LoRa *smart*BASIC Extensions Guide

RM1xx Series

Document version 1.3

Revision History

Version	Date	Notes	Contributors	Approver
1.0	27 Jan 2017	Initial version		Jonathan Kaye
1.1	2 Aug 2017	Updated to stack version 4.4.0. Included Class C functionality and various bug fixes.		Jonathan Kaye
1.2	11 Oct 2017	Updates for latest stack.		Colin Anderson
1.3	13 June 2018	Converted to new template. Fixed sub-band 8 typo	Seokwoo Yoon	Colin Anderson

CONTENTS

1 Introduction

1.1 Documentation Overview

This RM1xx LoRa Extension Functionality user guide provides detailed information on LoRa-specific *smart*BASIC extensions which provide a high level managed interface to the underlying LoRa device and Bluetooth stack to manage the following:

- Joining a LoRa gateway and transmitting/receiving data payload
- Link checking on LoRa connection
- Managing LoRa sleep intervals and reading chipset registers
- Events related to the above

This document deals specifically with the *smart*BASIC APIs relating to the LoRa functionality in the RM1xx series of modules. For other details of programming the RM1xx, see any of the following documents:

- RM1xx LoRaMAC BLE Central Extensions Guide (central BLE functions)
- RM1xx BLE Peripheral Extensions Guide (peripheral BLE functions for the RM186_PE or RM191_PE modules)
- *smart*BASIC Core Reference Guide (common functions across all *smart*BASIC modules)

It is also very important to read and understand the appropriate Interfacing with LoRaWAN document. These documents explain how the LoRa modules actually work and how the apis and events described below should be used.

All the above documents are found in the documentation tab of the RM1xx product page:
http://www.lairdtech.com/products/rm1xx-lora-modules

1.2 What Does a LoRa/BLE Module Contain?

Laird's *smart*BASIC-based LoRa/BLE modules are designed to provide a complete wireless processing solution and contain the following:

- A highly integrated radio with an integrated antenna (external antenna options are also available)
- BLE Physical and Link Layer
- Higher level stack
- Multiple GPIO and ADC
- Wired communication interfaces such as UART, I2C, and SPI
- A *smart*BASIC run-time engine
- Program-accessible flash memory which contains a robust flash file system exposing a conventional file system and a database for storing user configuration data
- Voltage regulators and brown-out detectors

For simple end devices, these modules can completely replace an embedded processing system.

The following block diagram (Figure 1) illustrates the structure of the BLE + LoRa *smart*BASIC module from a hardware perspective on the left and a firmware/software perspective on the right.

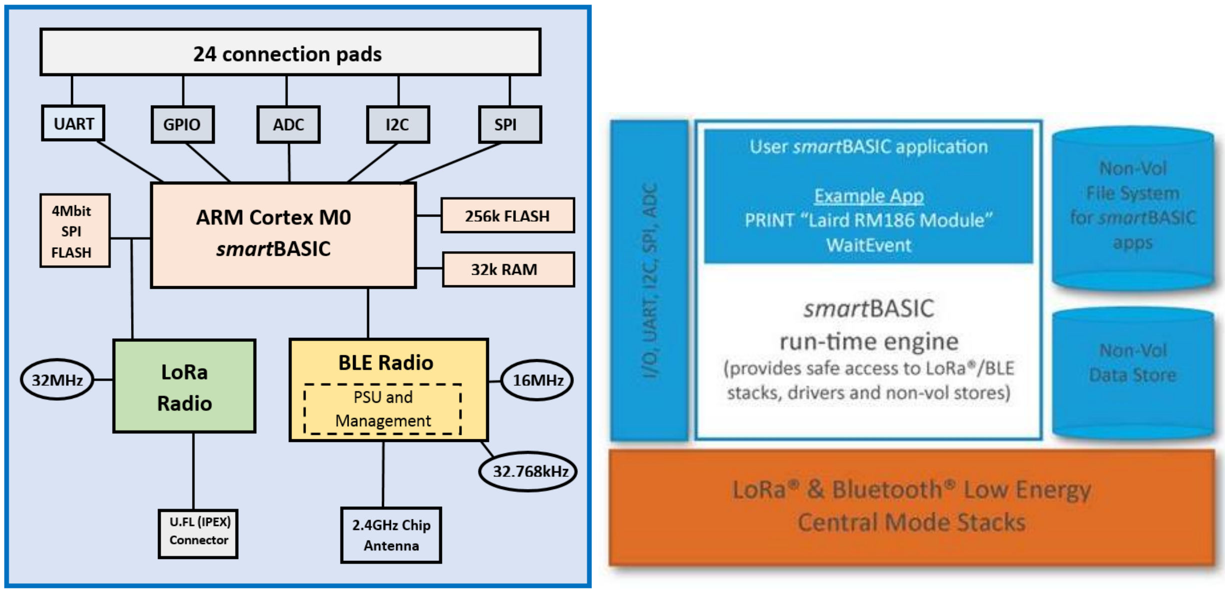

24 connection pads
UART
GPIO
ADC
I2C
SPI
4Mbit SPI FLASH
ARM Cortex M0 *smart*BASIC
256k FLASH
32k RAM
32MHz
LoRa Radio
BLE Radio
PSU and Management
16MHz
32.768kHz
U.FL (IPEX) Connector
2.4GHz Chip Antenna
I/O, UART, I2C, SPI, ADC
User *smart*BASIC application
Example App
PRINT "Laird RM186 Module"
WaitEvent
*smart*BASIC run-time engine
(provides safe access to LoRa®/BLE stacks, drivers and non-vol stores)
Non-Vol File System for *smart*BASIC apps
Non-Vol Data Store
LoRa® & Bluetooth® Low Energy Central Mode Stacks

Figure 1: RM1xx smartBASIC module block diagram

2 Transmit/Receive Sequence

Before looking at the various commands and events it is very important to understand that once you send a packet into the LoRa stack you are starting a predefined sequence that must be allowed to complete before you can send another packet.

In LoRaWAN an uplink packet refers to a packet transmitted by the LoRa module and a downlink packet refers to a packet transmitted by the network server/Lora Gateway.

