RF Transceiver Module, 868 MHz, Mesh, TSCH, AES Encryption

Applications

- Low power wireless Transceiver
- Consumer Electronics
- Alarm and security systems
- Home and building automation
- Wireless sensor networks
- Industrial monitoring and control

1 Electrical Specifications

1.1 Absolute Maximum Ratings

Parameter	Min.	Max.	Units
Supply Voltage, VDD and VRF with Respect to GND	0	3.8	V
Voltage on any pin with Respect to GND	-0.3	VDD+0.3	V
Input RF level		10	dBm
Storage temperature range	-50	150	°C
Ambient Temperature under Bias	-40	125	
Maximum soldering temperature		260	°C

1.2 General Operating Conditions

Parameter	Min.	Typ.	Max.	Units	Condition
Power Supply	1.98	3.3	3.6	V	**(1)**
Operating Temperature	-30		+70	°C	
GPIO Input low voltage			0.3VDD	V	
GPIO Input high voltage	0.7VDD			V	
Output high voltage		0.8VDD		V	Sourcing 0.1 mA, VDD=1.98 V
		0.9VDD		V	Sourcing 0.1 mA, VDD=3.0 V
		0.85VDD		V	Sourcing 1 mA, VDD=1.98 V
		0.9VDD		V	Sourcing 1 mA, VDD=3.0 V
	0.6VDD			V	Sourcing 20 mA, VDD=1.98 V
	0.8VDD			V	Sourcing 20 mA, VDD=3.0 V

(1): *Equipment is powered by a circuit (separately approved, not investigated) that is insulated from the mains supply by an insulation not less than that between the primary and secondary circuits of a safety isolating transformer according to IEC 61558-2-6 or equivalent.*
The system is considered (only) for the conditions of network environment 0 (see CEI CLC/TR 62102:2006). No over-voltage from telecommunication network possible, no subject to transient over voltages due to atmospheric discharges and faults in power distribution systems. ***Max VDD and VRF Ramp Time is 3 ms.***

1.3 RF Characteristic

Parameter	Min.	Typ.	Max.	Units	Condition
Frequency band	865.15		867.85	MHz	
Number of channels		28			
Channel Spacing		100		kHz	
Frequency Modulation		GFSK			
Frequency Deviation		+/- 20		kHz	
RF Rx Filter Bandwidth		83.2		kHz	
RF Data Rate		40		kbps	
Sensitivity		-108		dBm	
RF Output Power	-35		16	dBm	See 5.3.12

1.4 Current Consumption

Node Type	Min.	Typ.	Max.	Units	Condition
All		1	3	uA	@ Power Down
		16.5	25	mA	@ RX Continuous
		70	80	mA	@ TX Max Output Power
END NODE		16		uA	EM6 NO RX/TX **(2)**
		19		uA	EM6 1 RX/TX every 5 min **(3)**
		17		uA	EM5 NO RX/TX
		19		uA	EM4 NO RX/TX
		57		uA	EM0 NO RX/TX
ROUTER		18		uA	EM6 NO RX/TX
		180		uA	EM0 NO RX/TX
		295		uA	EM0 1 RX/TX every 5 sec **(3)**
COORDINATOR		4		mA	NO RX/TX

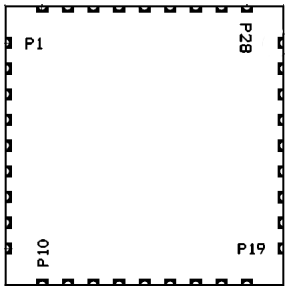
(2): *For* END NODE EM6 NO RX/TX *we mean a device configured as END NODE (see 5.3.9) in Energy Mode EM6 (see 5.3.4 and 5.3.8) without receiving and transmitting anything*

(3): *TX @ max RF Output Power (see 5.3.12)*

2 PIN-OUT

PIN #	BIT Assigned Function	Type	Optional			
			UC Pin	Analog	Timers	Comm
1	**GND**	**0V**				
2	**ANT**	**RF I/O**				
3	**GND**	**0V**				
4	**GND**	**0V**				
5	**GND**	**0V**				
6	**Module UART READY**	**DIG OUT**	PB_13	HFXTAL_P		LEU0_TX #1
7	**HOST UART READY**	**DIG IN**	PB_14	HFXTAL_N		LEU0_RX #1
8	**UART RX**	**DIG IN**	PD_1	ADC0_CH1 DAC0_OUT1ALT	TIM0_CC0 #3 PCNT2_S1IN #0	US1-RX #1

Top View



				#4/ OPAMP_OUT1ALT		
9	**UART TX**	**DIG OUT**	PD_0	ADC0_CH0 OPAMP_OUT2 #1	PCNT2_S0IN #0	US1-TX #1
10			PD_3	ADC0_CH3 OPAMP_N2	T0-CC2 #3	US1-CS #1
11			PD_5	ADC0_CH5 OPAMP_OUT2 #0		LEU0-RX #0
12			PD_4	ADC0_CH4 OPAMP_P2		LEU0-TX #0
13			PD_2	ADC0-CH2	T0-CC1 #3	US1_CLK #1
14			PC12	ACMP1_CH4 DAC0_OUT1ALT #0/ OPAMP_OUT1ALT		U1_TX #0
15			PC13	ACMP1_CH5 DAC0_OUT1ALT #1/ OPAMP_OUT1ALT	TIM0_CDTI0 #1/3 TIM1_CC0 #0 TIM1_CC2 #4 PCNT0_S0IN #0	U1_RX #0
16			PC14	ACMP1_CH6 DAC0_OUT1ALT #2/ OPAMP_OUT1ALT	TIM0_CDTI1 #1/3 TIM1_CC1 #0 PCNT0_S1IN #0	U0_TX #3
17	**VDD**	**3.3 V IN**				
18	**GND**	**0V**				
19	**RESETn**	**DIG IN**	Reset input, active low.To apply an external reset source to this pin, it is required to only drive this pin low during reset, and let the internal pull-up ensure that reset is released.			
20	**DGB-SWCLK # 0/1/2/3**	**DIG IN**	PF_0		TIM0_CC0 #5 LETIM0_ OUT0 #2	US1_CLK #2 LEU0_TX #3 I2C0_SDA #5
21	**DGB-SWDIO # 0/1/2/3**	**DIG I/O**	PF_1		TIM0_CC1 #5 LETIM0_ OUT1 #2	US1_CS #2 LEU0_RX#3 I2C0_SCL #5
22	**DBG-SWO #0**	**DIG I/O**	PF_2		T0-CC2 #5	LEU0-TX #4
23			PF_3		T0_CDTI0 #2/5	
24			PF_5		T0_CDTI2 #2/5	
25			PF_6		T0-CC0 #2	
26			PF_4		TIM0_CDTI1 #2/5	
27	**GND**	**0V**				
28	**VRF**	**3.3 V IN**				
29	**GND**	**0V**				
30			PC_15	ACMP1_CH7 DAC0_OUT1ALT #3/ OPAMP_OUT1ALT	TIM0_CDTI2 #1/3 TIM1_CC2 #0	U0_RX #3
31	**GND**	**0V**				
32	**GND**	**0V**				
33	**GND**	**0V**				
34	**EXT_PA_EN (1)**	**DIG OUT**	PB_4		PCNT1_S1IN #1	US2_RX #1
35	**EXT_LNA_EN (2)**	**DIG OUT**	PB_5			US2_CLK #1
36			PB_6			US2_CS #1

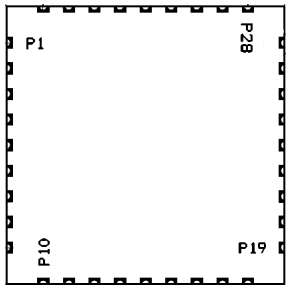
(1) This pin is normally set to logic low; it is set to logic high from module when a transmission is in progress; it could be used to control an external PA.

