Product	:	Nemeus – MM001
Doc	:	Datasheet
Reference	:	datasheet_MM001
History	:	v0.2 (preliminary)

NEMEUS

Long Range wireless solution

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Document history

Version	Date	Author	Comments
V0.1	08/04/2014	Isabelle Tocquer	Initial
V0 .2	07/05/2014	Gilles Ronco	Update

Table 1 : Document versions

References

[1] Semtech – Datasheet SX1276

[2] Semtech / IBM / Actility – LoRa MAC specification Release v1.0

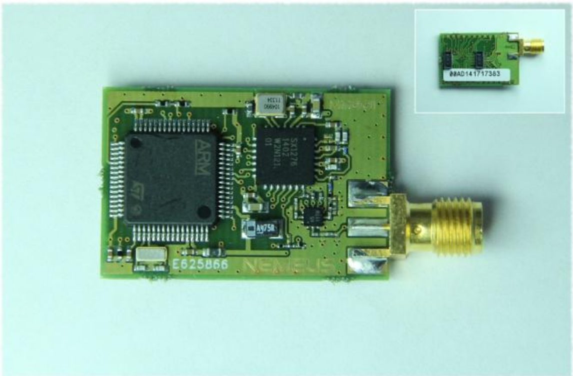
[3] ETSI EN300.220 specification

Revisions

This document is dedicated to Nemeus-MM001 (beta version) description.

Module features

The **Nemeus-MM001** is a long-range and low power wireless module based on LoRa™ technology and operating in 868MHz unlicensed band. With interferers' robustness and low power consumption, it is the best solution for applications requiring long range, maximum battery lifetime and secure radio link. This module integrates a SX1276 LoRa™ transceiver from Semtech and a low power ARM Cortex M3 controller. Modem stack software capable to communicate with LORA network is embedded.



Key product features

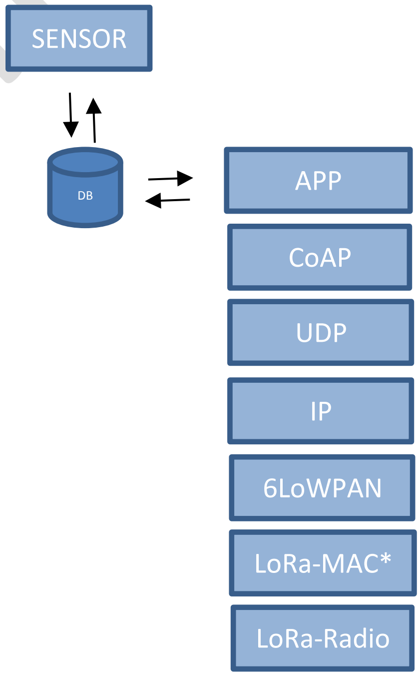
- ✓ Size 20mm x 30mm
- ✓ Modulation : LoRa™ / FSK
- ✓ Maximum output power +14 dBm[1]
- ✓ Maximum sensitivity -137 dBm
- ✓ Line of sight: 15 kms
- ✓ Good buildings penetration
- ✓ Protocol stack software dedicated to wireless sensor application
- ✓ Soldered like a SMD component or plugged through an optional connector
- ✓ SMA connector or 50Ω pad for antenna
- ✓ HW interfaces configuration for direct sensors control via I2C, SPI and UART bus
- ✓ Usable as Modem companion or with embedded customer application software
- ✓ RoHS conform

Applications

- ✓ Automated Meter Reading
- ✓ Home and Building Automation
- ✓ Industrial Monitoring and Control
- ✓ IoT (Internet of Things)
- ✓ Smart Cities

Modem software content

Based on Contiki OS, Nemeus protocol stack includes all layers from LoRa™ physical to CoAP application layer. In companion mode, modem can be accessed to different layers from LoRa-Radio to UDP. Default software includes LoRa radio and LoRa Mac (class A). Other layers are available on request.



*LoRa-MAC is compatible with class A nodes of Low Throughput Networks standard specified by ETSI (LTN).

