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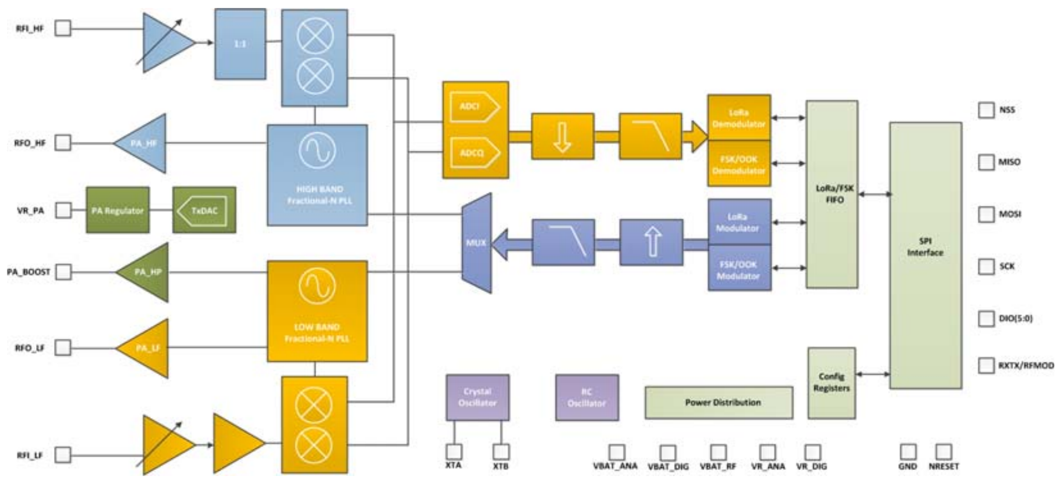
SEMTECH LoRa™ **SX1276/77/78/79**

WIRELESS, SENSING & TIMING **DATASHEET**

SX1276/77/78/79 - 137 MHz to 1020 MHz Low Power Long Range Transceiver



GENERAL DESCRIPTION

The SX1276/77/78/79 transceivers feature the LoRa™ long range modem that provides ultra-long range spread spectrum communication and high interference immunity whilst minimising current consumption.

Using Semtech's patented LoRa™ modulation technique SX1276/77/78/79 can achieve a sensitivity of over -148dBm using a low cost crystal and bill of materials. The high sensitivity combined with the integrated +20 dBm power amplifier yields industry leading link budget making it optimal for any application requiring range or robustness. LoRa™ provides significant advantages in both blocking and selectivity over conventional modulation techniques, solving the traditional design compromise between range, interference immunity and energy consumption.

These devices also support high performance (G)FSK modes for systems including WMBus, IEEE802.15.4g. The SX1276/77/78/79 deliver exceptional phase noise, selectivity, receiver linearity and IIP3 for significantly lower current consumption than competing devices.

ORDERING INFORMATION

Part Number	Delivery	MOQ / Multiple
SX1276IMLTRT	T&R	3000 pieces
SX1277IMLTRT	T&R	3000 pieces
SX1278IMLTRT	T&R	3000 pieces
SX1279IMLTRT	T&R	3000 pieces
SX1276WS	Wafer Form	1 Wafer (2000 dies)

- QFN 28 Package - Operating Range [-40;+85°C]
- Pb-free, Halogen free, RoHS/WEEE compliant product

KEY PRODUCT FEATURES

- LoRa™ Modem
- 168 dB maximum link budget
- +20 dBm - 100 mW constant RF output vs. V supply
- +14 dBm high efficiency PA
- Programmable bit rate up to 300 kbps
- High sensitivity: down to -148 dBm
- Bullet-proof front end: IIP3 = -11 dBm
- Excellent blocking immunity
- Low RX current of 9.9 mA, 200 nA register retention
- Fully integrated synthesizer with a resolution of 61 Hz
- FSK, GFSK, MSK, GMSK, LoRa™and OOK modulation
- Built-in bit synchronizer for clock recovery
- Preamble detection
- 127 dB Dynamic Range RSSI
- Automatic RF Sense and CAD with ultra-fast AFC
- Packet engine up to 256 bytes with CRC
- Built-in temperature sensor and low battery indicator

APPLICATIONS

- Automated Meter Reading.
- Home and Building Automation.
- Wireless Alarm and Security Systems.
- Industrial Monitoring and Control
- Long range Irrigation Systems

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1. General Description

The SX1276/77/78/79 incorporates the LoRa^{TM} spread spectrum modem which is capable of achieving significantly longer range than existing systems based on FSK or OOK modulation. At maximum data rates of LoRa^{TM} the sensitivity is 8dB better than FSK, but using a low cost bill of materials with a 20ppm XTAL LoRa^{TM} can improve receiver sensitivity by more than 20dB compared to FSK. LoRa^{TM} also provides significant advances in selectivity and blocking performance, further improving communication reliability. For maximum flexibility the user may decide on the spread spectrum modulation bandwidth (BW), spreading factor (SF) and error correction rate (CR). 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 GFSK, FSK, OOK, and GMSK modulation is also provided to allow compatibility with existing systems or standards such as wireless MBUS and IEEE 802.15.4g.

The SX1276 and SX1279 offer bandwidth options ranging from 7.8 kHz to 500 kHz with spreading factors ranging from 6 to 12, and covering all available frequency bands. The SX1277 offers the same bandwidth and frequency band options with spreading factors from 6 to 9. The SX1278 offers bandwidths and spreading factor options, but only covers the lower UHF bands.

