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Reference Manual

ETH-LORA-M-AX-01

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OVERVIEW

This document describes user manual for the developers to design a final product containing the module ETH-LORA-M-AX-01 (V1.2) acting as a LoRa module.

PRODUCT BRIEF

Ethertronics' LoRa Module ETH-LORA-M-AX-01 is an SMT mounted low cost and low power radio module that operates in the unlicensed 868/915 MHz band. It integrates STM32L151 as the main MCU and Semtech SX1272 as the LoRa IC. ETH-LORA-M-AX-xx is principally built with complete firmware to simplify its integration in the final product. Interfacing with this module is easy with two lines UART via AT commands.

ETH-LORA-M-AX-01 is designed with a power saving technique so that the current consumption is low even when in communication. All these features make ETH-LORA-M-AX-01 a perfect platform for a long range wireless communication with low throughput data. This module can be used in various applications such as smart metering, smart grids, smart city, industrial control, etc.

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.

NOTE: The grantee is not responsible for any changes or modifications not expressly approved by the party responsible for compliance. Such modifications could void the user's authority to operate the equipment

SCOPE

This document focuses on helping the developers to integrate ETH-LORA-M-AX-01 in the final product to fasten the time to market of their product. This document is not intended to provide an overall description of all software solutions and all products that may be designed. This document explains several AT commands in order to perform specific tasks. For a complete guide of AT commands supported by ETH-LORA-M-AX-01, please refer AT Command Reference Guide available on AVX's website. Developers are also highly advised to refer to all the necessary application notes available on AVX's website.

Link: ***http://www.avx.com/products/modules/lora-module/***

DOCUMENT ORGANIZATION

This document contains the following sections:

- Section Overview provides a product brief, scope for this manual and its organization.
- Section Getting Started describes briefly LoRa communication and the deployment architecture of ETH-LORA-M-AX-01.
- Section Basic Operation explains the basic operation to send a message over LoRa Network using this module.
- Section Advanced Operation provides in-depth information on more advanced operation and AT commands of the module.
- Section Appendix contains lists of the abbreviation, figures and table of this document and also the useful reference link.

GETTING STARTED

This section gives a general overview about LoRa communication and the module ETH-LORA-M-AX-01. LoRa part focuses more on the LoRa end devices since it is the core subject of this document.

INTRODUCING LORA COMMUNICATION

The Internet of Things is a network of connected objects able to collect and exchange information with each other through wireless networks. These objects embed electronics, firmware, sensors, and wireless connectivity protocols to execute its task. The Internet of Things (IoT) has been labeled as "the next Industrial Revolution" because of the way it will impact the way people live, work, entertain, and travel, as well as the interaction between governments and businesses with the world. Business Insider has predicted that there will be 24 billion IoT devices installed by 2020. The common wireless protocols such as Wifi, Bluetooth, Zigbee, Z-Wave etc, are well suited for short range application where and battery life is not a major issue. Hence more suitable protocols are needed and LoRa is one of them. [1]

LoRa (Long Range) is an innovation of Semtech which offers an impressive mix of long range, low power consumption and secure data transmission. Many legacy wireless systems use frequency shifting keying (FSK) modulation as the physical layer because it is a very efficient modulation for achieving low power. LoRa is based on chirp spread spectrum (CSS) modulation, which maintains the same low power characteristics as FSK modulation but significantly increases the communication range. CSS has been used in military and space communication for decades due to the long communication distances that can be achieved and robustness to interference, but LoRa is the first low cost implementation for commercial usage.

INTRODUCING LORA COMMUNICATION (CONTINUED)

Its low consumption makes it the best solution for a battery powered IoT applications. LoRa offers also a secured network with embedded end-to-end AES128 encryption. The MAC layer called LoRaWAN has been added to standardize and extend the LoRa physical layer onto internet networks. This specification is open sourced and supported by LoRa Alliance. LoRaWAN can be mapped in the 2nd and 3rd layer of the OSI model. [2]

LPWAN COMPARE TO TRADITIONAL NETWORK

	Local Area Network Short Range Communication	**Low Power Wide Area** (LPWAN) Internet of Things	**Cellular Network** Traditional M2M
	40%	**45%**	**15%**
	Well established standards In building	Low power consumption Low cost Positioning	Existing coverage High data rate
	Battery Live Provisioning Network cost & dependencies	High data rate Emerging standards	Autonomy Total cost of ownership
	Bluetooth 4.0, Zigbee, WiFi	LoRa	GSM, 3G+ / H+, 4G

Figure 1

GLOBAL LORAWAN NETWORK

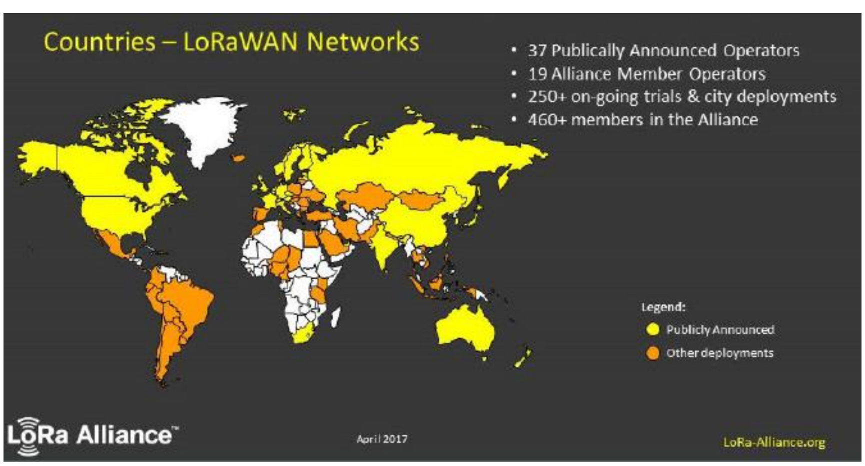

Figure 2

NETWORK ARCHITECTURE

LORA NETWORK DIAGRAM EXAMPLE

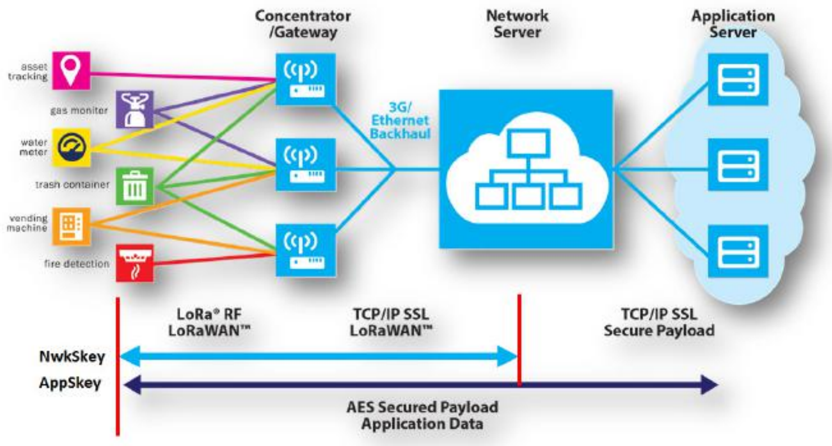

Figure 3

LoRa End Nodes: End device which contains the sensors necessary to execute their role (examples: temperature, humidity, water level, presence, etc). These devices embed also a LoRa RF transceiver (also known as radio) which will be used to send the information to the gateways using LoRa protocol.

LoRa Gateways: All gateways receive data on all channels all the time. Gateways act as transparent bridges forward the data to the network server or to the end devices without performing any data validation in both ways. Gateways forward message using LoRa RF to the end devices and using IP to LoRa servers.

