RAK831 Lora Gateway Datasheet V1.3

Content

Content....2
1. Introduction....3
1.1 Key Features....4
1.2 Applications....4
2.Module Package....5
2.1 Pinout Description....5
2.2 Module Dimensions....6
3.Module Overview....7
3.1 SX1301....7
3.1.1 Block Diagram....8
3.1.2 IF8 LORA channel....8
3.1.3 IF9 (G) FSK channel....9
3.1.4 IF0 to IF7 LORA channels....9
3.3 External Module Connector....10
3.3.1 SPI....10
3.3.2 GPS PPS....10
3.3.3 Digital IOs....10
4.LoRa Systems, Network Approach....11
4.1 Overview....11
4.2 Firmware....11
5.Electrical Characteristics&Timing specifications....12
5.1 Absolute Maximum Ratings....12
5.2 Global Electrical Characteristics....12
5.3 SPI Interface Characteristics....13
5.4 RF Characteristics....13
5.4.1 Transmitter RF Characteristics....13
5.4.2 Receiver RF Characteristics....14
5.5. RF Key Components....14
5.6. RF antenna interface....15
6.Ordering Information....17
7. Contact information....18
8.Appendix....19
9. Change Note....20

1.Introduction

The concentrator module RAK831 is targeted for a huge variety of applications like Smart Metering, IoT and M2M applications. It is a multi- channel high performance Transmitter/receiver module designed to receive several LoRa packets simultaneously using different spreading factors on multiple channels. The concentrator module RAK831 can be integrated into a gateway as a complete RF front end of this gateway. It provides the possibility to enable robust communication between a LoRa gateway and a huge amount of LoRa end-nodes spread over a wide range of distance. The RAK831 needs a host system for proper operation.

This is a ideal modular products to help you realize the whole Lora system development. With the USB-SPI converter module FT2232, you can quickly to make the software development in your PC. But also, you can integrate the concentrator module to your production product to realize the Lora gateway function.This is very economic way to address for a huge variety of applications like Smart Grid, Intelligent Farm,intelligent Farm and Other IoT applications.

The RAK831 needs a host system like Raspberry Pi or WisAP(OpenWRT based) or WisCam for proper operation . The host processor can be a PC or MCU that will be connected to RAK831 via USB or SPI

RAK831 is able to receive up to 8 LoRa packets simultaneously sent with different spreading factors on different channels. This unique capability allows to implement innovative network architectures advantageous over other short range systems:

End-point nodes (e.g. sensor nodes) can change frequency with each transmission in a random pattern. This provides vast improvement of the system robustness in terms of interferer immunity and radio channel diversity.

1.1 Key Features

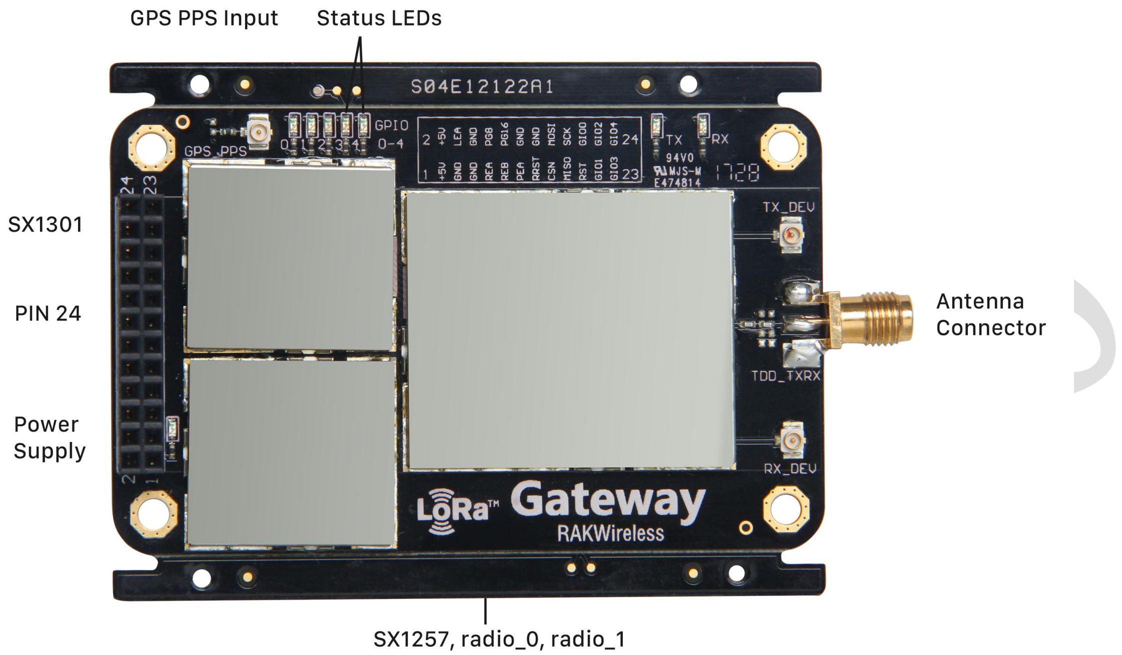
- Compact size 80.0 x 50.0 x 5.0mm
- LoRa^{TM} modulation technology
- Frequency band 433,470, 868,915MHz
- Orthogonal spreading factors
- Sensitivity down to -142.5 dBm
- Maximum link budget162 dB
- SPI interface
- SX1301 base band processor
- Emulates 49 x LoRa demodulators
- 12 parallel demodulation paths
- 1 (G)FSK demodulator
- 2 x SX1257 Tx/Rx front-ends High frequency
- 2 x SX1255 Tx/Rx front-ends low frequency
- Supply voltage 5 V
- RF interface optimized to 50
- Output power level up to 23 dBm
- GPS receiver (optional)
- Range up to 15 km (Line of Sight)
- Range of several km in urban environment
- Status LEDs
- HAL is available from
  https://github.com/RAKWireless/RAK831_LoRaGateway