[1] LoRa MAC maximum output power

Ordering information

Ordering part number	Description
MM001_2C20_SMA	Module MM001 with 2 x 20 pins connectors and SMA connector mounted
MM001_S27	Module MM001 in SMD version with 27 pads

General description

The Nemeus-MM001 is a long range, high-performance, pre-certified[2] (EN 300 220) module for wireless bi-directional communication using patented LoRa™ technology from Semtech company. It operates in the license free ISM 868 MHz frequency band and includes all necessary components for an easy integration in existing systems. With high interference robustness, a max sensitivity of -137dBm, a low consumption (less than 2uA in Idle mode with RTC), this module is the best solution for low throughput application requiring a long battery lifetime and a secured radio link. Integration of this module eases fast-time to market.

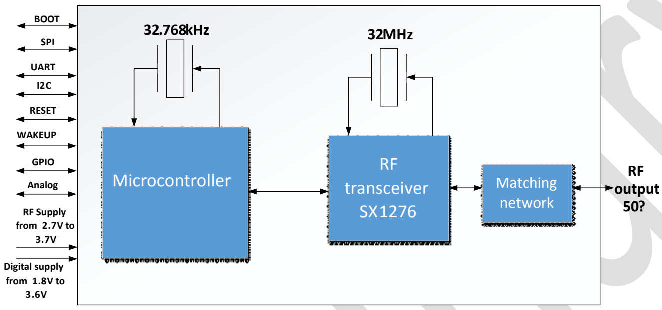


Figure 1. Simplified block diagram

By default, this module is provided with LoRa Mac (vers A) and Sx1276 driver software in order to be used as Modem only solution controlled through UART and wake-up pins. Other layers (IDP, UDP) or HW interfaces (SPI, I2C) are available on request.

Application software integration can be done on request.

The Nemeus-MM001 is declined into 2 versions :

MM001_2C20_SMA : Including an SMA and two Hirose connectors, this version allows the user to exploit all the microcontroller features. The rich interfaces on the Hirose connectors allow to develop a complete solution by connecting the module to a dedicated power/sensors board. Integration of application software into microcontroller allow to develop a low cost HW solution withn limited consumption.

MM001_S27 : With a more classical architecture, this version is provided without SMA and Hirose connectors. It must be soldered onto a dedicated power/sensors board. It is dedicated to application requesting a limited number of interfaces (UART, I2C, SPI) with cost reduction constraints. As the MM001_2C20_SMA, this version can integrate the application software for a global system cost reduction.

[2] Under certification

LoRa modulation characteristics

For further information on LoRa™ modulation characteristics and SX1276 RF chipset specification, please refer to [1].

The **Nemeus-MM001** module supports both FSK and LoRa™ spread spectrum modulation techniques. LoRa™ modulation is capable of achieving significantly longer range than existing systems based onto FSK or OOK modulation. At maximum data rate, this modulation allows to achieve sensitivity 8dB better than FSK modulation and up to 20dB with low data rate. The LoRa™ modulation provides also significant advances in selectivity and blocking performance, further improving communication reliability. Another benefit of the spread modulation is that each spreading factor is orthogonal - thus multiple transmitted signals can occupy the same channel without interfering. This also permits simple coexistence with existing FSK based systems. Standard FSK modulation is also provided to allow compatibility with existing systems or standards such as wireless MBUS and IEEE 802.15.4g.

The SX1276 RF chipset offers bandwidth options ranging from 7.8 kHz to 500 kHz with spreading factors ranging from 6 to 12. The LoRa MAC (Class A) limits the bandwidth utilization from 125khz to 250khz and spreading factor from 7 to 12.

Spreading factor

The spread spectrum LoRa™ modulation is performed by representing each bit of payload information by multiple chips of information. The rate at which the spread information is sent is referred to as the symbol rate (Rs), the ratio between the nominal symbol rate and chip rate is the spreading factor and represents the number of symbols sent per bit of information. The range of values accessible with the LoRa™ modem are shown in the following table.