LoRa Server: The typical roles of the server are monitoring and managing the gateways and the security, removing the redundancy data and performing the billing. The server also distributes the data to the application server (i.e. interface directly with AWS or directly with applications via web socket.

NwkSKey (Network Session Key) is shared between the end device and the network server. It's used in the message integrity verification for the communication and it also provides security for the end device towards the network server communication.

AppSkey (Application session Key) is shared between the end device and the application server. It guarantees the security of the application's payload as it is used to encrypt and decrypt the application data. This means that the network server cannot decipher the application data.

LORAWAN CLASS

LoRaWAN defines the communication protocol and system architecture for the network while the LoRa physical layer enables the long-range communication link. LoRaWAN has several different classes of end-point devices to address the different needs reflected in the wide range of applications.

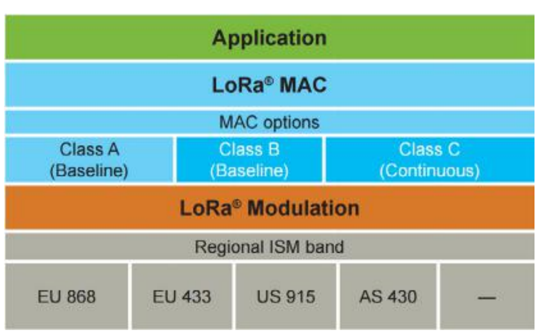

Figure 4

CLASS A

End-devices of Class A allow for bi-directional communications whereby each end-device's uplink transmission is followed by two short downlink receive windows. The transmission slot scheduled by the end-device is based on its own communication needs with a small variation based on a random time basis (ALOHA-type of protocol). This Class A operation is the lowest power end-device system for applications that only require downlink communication from the server shortly after the end-device has sent an uplink transmission. Downlink communications from the server at any other time will have to wait until the next scheduled uplink.

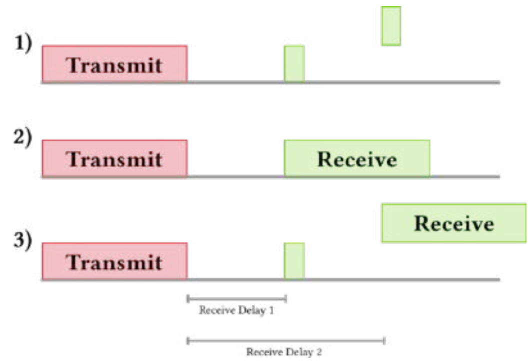

Figure 5

If the server does not respond in either of these receive windows (situation 1 in the figure), the next opportunity will be after the next uplink transmission from the device. The server can respond either in the first receive window (situation 2 in the figure), or the second receive window (situation 3 in the figure). Hence for every uplink, there are two possible downlink slots. It is always the end device which starts the communication first.

CLASS B

In addition to the Class A random receive windows, Class B devices open extra receive windows at scheduled times. Using time-synchronized beacons transmitted by the gateway, the devices periodically open receive windows. This allows the server to know when the end-device is listening. The preprogrammed downlink slots allow control within certain latency limits.

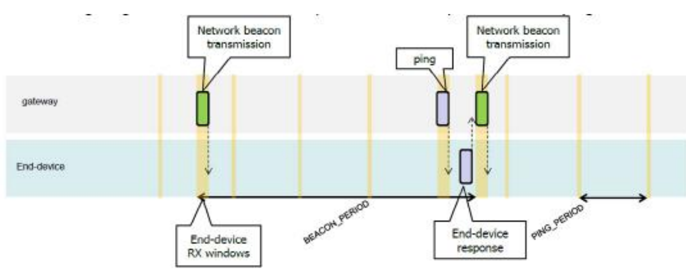

Figure 6

CLASS C

End-devices of Class C have nearly continuously open receive windows, only closed when transmitting. Class C end-device use more power to operate than Class A or Class B thus is suited for the mains powered application. There is almost no latency for downlink communication in this class. [3]

LORAWAN REGIONAL SUMMARY

LoRaWAN Specification diversifies from region to region. This is due to the different regional frequency spectrum allocations and regulation directives. The module ETH-LORA-M-AX-01 can be used in Europe and North America as it integrates Semtech SX1272 IC which covers the spectrum for those regions. The specification for Europe and North America are well defined. ISM radio spectrum use in Europe is defined by the ETSI while FCC regulations are imposed in US. The most significant different between these two regions is that the ERP is limited in Europe to 14 dBM while in US a maximum dwell time of 400ms is imposed.

In July 2016, LoRa Alliance Technical committee has provided a detailed document about LoRaWAN regional parameters. This document includes the specification for other region as well such as Australia, China, Korea and South East Asian countries. Users are advised to read this document for depth information about the LoRaWAN Regional Parameters. [4]

LORAWAN REGIONAL PARAMETERS

	Europe	North America	China	Korea	Japan	India
Frequency Band	867-869MHz	902-928MHz	470-510MHz	920-925MHz	920-925MHz	865-867MHz
Channels	10	64 + 8 + 8	In definition by Techical Committee	In definition by Techical Committee	In definition by Techical Committee	In definition by Techical Committee
Channel BW Up	125/250kHz	125/500kHz				
Channel BW Dn	125kHz	500kHz				
TX Power Up	+14dBm	+20dBm typ (+30dBm allowed)				
TX Power Dn	+14dBm	+27dBm				
SF Up	7-12	7-10				
Data rate	250bps-50kbps	980dps-21.9pbs				
Link Budget Up	155dB	154dB				
Link Budget Dn	155dB	157dB				

Figure 7

ETH-LORA-M-AX-01 OVERVIEW

Even though LoRa is a system with a narrow band and high sensitivity, a trade off exists between the link budget, the data rate and the time over the air. Besides that, any antennas, including the ones operating in LoRa unlicensed bands are sensitive to their environment and their performance can be degraded. For example the urban area can have a great impact on the coverage of the LoRa communication due to constant changing in the environment.

Compare to other available LoRa module in the market, ETH-LORA-M-AX-01 is embedded with proprietary impedance matching (IM) and active steering (MCD) capabilities to optimize the RF performance on its own. ETH-LORA-M-AX-01 can overcome this challenge in order to achieve an excellent ultra-long range spread spectrum communication.

Ethertronics' LoRa Module ETH-LORA-M-AX-01 is a LoRa modem which can be easily integrated in the final product. ETH-LORA-M-AX-01 is an SMT mounted low cost and low power radio module that operates in the unlicensed 868/915 MHz band. It combines a LoRa™ transceiver SX1272 of Semtech Corporation with Ethertronics chipset and technologies to maximize link budget and RF performances. With a sensitivity of up to -138 dBm and a maximum output power of +19 dBm results in a link budget of more than 156 dB. The increase in link budget results in much longer range and robustness without the need for any additional components. This module can be used with a passive or active antenna solution.

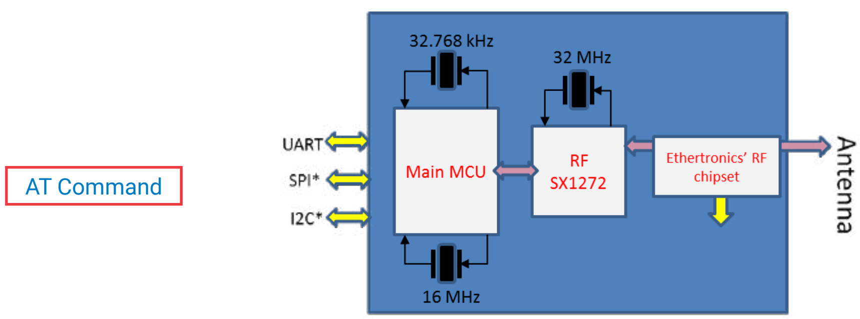

Figure 8

*SPI and I2C are available on customer request or on updated firmware.