1.2 Applications

- Smart Metering
- Wireless Star Networks
-.Home,Building,Industrial automation
- Remote Control
- Wireless Sensors
- M2M, IoT
- Wireless Alarm and Security Systems
- …

2.Module Package

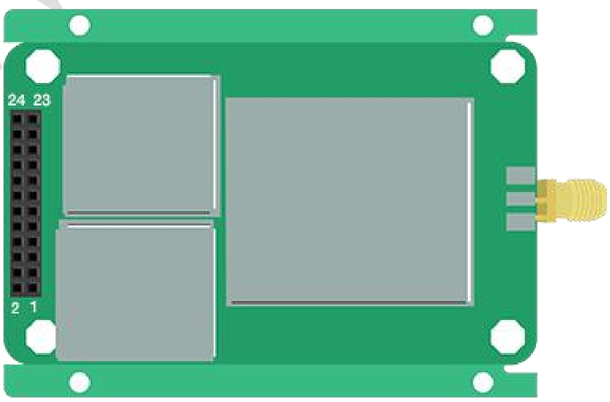
In the following the RAK831 module package is described. This description includes the RAK831 pinout as well as the modules dimensions.



2.1 Pinout Description

The RAK831 provides headers at the bottom side, which have a pitch of 2.54 mm. The description of the pins is given by belowTable .

+5V	1	+5V	2
GND	3	LNA_EN_A	4
GND	5	GND	6
RADIO_EN_A	7	PA_G8	8
RADIO_EN_B	9	PA_G16	10
PA_EN_A	11	GND	12
RADIO_RST	13	GND	14
CSN	15	MOSI	16
MISO	17	SCK	18
RESET	19	GPIO0	20
GPIO1	21	GPIO2	22
GPIO3	23	GPIO4	24

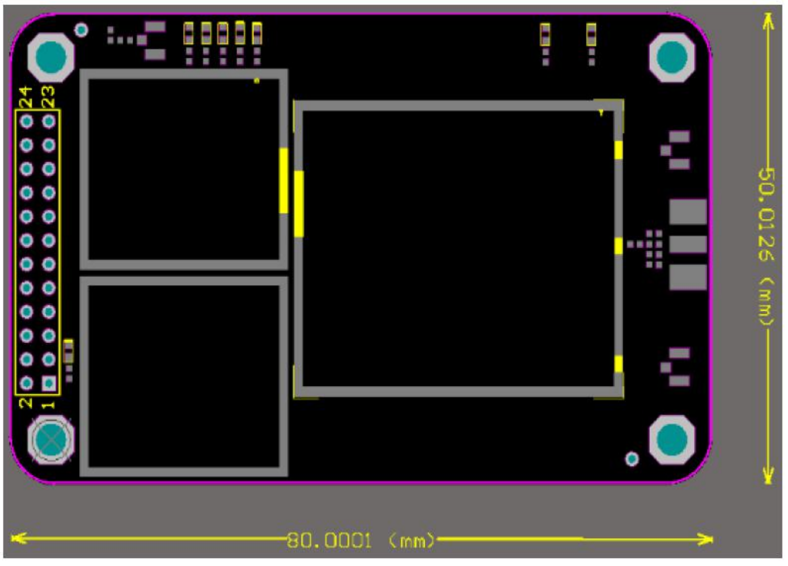


Pin	Name	Type	Description
1	+5V	POWER	+5V Supply Voltage
2			
3	GND	GND	GND
4	LNA_EN_A	Input	SX1301 Radio C Sample Valid
5	GND	GND	GPS Module LDO:Enable Pin

6	GND	GND	GND
7	RADIO_EN_A	Input	SX1257_A_EN
8	PA_G8	Input	PA GAIN 0
9	RADIO_EN_B	Input	SX1257_B_EN
10	PA_G16	Input	PA GAIN 1
11	PA_EN_A	Input	PA EN
12	GND	GND	GND
13	RADIO_RST	RST	SX1257_A_B RESET
14	GND	GND	GND
15	CSN	SPI	SX1301 SPI_NSS
16	MOSI	SPI	SX1301 SPI_MOSI
17	MISO	SPI	SX1301 SPI_MISO
18	SCK	SPI	SX1301 SPI_CLK
19	RESET	RST	SX1301 RESET
20	GPIO0	GPIO	SX1301 GPIO
21	GPIO1	GPIO	SX1301 GPIO
22	GPIO2	GPIO	SX1301 GPIO
23	GPIO3	GPIO	SX1301 GPIO
24	GPIO4	GPIO	SX1301 GPIO