1.1. Simplified Block Diagram

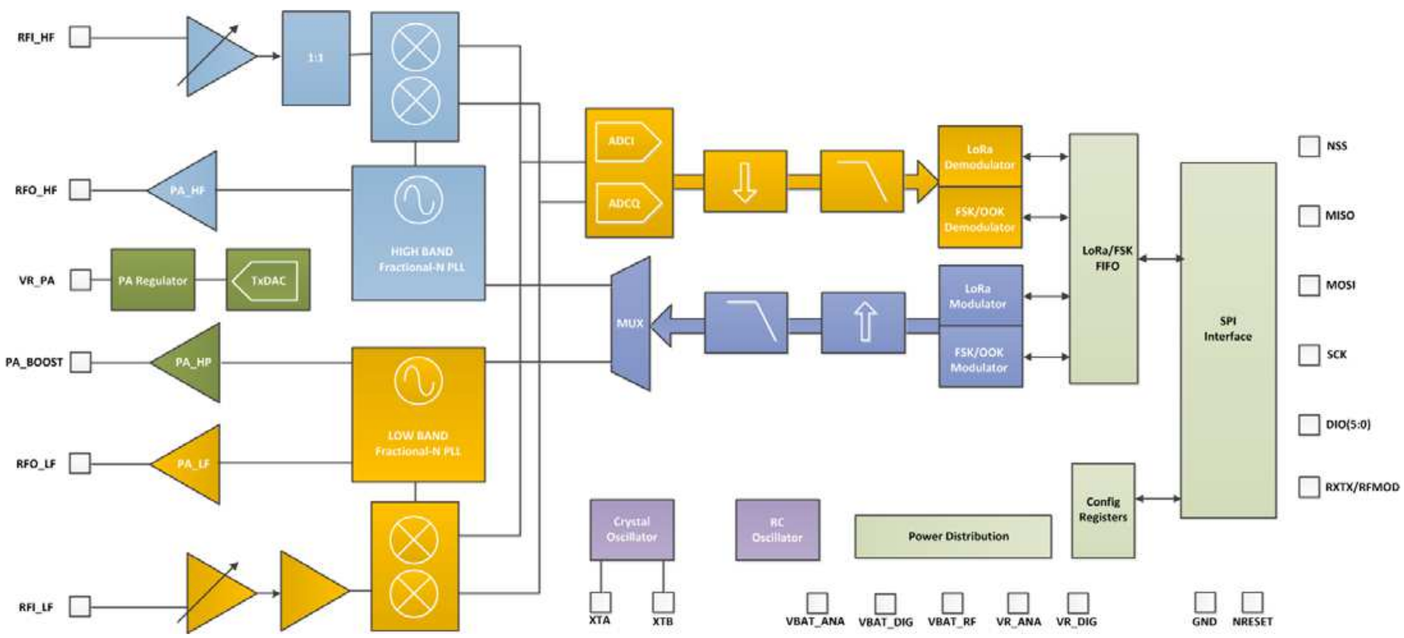

Figure 1. Block Diagram

1.2. Product Versions

The features of the four product variants are detailed in the following table.

Table 1 SX1276/77/78/79 Device Variants and Key Parameters

Part Number	Frequency Range	Spreading Factor	Bandwidth	Effective Bitrate	Est. Sensitivity
SX1276	137 - 1020 MHz	6 - 12	7.8 - 500 kHz	.018 - 37.5 kbps	-111 to -148 dBm
SX1277	137 - 1020 MHz	6 - 9	7.8 - 500 kHz	0.11 - 37.5 kbps	-111 to -139 dBm
SX1278	137 - 525 MHz	6- 12	7.8 - 500 kHz	.018 - 37.5 kbps	-111 to -148 dBm
SX1279	137 - 960MHz	6- 12	7.8 - 500 kHz	.018 - 37.5 kbps	-111 to -148 dBm

1.3. Pin Diagram

The following diagram shows the pin arrangement of the QFN package, top view.