PASSIVE ARCHITECTURE

BLOCK DIAGRAM OF THE MODULE USED WITH A PASSIVE ANTENNA

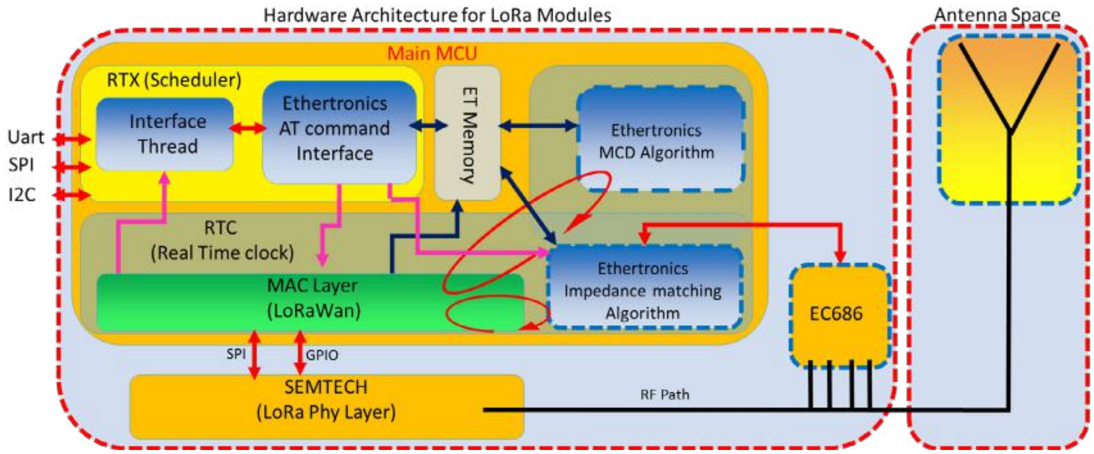

Figure 9

ETH-LORA-M-AX-01 can be used with a standalone antenna in a passive configuration. Ethertronics which are known in enabling innovative antenna and RF system solutions for wireless devices can provide a high performance antenna to work with module. Embedded with a proprietary impedance matching algorithm, this module is able to auto tune the impedance of the antenna to maximize the power transfer between the radio and the antenna. Hence extra range can be achieved.

Ethertronics has designed an evaluation board to help developers to evaluate the ETH-LORA-M-AX-01 with Ethertronics Prestta™ Multi band ISM antenna (P/N: 1002232) in passive configuration. This antenna itself has small form factor but high efficiency. User can take advantage of this feature to save space on the final product's PCB.

Link: LoRa_Module_Application_Note_ 1-Passive Evaluation Board from www.avx.com/products/modules/lora-module

ACTIVE ARCHITECTURE

BLOCK DIAGRAM OF THE MODULE USED WITH AN ETHERTRONICS ACTIVE STEERING ANTENNA

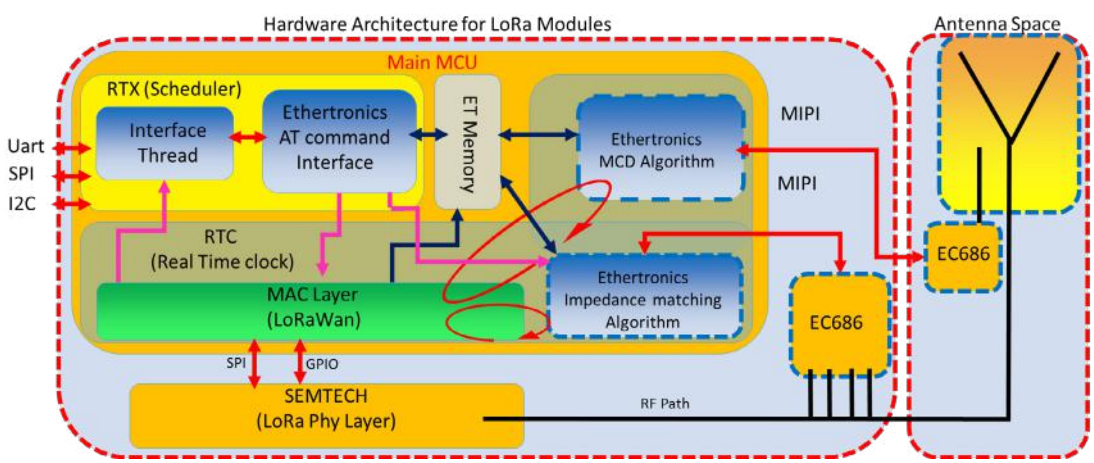

Figure 10

ETH-LORA-M-AX-01 can be used with active antenna solution to provide active steering capabilities. In this configuration both patented algorithms can be used to maximize to the link budget and increase the sensitivity of the device. An active antenna has several radiation patterns and the MCD algorithm helps steering to the best configuration regardless to the change of environment.

The evaluation board for the active configuration is also provided by Ethertronics to help designers of the final product in reducing the time consuming radio development process. This evaluation board can be used to test the features that ETH-LORA-M-AX-01 offers.

Link: LoRa_Module_Application_Note_4 Active Steering Evaluation Board from www.avx.com/products/modules/lora-module

COMMUNICATION INTERFACE

ETH-LORA-M-AX-01 is designed to support three commonly used communication interfaces:

- UART
- SPI
- I2C

With the current firmware version only UART interface is available. Both SPI and I2C are coming soon with the firmware update. The UART interface consists of only two lines RXD (input) and TXD (output) thus simplify the connection with the host.

UART CONFIGURATION

Parameter	Default Value
Baud rate	115200
Data length	8 bits
Parity	None
Stop bit	1 bit
Flow control	None

Table 2

These two lines RXD and TXD support a TTL level voltage. Please refer to the ETH-LORA-M-AX-01 Datasheet for detail on the electrical characteristics.

COMMUNICATION PROTOCOL

ETH-LORA-M-AX-01 is designed with a complete firmware version that contains a scheduler, RTC, LoRa stack and Ethertronics' proprietary algorithms. This firmware supports a well-defined AT commands set to facilitate user's development process.

At commands definitions:

<CR> Carriage Return character, its value is 0x0D.

<LF> Linefeed character, its value is 0x0A.

<...> Name enclosed in angle brackets is a syntactical element or parameters. Brackets themselves do not appear in the command line.

[...] ptional sub-parameter of a command or a response is enclosed in square brackets. Brackets themselves do not appear in the command line. When sub-parameter is not given in parameter type commands, new value equals to its previous value. In action type commands, action should be done on the basis of the recommended default setting of the sub-parameter.

Please refer to Ethertronics' AT Command Reference Guide from www.avx.com/products/modules/lora-module for detail on every supported AT command.

BASIC OPERATION

In this section the detail about the basic operations with ETH-LORA-M-AX-01 are explained. This also includes how to join a LoRa network and send a message using LoRa communication. ETH-LORA-M-AX-01 is designed with a complete firmware that support AT command set. This accelerates the integration process of the module in the user's final PCB. The developers need to configure the host to send the correct AT commands via the supported interface.

MODULE INFORMATION

Once the module is powered up, the host can start sending at command to get the information of the module. With this information the host can verify the firmware version. If there is a new firmware available, users are strongly advised to perform the update procedure. For upgrading the firmware please refer to the document LoRa_Module_Application_Note_2 Firmware Upgrade from www.avx.com/products/modules/lora-module.