Spreading Factor	Chips/Symbol	LoRa demodulator SNR	LoRa MAC (Class A) compatibility
6	64	-5 dB	No
7	128	-7.5 dB	Yes
8	256	-10 dB	
9	512	-12.5 dB	
10	1024	-15 dB	
11	2048	-17.5 dB	
12	4096	-20 dB	

Table 2 : Range of spreading factors

Note that the spreading factor must be known in advance on both transmit and receive sides of the link as different spreading factors are orthogonal to each other. Note also the resulting signal to noise ratio (SNR) required at the receiver input. It is the capability to receive signals with negative SNR that increases the sensitivity, so link budget and range, of the LoRa receiver.

Coding rate

To further improve the robustness of the link the LoRa™ modem employs cyclic error coding to perform forward error detection and correction. Such error coding incurs a transmission overhead - the resultant additional data overhead per transmission is shown in the table below.

Coding Rate	Cyclic redundancy Rate	Overhead Ratio	LoRA MAC (Class A) compatibility
1	4/5	1,25	Yes
2	4/6	1,5	No
3	4/7	1,75	
4	4/8	2	

Table 3 : Cyclic Coding Overhead

Forward error correction is particularly efficient in improving the reliability of the link in the presence of interference. So that the coding rate (and so robustness to interference) can be changed in response to channel conditions.

LoRa MAC characteristics

For further information on LoRa MAC specification, please refer to [2].

The LoRa MAC layer has been designed to match with battery powered wireless sensors/actuators constraints requiring low cost network. LoRa networks typically are laid out in a star-of-stars topology in which **gateways** relay messages between **end devices** (sensors) and a central **network server** in the backend. Gateways are connected to the network server via standard IP connections while end devices use single-hop LoRa communication to one or many gateways. All communication is generally bi-directional, although uplink communication from an end device to the network server is strongly favored.

Communication between end devices and gateways is spread out among different **frequency channels** and so-called **spreading factors**. In essence, selecting a spreading factor is a trade-off between communication range and data rate whereby communication with different spreading factors does not interfere with each other. Depending on the spreading factor used, LoRa data rates range from 0.3kbps to 40kbps. To maximize both battery life of end devices and overall network capacity, the LoRa network infrastructure and each end device cooperatively manage the spreading factor (i.e., data rate) and RF output for the end device individually by means of an **adaptive data rate** (ADR) scheme.

For time synchronization and the propagation of channel information, gateways periodically broadcast so-called **beacons**. Each beacon minimally contains a set of channels available for random access within a given network and the current GPS time. The broadcasting of beacons is done time-synchronously by all gateways of a network with no interference.

End devices may transmit on any channel available for random access at any time, using any available data rate, as long as the following rules are respected:

- Prior to transmission, the end device uses Listen Before Talk (LBT) to assess that the intended transmission channel is free. If the channel is not free, the end device changes to another channel and repeats the LBT procedure.
- The end device changes channel in a pseudo-random fashion for every transmission since the resulting frequency diversity makes the system more robust to interferences.
- The end device respects the maximum transmit duty cycle relative to the sub-band used (The LoRa MAC enforces a per sub-band transmit duty-cycle limitation that guarantees compliance with the ETSI EN300.220 regulation)

A LoRa network distinguishes between two classes of end devices:

Bi-directional end devices (Class A): End devices of class A allow bidirectional communication at the MAC and application layer whereby after each send operation two very short receive windows are opened. These windows are used to acknowledge the End message in acknowledge mode.

Bi-directional end devices with synchronized receive slots (Class B): End devices of class B allow bidirectional communication at the MAC and application layer whereby both send and receive operations may be scheduled based on the time information contained in the beacons that are broadcasted by all gateways within a network. In addition, like end devices of class A, two receive windows are opened after the end of each send operation.

Adaptative link mechanism

The LoRa MAC layer implements a link adaptation mechanism to minimize power consumption and Frequency spectrum use under transmission quality constraint. The End device link adaptation is controlled by the gateway with two parameters : The data rate and the Tx power.

