WiMOD iC880A

DATASHEET

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Version	Note
0.9	Created
0.10	DC Jack polarity added
0.11	Reference antenna added, current consumption updated (Table 5-2)
0.12	PA settings updated (Table 5 5), SPI electrical characteristics added
0.13	PA settings updated (Table 5 5) RSSI offset information added to chapter 5.4.2
0.14	Added new picture of iC880A
0.15	Please note that USB driver support for iC880A-USB isn't provided anymore on https://github.com/Lora-net/lora_gateway from version 3.2."
0.16	Electrical IO specification update
0.17	Update chapter 6.2
0.50	chapter 5.4.1 updated , Table 5-1 updated, Annex 8.1extended, Table 2-1 removed

Aim of this Document

The aim of this document is to give a product description including interfaces, features and performance of the concentrator module iC880A-USB/SPI.

Important Note

Caution: Operating the iC880A outside the given specification may harm the device.

Please note that USB driver support for iC880A-USB isn't provided anymore on https://github.com/Lora-net/lora_gateway from version 3.2."

Table of Contents

1.   Introduction

The concentrator module iC880A 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 iC880A 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 iC880A needs a host system for proper operation. This host system can be a PC or MCU that will be connected to iC880A via USB or SPI.

Figure 1-1: Picture of iC880A-USB

iC880A 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.

- End-point nodes can dynamically perform link rate adaptation based (by adapting their spreading factors) on their link margin without adding complexity to the protocol. There is no need to maintain a table of which end point uses which data rate, because all data is demodulated in parallel.

- The capacity of the air interface can be increased due to orthogonal spreading factors.

- Due to the high range a star topology can be used. This results in simple implementation avoiding complex network layers, wireless routers and additional network protocol traffic.

1.1   Key Features

- Compact size 79.8 x 67.3 mm
- LoRa^{TM} modulation technology
- Frequency band 868MHz
- Orthogonal spreading factors
- Sensitivity down to -138 dBm
- USB or SPI interface
- SX1301 base band processor
- Emulates 49 x LoRa demodulators
- 10 parallel demodulation paths
- 1 (G)FSK demodulator
- 2 x SX1257 Tx/Rx front-ends
- Supply voltage 5 V
- RF interface optimized to 50 Ω
- Output power level up to 20 dBm
- GPS receiver (optional)
- Range up to 15 km (Line of Sight)
- Range of several km in urban environment[1]
- Status LEDs
- HAL is available from https://github.com/Lora-net/lora_gateway

1.2   Applications

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

Please visit our web site www.wireless-solutions.de for further information.

! Please note that USB driver support for iC880A-USB isn't provided anymore on https://github.com/Lora-net/lora_gateway from version 3.2."

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[1] Depending on the environment

2.   LoRa Modulation Technique

The iC880A uses Semtech's LoRa spread spectrum modulation technique. This modulation, in contrast to conventional modulation techniques, permits an increase in link budget and increased immunity to in-band interference.

LoRa also provides significant advantages in both blocking and selectivity, solving the traditional design compromise between range, interference immunity and energy consumption, please refer to [6].

Semtech's LoRa technology transceivers support several bandwidth options and spreading factors ranging from 7 to 12. The spread spectrum LoRa modulation is performed by representing each bit of payload information by multiple chips of information. The rate at which the payload information is sent is referred to as the nominal symbol rate (Rs), the ratio between the nominal symbol rate and chip rate is the spreading factor and represents the number of modulation symbols sent per bit of information. Note that the spreading factor must be normally known in advance on both transmit and receive sides of the radio 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.

For further information on LoRa please refer to [7].

2.1.1   Applicable Frequency Bands and Sub-Bands

Following table depicts the applicable frequency bands within the 868 MHz band for "Non-Specific Short Range Devices" specified in the ERC Recommendation 70-03, [2].

> **Note:** National laws and regulations, as well as their interpretation can vary with the country. In case of uncertainty, it is recommended to contact either IMST's accredited Test Center or to consult the local authorities of the relevant countries.

For further information about frequency and RF power setting please refer to [5].