AT Command	**ATI**[<flag>] or **AT+LORA#I**[<flag>]	
Description	Command to read the information of the module	
Parameter <flag>	none	Return the version and copyright of the module.
	0	Return the firmware version.
	1	Return the firmware release date.
Return Value based on the <flag>	none	<CR><LF>**Ethertronics LoRa Module 1.1.0 <EU868>**<CR><LF> **Copyright (c) 2016, 2017 Ethertronics Inc**<CR><LF> **All rights reserved**<CR><LF> <CR><LF>**OK**<CR><LF>
	0	<CR><LF>**MAJOR.MINOR.REV**<CR><LF> **OK**<CR><LF>
	1	<CR><LF> **MM DD YYY – HH:MM:SS** <CR><LF> **OK**<CR><LF>

SERIAL NUMBER

Every module has its unique serial number. This number is pre-programmed by the manufacturer during the factory programming and it cannot be changed by the user. Host can only read this value via AT Command.

AT Command	**AT+LORA@SYS%SN?**	
Return Value	<CR><LF>***Serial Number***: ***E-170809-01-00000006***<CR><LF> <CR><LF>***OK***<CR><LF>: Operation successful.	
Description	The serial number format is: **T-YYMMDD-B-<24bit of EUI>**	
	T	The product type
	YYMMDD	<Year start from 2000>< Month >< Day >
	B	Flash Batch number
	<24bit of EUI>	24bit of EUI

CALENDAR AND TIME

The module has an RTC engine running. But the RTC calendar and time is not updated with the real calendar. The host can set and read the calendar and time using the AT command.

Set the date:

AT Command Syntax	**AT+LORA@SYS%DATE**=<dd>,<mm>,<yyyy>	
Parameter	<dd>	Days field must be between 1 and 31
	<mm>	Month field must be between 1 and 12
	<yyyy>	Year field must be between 2000 and 2099
Return Value	<CR><LF>**OK**<CR><LF>: Operation successful. <CR><LF>**ERROR**<CR><LF>: Parameters is expected.	
Example	AT+LORA@SYS%DATE =18,05,2017	
Example description	Set the date to 18 May 2017	

Read the date:

AT Command Syntax	**AT+LORA@SYS%DATE?**
Return Value	<CR><LF>Thur **18/05/2017** <CR><LF>**OK**<CR><LF>: Operation successful.
Description	The module current date is 18/05/2017 (Thursday)

Set the time:

AT Command Syntax	**AT+LORA@SYS%TIME**=<hh>,<mn>,<ss>	
Parameter	<hh>	Hour field must be between 0 and 23 (24 hour format)
	<mn>	Minute field must be between 0 and 59
	<ss>	Second field must be between 0 and 59
Return Value	<CR><LF>**OK**<CR><LF>: Operation successful. <CR><LF>**ERROR**<CR><LF>: Parameters is expected.	
Example	AT+LORA@SYS%TIME=17,30,15	
Example description	Set the time to 17:30:15 (in 24 hour format)	

Read the time:

AT Command Syntax	AT+LORA@SYS%TIME?
Return Value	<CR><LF>17:31:15 <CR><LF>OK<CR><LF>: Operation successful.
Description	The module current time is 17:31 (24 hour format) which is 5:31pm (12 hour format)

SELF-TEST

The self-test AT command can be used to check the sub modules' availability. For the current firmware, there are 5 sub modules:

SUB MODULES FOR THE SELF-TEST COMMAND

Sub Module	Description
Core MCU	State of the core MCU on the module
Internal IM	The activation of the IM Algorithm and the presence of its hardware (internal EC686)
MCD	The activation of the MCD Algorithm and the presence of its hardware (external EC686, only in active configuration)
LoRa MAC	State of the LoRa MAC stacks
LoRa PHY	State of the LoRa PHY stacks and its hardware (SX127x)

Table 3

SELF-TEST COMMAND EXAMPLE IN PASSIVE CONFIGURATION

```
at&t
Self-Test results:
=================

Core MCU:                Enable, OK.
Internal IM:             Enable, OK.
MCD:                     Disable.
LoRa MAC:                Enable, OK.
LoRa PHY (sx127x):       Enable, OK.


OK
```

Table 4

In the example above, all sub modules are activated except for the MCD as in the passive configuration the external EC686 is not available. However, users can control the activation of both IM and MCD algorithms. See 4.3 Algorithm Control

LORA JOIN PROCEDURE

Before an end device can communicate on the LoRaWAN network, it must first be activated (join). The join procedure depends on the network join mode. There are two modes available which are Activation By Personalization (ABP) and Over The Air Activation (OTAA). The main difference between these modes is that user needs to generate the network keys used to authenticate the device when it joins the application in ABP mode while in OTAA these values are automatically derived.

ABP MODE

In this mode, the host is required to provide the following information:

1. LoRa Data Session Encryption Key (16 bytes). Also known as Application Session Key (AppSKey)
2. Network Session Key (16 bytes)

This means that users must know this information prior to join the network. Since the keys are configured manually, there is no need for a “handshake” procedure with the gateway.

The steps to join the network are as follow:

1. Set the network join mode to ABP:

AT Command	**AT+LORA@MAC%NJM=0**
Description	This command is a write command to set the network join mode 0: Manual configuration mode, known as “Activation By Personalization” (ABP) in LoRaWAN specification document.
Return Value	<CR><LF>OK<CR><LF>: Operation successful. <CR><LF>ERROR<CR><LF>: Parameter is expected.

2. Set LoRa public network mode:

AT Command	**AT+LORA@MAC%PN**=1
Description	This command is a write command to set the public network mode 0: set to private Network mode. 1: set to public Network mode.
Return Value	<CR><LF>**OK**<CR><LF>: Operation successful. <CR><LF>**ERROR**<CR><LF>: Parameter is expected.

3. Set LoRa Network EUI/Name:

AT Command	**AT+LORA@MAC%NI**=0, 1122334455667788 **AT+LORA@MAC%NI**=1,LoRaNetworkID
Description	This command is a write command to set the network EUI/Name which is also known as AppEUI in LoRaWAN specification document 0: Use digits as NETwork ID 1: Use string as NETwork ID
Return Value	<CR><LF>**OK**<CR><LF>: Operation successful. <CR><LF>**ERROR**<CR><LF>: Parameters are expected.

4. Set LoRa Network Key/passphrase:

AT Command	**AT+LORA@MAC%NK**=0,112233445566778899aabbccddeeff **AT+LORA@MAC%NK**=1,LoRaPassphrase
Description	This command is a write command to set the LoRa Network Key also known as AppKey in LoRaWAN specification document 0,1122334455..ccddeeff: Use digits as Network Key 1,LoRaPassphrase: Use string as Network Key
Return Value	<CR><LF>**OK**<CR><LF>: Operation successful. <CR><LF>**ERROR**<CR><LF>: Parameters are expected.

5. Set LoRa Network Session Key:

AT Command	**AT+LORA@MAC%NSK**=112233445566778899aabbccddeeff
Description	This command is a write command to set the Network Session Key 1122334455..ccddeeff: 16 bytes of the Network Session Key
Return Value	<CR><LF>**OK**<CR><LF>: Operation successful. <CR><LF>**ERROR**<CR><LF>: Parameter is expected.

6. Set LoRa Data Session Encryption Key:

AT Command	**AT+LORA@MAC%DSK**=112233445566778899aabbccddeeff
Description	This command is a write command to set the LoRa Data Session Encryption Key also known as Application Session Key in LoRaWAN specification document 1122334455..ccddeeff: 16 bytes of the Network Session Key
Return Value	<CR><LF>**OK**<CR><LF>: Operation successful. <CR><LF>**ERROR**<CR><LF>: Parameter is expected.

