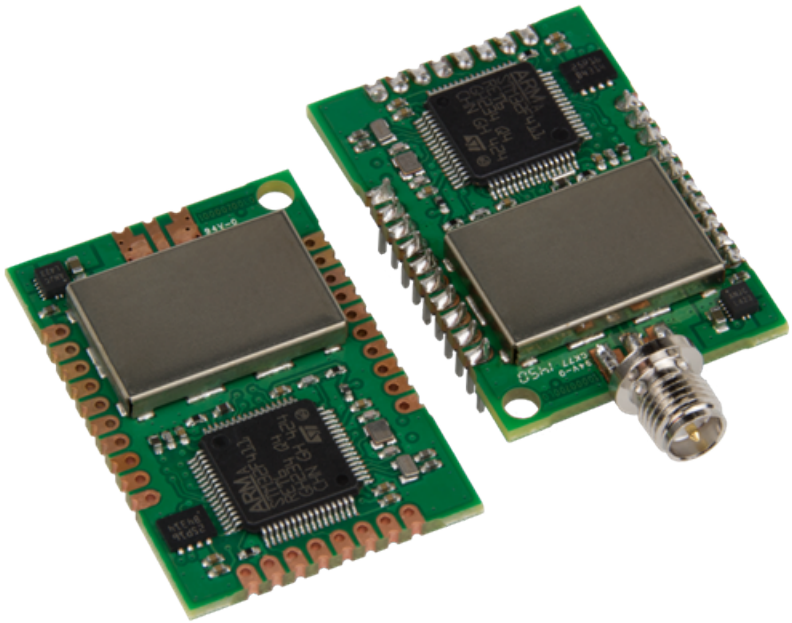
MULTITECH®



mDot™

MTDOT Developer Guide for Japan

mDot Developer Guide for Japan

Models: MTDOT-923-JP1 includes the MTUDK2-ST-MDOT Developer Kit

Part Number: S000688, Version 4.1

Copyright

Trademarks and Registered Trademarks

Legal Notices

The MultiTech products are not designed, manufactured or intended for use, and should not be used, or sold or re-sold for use, in connection with applications requiring fail-safe performance or in applications where the failure of the products would reasonably be expected to result in personal injury or death, significant property damage, or serious physical or environmental damage. Examples of such use include life support machines or other life preserving medical devices or systems, air traffic control or aircraft navigation or communications systems, control equipment for nuclear facilities, or missile, nuclear, biological or chemical weapons or other military applications ("Restricted Applications"). Use of the products in such Restricted Applications is at the user's sole risk and liability.

MULTITECH DOES NOT WARRANT THAT THE TRANSMISSION OF DATA BY A PRODUCT OVER A CELLULAR COMMUNICATIONS NETWORK WILL BE UNINTERRUPTED, TIMELY, SECURE OR ERROR FREE, NOR DOES MULTITECH WARRANT ANY CONNECTION OR ACCESSIBILITY TO ANY CELLULAR COMMUNICATIONS NETWORK. MULTITECH WILL HAVE NO LIABILITY FOR ANY LOSSES, DAMAGES, OBLIGATIONS, PENALTIES, DEFICIENCIES, LIABILITIES, COSTS OR EXPENSES (INCLUDING WITHOUT LIMITATION REASONABLE ATTORNEYS FEES) RELATED TO TEMPORARY INABILITY TO ACCESS A CELLULAR COMMUNICATIONS NETWORK USING THE PRODUCTS.

The MultiTech products and the final application of the MultiTech products should be thoroughly tested to ensure the functionality of the MultiTech products as used in the final application. The designer, manufacturer and reseller has the sole responsibility of ensuring that any end user product into which the MultiTech product is integrated operates as intended and meets its requirements or the requirements of its direct or indirect customers. MultiTech has no responsibility whatsoever for the integration, configuration, testing, validation, verification, installation, upgrade, support or maintenance of such end user product, or for any liabilities, damages, costs or expenses associated therewith, except to the extent agreed upon in a signed written document. To the extent MultiTech provides any comments or suggested changes related to the application of its products, such comments or suggested changes is performed only as a courtesy and without any representation or warranty whatsoever.

Contacting MultiTech

Knowledge Base

The Knowledge Base provides immediate access to support information and resolutions for all MultiTech products. Visit http://www.multitech.com/kb.go.

Support Portal

To create an account and submit a support case directly to our technical support team, visit: https://support.multitech.com.

Support

Business Hours: M-F, 8am to 5pm CT

Country	By Email	By Phone
Europe, Middle East, Africa:	support@multitech.co.uk	+(44) 118 959 7774
U.S., Canada, all others:	support@multitech.com	(800) 972-2439 or (763) 717-5863

Warranty

To read the warranty statement for your product, visit https://www.multitech.com/legal/warranty. For other warranty options, visit www.multitech.com/es.go.

World Headquarters

Multi-Tech Systems, Inc.

2205 Woodale Drive, Mounds View, MN 55112

Phone: (800) 328-9717 or (763) 785-3500

Fax (763) 785-9874

Contents

Chapter 1 – Product Overview

Overview

The MultiConnect mDot is a programmable, long-range RF module that provides encrypted data connectivity to sensors, industrial equipment, and remote appliances. By using LoRa™ Long Range Spread Spectrum technology, bi-directional data communication can be maintained for distances up to 5 miles/8 km line of sight, deep into buildings, or within noisy environments* using 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.

Related Documentation

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

mbed Documentation

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

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

Programming the mDot Microcontroller

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

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

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

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

- Development version: libmDot-dev-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

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

Differenital 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 requries Python v3.8 installed. To install the utility, open a command prompt and enter: pip install mtsmultitool

Product Build Options

Product	Description	Quanity to Order
Japan		
MTDOT-923-X1P-SMA	923 MHz LoRa SMA with Programming Header	1
Developer Kits		
MTUDK2-ST-MDOT	mDot Developer Kit	1
MTMDK-ST-MDOT	mDot Micro Developer Kit	1

Note:

- The complete product code may end in .Rx. For example, MTDOT-923-JP1-X1P.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.

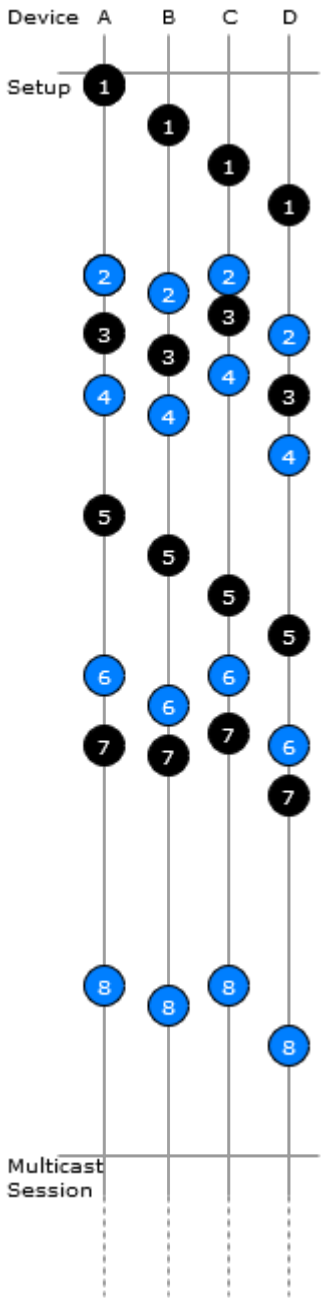
Class A devices must periodically send uplinks to open downlink windows making the time required to complete an operation setup directly tied to the frequency of device uplinks. For each device involved in the operation, some extra time should be added to the total setup time to account for latency in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

Setup messages are sent up to 3 times. Worst-case timing for operation setup would be ((3 * device_uplink_period * 2) + (overhead * 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

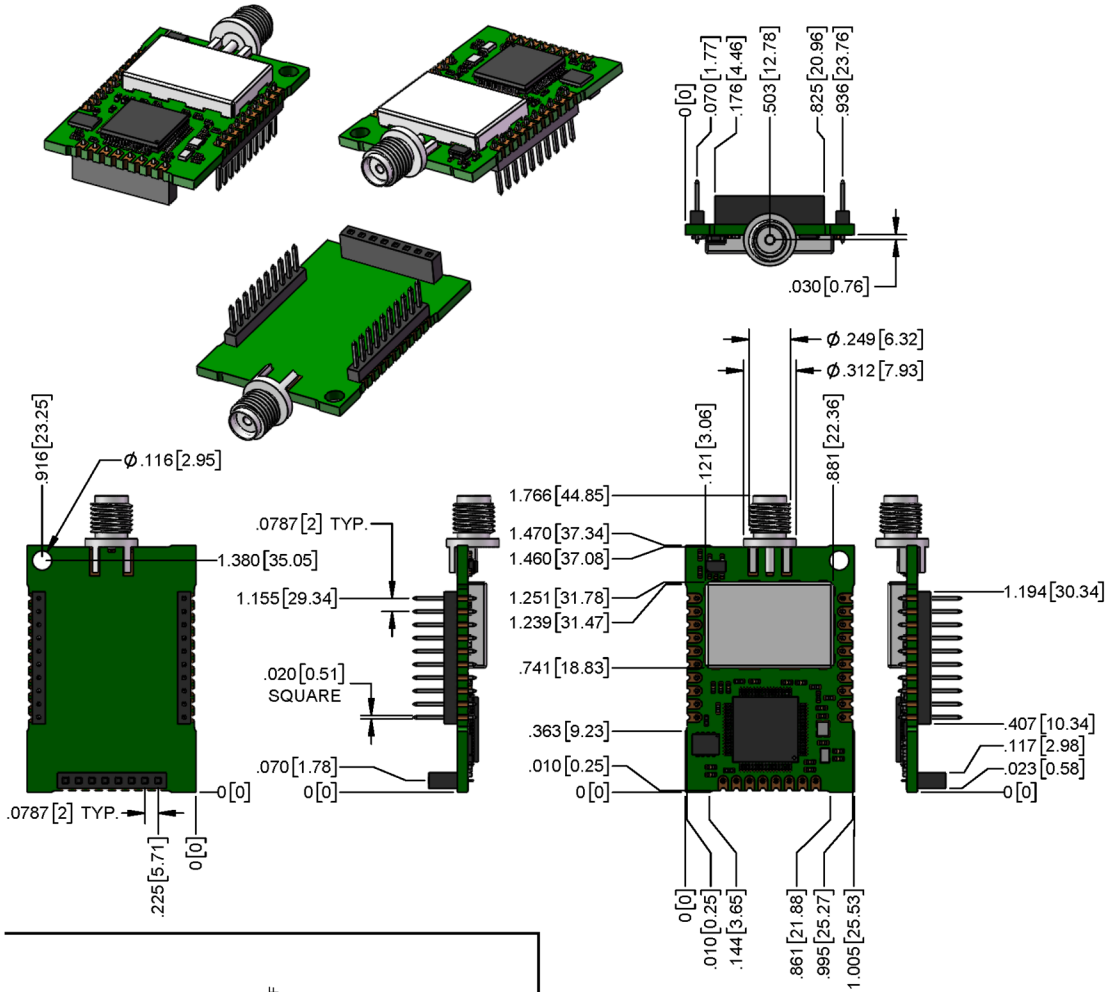
Troubleshooting:

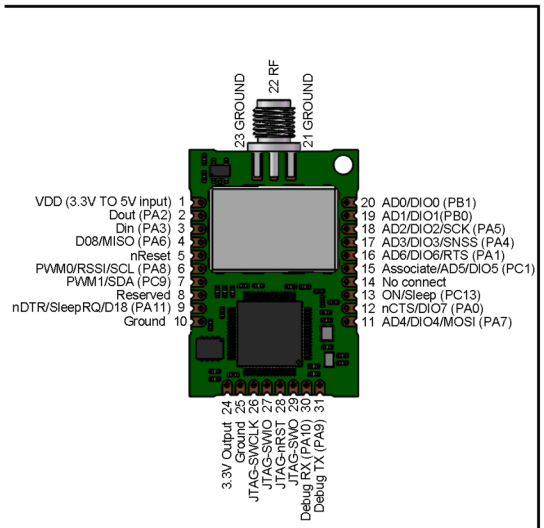
- To end a FOTA session that is in progress, send 'ps -A | grep fota'. Find the PID associated with lora-fota (not lora-fota-demo). Then send 'kill (pid of lora-fota)'.