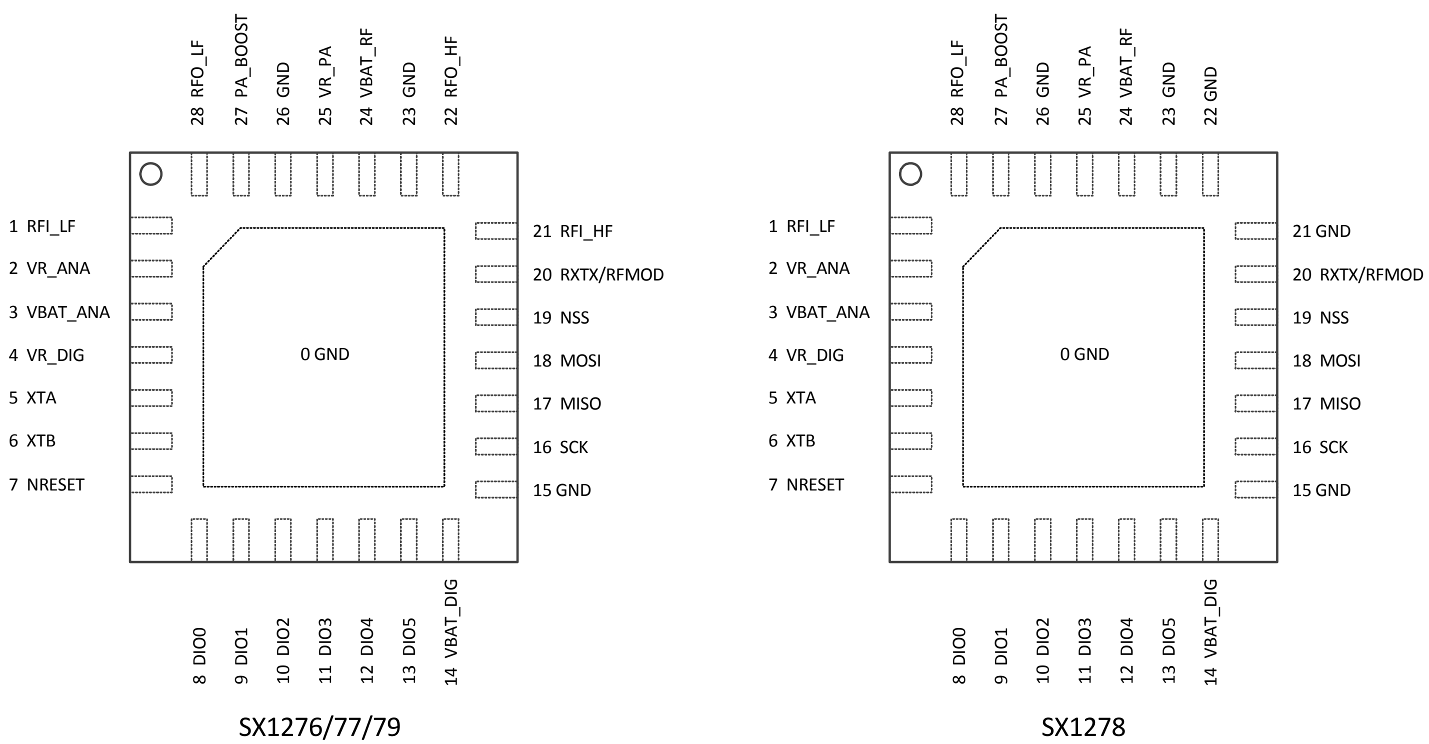

Figure 2. Pin Diagrams

1.4. Pin Description

Table 2 Pin Description

Number	Name	Type	Description
	SX1276/77/79/(78)	SX1276/77/79/(78)	SX1276/77/79/(78)
0	GROUND	-	Exposed ground pad
1	RFI_LF	I	RF input for bands 2&3
2	VR_ANA	-	Regulated supply voltage for analogue circuitry
3	VBAT_ANA	-	Supply voltage for analogue circuitry
4	VR_DIG	-	Regulated supply voltage for digital blocks
5	XTA	I/O	XTAL connection or TCXO input
6	XTB	I/O	XTAL connection
7	NRESET	I/O	Reset trigger input
8	DIO0	I/O	Digital I/O, software configured
9	DIO1/DCLK	I/O	Digital I/O, software configured
10	DIO2/DATA	I/O	Digital I/O, software configured
11	DIO3	I/O	Digital I/O, software configured
12	DIO4	I/O	Digital I/O, software configured
13	DIO5	I/O	Digital I/O, software configured
14	VBAT_DIG	-	Supply voltage for digital blocks
15	GND	-	Ground
16	SCK	I	SPI Clock input
17	MISO	O	SPI Data output
18	MOSI	I	SPI Data input
19	NSS	I	SPI Chip select input
20	RXTX/RF_MOD	O	Rx/Tx switch control: high in Tx
21	RFI_HF (GND)	I (-)	RF input for band 1 (Ground)
22	RFO_HF (GND)	O (-)	RF output for band 1 (Ground)
23	GND	-	Ground
24	VBAT_RF	-	Supply voltage for RF blocks
25	VR_PA	-	Regulated supply for the PA
26	GND	-	Ground
27	PA_BOOST	O	Optional high-power PA output, all frequency bands
28	RFO_LF	O	RF output for bands 2&3

1.5. Package Marking

TOP MARK	
CHAR	ROWS
7/7/7/7/7	5

Marking for the 6 x 6 mm MLPQ 28ld Lead package:

nnnnnn = Part Number (Example: SX1276)
yyww = Date Code (Example: 1352)
xxxxxxx = Semtech Lot No. (Example: EA90101)
xxxxxxx 0101-10)

Figure 3. Marking Diagram

2. Electrical Characteristics

2.1. ESD Notice

The SX1276/77/78/79 is a high performance radio frequency device. It satisfies:

- Class 2 of the JEDEC standard JESD22-A114 (Human Body Model) on all pins.
- Class III of the JEDEC standard JESD22-C101 (Charged Device Model) on all pins

It should thus be handled with all the necessary ESD precautions to avoid any permanent damage.

2.2. Absolute Maximum Ratings

Stresses above the values listed below may cause permanent device failure. Exposure to absolute maximum ratings for extended periods may affect device reliability.

Table 3 Absolute Maximum Ratings

Symbol	Description	Min	Max	Unit
VDDmr	Supply Voltage	-0.5	3.9	V
Tmr	Temperature	-55	+115	° C
Tj	Junction temperature	-	+125	° C
Pmr	RF Input Level	-	+10	dBm

Note Specific ratings apply to +20 dBm operation (see Section 5.4.3).

2.3. Operating Range

Table 4 Operating Range

Symbol	Description	Min	Max	Unit
VDDop	Supply voltage	1.8	3.7	V
Top	Operational temperature range	-40	+85	°C
Clop	Load capacitance on digital ports	-	25	pF
ML	RF Input Level	-	+10	dBm

Note A specific supply voltage range applies to +20 dBm operation (see Section 5.4.3).