Once all these steps are done successfully, the ETH-LORA-M-AX-01 is ready to send the data to the gateway.
Please refer to section 3.6 LoRa Send Message for sending a message.

OTAA MODE

In this configuration the module ETH-LORA-M-AX-01 need to perform the handshake with the gateway to derive the network keys. During the handshake, a dynamic device address is assigned and security keys (Network Session Key and Application Session Key) are negotiated.

The steps to join the network are as follow:

1. Set the network join mode to OTAA:

AT Command	AT+LORA@MAC%NJM=1
Description	This command is a write command to set the network join mode 1:" Over The Air Activation" (OTAA) in LoRaWAN specification document.
Return Value	<CR><LF>OK<CR><LF>: Operation successful. <CR><LF>ERROR<CR><LF>: Parameter is expected

2. Set LoRa public network mode:

AT Command	AT+LORA@MAC%PN=1
Description	This command is a write command to set the public network mode 0: set to private Network mode. 1: set to public Network mode.
Return Value	<CR><LF>OK<CR><LF>: Operation successful. <CR><LF>ERROR<CR><LF>: Parameter is expected.

3. Set LoRa Network EUI/Name:

AT Command	AT+LORA@MAC%NI=0, 1122334455667788 AT+LORA@MAC%NI=1,LoRaNetworkID
Description	This command is a write command to set the network EUI/Name which is also known as AppEUI in LoRaWAN specification document 0: Use digits as NETwork ID 1: Use string as NETwork ID
Return Value	<CR><LF>OK<CR><LF>: Operation successful. <CR><LF>ERROR<CR><LF>: Parameters are expected.

4. Set LoRa Network Key/passphrase:

AT Command	AT+LORA@MAC%NK=0,112233445566778899aabbccddeeff AT+LORA@MAC%NK=1,LoRaPassphrase
Description	This command is a write command to set the LoRa Network Key also known as AppKey in LoRaWAN specification document 0,1122334455..ccddeeff: Use digits as Network Key 1,LoRaPassphrase: Use string as Network Key
Return Value	<CR><LF>OK<CR><LF>: Operation successful. <CR><LF>ERROR<CR><LF>: Parameters are expected.

5. Join the network:

AT Command	AT+LORA@MAC%NK=0,112233445566778899aabbccddeeff AT+LORA@MAC%NK=1,LoRaPassphrase
Description	This command is a write command to set the LoRa Network Key also known as AppKey in LoRaWAN specification document 0,1122334455..ccddeeff: Use digits as Network Key 1,LoRaPassphrase: Use string as Network Key
Return Value	<CR><LF>OK<CR><LF>: Operation successful. <CR><LF>ERROR<CR><LF>: Parameters are expected.

6. Verify the join status. Normally after sending the message in step 5, once OK is received, user will receive the status below after ~5s

Status (after ~5s)	AT+LORA@MAC%NK=0,112233445566778899aabbccddeeff AT+LORA@MAC%NK=1,LoRaPassphrase
	This command is a write command to set the LoRa Network Key also known as AppKey in LoRaWAN specification document 0,1122334455..ccddeeff: Use digits as Network Key 1,LoRaPassphrase: Use string as Network Key
	<CR><LF>OK<CR><LF>: Operation successful. <CR><LF>ERROR<CR><LF>: Parameters are expected.

The read command below can be used to verify the join status if there is no status message above received after about ~5s the join command is issued.

AT Command	AT+LORA@MAC#JOIN?
Description	This command is a read command of join LoRa network status
Return Value	<CR><LF>0<CR><LF>: Device has not joined the network. <CR><LF>1<CR><LF>: Device has joined the network.

Once all these steps are done successfully, user can start sending the message. Please refer to section 3.6 LoRa Send Message for sending a message.

LORA SEND MESSAGE

After successfully join the network whether using ABP or OTAA mode, the host can send the message to the gateway. This is also done using the AT command. Here are the steps:

1. Choose the port to send the message (Optional):

AT Command syntax	AT+LORA@MAC%AP=<port>
Description	This command is a write command to set the port used for application data (1 - 223). The default value for the port is 1.
Return Value	<CR><LF>0<CR><LF>: Operation successful. <CR><LF>1<CR><LF>: Parameters is expected.

2. Send the message:

AT Command syntax	AT+LORA@MAC#SEND=[<data>,[<ack>,<iter>,<interval>]]	
Description	data	Data to send to the gateway
	ack	Acknowledgement request 0: no ack 1: ack
	iter	Iteration number (-1: indefinite loop)
	interval	Interval duration in ms (must be higher than 15000 ms)
	NOTE: issue the SEND command without parameters to stop the previous SEND loop.	
Return Value	<CR><LF>0<CR><LF>: Operation successful. <CR><LF>1<CR><LF>: Parameters is expected.	
Example	AT+LORA@MAC#SEND=Hello,1,-1,20000	
Example description	Sending in infinite loop, a message "Hello" with acknowledgment required and within the interval of 20 seconds	

If user sends a message in several iterations, user can always stop the sending using the escape command. See section 4.5 Escaping AT Command for the escaping sequence.

ADVANCED OPERATION

SOFTWARE RESET

In rare case where the user needs to reset only the module, software reset can be used.

AT Command	AT+LORA@SYS#SOFTRESET
Description	This command is an execution command to perform a software reset of this module. Use this command with caution.
Return Value	No return value

After this command is issued, the host needs to wait about ~1.5s so that the module can initialize its system before sending any AT commands. After perform the software reset and wait for ~1.5s, it is advised to send the basic at command "AT" to check whether the module is ready or not.

AT Command	AT
Description	Command to check if the module is ready
Return Value	<CR><LF>OK<CR><LF>: The module is ready No return value: The module is not ready yet. Wait for some more delay before retry.

LOW POWER MODE

ETH-LORA-M-AX-01 has been designed with low power mode feature to save the consumption which is vital in battery powered device. There are four low power modes available. The module enters the low power mode after configurable delay (LPDelay) when the module is in idle state. The most efficient mode to save the consumption is STOP Mode. However, in this mode the UART cannot be used to wake up the module. A GPIO's P11 should be set high by the user before sending any AT commands.

<table>
<tr><th>LPM Mode</th><th>Entry</th><th>Wake-up</th><th>Effect on V^{core} domain clocks</th><th>Effect on V_{DD} domain clocks</th><th>Voltage regulator</th></tr>
<tr><td>Normal Mode (0)</td><td>-</td><td>-</td><td rowspan="2">None</td><td rowspan="3">None</td><td rowspan="2">ON</td></tr>
<tr><td>LP Run (1)</td><td rowspan="3">After parameter LPDelay expired</td><td rowspan="2">UART, GPIO'sP11, RTC Alarm</td></tr>
<tr><td>DEEPSLEEP (2) (Factory default)</td><td>CPU CLK OFF no effect on other clocks or analog clock sources, Flash CLK OFF</td><td>In Low-Power Mode</td></tr>
<tr><td>STOP Mode (3)</td><td>GPIO'sP11, RTC Alarm</td><td>All V_{core} domain clock OFF</td><td>HSI and HSE and MSI oscillators OFF</td><td>In Low-Power Mode</td></tr>
</table>

Table 5

Please refer to the Module Integration Guide document for detail of the external P11 pin location
Link: www.avx.com/products/modules/lora-module

NOTE: The most efficient way to avoid any communication error is systematically send a CARRIER RETURN (0x0d) and wait the module answers with a string "OK" before sending any AT command.

In passive architecture there is one EC686 which is used for IM algorithm, while in active configuration one more EC686 is used for MCD algorithm. The state of both EC686 can be controlled in low power mode.

