



TWIMO HP & MP Modules

RTU & API

User's guide

Table of contents

TWIMO REGULATORY CONSIDERATIONS	4
1. TWIMO module range	5
1.1. Form factor and footprint	5
1.2. Module's hardware architecture	6
1.3. Technical Specifications	6
1.4. Hardware integration	7
1.5. Antenna	7
1.6. Power Supply	8
2. TWIMO concept	9
2.1. "Ready to Use" version: configurable RF gateway	9
2.2. "Programmable" version: embedding your application in it!	9
3. "Ready To Use" version	9
3.1. Operating modes	9
3.1.1 Command Mode	10
3.1.2 Communication mode	10
3.1.2.01 Asynchronous mode of communication	10
3.1.2.02 Synchronous (TDMA) mode of communication	10
3.1.2.03 Synchronous vs Asynchronous (drawback and advantage)	11
3.2. Command Interface	11
3.2.1 Entering Command Mode	11
3.2.1.01 Through the RS232 serial link	11
3.2.1.02 Through a dedicated pin of the module (pin n° 8: Cmd_Mode):	12
3.2.2 AT Commands	12
3.2.2.01 AT Commands : module configuration	12
3.2.2.02 AT Commands : module test	12
3.2.3 Register parameter	13
3.2.4 Default settings	14
3.3. Communication mode: Sending and Receiving datas	14
3.3.1 Modem state machine	15
3.3.2 Data flow	15
3.3.3 Packet format	15
3.3.4 Addressing modes	16
3.3.4.01 Transparent mode	16
3.3.4.02 Addressed mode	17
3.3.5 Receiving mode	17
3.3.6 LED Status	17
3.3.7 Synchronous TDMA mode	17
3.4. Radio characteristics	18
3.4.1 Narrow band system	18
3.4.2 Medium band system	18
3.4.3 Wide band system	18
3.4.4 Summary	18
4. Firmware upgrade	19
5. "Programmable" version	20
5.1. API concept	20

5.2. Hardware Interface description	21
5.2.1 Pin Description	21
5.3. Resources availability and partitioning	21
5.3.1 Flash memory	21
5.3.2 RAM memory	21
5.3.3 E2PROM memory	22
5.3.4 TWIMO firmware requirement in terms of memory	22
5.3.5 Peripheral (GPIO, ADC/DAC, Communication etc...)	22
5.3.6 Hardware Timer	22
5.3.7 DMA	23
5.3.8 GPIO Interrupt line and vectors	23
5.3.9 Interrupt vector priority	24
5.3.10 CPU Frequency	24
5.4. API TWIMO	25
5.4.1 Radio related APIs	25
5.4.1.01 TWIMO_API_SystemInit()	25
5.4.1.02 TWIMO_API_Radio_BackgroundTask()	25
5.4.1.03 TWIMO_API_Radio_SendData ()	26
5.4.1.04 TWIMO_API_Radio_ReceiveData()	26
5.4.1.05 TWIMO_API_GetFirmwareVersion()	27
5.4.2 TWIMO API data structure	27
5.4.2.01 TWIMO_INIT	27
5.4.2.02 TWIMO_RADIO_TX	29
5.4.2.03 TWIMO_RADIO_RX	29
5.4.3 TWIMO firmware operating	30
5.4.4 Application Template	31
5.5. TWIMO API: how to use it ?	31
5.6. Code Integration	32
5.6.1 Application background task execution	32
5.6.2 Application interrupt execution	32
5.6.3 Miscellaneous	32
5.7. Compiling code	32
5.7.1 Code Generation tool	32
5.7.2 Project/Workspace exemple	33
5.8. Bootloading	33
6. Process	33
6.1. Description of module 7581-A and board ARF7628/B	33
6.2. BOM analysis	34
6.3. Risk linked to number of reflows	34
6.4. Risk Management for Moisture sensitivity	36
6.5. Soldering curve	37

TWIMO REGULATORY CONSIDERATIONS

Ready to Use" versions ARF7580AA & ARF 7581AA

DECLARATION OF CONFORMITY (CE0081)

We **ADEUNIS RF**
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38920 CROLLES FRANCE

declare under our own responsibility that the TWIMO modules ARF7580AA&ARF7581AA to which this declaration refers conforms with the relevant standards or other standardising documents:

- EN 300 220-2 (v2.1.2) (2007-06)
- EN 300 220-2 (V2.3.1) (2010-02)
- EN 60950-1 (2001) + A11 (2004)
- EN50371 (2002) / EN62311 (2008) / EN50385 (2008)
- EN301 489-1 (v1.8.1) (2008-04)
- EN 301 489-3 (v1.4.1) (2002-08)
- EN 62311 (2008)

According to the RTTE Directive 99/5/EC

Notes:

- Conformity has been evaluated according to the procedure described in Annex IV of the RTTE directive (Statement of opinion from a notify body N°102158-604317-1/2)
- Conformity has been evaluated with ARF7580AA module integrated on ADEUNIS RF TWIMO Starter Kit ARF7659B and with ARF7581AA module integrated on ADEUNIS RF TWIMO Starter Kit ARF7659C.
- According to the 1999/519/EC «RF signal» recommendations, a minimum distance of 10cm between the product and the body is required.
- Receiver class (if applicable): 2

RTTE COMPLIANT END PRODUCT

To get a RTTE COMPLIANT END PRODUCT with the ready to use version, user or integrator must follow the integration proposed in the ADEUNIS RF TWIMO SK ARF7659B or ARF7659C. Please have a look on the TWIMO SK user guide (www.adeunis-rf.com) for information about schematics, PCB, battery, antenna, software version...

If one of the conditions described in the SK user guide is not respected or is modified, additional normative tests will be necessary on the end product to ensure the RTTE conformity. As the integration of a radio module requires wireless technological knowledge, ADEUNIS RF proposes its technical proficiency to its customers for a pre-compliance qualification of end products.

If the software of the module is changed or modified, the module becomes a programmable version and loses the CE conformity.

PROGRAMMABLE" versions ARF7734 / ARF7735 / ARF7736

For these versions, the RF behavior of the product and of the module will among others depend on the software included by the user or integrator in the module. Thus :

- There is no sense to speak about CE conformity of the module
- The RTTE conformity of the end product shall have to be evaluated with the module integrated the final software.

According the customer software, conformity of the end product shall be evaluated case by case. Moreover, as the integration of a radio module requires wireless technological knowledge, ADEUNIS RF proposes its technical proficiency to its customers for a pre-compliance qualification of end products

Pinout of the modules:

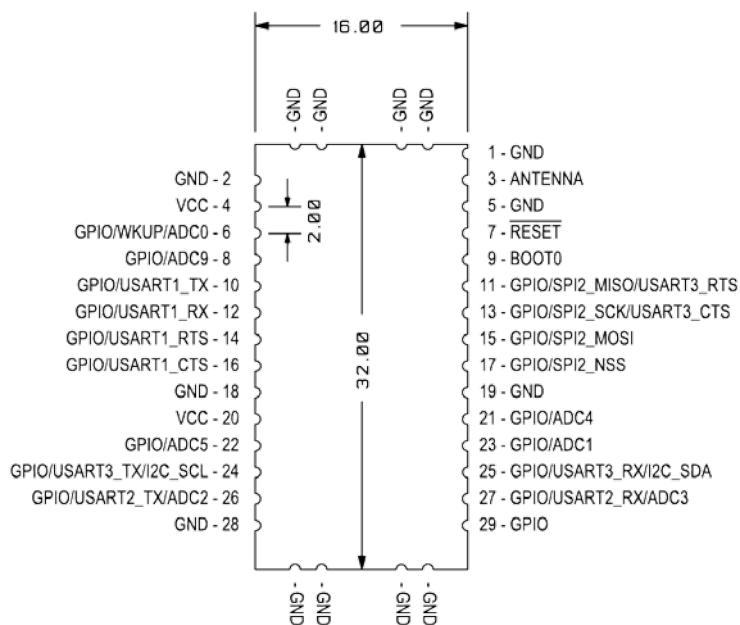


Figure 2. Module's pinout

The description and the functionalities associated with each pin are described further in this document.

1.2. Module's hardware architecture

The modules are made up of 2 parts:

- 1 "Digital" part which mainly consist of a microcontroller belonging to the STM32F101x family.
- 1 "Radio" part which mainly consists of a radio chip (SX1231) combined to an optimized RF front-end.

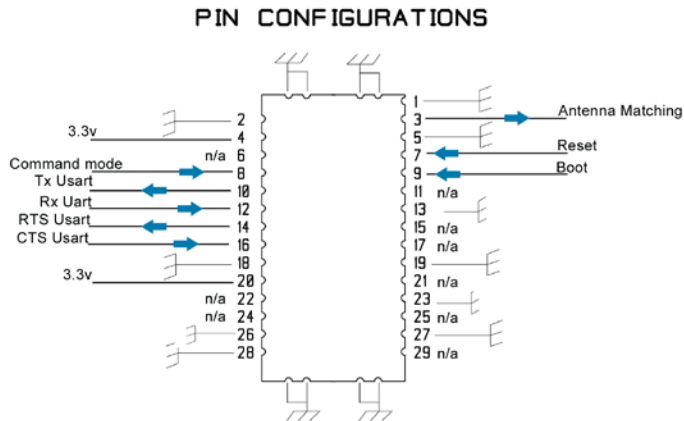
The radio part is in charge of the modulation and demodulation of the data while the digital part is in charge of managing the radio engine and handling the end-user application.

