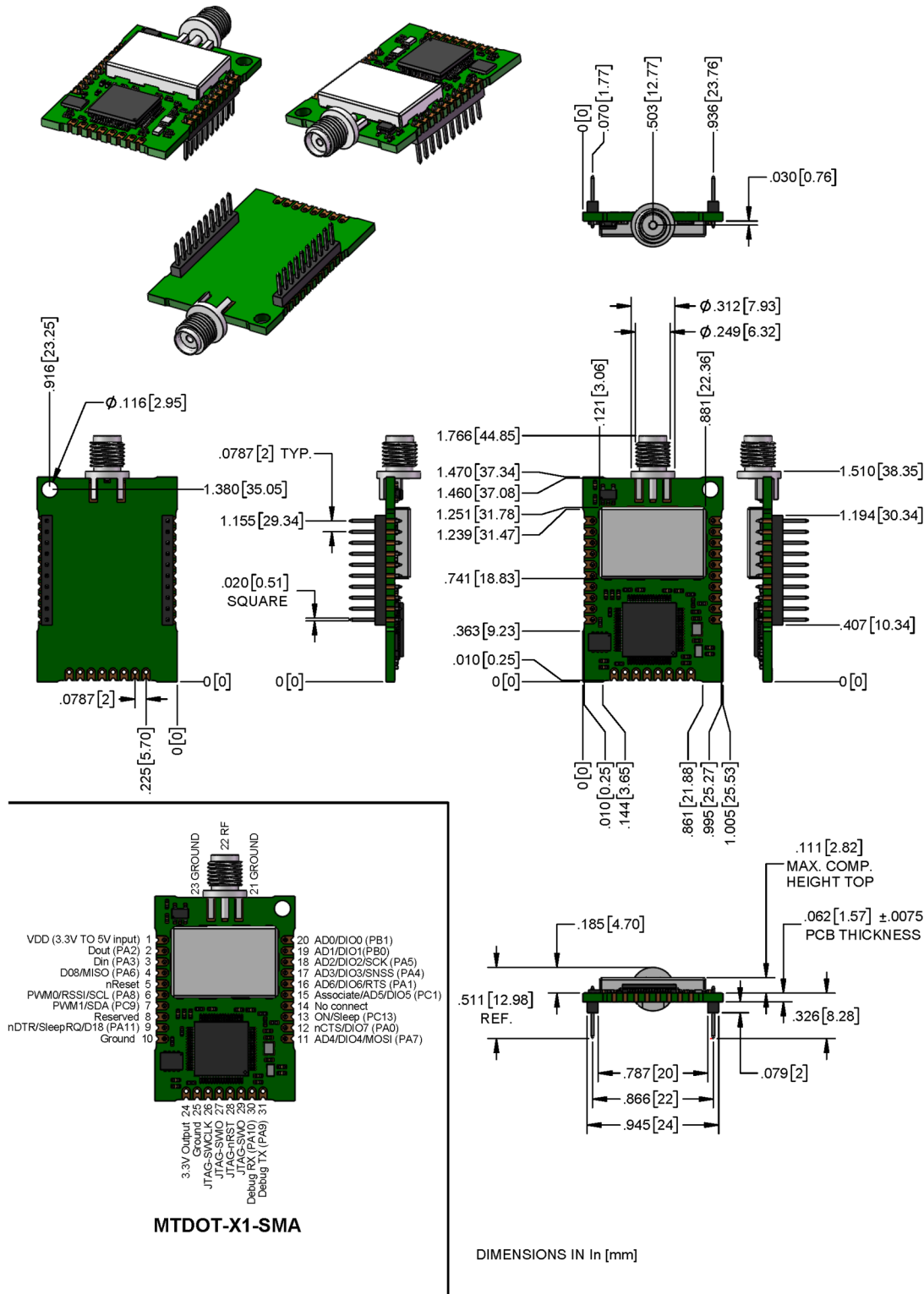
- Also send 'rm -r -f ~/.fota/'. Devices may be in Class C or Class A depending on the FOTA session status before it ended. Make sure to change the devices back to their appropriate class. Make sure the FOTA daemon is running by '/etc/init.d/fotad restart'.
- To end a Multicast session that is in progress, use 'ps -A | grep mcm'. Find the PID associated with lora-mcm. Then use 'kill (pid of lora-mcm)'. Also send 'rm -r -f ~/.fota/'.
- Wiping out the .fota directory removes any future FOTA/multicast sessions scheduled that have not setup.

# Chapter 4 – Mechanical Drawings with Pinouts

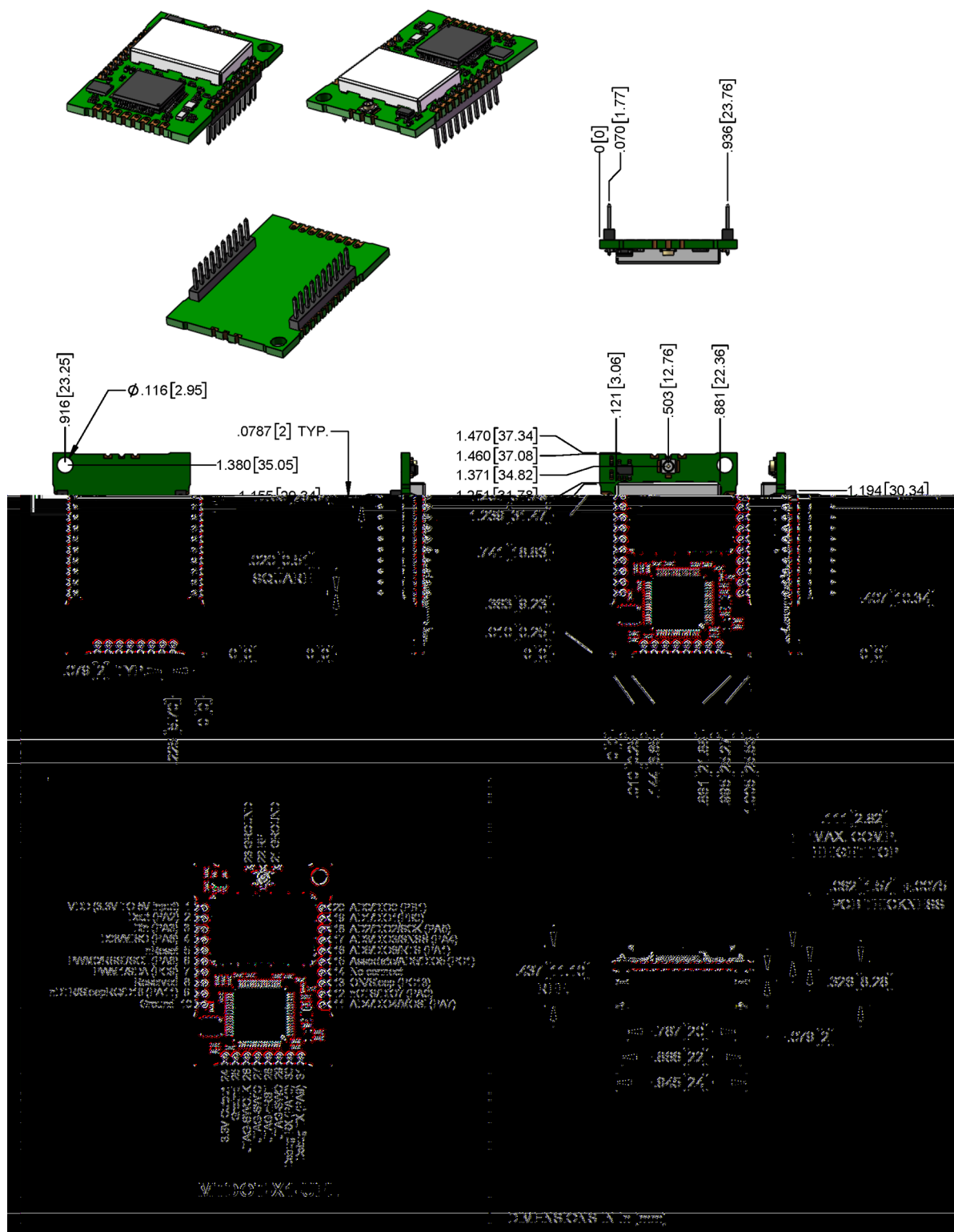
## MTDOT-xxx-X1P-SMA



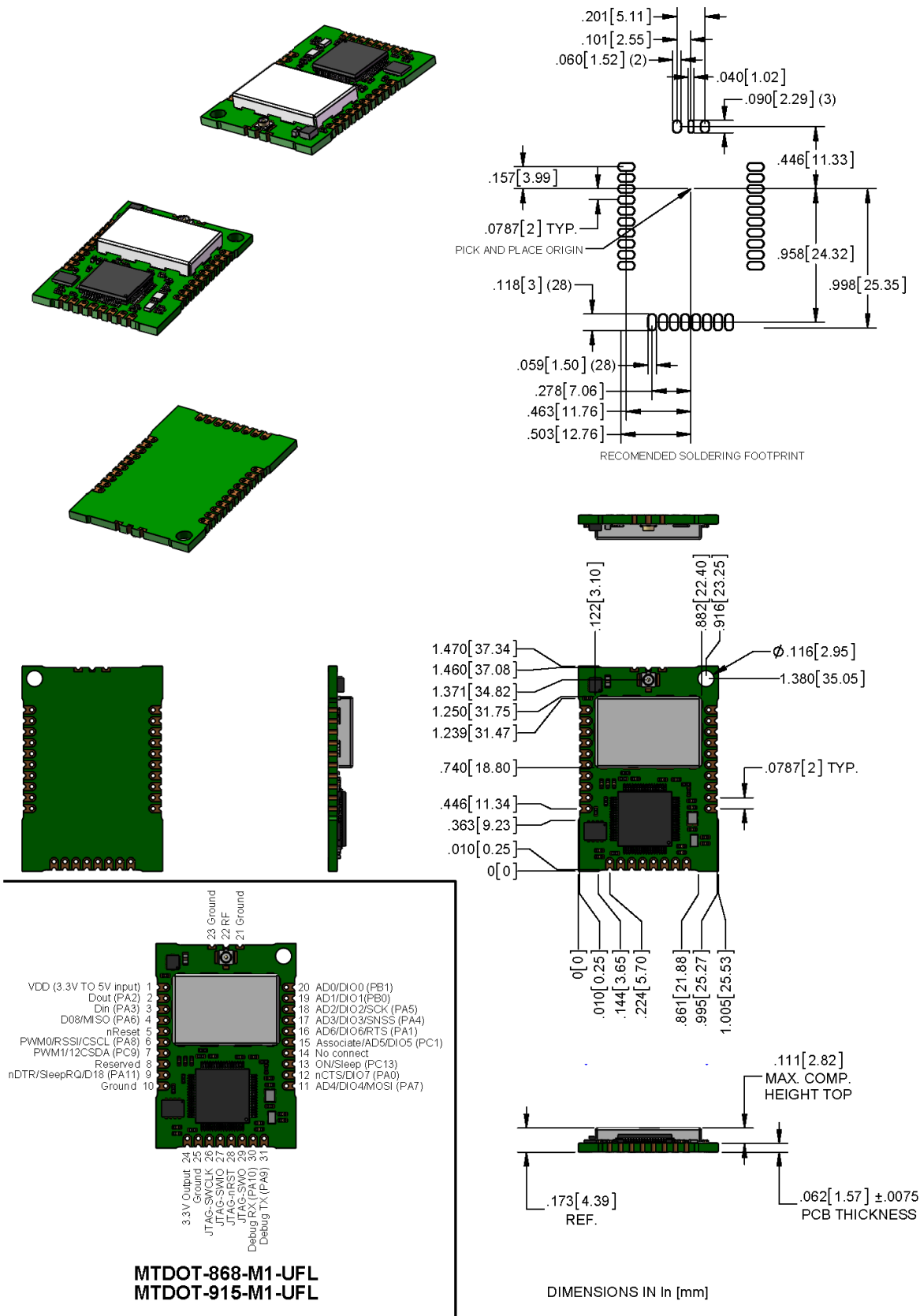
# MTDOT-xxx-X1-SMA



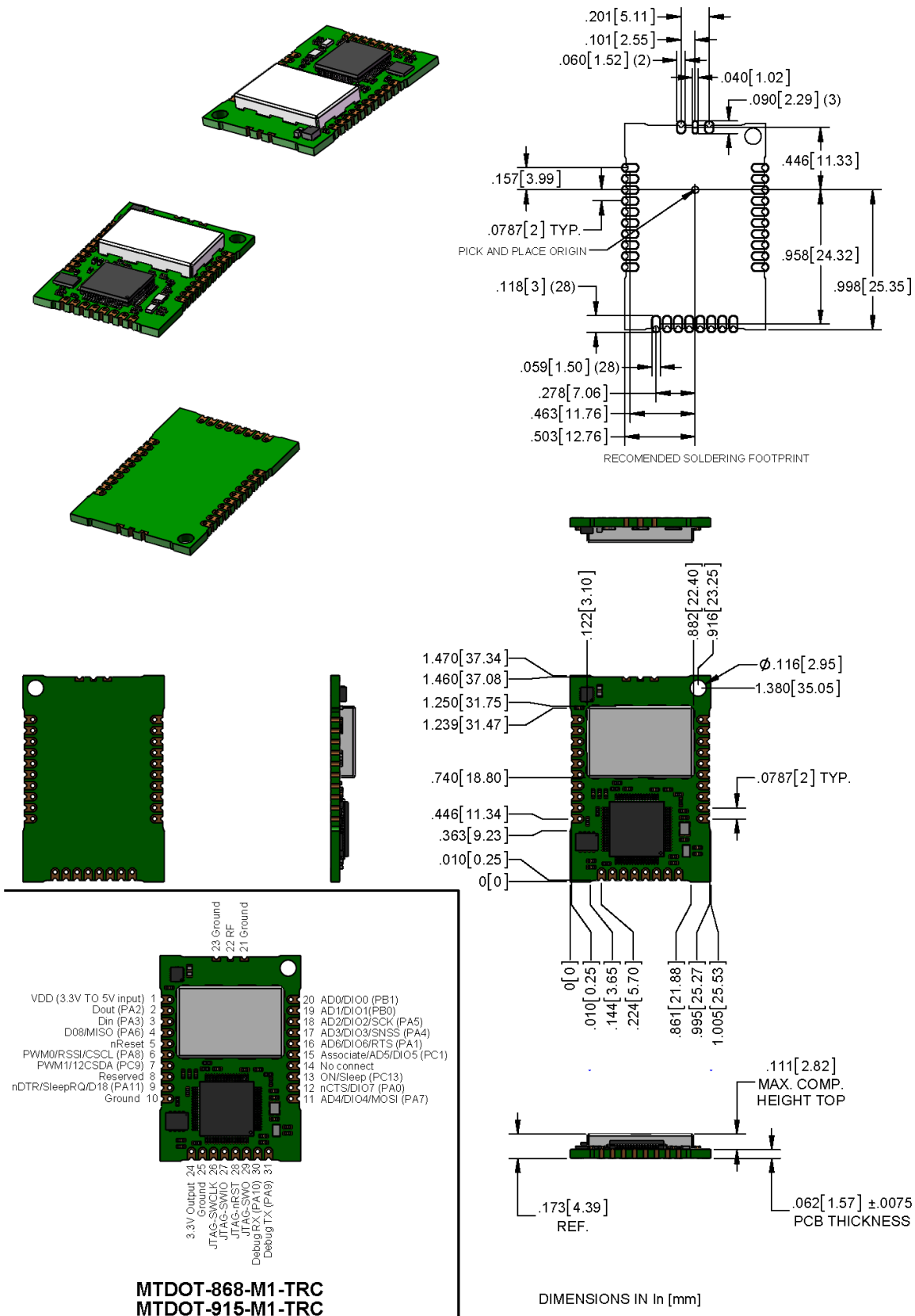
## MTDOT-xxx-X1-UFL



# MTDOT-xxx-M1-UFL



# MTDOT-xxx-M1-TRC



## Chapter 5 – Specifications and Pin Information

### MTDOT Specifications

| Category                    | Description                                                       |
|-----------------------------|-------------------------------------------------------------------|
| <b>General</b>              |                                                                   |
| Compatibility               | LoRaWAN 1.0.4 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)                                           |
| <b>CPU Performance</b>      |                                                                   |
| CPU                         | STM32                                                             |
| Max Clock                   | 96 MHz                                                            |
| Flash Memory                | 512 KB (400 KB available)                                         |
| RAM                         | 128 KB                                                            |
| <b>Radio Frequency</b>      |                                                                   |
| ISM Bands                   | EU 863 MHz - 868 MHz, NAM 902 MHz - 928 MHz, AU 915 MHz - 928 MHz |
| <b>Physical Description</b> |                                                                   |
| Weight <sup>1</sup>         | 0.2 oz. (5g)                                                      |
| Dimensions                  | Refer to Mechanical Drawings for Dimensions.                      |
| <b>RF Connectors</b>        |                                                                   |
| SMA Models                  | SMA                                                               |
| UFL Models                  | U.FL                                                              |
| Trace Models                | Trace Connection                                                  |
| <b>Environment</b>          |                                                                   |
| Operating Temperature       | -40° C to +85° C                                                  |
| Storage Temperature         | -40° C to +85° C                                                  |
| Humidity                    | 20%-90% RH, non-condensing                                        |
| <b>Power Requirements</b>   |                                                                   |
| Operating Voltage           | 3.3 V to 5 V (See Important note regarding voltage)               |

| Category                             | Description                  |
|--------------------------------------|------------------------------|
| <b>Certifications and Compliance</b> |                              |
| 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               |