Set the Low Power Mode:

AT Command Syntax	AT+LORA@SYS%LPMODE=<mode>[,<EC686LPState>]		
Parameter	<mode >	Low Power mode	
		0	Disable Low Power mode.
		1	Enable Low Power Run mode.
		2	Enable Low Power DEEPSLEEP mode. (Factory Default mode)
		3	Enable Low Power STOP mode.
	[<EC686LPState >]	EC686 State in low power mode (if available) (optional parameter)	
		0	Both EC686 are ON (IM and MCD)
		1	Internal EC686 OFF (IM), External EC686 ON(MCD)
		2	Internal EC686 ON (IM), External EC686 OFF(MCD)
		3	Both EC686 are OFF (IM and MCD)
Return Value	<CR><LF>OK<CR><LF>: Operation successful. <CR><LF>ERROR<CR><LF>: Parameters is expected or wrong parameter		
Example	AT+LORA@SYS%LPMODE=3,3		
Example description	Set the low power mode to STOP mode Both EC686 (if available) will be turn off when the device enter the STOP mode		

Read the Low Power Mode:

AT Command Syntax	AT+LORA@SYS%LPMODE?
Return Value	<CR><LF>3, 3<CR><LF>OK<CR><LF>: Operation successful.
Description	The module is using STOP mode as low power mode and the both EC686 (if available) will turn off when device enter the low power mode

As mention in the previous table, the module enters certain low power modes after the parameter LPDelay expired. This LPDelay can be configurable, but the minimum value for this parameter is 30000ms.

Set the Low Power Mode Delay:

AT Command Syntax	AT+LORA@SYS%LPDELAY=<delay>	
Parameter	< delay >	Delay in millisecond. Must be greater than 30000
Return Value	<CR><LF>OK<CR><LF>: Operation successful. <CR><LF>ERROR<CR><LF>: Parameters is expected or Wrong parameter (<30000)	
Example	AT+LORA@SYS%LPDELAY=45000	
Example description	Set the delay to 45s	

Read the Low Power Mode Delay:

AT Command Syntax	AT+LORA@SYS% LPDELAY?
Return Value	<CR><LF>45000<CR><LF> <CR><LF>OK<CR><LF>: Operation successful.
Description	The current low power mode delay is 45s

ALGORITHM CONTROL

The uniques features of ETH-LORA-M-AX-01 compare to other available modules on the markets are the two proprietary algorithms designed by Ethertronics to improve the RF performance. A metric (RSSI or SNR) are needed to feed the algorithms. Hence to take advantage of the technologies, the **DOWNLINK** from the gateway to ETH-LORA-M-AX-01 is necessary. The closed loop impedance matching algorithm is available in both passive and active configurations of this module while the active steering algorithm is only available in the active configuration.

1. Set the metric input:

AT Command Syntax	AT+LORA@SYS%ALGOMETRIC=<metric>	
Parameter	<metric>	Metric values 0: SINR 2: RSSI(default)
Return Value	<CR><LF>OK<CR><LF>: Operation successful. <CR><LF>ERROR<CR><LF>: Input value is expected or invalid value	
Example	AT+LORA@SYS%ALGOMETRIC=2	
Example description	Set the metric to RSSI	

2. Set the number of average of metric input of the IM:

AT Command Syntax	AT+LORA@SYS%ALGOAVG=<avg>	
Parameter	<avg>	The average number must be between 5 and 20.
Return Value	<CR><LF>OK<CR><LF>: Operation successful. <CR><LF>ERROR<CR><LF>: Input value is expected or invalid value	
Example	AT+LORA@SYS%ALGOAVG=10	
Example description	Set the average number to 10	

CLOSED LOOP IMPEDANCE MATCHING ALGORITHM

The goal of the impedance matching (IM) algorithm is to maximize the power transferred to the antenna when the antenna is detuned by its environment. By activating this algorithm, the adjustment of the antenna's matching will be done automatically regardless its installation place (concrete wall, wood, plastic, etc.). For more information about this algorithm, **please refer to Closed Loop Impedance Matching** application note. Link: www.avx.com/products/modules/lora-module

Steps to activate IM algorithm:

1. Activate the IM

AT Command	AT+LORA@IM%ACTIVATE=<Activation>	
Parameter	<Activation >	1: To enable the IM 0: To disable the IM
Return Value	<CR><LF>OK<CR><LF>: Operation successful. <CR><LF>ERROR<CR><LF>: Unknown parameter.	
Example	AT+LORA@IM% ACTIVATE =1	
Example description	Activate the IM	

2. Initialize the IM

AT Command	AT+LORA@IM#INIT
Return Value	<CR><LF>OK<CR><LF>: Operation successful.
Example	AT+LORA@IM#INIT
Example description	Initialize the IM algorithm

3. Start the IM control flag:

AT Command	AT+LORA@IM%CTRLFLAG=<flag>	
Parameter	<flag >	Set this flag to IM_CTRL_REG_START
Return Value	<CR><LF>OK<CR><LF>: Operation successful. <CR><LF>ERROR<CR><LF>: Unknown parameter.	
Example	AT+LORA@IM%CTRLFLAG=1	
Example description	Start the IM algorithm	

Once the IM is started, developer can pause or stop the IM by changing the IM control flag value.

Control Flag	Value
IM_CTRL_REG_RESET	0
IM_CTRL_REG_START	1
IM_CTRL_REG_PAUSE	2
IM_CTRL_REG_RESUME	3

Table 6

ACTIVE STEERING ALGORITHM

Modal Cognitive Diversity (MCD) is a proprietary predictive algorithm developed by Ethertronics to perform active steering capabilities of the multi radiation patterns antenna in order to improve the link budget and sensitivity. Any antennas are sensitive to the change in their environment and their performance can be degraded. Hence the goal of the MCD algorithm is to overcome this problem by determining the best radiation pattern for the current position of the module. To be able to use this algorithm, the developer must integrate ETH-LORA-M-AX-01 using the active architecture (see section 2.2.2). Ethertronics provide an active evaluation board which can be used to test this algorithm. Steps to activate MCD algorithm:Steps to activate IM algorithm:

1. Activate the MCD

AT Command	AT+LORA@MCD%ACTIVATE=<Activation>	
Parameter	<Activation >	1: To enable the MCD 0: To disable the MCD
Return Value	<CR><LF>OK<CR><LF>: Operation successful. <CR><LF>ERROR<CR><LF>: Unknown parameter.	
Example	AT+LORA@MCD# ACTIVATE =1	
Description	Activate the MCD	

2. Initialize the MCD

AT Command	AT+LORA@MCD#INIT=[<mode>]	
Parameter	[<mode>]	Mode/Radiation pattern number (max is 3) Please consult with Ethertronics for this parameter
Return Value	<CR><LF>OK<CR><LF>: Operation successful. <CR><LF>ERROR<CR><LF>: Unknown parameter.	
Example	AT+LORA@MCD#INIT=2	
Description	Set the available modes to two and initialize the MCD algorithm	

3. Start the MCD via MCD control flag:

AT Command	AT+LORA@MCD%CTRLFLAG=<flag>	
Parameter	<flag >	Set this flag to MCD_CTRL_REG_START
Return Value	<CR><LF>OK<CR><LF>: Operation successful. <CR><LF>ERROR<CR><LF>: Unknown parameter.	
Example	AT+LORA@MCD%CTRLFLAG=1	
Description	Start the MCD algorithm	

Once the MCD is started, developer can pause or stop the MCD by changing the MCD control flag value.