1.3. Technical Specifications

Communication	Asynchronous and Synchronous (TDMA)
Module configuration	Through AT commands
Radio data rate	10, 38.4 and 57.6 kbps
UART data rate	9600, 38400 and 57600 bauds
UART TTL ports	TXD - RXD - RTS - CTS
Adressing mode	Transparent or Addressed
Programmable frequency	Europe 869 MHz
Programmable RF output power	Up to 500 mW (27 dBm)
Sensitivity	Down to -110 dBm
Operating range (open space)	External antenna: up to 6000 m
Operating voltage	3v to 3.6v (3.3v nominal)
Tx HP/Tx MP/Rx consumption (maxi)	650 /150 /30 mA
Operating temperature	-30°C / +70°C
Dimensions	32x 16 x 2.8mm
Standard compliance	EN 300-220

1.4. Hardware integration

TWIMO «RTU» (ready-to-use) module:

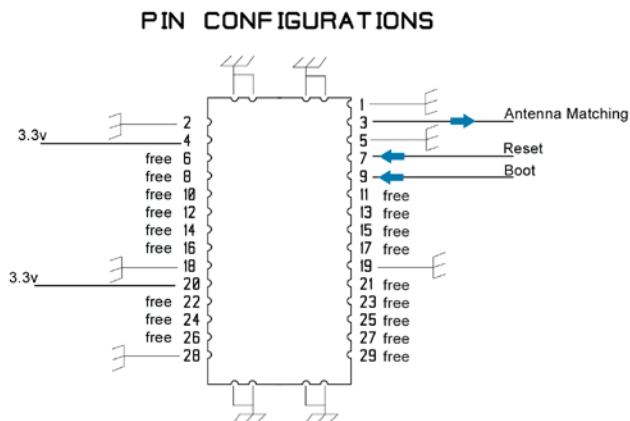


When integrating the TWIMO RTU module, pins 13, 23, 26 & 27 **MUST BE CONNECTED TO THE GROUND.** If not done, the module won't work.

Schematic on the left: typical hardware integration of the TWIMO RTU module.

Note : the n/a pins are set in high impedance state.

TWIMO «API» (programmable) module:

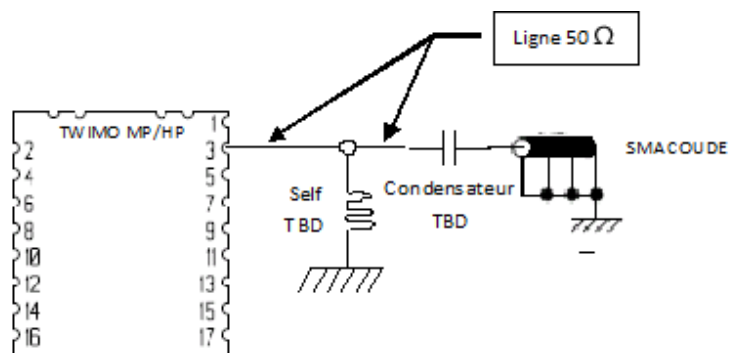


- The *Reset* pin enables to reset the module by applying a low level Gnd signal.
- The *Boot* pin enables to upgrade the flash memory content. When not used, this pin must be connected to the ground via a pull-down (47K) resistor.
- The *USART TX-RX-RTS-CTS* are TTL signals.
- *Free* indicates that those pin can be used as needed by the customer (please refer to «programmable» part of this manual).

1.5. Antenna

ADEUNIS RF will assist you in your choice of antennas so as to optimize the performance of your products. Feel free to contact us for more information.

We suggest the schematic below:



- The footprint of the inductor and capacitor are useful to ensure good impedance matching between antenna and TWIMO modules. The values will depend on the working RF frequency and characteristics of the antenna.
- The SMA connector can be bent or straight depending on the selected antenna but is not essential. We could very well consider 8.6 cm welded wire antennas directly on the PCB either horizontally or vertically. However and wherever possible, it is interesting to keep the footprint of SMAs as to facilitate the development for the degrees of freedom offered an application point of view (offset antenna, etc ...). We would offer the antennas associated with these connectors.
- For a quick set-up, we recommend not to get the self, to install the capacitor to 27 pF (or replace it by a short circuit or a 0 ohm resistor) and solder a 8.6 cm length wire behind the capacitor.

1.6. Power Supply

The table below summarizes all the different electrical input/output generic characteristics of the modules.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V _{IL}	Input low level voltage	TTL ports	-0.5		0.8	V
V _{IH}	Std I/O input level voltage		2		V _{DD} +0.5	
	I/O FT input high level voltage		2		5.5	
V _{IL}	Input low level voltage	CMOS ports	-0.5		0.35V _{DD}	V
V _{IH}	Input high level voltage		0.65V _{DD}		V _{DD} +0.5	
Symbol	Parameter	Conditions	Min	Max	Unit	
V _{OL}	Output Low level voltage for an I/O pin when 8 pins are sunk at the same time	TTL port I _{IO} =+8mA 2.7 V <V _{DD} <3.6V		0.4	V	
V _{OH}	Output High level voltage for an I/O pin when 8 pins are sourced at the same time		V _{DD} -0.4			
V _{OL}	Output Low level voltage for an I/O pin when 8 pins are sunk at the same time	CMOS port I _{IO} =+8mA 2.7 V <V _{DD} <3.6V		0.4	V	
V _{OH}	Output High level voltage for an I/O pin when 8 pins are sourced at the same time		2.4			
V _{OL}	Output Low level voltage for an I/O pin when 8 pins are sunk at the same time	I _{IO} =+20mA 2.7 V <V _{DD} <3.6V		1.3	V	
V _{OH}	Output High level voltage for an I/O pin when 8 pins are sourced at the same time		V _{DD} -1.3			
V _{OL}	Output High level voltage for an I/O pin when 8 pins are sourced at the same time	I _{IO} =+6mA 2 V <V _{DD} <2.7V		0.4	V	
V _{OH}	Output High level voltage for an I/O pin when 8 pins are sourced at the same time		V _{DD} -0.4			

2. TWIMO concept

The idea behind TWIMO is to provide the user with a module which is ready for sending and receiving data over a radio link thus enabling the user to focus on the development of its application. The aim is to relieve the user of having to deal with the complex radio management.

TWIMO comes in two different versions:

- A “Ready To Use” version
- A “Programmable” version

Both versions use the same hardware base. The difference lies in the firmware which is running in the module. However, from the user standpoint, both versions of the firmware provide an abstraction layer in charge of the radio operating management.

2.1. “Ready to Use” version: configurable RF gateway

The “Ready To Use” version is intended for user willing to embed a radio functionality onto their already existing electronic design.

In the “Ready To Use” version the module operates in a standalone way and behaves like a *Serial <-> RF gateway*. So in this case the user has to interface the module with a host processor where the application code will be running.

Here is below represented the way it works: on the transmitter side the module will send data coming from the serial link over the RF link and on the receiver side it will pass the data coming from the RF link to the serial link. The communication is half-duplex.

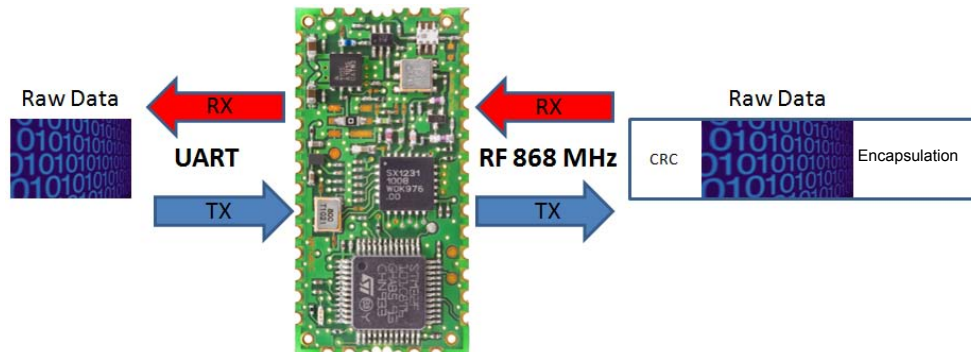


Figure 3. “Ready To Use” operating

2.2. “Programmable” version: embedding your application in it!

The “Programmable” version is intended for user willing to embed their application onto the TWIMO module itself. In this case the user is provided with an API library which purpose is to abstract the radio management. All the user has to do is to focus on the development of its application code and invoke the API functions when the application needs to send or receive data over the RF link.

3. “Ready To Use” version

3.1. Operating modes

The “Ready To Use” version of the module may be operating in 2 different modes:

- The command mode
- &
- The communication mode (default mode after reset)

3.1.1 Command Mode

When the module is set to command mode the user is able to send command to the module in order to:

- Configure its parameters (radio parameters, serial parameters, communications parameters, etc.).
- Test its RF characteristics.

The chapter ¶3.2 describes all the commands which are available.

3.1.2 Communication mode

When the module is set to communication mode the user is able to exchange data with a remote module.

When in communication mode, there are basically 2 different “schemes” of communication: the communication could be either **asynchronous** or **synchronous**.

3.1.2.01 Asynchronous mode of communication

The communication is said to be asynchronous when there is no coordination in the way the modules will access the radio channel. So when a module is configured in asynchronous mode, the data coming on its serial interface will be immediately sent over the radio link without any consideration regarding the radio channel occupancy. As a consequence it is up to the user's application protocol to manage the access to the radio channel in order to avoid packets collision between equipments.

3.1.2.02 Synchronous (TDMA) mode of communication

The communication is said to be synchronous when there exists coordination in the way the modules will access the radio channel. So when a module is configured in synchronous mode, the data coming on its serial interface will be sent over the radio link at pre-defined instants, instants at which all the other equipment will be listening (that is in radio reception mode).