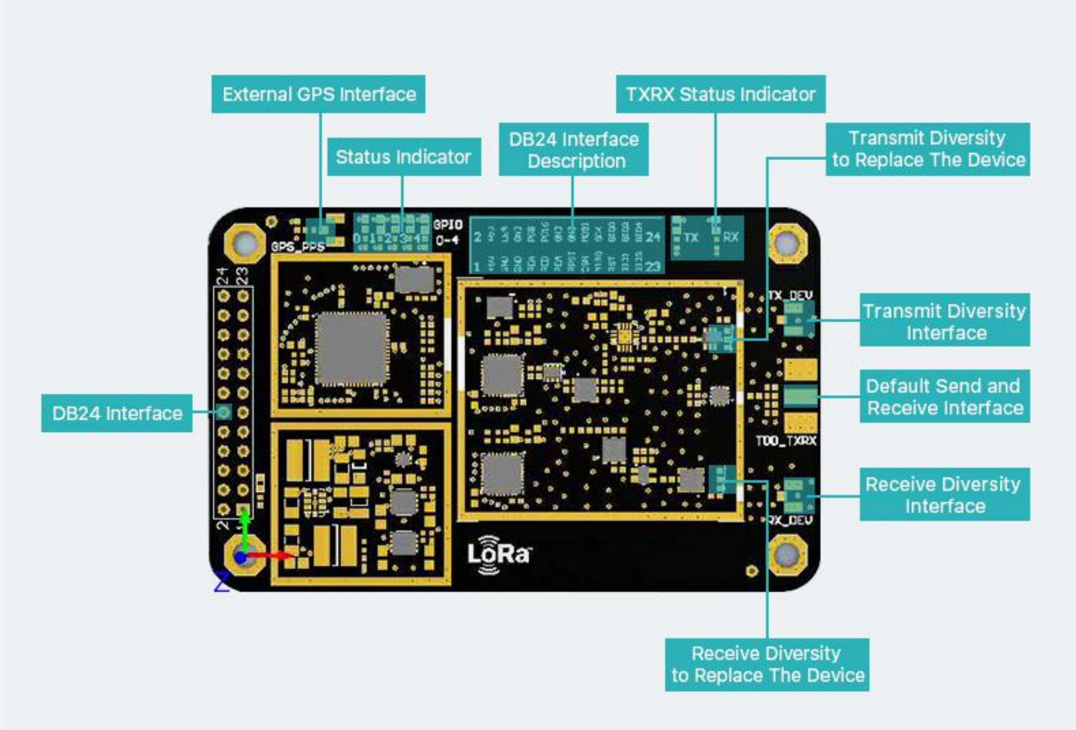
2.2 Module Dimensions

The outer dimensions of the RAK831 are given by 80.0 x 50.0 mm ± 0.2 mm. The RAK831 provide four drills for screwing the PCB to another unit each with a drill diameter of 3 mm.



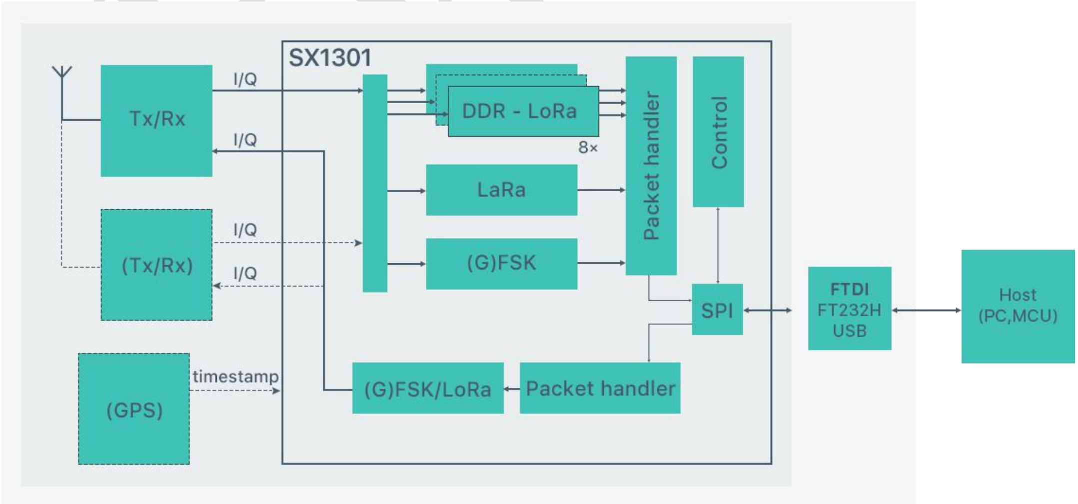
3.Module Overview

The Concentrator Module is currently available in one versions with SPI interface.