2) This pin is normally set to logic low; it is set to logic high from module when the receive state is active; it could be used to control an external LNA.

3 Optional custom PIN-OUT with USB support

PIN #	BIT Assigned Function	Type	Optional			
			UC Pin	Analog	Timers	Comm
1	GND	0V				
2	ANT	RF I/O				
3	GND	0V				
4	GND	0V				
5	GND	0V				
6	Module UART READY	DIG OUT	PB_13	HFXTAL_P		LEU0_TX #1
7	HOST UART READY	DIG IN	PB_14	HFXTAL_N		LEU0_RX #1
8	UART RX	DIG IN	PD_1	ADC0_CH1 DAC0_OUT1ALT #4/ OPAMP_OUT1ALT	TIM0_CC0 #3 PCNT2_S1IN #0	US1-RX #1
9	UART TX	DIG OUT	PD_0	ADC0_CH0 OPAMP_OUT2 #1	PCNT2_S0IN #0	US1-TX #1
10			PD_3	ADC0_CH3 OPAMP_N2	T0-CC2 #3	US1-CS #1
11			PD_5	ADC0_CH5 OPAMP_OUT2 #0		LEU0-RX #0
12			PD_4	ADC0_CH4 OPAMP_P2		LEU0-TX #0
13			PD_2	ADC0-CH2	T0-CC1 #3	USB_DMPU #0 US1_CLK #1
14	USB_VREGI					
15	USB_VREGO					
16	USB_DM		PF10			
17	VDD	3.3 V IN				
18	GND	0V				
19	RESETn	DIG IN	Reset input, active low.To apply an external reset source to this pin, it is required to only drive this pin low during reset, and let the internal pull-up ensure that reset is released.			
20	DGB-SWCLK # 0/1/2/3	DIG IN	PF_0		TIM0_CC0 #5 LETIM0_ OUT0 #2	US1_CLK #2 LEU0_TX #3 I2C0_SDA #5
21	DGB-SWDIO # 0/1/2/3	DIG I/O	PF_1		TIM0_CC1 #5 LETIM0_ OUT1 #2	US1_CS #2 LEU0_RX#3 I2C0_SCL #5
22	DBG-SWO #0	DIG I/O	PF_2		T0-CC2 #5	LEU0-TX #4
23			PF_3		T0_CDTI0 #2/5	
24			PF_5		T0_CDTI2 #2/5	
25			PF_6		T0-CC0 #2	
26	USB_VBUS	USB 5.0 V VBUS input.				
27	GND	0V				
28	VRF	3.3 V IN				
29	GND	0V				

Top View

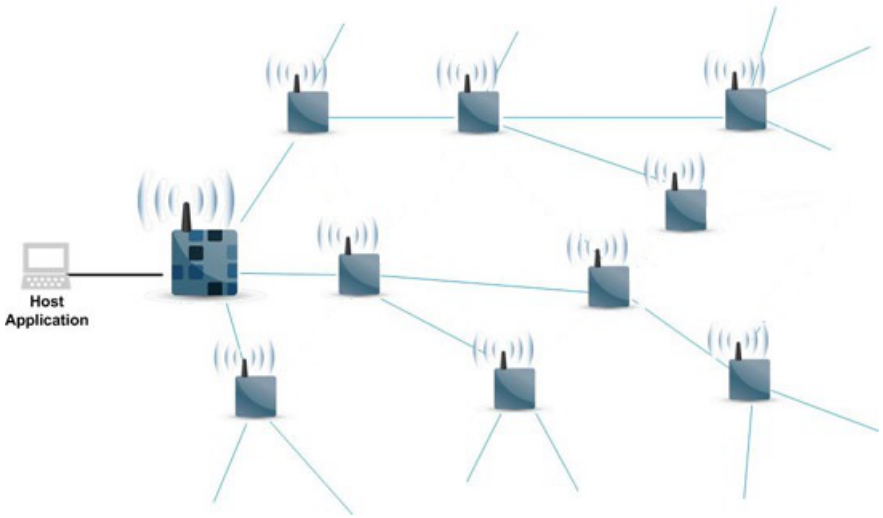


(1) This pin is normally set to logic low; it is set to logic high

30	**USB_DP**		PF_11				*from module when a transmission is in progress; it could be used to control an external PA.*
31	**GND**	**0V**					
32	**GND**	**0V**					
33	**GND**	**0V**					
34	**EXT_PA_EN (1)**	**DIG OUT**	PB_4		PCNT1_S1IN #1	US2_RX #1	*2) This pin is normally set to logic low; it is set to logic high from module when the receive state is active; it could be used to control an external LNA.*
35	**EXT_LNA_EN (2)**	**DIG OUT**	PB_5			US2_CLK #1	
36			PB_6			US2_CS #1	

4 Description

BIT868MN is a transceiver module designed for low-power applications. The module operates in the 863-870 MHz band.
The module implements a proprietary Low Power, Secure, Time Synchronized Mesh Network Protocol (hereinafter ***BITMESH***)



A Mesh Network consists of a Network Manager (Coordinator) that monitors and manages network performance and relays data to the host application, and network nodes, that relay data to and from each other and the manager.

The primary benefits of ***BITMESH*** are

- Low power consumption
- Power management and optimization
- Auto-forming mesh technology for a self-healing and self-sustaining network
- Network management and configuration
- Zero collision low power packet exchange
- Scalability to large, dense, deep networks

BITMESH includes a Time Slotted Channel Hopping (TSCH) media access layer (MAC). TSCH works by dividing time into ‘slots’, and providing a mechanism to map time-slots to channels with a pre-assigned hopping sequence.

BITMESH also implements Time Division Multiple Access (TDMA) and also encrypts the frame according to the Advanced Encryption Standard (AES) algorithm. Automatic Frequency Compensation (AFC) and Listen Before Talk (LBT) are also implemented.