One particularity of the synchronous mode is the presence of a Master equipment in the network. Its role is to keep all the equipment involved in the network in sync: this is done by periodically sending synchronization frame in order to re-adjust the timing of all equipment in the network.

When selecting this mode of communication the application does not have to deal (at all) with the radio channel access => the module's firmware is in charge of scheduling and coordinating the access to the radio channel and thus making sure that no collision will never happen.

Here are described below the 2 main parameters that come into play when dealing with synchronous communication:

- The *Number of slots*: represents the number of equipment involved in the communication.
- The *Slot Duration*: represents the duration during which one of the equipment is transmitting data and all the other equipment are listening (cf: ¶ 3.3.7 for detailed information).

Those 2 parameters are defined statically, which means that they cannot change dynamically during execution.

- The *Slot Number* x *Slot Duration* gives the *Cycle Duration*.
- The *Cycle Duration* must not exceed a maximum value above which the frequency deviation is such that the equipments are not able to synchronize anymore. So the maximum number of slots in TDMA network is limited to 50.

Find below the scheme of a synchronous network with 4 equipments:

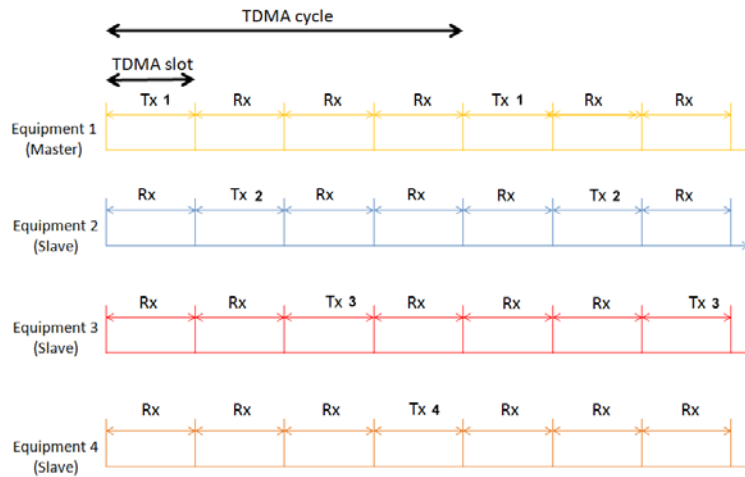


Figure 6. TDMA network with 4 equipments

3.1.2.03 Synchronous vs Asynchronous (drawback and advantage)

The main advantage of the synchronous mode over the asynchronous mode is that the user does not have to worry about the radio channel access instant and thus does not have to worry about RF collision.

However the synchronous mode may suffer from poor response time as well as decreased data rate compare to asynchronous mode. Indeed as the number of equipment in a synchronous network will increased, the data rate will decrease and the response time will increase.

For instance the synchronous mode will be useful in application where a user wants several independent systems to coexist.

As an example let us take status reporter application where 2 sets of equipment have to operate within the same geographic area. Selecting asynchronous mode will require the 2 sets of equipment to communicate on 2 different frequency channels (with a channel spacing large enough in order to avoid interference). In some cases this requirement might not be achievable. So the only solution is to go for a synchronous mode of communication where several set of independent equipment will be able to communicate without interfering each other.

So the decision to go for one mode or another is very dependent on the application's requirements: data rate expected, response time needed, deployment scheme, 1/2-way communication etc...

3.2. Command Interface

The command interface consists of a set of command enabling the user to configure the radio module and run test on the radio module.

3.2.1 Entering Command Mode

Entering the command mode can be achieved in 2 different ways:

3.2.1.01 Through the RS232 serial link

Using a specific sequence of ASCII character: only upon reset with the serial link speed fixed to 9600 bauds and flow control disabled. The sequence of character to use is the following:

- > Hold the «!» key pressed and reset the module.
- > Wait for the module to send the "O" character
- > Send the "K" character to the module
- > The module will send the message "CMD_MODE_ON" when entering the command mode.

ATEX (see fig.7) command does not enable to switch to communication mode. The user must reset the module.

3.2.1.02 Through a dedicated pin of the module (pin n° 8: Cmd_Mode):

- > Upon reset using a level detection (the level must be held for at least 500ms): in this case the serial link speed is fixed to 9600 bauds and flow control is disabled.
- or
- > During execution using rising edge detection: in this case the serial link speed and flow control type are set with user's setting.

ATEX (see fig.7) command, allows you to quit the command mode ONLY if «During execution» procedure has been chosen to enter command mode. If not chosen, the user must reset the module.

3.2.2 AT Commands

A command starts with the 2 ASCII characters "A" + "T" and ends with the 2 characters "CR" + "LF".

A response is sent back to the user after each command.

The «command» can be divided in 2 groups:

3.2.2.01 AT Commands : module configuration

The first group contains commands which are mainly used to read and update the modem parameters:

Commands	Descriptions	Responses
ATSn?	Returns the content of the Sn register	Sn=y<cr><lf>, y is the content of the Sn register
ATSn=m	Set the content of the Sn register with the value m The register content is updated in volatile memory	«O»<cr> if operation OK, «E»<cr> if error
AT/S	Display as a list, the content of each register	Sxxx=y<cr><lf> for each register
AT/V	Displays the firmware version	TW_AA_Vx.x.xx_AA_A_x.xx
ATR	Restore the content of registers (in <u>non-volatile memory</u>) with default values.	«O»<cr> if operation OK, «E»<cr> if error
ATEX	Exit command mode	«O»<cr> if operation OK, «E»<cr> if error
AT&W	Save the register configuration in non-volatile memory	«O»<cr> if operation OK, «E»<cr> if error

Figure 7. AT Command configuration

3.2.2.02 AT Commands : module test

The second group contains commands which are used to run RF test on the module:

Commands	Descriptions	Responses
ATT11	Configure the radio in continuous reception mode	«O»<cr> if operation OK, "E"<cr> if error
ATT12	Reset the packet counter	«O»<cr> if operation OK, «E»<cr> if error
ATT13	Return the number of correctly received packet (and configure the radio in Standby mode)	«O»<cr> if operation OK, «E»<cr> if error
ATT21	Pure carrier (data=0) transmission using current RF channel	«O»<cr> if operation OK, "E"<cr> if error
ATT22	Pure carrier (data=1) transmission using current RF channel	«O»<cr> if operation OK, «E»<cr> if error
ATT23	0x55 modulated carrier using the current data rate and RF channel	«O»<cr> if operation OK, «E»<cr> if error
ATT24xx	Burst packet mode. Send xx data packet (15 bytes) consecutively with 100 ms spacing between 2 packets.	«O»<cr> if operation OK, «E»<cr> if error

NB 1: *ATT21 to ATT24 commands are only dedicated to test purposes. The end product can't be used in this conditions*

NB 2: the test commands are available only if the module is configured in asynchronous mode.

3.2.3 Register parameter

All the user settings are contained in registers located in E2PROM memory.

At power up, the previous configuration is loaded from E2PROM to RAM memory. Then every register update (using the $ATSn=m$) will modify the register content in RAM memory. In order to save the current configuration in non-volatile memory (E2PROM) the user has to use the command AT&W.

List of registers with their descriptions:

Register	Type	Default	Note	Effect
200	Radio Data Rate 0: Narrow Band (10 kbps) 1: Medium band (38,4 kbps) 2: Wide Band (57,6 kbps)	0	Correspond to the gross data rate	Immediate
201	RS232 baudrate 0: 9600 bauds 1: 38400 bauds 2: 57600 bauds	0	The other RS232 parameters are fixed: - 1 stop bit - No parity - 8 bit of data	At next reset
202	RS232 hw flow control 0: disable 1: Enable	0	Only RTS signal is managed in order to inform the host to stop sending data	At next reset
203	RS232 condition for packet transmission 0: MaxPacSize Only 1: MaxPacSize or RS232 Timeout	1	RS232 timeout si timeout for silence detection. This timeout is fixed to 100ms.	At next reset
204	Adressing mode 0: Transparent 1: Addressed	0		Immediate
205	N/A			
206	MAC 0: ASYNC 1: TDMA	0	Select the medium access scheme	At next reset
207	Device Role 0: Master 1: Slave	1	Applies only if register 206=1	At next reset
208	N/A			
209				
210				
211				
212				
213				
214	Radio channel for communication (MHz)			Immediate
	868	433	915	
	0: N.A 1: N.A 2: 868,120 3: 868,170 4: 868,220 5: 868,270 6: 868,320 7: 868,370 8: 868,420 9: 868,470 10: 869,500 11: 869,525 12: 869,550	N.A	N.A	

Figure 9. Register description

Register	Type			Default	Note	Effect
215	RF output power (dBm)			2		Immediate
	LP	MP	HP			
	N.A	0: 10 1: 14 2: 17	0: 20 1: 23 2: 27			
216	Op Freq 0: 868MHz 1: 434MHz 2: 915Mhz			0		At next reset
217	Source Address (=local device @) from 1 to 254			default value: 1	Applies only if register 204=1 Value 0 is reserved for master device in TDMA mode	Immediate
218	TDMA device slot offset from 1 to 49				Applies only if register 206=1 Value 0 is reserved for master device	At next reset
219	Number of slots inTDMA network from 2 to 50				Applies only if register 206=1	At next reset
220	Destination Address (=remote device @) from 0 to 255			default value: 255	Applies only if register 204=1 225 is <u>Broadcast</u> @	Immediate
221	N/A					
222						
223	DC Free 0: Disable 1: Enable			1	Scrambling the user data before radio transmission so to prevent DC bias in the transmitted signal.	No
224	Low Bat detect Level				<u>For test purposes only !</u> If the voltage goes below 2.6V an onboard LED will light and the radio will stop working. The user must reset the module.	No

3.2.4 Default settings

By default the USART is configured at 9600 baud with no flow control enabled, 8 bit data, 1 stop bit and no parity.