3.1 SX1301

The RAK831 includes Semtech's SX1301 which is a digital baseband chip including a massive digital signal processing engine specifically designed to offer breakthrough gateway capabilities in the ISM bands worldwide. It integrates the LoRa concentrator IP.



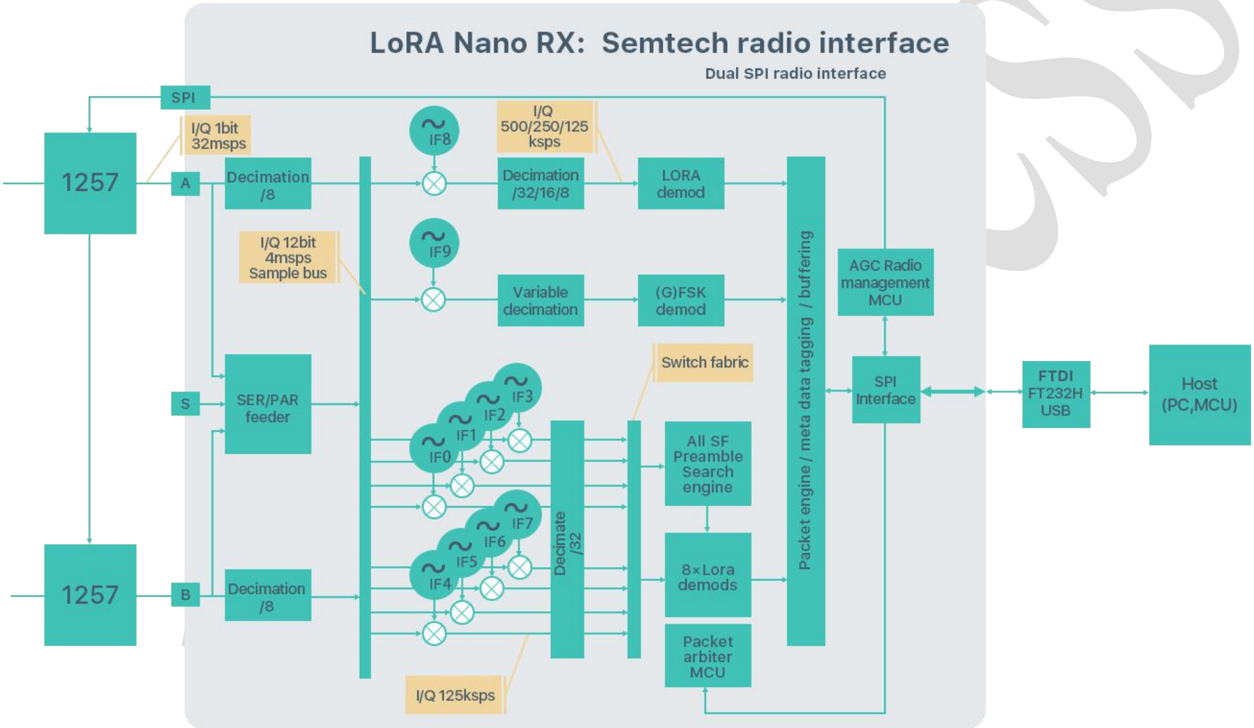
The SX1301 is a smart baseband processor for long range ISM communication. In the receiver part, it receives I and Q digitized bit stream for one or two receivers (SX1257), demodulates these signals using several demodulators, adapting the demodulators settings to the received signal and stores the received demodulated packets in a FIFO to be retrieved from a host system (PC, MCU). In the transmitter part, the packets are modulated using a programmable (G)FSK/LoRa modulator and sent to one transmitter (SX1257). Received packets can be time-stamped using a GPS PPS input.

The SX1301 has an internal control block that receives microcode from the host system (PC, MCU). The microcode is provided by Semtech as a binary file to load into the SX1301 at power-on (see Semtech application support for more information).

The control of the SX1301 by the host system (PC, MCU) is made using a Hardware Abstraction Layer (HAL). The Hardware Abstraction Layer source code is provided by Semtech and can be adapted by the host system developers.

It is highly recommended to fully re-use the latest HAL as provided by Semtech on https://github.com/Lora-net.

3.1.1 Block Diagram



The SX1301 digital baseband chip contains 10 programmable reception paths. Those paths have differentiated levels of programmability and allow different use cases. It is important to understand the differences between those demodulation paths to make the best possible use from the system.

3.1.2 IF8 LORA channel

This channel is connected to one SX1257 using any arbitrary intermediate frequency within the allowed range. This channel is LoRa only. The demodulation bandwidth can be configured to be 125, 250 or 500 kHz. The data rate can be configured to any of the LoRa available data rates (SF7 to SF12) but, as opposed to IF0 to IF7, only the configured data rate will be demodulated. This channel is intended to serve as a high speed backhaul link to other gateways or infrastructure equipment. This demodulation path is compatible with the signal transmitted by the SX1272 and SX1276 chip family.