In Class A devices, once an uplink packet is transmitted, the module waits a predefined time for a downlink packet. This packet may or may not be transmitted by the gateway, however, the module must still open up receive windows to receive it if necessary.

For unconfirmed packets this is the end of the cycle. There are no resends. The module assumes that the transmitted packet has been received at the gateway and onto the server. The server may have data to send back to the module and these should be picked up in whichever Receive window they coincide with and dealt with accordingly by the stack.

However, in the case of confirmed uplink packets the cycle is more complicated as the stack actively waits or an acknowledgement. If that acknowledgment isn't received the stack automatically resends the packet a set number of times. The sequence only finishes after an acknowledgement is received or all the retries are attempted or an error has occurred causing the sequence to abort.

Similarly, for the JoinRequest, if the stack fails to receive a JoinAccept, it resends the JoinRequest a set number of times. Again, the sequence only finishes after a JoinAccept is received or all retries are attempted or an error has occurred.

This can be very offputting in the RM1xx because there is no indication of all that was happening in the background; it could seem that the module had frozen. However, this is not the case so it is very important not to interfere with this sequence by sending another packet to the stack.

The events that mark the end of the sequence are indicated in section 5.3 Events and Messages. It is very important to monitor all these sequence complete events and act on them accordingly.

For testing purposes, it is possible to use the LoramacSetDebug command or monitor the EVLORAMACTXDONE or LORAMACNOSYNC events. These should reassure that there is actually something happening in the background. In the case of the US/AU modules this should be quite quick as there are no duty cycle restrictions. In the case of the EU modules, however, it is likely to be minutes between resends. However here you can use the LoramacGetOption(LORAMAC_OPT_NEXT_TX) command to check if there is another packet due for transmission.

There is a more complete description of this process in the ***Interfacing with LoRaWAN*** documents, which are available on the documentation tab of the RM1xx product page: http://www.lairdtech.com/products/rm1xx-lora-modules .

3 Interactive Mode Commands

Interactive mode commands allow a host processor or terminal emulator to interrogate and control the operation of a *smart*BASIC-based module. Many of these emulate the functionality of AT commands. Others add extra functionality for controlling the filing system and compilation process.

Syntax Unlike commands for AT modems, a space character must be inserted between AT, the command, and subsequent parameters. This allows the *smart*BASIC tokeniser to efficiently distinguish between AT commands and other tokens or variables starting with the letters **AT**.

```
'Example:
AT I 3
```

The response to every Interactive mode command has the following form:

<linefeed character> response text <carriage return>

This format simplifies the parsing within the host processor. The response may be one or multiple lines. Where more than one line is returned, the last line has one of the following formats:

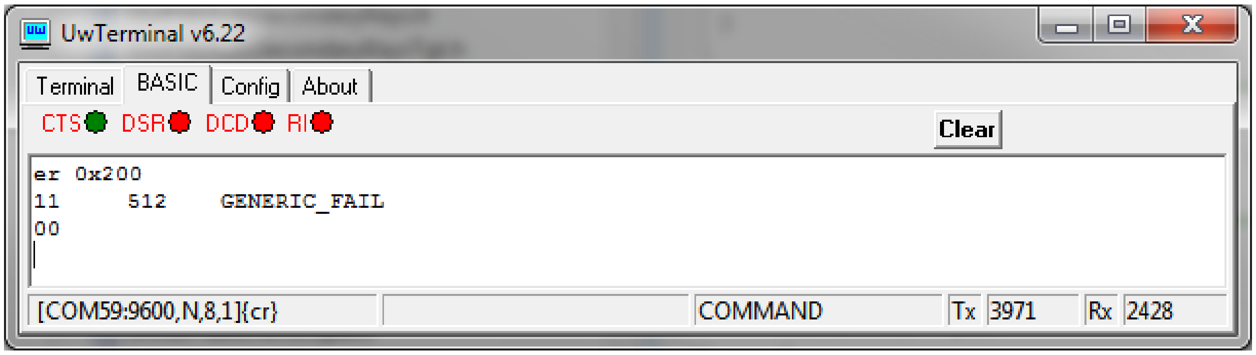
<lf>00<cr> for a successful outcome, or

<lf>01<tab> hex number <tab> optional verbose explanation <cr> for failure.

Note: In the case of the 01 response, the **<tab>optional_verbose_explanation** is missing in resource constrained platforms like the RM1xx modules. The *verbose explanation* is a constant string and since there are over 1000 error codes, these verbose strings can occupy more than 10 kilobytes of flash memory.

The hex number in the response is the error result code consisting of two digits which can be used to help investigate the problem causing the failure. Rather than provide a list of all the error codes in this manual, you can use UWTerminalX to obtain a verbose description of an error when it is not provided on a platform.

To get the verbose description, click the BASIC tab (in UWTerminalX) and, if the error value is hhhh, enter the command ER 0xhhhh and note the 0x prefix to hhhh. This is illustrated in Figure 2.



```
er 0x200
11      512     GENERIC_FAIL
00
```

```
[COM59:9600,N,8,1]{cr}    COMMAND    Tx 3971    Rx 2428
```

Figure 2: Optional verbose explanation

You can also obtain a verbose description of an error by highlighting the error value, right-clicking, and selecting **Lookup Selected ErrorCode** in the Terminal window.

If you get the text UNKNOWN RESULT CODE 0xHHHH, please contact Laird for the latest version of UWterminal.

3.1.1 AT+CFG

COMMAND

AT+CFG is used to set a non-volatile configuration key with an integer. The syntax of this command is defined in the *smart*BASIC Core Functionality Manual.

The following configuration key IDs are specific to the RM1xx module.