The default radio settings are: narrow band (10 kbps) on frequency channel 869.525 MHz with an output power set to the maximum value (that is 27dBm for HP module and 17dBm for MP module).

The default medium access scheme is asynchronous in transparent mode.

3.3. Communication mode: Sending and Receiving datas

The communication is always half-duplex.

By default the radio is in reception mode waiting for an incoming packet. It goes to transmission mode when datas have to be sent.

Whatever the medium access scheme (whether it is asynchronous or synchronous) the transmission of a radio packet starts as soon as one of the 2 following conditions is met:

- The number of character received from the serial link is equal to the maximum packet size (i.e 60 bytes).
- A silence greater then 100ms has been detected on the serial link since the reception of the last character.

3.3.1 Modem state machine

The internal system architecture is made up of 2 software tasks:

- 1 task dedicated to the management of the Transmission path (i.e. path going from the serial link to the radio link).
- and
- 1 task dedicated to the management of the Reception path (i.e. path going from the radio link to the serial link).

Both tasks make use of different FIFO buffer. As a consequence the Transmission and Reception path are completely independent. Basically it means that data coming from the serial link will be accepted even if a radio frame is being demodulated.

Both the transmission and reception FIFO contains 4 buffers. Waiting for the radio engine to be available for transmission, the system will be able to buffer up to 4 consecutives data frame coming from the serial link.

So by default the system is waiting for incoming data on the serial link and waiting for incoming data on the radio link.

On the serial link side, as soon as one of the two conditions (mentionned before - see ¶3.3) is met, a radio packet is built up and put into the transmission FIFO buffer. Then the packet will be sent over the air as soon as the radio engine becomes available for transmission.

3.3.2 Data flow

Radio data rate and serial data rate must be carefully chosen in order to avoid losing data.

If the radio data rate is higher than the serial data rate:

The bottleneck will occur on the receiver side:

On the radio transmitter side, an inter-frame time must be respected in order to avoid overrun on receiver side.

If the radio data rate is lower than the serial data rate:

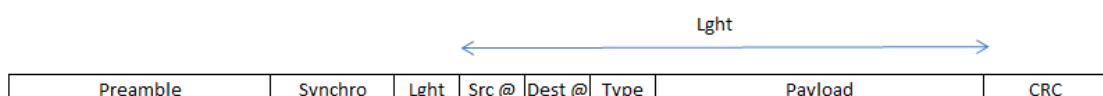
The bottleneck will occur on the transmitter side:

The radio transmitter will not be able to send data fast enough to release the buffer for new data.

To solve this problem, the serial hardware flow control must be used. So the host connected to the transmitter equipment will wait for the buffer to become free before sending new data.

3.3.3 Packet format

Find below a description of the TWIMO packet format:



The Preamble duration depends on the radio data rate selected through the register 200:

- For narrow band communication (i.e. 10 kbps), the preamble duration is 20 ms that is 25 bytes length.
- For medium band communication (i.e. 38.4 kbps), the preamble duration is 6.5 ms that is 32 bytes length.
- For wide band communication (i.e. 57.6 kbps), the preamble duration is 5 ms that is 36 bytes length.

The purpose of the preamble is to enable the receiver to set up the AFC and AGC blocks so to correctly received the subsequent data.

The Synchronization field is 4 bytes length.

After the Synchronization bytes, the packet contains a 4 bytes "packet header":

The Length field is 1 byte length and contains the length of the Payload plus 1 or 3 bytes (depending on the Addressing mode settings) to account for the Type byte and the Source and Destination address bytes.

The Source and Destination address bytes are there only if the register 204 is set to 1 (that is Addressed mode selected). The Source is the address of the "local" equipment. The Destination field indicates the address of the remote device to whom the packet is intended for.

Nb : in synchronous mode, the source byte is always present even if addressing mode is set to «transparent».

So in transmission the Source field contains the transmitter address and the Destination field contains the remote device address.

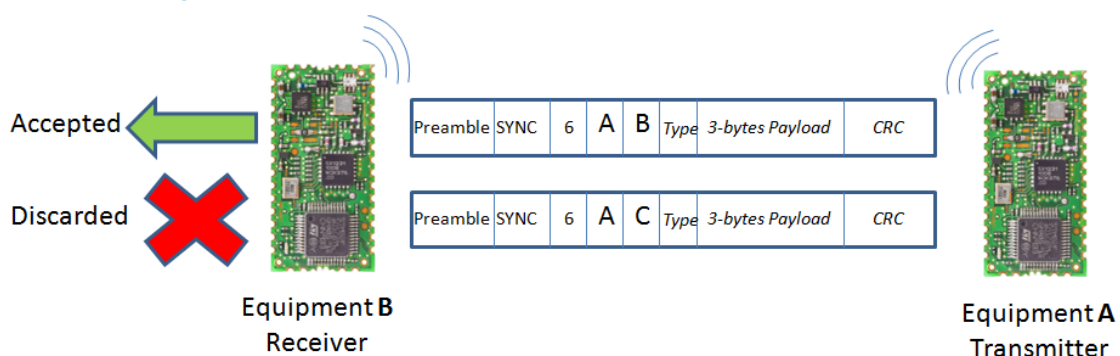
So on the receiver side, the Destination field is compared with the receiver's Source address to decide whether the packet should be accepted or rejected.

The Type field (1 byte) indicates the type of the packet. A packet could be of different type: Data packet, Control packet etc... This field is handled internally by the modem's firmware. The user does not have to worry about this field.

The Payload contains the data message to transmit from one equipment to another. The size of the payload is in the range [1 -> 60] bytes.

The CRC checksum is a 2 bytes field which enables the receiver to perform error detection.

3.3.4 Addressing modes



3.3.4.01 Transparent mode

When "Transparent" mode is set:

On the transmitter side, the data are sent without any specific destination address. So it is up to the user's application to encapsulate the destination address in the payload of the packet.

On the receiver side, it is up to the user's application to strip off the encapsulated destination address from the received data stream.

3.3.4.02 Addressed mode

When "Adressed" mode is set:

On the transmitter side, the data are sent with a specific destination address (the value contained in the register 204). Broadcast packet can be sent by using the destination address 255.

On the receiver side, only the packets whom the destinations address match the local equipment address will be processed. The other will be discarded.

3.3.5 Receiving mode

In reception, the TWIMO RF engine employs a preamble-detection based mechanism, which guarantees optimal performances in sensitivity.

3.3.6 LED Status

The TWIMO module is equipped with an onboard LED.

- LED blinks : following packet reception or packet transmission.
- LED lights : voltage goes below the «low batt detect» threshold.

3.3.7 Synchronous TDMA mode

The slot duration is fixed and set to the time it would take to send over the radio a packet with the maximum size, that is 60 bytes.

- So for Narrow band communication, the slot duration is equal to:
=> 70 ms.
- For Medium band communication, the slot duration is equal to:
=> 20 ms.
- So for Wide band communication, the slot duration is equal to:
=> 15 ms.

As said in previous chapter (cf. 3.1.2.2), the cycle duration is equal to the slot duration multiply by the number of slot. However to be compliant with the authorities certification, the radio system must respect certain duty cycle in terms of transmit duration.

For instance on the 869.525 MHz channel, the duty cycle is 10%, which means that any single equipment should not transmit for more than 10% of the time.

As a consequence for a TDMA network with less than 10 equipments, the cycle duration is equal to the slot duration multiply by 10.

Then for a TDMA network with 10 or more equipment, the cycle duration is equal to the slot duration multiply by the actual number of slot.

This adjustment is automatically carried out by the module's embedded firmware.

3.4. Radio characteristics

3.4.1 Narrow band system

Narrow band operating characteristics:

Module	Data Rate (kbps)	Channel available	Sensitivity (dBm)	Preamble (ms)
High Power	10	3	-110	20
Medium Power				

3.4.2 Medium band system

Medium band operating characteristics:

Module	Data Rate (kbps)	Channel available	Sensitivity (dBm)	Preamble (ms)
High Power	38.4	1	-106	6.5
Medium Power		9		

3.4.3 Wide band system

Wide band operating characteristics:

Module	Data Rate (kbps)	Channel available	Sensitivity (dBm)	Preamble (ms)
High Power	57.6	1	-102	5
Medium Power				

3.4.4 Summary

The table below summarizes the {frequency channel, output power, data rate} combination allowed according to the normative requirements:

TWIMO module	ARF7581 (HP868)		ARF7580 (MP868)	
RF Data Rate	Authorized frequencies	RF Power	Authorized frequencies	RF Power
Narrow Band 10kbps	869.500 MHz 869.525 MHz 869.550 MHz	27dBm 27dBm 27dBm	869.500 MHz 869.525 MHz 869.550 MHz	17dBm 17dBm 17dBm
Middle Band 38.4kbps	869.525 MHz	27dBm	869.525 MHz 868.120 MHz 868.170 MHz 868.220 MHz 868.270 MHz 868.320 MHz 868.370 MHz 868.420 MHz 868.470 MHz	17dBm 14dBm 14dBm 14dBm 14dBm 14dBm 14dBm 14dBm 14dBm
Wide Band #1 57.6kbps	869.525 MHz	27dBm	869.525 MHz	17dBm

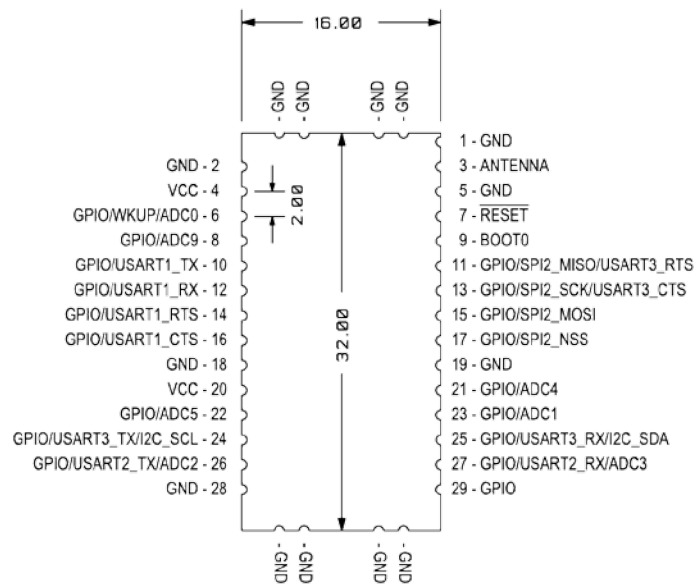
4. Firmware upgrade

Firmware upgrade is possible through the UART (only Tx and Rx are required) communication link. The Boot signal must be maintained to Vcc (3.3v) while resetting the module (that is low level on Reset pin for 500 ms).