3.1.3 IF9 (G) FSK channel

The IF9 channel is connected to a GFSK demodulator. The channel bandwidth and bit rate can be adjusted. This demodulator offers a very high level of configurability, going well beyond the scope of this document. The demodulator characteristics are essentially the same than the GFSK demodulator implemented on the SX1232 and SX1272 Semtech chips. This demodulation path can demodulate any legacy FSK or GFSK formatted signal.

3.1.4 IF0 to IF7 LORA channels

Those channels are connected to one SX1257. The channel bandwidth is 125 kHz and cannot be modified or configured. Each channel IF frequency can be individually configured. On each of those channels any data rate can be received without prior configuration.

Several packets using different data rates (different spreading factors) may be demodulated simultaneously even on the same channel. Those channels are intended to be used for a massive asynchronous star network of 10000's of sensor nodes. Each sensor may use a random channel (amongst IF0 to IF7) and a different data rate for any transmission.

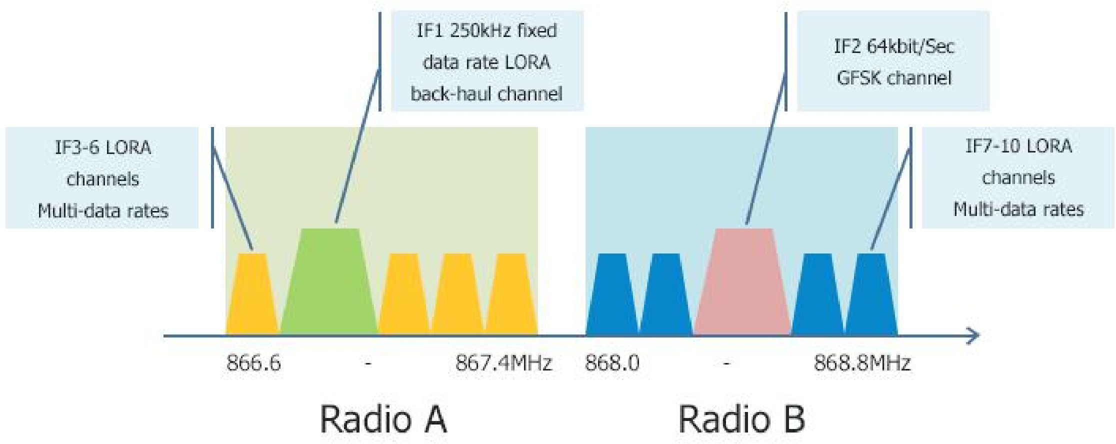
Sensors located near the gateway will typically use the highest possible data rate in the fixed 125 kHz channel bandwidth (e.g. 6 kbit/s) while sensors located far away will use a lower data rate down to 300 bit/s (minimum LoRa data rate in a 125 kHz channel).

The SX1301 digital baseband chip scans the 8 channels (IF0 to IF7) for preambles of all data rates at all times.

The chip is able to demodulate simultaneously up to 8 packets. Any combination of spreading factor and intermediate frequency for up to 8 packets is possible (e.g. one SF7 packet on IF0, one SF12 packet on IF7 and one SF9 packet on IF1 simultaneously).

The SX1301 can detect simultaneously preambles corresponding to all data rates on all IF0 to IF7 channels. However, it cannot demodulate more than 8 packets simultaneously. This is because the SX1301 architecture separates the preamble detection and signal acquisition task from the demodulation process. The number of simultaneously demodulated packets (in this case 8) is an arbitrary system parameter and may be set to other values for a customer specific circuit.

The unique multi data-rate multi-channel demodulation capacity SF7 to SF12 and of channels IF0 to IF7 allows innovative network architectures to be implemented.



3.3 External Module Connector

3.3.1 SPI

The connector on the bottom side provides an SPI connection, which allows direct access to the Sx1301 SPI interface. This gives the target system the possibility to use existing SPI interfaces to communicate.

After powering up RAK831 ,it is required to reset SX1301 via PIN 13. If the Hal driver from Github is used this functionality is already implemented.

3.3.2 GPS PPS

In case of available PPS signals in the target system, it is possible to connect this available signal to the appropriate pin at the connector.

3.3.3 Digital IOs

There are five GPIOs of the Sx1301 available, which gives the user some possibilities to get information about the system status. Theses pins are the same, as they are used for the LEDs on the RAK831 .

As default setting the LEDs :

1) Backhaul packet
2) TX packet
3) RX Sensor packet
4) RX FSK packet
5) RX buffer not empty
6) Power

4.LoRa Systems, Network Approach

The use of LoRa technology can be distinguished in “Public” and “Private” networks. In both cases the usage of a concentrator module can be reasonable. Public networks are operator (e.g. telecom) managed networks whereas private networks are individually managed networks.