<sup>1</sup>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 <sup>2</sup>                     |                         |                       |
|                                               | North America/Australia | EMEA                  |
| Max Transmitter Power Output (TPO)            | 19 dBm                  | 14 dBm                |
| Maximum Receive Sensitivity                   | -137 dBm                | -137 dBm              |
| Link Budget <sup>3</sup>                      | 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 <sup>4</sup> | EMEA Typical Sensitivity <sup>5</sup> |
| 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                              |

<sup>2</sup>Using the Pulse Electronics W1063 antenna, described in the *Chapter 4, Antennas*.

<sup>3</sup>Greater link budget is possible with higher gain antenna.

<sup>4</sup>RFS\_L500: RF sensitivity, Long-Range Mode, highest LNA gain, LNA boost, 500 kHz bandwidth using split Rx/Tx path.

<sup>5</sup>RFS\_L125: RF sensitivity, Long-Range Mode, highest LNA gain, LNA boost, 125 kHz bandwidth using split Rx/Tx path.

<sup>2</sup>Using the Pulse Electronics W1063 antenna, described in the *Chapter 4, Antennas*.

<sup>3</sup>Greater link budget is possible with higher gain antenna.

<sup>4</sup>RFS\_L500: RF sensitivity, Long-Range Mode, highest LNA gain, LNA boost, 500 kHz bandwidth using split Rx/Tx path.

<sup>5</sup>RFS\_L125: RF sensitivity, Long-Range Mode, highest LNA gain, LNA boost, 125 kHz bandwidth using split Rx/Tx path.

## LoRa Transmission Output Power

### 868 Models

Max output 25 dBm

| Power | Frequency   | On Power-up (dBm) | 18 Hours After Power-up (dBm) | Bandwidth |
|-------|-------------|-------------------|-------------------------------|-----------|
| 27    | 869.525 MHz | 24.18             | 25                            | 125 kHz   |
| 27    | 869.525 MHz | 24.18             | 24.83                         | 250 kHz   |

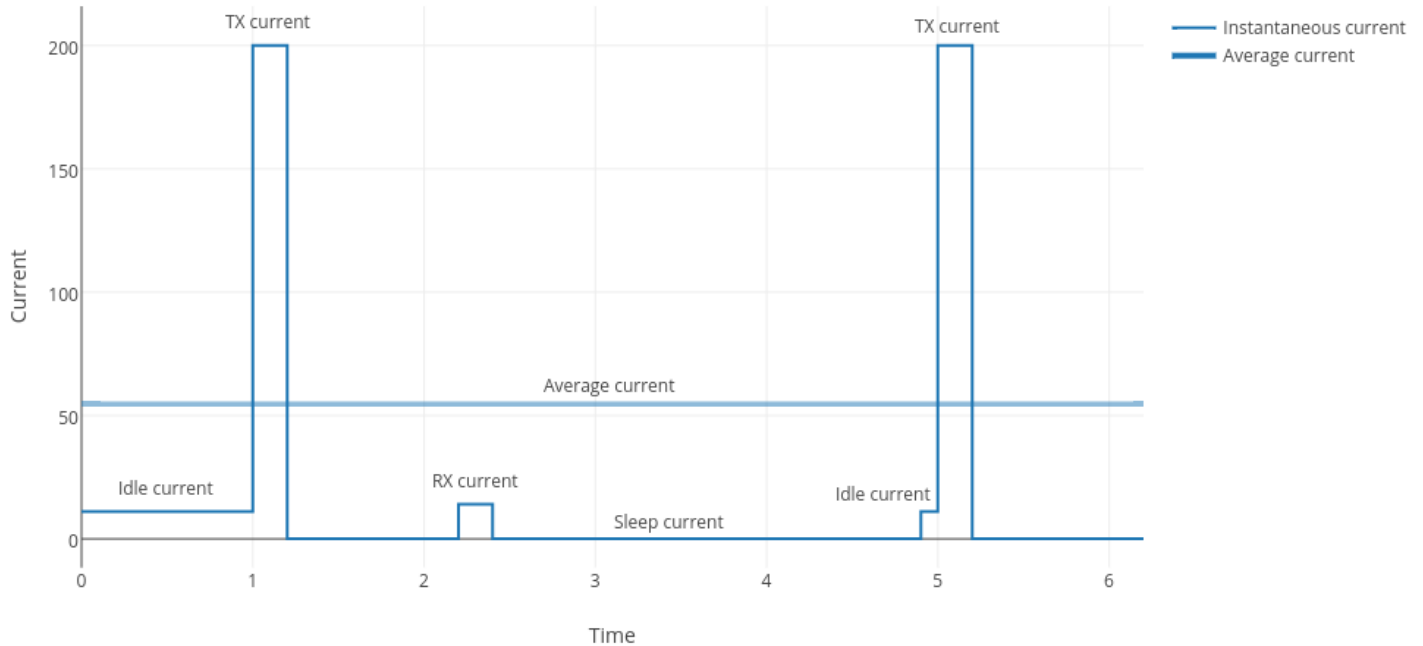
### 915 Models

Max output 27 dBm

| Power | Frequency | On Power-up (dBm) | 18 Hours After Power-up (dBm) | Bandwidth |
|-------|-----------|-------------------|-------------------------------|-----------|
| 26    | 923.3 MHz | 26.58             | 25.88                         | 500 kHz   |
| 26    | 925.1 MHz | 26.76             | 26.34                         | 500 kHz   |
| 26    | 927.5 MHz | 27.22             | 26.8                          | 500 kHz   |

## 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.



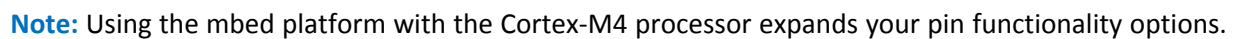
Use the current consumption values from the following Electrical Characteristics table when calculating average power consumption.

## Electrical and Timing 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    |
| T <sub>NRESET</sub>      | NRESET minimum pulse duration | --                                                                                                                                   | 1   | --      | --  | ms    |
| V <sub>NRESET</sub> Low  | NRESET input low level        | --                                                                                                                                   | --  | --      | 0.9 | V     |
| V <sub>NRESET</sub> High | NRESET input high level       | Note: The mDot has an internal pull-up resistor.                                                                                     | 2.1 | --      | --  | V     |



| mDot Pin | STM32411 (Where applicable) | SW Name    | Notes                                           |
|----------|-----------------------------|------------|-------------------------------------------------|
| 1        |                             |            | 3.3 V to 5 V input                              |
| 2        | PA2                         | UART_TX    | GPIO                                            |
| 3        | PA3                         | UART_RX    | GPIO                                            |
| 4        | PA6                         | SPI1_MISO  |                                                 |
| 5        | NRST                        | Reset      | nReset input                                    |
| 6        | PA8                         | I2C_SCL    | I2C clock                                       |
| 7        | PC9                         | I2C_SDA    | I2C Serial data                                 |
| 8        | PA12                        |            | GPIO                                            |
| 9        | PA11                        | SLEEP_RQ   | GPIO                                            |
| 10       | VSSA/VSS_3/VSS_4            |            | Ground for VCC                                  |
| 11       | PA7                         | SPI1_MOSI  |                                                 |
| 12       | PA0-WKUP                    | GPIO5      | Wake up from low power modes on rising edge     |
| 13       | PC13                        | ON_SLEEP   | Sleep On                                        |
| 14       | No Connect                  |            | Not routed on board                             |
| 15       | PC1                         | ASSOCIATE  | GPIO                                            |
| 16       | PA1                         | GPIO4      | GPIO                                            |
| 17       | PA4                         | SPI1_CS    |                                                 |
| 18       | PA5                         | SPI1_SCK   |                                                 |
| 19       | PB0                         | GPIO1      |                                                 |
| 20       | PB1                         | GPIO0      |                                                 |
| 24       | VDDA                        |            | 3V @25ma reference voltage                      |
| 25       | VSSA/VSS_3/VSS_4            |            | Ground                                          |
| 26       | PA14                        | JTMS-SWCLK | STMicro - JTAG Clock /Serial Wire Debug Clock   |
| 27       | PA13                        | JTMS-SWIO  | STMicro - JTAG Data I/O /Serial Wire Debug Data |
| 28       | PB4                         | JTMS-nRst  | STMicro - JTAG reset                            |
| 29       | PB3                         | JTDO-SO    | STMicro - SWO - Trace View                      |
| 30       | PA10                        | USB_RX     | Debug RX routes to USB on developer board       |
| 31       | PA9                         | USB_TX     | Debug TX routes to USB on developer board       |

## SPI Flash

**Note:** Using the SPI Flash, Micron M25P16 Family.

| Pin   | Function    | Description                                                                                            |
|-------|-------------|--------------------------------------------------------------------------------------------------------|
| PC_12 | SPI3_MOSI   | SPI serial data                                                                                        |
| PC_11 | SPI3_MISO   | SPI serial data                                                                                        |
| PC_10 | SPI3_SCK    | SPI clock                                                                                              |
| PC_6  | SPI3_CS     | SPI chip select                                                                                        |
| PC_7  | FLASH_HOLD# | Use the HOLD# signal to pause any serial communications with the device without deselecting the device |
| PC_8  | FLASH_WP#   | Flash write protect                                                                                    |

### Pull-Up/Down

| mDot Pin | Pin Name | SW Name   | PU/PD   |
|----------|----------|-----------|---------|
| 5        | NRST     | NRESET    | 10K PU  |
|          | PB12     | LORA_NSS  | 100K PU |
|          | PC6      | SPI3_NCS  | 10K PU  |
|          | P88      | Flash_WPn | 10K PD  |
|          | PB4      | NRESET    | 10K PU  |

### LoRa

| Pin              | Function   |
|------------------|------------|
| PC_0             | LORA_RESET |
| PC_2             | LORA_RXCTL |
| PC_3             | LORA_TXCTL |
| PB_5             | LORA_DIO0  |
| PB_6             | LORA_DIO1  |
| PB_7             | LORA_DIO2  |
| PB_8             | LORA_DIO3  |
| PB_9             | LORA_DIO4  |
| PB_10            | LORA_DIO5  |
| <b>LoRa/SPI2</b> |            |
| PB_12            | LORA_NSS   |
| PB_13            | LORA_RXCTL |
| PB_14            | LORA_MISO  |
| PB_15            | LORA_MOSI  |

## Crystals/Oscillator

| Pin         | Description             |
|-------------|-------------------------|
| PC14        | Real-time clock         |
| PC15        | Real-time clock         |
| PH0-OSC_IN  | High speed system clock |
| PH1-OSC_OUT | High speed system clock |

## Route Pads

For U.FL models, use the U.FL connector or route pads as follows. These are also available on trace models.

| Pads | Function | Description           |
|------|----------|-----------------------|
| 21   | GND      | RF Ground for antenna |
| 22   |          | RF Antenna In/Out     |
| 23   | GND      | RF Ground for antenna |

## mDot Pinout Design Notes

Refer to the mechanical drawing for your model for pin locations.

- All pins that go to connectors are directly connected to the processor.
- Reset is the only pin with pull up.
- I/O is 5V tolerant.

mDots allow you to program pins depending on your application:

- **Serial:** Available out of the box. See Serial Pinout Notes for details.
- **mbed:** Designed with the mbed STM32F411 RET 64-pin processor, this option provides the most flexibility. For more information about processor capabilities, see the STM32F411 RET datasheet.

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

## Serial Pinout Notes

Out of the box, these pins are available for serial applications. Refer to the mechanical drawing for your model for pin locations.

- 2 Dout/TX
- 3 Din/RX
- 9 DTR
- 12 CTS
- 13 On/Sleep
- 16 RTS

## LoRa

### Throughput Rates

Theoretical maximum speeds for LoRa mode with ACKs off are:

- Using spreading factor 7 at 125kHz, the throughput rate is 5470 bps (5.47 kbps).
- Using spreading factor 7 at 500kHz the receiving throughput rate is 21900 bps (21.9 kbps).

**Note:** Data rates in the LoRaWAN specification vary by geographic region.

### Range

Variables effecting the range include TX power, antenna gain, RX sensitivity, fade margin, earth's curvature. Use the following formula to calculate the maximum range:

$$Range_{Miles} = 10^{\left(\frac{TxPower + Antenna\ gain\ total - RX\ Sensitivity - Fade\ Margin - 36.56}{20}\right) - LOG_{10}(F_{MHz})}$$

The following table provides example settings and the theoretical maximum range based on these settings.

| Example   | 18dB Transmit Power for 915 MHz Models | Units | Example 14dB Transmit Power for 868MHz Models |
|-----------|----------------------------------------|-------|-----------------------------------------------|
| Frequency | 915                                    | MHz   | 868                                           |

| Example                     | 18dB Transmit Power for 915 MHz Models | Units | Example 14dB Transmit Power for 868MHz Models |
|-----------------------------|----------------------------------------|-------|-----------------------------------------------|
| TX Power                    | 19                                     | dBm   | 14                                            |
| TX Antenna Gain             | 3                                      | dB    | 3                                             |
| RX Sensitivity <sup>1</sup> | -120                                   | dBm   | -120                                          |
| RX Antenna Gain             | 3                                      | dB    | 3                                             |
| Fade Margin <sup>2</sup>    | 30                                     | dB    | 30                                            |
| Distance                    | 8.14                                   | Miles | 5.41                                          |
| Distance                    | 13.08                                  | Km    | 8.70                                          |

<sup>1</sup>RX Sensitivity is set to a conservative -120dBm, but can vary from -117 to -137dBm.