The module enters a bootloading mode which enables the user to proceed with a firmware upgrade.

The STM32 flash loader application must be used on the PC side to download the binary. The STM32 flash loader application can be executed from a user friendly graphical interface but also from the Windows command line (more information and download can be found on Adeunis RF website www.adeunis-rf.com).

5. “Programmable” version



The “Programmable” version is intended for user willing to embed their application onto the TWIMO module itself.

In order to abstract the radio management, Adeunis-RF provides the user with an API library containing a set of functions used to send and receive data without having to worry about all the complexity involved in the radio operating management.

In other words, all the user has to do is to focus on the development of its application code and invoke the API functions when the application needs to send or receive data over the RF link.

5.1. API concept

The TWIMO concept consists in:

- Enabling the user to develop and embed its application onto the module’s microcontroller.
- Providing the user with an Application Programming Interface in charge of abstracting the radio operating.

So it becomes easy for anyone with programming skills (but no radio skills at all) to come up with a wireless enabled product.

As described further, a TWIMO module has got a very rich hardware interface that makes it possible for the user to interface a TWIMO module with a lot of different external hardware peripherals.

5.2. Hardware Interface description

5.2.1 Pin Description

Pin module	I/O μ C	Default config*	Interrupt capability	Alternate Config 1	Alternate Config 2	Alternate Config 3
6	PA0	GPIO	Yes (WakeUp)	ADC_0	USART2_CTS	TIMER
8	PB1	GPIO	Yes	ADC_9	TIMER	
10	PA9	GPIO	No	USART1_TX		
11	PB14	GPIO	No	SPI_MISO	USART3_RTS	
12	PA10	GPIO	No	USART1_RX		
13	PB13	GPIO	No	SPI_SCK	USART3_CTS	
14	PA12	GPIO	No	USART1_RTS		
15	PB15	GPIO	No	SPI_MOSI		
16	PA11	GPIO	No	USART1_CTS		
17	PB12	GPIO	No	SPI_NSS	USART3_CK	
21	PA4	GPIO	Yes	ADC_4	USART2_CK	
22	PA5	GPIO	No	ADC_5		
23	PA1	GPIO	Yes	ADC_1	USART2_RTS	TIMER
24	PB10	GPIO	No	TIMER	USART3_TX	I2C_SCL
25	PB11	GPIO	No	TIMER	USART3_RX	I2C_SDA
26	PA2	GPIO	Yes	ADC_2	USART2_TX	
27	PA3	GPIO	Yes	ADC_3	USART2_RX	
29	PA8	GPIO	No	MCO	USART1_CK	

* the GPIOs are configured as floating inputs

- The pin 6,8,23,24 & 25 can be configured as timer input or output (Input Capture, Output Compare, PWM).
- Pin 6 can be used to wake up the μ C from sleep mode.
- Pin 3 is the Antenna pin. Special care should be taken when designing the antenna in order to obtain an optimal matching.
- Pin 7 is the Reset pin. This pin is used to reset the module. Reset occurs when this pin is put to low for at least 500 ms.
- Pin 9 is the Boot pin. This pin is used to set the module in bootload mode. This mode can be used to upgrade the flash content.

5.3. Resources availability and partitioning

The hardware resources available must be shared between the TWIMO API code and the user application code.

The TWIMO API code being in charge of the radio management, a lot of resources are required.

5.3.1 Flash memory

The module's microcontroller has got 64 Kbytes of flash memory.

This memory is used to:

- Store and execute code
- Store constant variable

5.3.2 RAM memory

The module's microcontroller has got 10 Kbytes of RAM memory.

This memory is used to:

- Store local variables.
- Store a copy of the global variables used in TWIMO API code: the purpose is to speed up the API code execution.

- Store the stack and heap: API code requires a certain amount of stack (default value in .icf file). Then it is up to the user to increase this size if required.

5.3.3 E2PROM memory

- The μ C does not contain E2PROM memory. So flash memory must be used to emulate E2PROM (E2PROM memory driver are not provided by Adeunis RF).

5.3.4 TWIMO firmware requirement in terms of memory

The TWIMO API library (Radio API) occupies about 20 KBytes of flash memory and requires about 3 Kbytes of RAM memory (this does not take into account the stack space needed!).

In spite of the fact that the TWIMO API code requires only 20 Kbytes of flash, only 16 Kbytes of flash memory are left for the user to put its application code.

5.3.5 Peripheral (GPIO, ADC/DAC, Communication etc...)

Available peripherals :

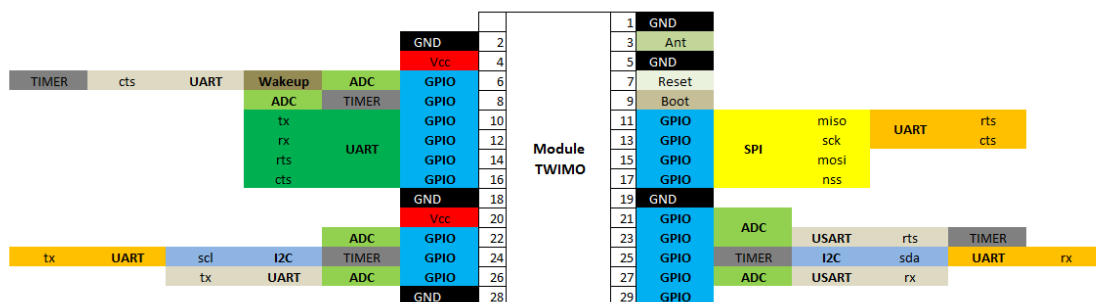
- Up to 3 USARTs can be used simultaneously.
- Another possible configuration is 1 USART, 1 I2C and 1 SPI simultaneously.

All pin can also behave like GPIO. When configured as GPIO, only pin 6.8.21.23.26 & 27 will have interrupt capability.

As of now Adeunis-RF doesn't provide any peripheral's driver. However ST provides a peripheral's library which enables the user to quickly get started with using the peripherals. Please contact us for any additional details.

For any information related to the peripheral implementation, the user must report to the microcontroller User Manual.

5.3.6 Hardware Timer



Three 16-bit timers are available, each one with 4 Output Compare/Input Capture/PWM counter: TIM2/3/4.

One 24-bit systick timer is also available.

Two of the three 16-bit timers are dedicated to the radio management: TIM3 and TIM2.

So only the TIM4 remains available for the user.

The 24-bit systick timer is used by the TWIMO API code as a free running timer in order to provide a 1 ms time base.

5.3.7 DMA

The microcontroller embeds a 7-channel DMA controller.

Here is below the different channel with their possible usage (extracted from STM32 User Manual):

Channels 2, 3, 6 and 7 are not available to the user application code since they are dedicated to the radio driver operating

So only DMA channels 1, 4 and 5 remain available for the user application code.

5.3.8 GPIO Interrupt line and vectors

Peripherals	Channel 1	Channel 4	Channel 5
ADC1	ADC1		
SPI/I ² S		SPI2/I2S2_RX	SPI2/I2S2_TX
USART		USART1_TX	USART1_RX
I ² C		I2C2_TX	I2C2_RX
TIM2	TIM2_CH3		TIM2_CH1
TIM3			
TIM4	TIM4_CH1	TIM4_CH2	TIM4_CH3

The interrupt vectors associated with peripherals (that are free for the application) are available for use by the application code.

However the interrupt vector associated with the GPIO (that are free for the application) are not all available to the application code.

Indeed some of the GPIO interrupt lines are multiplexed on a single interrupt line: this is the case for interrupt lines 5, 6, 7, 8 and 9 as well as for interrupt lines 10, 11, 12, 13, 14 and 15.

It happens that interrupt line 6, 7, 8, 9 and 13 are dedicated to the radio driver operating.

As a consequence the interrupt vector corresponding to the interrupt line onto which line 6, 7, 8 and 9 are multiplexed is not available to the application code. The same applies for the interrupt vector corresponding to the hardware interrupt line onto which line 10, 11, 12, 13, 14 and 15 are multiplexed.

The reason why this access is not given is because it may jeopardizes the radio operating.

So this is below the GPIO lines for which an interrupt vector is available to the application code:

NB: It is important to note the following: pin 8 and pin 23 of the module cannot be simultaneously connected to

Pin module	I/O μ C	Interrupt line
6	PA0	0
23	PA1	1
8	PB1	
26	PA2	2
27	PA3	3
21	PA4	4

the interrupt line number 1.