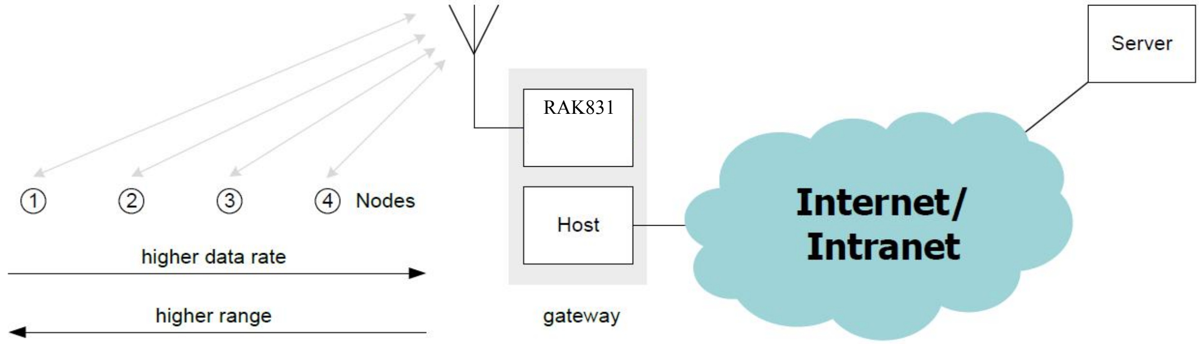
LoRa networks are typically star or multiple star networks where a gateway relays the packets between the end-nodes and a central network server. For private network approaches the server can also be implemented on the gateway host.

Due to the possible high range the connection between end-nodes and the concentrator RAK831 is always a direct link. There are no repeaters or routers within a LoRa network.

Depending on the used spreading factor and signal bandwidth different data rates1 (0.3 kbps to ~22 kbps) and sensitivities down to -142.5 dBm are possible. Spreading factor and signal bandwidth are a trade-off between data rate and communication range.

4.1 Overview

The RAK831 is able to receive on different frequency channels at the same time and is able to demodulate the LoRa signal without knowledge of the used spreading factor of the sending node.



Due to the fact that the combination of spreading factors and signal bandwidths results in different data rates the use of “Dynamic Data-Rate Adaption” becomes possible. That means that LoRa nodes with high distances from the RAK831 must use higher spreading factors and therefore have a lower data rate. LoRa nodes which are closer to the concentrator can use lower spreading factors and therefore can increase their data rate.

Due to the fact that spreading factors are orthogonal and RAK831 supports up to 10 demodulations paths the channel capacity of a LoRa cell can be increased using RAK831 compared to conventional modulation techniques.

4.2 Firmware

The LoRa MAC specification is currently driven by the companies Semtech, IBM and Actility. Currently all available software, firmware and documentation can be found and downloaded from the open source project LoRa-net hosted on https://github.com/Lora-net

This project considers all parts that are needed to run a network based on LoRa technology. It includes the node firmware (several hardware platforms are supported), the gateway host software (HAL driver for SX1301, packet forwarder) and a server implementation.

It is highly recommended to fully re-use the latest HAL as provided by Semtech.

5.Electrical Characteristics&Timing specifications

In the following different electrical characteristics of the RAK831 are listed. Furthermore details and other parameter ranges are available on request.

Note: Stress exceeding of one or more of the limiting values listed under “Absolute Maximum Ratings” may cause permanent damage to the radio module.

5.1 Absolute Maximum Ratings

Parameter	Condition	Min	Typ.	Max	Unit
Supply Voltage(VDD)		-0.3	5.0	5.5	V
Operating Temperature		-40		+85	℃
RF Iuput Power				-15	dBm
Note:					

Note: With RF output power level above +15 dBm a minimum distance to a transmitter should be 1 m for avoiding too large input level.

5.2 Global Electrical Characteristics

Parameter	Condition	Min	Typ.	Max	Unit
Supply Voltage(VDD)		4.8	5.0	5.2	V
Current Consumption	RX Current		100		mA
	TX Current		80		
Note:					

T=25℃,VDD=5V(Typ.) if nothing else stated

Parameter	Condition	Min	Typ.	Max	Unit
Logic low input threshold(VIL)	“0”logic input			0.4	V
Logic high input threshold(VIH)	“1”logic input	2.9		3.3	V
Logic low output level(VOL)	“0”logic output,2mA sink			0.4	V
Logic high output level(VOH)	“1”logic output,2mA source	2.9		3.3	V
Note:					

5.3 SPI Interface Characteristics

T=25℃,VDD=5V(Typ.) if nothing else stated

Parameter	Condition	Min	Typ.	Max	Unit
SCK frequency				10	MHz
SCK high time		50			ns
SCK low time		50			ns
SCK rise time			5		ns
SCK fall time			5		ns
MOSI setup time	From MOSI change to SCK rising edge	10			ns
MOSI hold time	From SCK rising edge to MOSI change	20			ns
NSS setup time	From NSS falling edge to SCK rising edge	40			ns
NSS hold time	From SCK falling edge to NSS rising edge	40			ns
NSS high time between SPI accesses		40			ns
Note:					

5.4 RF Characteristics

5.4.1 Transmitter RF Characteristics

The RAK831 has an excellent transmitter performance . It is highly recommended, to use an optimized configuration for the power level configuration, which is part of the HAL. This results in a mean RF output power level and current consumption .