2.4. Thermal Properties

Table 5 Thermal Properties

Symbol	Description	Min	Typ	Max	Unit
THETA_JA	Package θ_{ja} (Junction to ambient)	-	22.185	-	°C/W
THETA_JC	Package θ_{jc} (Junction to case ground paddle)	-	0.757	-	°C/W

2.5. Chip Specification

The tables below give the electrical specifications of the transceiver under the following conditions: Supply voltage VDD=3.3 V, temperature = 25 °C, *FXOSC* = 32 MHz, F_{RF} = 169/434/868/915 MHz (see specific indication), Pout = +13dBm, 2-level FSK modulation without pre-filtering, FDA = 5 kHz, Bit Rate = 4.8 kb/s and terminated in a matched 50 Ohm impedance, shared Rx and Tx path matching, unless otherwise specified.

Note Specification whose symbol is appended with "_LF" corresponds to the performance in Band 2 and/or Band 3, as described in section 5.3.3. "_HF" refers to the upper Band 1

2.5.1. Power Consumption

Table 6 Power Consumption Specification

Symbol	Description	Conditions	Min	Typ	Max	Unit
IDDSL	Supply current in Sleep mode		-	0.2	1	uA
IDDIDLE	Supply current in Idle mode	RC oscillator enabled	-	1.5	-	uA
IDDST	Supply current in Standby mode	Crystal oscillator enabled	-	1.6	1.8	mA
IDDFS	Supply current in Synthesizer mode	FSRx	-	5.8	-	mA
IDDR	Supply current in Receive mode	*LnaBoost* Off, band 1 *LnaBoost* On, band 1 Bands 2&3	- - -	10.8 11.5 12.0	- - -	mA
IDDT	Supply current in Transmit mode with impedance matching	RFOP = +20 dBm, on PA_BOOST RFOP = +17 dBm, on PA_BOOST RFOP = +13 dBm, on RFO_LF/HF pin RFOP = + 7 dBm, on RFO_LF/HF pin	- - - -	120 87 29 20	- - - -	mA mA mA mA

2.5.2. Frequency Synthesis

Table 7 Frequency Synthesizer Specification

Symbol	Description	Conditions	Min	Typ	Max	Unit
FR	Synthesizer frequency range	Programmable (*for SX1279) Band 3 Band 2 Band 1	137 410 862 (*779)	- - -	175 (*160) 525 (*480) 1020 (*960)	MHz
FXOSC	Crystal oscillator frequency		-	32	-	MHz
TS_OSC	Crystal oscillator wake-up time		-	250	-	us
TS_FS	Frequency synthesizer wake-up time to PllLock signal	From Standby mode	-	60	-	us

TS_HOP	Frequency synthesizer hop time at most 10 kHz away from the target frequency	200 kHz step 1 MHz step 5 MHz step 7 MHz step 12 MHz step 20 MHz step 25 MHz step	- - - - - - -	20 20 50 50 50 50 50	- - - - - - -	us us us us us us us
FSTEP	Frequency synthesizer step	$FSTEP = FXOSC/2^{19}$	-	61.0	-	Hz
FRC	RC Oscillator frequency	After calibration	-	62.5	-	kHz
BRF	Bit rate, FSK	Programmable values (1)	1.2	-	300	kbps
BRA	Bit rate Accuracy, FSK	ABS(wanted BR - available BR)	-	-	250	ppm
BRO	Bit rate, OOK	Programmable	1.2	-	32.768	kbps
BR_L	Bit rate, LoRa Mode	From SF6, BW=500kHz to SF12, BW=7.8kHz	0.018	-	37.5	kbps
FDA	Frequency deviation, FSK (1)	Programmable FDA + BRF/2 =< 250 kHz	0.6	-	200	kHz

Note: For Maximum Bit rate, the maximum modulation index is 0.5.

2.5.3. FSK/OOK Mode Receiver

All receiver tests are performed with RxBw = 10 kHz (Single Side Bandwidth) as programmed in *RegRxBw*, receiving a PN15 sequence. Sensitivities are reported for a 0.1% BER (with Bit Synchronizer enabled), unless otherwise specified. Blocking tests are performed with an unmodulated interferer. The wanted signal power for the Blocking Immunity, ACR, IIP2, IIP3 and AMR tests is set 3 dB above the receiver sensitivity level.