Control Flag	Value
MCD_CTRL_REG_RESET	0
MCD_CTRL_REG_START	1
MCD_CTRL_REG_PAUSE	2
MCD_CTRL_REG_RESUME	3

Table 7

BYPASSING THE ALGORITHMS

Both algorithms IM and MCD are implemented to help the final product developers to create LoRa end devices with a great RF performance. Nonetheless, if users wish not to use these algorithms, they can be deactivated using AT commands.

Disable the IM algorithm:

AT Command Syntax	AT+LORA@IM%ACTIVATE=0
Return Value	<CR><LF>OK<CR><LF>: Operation successful. <CR><LF>ERROR<CR><LF>: Unknown parameter.

Disable the MCD algorithm:

AT Command Syntax	AT+LORA@MCD%ACTIVATE=0
Return Value	<CR><LF>OK<CR><LF>: Operation successful. <CR><LF>ERROR<CR><LF>: Unknown parameter.

When both algorithms are disable, the RF vector of the internal EC686 (IM) and external EC686 (MCD, if available) can be set using a bypass command.

Set the RF Vector of the internal EC686 (IM) using bypass command:

AT Command Syntax	AT+LORA@IM%CTRLFLAG=<flag>	
Parameter	<flag >	Set this flag to any of the bypass configurations (see Bypass table)
Return Value	<CR><LF>OK<CR><LF>: Operation successful. <CR><LF>ERROR<CR><LF>: Unknown parameter.	
Example	AT+LORA@IM%CTRLFLAG=129	
Example description	The RF configuration of the internal EC686 (IM) is set to 0x01 which means RF port 1 is connected to RFC port.	

Set the RF Vector of the external EC686 (MCD) using bypass command:

AT Command Syntax	AT+LORA@MCD%CTRLFLAG=<flag>	
Parameter	<flag >	Set this flag to any of the bypass configurations (see Bypass table)
Return Value	<CR><LF>OK<CR><LF>: Operation successful. <CR><LF>ERROR<CR><LF>: Unknown parameter.	
Example	AT+LORA@MCD%CTRLFLAG=130	
Example description	The RF configuration of the external EC686 (MCD) is set to 0x02 which means RF port 2 is connected to RFC port.	

BYPASS CONTROL FLAG

Control Flag (Bypass)	Value	Internal/External EC686 (IM/MCD) RF vector state
CTRL_REG_BYPASS_0	128	0x00
CTRL_REG_BYPASS_1	129	0x01
CTRL_REG_BYPASS_2	130	0x02
CTRL_REG_BYPASS_3	131	0x03
CTRL_REG_BYPASS_4	132	0x04
CTRL_REG_BYPASS_5	133	0x05
CTRL_REG_BYPASS_6	134	0x06
CTRL_REG_BYPASS_7	135	0x07
CTRL_REG_BYPASS_8	136	0x08
CTRL_REG_BYPASS_9	137	0x09
CTRL_REG_BYPASS_10	138	0x0A
CTRL_REG_BYPASS_11	139	0x0B
CTRL_REG_BYPASS_12	140	0x0C
CTRL_REG_BYPASS_13	141	0x0D
CTRL_REG_BYPASS_14	142	0x0E
CTRL_REG_BYPASS_15	143	0x0F

Table 8

To verify the whether the bypass command work users can check the status of the both EC686.

Read the RF Vector of the internal EC686 (IM) after using bypass command:

AT Command Syntax	AT+LORA@IM%STATUS?	
Return Value	<CR><LF>XX, YY <CR><LF>OK<CR><LF>	XX: Status value(see status Table) YY: Internal EC686 (IM) RF vector value
Example	AT+LORA@MCD%STATUS? 143,1 OK	
Example description	The XX is 143 which means that the internal EC686 (IM) is in bypass mode The YY is 1 which means that the RF Vector of the internal EC686 (IM) is 0x01	

Status Value		Description
Decimal	Hex	
0	0x00	IM is Reset and paused
16	0x10	IM is Running
32	0x20	IM is paused
143	0x8F	Internal EC686 is in Bypass Mode
255	0xFF	Error Occurred

Table 9

Read the RF Vector of the internal EC686 (MCD) after using bypass command:

AT Command Syntax	AT+LORA@MCD%STATUS?	
Return Value	<CR><LF>XX, YY <CR><LF>OK<CR><LF>	XX: Status value(see status Table) YY: Internal EC686 (MCD) RF vector value
Example	AT+LORA@MCD%STATUS? 143,1 OK	
Example description	The XX is 143 which means that the internal EC686 (MCD) is in bypass mode The YY is 2 which means that the RF Vector of the internal EC686 (MCD) is 0x01	

Status Value		Description
Decimal	Hex	
0	0x00	MCD is Reset and paused
16	0x10	MCD is Running
31	0x1F	MCD is running, Force to a mode
32	0x20	MCD is paused
47	0x2F	MCD is paused, Force to a mode
143	0x8F	External EC686 is in Bypass Mode
255	0xFF	Error Occurred

Table 10

SWITCHING FIRMWARE VERSION

ETH-LORA-M-AX comes with a preprogrammed factory firmware. If in future the Ethertronics provide an updated firmware for this module, users can upload the latest firmware on to module using the software tool available on the Ethertronics' website. To perform the firmware update, **please refer to Upgrading Firmware** application note.

Link: www.avx.com/products/modules/lora-module

After performing the upgrading firmware process, user can always switch back to factory firmware as the new firmware will not overwrite the factory one.

Here is the command to switch between firmware:

AT Command Syntax	AT+LORA&F0 or AT&F0
Description	To configure ETH-LORA-M-AX-01 to run on the factory firmware
Return Value	<CR><LF>OK<CR><LF>: Operation successful.

1. Switch to factory firmware:

AT Command Syntax	AT+LORA&F1 or AT&F1
Description	To configure ETH-LORA-M-AX to run on the updated firmware if available, otherwise run back on the factory firmware.
Return Value	<CR><LF>OK<CR><LF>: Operation successful.

2. Switch to updated firmware:

After this command is issued, the host needs to wait for ~1.5s before sending next AT command to let ETH-LORA-M-AX-01 jumps to its updated firmware and initialize its system. If there is no available updated firmware, the module switches automatically to its factory firmware.

ESCAPING AT COMMAND

Some of the AT commands are deferred commands which mean that these commands take time to finish their execution. If user wishes to send other AT command while these commands are still in their executing phase, the following procedure needs to be done:

1. Switch to factory firmware:

AT Command Syntax	+++	
Description	Escape Sequence to return to the command line prompt during a pending AT command	
Return Value	<CR><LF>OK<CR><LF>	Ready for new AT command. **NOTE:** The pending command is still running.

Once this command is issued and the return value is received by the host, the host can start sending next AT command. This command will not stop the pending command. User can choose whether to resume the pending command or completely abort it.

AT Command Syntax	AT+LORA#RESUME
Description	Resume the last pending command after issuing +++ command
Return Value	Depend on the resumed AT command.

AT Command Syntax	AT+LORA#ABORT	
Description	Abort the last pending command after issuing +++ command	
Return Value	<CR><LF>OK<CR><LF>	Operation successful.

2. Resume the pending AT command:
3. Abort the pending command:

LORA PARAMETERS

Certain LoRa parameters which are necessary to join and send data over the LoRa network have a default (factory) values in the firmware of the ETH-LORA-M-AX-01. However these parameters should be adjusted depending on the LoRa network configuration where this device will be used. Hence, the user needs to update these parameters to match the configuration of the LoRa network.

These parameters are stored in the RAM and their values are kept until the device is powered off.