Key ID	Definition	Notes
1000	Class of Device	Sets the Class of the module. Only 2 classes are supported, A and C 0 – Class A 1 – Not supported at the moment 2 – Class C
1001	Sub-band	Sets the channels map by means of a sub-band. There are eight sub-bands available (1-8). Please refer section 5.2, SettingRM191 ChannelsMask, for more details of this command. Must be used in conjunction with the at+cfg 1002 command below. Only relevant to the RM191 and RM191_PE series of modules.
1002	Channels Map select type	This parameter defines how the channels map is defined 0 – default (all channels are enabled) 1 – defined by the value set by at+cfg 1001 2 – defined by the value set by at+cfgex 1009 Only relevant to the RM191 and RM191_PE series of modules.
1003	Sequence number incremental step	When using personalisation the module must keep track of the sequence number over a module reset. Therefore a value is stored in the serial EEPROM that will be used to initialise the sequence number when the module resets. This value in EEPROM is incremented by this step whenever the sequence number matches the value. The default incremental step is 256 and this is the maximum possible value for the step. This reduces the amount of writes to the serial EEPROM. See the Interfacing with LoRaWAN document for more information regarding this feature, available in the documentation tab of the RM1xx Product Page.

3.1.2 AT+CFGEX

COMMAND

AT+CFGEX is used to set a non-volatile configuration key with a string. The syntax of this command is defined in the *smart*BASIC Core Functionality Manual.

The following configuration key IDs are specific to the RM1xx module.

Key ID	Definition	Notes
1009	ChannelsMask	Sets the ChannelsMask. Only valid for the RM191. See the Setting RM191 ChannelsMask section below

Key ID	Definition	Notes
1010	AppEui	Application Identifier – 8 Bytes/16 Hex Characters
1011	DevEui	End Device Identifier – 8 Bytes/16 Hex Characters
1012	AppKey	Application Key – 16 Bytes/32 Hex Characters
1013	NwkSKey	Network Session Key – 16 Bytes/32 Hex Characters
1014	AppSKey	Application Session Key – 16 Bytes/32 Hex Characters
1015	DevAddr	End device Address – 8-character Hex string

The at+cfgex command returns an invalid key error (7312) if an invalid Key id is entered or the length of the entered string is incorrect for that specific Key id.

The new config value is only available for use after a system reset.

Note: The NwkSKey, AppSKey and AppKey values are write only. These values cannot be read back using the **at+cfgex xxxx?** command.

Prior to firmware versions 17/18.4.1.0 the Key Ids in the table above were in the range of 1000 – 1005 instead of the new range of 1010-1015.

4 Core Language Built-in Routines

Core Language built-in routines are present in every implementation of smartBASIC. These routines provide the basic programming functionality. They are augmented with target specific routines for different platforms which are described in the next chapter.

4.1.1 SYSINFO

FUNCTION

Returns an informational value depending on the value of the varid argument

SYSINFO (varId)

Returns	INTEGER – value corresponding to the varID requested
Arguments	byVal varID as INTEGER
varId	**ID** / **Definition** 1010 – Module version 100 – EU BLE Central 101 – US BLE Central 102 – AU BLE Central 103 – AS BLE Central 110 – EU BLE Peripheral 111 – US BLE Peripheral 112 - AU BLE Peripheral 113 - AS BLE Peripheral
Interactive Command	No

SYSINFO is a core language function.

5 LoRa Extensions Built-in Routines

5.1 LoRaMAC APIs

The following commands are specific to the LoRa functionality of the RM1xx.

5.1.1 LoRaMACSleepMode

FUNCTION

This command places the LoRa chipset in ultra-low power sleep mode. This closes the SPI driver and places the chipset in an unusable state. To put the BLE chipset into deep sleep the SytemStateSet(0) command must also be called.

LORAMACSleepMode ()

Returns	None
Arguments: None	
Interactive Command	No

```
  rc = Loramacsleepmode()
  rc = SystemStateSet(0)
```

LORAMACSleepMode is an extension function.

5.1.2 LORAMACJoin

FUNCTION

This command begins the Join process to connect a module to a LoRa network server. Before starting the Join process, the module reverts to its default state, specifically with respect to the data rate, transmit power and, in the case of the RM186, the default mandatory frequency channels. All appropriate network parameters must be configured using the AT+CFGEX commands prior to making this call.

There are two possible Join options:

- OTAA – where the RM1xx sends IDs to the server and both ends of the link use these IDs to calculate the NwkSKey and the AppSKey that are used in the encryption and decryption of the subsequent data packets.
- Personalization – where both the RM1xx and server are preconfigured with the NwkSKey, AppSKey keys and the DevAddr

For more information on the Join options, see the *Interfacing with LoRaWAN* app notes on the documentation tab of the RM1xx product page: http://www.lairdtech.com/products/rm1xx-lora-modules

Once the LORAMACJoin command is sent an EVLORAMACJOINING event is thrown. In the case of personalization there is no actual joining process, the module just transitions to the Joined state. However, the event is still thrown.

Then, on successful completion of the process, the EVLORAMACJOINED event is thrown.

5.1.3 LORAMACJoin (nFlags)

Returns	0x0000 = Successfully started Join process 0xnnnn = resultCode
Arguments:	
nFlags	**ByVal nFlags INTEGER** LORAMAC_JOIN_BY_PERSONALIZATION (0) LORAMAC_JOIN_BY_REQUEST (1)
Interactive Command	No

```
rc = LORAMACJoin(LORAMAC_JOIN_BY_REQUEST);
#define LORAMAC_JOIN_BY_REQUEST          1 // Used with LORAMACJoin
#define LORAMAC_JOIN_BY_PERSONALIZATION      0 // Used with LORAMACJoin

DIM rc

FUNCTION LoramacJoining() As Integer
 print "\nJoining"
endfunc 1

FUNCTION LoramacJoined() As Integer
 print "\nJoined"
endfunc 1


ONEVENT EVLORAMACJOINING CALL LoramacJoining
ONEVENT EVLORAMACJOINED  CALL LoramacJoined


rc = LORAMACJoin(LORAMAC_JOIN_BY_REQUEST)

WAITEVENT
```

LORAMACJoin is an extension function.

5.1.4 LORAMACLinkCheck

FUNCTION

This command sends a link check request upstream to the gateway. When a link check response is received from the gateway device, an EVLORAMACLINKCHECKRESPMSG message is sent to the application. This message contains two 8-bit values. The first represents the gateway's link margin, in dB, of the last successfully received link check request. The second represents the number of gateways that successfully received the last link check request.