5.3.9 Interrupt vector priority

It is important to grant high priority to interrupt vector involved in the radio driver operating.

So this is below the list of available interrupt vectors as well as the priorities assigned to each of them:
The interrupt vectors involved in the TWIMO firmware have a fixed and higher priority than the interrupt vectors

Interrupt Vector	Priority (Preemption)	Sub-Priority	Settable	
Reset, Watchdog, NMI etc...	High (0,-1,-2,-3)	n.a	Fixed	Core interrupt
EXTI 5-9	1	0	Fixed	
EXTI 10-15			Fixed	TWIMO firmware interrupt
DMA1 ch 2			Fixed	
DMA1 ch 3			Fixed	
DMA1 ch 6			Fixed	
DMA1 ch 7			Fixed	
TIM2			Fixed	
TIM3			Fixed	
EXTI 0	2	0	Settable	Application code interrupt
EXTI 1			Settable	
EXTI 2			Settable	
EXTI 3			Settable	
EXTI 4			Settable	
DMA1 ch 1			Settable	
DMA1 ch 4			Settable	
DMA1 ch 5			Settable	
TIM4			Settable	
USART1/2/3			Settable	
SPI2			Settable	
I2C			Settable	
ADCx			Settable	

reserved for the application code. The purpose is to make it possible for TWIMO's interrupt vectors to preempt the Application's interrupt vector if needed.

By default the priority of the application's interrupt vectors are set to 2 and the sub-priority is set to 0. If needed the user may also use a level 3 of priority and level 1, 2 or 3 for the sub-priority.

The sub-priority is there to determine the order of execution in case there are multiple pending interrupt with the same priority level.

5.3.10 CPU Frequency

The CPU frequency is set to about 16 MHz (15.75 MHz exactly). As of now only one frequency operating is available. In the future Adeunis RF will be offering other CPU frequencies in order to better fit the application requirement: for instance a 2 or 4 MHz CPU frequency for battery powered application, a 24 or 32 MHz CPU frequency for application with "hard" real time constraints.

Then user should not attempt to change the CPU frequency by himself since the radio related timing are computed considering a 16MHz CPU clock.

5.4. API TWIMO

This chapter presents all the TWIMO API functions: parameter(s), return value and description. This chapter also describes all the data structures that the user has to manipulate in order to use the API functions.

5.4.1 Radio related APIs

5.4.1.01 TWIMO_API_SystemInit()

i) Prototype

Here is the function prototype:

TWIMO_ERROR_CODE TWIMO_API_SystemInit (struct TWIMO_INIT *);

This function takes 1 parameter:

- A pointer to an instance of the TWIMO_INIT structure (cf. chapter 1.5.4 for the definition of this structure).

This function returns TWIMO_OK if everything went OK and TWIMO_NOK_4 if something went wrong with the initialization.

ii) Description

This function is in charge of carrying out all the hardware and software initializations required for the TWIMO firmware to work.

This function configures:

- The system clock
- The radio register
- The µC hardware peripherals: SPI_1, DMA1_CH2/3/6/7, TIM2/3, SysTick timer, GPIO configuration, Interrupt....
- The memory buffering system
- The software contexts
- Etc...

This function must be invoked at the beginning of the application program (cf. Adeunis Application example).

5.4.1.02 TWIMO_API_Radio_BackgroundTask()

i) Prototype

Here is the function prototype:

void TWIMO_API_Radio_BackgroundTask (struct TWIMO_INIT *);

This function takes 1 parameter:

- A pointer to an instance of TWIMO_INIT structure (cf. chapter 1.5.4 for the definition of this structure).

This function does not return anything.

ii) Description

This function must be **regularly** invoked in background by the application code (cf. chapter 5.6 Integration).

This function is the main part of the radio driver.

5.4.1.03 TWIMO_API_Radio_SendData ()

i) Prototype

Here is the function prototype:

```
TWIMO_ERROR_CODE TWIMO_API_Radio_SendData ( struct TWIMO_INIT *, struct TWIMO_RADIO_TX * );
```

This function takes 2 parameters:

- A pointer to an instance of the TWIMO_INIT structure (cf. chapter 1.5.4 for the definition of this structure).
- A pointer to an instance of the TWIMO_RADIO_TX structure (cf. chapter 1.5.4 for the definition of this structure).

The TWIMO_RADIO_TX structure basically contained 3 fields:

- Input parameter: A pointer to the “source” buffer that is the buffer containing the data to be sent over the radio.
- Input parameter: The size (in bytes) of the data buffer. The size must be comprised between 1 and 60 bytes maximum.
- Input parameter: The Destination address (address of the remote receiver device to whom the data are intended to): value between 0x00 and 0xFF. This field is ignored by the API function if Transparent mode is selected. **0xFF is a broadcast address!**

From the API function point of view those 3 fields are input parameters.

This function returns *TWIMO_OK* if the data has been accepted and *TWIMO_NOK_1* if the data cannot be accepted (because the transmit FIFO is full).

If *TWIMO_OK* is returned the application code can release its «source» buffer.

ii) Description

This function is in charge of inserting the data buffer onto the transmission FIFO (which can contain up to 4 buffers).

The data will then be sent over the air as soon as the radio engine will be available for it.

5.4.1.04 TWIMO_API_Radio_ReceiveData()

i) Prototype

Here is the function prototype:

```
TWIMO_ERROR_CODE TWIMO_API_Radio_ReceiveData ( struct TWIMO_INIT *, struct TWIMO_RADIO_RX * );
```

This function takes 2 parameters:

- A pointer to an instance of the TWIMO_INIT structure (cf. chapter 5.4.3 for the definition of this structure).
- A pointer to an instance of the TWIMO_RADIO_RX structure (cf. chapter 5.4.3 for the definition of this structure).

The TWIMO_RADIO_RX structure basically contained 3 fields:

- Input parameter: A pointer to the “destination” buffer that is the buffer onto which the received data will be

stored.

Caution: as the application does not know in advance what the received packet's size will be, it must allocate room for the maximum size, which is 60 bytes

- Output parameter: The size (in bytes) of the received packet's payload. The size is comprised between 1 and 60 bytes.
- Output parameter: The Source address of the received packet (address of the remote sender device): value between 0x00 and 0xFE.

From the API function point of view the first field is an input parameter and the two last fields are output parameters.

This function returns *TWIMO_NOK_2* when no data have been received (that is the reception FIFO is empty); else the function returns *TWIMO_OK*.

ii) Description

This function is in charge of extracting a data buffer from the reception FIFO (which can contain up to 4 buffers) and copy the data onto the buffer passed in parameter.

This function must be called on a **regular** basis in order to make sure that no overflow occurs at the reception FIFO level. In case of overflow, there is a risk of packet loss.

If Addressed mode is selected (cf. chapter 5.4.3 *TWIMO_INIT* structure definition), the TWIMO firmware will automatically filter out received packet whom destination address does not match the local device address. If there is a match then the received packet will be put into the reception FIFO.

If Transparent mode is selected (cf. chapter 5.4.3 *TWIMO_INIT* structure definition), the TWIMO firmware will put every received packet into the reception FIFO.

5.4.1.05 *TWIMO_API_GetFirmwareVersion()*

i) Prototype

Here is the function prototype:

```
void TWIMO_API_GetFirmwareVersion (uint8_t * );
```

This function takes 1 parameter:

- A pointer to a string of character. The string of character must be at least 23 character.
- This function does not return anything.

ii) Description

This function returns the firmware version.

5.4.2 TWIMO API data structure

5.4.2.01 *TWIMO_INIT*

TWIMO_INIT is a typedef structure containing the user settable parameters. Here is below the structure definition:

```
typedef struct TWIMO_INIT
{
    TWIMO_RADIO_CHANNEL        Radio_FreqChannel;
    TWIMO_RADIO_DATARATE       Radio_DataRate;
    TWIMO_RADIO_OUTPOWER       Radio_OutputPower;
    TWIMO_RADIO_MAC            Radio_MediumAccess;
    TWIMO_RADIO_ADDRESSING     Radio_AdressingMode;
    Uint8                      Radio_DeviceAddress;
    TWIMO_RADIO_MODULE         Radio_ModuleType;
    TWIMO_RADIO_ROLE           Radio_DeviceRole;
    Uint8                      Radio_TdmaNetworkSlotNum;
    Uint8                      Radio_TdmaSlotOffset;
    struct TWIMO_CONTEXT *     Twimo_Context_Ptr
} TWIMO_INIT;
```

Radio_FreqChannel enables the user to select the frequency communication channel. Around 70 frequency channels (between 863 Mhz and 870 MHz) are available to the user.

Radio_DataRate enables the user to select the air data rate. There are 3 possible values: 10 kbps, 38.4 kbps and 57.6 kbps.

Radio_OutputPower enables the user to select the radiated RF power. There are 3 possible values (which are different depending on the Radio_ModuleType setting): 10 dBm, 14 dBm and 17 dbm for Medium Power module and 20 dBm, 23 dBm and 27 dbm for High Power module.

Radio_MediumAccess enables the user to select the medium access scheme. As explained in the TWIMO User Guide, there exist 2 possible schemes: Asynchronous or Synchronous (also referred as TDMA).

Radio_AdressingMode enables the user to select the addressing mode. As explained in the TWIMO User Guide, there exist 2 possibilities: Transparent or Addressed.