Table 8 FSK/OOK Receiver Specification

Symbol	Description	Conditions	Min	Typ	Max	Unit
RFS_F_LF	Direct tie of RFI and RFO pins, shared Rx, Tx paths FSK sensitivity, highest LNA gain. Bands 2&3	FDA = 5 kHz, BR = 1.2 kb/s FDA = 5 kHz, BR = 4.8 kb/s FDA = 40 kHz, BR = 38.4 kb/s* FDA = 20 kHz, BR = 38.4 kb/s** FDA = 62.5 kHz, BR = 250 kb/s***	- - - - -	-121 -117 -107 -108 -95	- - - - -	dBm dBm dBm dBm dBm
	Split RF paths, the RF switch insertion loss is not accounted for. Bands 2&3	FDA = 5 kHz, BR = 1.2 kb/s FDA = 5 kHz, BR = 4.8 kb/s FDA = 40 kHz, BR = 38.4 kb/s* FDA = 20 kHz, BR = 38.4 kb/s** FDA = 62.5 kHz, BR = 250 kb/s***	- - - - -	-123 -119 -109 -110 -97	- - - - -	dBm dBm dBm dBm dBm
RFS_F_HF	Direct tie of RFI and RFO pins, shared Rx, Tx paths FSK sensitivity, highest LNA gain. Band 1	FDA = 5 kHz, BR = 1.2 kb/s FDA = 5 kHz, BR = 4.8 kb/s FDA = 40 kHz, BR = 38.4 kb/s* FDA = 20 kHz, BR = 38.4 kb/s** FDA = 62.5 kHz, BR = 250 kb/s***	- - - - -	-119 -115 -105 -105 -92	- - - - -	dBm dBm dBm dBm dBm
	Split RF paths, *LnaBoost* is turned on, the RF switch insertion loss is not accounted for. Band 1	FDA = 5 kHz, BR = 1.2 kb/s FDA = 5 kHz, BR = 4.8 kb/s FDA = 40 kHz, BR = 38.4 kb/s* FDA = 20 kHz, BR = 38.4 kb/s** FDA = 62.5 kHz, BR = 250 kb/s***	- - - - -	-123 -119 -109 -109 -96	- - - - -	dBm dBm dBm dBm dBm
RFS_O	OOK sensitivity, highest LNA gain shared Rx, Tx paths	BR = 4.8 kb/s BR = 32 kb/s	- -	-117 -108	- -	dBm dBm
CCR	Co-Channel Rejection, FSK		-	-9	-	dB
ACR	Adjacent Channel Rejection	FDA = 5 kHz, BR=4.8kb/s Offset = +/- 25 kHz or +/- 50kHz Band 1 Band 2 Band 3	- - -	50 56 60	- - -	dB dB dB
BI_HF	Blocking Immunity, Band 1	Offset = +/- 1 MHz Offset = +/- 2 MHz Offset = +/- 10 MHz	- - -	71 76 84	- - -	dB dB dB
BI_LF	Blocking Immunity, Bands 2&3	Offset = +/- 1 MHz Offset = +/- 2 MHz Offset = +/- 10 MHz	- - -	71 72 78	- - -	dB dB dB

IIP2	2nd order Input Intercept Point Unwanted tones are 20 MHz above the LO	Highest LNA gain	-	+55	-	dBm
IIP3_HF	3rd order Input Intercept point Unwanted tones are 1MHz and 1.995 MHz above the LO	Band 1 Highest LNA gain G1 LNA gain G2, 5dB sensitivity hit	- -	-11 -6	- -	dBm dBm
IIP3_LF	3rd order Input Intercept point Unwanted tones are 1MHz and 1.995 MHz above the LO	Band 2 Highest LNA gain G1 LNA gain G2, 2.5dB sensitivity hit	- -	-22 -15	- -	dBm dBm
		Band 3 Highest LNA gain G1 LNA gain G2, 2.5dB sensitivity hit	- -	-15 -11	- -	dBm dBm
BW_SSB	Single Side channel filter BW	Programmable	2.7	-	250	kHz
IMR	Image Rejection	Wanted signal 3dB over sensitivity BER=0.1%	-	50	-	dB
IMA	Image Attenuation		-	57	-	dB
DR_RSSI	RSSI Dynamic Range	AGC enabled Min Max	- -	-127 0	- -	dBm dBm

* *RxBw = 83 kHz (Single Side Bandwidth)*

** *RxBw = 50 kHz (Single Side Bandwidth)*

*** *RxBw = 250 kHz (Single Side Bandwidth)*

2.5.4. FSK/OOK Mode Transmitter

Table 9 Transmitter Specification

Symbol	Description	Conditions	Min	Typ	Max	Unit
RF_OP	RF output power in 50 ohms on RFO pin (High efficiency PA).	Programmable with steps Max Min	- -	+14 -1	- -	dBm dBm
ΔRF_OP_V	RF output power stability on RFO pin versus voltage supply.	VDD = 2.5 V to 3.3 V VDD = 1.8 V to 3.7 V	- -	3 8	- -	dB dB
RF_OPH	RF output power in 50 ohms, on PA_BOOST pin (Regulated PA).	Programmable with 1dB steps Max Min	- -	+17 +2	- -	dBm dBm
RF_OPH_MAX	Max RF output power, on PA_BOOST pin	High power mode	-	+20	-	dBm
ΔRF_OPH_V	RF output power stability on PA_BOOST pin versus voltage supply.	VDD = 2.4 V to 3.7 V	-	+/-1	-	dB
ΔRF_T	RF output power stability versus temperature on PA_BOOST pin.	From T = -40 °C to +85 °C	-	+/-1	-	dB

PHN	Transmitter Phase Noise	169 MHz, Band 3 10kHz Offset 50kHz Offset 400kHz Offset 1MHz Offset	- - - -	-118 -118 -128 -134	- - - -	dBc/Hz
		433 MHz, Band 2 10kHz Offset 50kHz Offset 400kHz Offset 1MHz Offset	- - - -	-110 -110 -122 -129	- - - -	dBc/Hz
		868/915 MHz, Band 1 10kHz Offset 50kHz Offset 400kHz Offset 1MHz Offset	- - - -	-103 -103 -115 -122	- - - -	dBc/Hz
ACP	Transmitter adjacent channel power (measured at 25 kHz offset)	BT=1. Measurement conditions as defined by EN 300 220-1 V2.3.1	-	-	-37	dBm
TS_TR	Transmitter wake up time, to the first rising edge of DCLK	Frequency Synthesizer enabled, *PaRamp* = 10us, BR = 4.8 kb/s	-	120	-	us

2.5.5. Electrical Specification for LoRa™ Modulation

The table below gives the electrical specifications for the transceiver operating with LoRa™ modulation. Following conditions apply unless otherwise specified:

- Supply voltage = 3.3 V
- Temperature = 25° C
- f_{XOSC} = 32 MHz
- bandwidth (BW) = 125 kHz
- Spreading Factor (SF) = 12
- Error Correction Code (EC) = 4/6
- Packet Error Rate (PER)= 1%
- CRC on payload enabled
- Output power = 13 dBm in transmission
- Payload length = 64 bytes
- Preamble Length = 12 symbols (programmed register *PreambleLength=8*)
- With matched impedances