- 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.

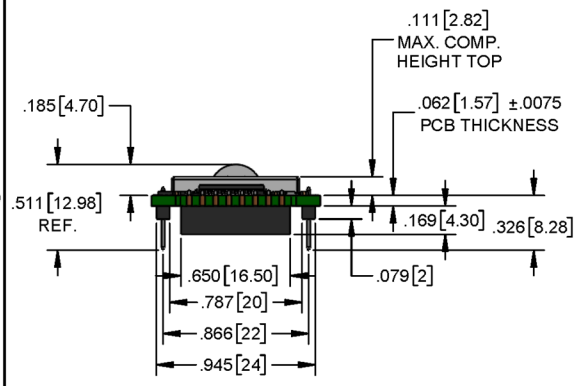
Chapter 4 – Mechanical Drawings with Pinouts

MTDOT-xxx-X1P-SMA





MTDOT-X1P-SMA



DIMENSIONS IN In [mm]

Chapter 5 – Specifications and Pin Information

MTDOT Specifications

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

Category	Description
Transmission (Japan)	
Max Transmitter Power Output (TPO)	20 mW

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

Important:

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

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

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

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

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

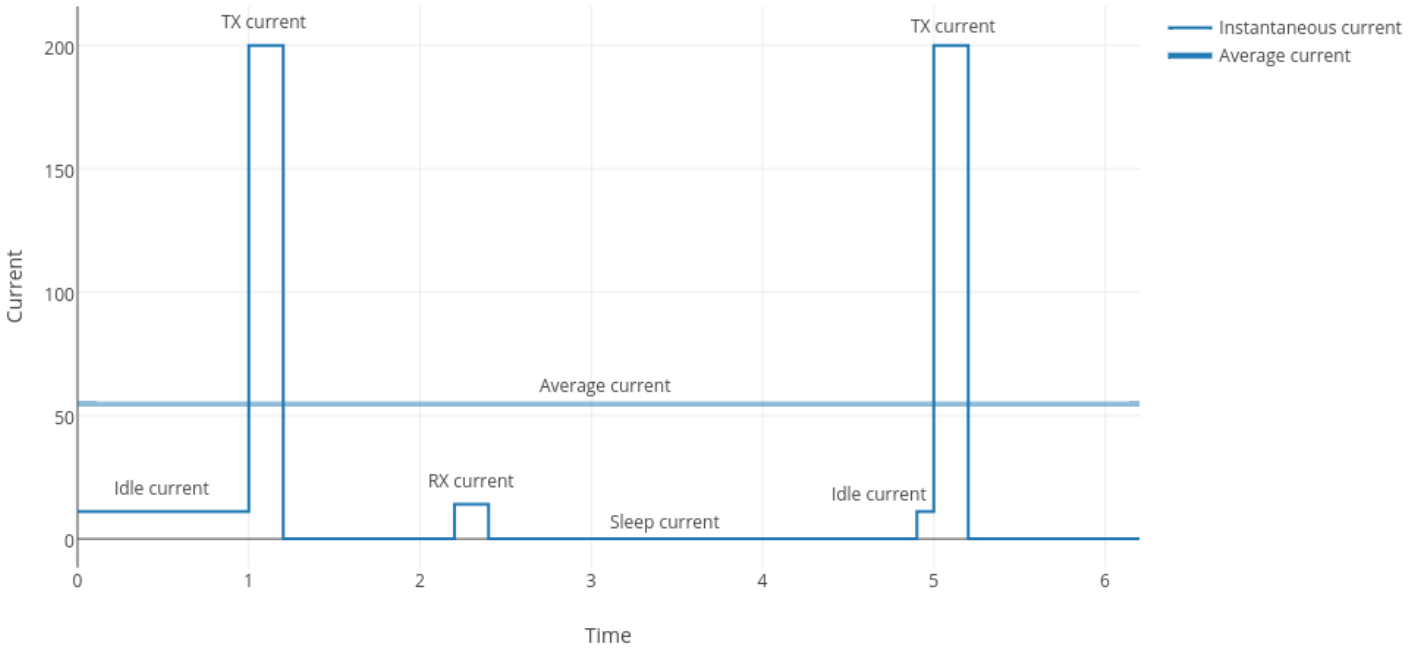
LoRa Transmission Output Power

923 Models

Power	Frequency	Bandwidth
20 mW	920.6 - 928 MHz	125 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.

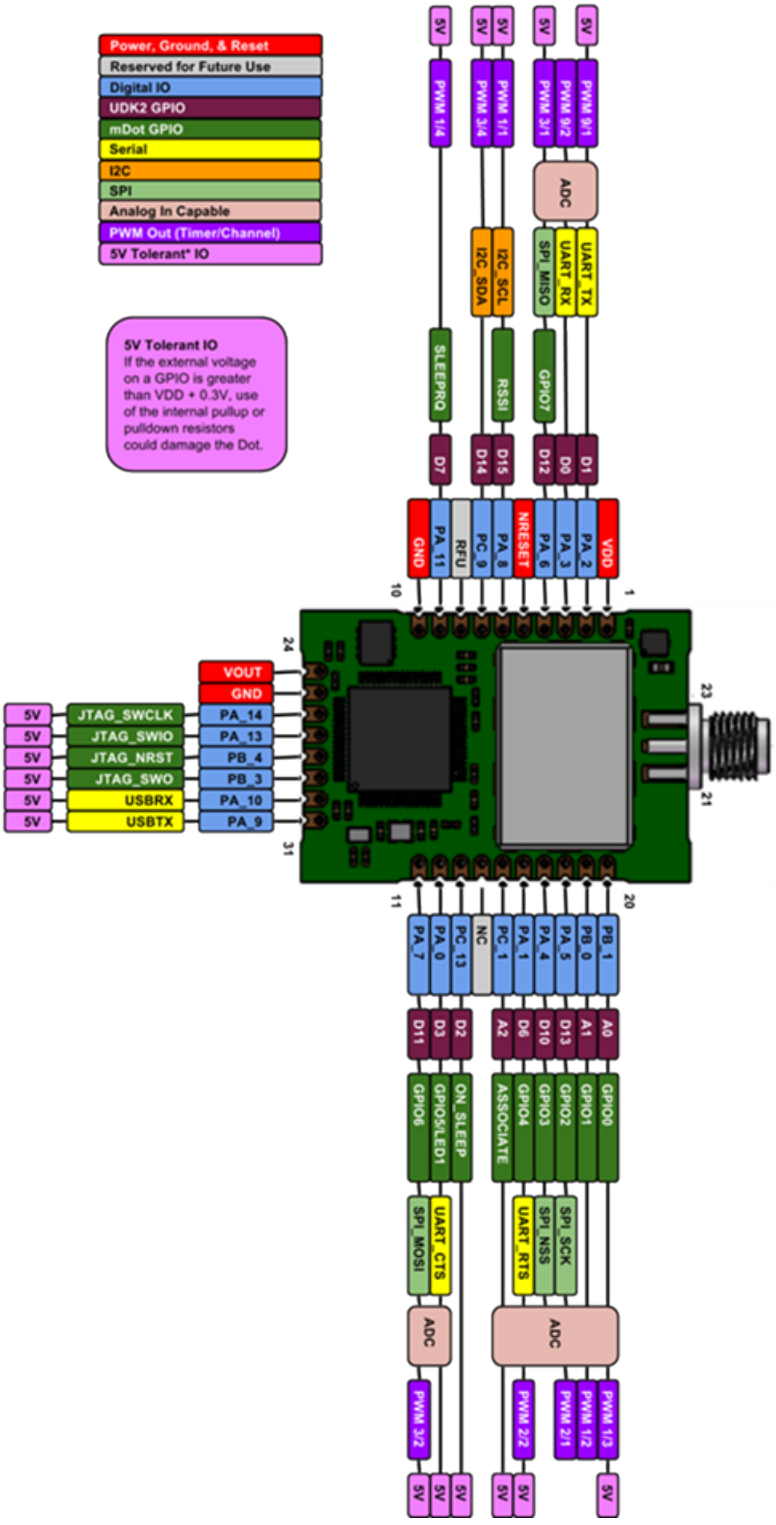
Electrical and Timing Characteristics

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_{NRESET}	NRESET minimum pulse duration	--	1	--	--	ms
V_{NRESET} Low	NRESET input low level	--	--	--	0.9	V
V_{NRESET} High	NRESET input high level	Note: The mDot has an internal pull-up resistor.	2.1	--	--	V

Pin Information



Note: Using the mbed platform with the Cortex-M4 processor expands your pin functionality options.

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	SLEEPRQ	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	USBRX	Debug RX routes to USB on developer board
31	PA9	USBTX	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
LoRa/SPI2	
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).

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:

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

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/miscrostrip 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	≤ 2.0
Gain	3.0 dBi
Radiation	Omni
Polarization	Vertical

Chapter 7 – Safety Information

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.

RF exposure: Separation between Antenna and User

Regarding RF Exposure, there is a minimum distance of 20 cm between the devices radiating structures (the antenna) and the body of users.

Wireless devices could generate radiation. Other nearby electronic devices, like microwave ovens, may also generate additional radiation to the user causing a higher level of RF exposure.

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.

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 – Environmental Notices

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[1]:

- 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)

[1]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.

Chapter 9 – 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

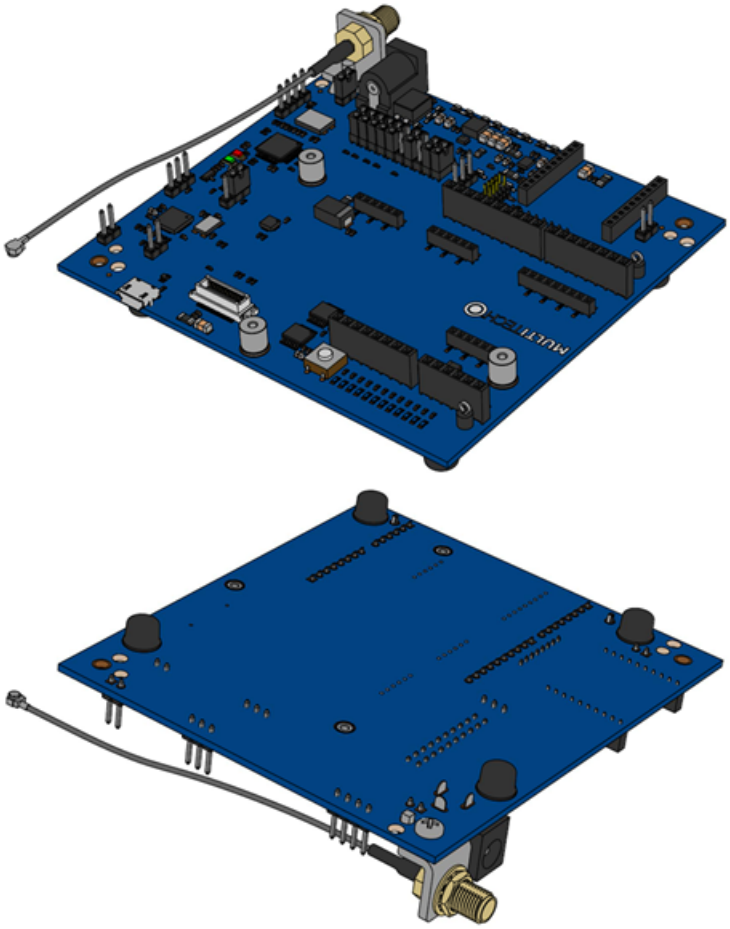
MTUDK2-ST-MDOT Developer Kit Contents

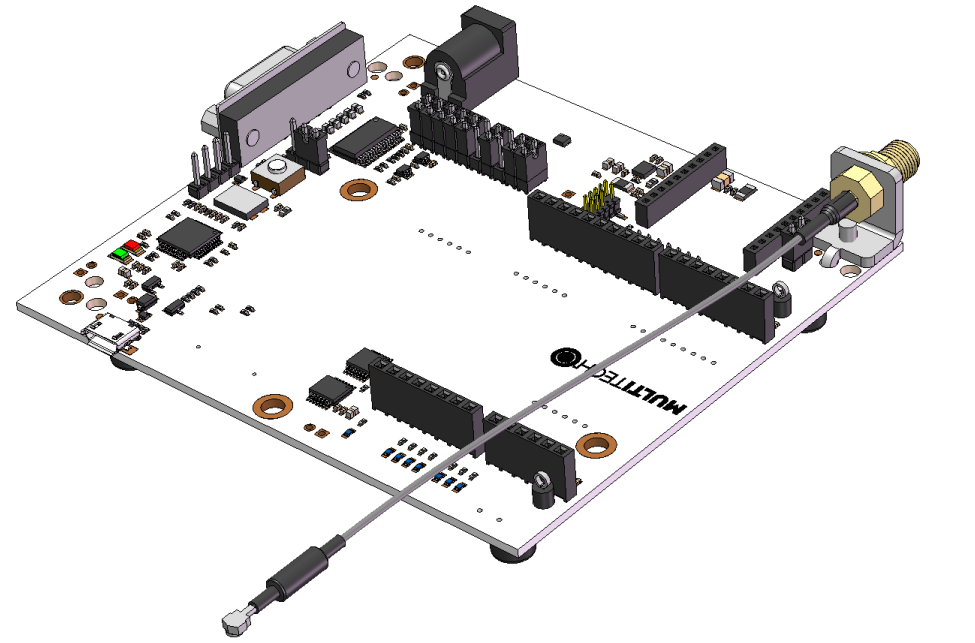
The MTUDK2-ST-MDOT Developer Kit includes the following:

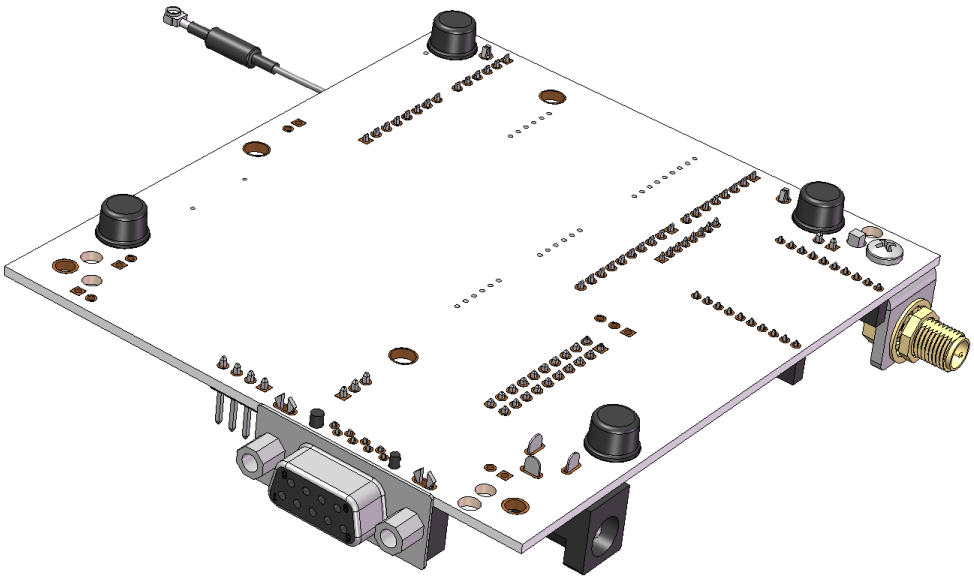
Developer Board	1 - MTUDK 2.0 mDot Developer Board
Cables	1 - Micro USB Cable
	1 - RSMA-U.FL Antenna Cables (attached to developer board)
Antennas	1 - 868-945 MHz Antenna
Customer Notices	Quick Start
Additional	One promotional screwdriver

Chapter 10 – Board Components

Developer Board

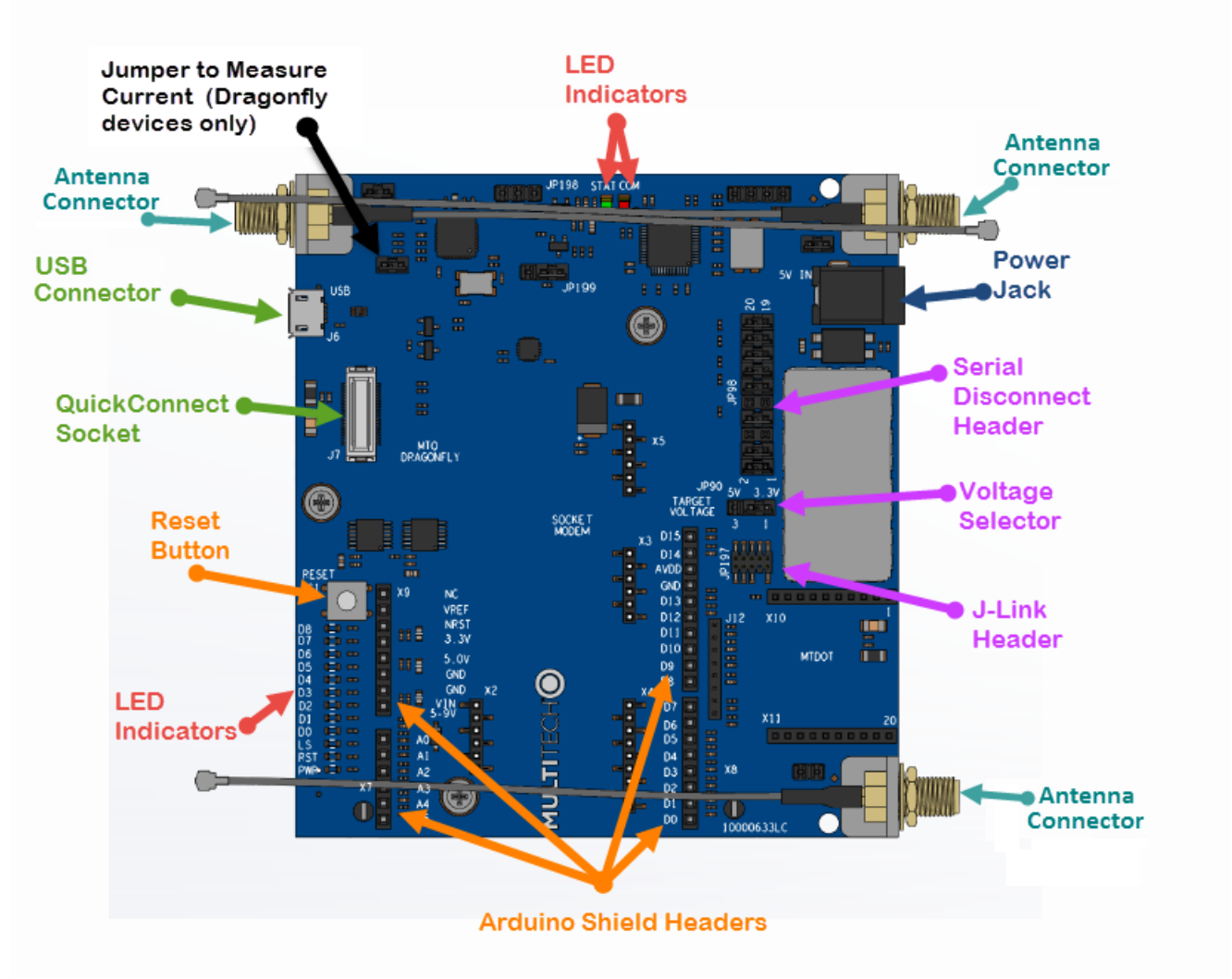






Note: mDot developer boards may be white or dark blue.

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 *Chapter 12 Developer Board Schematics*.
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

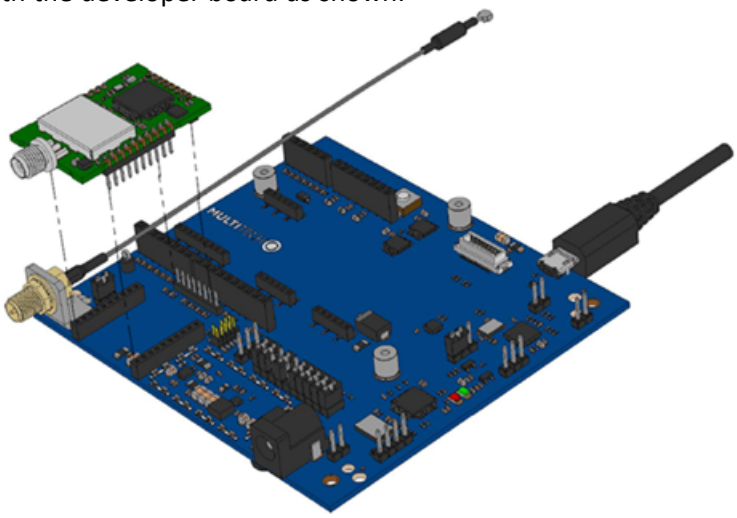
Label	LED	Location
STAT	LED1	Near JP198
COM	LED2	Near JP198
D7	LED3	Across the mDot connectors.
D6	LED7	Directly across from the mDot connectors.
D3	LED8	Directly across from the mDot connectors.
D0	LED9	Directly across from the mDot connectors.
D1	LED10	Directly across from the mDot connectors.
RST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

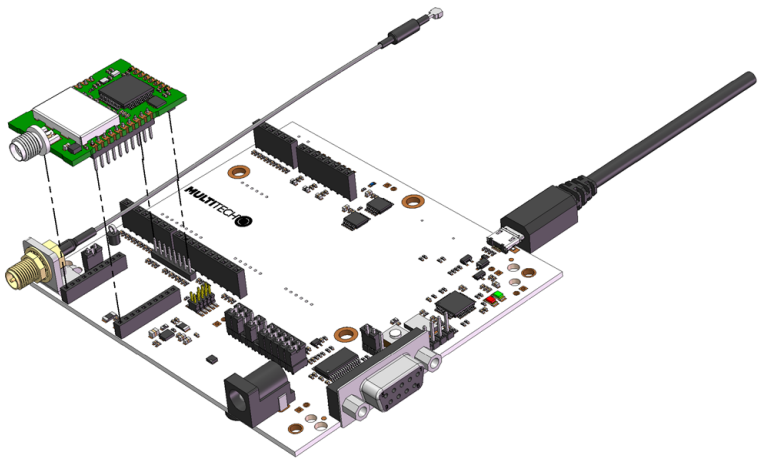
Chapter 11 – Developer Board Installation

Installing an mDot on the Developer Board

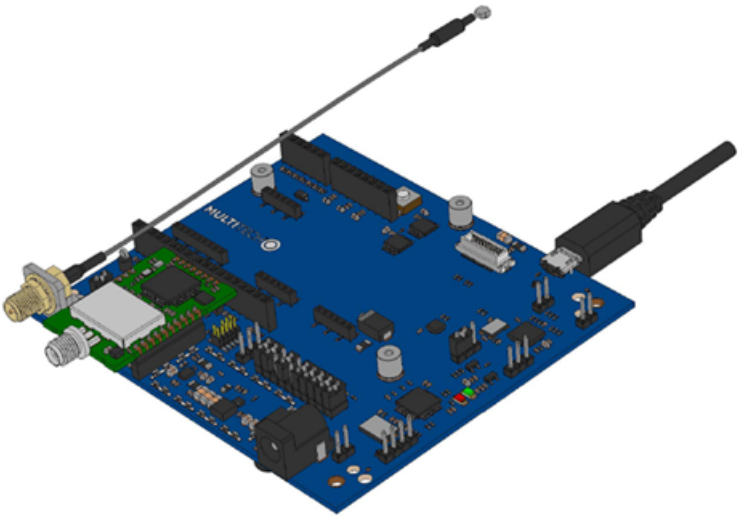
To install an mDot on the Developer Board:

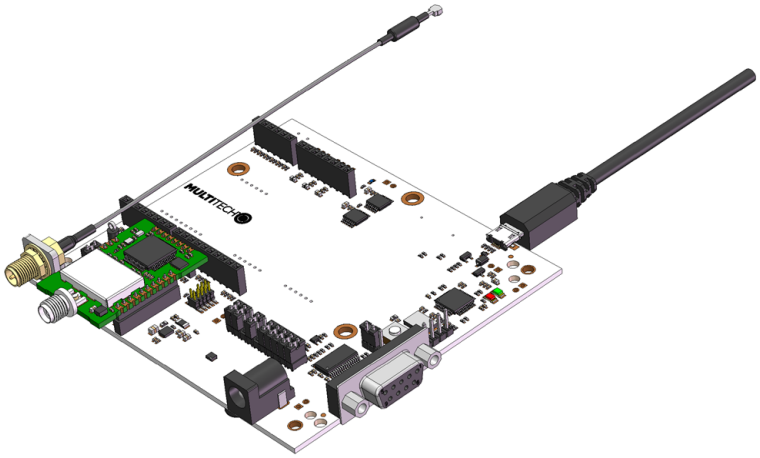
1. Align the mDot with the developer board as shown.