Radio_DeviceAddress enables the user to select an address (value between 0x00 and 0xFE) for the local device. In Synchronous mode (TDMA) this field is used to allocate a slot position in the TDMA cycle: the value 0x00 is reserved for the Master device. In transmission, this address will always appear as the “source” address in the packet header (refer to TWIMO User Guide). In reception, this address will be compared with the receive packet’s destination address to decide on the packet acceptance.

Radio_ModuleType enables the user to select the type of radio module he is working on. There are 2 possibilities: MP (Medium Power) or HP (High Power).

Radio_DeviceRole enables the user to select the role of the local device when Synchronous (TDMA) mode is selected. There are 2 possibilities: Master or Slave. Please refer to the TWIMO User Guide for more information about TDMA mode.

Radio_TdmaNetworkSlotNum enables the user to select the total number of slot which corresponds to the total number of devices involved in the TDMA network (including the Master device). The minimum value is 0x02 and the maximum value is 50.

Radio_TdmaSlotOffset enables the user to select the slot offset for the local device. The slot offset (in relative

to the Master slot that is equal to 0x00) gives the slot into which the device will transmit its data. The value 0x00 is reserved for the Master device. So the possible values for a Slave device are: 0x01 -> 0xFF. total number of devices involved in the TDMA network (including the Master device).

Twimo_Context_Ptr is a pointer to an instance of the TWIMO_CONTEXT structure. This structure contains pointer to the context of all the block of the TWIMO firmware. The user needs to declare an instance of this structure (cf. example of Application based on TWIMO API).

It is kindly recommended to refer to Adeunis-RF for the choice of the { **Radio_FreqChannel**, **Radio_DataRate**, **Radio_OutputPower** } combination. Indeed this choice must match the RTTE recommendations...

TWIMO_RADIO_CHANNEL, **TWIMO_RADIO_DATARATE**, **TWIMO_RADIO_OUTPOWER**, **TWIMO_RADIO_MAC**, **TWIMO_RADIO_ADDRESSING**, **TWIMO_RADIO_MODULE** and **TWIMO_RADIO_ROLE** are typedef ENUM defined in the api_twimo.h interface file.

5.4.2.02 TWIMO_RADIO_TX

TWIMO_RADIO_TX is a typedef structure containing the user settable parameters. Here is below the structure definition:

```
typedef struct TWIMO_RADIO_TX
{
    UInt8    * DataBufferPtr;
    UInt8     DataBufferSize;
    UInt8     DestinationAddress;
} TWIMO_RADIO_TX;
```

[IN] DataBufferPtr is a pointer to the memory buffer containing the data to send over the air.

[IN] DataBufferSize is the data buffer size. Value comprises between 1 and 60 bytes.

[IN] DestinationAddress is the address of the remote receiver device. Value comprises between 0 and 255. This field is ignored if in Transparent mode.

NB: The value 255 corresponds to a **broadcast** address.

5.4.2.03 TWIMO_RADIO_RX

TWIMO_RADIO_RX is a typedef structure containing the user settable parameters. Here is below the structure definition:

```
typedef struct TWIMO_RADIO_RX
{
    UInt8    * DataBufferPtr;
    UInt8     DataPayloadSize;
    UInt8     SourceAddress;
} TWIMO_RADIO_RX;
```

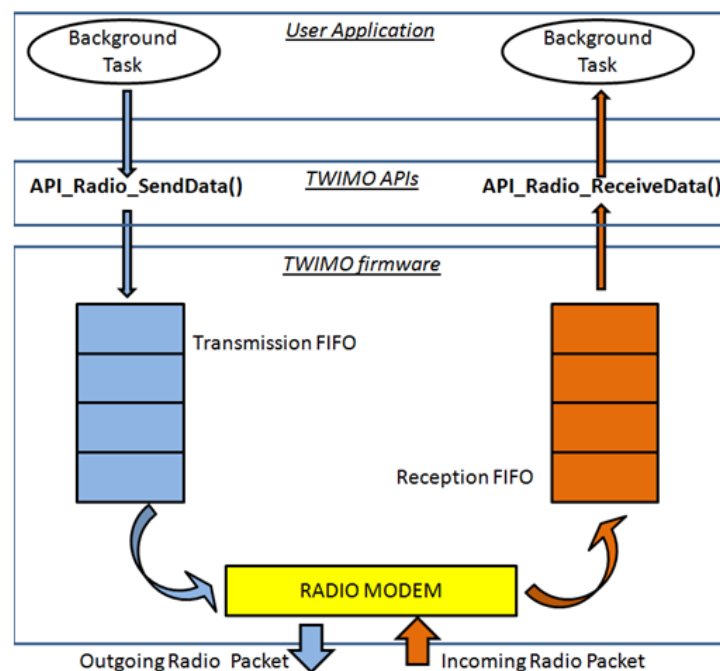
[IN] DataBufferPtr is a pointer to a memory buffer where the data received from the radio will be stored. **This buffer must be of size max, which is 60 bytes.**

[OUT] DataPayloadSize is the size of the received packet's payload. Value comprises between 1 and 60 bytes.

[OUT] SourceAddress is the address of the remote sender device. Value comprises between 0 and 254.

5.4.3 TWIMO firmware operating

The figure below gives an overview of the firmware operating.



The TWIMO firmware can basically be seen as a completely independant task which is running in background and which purpose is to handle the transmission and reception of radio frames.

When the application calls the `TWIMO_API_Radio_SendData ()` function, a new element is put onto the transmission FIFO (FIFO size is 4 elements). Then the application does not have to deal with the transmission of the packet over the radio. The TWIMO firmware will proceed with the packet radio transmission as soon as it can.

When receiving a radio packet, the TWIMO firmware puts a new element onto the reception FIFO (FIFO size is 4 elements). When application calls `TWIMO_API_Radio_ReceiveData ()` function, the TWIMO firmware will return the oldest element contained in the FIFO.

5.4.4 Application Template

```
#include "api_twimo.h"

/*
 * GLOBAL VARIABLES
 */
/*
 * TWIMO variables
 */
TWIMO_CONTEXT TWIMO_Context;
TWIMO_RADIO_TX RadioTxDataStruct;
TWIMO_RADIO_RX RadioRxDataStruct;
TWIMO_INIT SystemInitStruct;

/*
 * Application variables
 */
/* Add your code here */

/*
 * FUNCTION
 */
/*
 * main()
 */
{
    /* Global variables initialisation */
    /* Add your code here */

    /* TWIMO initialisation */
    TWIMO_API_SystemInit(&SystemInitStruct);

    /* User Application initialisation */
    /* Add your code here */

    /* Infinite loop <=> Background task */
    while (1)
    {
        /* TWIMO background task */
        TWIMO_API_Radio_BackgroundTask(&SystemInitStruct);

        /* User Application Background task */
        /* Add your code here */
    }
}
```

5.5. TWIMO API: how to use it ?

Adeunis RF is providing the customer with a demonstration package containing the following elements:

- A .c file, *app_main.c*, containing an application template, i.e. the main() function and all the global variables needed for the TWIMO API code to execute properly. The purpose of this application is to demonstrate how to make use of the TWIMOP API to send and receive data over the radio link.
- A .c file, *app_it.c*, containing most of the interrupt vectors available for the user application.
- A .h file, *api_twimo.h*, containing the TWIMO API's global structures definition, the #define constant needed and the TWIMO API function prototypes.
- An .icf file containing the memory section and placement information. The user must include this file into its development workspace (IAR). The Stack and Heap size may be changed in this file. However it is recommended to the user not to change the other parameters.
- A startup file in charge of all the initialization.

- An IAR development tool workspace template with correct option settings.
- The STM32 peripherals driver library.
- The TWIMO API firmware, which is provided as a library of functions (.a file).

The purpose of this “demonstration package” is to help the user to quickly get started with the TWIMO API functions and all the aspects pertaining to the code generation tool environment.

NB: by default all modules delivered by Adeunis-RF to customer contains the “Ready To Use” Adeunis-RF application in it. On top of that the μ C access is locked for security reason. So it is up to the user to unlock the flash memory in order to be able to flash it again or to be able to debug its application. For this the user must run the STM flash loader.

5.6. Code Integration

Here are the constraints that have to be taken into account when integrating application code with the TWIMO API firmware:

5.6.1 Application background task execution

It is important for the user to make sure that the application firmware does not prevent the TWIMO firmware from properly operating (to prevent packet loss from happening): this means that the application background task should be as short as possible in order to let the TWIMO background task to execute on a regular basis.

The latency allowed between 2 consecutives call to this function mainly depends on 2 parameters:

- The radio data rate which is employed
- The inter-frame duration employed.

The higher the data rate the lower is the allowed latency.

By the same token, the lower the inter-frame duration the lower is the allowed latency.

So as a general rules, it is recommended to cut out as much as possible the background processing.

To give an order of magnitude:

If there is no constraint on the inter-frame duration, then the max latency allowed will be about 10ms (NB), 3 ms (MB) and 2 ms (WB).

In case there is harsh constraint on the inter-frame duration (for instance back to back packet), then the max latency allowed might fall down to 3 ms (NB), 0.8 ms (MB) and 0.5 ms (WB).

5.6.2 Application interrupt execution

By the same token, it is very important for the user to make sure that the execution of the interrupt handlers is as short as possible in order to avoid jeopardizing the radio driver operating.

5.6.3 Miscellaneous

The user must respect all the integration rules regarding the peripheral available, the interrupt priority and so on.

5.7. Compiling code

5.7.1 Code Generation tool

As of now, the only tool compatible with the TWIMO firmware is the IAR development tool for ARM.

A licence-free version (KickStart version 5.41) is available and might be downloaded from Adeunis web site.

However this version is limited to 32 Kbytes of compiled code.