3.   Module Overview

The Concentrator Module is currently available in two versions, the "iC880A-USB" and the "iC880A-SPI". A future version with an integrated GPS receiver is planned.
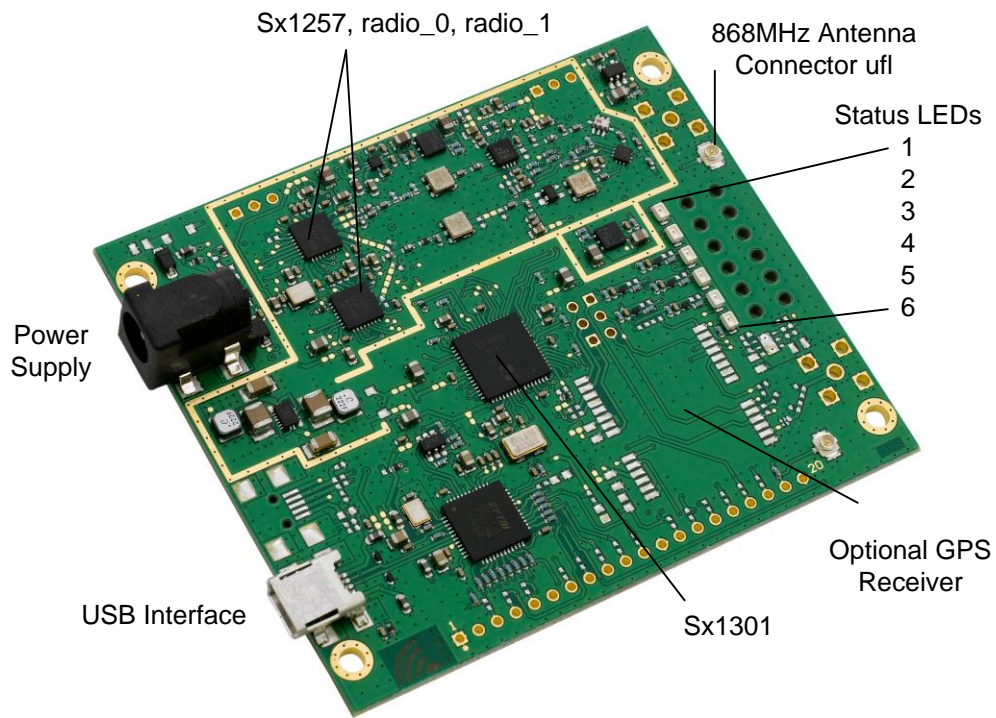

Figure 3-1: Component Overview iC880A-USB

3.1   SX1301

The iC880A 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.
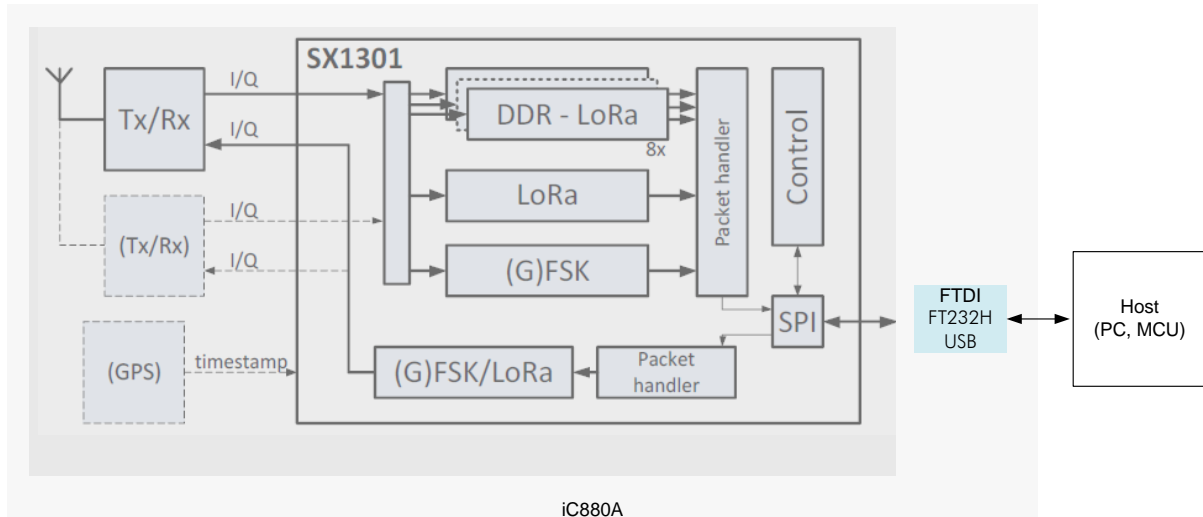

Figure 3-2: Block Diagram of iC880A with SX1301 Base Band Processor .