<sup>2</sup>Fade Margin is set at the worst case of 30dB. Fade margin is an allowance a system designer includes to account for unknown variables. The higher the fade margin, the better the overall link quality will be. With a fade margin set to zero, the link budget is still valid, but only in LOS conditions, which is not practical for most designs. The amount of fade margin to include in a calculation depends on the environment in which you will deploy the system. A fade margin of 12 dBm is good, but a better number would be 20 to 30 dBm.

## Resetting the mDot

To reset the mDot

1. Drive the RESET signal low for at least  $T_{NRESET}$ .
2. Select either:
  - Allow RESET to float. The internal pull-up resistor pulls it up.
  - Drive the RESET line high.

The processor starts executing code after the RESET line is high.

## Chapter 6 – Antennas

### Antenna System

The LoRa antenna performance depends on the implementation and antenna design. The integration of the antenna system into the product is a critical part of the design process; therefore, it is essential to consider it early so the performance is not compromised. If changes are made to the device's certified antenna system, then recertification will be required.

This radio transmitter has been approved with the antenna types listed below. The antenna used must maintain the same specifications. The antenna must be of the same type, with similar in-band and out-of-band radiation patterns. Antenna types not included on this list, or having a greater gain than the maximum gain indicated for the listed type, are strictly prohibited for use with this device.

### U.FL and Trace Antenna Options

Currently, FCC approval includes Pulse Electronics SMA antenna only. If using U.FL or trace antennas, note the following:

- **For a simple trace to RF antennas:** Routing must follow standard RF design rules and practices for stripline/microstrip for a 50 ohm impedance line. Use the developer board schematics for a reference circuit for the trace antenna. This option may require additional certification testing.
- **For U.FL antennas:** The antenna and cable combination in your design cannot exceed the performance of the SMA antenna as listed in the next topic.
- To design a custom antenna (PCB trace antenna, chip antenna, PCB trace leading to external antenna connection) do not connect anything to the U.FL connector. Use the RF pin for this connection.

### LoRa Antenna

|               |                                |
|---------------|--------------------------------|
| Manufacturer: | Pulse Electronics              |
| Description:  | 868-928 MHz RP-SMA Antenna, 8" |
| Model Number: | W1063                          |

#### MultiTech ordering information:

| Ordering Part Number | Quantity |
|----------------------|----------|
| AN868-915A-1HRA      | 1        |
| AN868-915A-10HRA     | 10       |
| AN868-915A-50HRA     | 50       |

### LoRa Antenna Specifications

| Category        | Description |
|-----------------|-------------|
| Frequency Range | 868-928 MHz |
| Impedance       | 50 Ohms     |

| Category     | Description |
|--------------|-------------|
| VSWR         | $\leq 2.0$  |
| Gain         | 3.0 dBi     |
| Radiation    | Omni        |
| Polarization | Vertical    |

## OEM Integration

### FCC & IC Information to Consumers

The user manual for the consumer must contain the statements required by the following FCC and IC regulations: 47 C.F.R. 15.19(a)(3), 15.21, 15.105 and RSS-Gen Issue 3, Dec 2010; 7.1.2 and 7.1.3

### FCC Grant Notes

The OEM should follow all the grant notes listed below. Otherwise, further testing and device approvals may be necessary.

#### FCC Definitions

**Portable: (§2.1093)** — A portable device is defined as a transmitting device designed to be used so that the radiating structure(s) of the device is/are within 20 centimeters of the body of the user.

**Mobile: (§2.1091)** — A mobile device is defined as a transmitting device designed to be used in other than fixed locations and to generally be used in such a way that a separation distance of at least 20 centimeters is normally maintained between the transmitter's radiating structure(s) and the body of the user or nearby persons.

**Actual content pending Grant:** *This device is a mobile device with respect to RF exposure compliance. The antenna(s) used for this transmitter must be installed to provide a separation distance of at least 20 cm from all persons, and must not be collocated or operate in conjunction with any other antenna or transmitter except in accordance with FCC multi-transmitter product guidelines. Installers and end-users must be provided with specific information required to satisfy RF exposure compliance for installations and final host devices. (See note under Grant Limitations.) Compliance of this device in all final host configurations is the responsibility of the Grantee.*

**Note:** Host design configurations constituting a device for portable use (<20 cm from human body) require separate FCC/IC approval.

### Host Labeling

The following statements are required to be on the host label:

This device contains FCC ID: {Add the FCC ID of the specific device}

This device contains equipment certified under IC ID: {Add the IC ID of the specific device}

For additional labeling requirements, see the product's Labeling Requirements. For the FCC and IC IDs, see specific certificate information in the Regulatory Statement chapter.

## Chapter 7 – Safety Information

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### Handling Precautions

To avoid damage due to the accumulation of static charge use proper precautions, such as an ESD strap, when handling any cellular device to avoid exposure to electronic discharge during handling and mounting the device.

### Radio Frequency (RF) Safety

Due to the possibility of radio frequency (RF) interference, it is important that you follow any special regulations regarding the use of radio equipment. Follow the safety advice given below.

- Operating your device close to other electronic equipment may cause interference if the equipment is inadequately protected. Observe any warning signs and manufacturers' recommendations.
- Different industries and businesses restrict the use of cellular devices. Respect restrictions on the use of radio equipment in fuel depots, chemical plants, or where blasting operations are in process. Follow restrictions for any environment where you operate the device.
- Do not place the antenna outdoors.
- Switch OFF your wireless device when in an aircraft. Using portable electronic devices in an aircraft may endanger aircraft operation, disrupt the cellular network, and is illegal. Failing to observe this restriction may lead to suspension or denial of cellular services to the offender, legal action, or both.
- Switch OFF your wireless device when around gasoline or diesel-fuel pumps and before filling your vehicle with fuel.
- Switch OFF your wireless device in hospitals and any other place where medical equipment may be in use.

### Sécurité relative aux appareils à radiofréquence (RF)

À cause du risque d'interférences de radiofréquence (RF), il est important de respecter toutes les réglementations spéciales relatives aux équipements radio. Suivez les conseils de sécurité ci-dessous.

- Utiliser l'appareil à proximité d'autres équipements électroniques peut causer des interférences si les équipements ne sont pas bien protégés. Respectez tous les panneaux d'avertissement et les recommandations du fabricant.
- Certains secteurs industriels et certaines entreprises limitent l'utilisation des appareils cellulaires. Respectez ces restrictions relatives aux équipements radio dans les dépôts de carburant, dans les usines de produits chimiques, ou dans les zones où des dynamitages sont en cours. Suivez les restrictions relatives à chaque type d'environnement où vous utiliserez l'appareil.
- Ne placez pas l'antenne en extérieur.
- Éteignez votre appareil sans fil dans les avions. L'utilisation d'appareils électroniques portables en avion est illégale: elle peut fortement perturber le fonctionnement de l'appareil et désactiver le réseau cellulaires. S'il ne respecte pas cette consigne, le responsable peut voir son accès aux services cellulaires suspendu ou interdit, peut être poursuivi en justice, ou les deux.
- Éteignez votre appareil sans fil à proximité des pompes à essence ou de diesel avant de remplir le réservoir de votre véhicule de carburant.
- Éteignez votre appareil sans fil dans les hôpitaux ou dans toutes les zones où des appareils médicaux sont susceptibles d'être utilisés.

## Interference with Pacemakers and Other Medical Devices

### Potential interference

Radio frequency energy (RF) from cellular devices can interact with some electronic devices. This is electromagnetic interference (EMI). The FDA helped develop a detailed test method to measure EMI of implanted cardiac pacemakers and defibrillators from cellular devices. This test method is part of the Association for the Advancement of Medical Instrumentation (AAMI) standard. This standard allows manufacturers to ensure that cardiac pacemakers and defibrillators are safe from cellular device EMI.

The FDA continues to monitor cellular devices for interactions with other medical devices. If harmful interference occurs, the FDA will assess the interference and work to resolve the problem.

### Precautions for pacemaker wearers

If EMI occurs, it could affect a pacemaker in one of three ways:

- Stop the pacemaker from delivering the stimulating pulses that regulate the heart's rhythm.
- Cause the pacemaker to deliver the pulses irregularly.
- Cause the pacemaker to ignore the heart's own rhythm and deliver pulses at a fixed rate.

Based on current research, cellular devices do not pose a significant health problem for most pacemaker wearers. However, people with pacemakers may want to take simple precautions to be sure that their device doesn't cause a problem.

- Keep the device on the opposite side of the body from the pacemaker to add extra distance between the pacemaker and the device.
- Avoid placing a turned-on device next to the pacemaker (for example, don't carry the device in a shirt or jacket pocket directly over the pacemaker).

## Device Maintenance

Do not attempt to disassemble the device. There are no user serviceable parts inside.

When maintaining your device:

- Do not misuse the device. Follow instructions on proper operation and only use as intended. Misuse could make the device inoperable, damage the device and/or other equipment, or harm users.
- Do not apply excessive pressure or place unnecessary weight on the device. This could result in damage to the device or harm to users.
- Do not use this device in explosive or hazardous environments unless the model is specifically approved for such use. The device may cause sparks. Sparks in explosive areas could cause explosion or fire and may result in property damage, severe injury, and/or death.
- Do not expose your device to any extreme environment where the temperature or humidity is high. Such exposure could result in damage to the device or fire. Refer to the device specifications regarding recommended operating temperature and humidity.
- Do not expose the device to water, rain, or spilled beverages. It is not waterproof. Exposure to liquids could result in damage to the device.
- Do not place the device alongside computer discs, credit or travel cards, or other magnetic media. The information contained on discs or cards may be affected by the device.

- Using accessories, such as antennas, that MultiTech has not authorized or that are not compliant with MultiTech's accessory specifications may invalidate the warranty.

If the device is not working properly, contact MultiTech Technical Support.

## User Responsibility

Respect all local regulations for operating your wireless device. Use the security features to block unauthorized use and theft.

## Chapter 8 – Regulatory Information

### EMC, Safety, and Radio Equipment Directive (RED) Compliance



The CE mark is affixed to this product to confirm compliance with the following European Community Directives:

Council Directive 2011/65/EU on the restriction of the use of certain hazardous substances in electrical and electronic equipment;  
and  
Council Directive 2014/53/EU on radio equipment and telecommunications terminal equipment and the mutual recognition of their conformity.

MultiTech declares that this device is in compliance with the essential requirements and other relevant provisions of Directive 2014/53/EU. The declaration of conformity may be requested at <https://www.multitech.com/landing-pages/events/campaigns/promotions/products/certifications/red-certifications>.

### 47 CFR Part 15 Regulation Class B Devices

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 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.

**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.

### FCC Interference Notice

Per FCC 15.19(a)(3) and (a)(4) 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 Grant

### FCC Part 15

|                         |                             |
|-------------------------|-----------------------------|
| <b>FCC Identifier:</b>  | AU792U13A16857              |
| <b>Equipment Class:</b> | Digital Transmission System |
| <b>Notes:</b>           | MTDOT-915                   |
| <b>FCC Rule Parts:</b>  | 15C                         |
| <b>Approval:</b>        | Single Modular              |
| <b>Frequency Range:</b> | 902.3-914.9                 |
| <b>Output Watts:</b>    | 0.0772                      |

Output power is conducted. This transmitter is a hybrid per FCC 15.247(f) and FCC KDB 453039. The antenna(s) used for this transmitter must be installed to provide a separation distance of at least 20 cm from all persons and must not be collocated or operating in conjunction with any other antenna or transmitter within a host device, except in accordance with FCC multi-transmitter product procedures. End-users and installers must be provided with antenna installation instructions and transmitter operating conditions for satisfying RF exposure compliance.

## FCC Notice

Per FCC 15.19(a)(3) and (a)(4) 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.

MTDOT-x products are open development based products that contain a sub GHz radio technology. MultiTech has certified for compliance with US and Foreign compliance bodies including FCC, R&TTE and others. (e.g. FCC 15.247:2015 & IC RSS-210:2010)

This device is open development based product that contains a sub GHz radio technology. MultiTech has certified for compliance with US and Foreign compliance bodies including FCC, R&TTE and others. (e.g. FCC 15.247:2015 & IC RSS-210:2010)

This device is open development based product that contains a sub GHz radio technology. MultiTech has certified for compliance with US and Foreign compliance bodies including FCC, R&TTE and others. (e.g. FCC 15.247:2015 & IC RSS-210:2010)

MultiTech provides software code meant to operate the radio to a level that maintains compliance with the operating modes under which these radio devices were certified. To ensure this level of compliance, the software code is provided in binary form only. Users are prohibited from making any changes that affect the operation of the radio performance. Accessing or controlling the radio through any means other than the provided binary software will require the user to obtain their own intentional radiator license from the certification body governing their locality, as all pre-certification provided with Conduit Base Station IP67 mDot will have been made invalid.

## Industry Canada Class B Notice

This Class B digital apparatus meets all requirements of the Canadian Interference-Causing Equipment Regulations.

Cet appareil numérique de la classe B respecte toutes les exigences du Règlement Canadien sur le matériel brouilleur.

This device complies with Industry Canada license-exempt RSS standard(s). The operation is permitted for the following two conditions:

1. the 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'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

## Industry Canada

|                                                  |                                              |
|--------------------------------------------------|----------------------------------------------|
| <b>Certification Number/No. de Certification</b> | 125A-0054                                    |
| <b>Type of Radio Equipment/Genre de Matériel</b> | Spread Spectrum/Digital Device (902-928MHz)/ |
|                                                  | Modular Approval/Approbation modulaire       |
| <b>Model/Modèle</b>                              | MTDOT-915                                    |

| Specification/<br>Cahier des<br>Charges | Issue/<br>Édition | From<br>Frequency/<br>De<br>Fréquences | To<br>Frequency/<br>À<br>Fréquences | Emission<br>Designation/<br>D'émission | Minimum Power | Maximum<br>Power |
|-----------------------------------------|-------------------|----------------------------------------|-------------------------------------|----------------------------------------|---------------|------------------|
| RSS247                                  | 1.0               | 902.3 MHz                              | 914.9 MHz                           | GXDXX                                  | 77.2 mW       | 77.2 mW          |

Certification of equipment means only that the equipment has met the requirements of the above noted specification. License applications, where applicable to use certified equipment, are acted on accordingly by the Industry Canada issuing office and will depend on the existing radio environment, service and location of operation. This certificate is issued on condition that the holder complies and will continue to comply with the requirements and procedures issued by Industry Canada. The equipment for which this certificate is issued shall not be manufactured, imported distributed, leased, offered for sale or sold unless the equipment complies with the applicable technical specifications and procedures issued by Industry Canada.

La certification du matériel signifie seulement que le matériel a satisfait aux exigences de la norme indiquée ci-dessus. Les demandes de licences nécessaires pour l'utilisation du matériel certifié sont traitées en conséquence par le bureau de délivrance d'Industrie Canada et dépendent des conditions radio ambiantes, du service et de l'emplacement d'exploitation. Le présent certificat est délivré à la condition que le titulaire satisfasse et continue de satisfaire aux exigences et aux procédures d'Industrie Canada. Le matériel à l'égard duquel le présent certificat est délivré ne doit pas être fabriqué, importé, distribué, loué, mis en vente ou vendu à moins d'être conforme aux procédures et aux spécifications techniques applicable publiées par Industrie Canada.

## Chapter 9 – Environmental Notices

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### Waste Electrical and Electronic Equipment Statement

**Note:** This statement may be used in documentation for your final product applications.

#### WEEE Directive

The WEEE Directive places an obligation on EU-based manufacturers, distributors, retailers, and importers to take-back electronics products at the end of their useful life. A sister directive, ROHS (Restriction of Hazardous Substances) complements the WEEE Directive by banning the presence of specific hazardous substances in the products at the design phase. The WEEE Directive covers all MultiTech products imported into the EU as of August 13, 2005. EU-based manufacturers, distributors, retailers and importers are obliged to finance the costs of recovery from municipal collection points, reuse, and recycling of specified percentages per the WEEE requirements.