Then the user must switch to a licensed version with a 256 Kbytes limitation.

5.7.2 Project/Workspace example

Like mentioned previously, Adeunis RF is providing a template of the workspace with the correct option to select in order to be compatible with the TWIMO API firmware.

5.8. Bootloading

The bootloading will enable the user to upgrade the firmware. As of now only serial (through USART, TX and Rx only) bootload is possible.

To enter bootloader mode, the BOOT pin (number 9) must be held to high and then the RESET pin (number 9) must be pulled down for at least 500 ms.

6. Process

6.1. Description of module 7581-A and board ARF7628/B

7581 module is fully SMT, single side. Assembly process is based on leadfree alloy, no clean flux residues
Main component families are:

- Ceramic chip resistors and capacitors, 0201 size (0.5 mm x 0.25 mm)
- Ceramic chip resistors and capacitors, 0402 (1 mm x 0.5 mm)
- Ceramic chip resistors and capacitors, 0603 (1.6 mm x 0.8 mm)
- low profile PQFP48 , 0.5 mm pitch - U4 ; MSL level 3
- TQFN24 - U1 ; MSL 1
- QFN 8-U2 ; MSL 3
- LCC ceramic packages , sealed cavity Q1 and F2
- BGA 5-RG1 ; MSL 1
- Smt LED, size 0603, MSL level un-identified
- other packages, more standard

Bare PCB is FR4 material, 6 layers, class 6 , nickel-gold finish (ENIG); module involves 66 SMT components;

Assembly process of module on mother board ARF7628/B is also based on leadfree, no clean, solder paste used is ALPHA Omnix OM-338 T; Assembled module is considered as a component, just like the switch, tantalum chip capacitor and few other chips visible on mother boards.

The assembly of the module is considered as already mastered by the EMS, then the risk analysis is just on the assembly of the module on the mother board;

6.2. BOM analysis

BOM was analyzed after loading and comparison with SERMA databases; from this job, we get the following data:

- Rohs status
- Obsolescence
- MSL level
- Max peak temp during reflow
- Time max at peak temp
- Number of reflow
- Lead finish of the package
- Termination description for resistor and capacitor chips; presence of nickel barrier or not

The worst case MSL level is 3, it is about U2 and U4. Other parts are level 1 classified.

Most parts are compliant with max peak temperature of 260°C during 10 seconds; RG1 and U4 are able to withstand 260°C for 40 seconds. U2 is able to withstand only 250°C.

Most parts are compatible with 3 reflows. Only 0201 ROHM resistors are supposed to withstand only two reflows.

All resistors and capacitors have nickel barriers in their terminations, which is necessary to avoid leaching effect.

6.3. Risk linked to number of reflows

	drying pcb before SMT assembly	reflow soldering (module)	drying	reflow soldering (mother board)	Number of possible reflows	COMMENTS
PCB of module	X	X	X	X	2	
components of module		X	X	X	2 to 4 ; most 3	Only resistors Rohm 0201 withstand 2 reflows
PCB of mother board			X	X	2	
components of mother board				X		

All component reference can withstand 2 reflows of more; then it is no significant risk from this point of view. But for drying steps, we will recommend to choose the lowest possible temperature

ASSEMBLY RISK ANALYSIS

ITEM	DETAIL	POTENTIAL RISK	RISK LEVEL IDENTIFIED	RECOMMENDATION - RISK KILLING
components	all	obsolescence	++	identify obsolete references
	res/capa chip	leaching during soldering	+++	nickel barrier presence check
	res/capa chips	origin of components no well identified	+	identification of original references behind references from distributors
	all	maximum temperature achievable is	++	check for temperature / time to fit with reflow thermal profile
	"large" SMT plastic package	high moisture sensitivity	++	check MSL levels of the various references
assembled module 7581		moisture sensitivity	+++	Consider this module has same level of sensitivity as the worst component of the module, ie level 3
		moisture sensitivity	+++	after reflow 1, AOI and FCT test, provided that time between first package opening and fct test is less than 1 week, store the modules in dry cabinet with less than 10% RH ; this is stopping the clock and you can do reflow 2 with low risk (paragraph 4.1.2.1. JSTD 033)
		moisture sensitivity	+++	if time between first package opening and fct test is larger than 1 week, then baking will have to be done before reflow 2: 90°C 24h if time is less than 10 days, 33 hours if time is higher than 10 days
		moisture sensitivity	+++	If long storage in various areas has to be done between reflow 1 and reflow 2, then, it is better to dry the parts after FCT test, and put them in MBB bags under vacuum with humidity indicator and dessicant
bare PCB ARF 7628		no compatibility with lead free assembly	+	Glass transition temperature verification for current FR4 PCB's
		sensitivity to "black pad" phenomenon	+	check for thicknesses of gold (0,07 to 0,1 mm) and Nickel (4 to 5 microns)

ASSEMBLY RISK ANALYSIS (CONT'ED)

ITEM	DETAIL	POTENTIAL RISK	RISK LEVEL IDENTIFIED	RECOMMENDATION - RISK KILLING
SMT PROCESS	PRINTING	not enough solder along the module connections	+++	implementation of a 150 or 175 micron stencil to ensure enough solder fillet in the half-circle side pads (edge soldering areas of the module)
	PRINTING	solder balling during reflow soldering component	+++	reduce aperture size by 150 microns in width and length versus the pad size -
	COMPONENT PLACEMENT	machine is at the capability limit to place this kind of component	++	Check for specification of placement machines JUKI FX1R in term of weight and compare with actual weight of the module
	REFLOW	risk of ageing of the solderjoints of modules during the reflow of module to mother board assembly	+	low risk, considering the thermal profile provided for module assembly : max peak temperature seems to be 240°C only : recommendation: measure the body temperature of U2 during the first and the second reflow to check that maximum temperature is not higher than 250°C for 10 seconds
	REFLOW	Risk of overheating the components (from modules and from mother board)	+	
	REFLOW	risk of module slip during reflow	+	land pattern is 67% larger in length than the "leads" of the module themselves, and 55% larger in width; 30 to 40% is generally enough, and would limit possible slip of the module during reflow soldering

There is no high risk regarding the assembly of the module on mother board, since the land pattern is larger than the "leads" (maybe the land pattern may be little bit large compared to the "leads" and then there is risk of module slip during reflow soldering)

The stencil foil thickness should be 150 to 170 microns to ensure enough solder fillet; the stencil aperture should be reduced in length and width by 150 microns roughly to avoid solder balling in case misalignment occurs.

Check of maximum temperature (during reflow) on sensitive component body has to be done.

The trickiest point is regarding the moisture sensitivity and the way to consider the module for the assembly on mother board;

Considering the components on the module, we can define the module as a level 3 component, whose

floor life under 60% max RH is 168 hours.

Having in mind that module to mother board assembly delay is not under control, same for temporary storage atmosphere, the best solution is to dry the module after test and put it in reels and then pack them in MBB bags.

Jedec JSTD 033 standard is helping us to define the conditions of drying: refer to table next page.

If drying occurs less than 10 days after first reflow,

24 hours 90°C seems a good compromise between time and temperature;

If drying occurs more than 10 days after first reflow,

The drying condition becomes 36 hours 90°C ;

Refer to schematics next page

Notes:

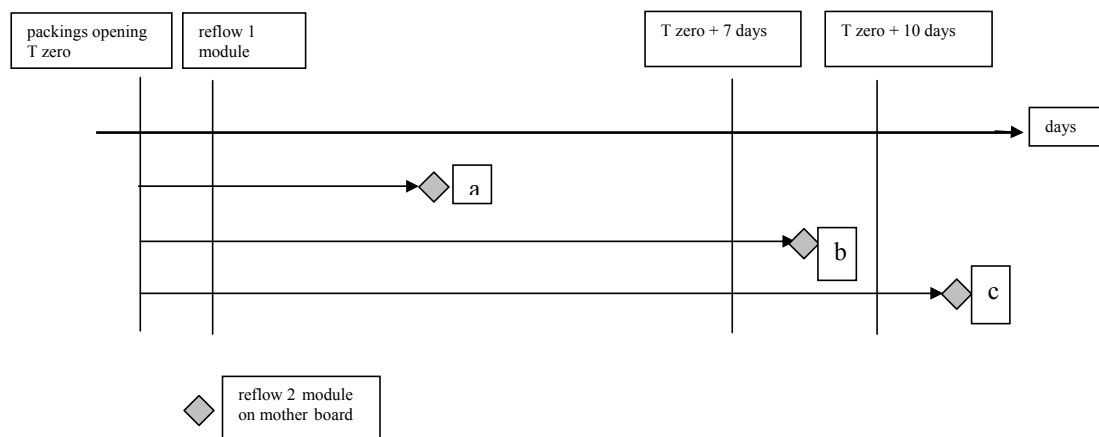
1) at end of drying , let the parts come back to room temperature slowly to avoid condensation.

2) take care that reel material cannot withstand 90°C .Then it is needed to dry prior reeling.

Reeling should occur within a few hours after drying;

6.4. Risk Management for Moisture sensitivity

Sensitive components and module PCB are 1.4 mm thick



Drying and vacuum packing should be done after module assembly and test, because there is low chance that reflow 2 occurs less than 7 (a) or 10 days (b) after reflow 1. In addition, atmosphere may be uncontrolled during transportation in term of RH%;

Drying at 90°C is better than 125°C in term of component and solder joint ageing;

provided that drying occurs less than 10 days after T zero, 24 hours drying is enough;

if drying occurs more than 10 days after T zero, 36 hours drying is necessary to reset the “moisture sensitivity clock”.

6.5. Soldering curve