LORAMACLinkCheck ()

Returns	0x0000 = Successfully sent a LoRa Link Check request message upstream 0xnnnn = resultCode
Arguments: None	
Interactive Command	No

```
//==========================================================================
// This handler is called when a Link Check Response is received
//==========================================================================
FUNCTION HandlerLoRaLinkCheckResponse(BYVAL nMargin AS INTEGER, BYVAL nGwCnt AS INTEGER) AS
INTEGER
       PRINT "Link Check Response: Margin = ";nMargin;"dB  Gateway Count = ";nGwCnt;"\n"
endfunc 1

OnEvent EVLORAMACLINKCHECKRESPMSG call HandlerLoRaLinkCheckResponse
…
LORAMACLinkCheck()
```

LORAMACLinkCheck is an extension function.

5.1.5 LORAMACTxData

FUNCTION

This command sends data upstream to the LoRa gateway and Network Server on the specified port.

Note: Port 0 is reserved for MAC commands between the gateway and the end node.

LORAMACTxData (nPort, Data$, nFlags)

Returns	0x0000 – Successfully queued data for upstream transmission 0xnnnn – resultCode
Arguments:	
nPort	**ByVal nPort INTEGER** The port to be used by the transmission.
Data$	**ByRef data$ STRING** The data to be sent upstream.
nFlags	**ByVal nFlags INTEGER** Bit mask for options. ▪ 0 – Do not request confirmation ▪ 1 – Request confirmation
Interactive Command	No

```
#define LORAMAC_JOIN_BY_REQUEST               1 // Used with LORAMACJoin
#define LORAMAC_JOIN_BY_PERSONALIZATION       0 // Used with LORAMACJoin

DIM rc
DIM data$
DIM ncurrentsize, nmaxsize
DIM joined

FUNCTION HandlerLoramacJoining() As Integer
  print "\nJoining"
endfunc 1

FUNCTION HandlerLoramacJoined() As Integer
  //JoinAccept has been received.  You are now free to transmit data packets
  print "\nJoined"
  joined = 1
endfunc 1

FUNCTION HandlerLoramacRxTimeout() As Integer
  // A JoinAccept has still not been received after the JoinRequest has been
  // attempted a configured number of times
  print "\nRxTimeout"
endfunc 1

FUNCTION HandlerLoramacTxTimeout() As Integer
  // Something has gone wrong so you need to resend the JoinRequest or data packet
  print "\nTxTimeout"
endfunc 1
```

```
FUNCTION HandlerLoramacRxError() As Integer
  // Something has gone wrong so you need to resend the JoinRequest
  print "\nRxError"
endfunc 1

FUNCTION HandlerLoramacTxComplete() As Integer
  // TxComplete has been received
  print "\nTxComplete"
endfunc 1

FUNCTION HandlerLoramacRxComplete() As Integer
  // RxComplete has been received
  print "\nRxComplete"
endfunc 1

FUNCTION HandlerNextTx() As Integer
  print "\nNextTx"

  if joined == 1 then
    print "\n--------------------------------------\n"
    rc = LoramacQueryTxPossible(strlen(data$),ncurrentsize,nmaxsize)
    if rc == 0 then
      print "\ncurrent ";ncurrentsize
      print "\nmax ";nmaxsize
    else
      print "current ";ncurrentsize
    endif
    rc = LORAMACTxData(2,data$, 1)
    if rc != 0 then
      print "\nData payload too large"
    endif
  else
    rc = LORAMACJoin(LORAMAC_JOIN_BY_REQUEST)
  endif
endfunc 1

FUNCTION HandlerSequenceComplete(flag, netxtime) As Integer
  print "\nSequence complete ";flag
  print "\nNext time ",netxtime
endfunc 1

FUNCTION HandlerLoramacRxData() As Integer
  dim rxdata$
  dim nRSSI,nPort,nSNR,nFramePending,nPacketType

  rc = LORAMACRxData(rxdata$, nRSSI, nPort, nSNR, nFramePending, nPacketType)
  print "\nStatus ";nPort;"\nRSSI: ";nRSSI;"  SNR: ";nSNR;"\n"
  print "\nData ";rxdata$
endfunc 1

ONEVENT EVLORAMACJOINING CALL HandlerLoramacJoining
ONEVENT EVLORAMACJOINED CALL HandlerLoramacJoined
ONEVENT EVLORAMACRXTIMEOUT CALL HandlerLoramacRxTimeout
ONEVENT EVLORAMACTXTIMEOUT CALL HandlerLoramacTxTimeout
ONEVENT EVLORAMACRXERROR CALL HandlerLoramacRxError
ONEVENT EVLORAMACTXCOMPLETE CALL HandlerLoramacTxComplete
ONEVENT EVLORAMACRXCOMPLETE CALL HandlerLoramacRxComplete
ONEVENT EVLORAMACRXDATA CALL HandlerLoramacRxData
ONEVENT EVLORAMACNEXTTX CALL HandlerNextTx
ONEVENT EVLORAMACSEQUENCECOMPLETE CALL HandlerSequenceComplete

data$ = "hello"
joined = 0

rc = LORAMACJoin(LORAMAC_JOIN_BY_REQUEST)

WAITEVENT
```

LORAMACTxData is an extension function.

5.1.6 LORAMACRxData

FUNCTION

This function returns downlink data received from the LoRa gateway. It should only be called from the EVLORAMACRXDATA event handler.

LORAMACRxData (stData$, pRxRSSI, pRxPort, pRxSNR, pFramePending, pPacketType)

Returns	0x0000 : Success
Arguments:	
stData$	**ByRef stData$ STRING** The data read from the received packet.
pRxRSSI	**ByRef pRxRSSI INTEGER** The RSSI value of the received packet.
pRxPort	**ByRef pRxPort INTEGER** The port on which the packet is received.
pRxSNR	**ByRef pRxSNR INTEGER** The SNR value of the received packet.
pFramePending	**ByRef pFramePending INTEGER** 0 – No downlink packets ramaining in the server 1 – Downlink packets remaining in the server
pPacketType	**ByRef pPacketType INTEGER** Indicates whether the downlink packet was a confirmed or unconfirmed packet. If it is a confirmed packet the the stack will automatically send an acknowledgement in the next uplink packet. 3 – unconfirmed packet 5 – confirmed packet
Interactive Command	No

See LORAMACTXDATA above for an example of this functionality

LORAMACRxData is an extension function.