#### Instructions for Disposal of WEEE by Users in the European Union

The symbol shown below is on the product or on its packaging, which indicates that this product must not be disposed of with other waste. Instead, it is the user's responsibility to dispose of their waste equipment by handing it over to a designated collection point for the recycling of waste electrical and electronic equipment. The separate collection and recycling of your waste equipment at the time of disposal will help to conserve natural resources and ensure that it is recycled in a manner that protects human health and the environment. For more information about where you can drop off your waste equipment for recycling, please contact your local city office, your household waste disposal service or where you purchased the product.

July, 2005



### REACH Statement

#### Registration of Substances

**Multi-Tech Systems, Inc.** confirms that none of its products or packaging contain any of the Substances of Very High Concern (SVHC) on the REACH Candidate List, in a concentration above the 0.1% by weight allowable limit

The latest **197** substances restricted per the REACH Regulation were **last updated January 2019**. Refer to the following for the most current candidate list of substances: <http://echa.europa.eu/candidate-list-table>.

## Restriction of the Use of Hazardous Substances (RoHS)

**Multi-Tech Systems, Inc.**

### **Certificate of Compliance**

#### **2015/863**

Multi-Tech Systems, Inc. confirms that its embedded products comply with the chemical concentration limitations set forth in the directive 2015/863 of the European Parliament (Restriction of the use of certain Hazardous Substances in electrical and electronic equipment - RoHS 3).

These MultiTech products do not contain the following banned chemicals<sup>1</sup>:

- Lead, [Pb] < 1000 PPM
- Mercury, [Hg] < 100 PPM
- Cadmium, [Cd] < 100 PPM
- Hexavalent Chromium, [Cr+6] < 1000 PPM
- Polybrominated Biphenyl, [PBB] < 1000 PPM
- Polybrominated Diphenyl Ethers, [PBDE] < 1000 PPM
- Bis(2-Ethylhexyl) phthalate (DEHP): < 1000 ppm
- Benzyl butyl phthalate (BBP): < 1000 ppm
- Dibutyl phthalate (DBP): < 1000 ppm
- Diisobutyl phthalate (DIBP): < 1000 ppm

Environmental considerations:

- Moisture Sensitivity Level (MSL) =1
- Maximum Soldering temperature = 260C (in SMT reflow oven)

<sup>1</sup>Lead usage in some components is exempted by the following RoHS annex, therefore higher lead concentration would be found in some modules (>1000 PPM);

- Resistors containing lead in a glass or ceramic matrix compound.

## Information on HS/TS Substances According to Chinese Standards

In accordance with China's Administrative Measures on the Control of Pollution Caused by Electronic Information Products (EIP) # 39, also known as China RoHS, the following information is provided regarding the names and concentration levels of Toxic Substances (TS) or Hazardous Substances (HS) which may be contained in Multi-Tech Systems Inc. products relative to the EIP standards set by China's Ministry of Information Industry (MII).

### Hazardous/Toxic Substance/Elements

| Name of the Component            | Lead (PB) | Mercury (Hg) | Cadmium (CD) | Hexavalent Chromium (CR6+) | Polybrominated Biphenyl (PBB) | Polybrominated Diphenyl Ether (PBDE) |
|----------------------------------|-----------|--------------|--------------|----------------------------|-------------------------------|--------------------------------------|
| Printed Circuit Boards           | O         | O            | O            | O                          | O                             | O                                    |
| Resistors                        | X         | O            | O            | O                          | O                             | O                                    |
| Capacitors                       | X         | O            | O            | O                          | O                             | O                                    |
| Ferrite Beads                    | O         | O            | O            | O                          | O                             | O                                    |
| Relays/Opticals                  | O         | O            | O            | O                          | O                             | O                                    |
| ICs                              | O         | O            | O            | O                          | O                             | O                                    |
| Diodes/ Transistors              | O         | O            | O            | O                          | O                             | O                                    |
| Oscillators and Crystals         | X         | O            | O            | O                          | O                             | O                                    |
| Regulator                        | O         | O            | O            | O                          | O                             | O                                    |
| Voltage Sensor                   | O         | O            | O            | O                          | O                             | O                                    |
| Transformer                      | O         | O            | O            | O                          | O                             | O                                    |
| Speaker                          | O         | O            | O            | O                          | O                             | O                                    |
| Connectors                       | O         | O            | O            | O                          | O                             | O                                    |
| LEDs                             | O         | O            | O            | O                          | O                             | O                                    |
| Screws, Nuts, and other Hardware | X         | O            | O            | O                          | O                             | O                                    |
| AC-DC Power Supplies             | O         | O            | O            | O                          | O                             | O                                    |
| Software /Documentation CDs      | O         | O            | O            | O                          | O                             | O                                    |
| Booklets and Paperwork           | O         | O            | O            | O                          | O                             | O                                    |
| Chassis                          | O         | O            | O            | O                          | O                             | O                                    |

**X** Represents that the concentration of such hazardous/toxic substance in all the units of homogeneous material of such component is higher than the SJ/Txxx-2006 Requirements for Concentration Limits.

**O** Represents that no such substances are used or that the concentration is within the aforementioned limits.

## Information on HS/TS Substances According to Chinese Standards (in Chinese)

### 依照中国标准的有毒有害物质信息

根据中华人民共和国信息产业部 (MII) 制定的电子信息产品 (EIP) 标准—中华人民共和国《电子信息产品污染控制管理办法》（第 39 号），也称作中国 RoHS, 下表列出了 Multi-Tech Systems, Inc. 产品中可能含有的有毒物质 (TS) 或有害物质 (HS) 的名称及含量水平方面的信息。

### 有害/有毒物质/元素

| 成分名称         | 铅 (PB) | 汞 (Hg) | 镉 (CD) | 六价铬 (CR6+) | 多溴联苯 (PBB) | 多溴二苯醚 (PBDE) |
|--------------|--------|--------|--------|------------|------------|--------------|
| 印刷电路板        | O      | O      | O      | O          | O          | O            |
| 电阻器          | X      | O      | O      | O          | O          | O            |
| 电容器          | X      | O      | O      | O          | O          | O            |
| 铁氧体磁环        | O      | O      | O      | O          | O          | O            |
| 继电器/光学部件     | O      | O      | O      | O          | O          | O            |
| ICs          | O      | O      | O      | O          | O          | O            |
| 二极管/晶体管      | O      | O      | O      | O          | O          | O            |
| 振荡器和晶振       | X      | O      | O      | O          | O          | O            |
| 调节器          | O      | O      | O      | O          | O          | O            |
| 电压传感器        | O      | O      | O      | O          | O          | O            |
| 变压器          | O      | O      | O      | O          | O          | O            |
| 扬声器          | O      | O      | O      | O          | O          | O            |
| 连接器          | O      | O      | O      | O          | O          | O            |
| LEDs         | O      | O      | O      | O          | O          | O            |
| 螺丝、螺母以及其它五金件 | X      | O      | O      | O          | O          | O            |
| 交流-直流电源      | O      | O      | O      | O          | O          | O            |
| 软件/文档 CD     | O      | O      | O      | O          | O          | O            |
| 手册和纸页        | O      | O      | O      | O          | O          | O            |
| 底盘           | O      | O      | O      | O          | O          | O            |

X 表示所有使用类似材料的设备中有害/有毒物质的含量水平高于 SJ/Txxx-2006 限量要求。

O 表示不含该物质或者该物质的含量水平在上述限量要求之内。

# Chapter 10 – Labels

## Approvals and Certification

In most cases, when integrated and used with an antenna system that was part of the MultiTech modem certification, additional approvals or certifications are not required for the device you develop as long as the following are met.

- **PTCRB Requirements:** The antenna system cannot be altered.
- **Model Identification:** The MultiTech model identification allows the carrier to verify the modem as one of its approved models. This information is located on the modem's label below the bar code.

## Example Labels

**Note:** Actual labels vary depending on the regulatory approval markings and content.

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.

The label shown is not the actual size.

- 1 - MultiTech Model Identification.
- 2 - MultiTech Ordering Part Number.
- 3 - Device Node Number.

Example North America Package Label



North America Device Label



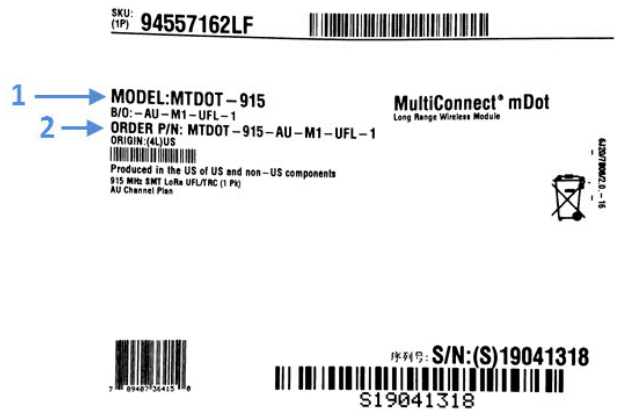
Example EMEA Package Label



EMEA Device Label



### Example Australia Package Label



### Australia Device Label



# Chapter 11 – Developer Kit Overview

## Developer Board Overview

MultiTech offers two Developer Kits for prototyping and developing with the mDot:

- **MTUDK2-ST-MDOT** is a scaled down version of the developer board and kit for the mDot.
- **MTMDK-ST-MDOT** is a mini developer board exclusively for the mDot. If using the Micro DK, go to *Chapter 13 Micro Developer Kit* for details on this developer board.

Developer kits help streamline your development efforts and evaluate your products and applications. Easily plug in your communications device and use the developer kit for testing, programming and evaluation.

**Note:** Developer information in this section applies to using either MTUDK2 developer kit with an mDot; however, the illustrations show the MTUDK2-ST-MDOT model.

## Developer Board Features

- USB and serial interfaces
- USB port for mbed development environment
- Arduino shield socket

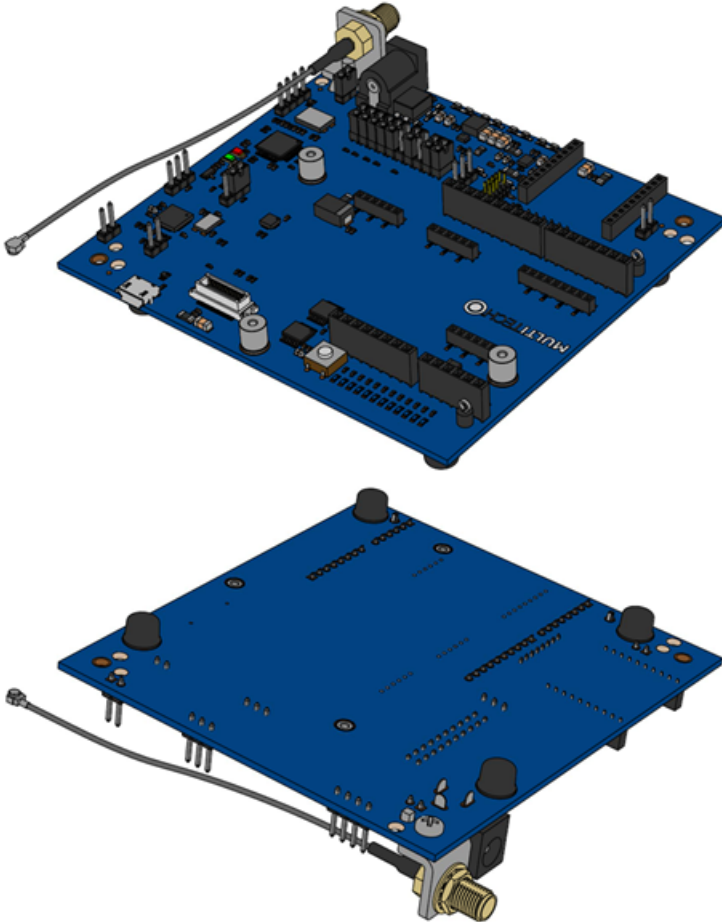
## MTUDK2-ST-MDOT Developer Kit Contents

The MTUDK2-ST-MDOT Developer Kit includes the following:

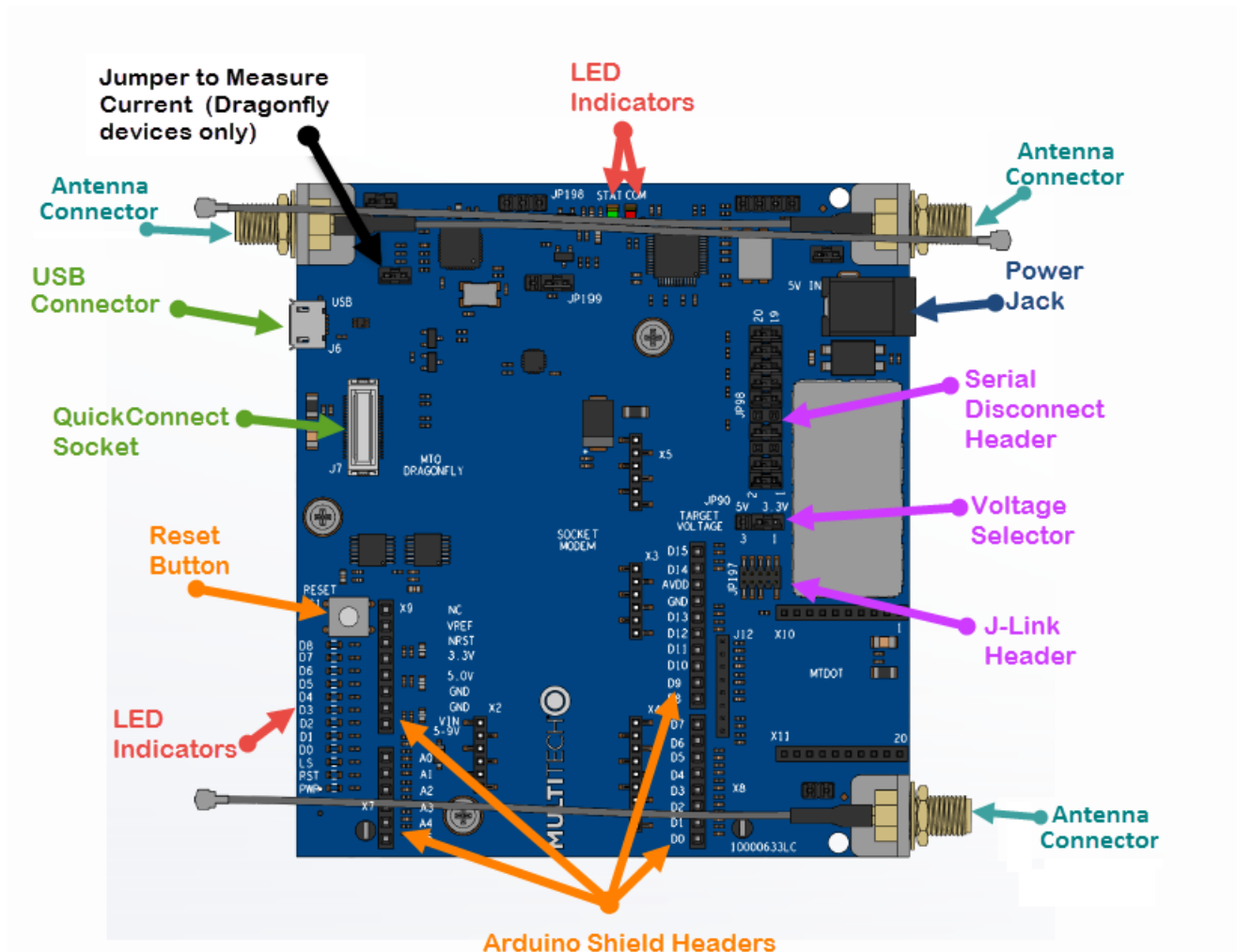
|                  |                                                            |
|------------------|------------------------------------------------------------|
| Developer Board  | 1 - MTUDK 2.0 mDot Developer Board                         |
| Cables           | 1 - Micro USB Cable                                        |
|                  | 1 - RSMA-U.FL Antenna Cables (attached to developer board) |
| Antennas         | 1 - 868-945 MHz Antenna                                    |
| Customer Notices | Quick Start                                                |
| Additional       | One promotional screwdriver                                |

## Chapter 12 – Board Components

### Developer Board



## Developer Board Connectors



**Note:** The development board derives power from the USB connection. The Power Jack connects to the Arduino shield socket. If the Arduino shield needs 5 V, use a 5 V power supply. A 9 V supply will not be regulated down to 5 V.