LoRa Parameters	Size (bytes)	Description	AT Commands
Device LoRa Class	1	LoRa class of the end device	AT+LORA@MAC%DC
Activation Mode (Join Mode)	1	The Join/Activation mode of the end device. Two possible modes: ABP(0) or OTAA(1)	AT+LORA@MAC%NJM
Public Network Type	1	The type of the network. Two possible options: Private(0) or Public (1)	AT+LORA@MAC%PN
Device EUI	8	End device unique identifier (DevEUI)	AT+LORA@MAC%DI
Application EUI	8	Application identifier (AppEUI) is a global application ID in IEEE EUI64 address space.	AT+LORA@MAC%NI
Application Key	16	The Application Key (AppKey) is an AES-128 root key specific to the end-device. It is used in OTAA to derive the NwkSKey and AppSKey specific for that end-device to encrypt and verify network communication and application data	AT+LORA@MAC%NK
Network Sessions Key	16	Network Session Key (NwkSKey) is specific for the end-device. It is used by both the network server and the end-device to calculate and verify the MIC (message integrity code) of all data messages to ensure data integrity.	AT+LORA@MAC%NSK
Application Session Key	16	The application session key (AppSKey) is specific for the end-device and is used by both the application server and the end-device to encrypt and decrypt the payload field of application-specific data messages.	AT+LORA@MAC%DSK
End Device Address	4	The End Device Address (DevAddr) consists of 32 bits identifies the end-device within the current network	AT+LORA@MAC%NA
Application Port	1	Port to be used for application to send data	AT+LORA@MAC%AP

Table 11

Please refer to Ethertronics' AT Command Reference Guide from www.avx.com/products/modules/lora-modulefor detail on every supported AT command.

STORE LORA PARAMETERS

Once the updating procedure is done, user can save the values of these parameters, so that on the next reboot of the module, these parameters can keep the updated values and the user does not need to redo the same procedure.,

Store the LoRa parameters values in the EEPROM:

AT Command Syntax	AT+LORA&W or AT&W
Return Value	<CR><LF>OK<CR><LF>: Operation successful.
Example	AT&W
Example description	The internal memory in RAM will be copied to EEPROM. Note: This command takes time (~8s) to execute before send back the return value to the host.

RESET LORA PARAMETERS

Once the updating procedure is done, user can save the values of these parameters, so that on the next reboot of the module, these parameters can keep the updated values and the user does not need to redo the same procedure.,

Store the LoRa parameters values in the EEPROM:

AT Command Syntax	AT+LORA&F or AT&F
Return Value	<CR><LF>OK<CR><LF>: Operation successful.
Example	AT&F
Example description	Using this command without any parameters will reset the LoRa parameters to the factory values.

LIST OF ABBREVIATIONS

LoRa/LoRaWAN: Long range/ Long rang wide area network
SMT: Surface-mount technology
MHz: MegaHertz
IC: Integrated circuit
UART: Universal Asynchronous Receiver/Transmitter
SPI: Serial Peripheral Interface
I2C: Inter-Integrated Circuit
GPIO: General-purpose input/output
TTL: Transistor–transistor logic level
AT: Attention
IM: Impedance matching
MCD: Modal cognitive diversity
PCB: Printed circuit board
RF: Radio frequency
IoT: Internet of things
M2M: Machine-to-machine
FSK: Frequency-shift keying
CSS: chirp spread spectrum
BW: bandwidth
AES: Advanced Encryption Standard
OSI: Open Systems Interconnection
TCP/IP: Transmission Control Protocol/Internet Protocol
SSL: Secure Sockets Layer
MAC: Medium Access Control
MCU: Microcontroller Unit
RTC: Real time clock
RTX: real-time operating system extensions
ISM: Industrial, Scientific and Medical (radio spectrum)
CR: Carriage return
LF: Line feed
OTAA: Over the Air Activation
ABP: Activation by personalization
SINR: Signal to Interference-plus-Noise Ratio
RSSI: Received Signal Strength Indicator

LIST OF FIGURES

LIST OF TABLES

REFERENCE

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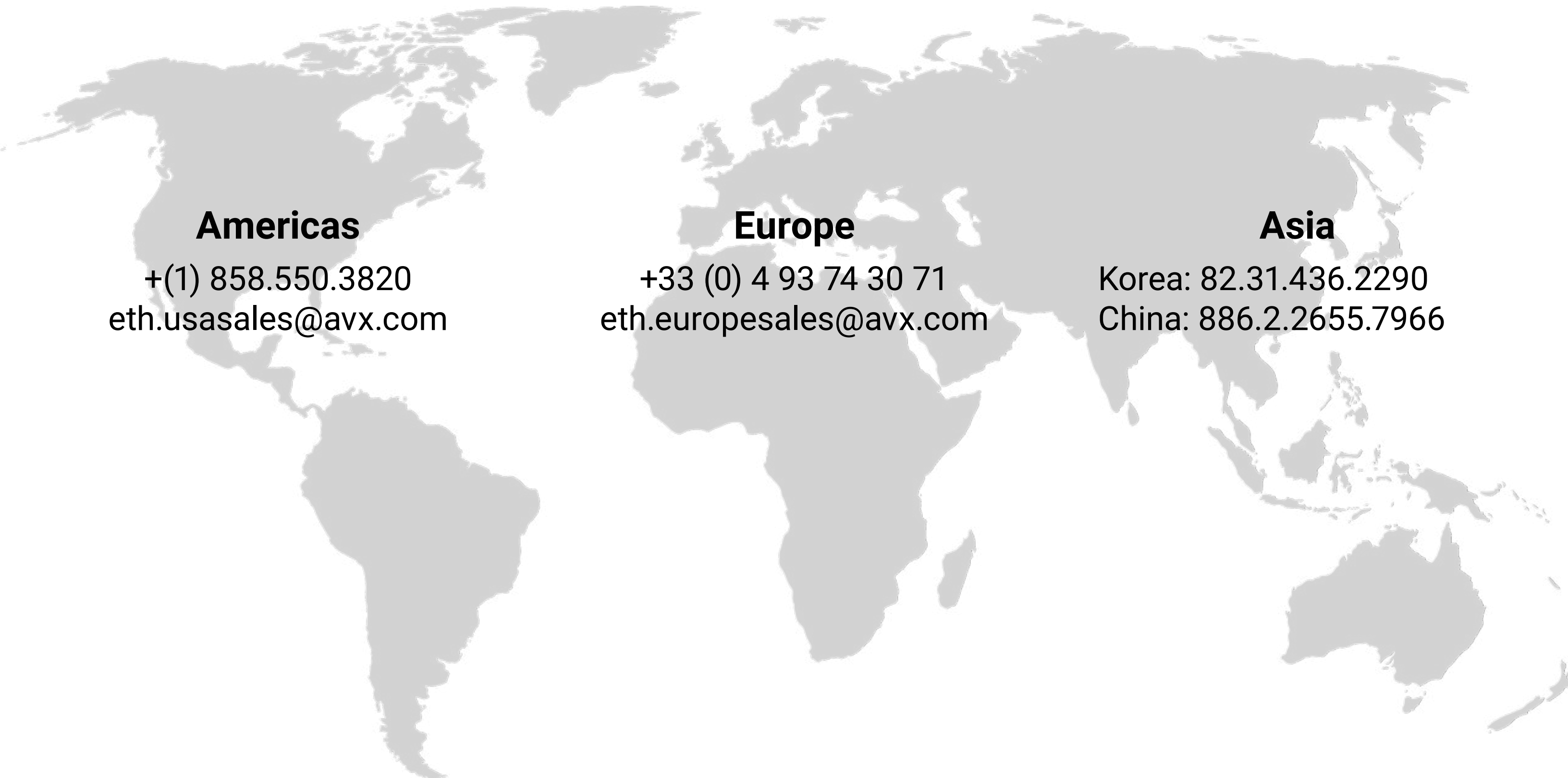

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