Table 10 LoRa Receiver Specification

Symbol	Description	Conditions	Min.	Typ	Max	Unit
IDDR_L	Supply current in receiver LoRa™ mode, *LnaBoost* off	Bands 2&3, BW=7.8 to 62.5 kHz Bands 2&3, BW = 125 kHz Bands 2&3, BW = 250 kHz Bands 2&3, BW = 500 kHz	- - - -	11.0 11.5 12.4 13.8	- - - -	mA mA mA mA
		Band 1, BW=7.8 to 62.5 kHz Band 1, BW = 125 kHz Band 1, BW = 250 kHz Band 1, BW = 500 kHz	- - - -	9.9 10.3 11.1 12.6	- - - -	mA mA mA mA
IDDT_L	Supply current in transmitter mode	RFOP = 13 dBm RFOP = 7 dBm	- -	28 20	- -	mA mA
IDDT_H_L	Supply current in transmitter mode with an external impedance transformation	Using PA_BOOST pin RFOP = 17 dBm	-	90	-	mA
BI_L	Blocking immunity, CW interferer	offset = +/- 1 MHz offset = +/- 2 MHz offset = +/- 10 MHz	-	89 94 100	-	dB dB dB
IIP2_L	2nd order Input Intercept Point Unwanted tones are 20 MHz above the LO	Highest LNA gain	-	+55	-	dBm
IIP3_L_HF	3rd order Input Intercept point Unwanted tones are 1MHz and 1.995 MHz above the LO	Band 1 Highest LNA gain G1 LNA gain G2, 5dB sensitivity hit	 - -	 -11 -6	 - -	 dBm dBm

Symbol	Description	Conditions	Min.	Typ	Max	Unit
IIP3_L_LF	3rd order Input Intercept point Unwanted tones are 1MHz and 1.995 MHz above the LO	Band 2 Highest LNA gain G1 LNA gain G2,2.5dB sensitivity hit	 - -	 -22 -15	 - -	 dBm dBm
RFS_L10_HF	RF sensitivity, Long-Range Mode, highest LNA gain, *LnaBoost* for Band 1, using split Rx/Tx path 10.4 kHz bandwidth	SF = 6 SF = 7 SF = 8 SF = 11	- - - -	-131 -134 -138 -146	- - - -	dBm dBm dBm dBm
RFS_L62_HF	RF sensitivity, Long-Range Mode, highest LNA gain, *LnaBoost* for Band 1, using split Rx/Tx path 62.5 kHz bandwidth	SF = 6 SF = 7 SF = 8 SF = 9 SF = 10 SF = 11 SF = 12	- - - - - - -	-121 -126 -129 -132 -135 -137 -139	- - - - - - -	dBm dBm dBm dBm dBm dBm dBm
RFS_L125_HF	RF sensitivity, Long-Range Mode, highest LNA gain, *LnaBoost* for Band 1, using split Rx/Tx path 125 kHz bandwidth	SF = 6 SF = 7 SF = 8 SF = 9 SF = 10 SF = 11 SF = 12	- - - - - - -	-118 -123 -126 -129 -132 -133 -136	- - - - - - -	dBm dBm dBm dBm dBm dBm dBm
RFS_L250_HF	RF sensitivity, Long-Range Mode, highest LNA gain, *LnaBoost* for Band 1, using split Rx/Tx path 250 kHz bandwidth	SF = 6 SF = 7 SF = 8 SF = 9 SF = 10 SF = 11 SF = 12	- - - - - - -	-115 -120 -123 -125 -128 -130 -133	- - - - - - -	dBm dBm dBm dBm dBm dBm dBm
RFS_L500_HF	RF sensitivity, Long-Range Mode, highest LNA gain, *LnaBoost* for Band 1, using split Rx/Tx path 500 kHz bandwidth	SF = 6 SF = 7 SF = 8 SF = 9 SF = 10 SF = 11 SF = 12	- - - - - - -	-111 -116 -119 -122 -125 -128 -130	- - - - - - -	dBm dBm dBm dBm dBm dBm dBm
RFS_L7.8_LF	RF sensitivity, Long-Range Mode, highest LNA gain, Band 2 or 3, using split Rx/Tx path 7.8 kHz bandwidth	SF = 12 SF = 11	- -	-148 -145	- -	dBm dBm
RFS_L10_LF	RF sensitivity, Long-Range Mode, highest LNA gain, Band 3, 10.4 kHz bandwidth	SF = 6 SF = 7 SF = 8	- - -	-132 -136 -138	- - -	dBm dBm dBm
RFS_L62_LF	RF sensitivity, Long-Range Mode, highest LNA gain, Band 3, 62.5 kHz bandwidth	SF = 6 SF = 7 SF = 8 SF = 9 SF = 10 SF = 11 SF = 12	- - - - - - -	-123 -128 -131 -134 -135 -137 -140	- - - - - - -	dBm dBm dBm dBm dBm dBm dBm