## Board Components

| Label | Description                                                                                                                                                                                   |
|-------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| J6    | USB connection for mbed, serial, and SocketModem. Attaches to the ST Micro controller. This provides access to two interfaces, one used to program the mDot and the other for debug messages. |
| JP98  | Serial Disconnect Header. Pins D0-D8 are connected to the Arduino headers and the DB9 serial port. Remove these jumpers to disconnect from the RS232 transceiver chip.                        |
| JP197 | J-Link Header used for JTAG access to the mDot. This requires installing resistors R94-96 & 98 and removing R88-990 & 92. See <a href="#">Chapter 12 Developer Board Schematics</a> .         |
| S1    | Reset Button. Use to reset the processor of the device attached to the board.                                                                                                                 |

| Label | Description               |
|-------|---------------------------|
| X6    | Arduino Shield Connector. |
| X7    | Arduino Shield Connector. |
| X8    | Arduino Shield Connector. |
| X9    | Arduino Shield Connector. |
| X10   | MTDOT Connector.          |
| X11   | MTDOT Connector.          |
| J12   | MTDOT Programming Header. |

**CAUTION:** Take care when connecting or disconnecting USB cables to avoid detaching the connector from the board.

## LED Indicators

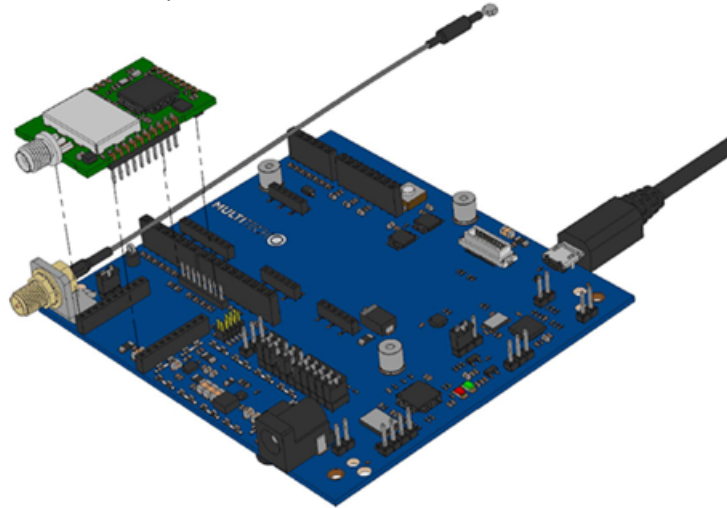
| Label | LED   | Location                                  |
|-------|-------|-------------------------------------------|
| STAT  | LED1  | Near JP198                                |
| COM   | LED2  | Near JP198                                |
| D7    | LED3  | Across the mDot connectors.               |
| D6    | LED7  | Directly across from the mDot connectors. |
| D3    | LED8  | Directly across from the mDot connectors. |
| D0    | LED9  | Directly across from the mDot connectors. |
| D1    | LED10 | Directly across from the mDot connectors. |
| RST   | LED12 | Directly across from the mDot connectors. |
| PWR   | LED13 | Directly across from the mDot connectors. |
| D2    | LED14 | Directly across from the mDot connectors. |

## Chapter 13 – Chapter 11 Developer Board Installation

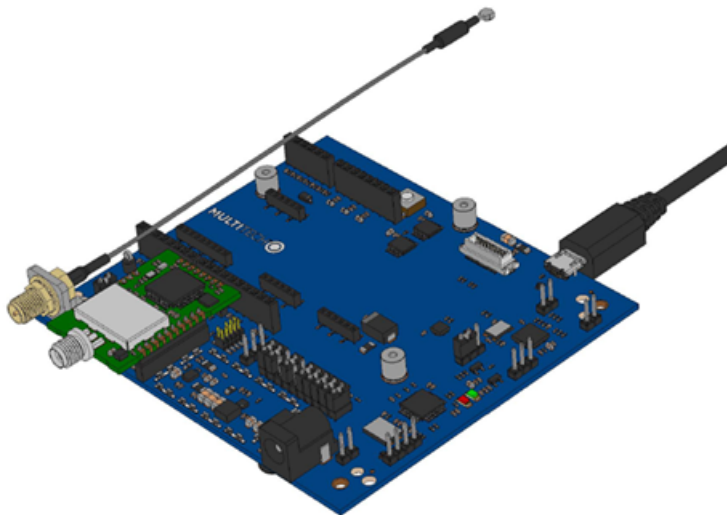
### Installing an mDot on the Developer Board

To install an mDot on the Developer Board:

1. Align the mDot with the developer board as shown.



2. Gently press the mDot into the connectors.



## Arduino Shield

### mDot Arduino Pins

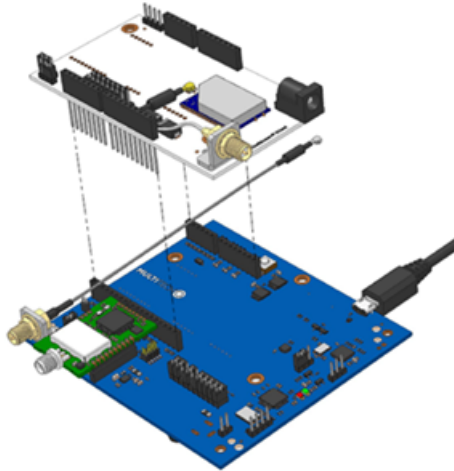
| Signals (module pin) micro pin |    | Arduino Shield |      |  |      | Signals (module pin) micro pin |                           |
|--------------------------------|----|----------------|------|--|------|--------------------------------|---------------------------|
|                                |    |                |      |  | D15  |                                | PWM0/RSSI/I2CSCL (6) PA8  |
|                                |    |                |      |  | D14  |                                | PWM1/I2CSDA (7) PC9       |
|                                |    |                |      |  | AVDD |                                | 3.3V                      |
|                                |    |                |      |  | GND  |                                | Ground                    |
|                                |    |                |      |  | D13  | X6                             | AD2/DIO2/SCK (18) PA5     |
| 3.3V                           |    |                | NC   |  | D12  |                                | DO8/MISO (4) PA6          |
| nReset, from pushbutton        |    |                | VREF |  | D11  |                                | AD4/DIO4/MOSI (11) PA7    |
| 3.3V                           |    |                | nRST |  | D10  |                                | AD3/DIO3/SNSS (17) PA4    |
| 5.0V                           | X9 |                | 3.3V |  | D9   |                                | no connect                |
| Ground                         |    |                | 5.0V |  | D8   |                                | no connect                |
| Ground                         |    |                | GND  |  |      |                                |                           |
| Ground                         |    |                | GND  |  |      |                                |                           |
| 5-9V input from J3             |    |                | VIN  |  | D7   |                                | nDTR/SleepRQ/DI8 (9) PA11 |
|                                |    |                |      |  | D6   |                                | nRTS/AD6/DIO6 (16) PA1    |
| AD0/DIO0 (20) PB1              |    |                |      |  | D5   |                                | no connect                |
| AD1/DIO1 (19) PB0              |    |                | A0   |  | D4   | X8                             | no connect                |
| Associate/AD5/DIO5 (15) PC1    | X7 |                | A1   |  | D3   |                                | nCTS/DIO7 (12) PA0        |
| no connect                     |    |                | A2   |  | D2   |                                | ON/nSleep (13) PC13       |
| no connect                     |    |                | A3   |  | D1   |                                | Dout (2) PA2              |
| no connect                     |    |                | A4   |  | D0   |                                | Din (3) PA3               |
|                                |    |                | A5   |  |      |                                |                           |

### Installing an Arduino Shield with an mDot

**Note:** When using an Arduino Shield with an mDot, install the mDot on the developer board before installing the Arduino shield.

To use an Arduino Shield with an mDot:

1. Disable the developer card's serial port by removing jumper from JP95.
  - Jumper pins 1-2: Disable U5 on USB VCC high.
  - Jumper pins 2-3: U5 always disabled.
  - Default jumper position is on pins 1-2.
2. Align the Arduino Shield on the developer board as shown.



## RSMA to U.FL Cables

The developer kit includes one 4.5" RSMA to U.FL cables which is preinstalled on the developer board.



## Connecting an Antenna through the Developer Board Connectors

Depending on the device model, you can either connect antennas directly to the device or through the RSMA-to-U.FL antenna cable on the developer board.

To connect an antenna to the device through the developer board:

1. Finger tighten the antenna to the SMA connector.

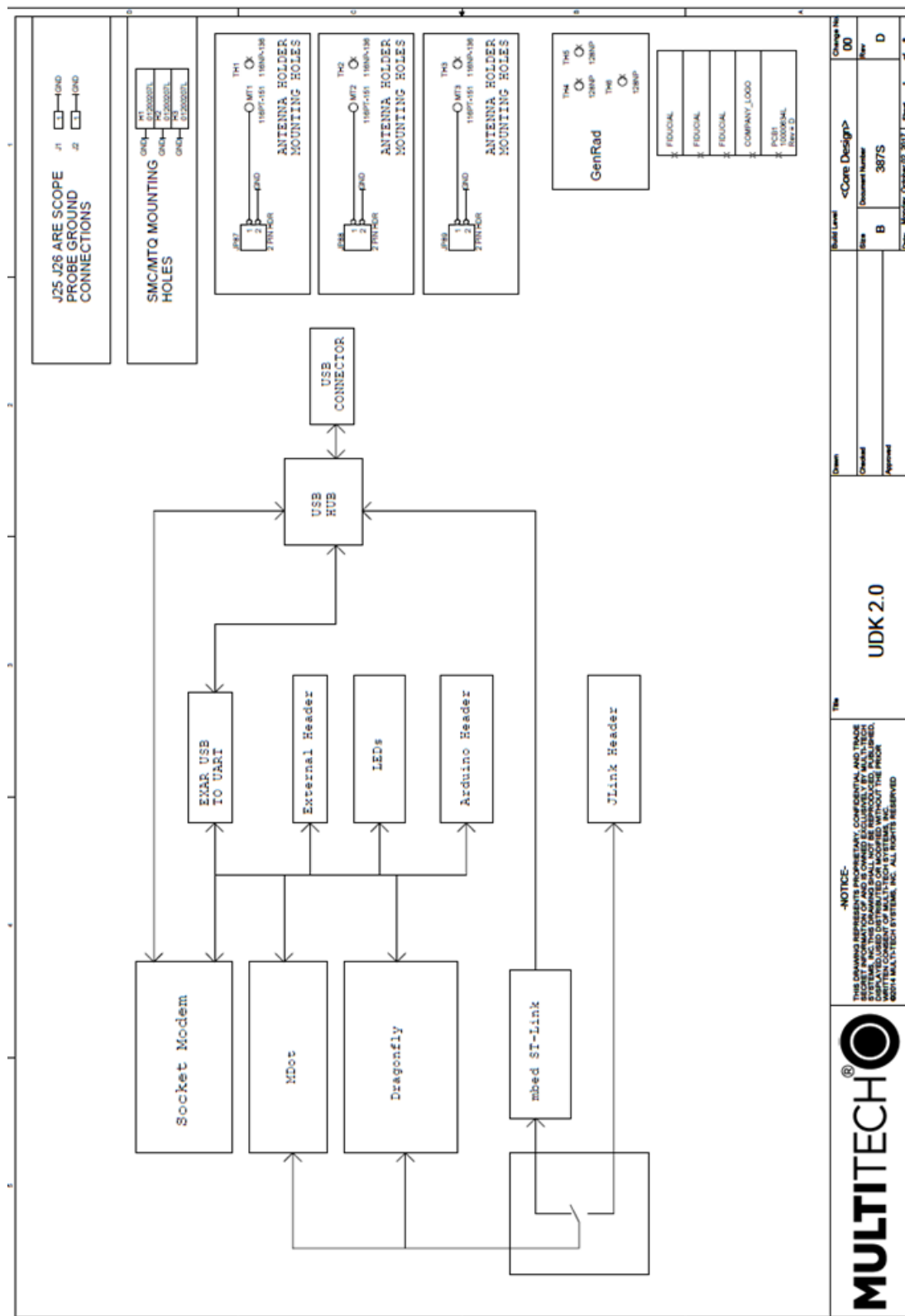
## Chapter 14 – Chapter 12 Developer Board Schematics