5.1.7 LORAMACGetOption

FUNCTION

This function retrieves the value for a specified option.

Note: A list of options and their descriptions can be found in Table 1. RM1xx-defs.h should be included by any *smart*BASIC app using this function. It can be downloaded fom the Laird website and will be included with every firmware release.

LORAMACGetOption (nOptID, optValue$)

Returns	0x0000 – Successfully retrieved option value 0xnnnn – Result code
Arguments:	
nOptID	**ByVal nOptID INTEGER** The Option ID as defined in TargetRM1xx-defs.h
optValue$	**ByRef optValue$ STRING** The string in which to return the option value.
Interactive Command	No

```
//Example Code
dim reg
dim stringVal$
dim rc

// Retrieve the current data rate and print it
rc = LORAMACGetOption(LORAMAC_OPT_DATA_RATE, stringVal$)
print stringVal$
```

LORAMACGetOption is an extension function.

5.1.8 LORAMACSetOption

FUNCTION

This function sets the value for a specified option.

Note: Values set using this command are not persisted and are lost over a power cycle. Certain of the values listed in the LORAMAC Option List below can be set and saved using the at+cfg or at+cfgex commands above.

Note: A list of options and their descriptions can be found in Table 1. RM1xx-defs.h should be included by any *smart*BASIC app using this function. It can be downloaded fom the Laird website and will be included with every firmware release.

LORAMACSetOption (nOptID, optValue$)

Returns	0x0000 – Successfully set option value 0xnnnn – Result code

Arguments:	
nOptID	**ByVal nOptID INTEGER** The Option ID as defined in TargetRM1xx-defs.h
optValue$	**ByRef optValue$ STRING** The value to set.
Interactive Command	No

```
//Set the data rate to 5
temp$ = "5"
rc = LORAMACSetOption(LORAMAC_OPT_DATA_RATE, temp$)
```

LORAMACSetOption is an extension function.

5.1.9 LORAMAC Option List

These options are available for use with the LORAMACGetOption and LORAMACSetOption (as specified in the *Get* and *Set* columns. Enumerations of these options can be found in RM1xx-defs.h.

Table 1: LORAMAC Option List

Option	Option Name	Get	Set	Description
1	LORAMAC_OPT_TX_POWER	YES	YES	The output power in dB of the LoRa radio. The value entered must be one of the values specified in the LoRaWAN specification. For the RM186 valid values are 2, 5, 8, 11, 14 and 20dBm and for the RM191 10 to 30dBm in 2dBm steps. If an invalid value is entered, the code sets the power to the nearest value lower than the one entered. ***Note:*** *The RM1xx is limited to a maximum output power of 13dBm. If a value higher than that is entered, the code automatically limits the power.*
2	LORAMAC_OPT_DATA_RATE	YES	YES	The data rate of the LoRa radio. Valid values are 0 to 5 for the RM186 and 0 to 4 for the RM191.
3	LORAMAC_OPT_JOIN_STATE	YES	NO	LoRaWAN network joined attribute
4	LORAMAC_OPT_DEV_EUI	YES	NO	The device EUI assigned by Laird
5	LORAMAC_OPT_CUSTOM_DEV_EUI	YES	YES	An optional custom device EUI *not* provided by Laird
6	LORAMAC_OPT_DEV_ADDR	YES	NO	The end-device address
7	LORAMAC_OPT_APP_EUI	YES	YES	The application EUI
8	LORAMAC_OPT_APP_KEY	NO	YES	The application key
9	LORAMAC_OPT_VERSION	YES	NO	The version number of the device

Option	Option Name	Get	Set	Description
10	LORAMAC_OPT_RSSI	YES	NO	The Received Signal Strength Indicator of the last received packet available after an RX Complete event
11	LORAMAC_OPT_SNR	YES	NO	The Signal-to-Noise Ratio of the last received packet available after an RX Complete event.
12	LORAMAC_OPT_DOWNLINK_COUNTER	YES	NO	Number of down-link packets received
13	LORAMAC_OPT_UPLINK_COUNTER	YES	NO	Number of up-link packets sent
14	LORAMAG_OPT_SOURCE_VOLTAGE	YES	NO	The supply voltage of the device in millivolts
15	LORAMAC_OPT_915_HYBRID_MODE	-	-	Deprecated in version 17/18.4.1.0 in RM1xx and never supported in RM1xx_PE.
16	LORAMAC_OPT_BIRTHDAY	YES	NO	The date the device is created
17	LORAMAC_OPT_ADR_ENABLE	YES	YES	Enable (1) and disable (0) automatic data rate adaptation.
18	LORAMAC_OPT_CHANNELLIST	YES	NO	Lists the channel number, frequency and maximum data rate of all the enabled channels. Only valid in EU mode
19	LORAMAC_OPT_CHANNELMASK	YES	YES / NO	The channels mask designating the enabled channels. Set option can only be used on the 915(US) MHz radio. Get option is valid for both sets of modules The set option overrides the current value, but is not persisted. After a reboot, it reverts to the default or configured value. See the Setting RM191 ChannelsMask section below.
20	LORAMAC_OPT_NEXT_TX	YES	NO	Returns the time, in seconds, until the packet just loaded is transmitted to the gateway.
21	LORAMAC_OPT_TEMPERATURE	YES	NO	Temperature in degrees Celsius.
22	LORAMAC_OPT_TEMP_COMP_FACTOR	YES	NO	Temperature compensation factor – device specific.
23	LORAMAC_OPT_FREQ_ERROR	YES	NO	Frequency error (Hz) of the SX1272.
24	LORAMAC_OPT_FREQ_OFFSET	YES	NO	SX1272 frequency offset of the SX1272.
25	LORAMAC_OPT_MAX_RETRIES	YES	YES	Sets the number of times the module attempts to resend a confirmed packet if an acknowledgment is not received. The maximum and default values are 8.
26	LORAMAC_OPT_DEVICE_CLASS	YES	YES	Sets the Device class. 0 – Class A 2 – Class C
27	LORAMAC_OPT_MAX_JOIN_ATTEMPTS	YES	YES	Defines the number of Join Request attempts that are made using the same packet before an EVLORAMACRXTIMEOUT event is thrown. This command is only valid for the RM191 and RM191_PE series of modules.