Symbol	Description	Conditions	Min.	Typ	Max	Unit
RFS_L125_LF	RF sensitivity, Long-Range Mode, highest LNA gain, Band 3, 125 kHz bandwidth	SF = 6 SF = 7 SF = 8 SF = 9 SF = 10 SF = 11 SF = 12	- - - - - - -	-121 -125 -128 -131 -134 -136 -137	- - - - - - -	dBm dBm dBm dBm dBm dBm dBm
RFS_L250_LF	RF sensitivity, Long-Range Mode, highest LNA gain, Band 3 250 kHz bandwidth	SF = 6 SF = 7 SF = 8 SF = 9 SF = 10 SF = 11 SF = 12	- - - - - - -	-118 -122 -125 -128 -131 -133 -134	- - - - - - -	dBm dBm dBm dBm dBm dBm dBm
RFS_L500_LF	RF sensitivity, Long-Range Mode, highest LNA gain, Band 3 500 kHz bandwidth	SF = 6 SF = 7 SF = 8 SF = 9 SF = 10 SF = 11 SF = 12	- - - - - - -	-112 -118 -121 -124 -127 -129 -130	- - - - - - -	dBm dBm dBm dBm dBm dBm dBm
CCR_LCW	Co-channel rejection Single CW tone = Sens +6 dB 1% PER	SF = 7 SF = 8 SF = 9 SF = 10 SF = 11 SF = 12	- - - - - -	5 9.5 12 14.4 17 19.5	- - - - - -	dB dB dB dB dB dB
CCR_LL	Co-channel rejection	Interferer is a LoRa™ signal using same BW and same SF. Pw = Sensitivity + 3 dB		-6		dB
ACR_LCW	Adjacent channel rejection	Interferer is 1.5*BW_L from the wanted signal center frequency 1% PER, Single CW tone = Sens + 3 dB SF = 7 SF = 12	 - -	 60 72	 - -	 dB dB
IMR_LCW	Image rejection after calibration.	1% PER, Single CW tone = Sens +3 dB	-	66	-	dB
FERR_L	Maximum tolerated frequency offset between transmitter and receiver, no sensitivity degradation, SF6 thru 12	All BW, +/-25% of BW The tighter limit applies (see below)		+/-25%		BW
	Maximum tolerated frequency offset between transmitter and receiver, no sensitivity degradation, SF10 thru 12	SF = 12 SF = 11 SF = 10	-50 -100 -200	- - -	50 100 200	ppm ppm ppm

2.5.6. Digital Specification

Conditions: Temp = 25° C, VDD = 3.3 V, FXOSC = 32 MHz, unless otherwise specified.

Table 11 Digital Specification

Symbol	Description	Conditions	Min	Typ	Max	Unit
V_{IH}	Digital input level high		0.8	-	-	VDD
V_{IL}	Digital input level low		-	-	0.2	VDD
V_{OH}	Digital output level high	Imax = 1 mA	0.9	-	-	VDD
V_{OL}	Digital output level low	Imax = -1 mA	-	-	0.1	VDD
F_{SCK}	SCK frequency		-	-	10	MHz
t_{ch}	SCK high time		50	-	-	ns
t_{cl}	SCK low time		50	-	-	ns
t_{rise}	SCK rise time		-	5	-	ns
t_{fall}	SCK fall time		-	5	-	ns
t_{setup}	MOSI setup time	From MOSI change to SCK rising edge.	30	-	-	ns
t_{hold}	MOSI hold time	From SCK rising edge to MOSI change.	20	-	-	ns
t_{nsetup}	NSS setup time	From NSS falling edge to SCK rising edge.	30	-	-	ns
t_{nhold}	NSS hold time	From SCK falling edge to NSS rising edge, normal mode.	100	-	-	ns
t_{nhigh}	NSS high time between SPI accesses		20	-	-	ns
T_DATA	DATA hold and setup time		250	-	-	ns

3. SX1276/77/78/79 Features

This section gives a high-level overview of the functionality of the SX1276/77/78/79 low-power, highly integrated transceiver. The following figure shows a simplified block diagram of the SX1276/77/78/79.