Data Rate	Configuration
0	LoRa : SF12 / 125khz
1	LoRa : SF11 / 125khz
2	LoRa : SF10 / 125kkz
3	LoRa : SF9 / 125khz
4	LoRa : SF8 / 125khz
5	LoRa : SF7 / 125khz
6	LoRa : SF7 / 250khz
7	FSK : 100kbps

Table 4 : LoRa MAC data rate configuration

Tx Power	Configuration
0	20dBm (if supported)
1	14dBm
2	11dBm
3	8dBm
4	5dBm
5	2dBm

Table 5 : LoRa MAC TX power configuration

ETSI Applicable bands

The LoRa MAC is dedicated to transmission on 868Mhz ISM band. This band (called g – 865Mhz to 868Mhz) is sub-divided in sub-bands g1 to g4 (see [3]). The LoRa MAC implements channels on sub-bands g1 to g3 as follow :

Modulation	BW [khz]	Channel center frequency [Mhz]	FSK bit Rate / LoRa SF – Bit Rate	Nb channels	Sub-band
LoRa	250	868.30	SF7 / 10kbps	1	g1
FSK	250	868.30	100kbps	1	g1
LoRa	125	868.10 868.30 868.50	SF7-SF12/ 0.3-5kbps	3	g1
LoRa	125	868.85 869.05	SF7-SF12/ 0.3-5kbps	2	g2
LoRa	125	869.535	SF7-SF12/ 0.3-5kbps	1	G3

Table 6 : LoRa Mac channels

In order to access the physical medium the ETSI regulations impose some restrictions such maximum time the transmitter can be on or the maximum time a transmitter can transmit per hour. The ETSI regulations allow the choice of using either a duty-cycle limitation or a so-called **Listen Before Talk Adaptive Frequency Agility** (LBT AFA) transmissions management. The current LoRa MAC specification exclusively uses duty-cycled limited transmissions to comply with the ETSI regulations.

The LoRa MAC enforces a per sub-band duty-cycle limitation. Each time a frame is transmitted in a given sub-band (g1, g2, or g3), the time of emission and the on-air duration of the frame are recorded for this sub-band. The same sub-band cannot be used again during the next Toff seconds where:

Toff(subband) = TimeOnAir / DutyCycle(subband)

During the unavailable time of a given sub-band, the device may still be able to transmit on another sub-band. If all sub-bands are unavailable, the device has to wait before any further transmission. The device adapts its channel hoping sequence according to the sub-band availability.

Module control

By default, this module is provided with modem only software including RF SX1276 driver (LoRa radio) and LoRa MAC (class A). Both SX1276 driver and LoRa MAC layer can be controlled through UART 1 with AT commands[3].

For other layers or HW interfaces configuration, please ask Nemeus.

UART configuration

The UART configuration for Modem connection is following :

- Baud Rate : 115200
- Data : 8 bits
- Parity : None
- Stop : 1 bit
- Flow control : None
- End line character : LF

AT commands[4]

Generic commands

Command	Description	Answers
AT+MAC= ON	Radio layers start (MAC, RDC, LoRa-Radio, Radio driver)	OK/KO
AT+MAC= OFF	Radio layers stop (MAC, RDC, LoRa-Radio, Radio driver)	OK/KO

Table 7 : AT Generic commands

SX1276 drivers (LoRa Radio) commands

Command	Description	Answers
AT+RFTX= ?	Tx parameters read	+RFTX: <modulation>,<freq>,<pwr>,<bw>,<sf> **exemple :** +RFTX : LORA,868100000,14,125,7
AT+RFTX= SET, <modulation>, <freq>,<pwr>, <bw>, <sf>	Tx parameters write Only modified parameter can be specified. **example :** AT+RFTX= SET,,,12	OK/KO

[3] Nemeus recommends use of Tera Term application for PC to module connection on Windows
[4] Space after « = » is mandatory for any AT command