2. Gently press the mDot into the connectors.





Arduino Shield

mDot Arduino Pins

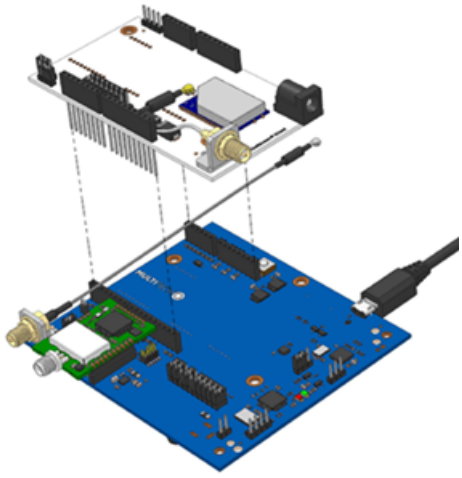
Signals (module pin) micro pin		Arduino Shield						Signals (module pin) micro pin
					D15			PWM0/RSSI/I2CSCL (6) PA8
					D14			PWM1/I2CSDA (7) PC9
					AVDD			3.3V
					GND			Ground
			NC		D13		X6	AD2/DIO2/SCK (18) PA5
3.3V			VREF		D12			DO8/MISO (4) PA6
nReset, from pushbutton			nRST		D11			AD4/DIO4/MOSI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

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:

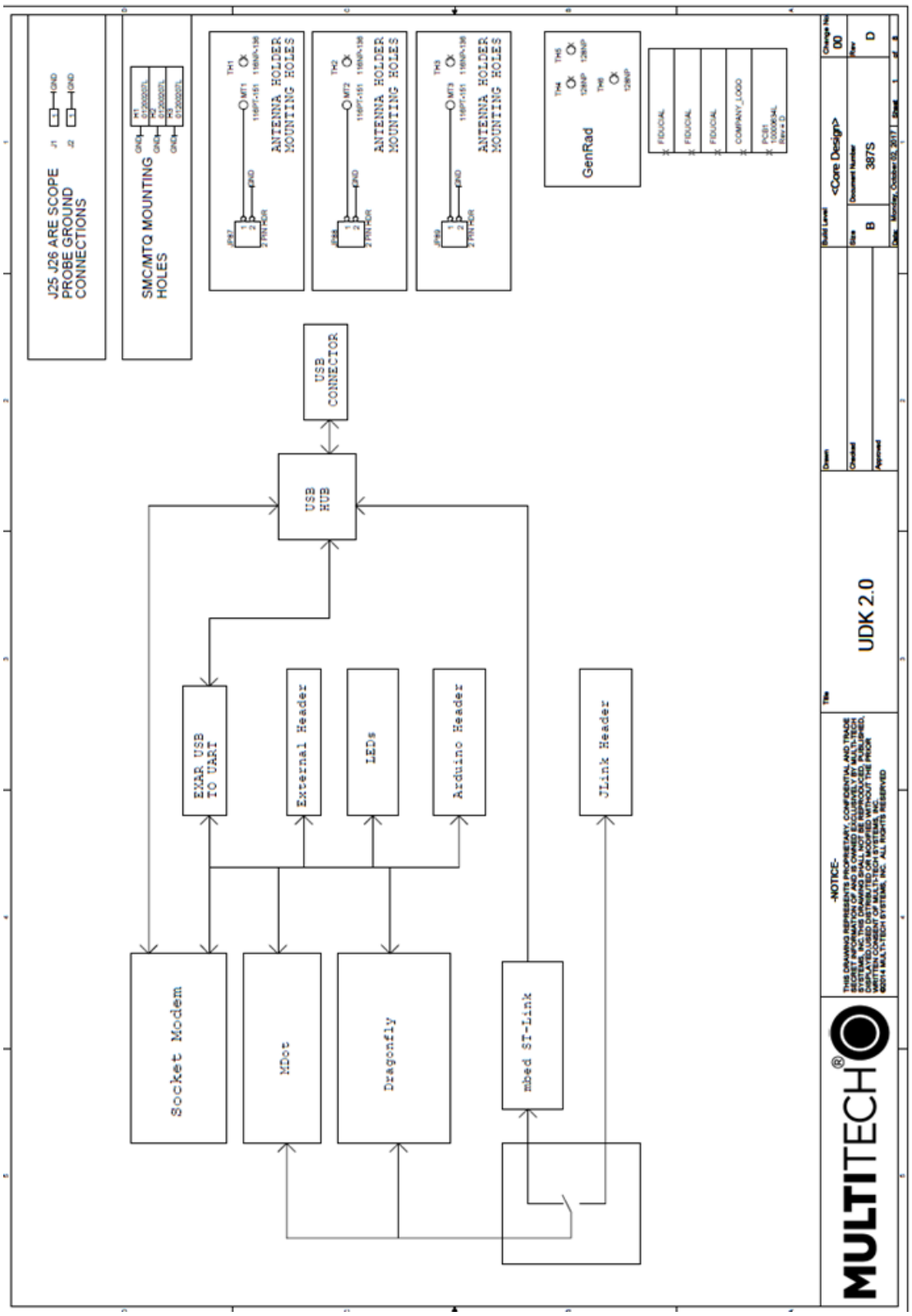
1. Finger tighten the antenna to the SMA connector.

Chapter 12 – Developer Board Schematics

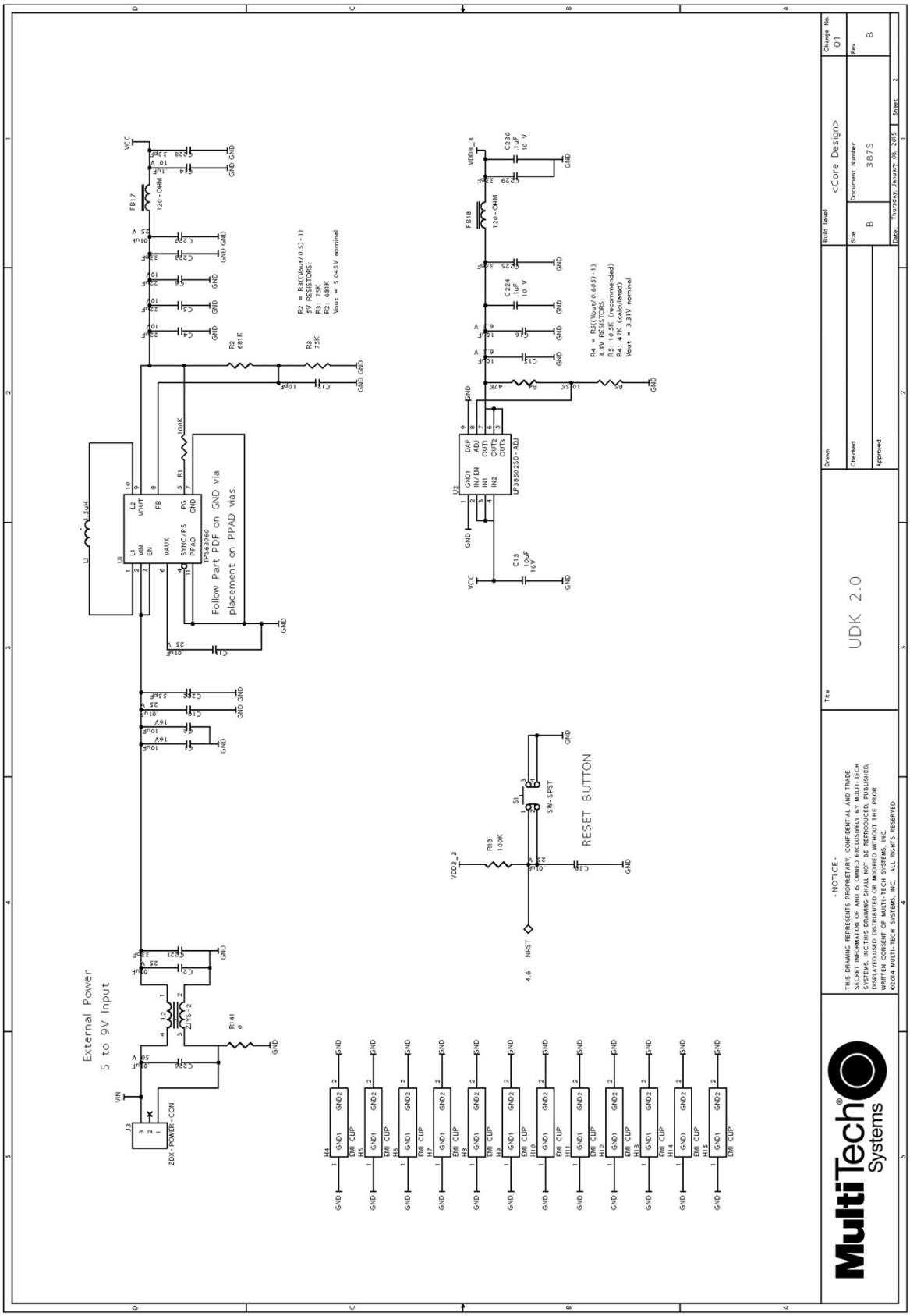
About Schematics

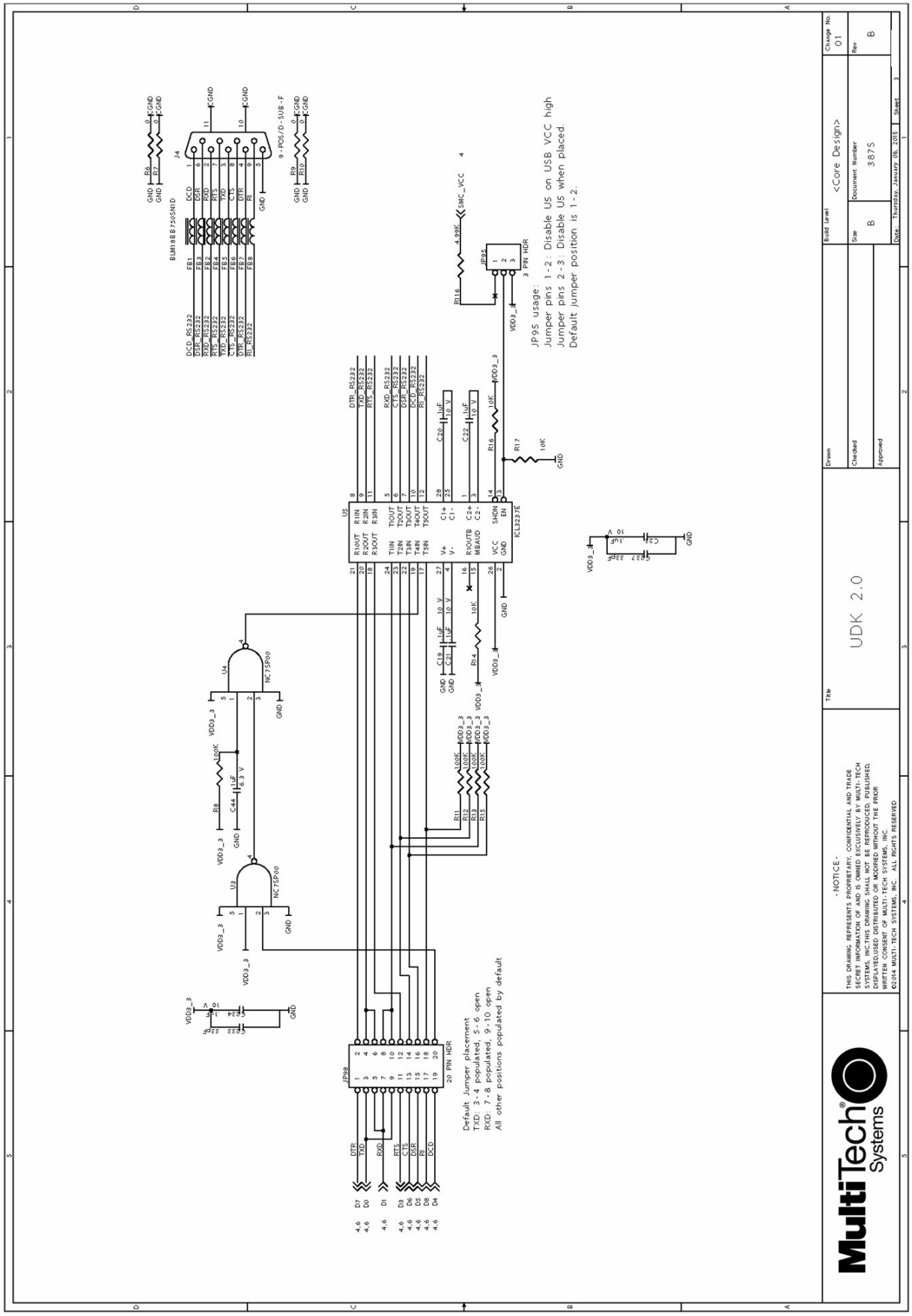
The following schematics are for the fully populated MTUDK2 developer board and contain components not included on the MTUDK2-ST-MDOT model.