The built-in ***BITMESH*** intelligence utilizes TDMA and TSCH to ensure:

- Nodes know precisely when to talk, listen, or sleep
- Packet exchanges are synchronized
- No packets collide on the network
- Every packet is scheduled and synchronized for energy efficiency with no extra preamble (TX side) or guard interval time (RX side)

Network synchronization also enables pair-wise channel hopping – also known as frequency diversity - that provides important benefits throughout the network:

- Multiple transmissions can occur simultaneously, increasing network bandwidth
- Automatically changes channels to avoid inevitable
- RF interference Allows networks to be dense and scale without creating debilitating RF interference

RF Power Level used in transmission is dynamically adjusted in order to reduce power consumption. For example, if two nodes are close, the RF Power is reduced to the minimum level allowed to securely communicate between the same.

BITMESH also addresses the hidden node problem. Beacon Frames are sent with the Max RF Output Power (see 5.3.12) – 3 dB in order to reduce this problem.
In wireless networking, the hidden node problem or hidden terminal problem occurs when a node is visible from a wireless access point (AP), but not from other nodes communicating with that AP. This leads to difficulties in media access control sub-layer; for example it is difficult to implement LBT (see 4.5).

The module is driven by the host via a UART interface.
The following describes the features of the network.

4.1 TDMA

To each Node, when it joins the network, it is assigned one time slot of 25 ms (nominal) and a virtual channel chosen between the 50 channels on which the system jumps, in which may communicate securely. Also a slot of 25 ms with a virtual channel chosen between the 10 Beacon channels is assigned for Beacon Frame forwarding.
A sequence of 50 slot form a SLOT FRAME (1.25 seconds); a sequence of 240 SLOT FRAME form a SUPER SLOT FRAME (300 seconds).
Every 4 SLOT FRAME (5 seconds) coordinator send a Beacon Frame for synchronization purpose. Instead for Node configured as ROUTER Energy Mode sets the interval at which BEACON frames are received and sent (see 5.3.4).

4.2 TSCH

The module hops on 28 channels following a table generated by a pseudo-random algorithm different for each COORDINATOR and will remain on each channel for 25 ms (nominal). 26 channels are used for synchronous communications and 2 channels are used for asynchronous communications.
The used RF channels are defined as: $Ch_n = (865.15 + i * 0.100)\,MHz\,,\ for\ 0 \le i \le 27$.

A SLOT FRAME is composed of 50 slot of 25 ms; for each slot 28 RF channels could be used. Thus the following example table is obtained for secure transmission every 1.25 sec.

Slot # / Ch #	00	01	02	03	04	...	48	49
00		CRD RX				...	RES	RES
01			NODE3 RX		NODE2 RX	...	RES	RES
02	RES	RES	RES	RES	RES	...	ASYNC1	ASYNC2
03	CRD BCN TX		Node2 BCN TX			...	RES	RES
04						...	RES	RES
...	...	...	...	...	...	...	RES	RES
24		NODE1 BCN TX		NODE3 BCN TX		...	RES	RES

25	RES	RES	RES	RES	RES	...	ASYNC3	ASYNC4
26			NODE1 RX				RES	RES
27					NODEn RX		RES	RES

Grey cells are not used.
Please note that every channel is one of the previous defined RF channels and varies for every SLOT FRAME.
Every cell could be used for Beacon TX/Forwarding or for data transmission. In the table above an example is reported

4.3 AES128

All communications are encrypted with AES 128-bit. There are 2 encryption keys: a public key and a private key. The less significant bits of the private key will be used as coefficients of a random number generation algorithm which will serve to generate a TSCH hopping table.
The public key has to be set equal in all modules of the same installation. The private key has to be set different for different facility. Different Encryption Key generate different BEACON Frames so avoiding synchronization of Nodes with coordinators of other installations.
The default public encryption key is composed by the 16 char ***`BITPBLENCRYPTKEY`***.
The default private encryption key is composed by the 16 char ***`BITPRVENCRYPTKEY`***.
Private encryption key can be set by the apposite command (see 5.3.6); alternatively it could be set only in the coordinator and then will be passed to the other nodes during the join procedure.
In this case, Coordinator has to be set to use the public key by the SKT command (see 5.3.7) during the join procedure. Once the join procedure is finished, Coordinator has to be set to use the Private Key.

4.4 AFC

The nodes implement the Automatic Frequency Compensation. It is an algorithm that causes the frequency (Transmit/Receive) of the PERIPHERAL is always centered on that of the COORDINATOR so as not to lose sensitivity and continue to operate even in the presence of temperature and/or supply voltage variations.
Important
If the temperature varies too quickly (for example from 25 to 70 ° C in less than 5 minutes when Network Variant is set in Low Power Mode – see 5.3.4), it is not guaranteed the continuity of operation; we mean that the NODE could go out-of-sync and could therefore not be able to communicate with the COORDINATOR for a round of synchronization (about 5 minutes if the Network Variant is set in low power mode). After receiving the next Beacon Frame, the NODE gets back in sync and thus is able to communicate with the COORDINATOR.
If the temperature varies slowly enough (for example 25 to 70 ° C for more than an hour) the AFC algorithm allows normal operation.

4.5 LBT

BITMESH implements the technique of Listen Before Talk to avoid interference in case of two nodes (in example a father and a child of a node) who want to transmit to the same node. This is similar to what Carrier Sense Multiple Access technique do:

- Sense the channel
- If the channel is idle, transmit
- if the channel is busy,
  - waits a random amount of time
  - sense the channel again

4.6 Asynchronous Slot

ASC is a system that allows a node enrolled in the network to communicate with a node outside from the network. This feature allows the implementation in the network of asynchronous devices such as radio commands.
Any node can request the CRD of an ASC slot through the UART command SAS.
Once the ASC parameters have been received, the node starts sending a periodically signal containing the data entered in the “Asynchronous Field” field that can be set with the SAF command.
At this signal, the Satellite nodes respond with a data contained in the “Satellite Answer” field that can be set using the SSA command.

5 UART Interface

Uart is the standard interface. USB interface is available only for custom design support.

5.1 General characteristics

UART is 8 bits char, None parity bit, 1 stop bit.
In order to communicate via the UART interface pin P6 (OUT for module) has to be HI and pin P7 (OUT for host) have to be HI.
If host want to send an UART message, it must set the pin P7 to logic HI (for wake-up module) and wait for the module to set pin P6 to logic HI. This can be disabled by pull-up to Vdd on pin P6
If module has to send an UART message, it must set pin P6 to logic HI (for wake-up host) and wait for the host to set pin P7 to logic HI. This can be disabled by pull-up to Vdd on pin P7.
Any UART message has to be terminated by a carriage return and a new line character (\r\n - 0x0D 0x0A).
At start-up and after any command, BIT868MN print the prompt: "\r\n>:\".