AT+RFTX= SEND,<nb_frames>, <interval>	Transmit numbered <nb_frames> with 32 bytes with a space of <interval> in ms. **<u>Default values :</u>** <nb_frames> = 1, <interval> = 500	OK/KO
AT+RFTX= START	FSK Tx continuous transmission (for RF test purpose)	OK/KO
AT+RFTX= STOP	Continuous TX transmission stop	OK/KO
AT+RFRX= ?	Rx parameters read	+RFRX: <modulation>,<freq>,<bw>,<sf> **<u>exemple :</u>** +RFRX : LORA,868100000,125,7
AT+RFRX= SET, <modulation>, <freq>, <bw>, <sf>	Rx parameters write Only modified parameter can be specified. **<u>example :</u>** AT+RFRX= SET,,7	OK/KO
AT+RFRX= RECV	Single Frame reception (come back to IDLE state after reception)	+RFRX: 100%,12000000CAFEDECA… First parameter is PER, Second parameter is received frame starting with frame number and frame payload.
AT+RFRX= START	RX continuous reception	OK/KO Received frame are returned like for AT+RFRX= RECV
AF+RFRX= STOP	RX continuous reception stop	OK/KO
AT+RFRXL= ?	Reception parameters read (RSSI, SNR, raw SNR)	+RFRXL : <rssi>,<snr>,<rawsnr> **<u>Exemple :</u>** +RFRXL: -77.000000,8.000000,34

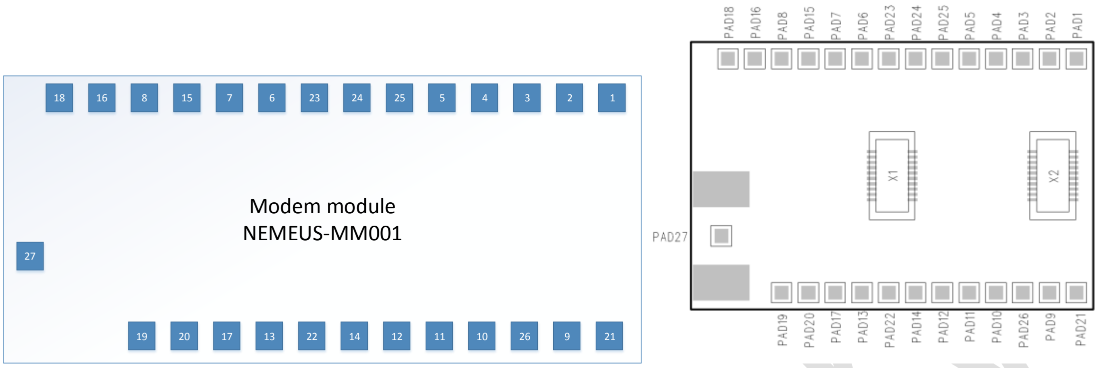
Table 8 : AT LoRa Lario commands

LoRa MAC commands

Command	Description	Answers
AT+MAC= SNDTXT, <text_payload>, <repeat>	Text frame transmission. If <repeat> > 1, frame is send in acknowledge mode with repetition	OK/KO
AT+MAC= SNDBIN, <bin_payload>, <repeat>	Binary frame transmission. If <repeat> > 1, frame is send in acknowledge mode with repetition	OK/KO
AT+MAC= RCVTXT	Continuous text frame reception activation	OK/KO Received data are send back as +MAC: RCVTXT, <text_payload>
AT+MAC= RCVBIN	Continuous binary frame reception activation	OK/KO Received data are send back as +MAC: RCVBIN, <binary_payload>
AT+MAC= STOPRCV	Stop continuous Text or Binary frame reception	OK/KO

Module pins diagram

The following figure gives the bottom side of the MM001_S27 and MM001_2C20_SMA versions.



Compared to MM001_S27, the module MM001_2C20_SMA integrates two Hirose™ connectors (X1 and X2) with reference DF40C-20DS-0.4V(51) and one SMA connector. This version must be "plugged" to a power/sensors board including connectors with reference DF40C-20DP-0.4V(51) whereas this other one must be soldered. On MM001_2C20_SMA, pads are unused (All signals or power line are on Hirose connectors except RF signal).

PAD27 is RF input/output 50Ω signal. On MM001_2C20_SMA module, this one is directly connected to SMA connector on which any 50Ω antenna can be plugged. With MM001_S27 module, this pad must be soldered to a 50Ω line without matching and antenna (external, SMD or PCB) must be as close as possible as the pad for better performances.