PA Control	DAC Control	MIX Control	DIG Gain	Nominal RF Power Level [dBm]
0	3	8	0	-5
0	3	9	0	-3
0	3	11	0	0
0	3	15	0	3
1	3	9	0	6
1	3	11	0	10
1	3	12	0	11
2	3	8	0	12
2	3	9	0	13
1	3	15	0	14
2	3	10	0	15
2	3	11	0	16
2	3	11	0	17
2	3	12	0	18
2	3	13	0	19
2	3	14	0	20

T=25℃,VDD=5V(Typ.) if nothing else stated

Parameter	Condition	Min	Typ.	Max	Unit
Frequency Range		863		870	MHz
Modulation Techniques	FSK/LoRaTM				
TX Frequency Variation vs. Temperature	Power Level Setting:20	-3		+3	KHz
TX Power Variation vs. Temperature		-5		+5	dB
TX Power Variation		-1.5		+1.5	dB

Note：Also support 433,470,915 Frequency Range.

5.4.2 Receiver RF Characteristics

It is highly recommended, to use optimized RSSI calibration values, which is part of the HAL v3.1. For both, Radio 1 and 2, the RSSI-Offset should be set -169.0.

The following table gives typically sensitivity level of the RAK831 :

Signal Bandwidth/[KHz]	Spreading Factor	Sensitivity/[dBm]
125	12	-137
125	7	-126
250	12	-136
250	7	-123
500	12	-134
500	7	-120

5.5. RF Key Components

This section introduces the key components in RAK831 and help the developer to utilize the system to realize own system level design.

1) LDO

The system power supply is provided by the external 5V DC power supply. SX1301 and related clock crystal is powered by Dual output LDO transformer outputs 1.8V and 3.3V in order to meet the normal working condition of SX1301. Other key components are powered by LDO transformer output 3.3V. To be aware of the system design of LDO's power supply enable is provided by the output GPIO of SX1301 as default. The connection method of pin enable should be kept same as Semtech official code. At the same time, System design also need to keep flexibility and all LDO enable should be connect to pin DB24. For this case, user can run the official reference code in this board, and also can change all external enable clock as they need for achieve the flexibility debugging.

2) Power amplifier

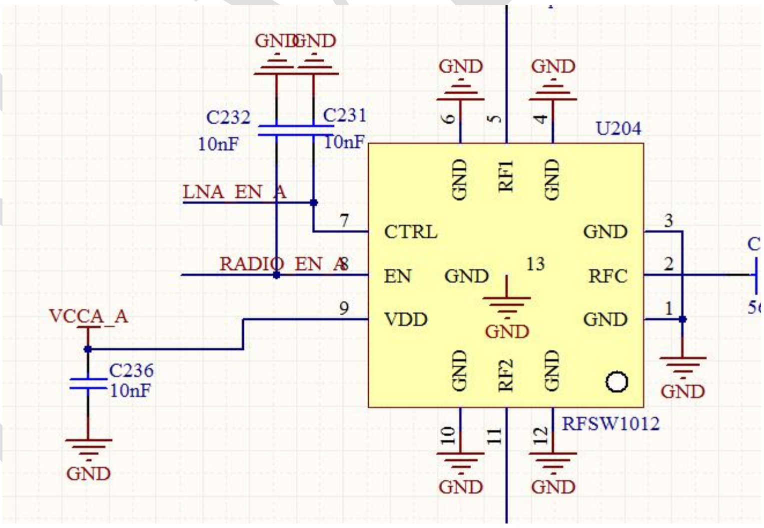
The Power amplifier chooses RFMD LF Power Amplifier and built in two steps gain. It realize the Max. 0.5w output power.The frequency range can cover from 380MHZ~960MHz. The two steps gain control table as:

Parameter	Specification			Unit	Condition
	Min.	Typ.	Max.		
Overall					T=25 °C, V_{CC}=3.6V, V_{PD}=V_{BIAS}=3.0V, P_{IN}=0dBm, Freq=915MHz
CW Output Power		27.5		dBm	V_{CC}=3.6V
CW Output Power		30		dBm	V_{CC}=5V
Small Signal Gain		32		dB	P_{IN}=-10dBm
Second Harmonic		23		dBc	Without external second harmonic trap
Third Harmonic		45		dBc	
CW Efficiency	55	63		%	G16="high", G8="high", P_{IN}=0dBm
Power Down "ON"		3.0		V	Voltage supplied to the input
Power Down "OFF"	0	0.5	0.8	V	Voltage supplied to the input
VPD Input Current		6		mA	Only in "ON" state
G16, G8 "ON"	1.7		3.0	V	Voltage supplied to the input
G16, G8 "OFF"	0		0.7	V	Voltage supplied to the input
G16, G8 Input Current		1.0		mA	Only in "ON" state
Output Power	26.5	27.5	29	dBm	G16="high", G8="high", P_{IN}=0dBm
	21	23	25	dBm	G16="high", G8="low", P_{IN}=0dBm
	14	16	18	dBm	G16="low", G8="high", P_{IN}=0dBm
	3	5	8	dBm	G16="low", G8="low", P_{IN}=0dBm
Turn On/Off Time		200		ns	

3）RF switch

The RF switch choose RFSW1012 which has advantage of high Isolation and low insertion loss. This chip handling the switch between Tx and Rx. The Control logic as below image.Specially need highlight that the pin of CTRL was controlled by SX1301's GPIO through output signal of LNA_EN_A, the Pin of EN was controlled by SX1301's GPIO through output signal of RADIO_EN_A. Simultaneously,it also can be controlled by external input signal through DB24.