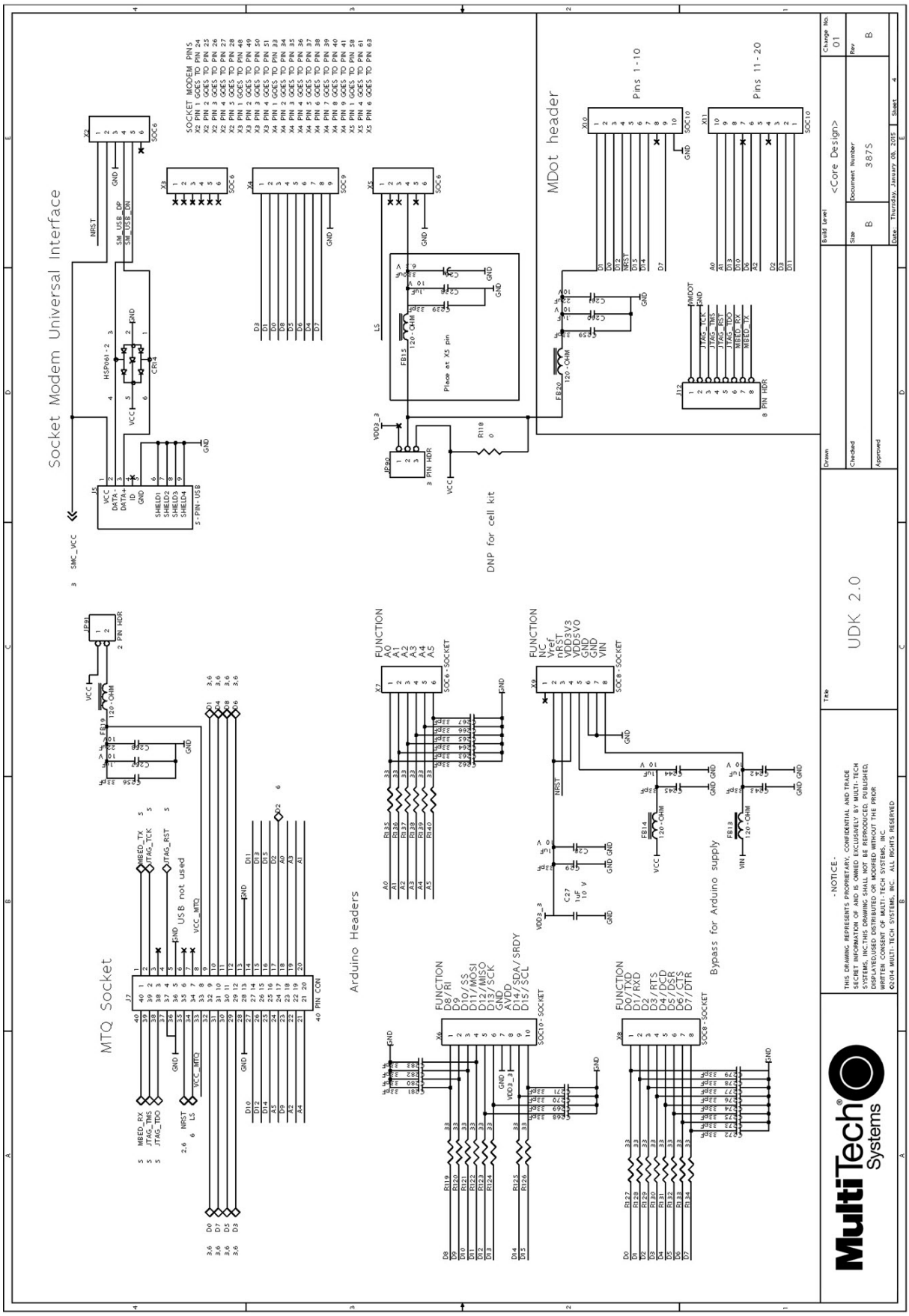
Block Diagram

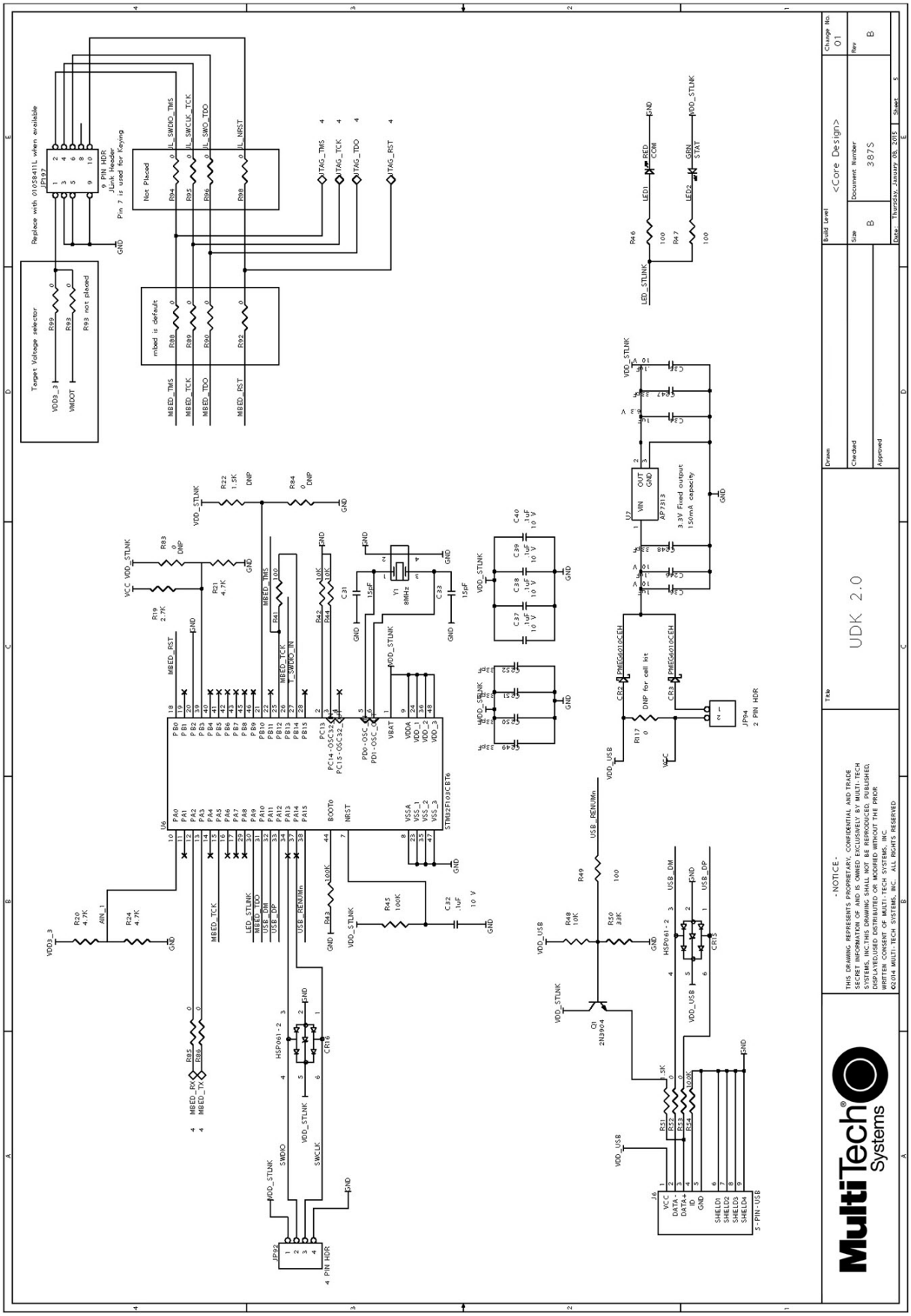


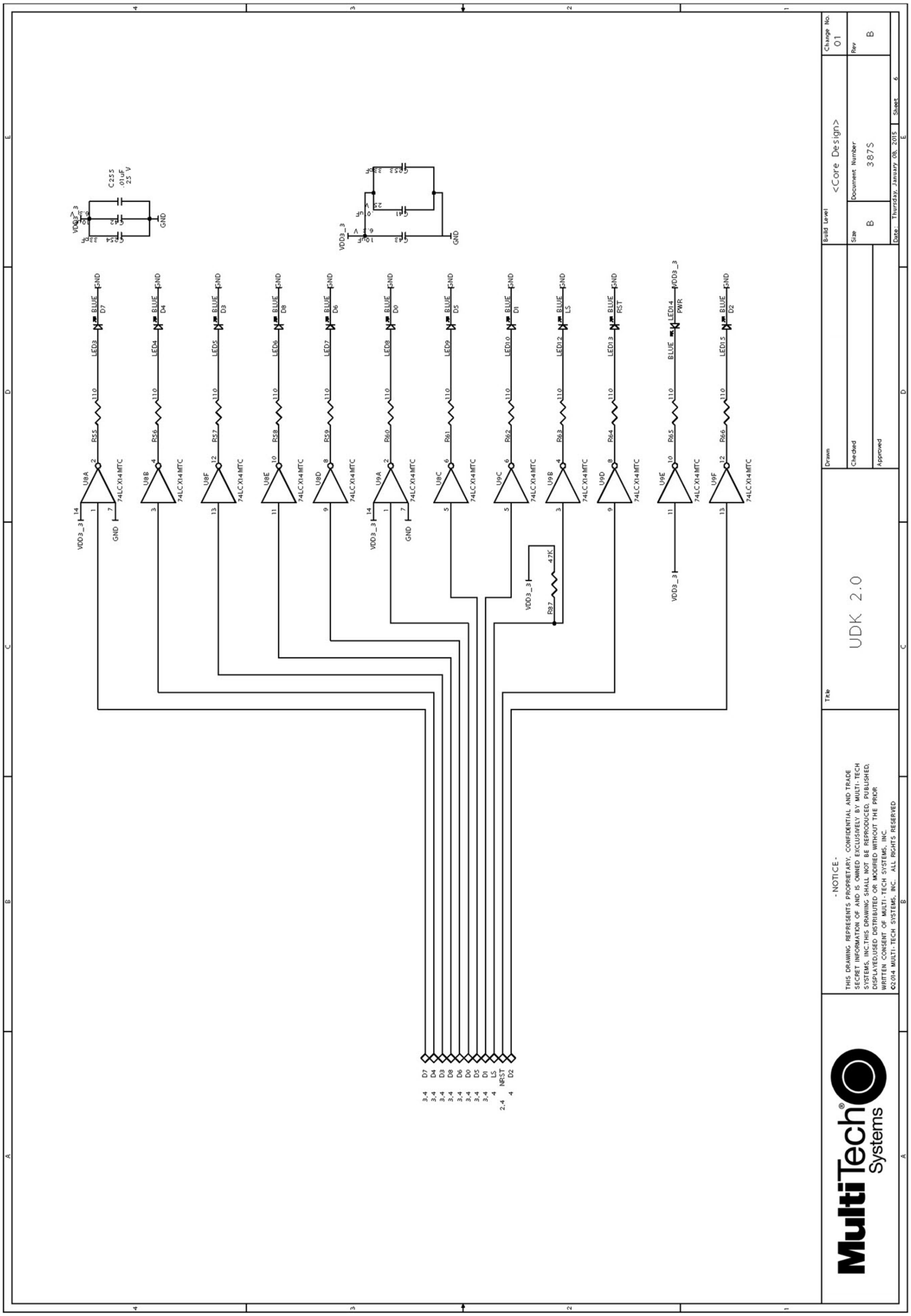
Schematics


UDK 2.0
RESET BUTTON
External Power
5 to 9V Input
Follow Part PDF on GND via placement on PPAD vias
<Core Design>
MultiTech Systems
- NOTICE -
THIS DRAWING REPRESENTS PROPRIETARY, CONFIDENTIAL AND TRADE SECRET INFORMATION OF AND IS OWNED EXCLUSIVELY BY MULTI-TECH SYSTEMS, INC. THIS DRAWING SHALL NOT BE REPRODUCED, PUBLISHED, DISPLAYED, USED, DISTRIBUTED OR MODIFIED WITHOUT THE PRIOR WRITTEN CONSENT OF MULTI-TECH SYSTEMS, INC.
©2004 MULTI-TECH SYSTEMS, INC. ALL RIGHTS RESERVED