5.2 UART API

UART API is a set of commands That can be sent to the module. They are all composed of 3 characters.
In the following ***C*** means the ASCII coded C char. First char has to be a ***W***, a ***R*** or a ***S*** char. ***W*** means that is a writing command; ***R*** means that is a reading command; ***S*** means that is a setting state command. The ***TX*** command can only be preceded by the character ***S***. Also ***CM***, ***KT*** and ***LP*** command are exceptions: they can be preceded by the character ***S*** or ***R***.
All writing (W) commands can be executed only if the Configuration mode is active.
When exiting from configuration mode (***SCM=RST\r\n***), BIT868MN save all current settings in NVM and forces a reboot.

In addition to the previous commands that are originated from the host, there are a series of messages that module can send autonomously; they are the unsolicited message and are; UJR, UOR, URX, UQF, UAR, UAT, ULT. See section 5.4 Unsolicited Messages for details.

5.3 UART Command table

In the following table the \r\n characters and the prompt: "\r\n>:\" are not reported.

Command Description	Syntax	Val	Def Fab Value
Read Configuration Mode Status	***RCM***		***RST***
Sets Configuration Mode Status	***SCM***=**val**	3 char ***SET*** or ***RST***	
Force all settings to fab values	***WDF***=**val**	3 char Only ***DEF***	
Read UART Baud Rate	***RBR***		***3***
Write UART Baud Rate	***WBR***=**val**	1 char ***0*** to ***3***	
Read Network Variant	***RNV***		0x00FA6300
Write Network Variant	***WNV***=**val**	See 5.3.4	
Read Public AES Encryption Key	***REK***		***BITPBLENCRYPTKEY***

Command Description	Syntax	Val	Def Fab Value
Write Public AES Encryption Key	***WEK=*val**	16 bytes from 0 to 0xFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF	
Read Private AES Encryption Key	***RPK***		***BITPRVENCRYPTKEY***
Write Private AES Encryption Key	***WPK=*val**	16 bytes from 0 to 0xFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF	
Read AES KEY in use	***RKT***		***PRV***
Sets AES KEY to use	***SKT=*val**	3 char ***PBL*** or ***PRV***	
Read Energy Mode	***REM***		***0***
Sets Energy Mode	***SEM=*val**	1 char from ***0*** to ***6***	
Read Node Type	***RNT***		***U***
Write Node Type	***WNT=*val**	***C*** , ***R*** or ***E***	
Read Long Address	***RLA***		0xFFFFFFF
Write Long Address	***WLA=*val**	4 bytes from 0 to 0xFFFFFFFE	
Read Life State Supervision Time	***RLT***		0x0003
Write Life State Supervision Time	***WLT*=val**	2 bytes from 0 to 0xFFFF	
Read Max RF Output Power	***RPA***		***99***
Write Max RF Output Power	***WPA=*val**	2 char ***00*** to ***99***	
Read Power Down Status	***RPD***		***0***
Write Power Down Status	***WPD=*val**	***0*** or ***1***	
Print Network Tree	***RPN***		
Read Firmware Version	***RFW***		
Sets an RF TX towards a node	***STX=*val**	See 5.3.16	
Sets Production test mode	***SPT=*val**	See 5.3.17	
Sets Asynchronous Slot	***SAS=v1,v2***	See 5.3.18	
Set Asynchronous Field	***SAF=val***	28 byte of data	
Set Satellite Answer	***SSA=val***	8 byte of data	

If the command is well formatted, BIT868MN returns the header of the command, if the command is of type 'R', at the end of the command header there are the requested data followed by the prompt string "\r\n>:\". Otherwise if the command is not well formatted BIT868MN returns the string ERR=0 and the prompt string

Following some examples.
Example1: host send “RNT\r\n”; module returns “RNT =C\r\n>:\”
Example2: host send “RNN\r\n”; module returns “ERR=0\r\n>:\”
Example3: host send “SCM=SET\r\n”; module returns “SCM=\r\n>:\”
Example4: host send “SCM=4\r\n”; module returns “ERR=0\r\n>:\”

5.3.1 CF: Configuration Mode

In order to accept the setting commands, BIT868MN must be in configuration mode.
To enter configuration mode host has to send the command ***SCM=SET***.
When host send command ***SCM=RST***, module saves all current settings in NVM and reboots itself.
RCM return current status.

5.3.2 DF: Default Fab Values

WDF=DEF sets all values to default as from Fab.
RDF ***is not allowed.***

5.3.3 BR: UART Baud rate

WBR=**val** sets the UART baud rate. The UART baud rate can be set to 4 different values. The possible settings are shown in next table.

val	UART Baud Rate (bps)
0	9600
1	38400
2	57600
3	**115200 (default)**

RBR return current setting.

5.3.4 NV: Network Variant

WNV=val sets some parameters of the network. Usually only the coordinator needs to be set with these parameters because, during the join procedure, the coordinator sends they to all nodes.
val is composed of 4 bytes: BYTE0, BYTE1, BYTE2, BYTE3

BYTE 0 is a bit field value as follows

BIT	7	6	5	4	3	2	1	0
Description	RES	VERB1	VERB0	AES Key to Use	Redundancy	Energy Mode		

Energy Mode can be a value from 0 to 6. This parameter set the power consumption of the nodes configured as ROUTER and also the reactivity of the network.
Coordinator send Beacon Frames every 4 Frames (5 sec). Instead for Node configured as ROUTER Energy Mode sets the interval at which BEACON frames are received and sent. This interval is as follow:

$$Time_{BCN} = \left(4 x 2^{EM}\right) x \; T_{FRAME} \; sec$$

EM is Energy Mode Value and T_{frame} is the duration of a FRAME (50 slot) 1.25 sec
Default fab value is 0.

Please note that this field can be set also by the command SEM (see 5.3.8): this way there is no need to enter in configuration mode with the command SCM and module is not rebooted.

Redundancy = 1 force all the nodes to search for at least 2 path to reach the Coordinator.
Default fab value is 0.

Please note that this feature is not yet implemented; it will be implemented in future FW revision.

AES Key to Use = 0 force module to use Private AES Key; AES Key to Use = 1 force module to use Public AES Key
Default fab value is 0.
Please note that this field can be set also by the command SKT (see 5.3.7): this way there is no need to enter in configuration mode with the command SCM and module is not rebooted.

VERB0, VERB1 set the Verbose mode of Unsolicited Messages (see section 5.4 Unsolicited Messages).

VERB1	VERB0	Verbose Level	Unsolicited Generation	Note
0	0	0	UJR, UOR, URX	UJR and UOR are only generated by the coordinator and by the node that join or loose the network.
0	1	1	UJR, UOR, URX, UQF	UJR and UOR are generated also by all the nodes of the tree between the node and the coordinator.
1	0	2	UJR, UOR, URX, UQF, UAR, UAT, ULT	
1	1	3	UJR, UOR, URX, UQF, UAR, UAT, ULT	in addition to level 2, more unsolicited messages are generated for debug purpose ***(*)***

(*) Please note that level 3 make a very intensive use of UART; so it is intended only for debug purpose: it must be not used in production design.
VERB0=0 and VERB1=0 are the default fab value.
RES are reserved fields: set always to 0

BYTE 1 is max level of network hops; it can takes values from 1 to 99; default fab value is 99
Please note that the nodes that have been associated in the max level do not send Beacon Frames in order to reduce power consumption.