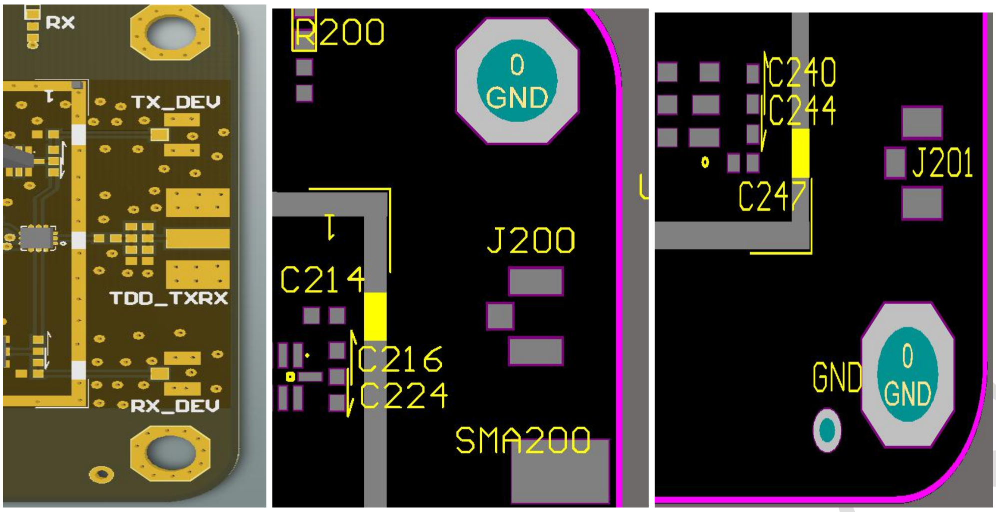
State	V_{DD}	CTRL	EN	RF Path
1	2.7V to 4.6V	V_{HIGH}	V_{HIGH}	ANT-RF2
2	2.7V to 4.6V	V_{LOW}	V_{HIGH}	ANT-RF1
Shutdown	2.7V to 4.6V	Don't Care	V_{LOW}	Shutdown



5.6. RF antenna interface

RAK831 provide three types of RF interface like SMA and other two IPEX connector.See the image as below for TDD_TXRX、TX_DEV、RX_DEV. Consider the developer may require supporting Tx/Rx simultaneously,therefore to make the compatible design. The Tx_DEV is the Tx channel, need change the C224 to NC and C216 with CAP(56pf/0402) or 0ohm resistance when using as standalone channel.RX_DEV is the Rx channel, need change C240 to NC and C244 with CAP(56pF/0402) or

0ohm resistance. The default design selects the Path to TDD_TXRX via RF switch and using external antenna.



6.Ordering Information

P/N	Band Frequency
RAK831_433	433MHz
RAK831_470	470MHz
RAK831_868	868MHz
RAK831_915	915MHz

We also can help customer to build customize version,pls contact with your sales window to get the detail information.

7.Contact information

Shenzhen Business

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Xili Block, Nanshan District, Shenzhen

Shenzhen Technical

E-Mail: steven.tang@rakwireless.com

Tel : 0755-86108311

Address: Room 506, Bldg. 3, Minqi Technology Park, No.65 Taoyuan Road,

Xili Block, Nanshan District, Shenzhen

8.Appendix

AFA	Adaptive Frequency Agility
BER	Bit Error Rate
BSC	Basic Spacing between Centers
GND	Ground
GPIO	General Purpose Input/Output
GPS	Global Positioning System
HAL	Hardware Abstraction Layer
IF	Intermediate Frequency
IoT	Internet of Things
ISM	Industrial, Scientific and Medical
LBT	Listen Before Talk
M2M	Machine to Machine
MAC	Medium Access Control
MCU	Microcontroller Unit
MPSSE	Multi-Protocol Synchronous Serial Engine (FTDI)
PCB	Printed Circuit Board
PPS	Pulse Per Second
RAM	Random Access Memory
RF	Radio Frequency
SMT	Surface Mounted Technology
SNR	Signal to Noise Ratio
SPI	Serial Peripheral Interface
TRX	Transceiver
USB	Universal Serial Bus

9.Change Note

Version	Date	Change
V1.0	2017-06-21	Draft
V1.1	2017-07-07	Modify picture
V1.2	2017-07-18	Modify the content
V1.3	2018-03-07	Modify the content and picture