UDK 2.0
MultiTech Systems
JP95 usage:
Jumper pins 1-2: Disable US on USB VCC high
Jumper pins 2-3: Disable US when placed.
Default jumper position is 1-2.
Default jumper placement
TXD: 3-4 populated, 5-6 open
RXD: 7-8 populated, 9-10 open
All other positions populated by default
- NOTICE -
THIS DRAWING REPRESENTS PROPRIETARY, CONFIDENTIAL AND TRADE SECRET INFORMATION OF AND IS OWNED EXCLUSIVELY BY MULTI-TECH SYSTEMS, INC.THIS DRAWING SHALL NOT BE REPRODUCED, PUBLISHED, DISCLOSED, USED OR MODIFIED, IN WHOLE OR IN PART, WITHOUT THE PRIOR WRITTEN CONSENT OF MULTI-TECH SYSTEMS, INC.
©2014 MULTI-TECH SYSTEMS, INC. ALL RIGHTS RESERVED


Socket Modem Universal Interface
MDot header
Pins 1-10
Pins 11-20
MTQ Socket
Arduino Headers
Bypass for Arduino supply
DNP for cell kit
USB not used
Place at X5 pin
UDK 2.0
<Core Design>
MultiTech Systems
-NOTICE-
THIS DRAWING REPRESENTS PROPRIETARY, CONFIDENTIAL AND TRADE SECRET INFORMATION OF AND IS OWNED EXCLUSIVELY BY MULTI-TECH SYSTEMS, INC. AND NOT TO BE DISCLOSED, REPRODUCED, DISPLAYED, LOANED, DISTRIBUTED OR MODIFIED WITHOUT THE PRIOR WRITTEN CONSENT OF MULTI-TECH SYSTEMS, INC.
©2014 MULTI-TECH SYSTEMS, INC. ALL RIGHTS RESERVED


UDK 2.0
MultiTech Systems
- NOTICE -
THIS DRAWING REPRESENTS PROPRIETARY, CONFIDENTIAL AND TRADE SECRET INFORMATION OF AND IS OWNED EXCLUSIVELY BY MULTI-TECH SYSTEMS, INC.THIS DRAWING SHALL NOT BE REPRODUCED, PUBLISHED, DISCLOSED,DISTRIBUTED OR MODIFIED WITHOUT THE PRIOR WRITTEN CONSENT OF MULTI-TECH SYSTEMS, INC.
©2014 MULTI-TECH SYSTEMS, INC. ALL RIGHTS RESERVED
<Core Design>
Document Number
3887S
Rev
B
Change No.
01
Sheet 5
Date: Thursday, January 08, 2015
Drawn
Checked
Approved
Build Level
Size
B
Target Voltage selector
Replace with 0105841IL when available
JP197
9 PIN HDR
JLink Header
Pin 7 is used for Keying
Not Placed
mbed is default
R93 not placed
JL_SWDIO_TMS
JL_SWCLK_TCK
JL_SWO_TDO
JL_NRST
JTAG_TMS
JTAG_TCK
JTAG_TDO
JTAG_RST
MBED_TMS
MBED_TCK
MBED_TDO
MBED_RST
VDD_STLINK
VCC VDD_STLINK
LED_STLINK
LED1
LED2
RED COM
GRN STAT
U7
AP7313
3.3V Fixed output
150mA capacity
VIN
OUT
GND
U6
STM32F103C8T6
BOOT0
NRST
VBAT
VDDA
VSSA
PC13
PC14-OSC32_IN
PC15-OSC32_OUT
PD0-OSC_IN
PD1-OSC_OUT
Y1
8MHz
SWDIO
SWCLK
MBED_PX
MBED_TX
USB_RENUMn
USB_DM
USB_DP
VDD_USB
CR2
CR3
PMEG6010CEH
DNP for cell kit
JP94
2 PIN HDR
JP92
4 PIN HDR
J6
5-PIN-USB
VCC
DATA-
DATA+
ID
GND
SHIELD1
SHIELD2
SHIELD3
SHIELD4
Q1
2N3904
CR16
CR5
HSP061-2
AIN_1


UDK 2.0
<Core Design>
3875
- NOTICE -
THIS DRAWING REPRESENTS PROPRIETARY, CONFIDENTIAL AND TRADE SECRET INFORMATION OF AND IS OWNED EXCLUSIVELY BY MULTI-TECH SYSTEMS, INC. THIS DRAWING SHALL NOT BE REPRODUCED, PUBLISHED, DISPLAYED, USED DISTRIBUTED OR MODIFIED WITHOUT THE PRIOR WRITTEN CONSENT OF MULTI-TECH SYSTEMS, INC.
©2014 MULTI-TECH SYSTEMS, INC. ALL RIGHTS RESERVED
MultiTech Systems

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

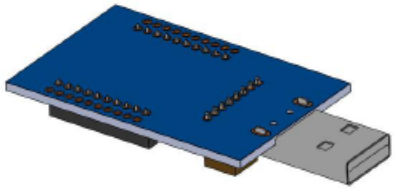
For Windows 10, you do not need additional drivers.

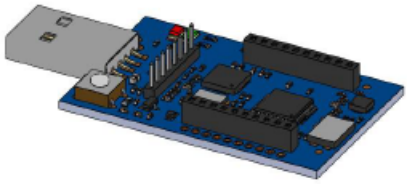
For Windows 7, the MTMDK board has an Exar chip for the serial communication port and you need an Exar driver to send AT Command to the mDot. You do not need the ST-Link driver for the serial communication port (AT Commands). https://www.exar.com/content/document.ashx?id=1596.

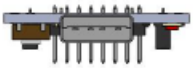
To debug the processor with Windows 7, you do the ST-Link driver with the MTMDK board.
https://developer.mbed.org/teams/st/wiki/ST-Link-Driver.

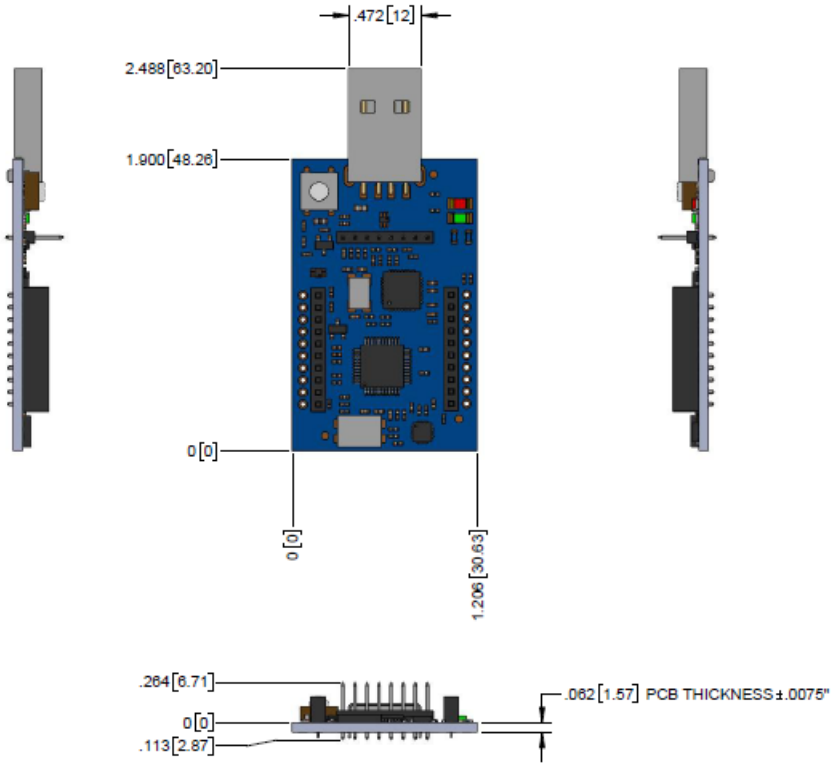
Note: You do not need a driver for the USB mass storage feature.

Micro DK Mechanical Drawings

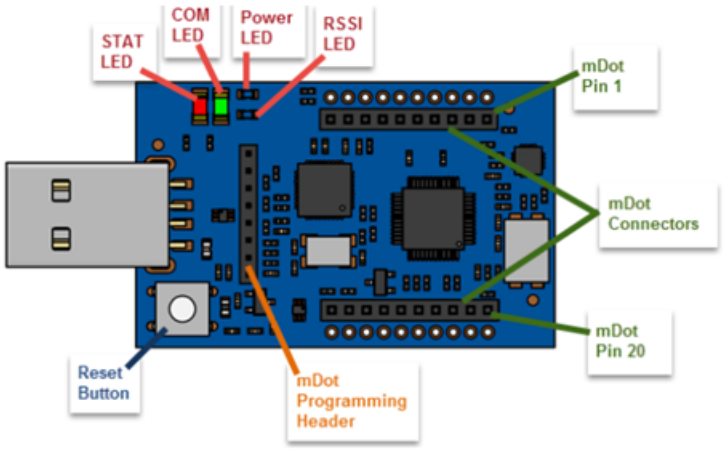








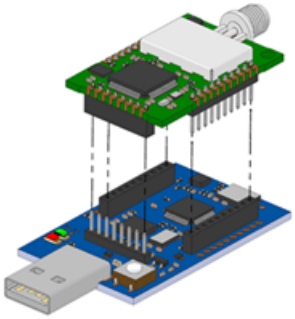
Micro Developer Board Components



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



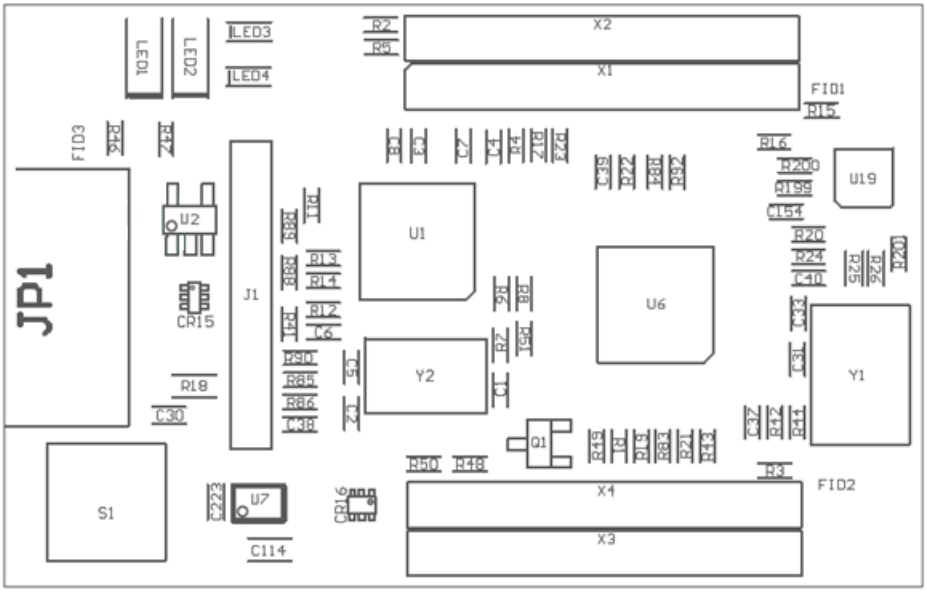
To install an mDot on the Micro Developer Board:

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

Assembly Diagrams and Schematics

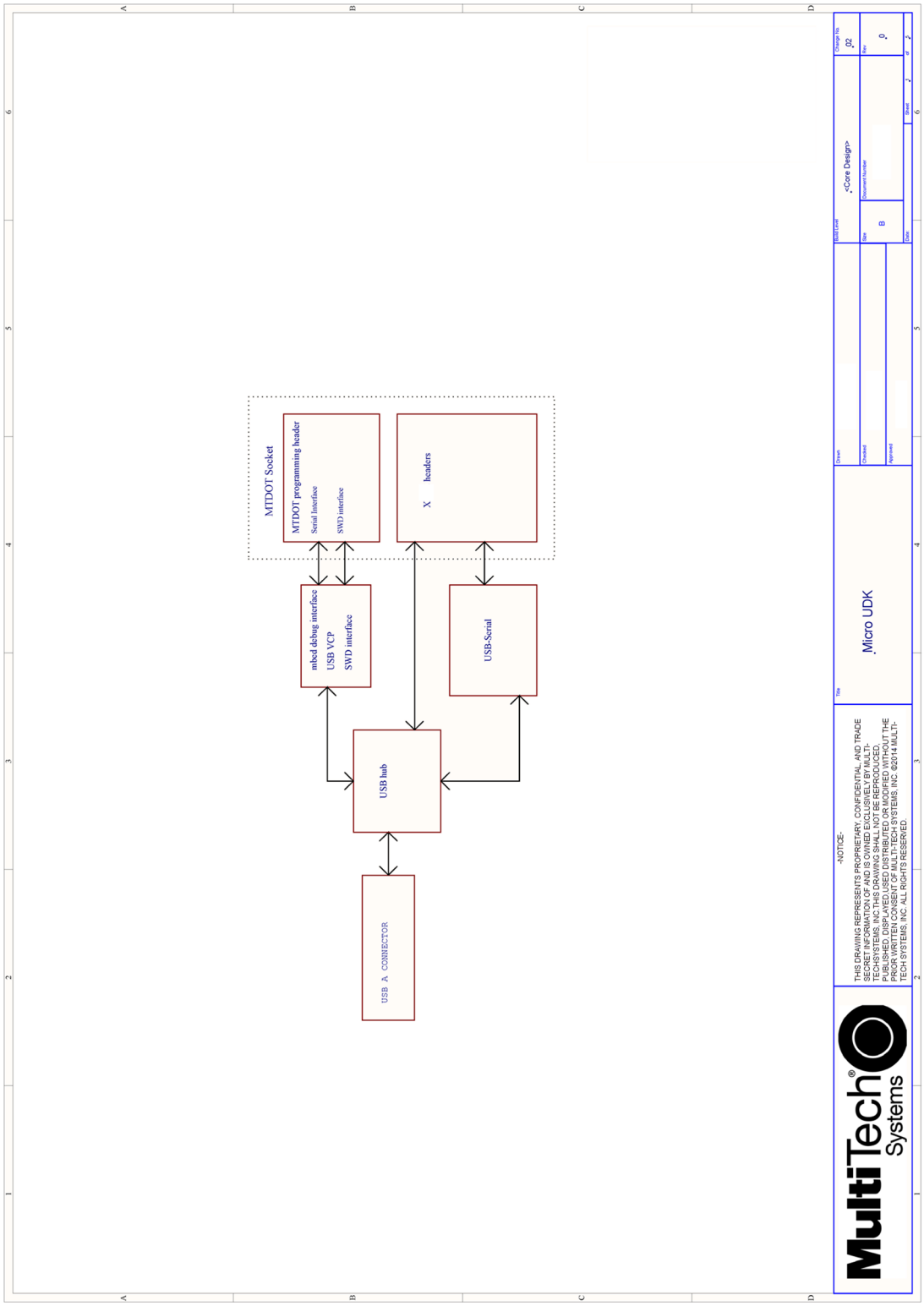
Assembly Diagrams

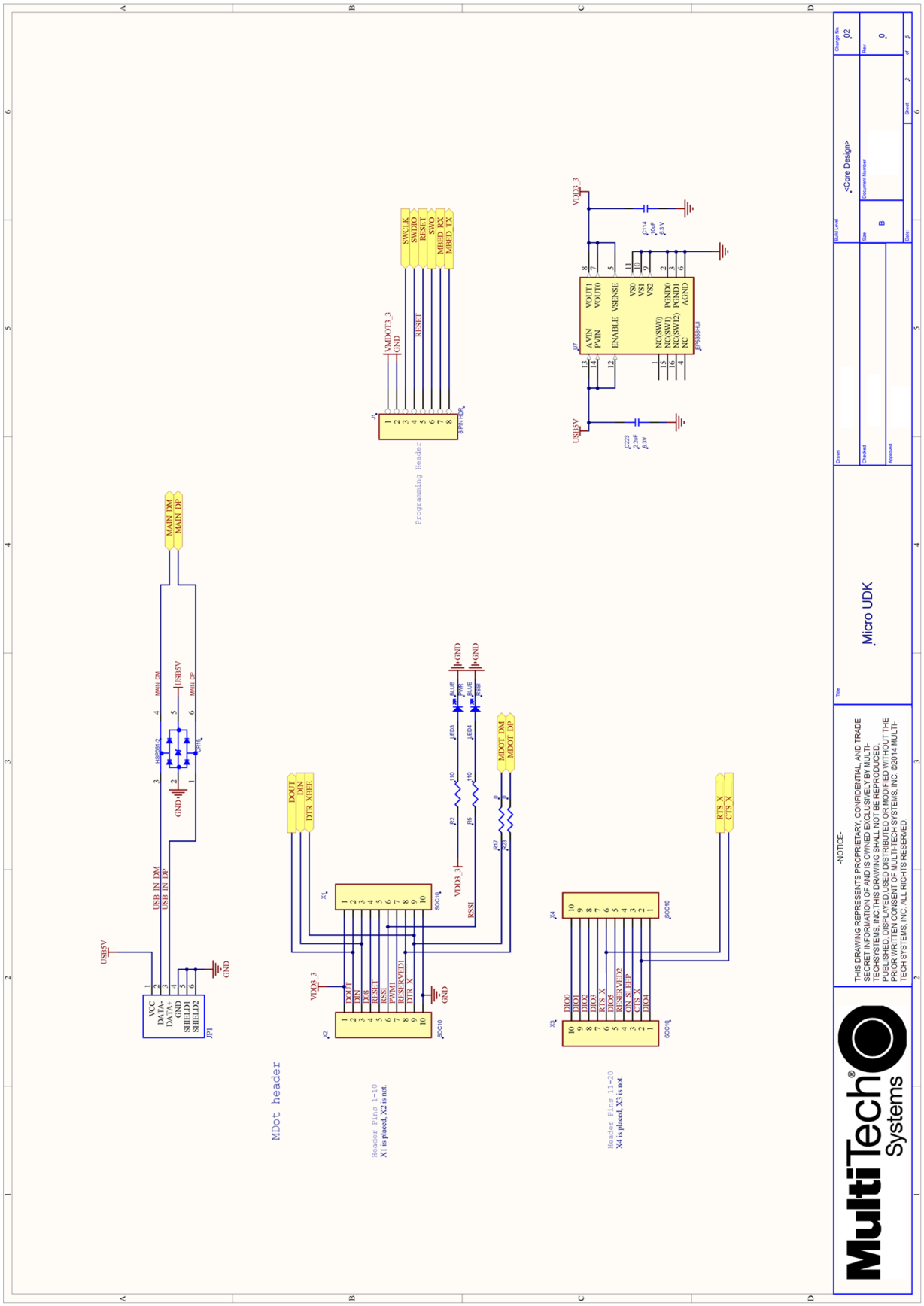
Top Assembly

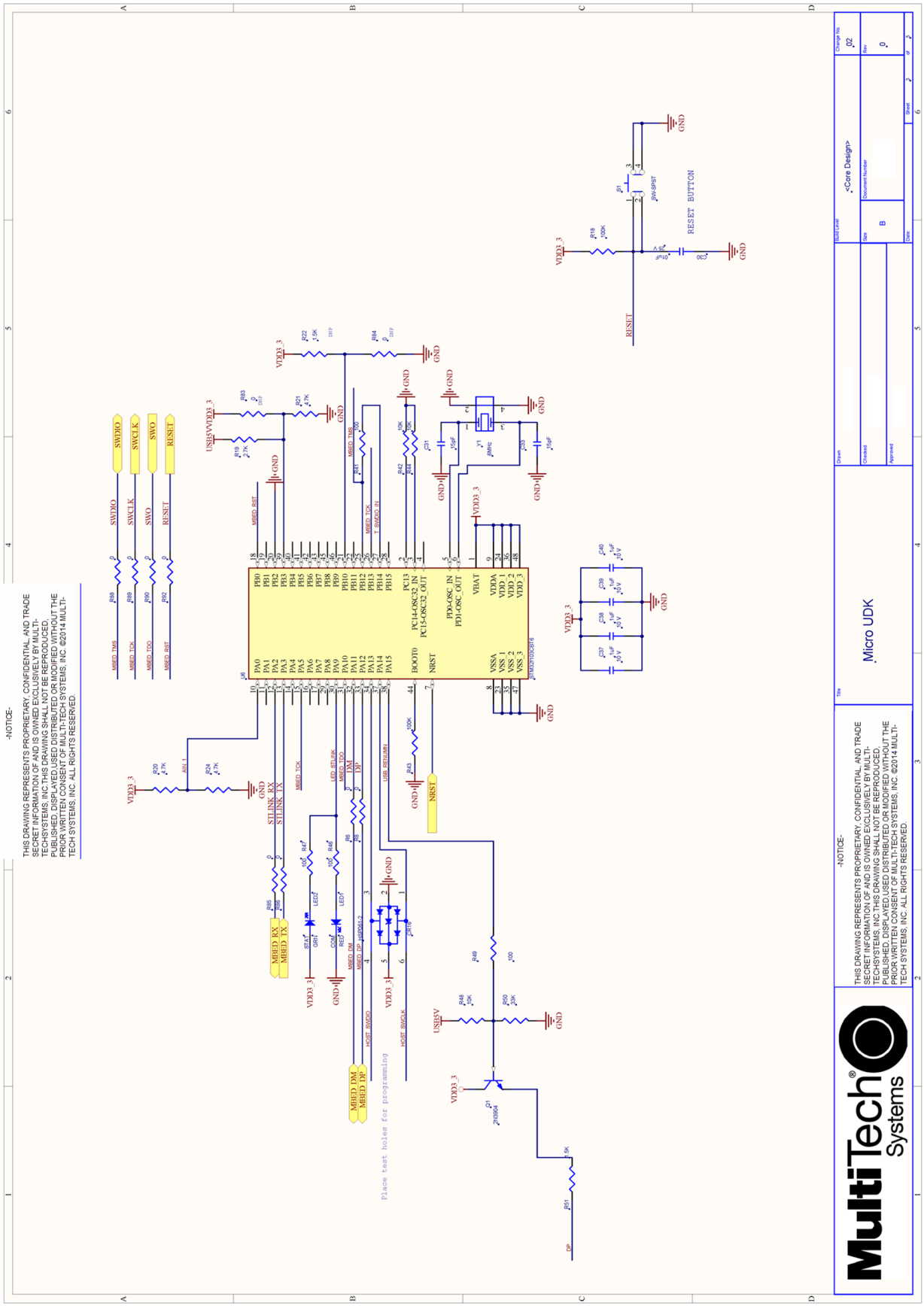


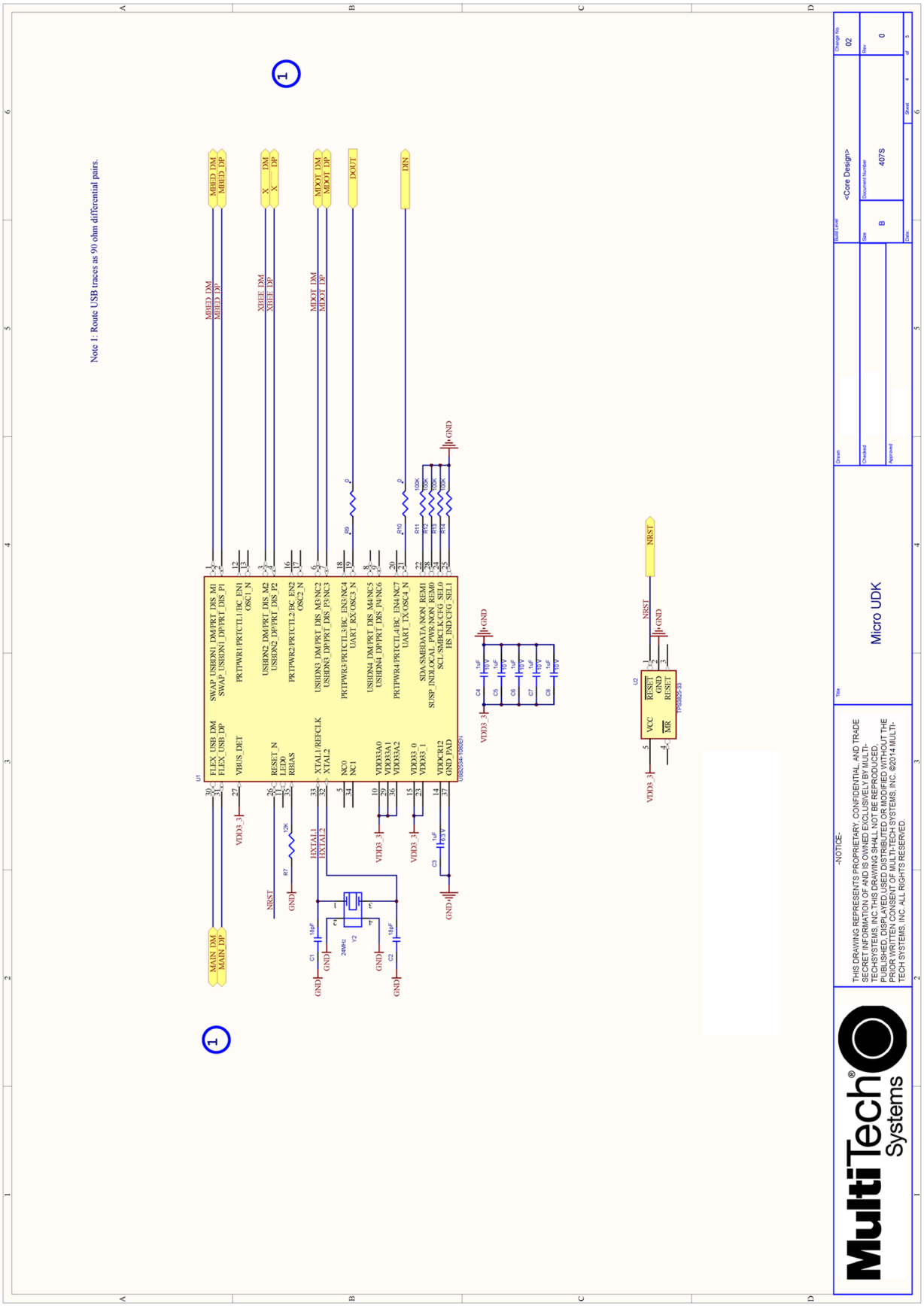
Bottom Assembly

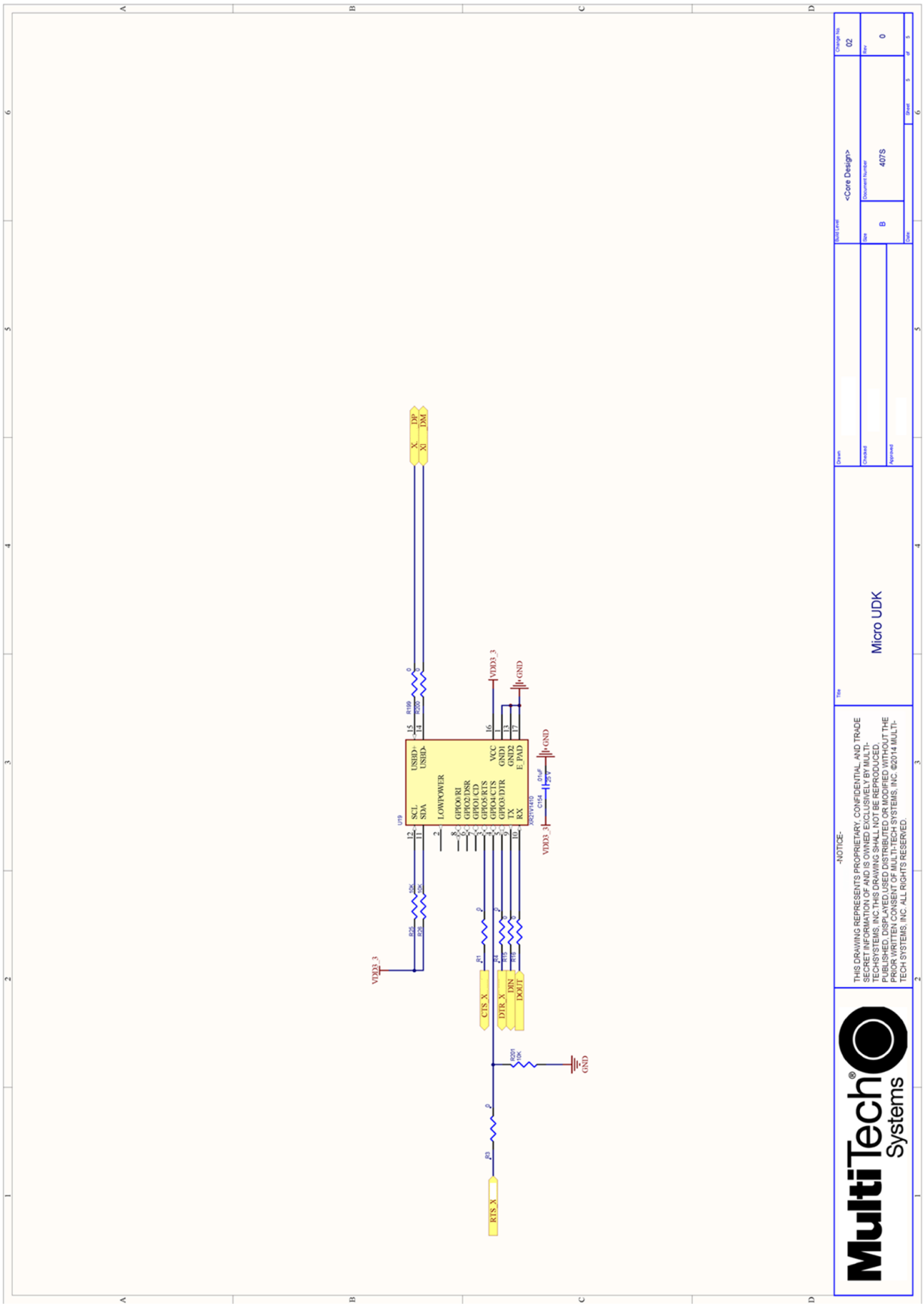
Schematics


MTDOT Socket
MTDOT programming header
Serial Interface
SWD interface
X headers
mbed debug interface
USB VCP
SWD interface
USB-Serial
USB hub
USB A CONNECTOR
Micro UDK
<Core Design>
MultiTech Systems
-NOTICE-
THIS DRAWING REPRESENTS PROPRIETARY, CONFIDENTIAL, AND TRADE SECRET INFORMATION AND IS OWNED BY, AND SHALL REMAIN THE PROPERTY OF, TECHSYSTEMS, INC. THIS DRAWING SHALL NOT BE REPRODUCED, PUBLISHED, DISPLAYED, USED, DISTRIBUTED OR MODIFIED WITHOUT THE PRIOR WRITTEN CONSENT OF MULTI-TECH SYSTEMS, INC. ©2014 MULTI-TECH SYSTEMS, INC. ALL RIGHTS RESERVED.


MultiTech Systems
Micro UDK
<Core Design>
-NOTICE-
THIS DRAWING REPRESENTS PROPRIETARY, CONFIDENTIAL, AND TRADE SECRET MATERIAL OWNED BY MULTI-TECH SYSTEMS, INC. THIS DRAWING SHALL NOT BE REPRODUCED, PUBLISHED, DISPLAYED, USED, DISTRIBUTED OR MODIFIED WITHOUT THE PRIOR WRITTEN CONSENT OF MULTI-TECH SYSTEMS, INC. ©2014 MULTI-TECH SYSTEMS, INC. ALL RIGHTS RESERVED.
MDot header
Programming Header
Header Pins 1-10
X1 is placed, X2 is not.
Header Pins 11-20
X4 is placed, X3 is not.
MAIN_DM
MAIN_DP
USB_IN_DM
USB_IN_DP
USB5V
VDD3_3
GND
SWCLK
SWDIO
RESET
SWO
MBED_RX
MBED_TX
DOUT
DIN
DTR_XBEE
RSSI
MDOT_DM
MDOT_DP
RTS_X
CTS_X


-NOTICE-
THIS DRAWING REPRESENTS PROPRIETARY, CONFIDENTIAL, AND TRADE SECRET INFORMATION OF AND IS OWNED EXCLUSIVELY BY MULTI-TECH SYSTEMS, INC. USE OF THIS DRAWING SHALL NOT BE REPRODUCED, PUBLISHED, DISPLAYED, USED, DISTRIBUTED, OR MODIFIED WITHOUT THE PRIOR WRITTEN CONSENT OF MULTI-TECH SYSTEMS, INC. ©2014 MULTI-TECH SYSTEMS, INC. ALL RIGHTS RESERVED.