---

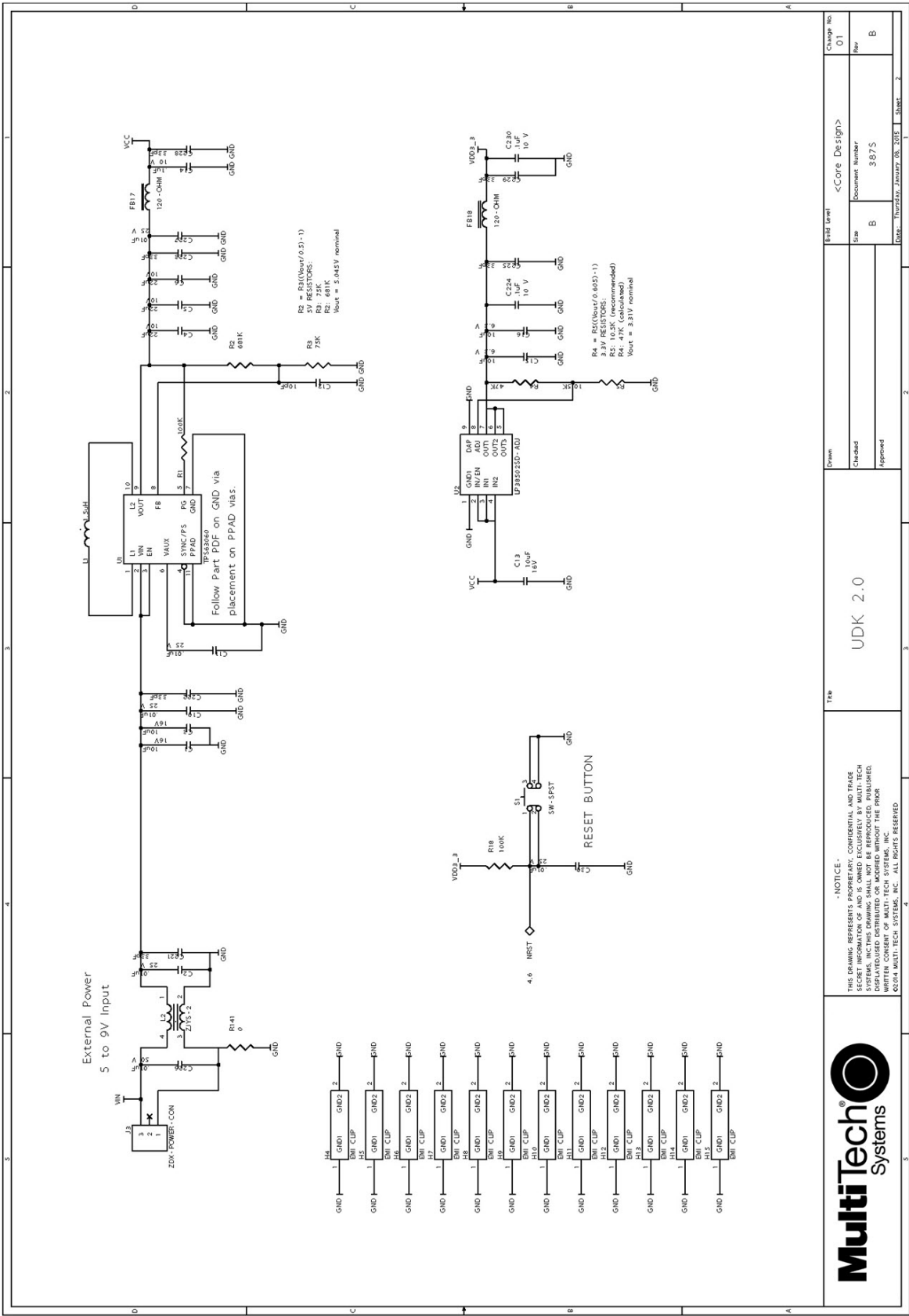
### About Schematics

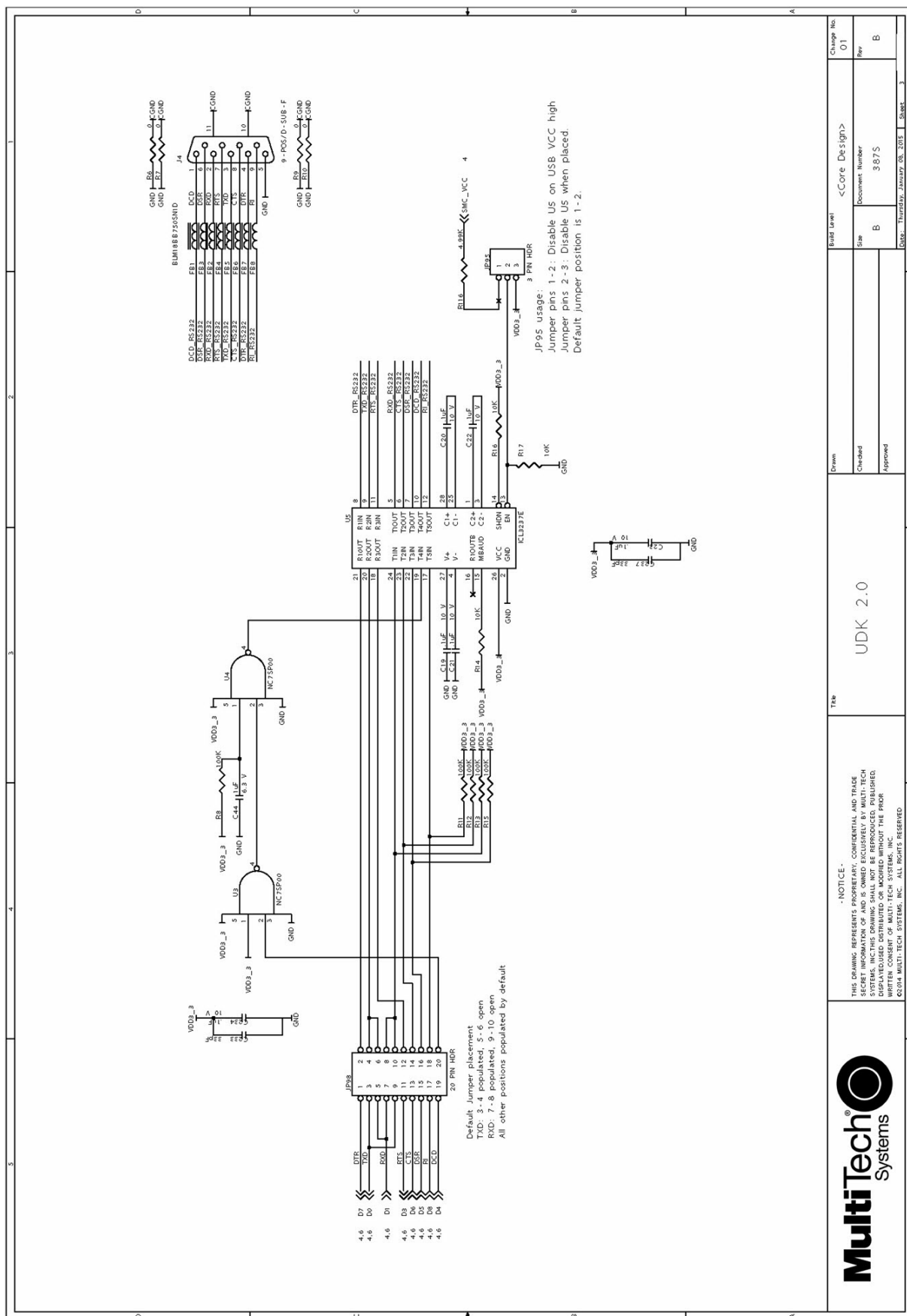
The following schematics are for the fully populated MTUDK2 developer board and contain components not included on the MTUDK2-ST-MDOT model.

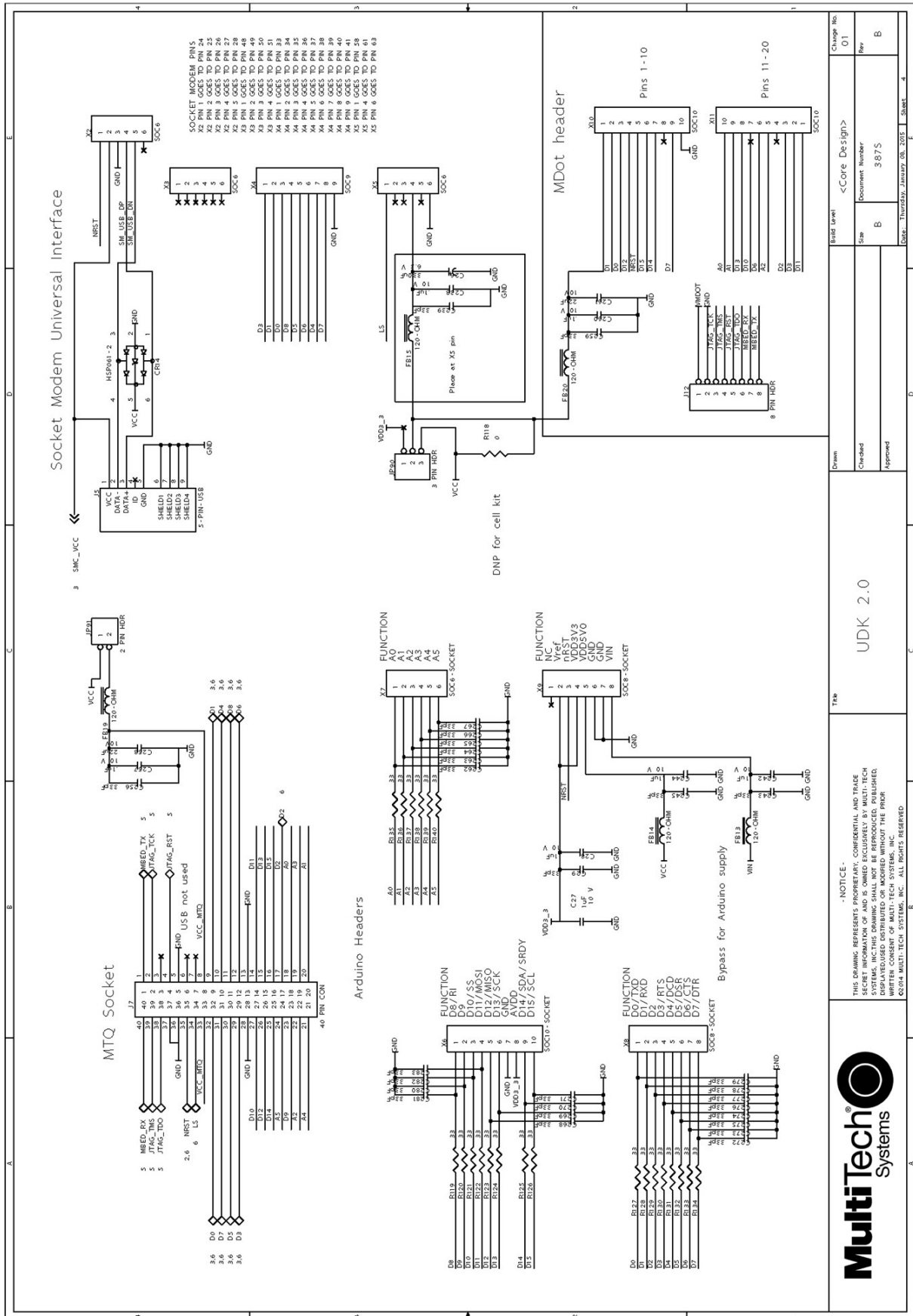
## mDot™ MTDOT Developer Guide

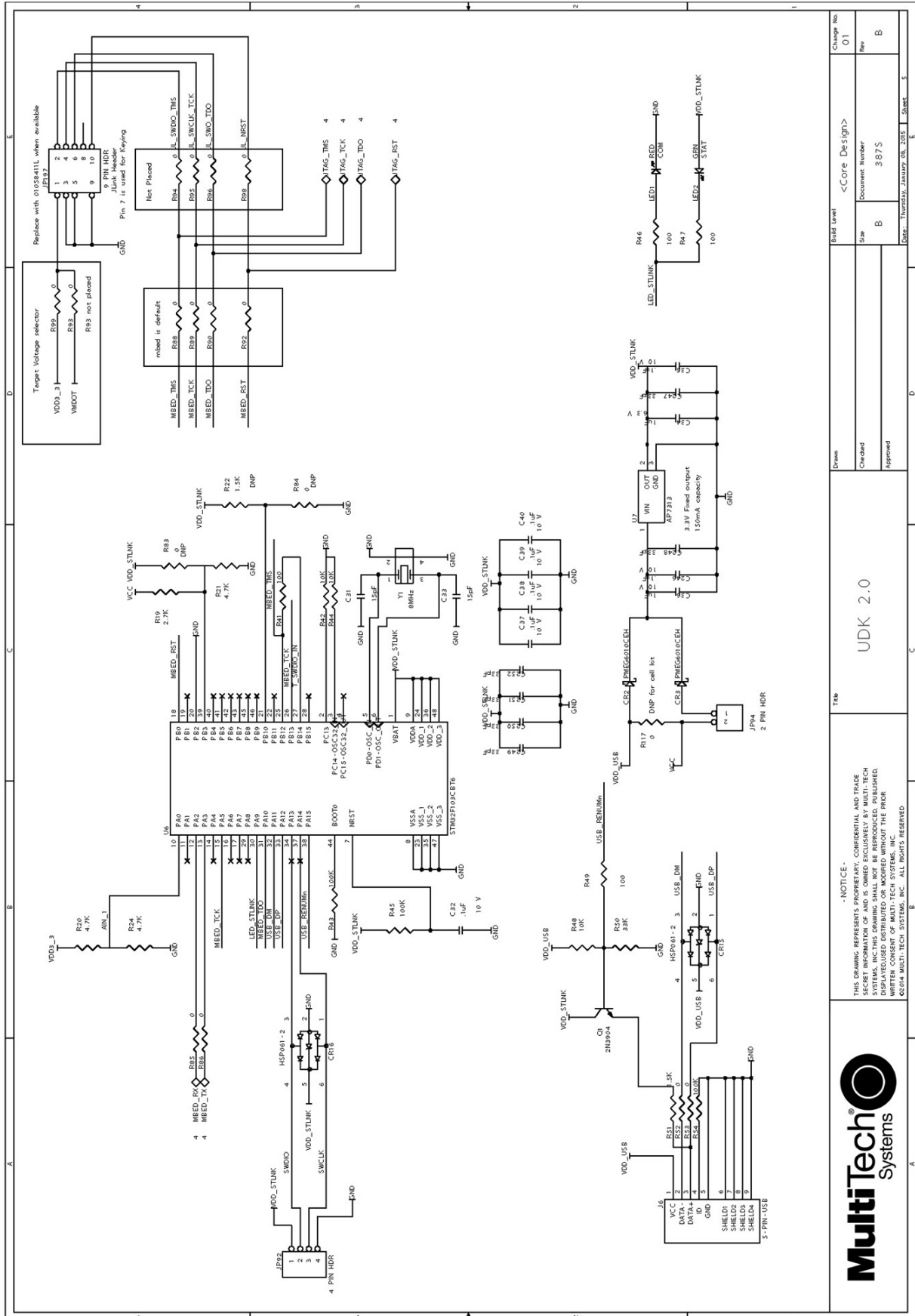


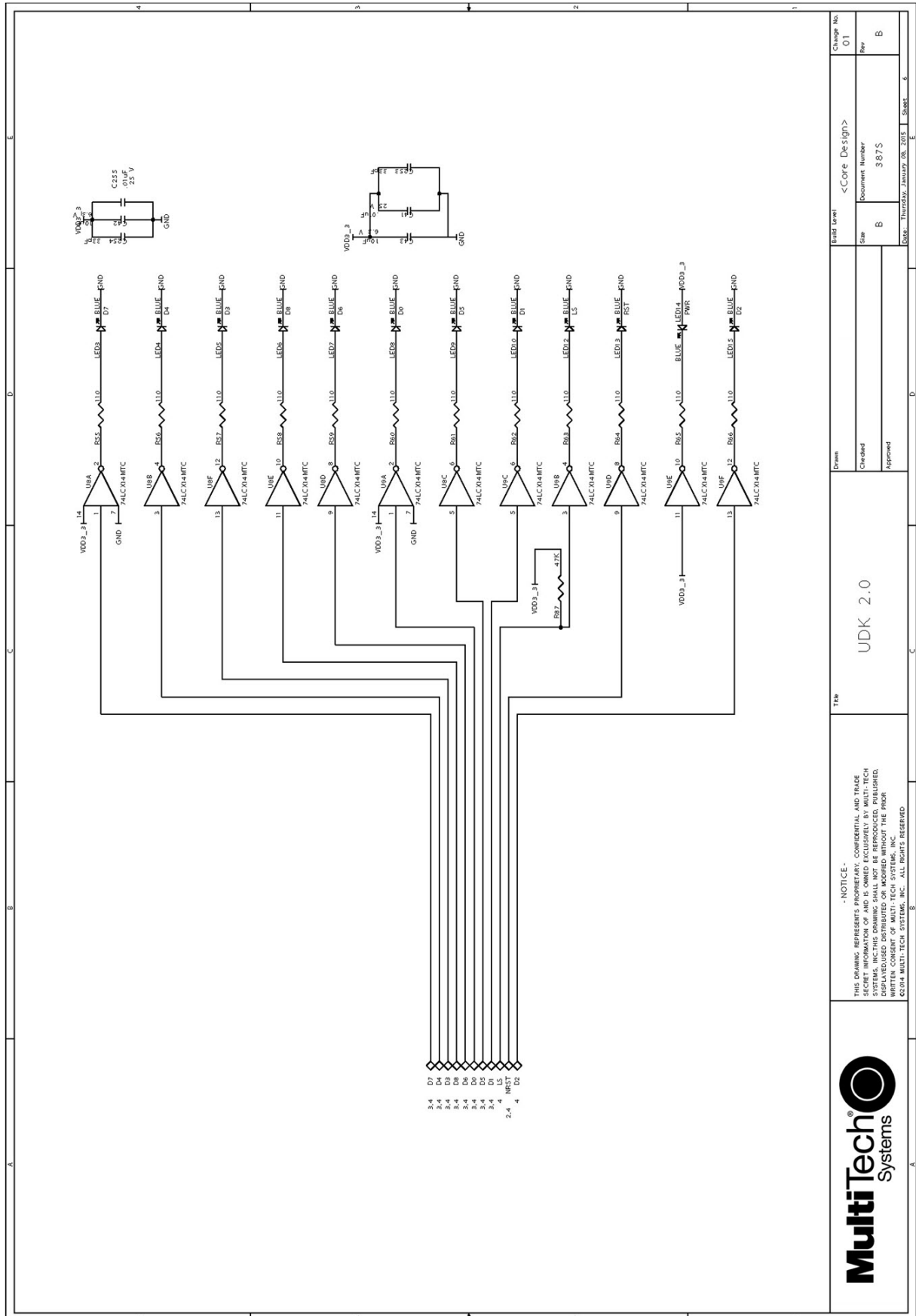
Schematics











## Chapter 15 – Chapter 13 Micro Developer Kit

### Micro Developer Kit

Designed specifically for mDot development, the Micro DK plugs directly into a USB port on your computer making it easy to use the developer kit for testing, programming, and evaluating your application.