Option	Option Name	Get	Set	Description
				This command must be sent before the first JoinRequest is transmitted.
28	LORAMAC_OPT_SUBBAND	YES	YES	Sets the channels map by means of a sub-band value. There are 8 available sub-bands, 1-8. See the Setting RM191 ChannelsMask section below for more details of this command. **Note:** *This command is only valid for the RM191 and RM191_PE series of modules.*
29	LORAMAC_OPT_NEXTTX_TIME	NO	YES	Returns the time to the NextTxEvent. This is also returned as as part of the EVLORAMACSEQUENCECOMPLETE event. This will always be 0 for the US and AU modules.
30	LORAMAC_OPT_SEQUENCE_INCREMENT	YES	YES	The maximum incremental step the sequence counter could jump after a module reset. This value is not persisted and temporarily replaces the value stored in Flash using the at+cfg 1003 command. This command is only valid when using Personalisation. See the Interfacing with Lorawan documents for more details of this command.
31	LORAMAC_OPT_EEPROM_UPCOUNTER	YES	YES	The value that is stored in the serial EEPROM that will be used to initialise the uplink sequence number after a module reboot. This command can also be used to set the counter value and is persisted over a reset. The get option returns 2 values, the first is the local value, thesecond is the value stored in the EEPROM. This command is only valid when using Personalisation. See the Interfacing with LoRaWAN documents for more details of this command.
32	LORAMAC_OPT_EEPROM_DOWNCOUNTER	YES	YES	The value that is stored in the serial EEPROM that will be used to initialise the downlink sequence number after a module reboot. This command can also be used to set the counter value and is persisted over a reset. The get option returns 2 values, the first is the local value, thesecond is the value stored in the EEPROM. This command is only valid when using Personalisation.

Option	Option Name	Get	Set	Description
				See the Interfacing with Lorawan documents for more details.

Note: There is a subtle difference between options LORAMAC_OPT_NEXT_TX (20) and LORAMAC_OPT_NEXTTX_TIME (29). The former is only returns a vaild value once a packet has been set to the LoRa stack. The latter returns the time until a radio band duty cycle will be available. For US and AU modules both these values will always be 0.

5.1.10 LORAMACSetDebug

This command should only be used during development. It is not recommended that this command is left active in any production version of a *smart*BASIC application.

FUNCTION

This function sets the module up to output certain debug information, either as a text string or as a waveform.

LORAMACSetDebug (nDebug, nTxSio, nRxSio)

Returns	0x0000 – Successfully actioned command 0xnnnn – Result code
Arguments:	
nDebug	**ByVal** nDebug **INTEGER** 0 – Disables debug mode 1 – Enables debug mode
nTxSio	**ByVal** nTxSio **INTEGER** The SIO pin that the Tx waveform is output on.
nRxSio	**ByVal** nRxSio **INTEGER** The SIO pin that the Rx waveform is output on.
Interactive Command	No

If debug mode is enabled, the module outputs the frequency on which a packet is transmitted, the data rate of that packet when transmitting, and the spreading factor/symbols timeout when receiving.

It also outputs two waveforms, on the selected SIOs, that mark when the module is in transmit or receive mode.

TxSio and RxSio cannot be the same value unless debug mode is being disabled.

Debug mode is not persisted. If debug mode was enabled and the module was then reset, it boots up with debug mode disabled.

More information on this functionality is available in the RM1xx Debug Features document, available under the documentation tab of the RM1xx product page: http://www.lairdtech.com/products/rm1xx-lora-modules

LORAMACSetOption is an extension function.

5.1.11 LoramacQueryTxPossible

This command allows the user to query the stack as to what is the maximum packet size for the current configuration.

FUNCTION

This function queries the module for the current maximum size of an uplink packet.

LORAMACQueryTxPossible (nSize, nCurrentSize, nMaxSize)

Returns	0x0000 – Successfully actioned command 0xnnnn – Result code 0x730E – Data packet is too large for the present configuration.
Arguments:	
nSize	**ByVal** nSize **INTEGER** The size of the packet you wish to send
nCurrentSize	**ByRef** nCurrentSize **INTEGER** The theoretical maximum size of an uplink packet, which is derived from the current data rate.
nMaxSize	**ByRef** nMaxSize **INTEGER** The actual maximum size of an uplink packet once all the internal options are taken into account.

```
dim rc
dim currentsize,maxsize
dim data$

data$ = "hello"

rc = LoramacQueryTxPossible(strlen(data$),currentsize,maxsize)
if rc == 0 then
  //Everything ok
  print "current ";currentsize
  print "max ";maxsize
else
  // Error has occurred
  print "current ";currentsize
endif
```

LORAMACSetOption is an extension function.

5.2 Setting RM191 ChannelsMask

Note that this section is only relevant to the US and AU series of modules. The setting of the ChannelsMask in the RM186 is handled completely differently and requires no input by the user.

The ChannelsMask is a hex string where each individual bit refers to a specific RF channel.

The US and AU modules modules have 64 125kHz upstream channels (channels 0-63) with a 200kHz spacing between consecutive channels and 8 500kHz upstream channels (channels 64-71) with 1.6MHz spacing between consecutive frequencies. The actual frequencies that these channels represent differ between LoRaWan regions. The values for the US and AU regions are shown in Table 2 below.

To make configuration easier most gateway/network providers also use the concept of a sub-band. Each sub-band contains 8 consecutive 125 kHz channels and 1 500kHz channel. So sub-band 1 contains channels 0-7 and 64, sub-band 2 contains channels 8-15 and 65 etc.

By default, on power up all channels are enabled by setting their bit in the ChannelsMask to 1. When the module is tasked with transmitting a packet to the gateway, it randomly selects one of the enabled channels and the packet is transmitted on that frequency. At the moment, most gateways only support 8 125 kHz channels and 1 500KHz channel so there is a one in eight chance of selecting a channel that is supported by a gateway.

There are MAC commands available to the network server to modify the channelsmask on a module but these are only available after a module has joined the network. However, it can take several attempts before a join request is transmitted on an enabled frequency.