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.
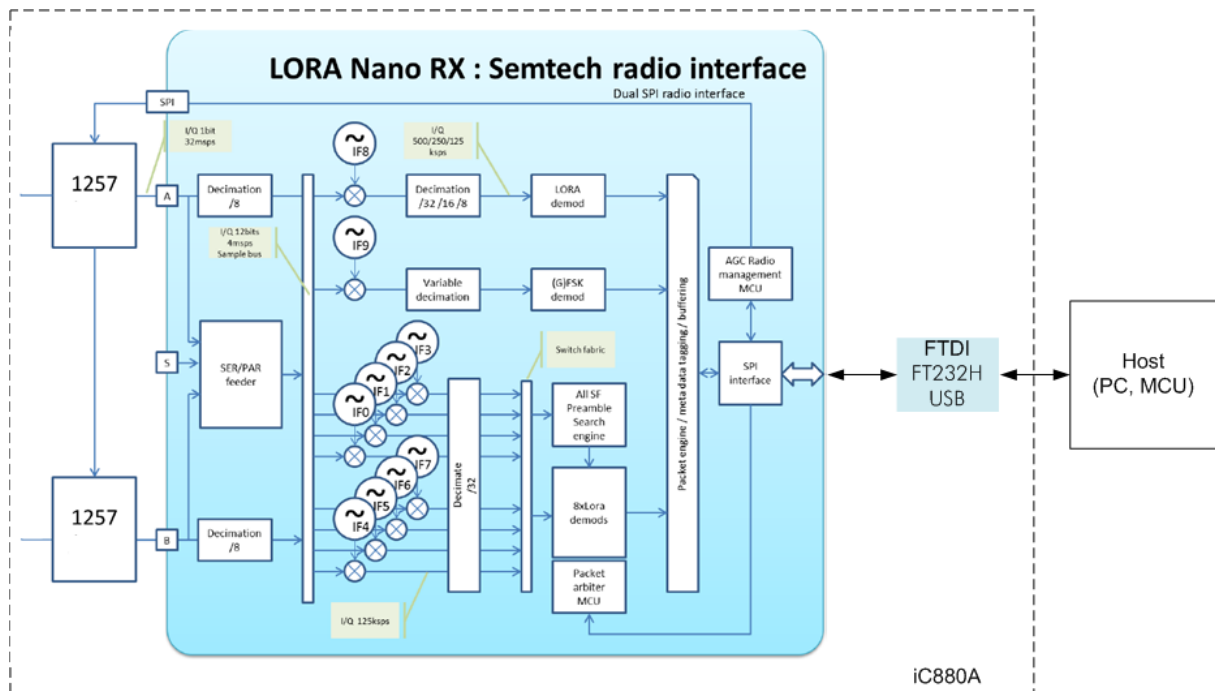
3.1.1   Block Diagram

Figure 3-3: Detailed Block Diagram of SX1301 taken from [3]

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 (iM880A-L) 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 (iM880A-L) 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.
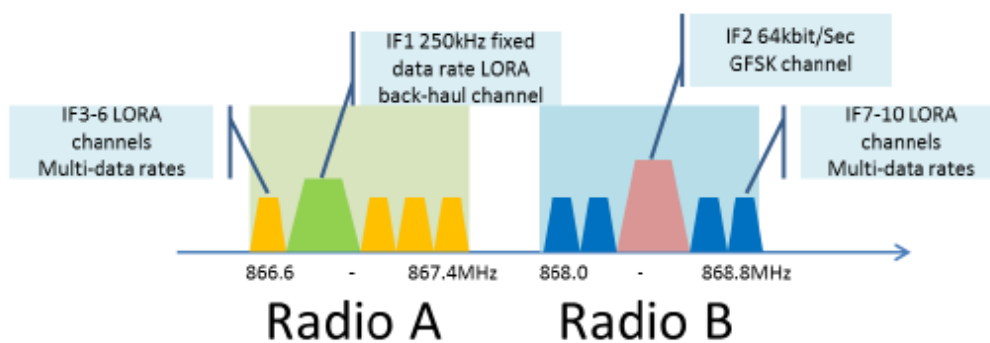

Figure 3-4: Possible use of radio spectrum taken from [3]

3.2   Power Supply

The iC880A-USB can be supplied with power by different ways: One possibility is via USB connection (refer to Chapter 3.3). But it is recommended to supply the iC880A using a more appropriate power supply source, especially if there is a need for high current consumption of the iC880A. The concentrator board should be supplied by typ. +5 V via the power connector or the appropriate pin of the connector on the bottom side of the iC880A. In case of external power supply, the iC880A disconnects the main supply from the USB connection and the main power is consumed via the external power supply.

The polarity of the fitted USB-Jack is positive, the connection diagram is given by Figure 3-1.

Figure 3-1: Polarity of the iC880A-USB DC jack

Note: When using an external power supply a certain order of connecting the cables must be followed: At first the iC880A-USB has to be powered-up with an external power supply. Next the USB cable has to be connected between the iC880A-USB and the host.

Make sure the external power supply is turned-on and supplies 5 V before connecting the power cable. If there is no power available and the connector is plugged into the DC jack, the internal voltage regulators of the iC880A-USB may get damaged!

3.3   USB Chip

The iC880A features an interface to connect SX1301 SPI interface to the host. For this the FTDI FT232H USB high speed SPI to USB single channel bridge chip is used. FTDI's Multi-Protocol Synchronous Serial Engine (MPSSE) provides a flexible means of interfacing synchronous serial devices (like SPI) to a USB port. In addition to the serial data pins, GPIO signals are also available.