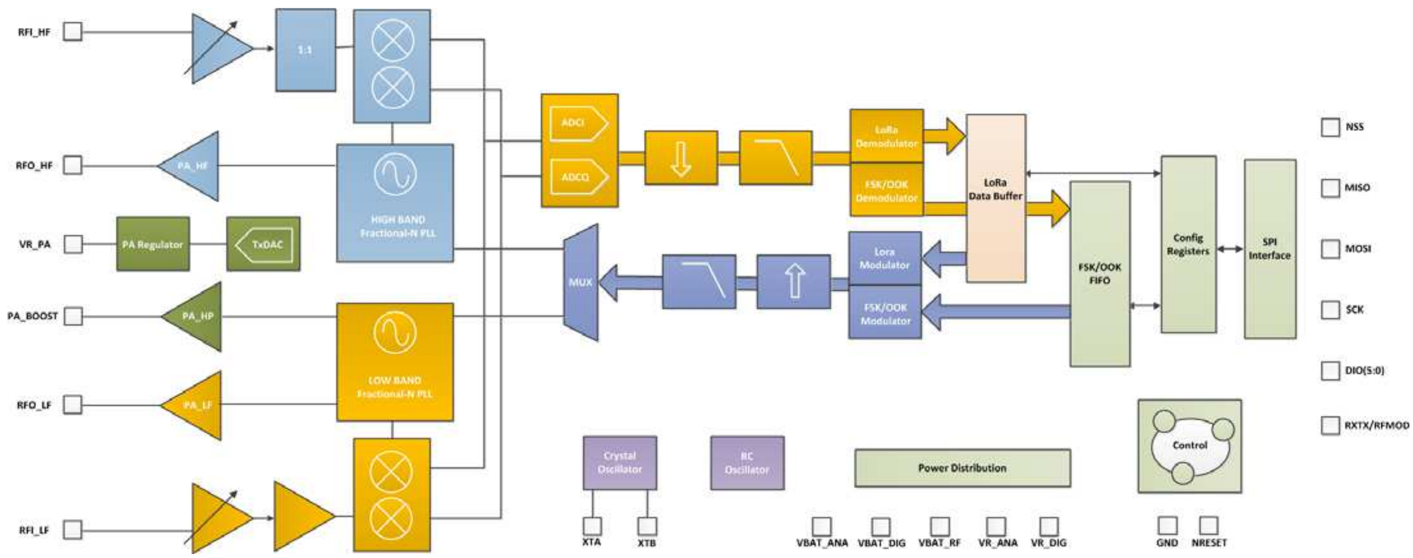

Figure 4. SX1276/77/78/79 Block Schematic Diagram

SX1276/77/78/79 is a half-duplex, low-IF transceiver. Here the received RF signal is first amplified by the LNA. The LNA inputs are single ended to minimize the external BoM and for ease of design. Following the LNA inputs, the conversion to differential is made to improve the second order linearity and harmonic rejection. The signal is then down-converted to in-phase and quadrature (I&Q) components at the intermediate frequency (IF) by the mixer stage. A pair of sigma delta ADCs then perform data conversion, with all subsequent signal processing and demodulation performed in the digital domain. The digital state machine also controls the automatic frequency correction (AFC), received signal strength indicator (RSSI) and automatic gain control (AGC). It also features the higher-level packet and protocol level functionality of the top level sequencer (TLS), only available with traditional FSK and OOK modulation schemes.

The frequency synthesizers generate the local oscillator (LO) frequency for both receiver and transmitter, one covering the lower UHF bands (up to 525 MHz), and the other one covering the upper UHF bands (from 779 MHz). The PLLs are optimized for user-transparent low lock time and fast auto-calibrating operation. In transmission, frequency modulation is performed digitally within the PLL bandwidth. The PLL also features optional pre-filtering of the bit stream to improve spectral purity.

SX1276/77/78/79 feature three distinct RF power amplifiers. Two of those, connected to RFO_LF and RFO_HF, can deliver up to +14 dBm, are unregulated for high power efficiency and can be connected directly to their respective RF receiver inputs via a pair of passive components to form a single antenna port high efficiency transceiver. The third PA, connected to the PA_BOOST pin and can deliver up to +20 dBm via a dedicated matching network. Unlike the high efficiency PAs, this high-stability PA covers all frequency bands that the frequency synthesizer addresses.

SX1276/77/78/79 also include two timing references, an RC oscillator and a 32 MHz crystal oscillator.

All major parameters of the RF front end and digital state machine are fully configurable via an SPI interface which gives access to SX1276/77/78/79's configuration registers. This includes a mode auto sequencer that oversees the transition and calibration of the SX1276/77/78/79 between intermediate modes of operation in the fastest time possible.

The SX1276/77/78/79 are equipped with both standard FSK and long range spread spectrum (LoRa^{TM}) modems. Depending upon the mode selected either conventional OOK or FSK modulation may be employed or the LoRa^{TM} spread spectrum modem.

3.1. LoRa^{TM} Modem

The LoRa^{TM} modem uses a proprietary spread spectrum modulation technique. This modulation, in contrast to legacy modulation techniques, permits an increase in link budget and increased immunity to in-band interference. At the same time the frequency tolerance requirement of the crystal reference oscillator is relaxed - allowing a performance increase for a reduction in system cost. For a detailed description of the design trade-offs and operation of the SX1276/77/78/79 please consult Section 4.1 of the datasheet.

3.2. FSK/OOK Modem

In FSK/OOK mode the SX1276/77/78/79 supports standard modulation techniques including OOK, FSK, GFSK, MSK and GMSK. The SX1276/77/78/79 is especially suited to narrow band communication thanks the low-IF architecture employed and the built-in AFC functionality. For full information on the FSK/OOK modem please consult Section 4.2 of this document.

4. SX1276/77/78/79 Digital Electronics

4.1. The LoRa™ Modem

The LoRa™ modem uses spread spectrum modulation and forward error correction techniques to increase the range and robustness of radio communication links compared to traditional FSK or OOK based modulation. Examples of the performance improvement possible, for several possible settings, are summarised in the table below. Here the spreading factor and error correction rate are design variables that allow the designer to optimise the trade-off between occupied bandwidth, data rate, link budget improvement and immunity to interference.

*Table 12 Example **LoRa™** Modem Performances, 868MHz Band*

Bandwidth (kHz)	Spreading Factor	Coding rate	Nominal Rb (bps)	Sensitivity indication (dBm)	Frequency Reference
10.4	6	4/5	782	-131	TCXO
	12	4/5	24	-147	
20.8	6	4/5	1562	-128	
	12	4/5	49	-144	
62.5	6	4/5	4688	-121	XTAL
	12	4/5	146	-139	
125	6	4/5	9380	-118	
	12	4/5	293	-136	

Notes - for all bandwidths lower than 62.5 kHz, it is advised to use a TCXO as a frequency reference. This is required to meet the frequency error tolerance specifications given in the Electrical Specification

- Higher spreading factors and longer transmission times impose more stringent constraints on the short term frequency stability of the reference. Please get in touch with a Semtech representative to implement extremely low sensitivity products.

For European operation the range of crystal tolerances acceptable for each sub-band (of the ERC 70-03) is given in the specifications table. For US based operation a frequency hopping mode is available that automates both the LoRa™ spread spectrum and frequency hopping spread spectrum processes.

Another important facet of the LoRa™ modem is its increased immunity to interference. The LoRa™ modem is capable of co-channel GMSK rejection of up to 20 dB. This immunity to interference permits the simple coexistence of LoRa™ modulated systems either in bands of heavy spectral usage or in hybrid communication networks that use LoRa™ to extend range when legacy modulation schemes fail.