BYTE 2 is Number of Nodes of the network; it can takes values from 1 to 250; default fab value is 250.

BYTE 3 is the min level value of the father to which a node can join; it can takes values from 0 to 99; default fab value is 0. This field has no effect for the coordinator.

RNV returns the current network parameters.

5.3.5 EK: Public AES Encryption Key

WEK=val sets module PUBLIC AES ENCRYPTION KEY. val is a 16 bytes value. Please note that all nodes in the network have to be set with same AES Key in order to work properly.
REK returns current PUBLIC AES ENCRYPTION KEY

5.3.6 PK: Private AES Encryption Key

WPK=val sets module PRIVATE AES ENCRYPTION KEY. val is a 16 bytes value. Please note that all nodes

in the network have to be set with same AES Key in order to work properly.
RPK returns current PRIVATE AES ENCRYPTION KEY

Private encryption key can be set by the apposite command; alternatively it could be set only in the coordinator and then will be passed to the other nodes during the join procedure.
In this case, Coordinator has to be set to use the public key by the SKT command (see 5.3.7) during the join procedure. Once the join procedure is finished, Coordinator has to be set to use the Private Key.

5.3.7 KT: Key type

SKT=val sets the AES KEY type.
val=***PBL*** force the module to use the public key for AES encryption.
val=***PRV*** force the module to use the private key for AES encryption.
Any other value is not allowed.
Default fab value is ***PRV***.
RKT return current AES KEY type.

This command set the bit 2 of BYTE 0 of Network Variant (see 5.3.4) without the need to enter in configuration mode: this way module is not rebooted.

5.3.8 EM: Energy Mode

SEM=val set the Energy Mode. val could be a character from ***0*** to ***6***
This parameter set the power consumption of the nodes configured as ROUTER and also the reactivity of the network.
Coordinator send Beacon Frames every 4 Frames (5 sec). Instead for Node configured as ROUTER Energy Mode sets the interval at which BEACON frames are received and sent. This interval is as follow:

$$Time_{BCN} = \left(4 \, x \, 2^{EM}\right) x \; T_{FRAME} \quad sec$$

EM is Energy Mode Value and T_{frame} is the duration of a FRAME (50 slot) 1.25 sec

Default fab value is ***0***.
REM return current Energy Mode.

This command set the bit 0, 1 and 2 of BYTE 0 of Network Variant (see 5.3.4) without the need to enter in configuration mode: this way module is not rebooted.

5.3.9 NT: Node Type

WNT=C sets node type COORDINATOR; ***WNT=R*** sets node type ROUTER; ***WNT=E*** sets node type END DEVICE.
COORDINATOR and ROUTER send Beacon Frames; END DEVICE does not send Beacon Frames.
RNT returns current node type.
Default fab value is ***U*** undefined.

5.3.10 LA: Long Address

WLA=val writes the module Long Address. val must be a unique identifier on the network. It is a 4 bytes value in Little Endian Order.
RLA returns current Long Address.
Default fab value is 0xFFFFFFFF.

5.3.11 LT: Life State Supervision Time

WLT=val writes the module Life State Supervision Time. val can takes values from 0 to 0xFFFF. It is a 2 bytes value in Little Endian Order. Val is expressed in multiple of 10 sec.
Life State Supervision Time is the time used by the nodes to monitor that all their children are alive.

Life State Supervision Time can be set by this command; alternatively it could be set only in the coordinator and then will be passed to the other nodes during the join procedure.

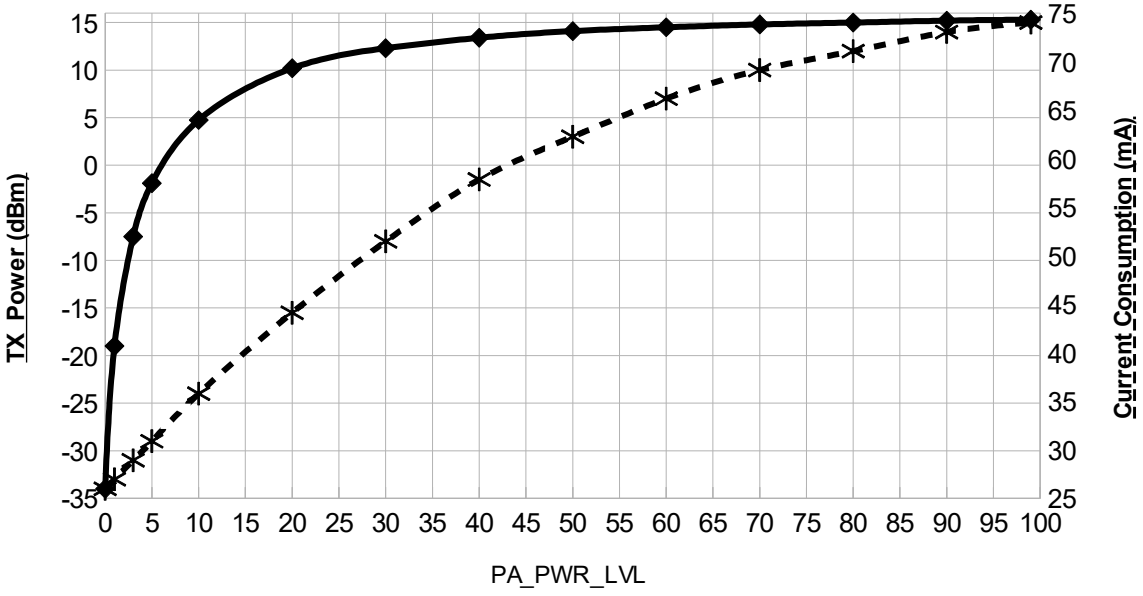
RLT returns current Life State Supervision Time.
Default fab value is 0x0003.

5.3.12 PA: Max RF Output Power

WPA=val writes the maximum output power of the module. val could be 2 ASCII coded chars from ***00*** to ***99***.
Please note that the RF Power Level used in transmission is dynamically adjusted in order to reduce power consumption. For example, if two nodes are close, the RF Power is reduced to the minimum level allowed to securely communicate between the same.

Beacon Frame are always sent with the Max RF Output Power – 3 dB in order to reduce the hidden node problem.
In wireless networking, the hidden node problem or hidden terminal problem occurs when a node is visible from a wireless access point (AP), but not from other nodes communicating with that AP. This leads to difficulties in media access control sub-layer (for example it is difficult to implement LBT).