The implementation of the MPSSE is part of the HAL included within the github project, refer to chapter 4.2. For further information concerning FT232H and LibMPSSE please refer to [4].

Furthermore it is possible to use this USB interface as power supply for the iC880A. If the target system is able to supply the iC880A (among other parameters, the current consumption depends on the number of used demodulation paths of the Sx1301), the iC880A can be connected with a single USB cable to the target system only.

3.4   RF Interface

The iC880A supports an RF interface for the 868 MHz frequency band. By connecting an appropriate antenna[1] to the antenna SMA connector, the iC880A is fully ready for communication.

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[1] Recommended antenna is CTA868/2/DR/SM/S2, available at CompoTEK GmbH, Germany

3.5   External Module Connector

The iC880A is primarily recommended for using the USB interface. In case of integration of the iC880A into a target system, there can be used the headers on the module's bottom side as well (refer to Table 6-1 for the pin description).

3.5.1   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 to the iC880A.

After powering up the iC880A it is required to reset SX1301 via PIN 13, refer to Table 6-1. If the Hal driver from Github is used this functionality is already implemented, but only for USB interface.

3.5.2   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.

3.5.3   UART

The bottom connector provides a UART interface. This is for future use.

3.5.4   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 iC880A.

As default setting the LEDs is (refer to Figure 3-1):

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, see Figure 4-1. 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 iC880A 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 rates[1] (0.3 kbps to ~22 kbps) and sensitivities down to -137 dBm are possible. Spreading factor and signal bandwidth are a trade-off between data rate and communication range.

4.1   Overview

The iC880A 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.
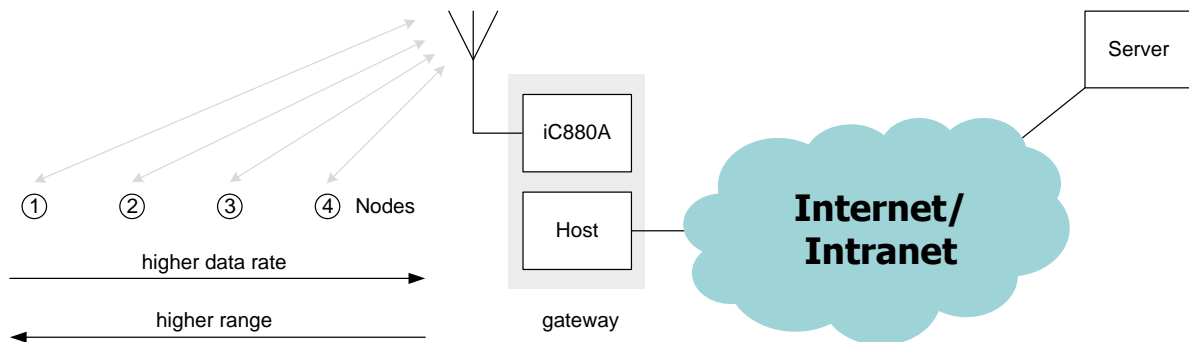
Figure 4-1: Public LoRa Network Approach

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 iC880A 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 iC880A supports up to 10 demodulations paths the channel capacity of a LoRa cell can be increased using iC880A compared to conventional modulation techniques.

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[1] Equivalent bit rate.

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.

The iC880A_QuickStartGuide.pdf is available on request.

5.   Electrical Characteristics & Timing specifications

In the following different electrical characteristics of the iC880A 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		-5		+55	°C
RF Input Power				-15	dBm
Notes:					

Table 5-1: Absolute Maximum Ratings

> **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

T = 25°C, VDD = 5 V (typ.) if nothing else stated

Parameter	Condition	Min	Typ.	Max	Unit
Supply Voltage (VDD)		4.5	5.0	5.5	V
Current Consumption [Note 1]	medium activity (4 active paths)		276		mA
	high activity (10 active paths, 1 receiving)		433		
Notes: For iC880A-USB (without GPS)					

Table 5-2: General Characteristics

T = 25°C, VDD = 5 V (typ.) if nothing else stated

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

Table 5-3: Electrical characteristics of IOs

5.3   SPI Interface Characteristics

T = 25°C, VDD = 5 V (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 risiing 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, normal mode	40			ns
NSS high time between SPI accesses		40			ns
Notes:					

Table 5-4: Timing characteristics of SPI Interface

5.4   RF Characteristics

5.4.1   Transmitter RF Characteristics

The iC880A has an excellent transmitter performance, which is generally given by Table 5-7. Generally there are a lot of possible settings for the power amplifier of the iC880A. It is highly recommended, to use an optimized configuration for the power level configuration, which is part of the HAL, as given by Table 5-5. The corresponding global_conf.json file is given in Appendix 8.1.