MultiTech Systems
Micro UDK
<Core Design>
RESET BUTTON
SWDIO
SWCLK
SWO
RESET
STLINK_RX
STLINK_TX
MBED RX
MBED TX
MBED DM
MBED DP
USB5V
VDD3_3
GND
NRST
Place test holes for programming


Note 1: Route USB traces as 90 ohm differential pairs.
MBED_DM
MBED_DP
XBEE_DM
XBEE_DP
MDOT_DM
MDOT_DP
DOUT
DIN
NRST
MAIN_DM
MAIN_DP
Micro UDK
<Core Design>
MultiTech Systems
-NOTICE-
THIS DRAWING REPRESENTS PROPRIETARY, CONFIDENTIAL AND TRADE SECRET MATERIAL OF AND OWNED BY MULTI-TECH SYSTEMS, INC. THIS DRAWING SHALL NOT BE REPRODUCED, PUBLISHED, DISPLAYED, USED, DISTRIBUTED OR MODIFIED WITHOUT THE PRIOR WRITTEN CONSENT OF MULTI-TECH SYSTEMS, INC. ©2014 MULTI-TECH SYSTEMS, INC. ALL RIGHTS RESERVED.


Micro UDK
<Core Design>
407S
MultiTech Systems
-NOTICE-
THIS DRAWING REPRESENTS PROPRIETARY, CONFIDENTIAL, AND TRADE SECRET INFORMATION OF AND IS OWNED EXCLUSIVELY BY MULTI-TECH SYSTEMS, INC. THIS DRAWING SHALL NOT BE REPRODUCED, PUBLISHED, DISCLOSED, DISTRIBUTED OR USED IN ANY MANNER WITHOUT THE PRIOR WRITTEN CONSENT OF MULTI-TECH SYSTEMS, INC. ©2014 MULTI-TECH SYSTEMS, INC. ALL RIGHTS RESERVED.
USBD+
USBD-
SCL
SDA
LOWPOWER
GPIO0/RI
GPIO2/DSR
GPIO1/CD
GPIO5/RTS
GPIO4/CTS
GPIO3/DTR
TX
RX
VCC
GND1
GND2
E_PAD
DP
DM
CTS_X
DTR_X
DIN
DOUT
RTS_X
VDD3_3
GND

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

  LinkADRReq: 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

  LinkADRReq 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 mulitcast 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+RECVC 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+SENDC - 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

LoRaWAN 1.0.2 Support

Adds AS923, extending support to Japan.

Listen Before Talk

Listen before talk (LBT) is required in Japan. This feature is automatically configured by the channel plan. For Japan, the AS923 has LBT enabled by default.

Index

R

S

T

U