The Max RF Output Power is changed in 100 steps through the PA_PWR_LVL val according to the following figure where the relative current consumption is also reported.



RPA returns the current maximum output power of the module.

5.3.13 PD: Power Down Mode

WPD=val sets the Power Down mode of the module.
If argument val is ***1***, module enter power down mode. If val is ***0***, BIT868MN resume normal operation.
RPD return current Power Down Status.

5.3.14 PN: Print Network Tree

WPN is not an allowed command
RPN prints current network tree.
Following an example of a RPN response of a coordinator in case of network of 8 nodes in 3 level + 1 coordinator:

L	A		/		L	V	L	|		|	0	0	|	0	1	|	0	2	|	0	3	|
1	2	3	4	5	6	7	8	|		<	0	0	>			|			|			|
1	2	3	4	5	6	7	9	|		|			|	0	1	|			|			|
1	2	3	4	5	6	7	D	|		|			|			|	0	5	|			|
1	2	3	4	5	6	7	F	|		|			|			|			|	0	7	|
1	2	3	4	5	6	8	0	|		|			|			|			|	0	8	|
1	2	3	4	5	6	7	A	|		|			|	0	2	|			|			|
1	2	3	4	5	6	7	B	|		|			|	0	3	|			|			|
1	2	3	4	5	6	7	C	|		|			|	0	4	|			|			|
1	2	3	4	5	6	7	E	|		|			|			|	0	6	|			|

In this example in level 0 there is only one node: coordinator with long address 12345678 and short address 00; in level 1 there are 4 nodes: long address 12345679 to 1234567C which are child of coordinator and have short address from 01 to 04; in level 2 there are 2 nodes: 1234567D (short address 05) that is child of 12345679 and 1234567E (short address 06) that is child of 1234567C; in level 3 there are 2 nodes: 1234567F (short addr 07) and 12345680 (short addr 08) that are children of 1234567D. Every cell is a char, so empty cells are white spaces. Long and Short Address are coded as ASCII code of every nibble hex value.

Please note that coordinator knows the entire network, while any other nodes know only the network below itself, the father and the coordinator.

Following an example of a RPN response of the node with long address 0x1234567F in case of same network of 8 nodes in 3 level + 1 coordinator:

L	A		/		L	V	L	|		|	0	0	|	0	1	|	0	2	|	0	3	|
1	2	3	4	5	6	7	8	|		|	0	0	|			|			|			|
1	2	3	4	5	6	7	D	|		|			|			|	0	5	|			|
1	2	3	4	5	6	7	F	|		|			|			|			<	0	7	>

5.3.15 FW: Firmware Version

WFW is non allowed.
RFW returns the firmware version in the form of 2 char of major version, a '.' char and 2 char of minor version
For example FW version ***01.23***.

5.3.16 TX: Force a RF Transmission

STX=val En-queues a RF Transmission towards another module.
val has several fields:
BYTE 0: Destination Long Address Byte 0 (LSByte)
BYTE 1: Destination Long Address Byte 1
BYTE 2: Destination Long Address Byte 2
BYTE 3: Destination Long Address Byte 3 (MSByte)
BYTE 4: Packet Len (max allowed value: 27)
BYTE 5: Data Byte 0
…
BYTE 5+Packet Len: Data Byte N

if Destination Long Address is equal at 0xFFFFFFFF the Tx is performed in BroadCast mode.

Please note that, due to the AES Encryption limitation (16 bytes data chunk), if Packet Len is less or equal to 11, 11 bytes will be transmitted in RF (5 bytes are reserved for network header); if Packet Len is greater of 11 (but less or equal to 27), 27 bytes will be transmitted.

5.3.17 PT: Production Test

SPT=**val** sets and start various production tests. This command is only valid when the node type is UNDEFINED (see 5.3.9)
val can be various string: for example ***START PRODUCTION TEST MST***, ***START PRODUCTION TEST SLV***, ***TEST TX***, ***TEST RX***, ***TEST PD***, etc.

This command is reserved for production test: host application must never trigger this command!

5.3.18 AS: Asynchronous Slot

SAS=**v1, v2** enable and disable the asynchronous slot (hereinafter ASC). The ASC is assigned by the CRD Node. Enable the ASC means sending a request to the CRD Node to obtain the ASC parameters. Disable ASC means sending a message to the CRD node to inform it that it must free the ASC parameters, in order to make them available for another node.

Function	**Key Type**	**Syntax**
Enable ASC	**Public Key**	SAS=SET,PBL
	Private Key	SAS=SET,PVR
Disable ASC	**Not Used**	SAS=RST,NUL

5.4 Unsolicited Messages

In addition to the previous commands that are originated from the host, there are a series of messages that module can send autonomously. Following there is a table of these unsolicited message.

In the following table the \r\n characters and the prompt: “\r\n>:\” are not reported.

Message Description	Syntax	Val
Node Join Report	***UJR*=val**	4 bytes Long Address Coordinator, 4 bytes Long Address Father, 4 bytes Long Address Node which is joined to the network, 1 byte Short Address, 1 byte Level, 1 byte Num Tot Nodes
Node Orphan Report	***UOR*=val**	4 bytes Long Address Coordinator, 4 bytes Long Address Father, 4 bytes Long Address Node which is joined to the network, 1 byte Short Address, 1 byte Level, 1 byte Num Tot Nodes
RF message received	***URX*=val**	4 bytes Long Address Source of the message, 1 byte Packet Length, n data Bytes
Queue Full	***UQF*=val**	See 5.4.4 Queue Full
ACK Received	***UAR*=val**	See 5.4.5 ACK Received
ACK Transmitted	***UAT*=val**	See 5.4.6 ACK Transmitted
Life State TX Request	***ULT*=val**	See 5.4.7 Life State Request TX

5.4.1 Node Join Report

When a node join a network, the node itself, the coordinator and all the nodes in the path between node and coordinator send a message to their host as follow.

***UJR*=val**. val has the following fields:

BYTE 0: Long Address Coordinator Byte 0 (LSByte)
BYTE 1: Long Address Coordinator Byte 1
BYTE 2: Long Address Coordinator Byte 2
BYTE 3: Long Address Coordinator Byte 3 (MSByte)
BYTE 4: Long Address Father Byte 0 (LSByte)
BYTE 5: Long Address Father Byte 1
BYTE 6: Long Address Father Byte 2
BYTE 7: Long Address Father Byte 3 (MSByte)
BYTE 8: Long Address Node Byte 0 (LSByte)
BYTE 9: Long Address Node Byte 1
BYTE 10: Long Address Node Byte 2
BYTE 11: Long Address Node Byte 3 (MSByte)
BYTE 12: Short Address assigned to node
BYTE 13: Level assigned to node
BYTE 14: Number of total nodes in the network

Long Address Coordinator is the long address of the coordinator of the network;
Long Address Father is the long address of the father of the node;
Long Address Node is the long address of the node who joined the network
For the coordinator BYTE 6 is populated with Number of total nodes in the network; for the node BYTE 6 is always 0.