Also, once joined, there is no guarantee that a network server supports altering the channelsmask, so it is possible that you may need several attempts to successfully transmit any packet to the gateway and onto the network server.

So for both the JoinRequest and transmitting data packets the module may need to send the same packet several times before it is eventually transmitted on a channel supported by the gateway.

In the RM191 and RM191_PE series of modules, however, it is possible to manually set the channels mask. Before using any of the commands below, it is important that you contact your network provider and ask which channels their gateways support. If you set up a module with the wrong channels mask, then it is not able to communicate with the network.

Note that the method the module uses to set the channlesmask is governed by the at+cfg 1002 command, which determines if the module reverts to the default value or uses one of the options below. This value is persisted.

The simplest method is to use either the at+cfg 1001 or LORAMACSetOption(LORAMAC_OPT_SUBBAND, x) commands. This allows the user to set a specific sub-band. As most gateways can only be configured to the sub-band level, these commands should suffice in the vast majority of cases.

The difference in the commands is that the value set using the at+cfg command is persisted in memory, so survives a power cycle. The LORAMACSetOption is not persisted and so the value reverts to the value determined by the at+cfg 1002 command.

Certain gateways, however, allow you to be more flexible when setting the channels map. The Laird RG1xx Sentrius, for example, allows you to set the channelsmap over multiple sub-bands. To support this, these modules allow you to enable individual channels by setting the bit that corresponds to their channel number in a hex string that is either loaded during bootup from a default value or from a value stored in Flash using the at+cfgex 1009 command.

The value that must be set is governed by which frequency channels are supported by the gateway or gateways with which you want to communicate; for that, you must consult your network administrator.

It is very unlikely you would want to use the at+cfgex 1009 method if a gateway is configured for a sub-band. In this case you are better using the sub-band methods described above. However, Table 2 shows the required strings as examples.

Table 2 : ChannelMask commands

Sub-Band	Frequency Range (MHz)		Channels	Command
	US	AU		
1	902.3–903.7	915.2-916.6	0-7	at+cfgex 1009 "000100000000000000ff"
2	903.9–905.3	916.8-918.2	8-15	at+cfgex 1009 "0002000000000000ff00"
3	905.5–906.9	918.4-919.8	16-23	at+cfgex 1009 "00040000000000ff0000"
4	907.1–908.5	920.0-921.4	24-31	at+cfgex 1009 "000800000000ff000000"
5	908.7–910.1	921.6-923.0	32-39	at+cfgex 1009 "0010000000ff00000000"
6	910.3–911.7	923.2-924.6	40-47	at+cfgex 1009 "00200000ff0000000000"
7	911.9–913.3	924.8-926.2	48-55	at+cfgex 1009 "004000ff000000000000"
8	913.5–914.9	926.4-927.8	56-63	at+cfgex 1009 "0080ff00000000000000"
All bands	902.3–914.9	915.9-917.1	0-63	at+cfgex 1009 "00ffffffffffffffff"

In the table above, channel 0 is the least significant bit on the extreme right-hand side of the string.

The *All Bands* option could be used if you don't know the configuration of a gateway. With this ChannelsMask, the RM191 continues to transmit a packet on random channels until it finds one that worked. However, it is much easier to set **at+cfg 1002** to 0.

Most gateways at present only support the one sub-band option as this is determined by the configuration of the SX1301 module. However, if a gateway contains more than one of these modules, then it is simply a case of enabling the extra bits. For example, to enable sub-bands 1 and 4, the following string is entered:

```
at+cfgex 1009 "000900000000ff0000ff"
```

While it is possible to set the hex string to any channel configuration, the present method of configuring the gateways means that the ChannelsMask is most likely grouped in bands of three, four, or five channels. For example, if a gateway supported channels 4-7, 28-31, and 67, then the following string is required:

```
at+cfgex 1009 "000800000000f00000f0"
```

Note that the 500kHz channel must fit in one of the 125kHz channel sub-bands.

However, again, it is important to stress that you must contact your network administrator to determine which settings you require.

As has previously been mentioned, the at+cfgex 1009 "xxx…" command is stored in flash and you must configure the module before running a *smart*BASIC app. However, you may also modify the channelsmask from a *smart*BASIC application using the LoramacSetOption(LORAMAC_OPT_CHANNELMASK,xxx…).

If you wanted to set the RM191 to sub-band 2, then you can enter:

```
LoramacSetOption(LORAMAC_OPT_CHANNELMASK, 00020000000000000ff00)
```

Note with this method you do not require the "" around the hex string. ChannelsMasks entered this way are not persisted. When the module reboots it reverts to the stored or default value.

5.3 Events and Messages

5.3.1 EVLORAMACJOINING

The device started the Join procedure. In the case of OTAA a Join Request message is sent and the device awaits the Join Response message from the server. For personalization the module just transitions to the Joined state.

5.3.2 EVLORAMACJOINED

The device successfully completed the Join procedure. If using the OTAA Join procedure, this indicates that a successful Join Response message was received from the server. This event is thrown immediately when joining the network using Activation by Personalization (ABP).

This event marks the end of the Join sequence.

5.3.3 EVLORAMACJOINFAIL

An event indicating that a JoinAccept message contains a mic error. This will result in the module retransmitting the uplink packet.

No action should be taken on receipt of this event. It is for information only. This event DOES NOT mark the end of the uplink/downlink sequence.

5.3.4 EVLORAMACTXCOMPLETE

The module successfully sent an uplink packet. This event is sent at the end of the uplink/downlink sequence and not at the same time as the EVLORAMACTXDONE event as you might expect. So in the case of confirmed packets or downlink data packets where an EVLORAMACRXCOMPLETE event would be raised, the 2 events are sent at the same time. In the case of confirmed packets, if the downlink packet is not received this event will not be sent.

This event marks the end of the uplink/downlink sequence.

5.3.5 EVLORAMACRXCOMPLETE

The device has received a downlink packet. This downlink may contain data or just an acknowledgment to a confirmed uplink. If the packet contains data there will also be an EVLORAMACRXDATA event.

This event marks the end of the uplink/downlink sequence.

5.3.6 EVLORAMACTXTIMEOUT

An ACK was not received for a confirmed uplink message

This event marks the end of the uplink/downlink sequence.