PA Gain	DAC Control	MIX Gain	DIG Gain	Nominal RF Power Level [dBm]
0	3	9	3	-4
0	3	10	3	-3
0	3	11	3	-1
0	3	12	3	1
0	3	13	3	2
0	3	15	3	3
2	3	8	3	9
2	3	9	3	11
2	3	10	3	13
2	3	11	3	15
2	3	12	3	17
2	3	13	3	19
2	3	14	3	20

Table 5-5: Transmitter power level configuration

The iC880A is specified for a max. RF output power of +20 dBm. Long-term operating of the iC880A with more than +20 dBm can destroy the internal power amplifier of iC880A.
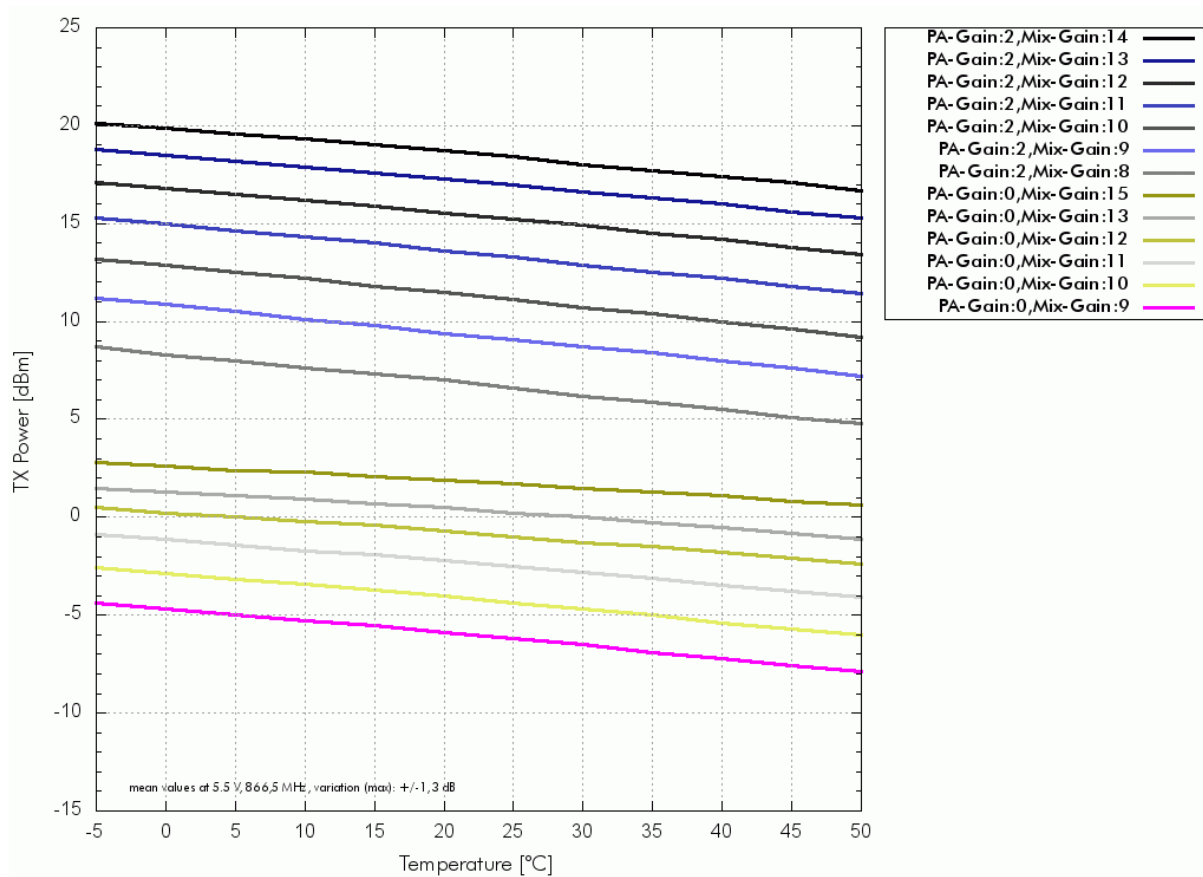
Figure 5-1: Output power vs. temperature for recommended settings

The diagram can be used, to maximize the transmitted power level according to the needs of the customer. PA-Gain=2 and Mix-Gain=10 need to be used not to exceed limits of +14 dBm sub-bands of EN 300 220 in the whole temperature range[1]. In the case of +14 dBm the RF output power level can be optimized by different power level configuration depending on the temperature:

Temperature Range	PA Gain	Mix Gain
-5 to +20°C	2	10
+20 to +45°C	2	11
+45°C to +50 °C	2	12

Table 5-6: Optimized gain settings for different temperature ranges for 14 dBm

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[1] Assuming an ideal dipole antenna

If you operate the iC880A with the github software you should ensure that the max. RF output power of +20 dBm is not exceeded. To ensure this you can edit the global_conf.json file according to Table 5-5 or Appendix 8.1.