Pins usage

Functions class	MM001_S27 PAD name	MM001_2C20_SMA Hirose connectors	Functions	Default function (modem only mode)	Reset/ Boot Mode	USB	USART1	USART2	USART3	SPI1	SPI2	I2C1	I2C2	ADC	DAC	WKUP	GPIO
JTAG	-	**X2-1**	JTMS-SWDAT	JTMS-SWDAT	N/A												
	-	**X2-3**	JTCK-SWCLK	JTCK-SWCLK													
	-	**X2-5**	JTDI	JTDI													
	-	**X2-7**	JTDO	JTDO													
	-	**X2-9**	NJTRST	NJTRST													
Reset/ Boot	**PAD9**	**X2-20**	NRESET	NRESET													
	PAD21	**X2-17**	BOOT0	BOOT0													
	PAD15	**X1-4**	GPIO/BOOT1	-	BOOT1												GPIO#0
Sensors/Actuators pins	**PAD14**	**X1-13**	WKUP1/USART2_CTS/ADC_IN0/TIM2_CH1_ETR/COMP1_INP/GPIO	-				USART#2						ADC#1		WKUP#1	GPIO#1
	-	**X1-15**	USART2_RTS/ADC_IN1/TIM2_CH2/LCD_SEG0/COMP1_INP/GPIO	-										ADC#2			GPIO#2
	-	**X1-17**	USART2_TX/ADC_IN2/TIM2_CH3/TIM9_CH1/LCD_SEG1/COMP1_INP/GPIO	-										ADC#3			GPIO#3
	-	**X1-18**	USART2_RX/ADC_IN3/TIM2_CH4/TIM9_CH2/LCD_SEG2/COMP1_INP/GPIO	-										ADC#4			GPIO#4
	PAD22	**X1-19**	SPI1_NSS/USART2_CK/ADC_IN4/DAC_OUT1/COMP1_INP/GPIO	-										ADC#5	DAC#1		GPIO#5

Functions?class	001_S27?PAD n	20_SMA?Hirose	Functions	Default function (modem only mode)	Reset/ Boot Mode	USB	USART1	USART2	USART3	SPI1	SPI2	I2C1	I2C2	ADC	DAC	WKUP	GPIO
	-	X2-1	JTMS-SWDAT	JTMS-SWDAT	N/A												
	-	X2-3	JTCK-SWCLK	JTCK-SWCLK													
	-	X2-5	JTDI	JTDI													
	-	X2-7	JTDO	JTDO													
	-	X2-9	NJTRST	NJTRST													
	PAD9	X2-20	NRESET	NRESET													
	PAD21	X2-17	BOOT0	BOOT0													
	PAD15	X1-4	GPIO/BOOT1	-	BOOT1												GPIO#0
	PAD14	X1-13	WKUP1/USART2_CTS/ADC_IN0/TIM2_CH1_ETR/COMP1_INP/GPIO	-				USART#2						ADC#1		WKUP#1	GPIO#1
	-	X1-15	USART2_RTS/ADC_IN1/TIM2_CH2/LCD_SEG0/COMP1_INP/GPIO	-										ADC#2			GPIO#2
	-	X1-17	USART2_TX/ADC_IN2/TIM2_CH3/TIM9_CH1/LCD_SEG1/COMP1_INP/GPIO	-										ADC#3			GPIO#3
	-	X1-18	USART2_RX/ADC_IN3/TIM2_CH4/TIM9_CH2/LCD_SEG2/COMP1_INP/GPIO	-										ADC#4			GPIO#4
	PAD22	X1-19	SPI1_NSS/USART2_CK/ADC_IN4/DAC_OUT1/COMP1_INP/GPIO	-										ADC#5	DAC#1		GPIO#5