**Note:** To work with the developer board, you need an X1P mDot model which includes a programming header.

### Developer Kit Package Contents

Your Developer Kit (MTMDK-ST-MDOT) includes the following:

|                  |                                |
|------------------|--------------------------------|
| Developer Board  | 1 - MTMDK mDot Developer Board |
| Antenna          | 1 - 868-945 MHz LoRa Antenna   |
| Cable            | 1 - Programming Cable          |
| Customer Notices | This Quick Start               |

Update your developer board ST-LINK/V2 firmware through the mDot mbed page at

<https://developer.mbed.org/platforms/MTS-mDot-F411/#general-technical-references>

### Firmware Updates

Before starting your project development, make sure you have the latest firmware for the Micro Developer Kit and mDot. Go to the mDot mbed page for MicroDK firmware. <https://developer.mbed.org/platforms/MTS-mDot-F411/>

### Windows Drivers

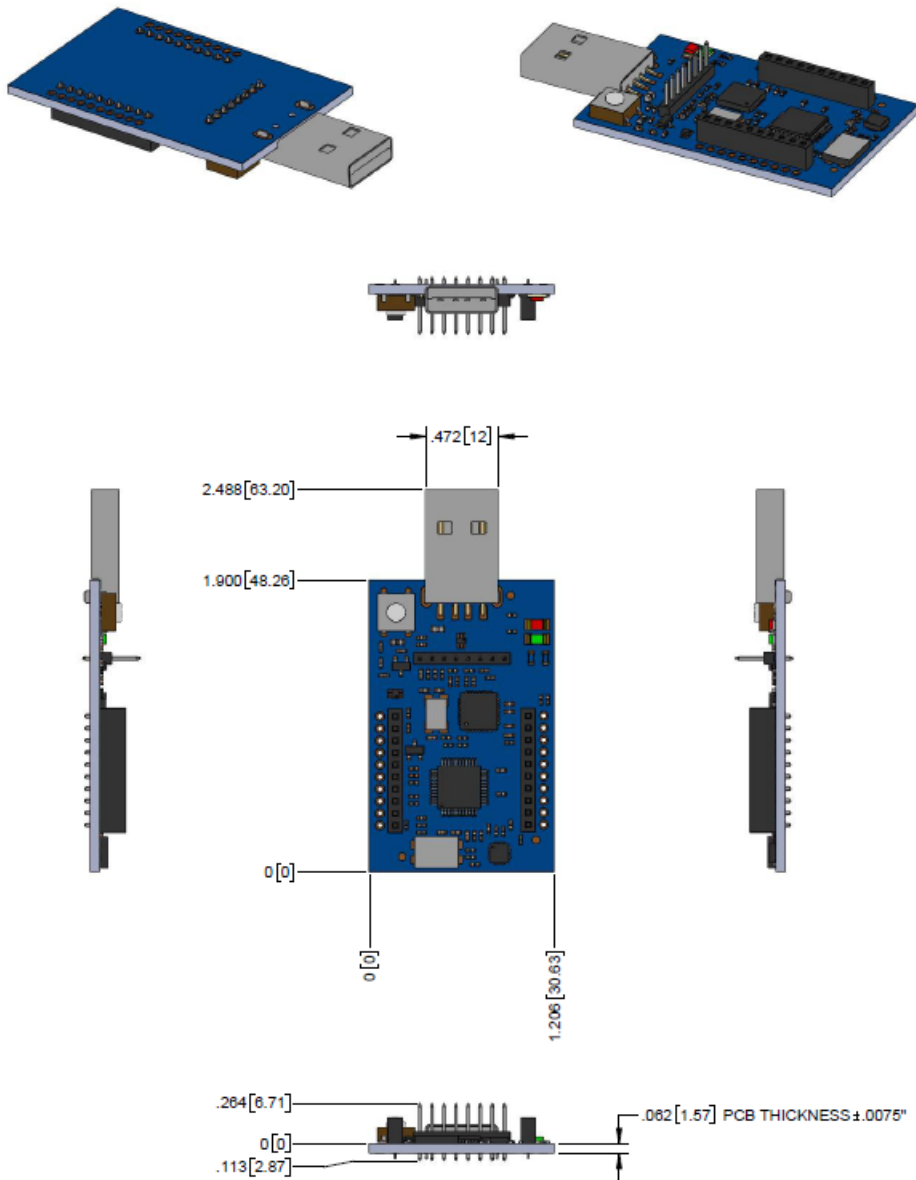
For Windows 10, you do not need additional drivers.

For Windows 7, the MTMDK board has an Exar chip for the serial communication port and you need an Exar driver to send AT Command to the mDot. You do not need the ST-Link driver for the serial communication port (AT Commands). <https://www.exar.com/content/document.ashx?id=1596>.

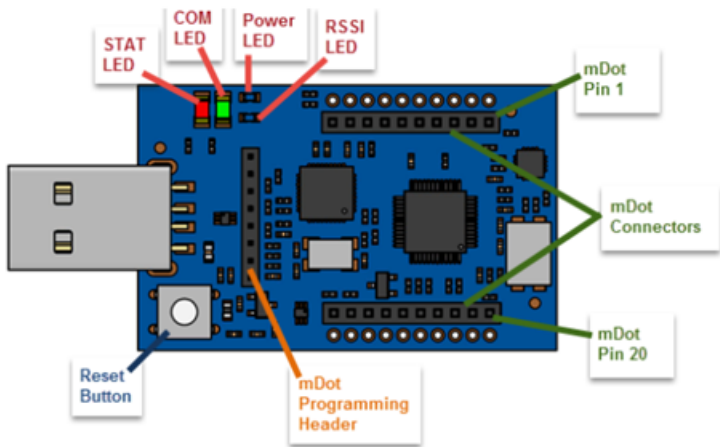
To debug the processor with Windows 7, you do the ST-Link driver with the MTMDK board.  
<https://developer.mbed.org/teams/st/wiki/ST-Link-Driver>.

**Note:** You do not need a driver for the USB mass storage feature.

## Micro DK Mechanical Drawings



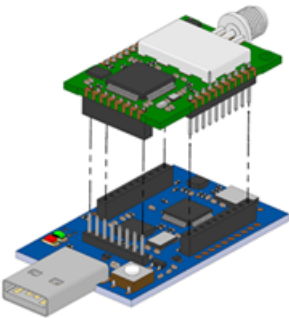
## Micro Developer Board Components



**Note:** The Reset Button resets the mDot processor.

| LED  | Description                                                              |
|------|--------------------------------------------------------------------------|
| STAT | LED1 Status, red light that blinks when device powers up.                |
| COM  | LED2 Communication, green light that shows when device is communicating. |
| PWR  | LED3 Power, blue lights when the board has power.                        |
| RSSI | LED4 Received Signal Strength Indicator.                                 |

## Installing an mDot on a Micro Developer Board



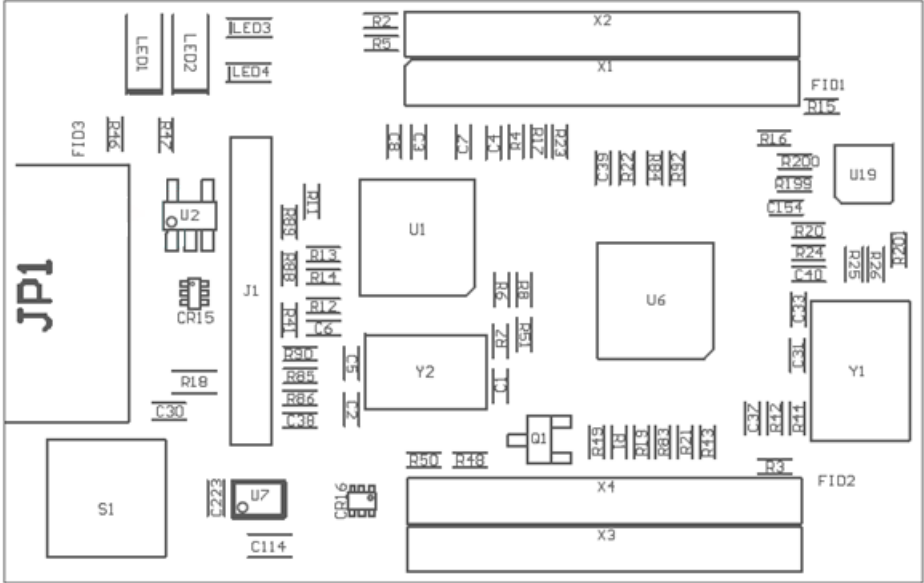
To install an mDot on the Micro Developer Board:

1. Align the mDot on the developer board as shown.
2. Gently press the mDot into the connectors.

# Assembly Diagrams and Schematics

## Assembly Diagrams

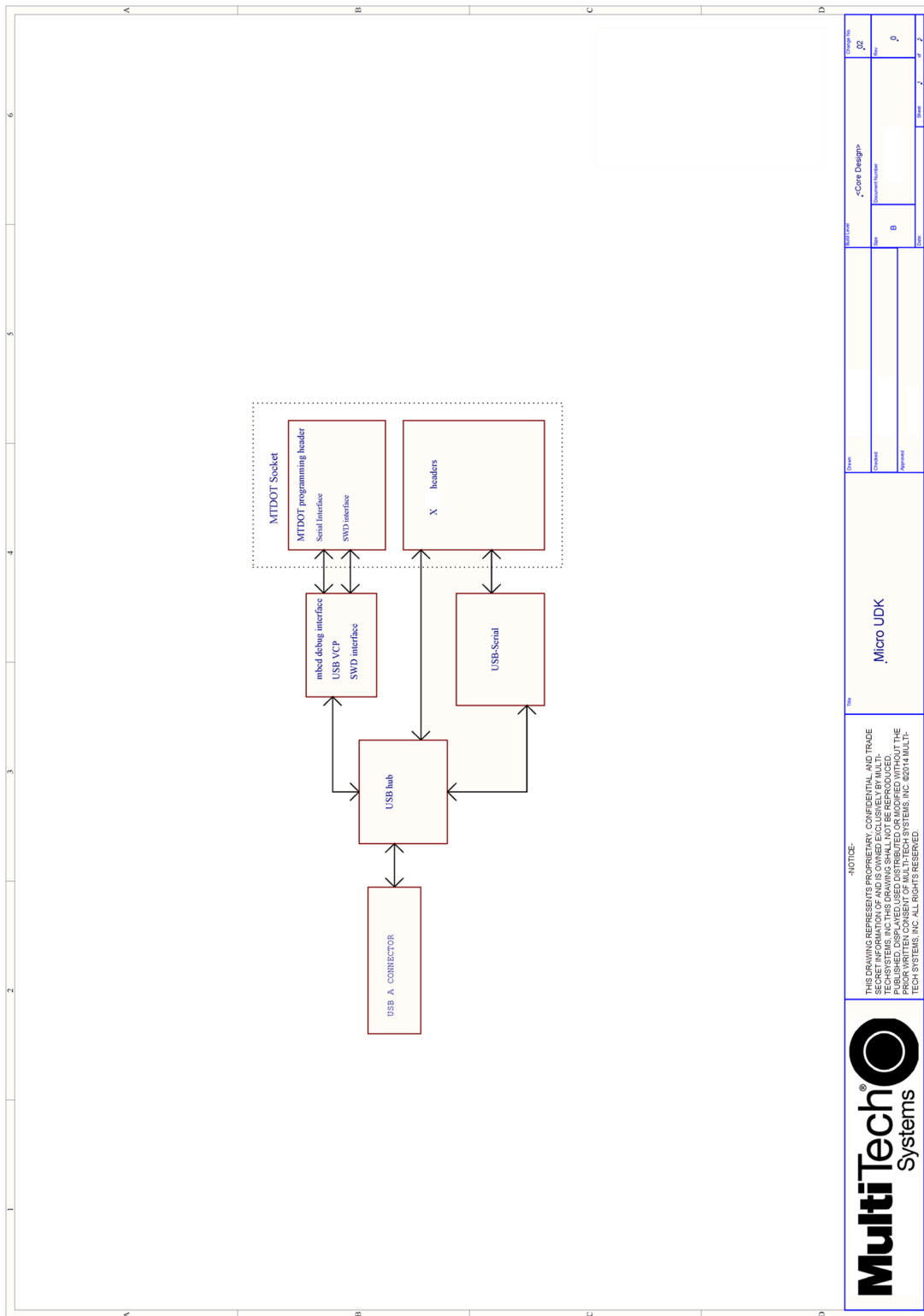
### Top Assembly



### Bottom Assembly



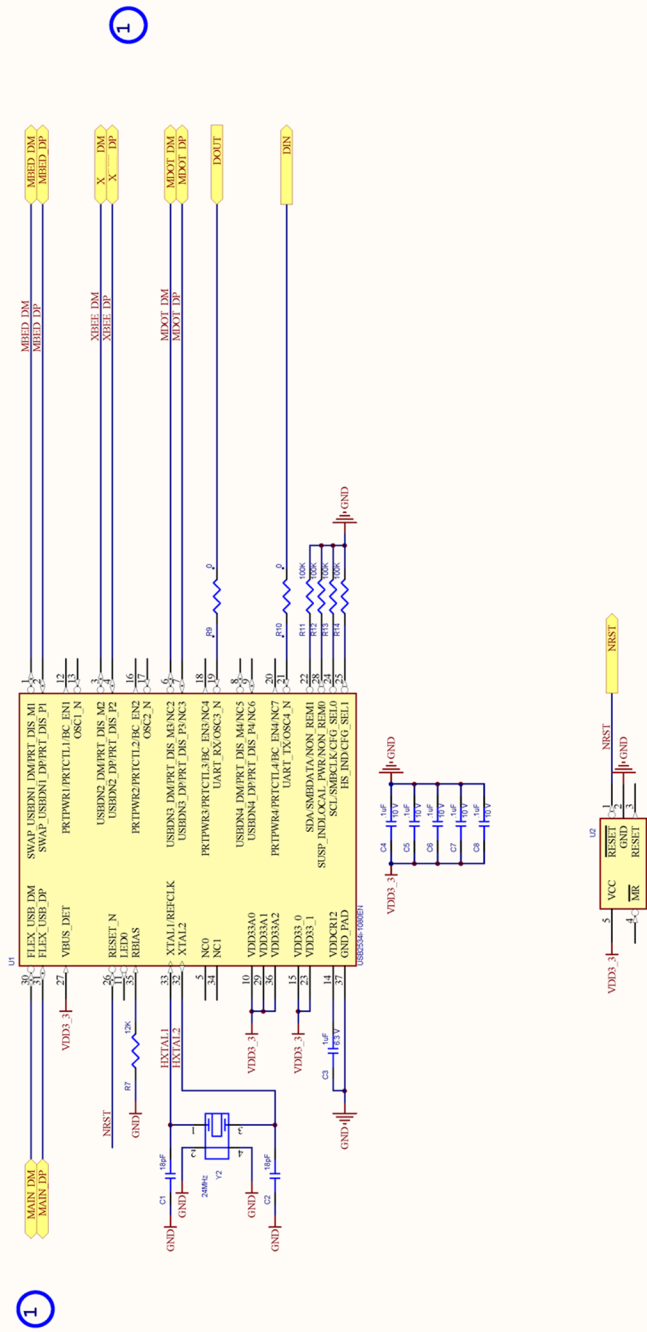
## mDot™ MTDOT Developer Guide



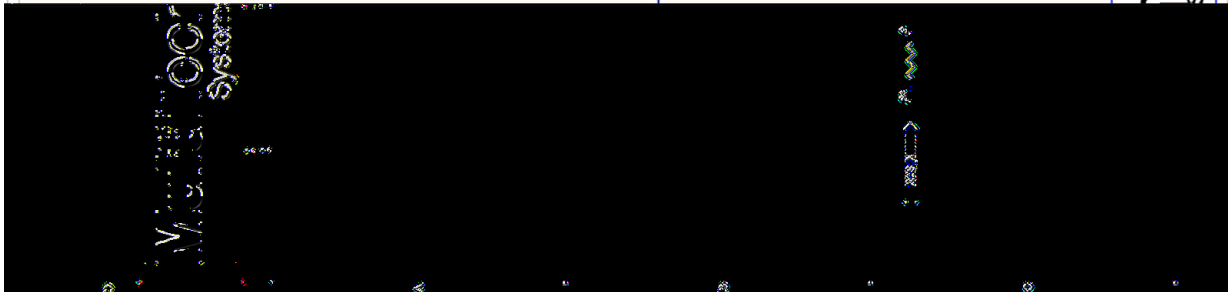




Note 1: Route USB traces as 90 ohm differential pairs.



|            |          |                                                                                                                                                                                                                                                                                                                                                       |                 |
|------------|----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|
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|            |          | B                                                                                                                                                                                                                                                                                                                                                     | 407S            |
| Revised    | Approved | Rev                                                                                                                                                                                                                                                                                                                                                   | 0               |
| Change No. | 02       | Rev                                                                                                                                                                                                                                                                                                                                                   | 0               |



## Chapter 16 – Chapter 14 Design Considerations

### Noise Suppression Design

Adhere to engineering noise-suppression practices when designing a printed circuit board (PCB). Noise suppression is essential to the proper operation and performance of the modem and surrounding equipment.

Any OEM board design must consider both on-board and off-board generated noise that can affect digital signal processing. Both on-board and off-board generated noise that is coupled on-board can affect interface signal levels and quality. Noise in frequency ranges that affect modem performance is of particular concern.

On-board generated electromagnetic interference (EMI) noise that can be radiated or conducted off-board is equally important. This type of noise can affect the operation of surrounding equipment. Most local government agencies have certification requirements that must be met for use in specific environments.

Proper PC board layout (component placement, signal routing, trace thickness and geometry, and so on) component selection (composition, value, and tolerance), interface connections, and shielding are required for the board design to achieve desired modem performance and to attain EMI certification.

Other aspects of proper noise-suppression engineering practices are beyond the scope of this guide. Consult noise suppression techniques described in technical publications and journals, electronics and electrical engineering text books, and component supplier application notes.

### PC Board Layout Guideline

In a 4-layer design, provide adequate ground plane covering the entire board. In 4-layer designs, power and ground are typically on the inner layers. Ensure that all power and ground traces are 0.05 inches wide.

The recommended hole size for the device pins is 0.036 in. +/-0.003 in. in diameter. Use spacers to hold the device vertically in place during the wave solder process.

### Electromagnetic Interference

The following guidelines are offered specifically to help minimize EMI generation. Some of these guidelines are the same as, or similar to, the general guidelines. To minimize the contribution of device-based design to EMI, you must understand the major sources of EMI and how to reduce them to acceptable levels.

- Keep traces carrying high frequency signals as short as possible.
- Provide a good ground plane or grid. In some cases, a multilayer board may be required with full layers for ground and power distribution.
- Decouple power from ground with decoupling capacitors as close to the device's power pins as possible.
- Eliminate ground loops, which are unexpected current return paths to the power source and ground.
- Decouple the telephone line cables at the telephone line jacks. Typically, use a combination of series inductors, common mode chokes, and shunt capacitors. Methods to decouple telephone lines are similar to decoupling power lines; however, telephone line decoupling may be more difficult and deserves additional attention. A commonly used design aid is to place footprints for these components and populate as necessary during performance/EMI testing and certification.
- Decouple the power cord at the power cord interface with decoupling capacitors. Methods to decouple power lines are similar to decoupling telephone lines.

- Locate high frequency circuits in a separate area to minimize capacitive coupling to other circuits.
- Locate cables and connectors to avoid coupling from high frequency circuits.
- Lay out the highest frequency signal traces next to the ground grid.
- If using a multilayer board design, make no cuts in the ground or power planes and be sure the ground plane covers all traces.
- Minimize the number of through-hole connections on traces carrying high frequency signals.
- Avoid right angle turns on high frequency traces. Forty-five degree corners are good; however, radius turns are better.
- On 2-layer boards with no ground grid, provide a shadow ground trace on the opposite side of the board to traces carrying high frequency signals. This will be effective as a high frequency ground return if it is three times the width of the signal traces.
- Distribute high frequency signals continuously on a single trace rather than several traces radiating from one point.

## Electrostatic Discharge Control

Handle all electronic devices with precautions to avoid damage due to the static charge accumulation.

See the ANSI/ESD Association Standard (ANSI/ESD S20.20-1999) – a document “for the Development of an Electrostatic Discharge Control for Protection of Electrical and Electronic Parts, Assemblies and Equipment.” This document covers ESD Control Program Administrative Requirements, ESD Training, ESD Control Program Plan Technical Requirements (grounding/bonding systems, personnel grooming, protected areas, packaging, marking, equipment, and handling), and Sensitivity Testing.

MultiTech strives to follow these recommendations. Input protection circuitry is incorporated in MultiTech devices to minimize the effect of static buildup. Take precautions to avoid exposure to electrostatic discharge during handling.

MultiTech uses and recommends that others use anti-static boxes that create a faraday cage (packaging designed to exclude electromagnetic fields). MultiTech recommends that you use our packaging when returning a product and when you ship your products to your customers.

## USB Design

MultiTech recommends that you review Intel's High Speed USB Platform Design Guidelines for information about USB signal routing, impedance, and layer stacking. Also:

- Shield USB cables with twisted pairs (especially those containing D+/D-).
- Use a single 5V power supply for USB devices. See Power Draw for current (ampere) requirements.
- Route D+/D- together in parallel with the trace spacing needed to achieve 90 ohms differential impedance for the USB pair and to maintain a 20 mil space from the USB pair and all other signals.
- If power is provided externally, use a common ground between the carrier board and the device.

# Appendix A – Appendix A Release Note Archive

## What's New in Firmware Version 4.0

The new release includes the following changes:

- Configuration Persistence
- Sleep
- FOTA Enhancements
- New and updated AT Commands

### Configuration Persistence

To safeguard your configuration, the device offers configuration persistence in the form of configuration redundancy and wear leveling.

**Note:** These features change the configuration storage and make the firmware update a one way process. The configuration is not backward compatible to any version less than 4.0.x. Once a device is flashed with 4.0.x firmware, the configuration is converted to a new format. Any versions earlier than 4.0.x cannot parse this new format.

### mDot Sleep

MDot sleep will use the provided wake mode when executed from application code. Previously it would use the value in the configuration.

### FOTA Enhancements

#### Bootloader Update

Bootloader can install firmware upgrades from regular files, compressed files, or patch files. Firmware upgrade images cannot contain a bootloader (application only). Use mbed tools to merge bootloader with application firmware.

#### Firmware image manifest

Firmware file manifests allow full images, compressed images, and differential updates.

#### Image Compression and Diff images

BSDiff and LZ4 compression can be used to reduce the size of firmware upgrades sent over-the-air. Smaller files reduce the time required to deliver an update. Smaller FOTA sessions increase end-device battery life.

#### Multicast Session Scheduling

Multicast sessions are now scheduled using LowPowerTimeout instead of events. Session schedules are maintained while sleeping.

### AT Command Additions and Modifications

**Note:** For AT Command details, refer to [S000643 mDot AT Command Reference Guide](#).

#### From LoRaWAN changes:

- Added AT+BTO - Class B timeout 0-120s

- Added AT+CTO - Class C timeout 0-120s

*For an archive of release notes, go to Appendix A.*

## What's New in Firmware Version 3.3

The new release includes the following changes:

- LoRaWAN Version 1.0.4 changes
- Pin Output changes
- New and updated AT Commands

### LoRaWAN Version 1.0.4 Changes

- MAX FCNT GAP check removed with mandatory 32-bit FCNT. (More than 16356 missed packets are allowed between two received transmissions. The previous check supported 16-bit FCNT.)
- ADR
  - LinkADRRReq: Power or Datarate field of 0xF should not change the current setting.
  - ACK Enabled Power/Datarate Back-off: When you enabled ACK, back-off uses ADR Limit and Delay settings.
- ACK Retries
  - LinkADRRReq sets the number of retries with the nbTrans field.
  - This also increases the maximum retries to 15.
- Join Dev and App Nonce:
  - Join Dev Nonce increments with each Join Request sent
  - Join App Nonce is validated to increment with each Join Accept received
  - Nonces reset when AppEUI/JoinEUI is changed
- Added support for multicast sessions in various areas including Network Address, Network Session Key, Data Session Key, Downlink Counter, and Multicast Receive Parameters.

### Pin Output Changes

- Join Status available on Associate Pin (mDot:A2, xDot:GPIO0).
- Rx Packet pin is brought high when packet is received. When you issue a command, the pin resets (mDot:D12, xDot:GPIO1).
  - AT+RECV can be used to retrieve the packet and reset the pin.

### AT Command Additions and Modifications

**Note:** For AT Command details, refer to [S000643 DOT Series AT Command Reference Guide](#).

- Added AT+JN - Join Nonces: Dev Nonce and App Nonce.
- Added AT+JNV - Enable/disable join app nonce validation.
- Added AT+REPAIR=1 - Erase the flash and rewrite configuration files.
- Added AT+LW - shows support LoRaWAN version.
- Added AT+URC - Unsolicited response code.
- Added AT+MEM - show available RAM.
- Added AT+MCRX - Multicast Rx parameters: <INDEX>,<DR>,<FREQ>,<PERIOD>.

- Changed AT+NA/NSK/DSK/DLC - support for modifying multicast sessions.
- Changed AT+BLS - Beacon lock status (includes setup example for a class B device).
- Changed AT+ACK – now accepts 0-15 as input.
- Changed AT&WP - Save Protected settings available in all firmware.
- Changed AT+DI - Protected DeviceEUI can be changed.
- Changed AT+NI=2,<EUI> - Set default AppEUI/JoinEUI, value if set will be used as the default AT+NI setting when AT&F is issued.
- Changed AT+NK=2,<KEY> - Set default AppKey, value if set will be used as the default AT+NK setting when AT&F is issued.
- Changed AT+DFREQ - Set protected default frequency band, informational use only, provisioned FrequencyBand.
- Changed AT+RXO - New option 3 for EXTENDED HEX format.

## What's New in Firmware Version 3.2

The new release includes the following changes:

- LoRaWAN Version 1.0.3 Class B support
- Russian channel plan support
- New and updated AT Commands

### LoRaWAN Version 1.0.3 Class B Support

The LoRaWAN Class B option allows devices to open receive windows at fixed time intervals for server-initiated downlink messages.

New AT Commands: +PP - Ping slot periodicity and +BLS - Beacon lock status

### Russian Channel Plan Support

RU864-870 ISM band channel frequencies as described in LoRaWAN Version 1.0.3. This allows devices to operate in the 864 to 870 MHz frequency band and store parameters for at least eight channels.

### AT Command Additions and Modifications

**Note:** For AT Command details, refer to [S000643 DOT Series AT Command Reference Guide](#).

- Deprecated AT+RECV and AT+RXF in production firmware versions
- Deprecated AT+AS.
- Added AT+PP - Ping slot periodicity.
- Added AT+FO - Frequency offset.
- Added AT+GPSTIME - Retrieving GPS synchronized time.
- Added AT+BAT - Device battery level.
- Added AT+BLS - Get the beacon's lock status
- Added AT+LBTRSSI - Listen Before Talk RSSI
- Added AT+SEND - Sends data continuously
- Changed AT+RXO - Receive output

## What's New in Firmware Version 3.1

The new release includes the following changes:

- Firmware over the Air
- Power Optimization
- Other Enhancements

### Firmware over the Air (FOTA)

This release features a new AT command, +FOTA, for wireless firmware updates. When you deploy Release 3.1, FOTA will be enabled by default.

With FOTA enabled, the Conduit initiates the FOTA session. The mDot responds downlink messages automatically as needed. When the FOTA session is complete, the mDot updates if the firmware successfully transferred or deletes the FOTA session if the firmware transfer failed.

New AT Command: +FOTA - Firmware over the Air

**Note:** For more information, go to [FOTA Overview](#).

### Power Optimization

To reduce power consumption during Class A transactions, Version 3.1 firmware includes a new auto sleep feature. When enabled, the microcontroller automatically goes into a stop sleep mode after an uplink transmit ends and in between two receive windows. In the stop sleep mode, RAM and register contents are retained, but all peripheral clocks are gated, so timers will not count during these intervals. Refer to the microcontroller datasheet for information regarding microcontroller sleep mode states.

New AT Command: +AS - Auto Sleep

### Other Enhancements

- Adaptive Data Rate (ADR) is now enabled by default.
- Public Network command, +PN, has been updated to include an MTS network in addition to the LoRaWAN public or private network options. This includes changes to parameter values. Refer to the +PN command in [S000643 DOT Series AT Command Reference Guide](#) for details.

## What's New in Firmware Version 3.0

The new release includes the following changes:

- LoRaWAN 1.0.2 Support
- Listen Before Talk
- Separate Channel Plans

For more information on using these features, visit <https://developer.mbed.org/platforms/MTS-mDot-F411/>.

### LoRaWAN 1.0.2 Support

Adds AS923-1, extending support to Brunei, Cambodia, Hong Kong, Indonesia, Japan, Laos, New Zealand, Singapore, South Korea, Taiwan, Thailand, and Vietnam.

Adds KR920, extending support to South Korea.

## Listen Before Talk

Listen before talk (LBT) is required in Japan and South Korea. This feature is automatically configured by the channel plan.

- For Japan, the AS923-1 has LBT enabled by default.
- For all other AS923-1 countries, LBT is disabled by default.
- For South Korea, KR920 has LBT enabled by default.

## Separate Channel Plans

Select a channel plan at compile time to integrate the channel plan with the firmware.

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