T = 25°C, VDD = 5 V (typ.), 866.5 MHz if nothing else stated

Parameter	Condition	Min	Typ.	Max	Unit
Frequency Range		863	-	870	MHz
Modulation Techniques	FSK / LoRa™				
TX Frequency Variation vs. Temperature	Power Level Setting: 20	-	-	+/- 3	kHz
TX Power Variation vs. Frequency		-	-	+/- 2	dB
TX Power Variation (initial)		-	-	+/- 1.5	dB
TX Current Consumption		-	330	-	mA

Table 5-7: Transmitter RF Characteristics

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 iC880A[1]:

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

Table 5-8: Typically Radio Performance of iC880A

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[1] Valid for LoRa-gateway v1.7.0

6.   Module Package

In the following the iC880A module package is described. This description includes the iC880A pinout as well as the modules dimensions.
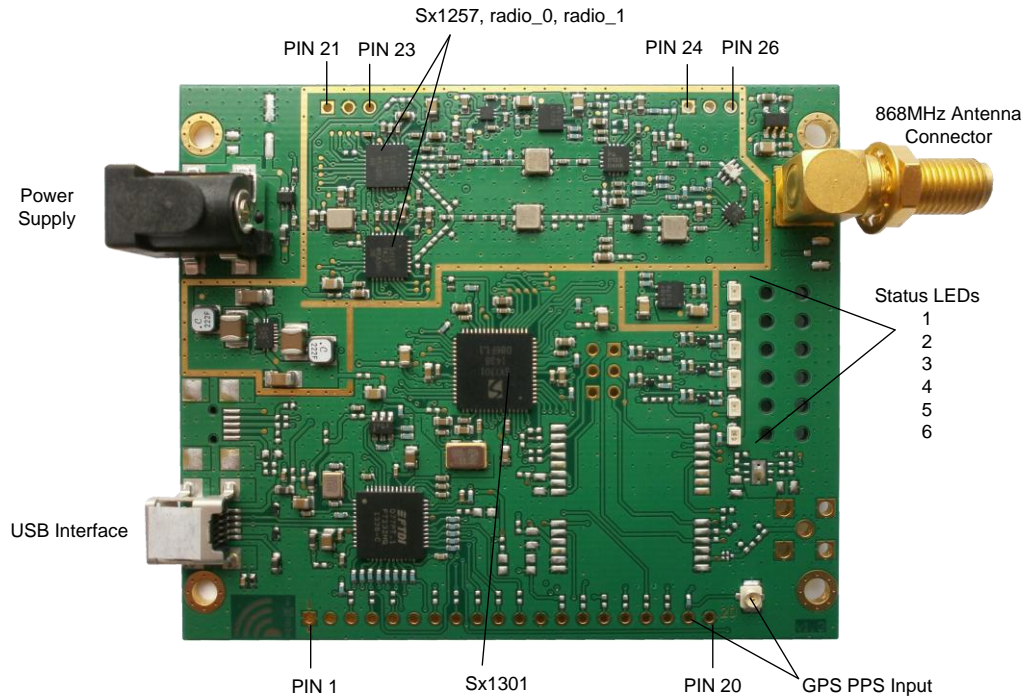

Figure 6-1: Pinout and interfaces of iC880A-USB

6.1   Pinout Description

The iC880A provides headers at the bottom side, which have a pitch of 2.54 mm. The description of the pins is given by Table 6-1. An additional overview gives Figure 6-2.

PIN	PIN Name	PIN Type	Description
1	GND	Power	
2	NC	NC	Reserved
3	nGPS_Reset	Input	GPS Module Reset (low active)
4	SPValid	Input	Sx1301 Radio C Sample Valid (don't connect)
5	EN_GPS_Supply	Input	GPS Module LDO: Enable Pin
6	NC	NC	Reserved
7	GPIO0	I/O	Sx1301 GPIO 0
8	GPIO1	I/O	Sx1301 GPIO 1
9	GPIO3	I/O	Sx1301 GPIO 3
10	GPIO2	I/O	Sx1301 GPIO 2
11	GPIO4	I/O	Sx1301 GPIO 4
12	GND	Power	
13	Reset	Reset	Sx1301 Reset, for a stable start-up Reset should be at high-level for 100 ns (min), once the supply voltage is stable . Internally pulled-down with 100 kΩ.
14	CLK	Input	Sx1301 SPI-Clock
15	MISO	Output	Sx1301 SPI-MISO
16	MOSI	Input	Sx1301 SPI-MOSI
17	NSS	Input	Sx1301 SPI-NSS
18	ScanMode	Input	Sx1301 ScanMode Signal
19	PPS	Input	GPS PPS Input Signal
20	GND	Power	
21	VDD	Power	+5 V Supply Voltage
22	GND	Power	
23	VDDB	Power	GPS backup supply voltage
24	GND	Power	
25	GPS_TX	Output	GPS UART TxD
26	GPS_RX	Input	GPS UART RxD