Sensors/Actuators pins	**PAD10**	**X2-16**	GPIO	RF_PWR_CTRL	**N/A**												
	PAD11	**X2-14**	ADC_IN12/LCD_SEG20/ COMP1_INP/GPIO	-										ADC#13			GPIO#23
	PAD12	**X2-12**	ADC_IN13/LCD_SEG21/ COMP1_INP/GPIO	-										ADC#14			GPIO#24
	PAD13	**X1-11**	ADC_IN14/LCD_SEG22/ COMP1_INP/GPIO	-										ADC#15			GPIO#25
	-	**X1-12**	ADC_IN15/LCD_SEG23/ COMP1_INP/GPIO	-										ADC#16			GPIO#26
	-	**X2-19**	RTC_AF1/WKUP2 /GPIO	-												WKUP#2	GPIO#27
PWR	**PAD17**	**X1-16**	VCC_DIG	VCC_DIG	**N/A**												
	PAD20	**X1-14**	VCC_DIG_RF	VCC_DIG_RF													
	PAD16	**X1-8**	VCC_ANA	VCC_ANA													
	PAD18	**X1-10**	GND	GND													
	PAD19	**X1-20**	GND	GND													
RF IN/OUT	**PAD27**	**-**	ANT	ANT													

For extra control of module pins and application software integration, please ask Nemeus.

Recommendations

BOOT0 pin

Except for downloading new modem software, BOOT0 pin must be pull-down to GND.

NRESET Pin

NRESET Pin must be set to GND before Module PWR-UP.

RF_PWR_CTRL Pin

Nemeus modem module does not embed power control feature, considering that this feature must be designed according to the global system constraints. This approach let the final designer to choose the best solution between basic power control or power IC.

Nevertheless, the power/sensors board must embed a mechanism to power-on the VCC_DIG_RF and VCC_ANA power lines when RF_PWR_CTRL pin is set to VCC_DIG. This signal must be pull-down to GND.

Electrical characteristics

Absolute maximum rating

Symbol	Description	Min	Max	Unit
VCC_ANA	RF analog power supply	2.7	3.9	V
VCC_DIG_RF	RF digital power supply	2.7	3.9	V
VCC_DIG	Digital power supply	1.65	4	V
Temperature		-40	+85	°C
PwIN	RF input power	-	+10	dBm

Operating range

Symbol	Description	Min	Max	Unit
VCC_ANA	RF analog power supply	2.7	3.7	V
VCC_DIG_RF	RF digital power supply	2.7	3.7	V
VCC_DIG	Digital power supply	1.8	3.6	V
Temperature		-40	+85	°C
PwIN	RF input power	-	+10	dBm

Current consumption

Three states must be considered for current consumption:

- Modem module in IDLE mode with RTC like function
- Modem module in TX mode
- Modem module in RX mode

Conditions: VCC_ANA=3.3V, VCC_DIG=3.3V, VCC_DIG_RF=3.3V, T=25°C

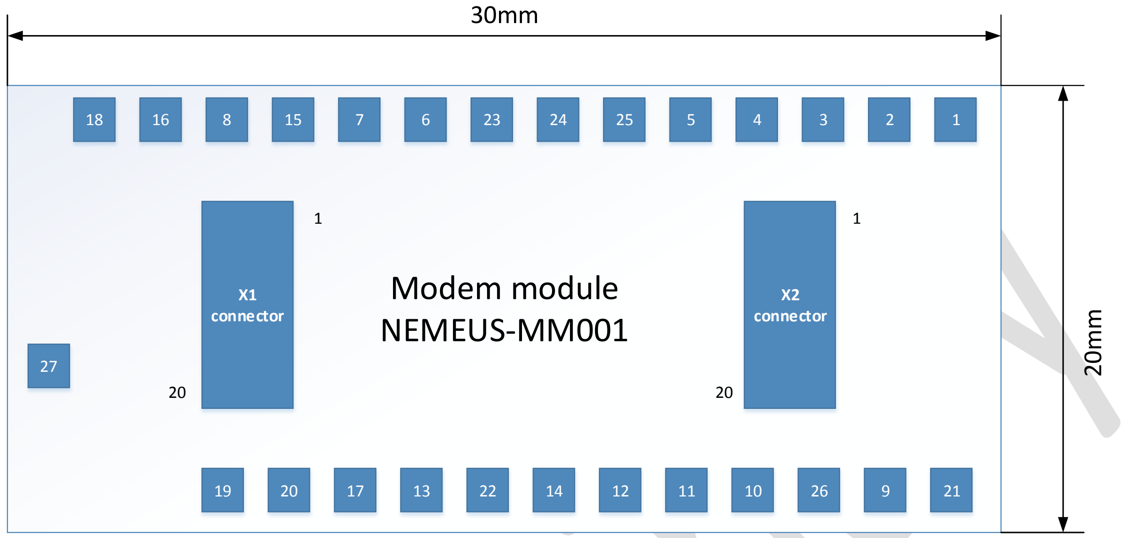
Symbol	Description	Conditions	Min	Typ.	Max	Unit
ICC_ANA_IDLE	Modem in IDLE mode	-	-	0 (*)	-	uA
ICC_DIG_RF_IDLE			-	0 (*)	-	uA
ICC_DIG_IDLE			-	1.5/1.7 (+)	-	uA
ICC_ANA_TX	Modem in TX mode	Tx power = +7dBm	-	20	-	mA
ICC_DIG_RF_TX						
ICC_DIG_TX			-	3.3	-	mA
ICC_ANA_TX	Modem in TX mode	Tx power = +13dBm	-	30	-	mA
ICC_DIG_RF_TX						
ICC_DIG_TX			-	3.3	-	mA
ICC_ANA_TX	Modem in RX mode	-	-	12.5	-	mA
ICC_DIG_RF_TX						
ICC_DIG_TX			-	3.3	-	mA