5.4.2 Node Orphan Report

When a node loose a network, the node itself, the coordinator and all the nodes in the path between node and coordinator send a message to their host as follow.

***UOR*=val**. val has the following fields:

BYTE 0: Long Address Coordinator Byte 0 (LSByte)
BYTE 1: Long Address Coordinator Byte 1
BYTE 2: Long Address Coordinator Byte 2
BYTE 3: Long Address Coordinator Byte 3 (MSByte)
BYTE 4: Long Address Father Byte 0 (LSByte)
BYTE 5: Long Address Father Byte 1
BYTE 6: Long Address Father Byte 2
BYTE 7: Long Address Father Byte 3 (MSByte)
BYTE 8: Long Address Node Byte 0 (LSByte)
BYTE 9: Long Address Node Byte 1
BYTE 10: Long Address Node Byte 2
BYTE 11: Long Address Node Byte 3 (MSByte)
BYTE 12: Short Address assigned to node
BYTE 13: Level assigned to node
BYTE 14: Number of total nodes in the network

Long Address Coordinator is the long address of the coordinator of the network;
Long Address Father is the long address of the father of the node;
Long Address Node is the long address of the node who joined the network
For the coordinator BYTE 6 is populated with Number of total nodes in the network; for the node BYTE 6 is always 0.

5.4.3 RF Message Received

When a node receive an RF message, it sends a UART message to host as follow.
URX=val. val has the following fields:

BYTE 0: Source Long Address Byte 0 (LSByte)
BYTE 1: Source Long Address Byte 1
BYTE 2: Source Long Address Byte 2
BYTE 3: Source Long Address Byte 3 (MSByte)
BYTE 4: Packet Len (max allowed value: 26)
BYTE 5: Data Byte 0
…
BYTE 5+Packet Len: Data Byte N

5.4.4 Queue Full

If verbose level is equal or greater than 1 (see VERB0, VERB1), this unsolicited message is generated.
The firmware of the module make use of two main queues: one for the UART and one for the RF messages. This message says that one or both the queues are full.

UQF=U,0 mean that UART queue is full, while RF queue is not full.
UQF=0,R mean that UART queue is not full, while RF queue is full.
UQF=U,R mean that both UART and RF queues are full.

5.4.5 ACK Received

If verbose level is equal or greater than 2 (see VERB0, VERB1), this unsolicited message is generated.

UAR=ACK val means that node received a generic Acknowledge from node address val (4 bytes Long Address).
For example this unsolicited is received after a STX command (see 5.3.16).

UAR=LSA val means that node received a Life State Acknowledge from node address val (4 bytes Long Address).
For example this unsolicited is received after a Life State Supervision check is performed by a node (see 5.3.11).

5.4.6 ACK Transmitted

If verbose level is equal or greater than 2 (see VERB0, VERB1), this unsolicited message is generated.

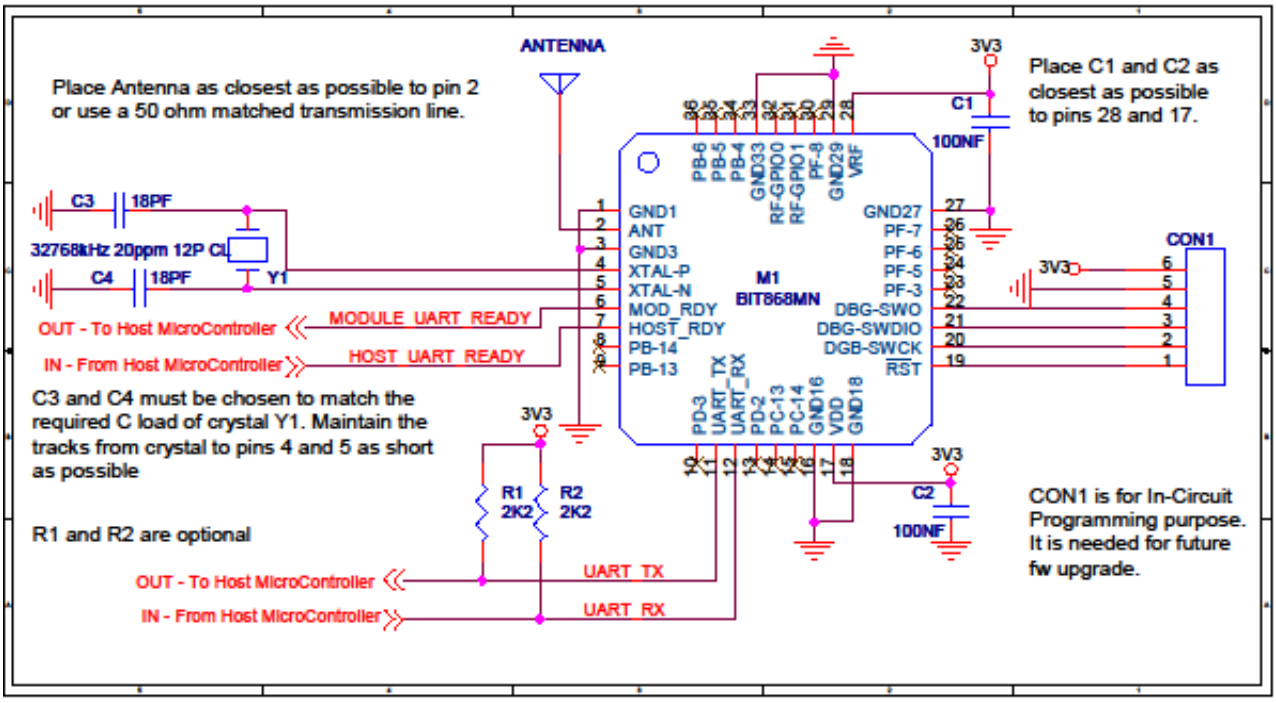
UAT=ACK val means that node transmitted a generic Acknowledge to node address val (4 bytes Long Address).
For example this unsolicited is generated together with a URX (see 5.4.3).
UAT=LSA val means that node transmitted a Life State Acknowledge to node address val (4 bytes Long Address).
For example this unsolicited is generated after a Life State Supervision check is received from a node (see 5.3.11).

5.4.7 Life State Request TX

If verbose level is equal or greater than 2 (see VERB0, VERB1), this unsolicited message is generated.

ULT= val means that node sent an alive request to node address val (4 bytes Long Address).
After this unsolicited also the ***UAR=LSA*** val is generated.