Table 6-1: iC880A Pinout Table

6.2   Module Dimensions

The outer dimensions of the iC880A are given by 79.8 x 67.3 mm ± 0.2 mm. The iC880A provide four drills for screwing the PCB to another unit each with a drill diameter of 3 mm.
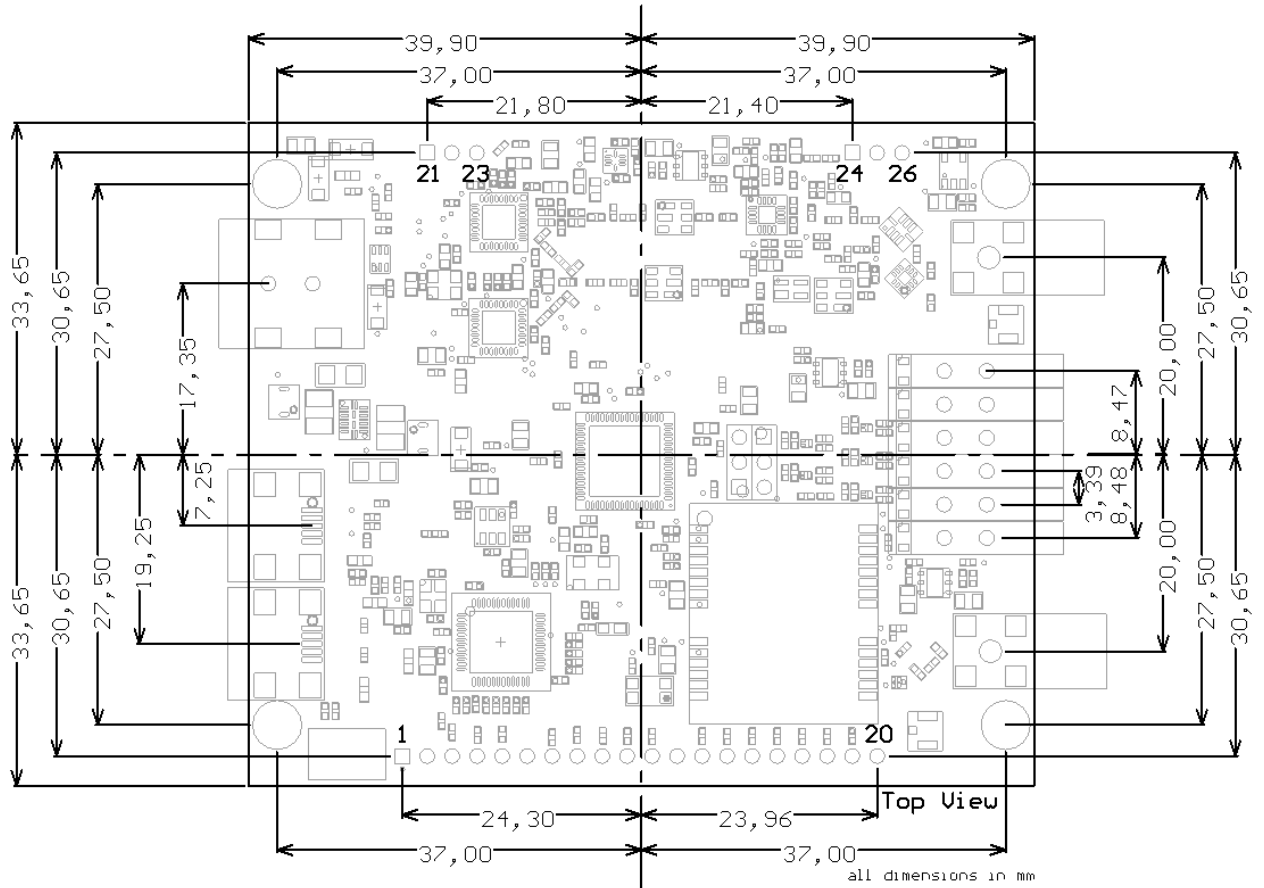

Figure 6-2: iC880A outlines and pins of bottom connector in top view

7.   Ordering Information

Ordering Part Number	Description	Distributor
iC880A-SPI	Concentrator Module with SPI interface	