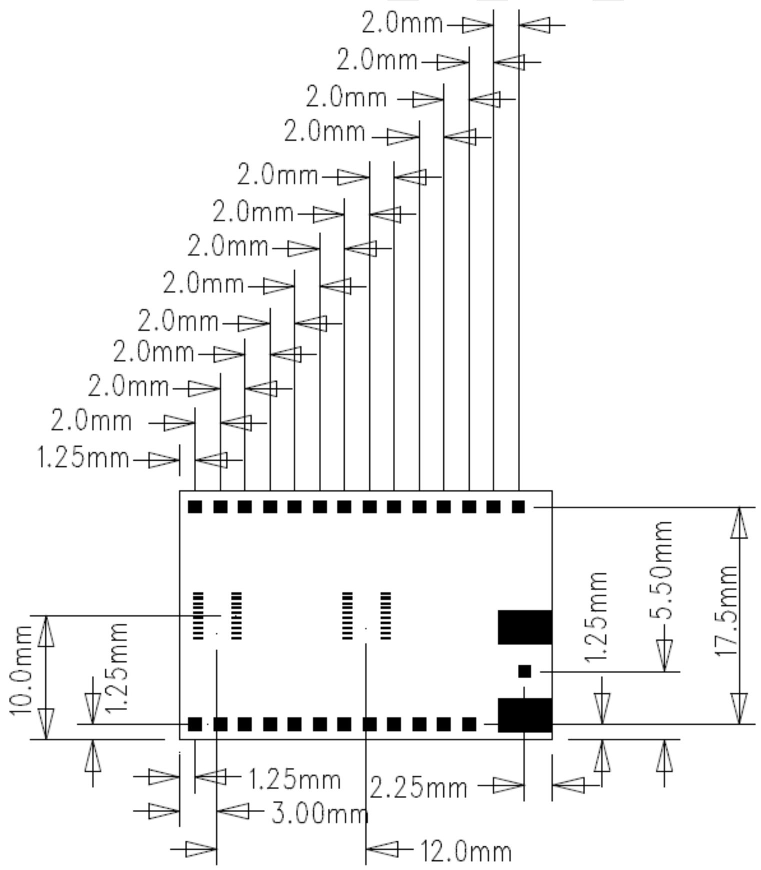
(*) With external control of VCC_ANA and VCC_DIG_RF power lines from RF_PWR_CTRL signal.

(+) Consumption depends on the uC RTC mode used. With High wake-up precision, the consumption equals 1.7uA. If high precision not needed, low precision RTC can be used and 1.5uA consumption can be reached.

Packaging information

Module dimension





Recommended footprints

Intentionally left blank