6 Typical Application

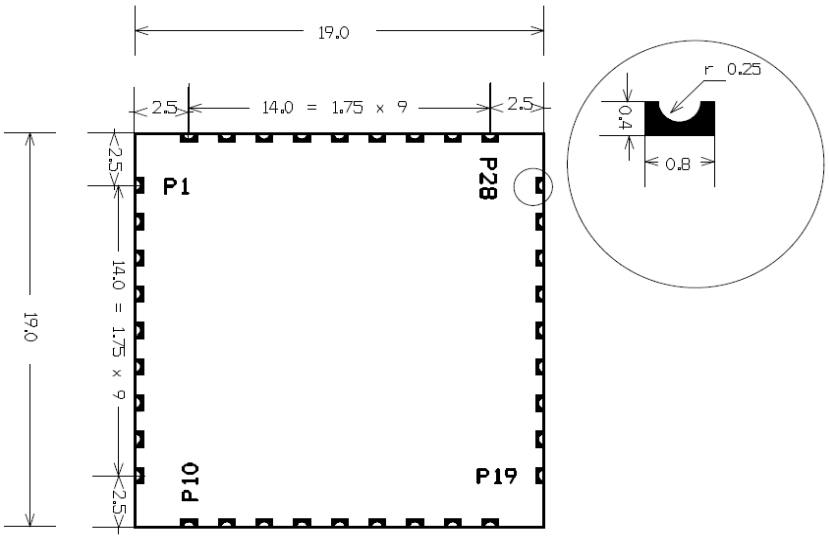


6.1 Product customization

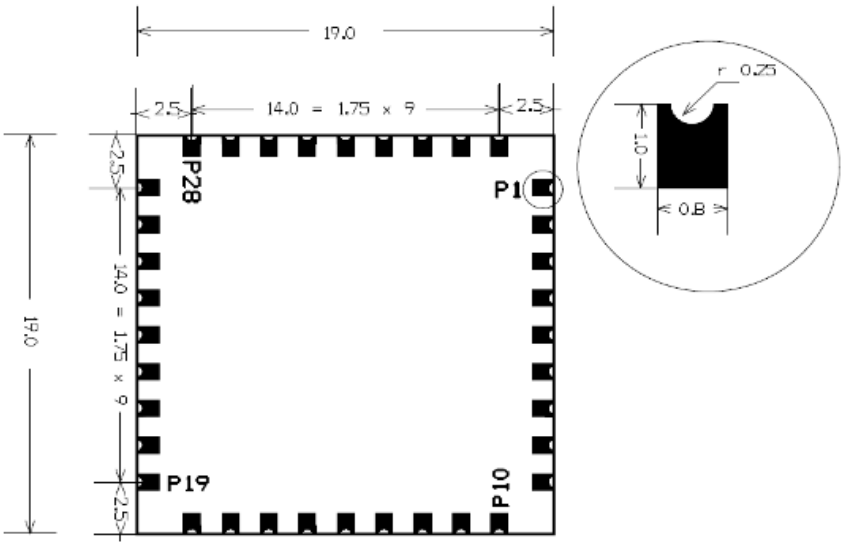
2 different version are available: one with USB and one without.
For USB version there are 13 I/O available; for NON USB version there are 19 I/O.
Ask us if you want to customize the module or if you want to develop your own application with the use of all the available I/O. The MCU on board is an ARM Cortex M3 @ 48 MHz with 128K Flash and 32K RAM. Please contact the Distributors closest to you for further information.
Leave unused pins unconnected.

7 Mechanical Dimension (mm)

Top View



Bottom View



8 Soldering profile Recommendation

JEDEC standard IPC/JEDEC J-STD-020D.1 (page 7 and 8), Pb-Free Assembly is recommended.
The standard requires that the heat dissipated in the "surroundings" on the PCB is taken into account. The peak temperature should be adjusted so that it is within the window specified in the standard for the actual motherboard.
Aperture for paste stencil is normally areal-reduced by 20-35%, please consult your production facility for best experience aperture reduction. Nominal stencil thickness of 0.1-0.12 mm recommended.

9 Packaging Information

Orderable device	Status	Package Type	Pins	Package Qty	Eco Plan	MSL Peak Temp
BIT868MN	ACTIVE	MLF	36	84	Green (RoHS & no Sb/Br)	Level-2-260C-1 YEAR

10 General Information

10.1 Disclaimer

B.I.T. srl believes the information contained herein is correct and accurate at the time of this printing. However, B.I.T. srl reserves the right to make changes to this product without notice. B.I.T. srl does not assume any responsibility for the use of the described product; neither does it convey any license under its patent rights, or the rights of others. The latest updates are available at the BIT website or by contacting BIT directly.

As far as possible, major changes of product specifications and functionality, will be stated in product specific Errata Notes published at the BIT website. Customers are encouraged to sign up to the Developers Newsletter for the most recent updates on products and support tools.

Compliance with regulations is dependent on complete system performance. It is the customer's responsibility to ensure that the system complies with regulations.

10.2 Life Support Policy

This BIT product is not designed for use in life support appliances, devices, or other systems where malfunction can reasonably be expected to result in significant personal injury to the user, or as a critical component in any life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness. B.I.T. srl customers using or selling these products for use in such applications do so at their own risk and agree to fully indemnify B.I.T. srl for any damages resulting from any improper use or sale.

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11 Revision list

Revision	Data	Description
00.01	2017-01-16	• First Release
00.9a	2017-03-20	• First Stable Alpha Release
00.9b	2017-05-15	• Modified UJR, UOR and RPN commands
00.9c	2017-06-12	• AES KEY Split-ted in two key: a public one and private one
00.9d	2017-06-21	• Low Power Network implemented • Min Level To Join implemented
00.9e	2017-06-27	• Hot switch between Low Power and Not Low Power Network implemented • Listen Before Talk implemented
00.9f	2017-06-29	• Unsolicited UQF added • Life State Supervision Time added • Various Optimizations
00.9g	2017-07-04	• Beacon Frames sent @ -3dBm • End Node and Nodes with max level do not send Beacon Frames • App, RX op, BCN RX and BCN TX Watchdogs enabled • Periodic App Reinit implemented • Changed Low Power Mode in Energy Mode
00.9h, 00.9i	2017-07-27	• Added support for Stress level of the nodes in forwarding messages
00.9j	2017-09-08	• Added support for UN-modulated and PN9 carrier TX (for testing purpose)
00.9k	2017-09-25	• Added production test procedure
00.9l	2017-10-20	• Added LBT to Beacon Frame TX • Modified used Number of Channels • 3 slot reserved for Asynchronous Communications • UAR, UAT, ULT unsolicited message added • Verbose modes changed
00.9m	2017-12-05	• Modified algorithm for channel sequence definition • Various enhancements
01.00	2018-01-30	• HW R 1.1 released • PIN-OUT changed • 32.768 kHz XTAL added on-board
01.01	2018-5-31	• Added USB version • Insert commands for ASC procedure (Asynchronous Communication) • Added Broadcast STX message
01.02	2018-6-5	• Added ASC Slot Function Description
01.03	2018-6-18	• Fixed BitMesh Image diagram in Cap. 4