Table 7-1: Ordering Information

8.   Appendix

8.1   Global_conf.json

```
Code-Snipet for global_conf.json
=================================

    "tx_lut_0": {
        /* TX gain table, index 0 */
        "pa_gain": 0,
        "mix_gain": 9,
        "rf_power": -4,
        "dig_gain": 3
    },
    "tx_lut_1": {
        /* TX gain table, index 1 */
        "pa_gain": 0,
        "mix_gain": 10,
        "rf_power": -3,
        "dig_gain": 3
    },
    "tx_lut_2": {
        /* TX gain table, index 2 */
        "pa_gain": 0,
        "mix_gain": 11,
        "rf_power": -1,
        "dig_gain": 3
    },
    "tx_lut_3": {
        /* TX gain table, index 3 */
        "pa_gain": 0,
        "mix_gain": 12,
        "rf_power": 1,
        "dig_gain": 3
    },
    "tx_lut_4": {
        /* TX gain table, index 4 */
        "pa_gain": 0,
        "mix_gain": 13,
        "rf_power": 2,
        "dig_gain": 3
    },
    "tx_lut_5": {
        /* TX gain table, index 5 */
        "pa_gain": 0,
        "mix_gain": 15,
        "rf_power": 3,
        "dig_gain": 3
    },
    "tx_lut_6": {
        /* TX gain table, index 6 */
        "pa_gain": 2,
        "mix_gain": 8,
        "rf_power": 9,
        "dig_gain": 3
    },
    "tx_lut_7": {
        /* TX gain table, index 7 */
        "pa_gain": 2,
        "mix_gain": 9,
```

```
            "rf_power": 11,
            "dig_gain": 3
        },
        "tx_lut_8": {
            /* TX gain table, index 8 */
            "pa_gain": 2,
            "mix_gain": 10,
            "rf_power": 13,
            "dig_gain": 3
        },
        "tx_lut_9": {
            /* TX gain table, index 9 */
            "pa_gain": 2,
            "mix_gain": 11,
            "rf_power": 15,
            "dig_gain": 3
        },
        "tx_lut_10": {
            /* TX gain table, index 10 */
            "pa_gain": 2,
            "mix_gain": 12,
            "rf_power": 17,
            "dig_gain": 3
        },
        "tx_lut_11": {
            /* TX gain table, index 11 */
            "pa_gain": 2,
            "mix_gain": 13,
            "rf_power": 19,
            "dig_gain": 3
        },
        "tx_lut_12": {
            /* TX gain table, index 12 */
            "pa_gain": 2,
            "mix_gain": 14,
            "rf_power": 20,
            "dig_gain": 3
        },
        "tx_lut_13": {
            /* TX gain table, index 13 */
            "pa_gain": 2,
            "mix_gain": 14,
            "rf_power": 20,
            "dig_gain": 3
        },
        "tx_lut_14": {
            /* TX gain table, index 14 */
            "pa_gain": 2,
            "mix_gain": 14,
            "rf_power": 20,
            "dig_gain": 3
        },
        "tx_lut_15": {
            /* TX gain table, index 15 */
            "pa_gain": 2,
            "mix_gain": 14,
            "rf_power": 20,
            "dig_gain": 3
        }
    },
```

8.2   List of Abbreviations

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

8.3   List of Figures

8.4   List of Tables

8.5   References

[1]   Semtech, SX1272 Data Sheet from www.semtech.com

[2]   REC Recommendation 70-03 "Relating to the use of Short Range Devices (SRD)", Tromsø 1997, CEPT ECC subsequent amendments 13 October 2017

[3]   Semtech, SX1301 Data Sheet from www.semtech.com

[4]   FTDI, FT232H Data Sheet from http://www.ftdichip.com

[5]   IMST, iM880B_AN016_RFSettings from www.wireless-solutions.de

[6]   IMST, iM880B-L Data sheet from www.wireless-solutions.de

[7]   Semtech, White Paper LoRa Modulation from www.semtech.com

9.   Regulatory Compliance Information

The use of radio frequencies is limited by national regulations. This component has been designed to comply with the European Union's RE-Directive (Radio Equipment Directive) 2014/53/EU. As the product is a component only, the assessment is done on EMC and ERM only. Certification process is not yet finalized. Nevertheless, restrictions in terms of maximum allowed RF power or duty cycle may apply.

This component has been designed to be embedded into other products (referred as "final products"). According to the RED, the declaration of compliance with essential requirements of the RED is within the responsibility of the manufacturer of the final product. A declaration of conformity for this component will be available from IMST GmbH on request.

The applicable regulation requirements are subject to change. IMST GmbH does not take any responsibility for the correctness and accuracy of the aforementioned information. National laws and regulations, as well as their interpretation can vary with the country. In case of uncertainty, it is recommended to contact either IMST's accredited Test Center or to consult the local authorities of the relevant countries.

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