5.3.7 EVLORAMACRXTIMEOUT

No acknowledgement was received for a confirmed uplink packet. This event will only be sent at the end of the uplink/downlink cycle (see Transmit/Receive Sequence) so several attempts will have been made to transmit the packet.

This event marks the end of the uplink/downlink sequence.

5.3.8 EVLORAMACRXERROR

An error occurred in the receive path.

This event marks the end of the uplink/downlink sequence.

5.3.9 EVLORAMACRXDATA

Downstream data received from the gateway. The application can read the data using LORAMACRxData().

5.3.10EVLORAMACLINKCHECKRESPMSG

This message is returned from the LoRa stack when a Link Check response is received from a LoRa gateway. The demodulation margin is reported as an 8-bit unsigned integer named **Margin** which ranges from 0 to 254. Margin indicates the link margin in dB of the last successfully reported LinkCheckReq command. The gateway count is returned as a variable named **GwCnt** and represents the number of gateways that successfully received the last LinkCheckReq command. See section 5.1 of the LoRaWAN specification for more details.

5.3.11 EVLORAMACTXDONE

This event indicates that a packet has successfully been transmitted from the radio. It is this event that all subsequent receive windows are timed with respect to.

No action should be taken on receipt of this event. It is for information only.

5.3.12 EVLORAMACNOSYNC

This event indicates that the receiver has failed to detect a sync message from the gateway during a receive window and so has exited the receive state. As there can be two potential receive windows for every transmitted packet, in worse case scenarios there can be two of these events for every uplink packet.

No action should be taken on receipt of this event. It is for information only.

5.3.13 EVLORAMACADR

This event indicates that the RM1xx has received an ADR command from the gateway/server and that a parameter setting on the module may have changed. The parameters that this command can change are the TxPower, Datarate or ChannelsMask.

This event also returns 2 parameters indicating the downlink packet type and whether there is any other downlink frames pending.

The downlink packet types are as follows:

Value	Packet Type
3	Unconfirmed downlink
5	Confirmed downlink

If another downlink frame is pending the value returned will be a 1.

```
FUNCTION HandlerLoramacAdrMessage(packettype,pending)
  sprint #strT$,"Adr packet: type ";packettype
  PrintMsg(strT$)
  sprint #strT$,"Pending ";pending
  PrintMsg(strT$)
endfunc 1
```

5.3.14 EVLORAMACNEXTTX

This event indicates that there as available duty cycle on one of the sub-bands. If a LORAMACTxData command is sent on receipt of this event, the data is sent without any delays. This event is only really valid in the modules that have duty cycle restrictions, such as the EU and AS regions.

For those modules that don't have this duty cycle restriction (US and AU), a packet can be sent to the stack on receipt of an end of uplink/downlink sequence event and will be transmitted immediately. However there is harm in still using this event, it is just not strictly necessary.

5.3.15 EVLORAMACDOWNLINKREPEATED

Event indicating that the module has received a downlink packet with the same sequence number as the previous downlink packet.

5.3.16 EVLORAMACMICFAILED

An event indicating that the module has received a downlink packet containing a MIC error. This will result in the module retransmitting the uplink packet.

No action should be taken on receipt of this event. It is for information only. This event DOES NOT mark the end of the uplink/downlink sequence.

5.3.17 EVLORAMACSEQUENCECOMPLETE

This event is an amalgamation of some of the above events and marks the end of uplink/downlink sequence and that it now possible to load a new uplink packet into the stack. In EU modules that packet may not be transmitted immediately due to duty cycle constraints.

This event also returns 2 parameters the flag indicating which event triggered the end of the sequence and the time to the next EVLORAMACNEXTTX event.

The possible flag values are as follows:

Table 3: Module version numbers

Value	Event
1	EVLORAMACTXCOMPLETE
2	EVLORAMACRXCOMPLETE
3	EVLORAMACRXTIMEOUT
4	EVLORAMACRXCRCERROR
5	EVLORAMACTXTIMEOUT
6	EVLORAMACRXERROR
7	EVLORAMACTXDRPAYLOADSIZEERROR

```
FUNCTION HandlerSequenceComplete(flag, nexttime) As Integer
  sprint #strT$,"Sequence complete ";flag
  PrintMsg(strT$)
  sprint #strT$,"Next time ",nexttime
  PrintMsg(strT$)
endfunc 1

ONEVENT EVLORAMACSEQUENCECOMPLETE CALL HandlerSequenceComplete
```

5.3.18 EVLORAMACFRAMESLOSS

This event indicates that the difference between the actual and expected receive downlink sequence number is larger than the maximum allowed value. This event should not be acted upon directly, the stack should correct this automatically.

5.3.19 EVLORAMACTXDRPAYLOADSIZEERROR

This event will only occur when a module has entered the resend sequence, due to the non-receipt of an acknowledgement. As part of the resend procedure the datarate could reduce which could mean that the packet size that was originally within limits is now too large. If this occurs this event will be thrown.

This event marks the end of the uplink/downlink sequence.

6 Acknowledgements

The following are required acknowledgements to address our use of open source code on the RM1xx to implement AES encryption.

Laird's implementation includes the following files: **aes.c** and **aes.h**.

Copyright (c) 1998-2008, Brian Gladman, Worcester, UK. All rights reserved.

6.1.1.1 License Terms

The redistribution and use of this software (with or without changes) is allowed without the payment of fees or royalties providing the following:

- Source code distributions include the above copyright notice, this list of conditions and the following disclaimer;
- Binary distributions include the above copyright notice, this list of conditions and the following disclaimer in their documentation;
- The name of the copyright holder is not used to endorse products built using this software without specific written permission.

6.1.1.2 Disclaimer

This software is provided 'as is' with no explicit or implied warranties in respect of its properties, including, but not limited to, correctness and/or fitness for purpose.

Issue 09/09/2006

This is an AES implementation that uses only 8-bit byte operations on the cipher state (there are options to use 32-bit types if available).

The combination of mix columns and byte substitution used here is based on that developed by Karl Malbrain. His contribution is acknowledged.

7 INDEX OF *SMART*BASIC COMMANDS