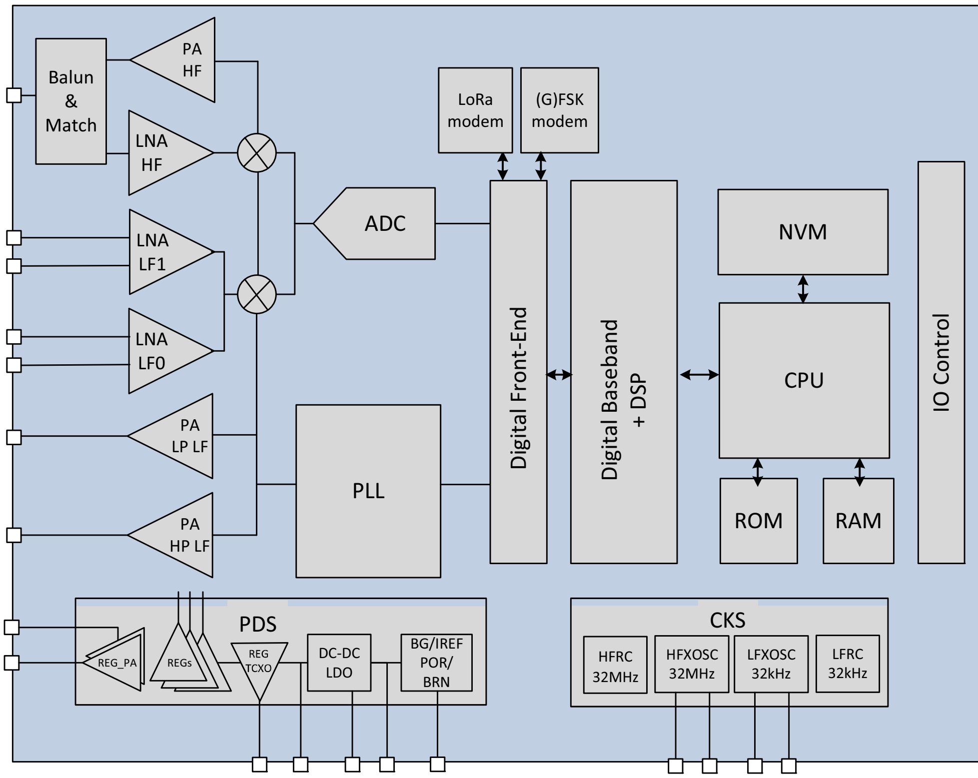
LR1120

Low Power Wi-Fi/ GNSS Scanner + LoRa® Transceiver



The LR1120 is an ultra-low power device targeting geolocation applications. It provides both sub-GHz and 2.4 GHz band communication, integrates a long range LoRa® modem, a multi-constellation global navigation satellite system (GNSS) scanner, and a passive Wi-Fi® Access Point address scanner.

For LPWAN use cases, the LR1120 supports LoRa® and (G)FSK modulation on both sub-GHz and 2.4 GHz bands. It also supports Long Range Frequency Hopping Spread Spectrum (LR-FHSS) on sub-GHz, and 2.4 GHz ISM bands.

The LR1120 complies with the physical layer requirements of the LoRa Alliance® LoRaWAN® specification, while remaining configurable to meet different application requirements and proprietary protocols.

The radio is suitable for systems targeting compliance with radio regulations including but not limited to ETSI EN 300 220, FCC CFR 47 Part 15, and Chinese regulatory requirements.

Besides world-wide sub-GHz and 2.4 GHz communication capabilities, the very-low-power multi-band front-end is capable of acquiring several signals of opportunity used for geolocation:

- 802.11b/g/n Wi-Fi Access Point MAC addresses
- GNSS (GPS, BeiDou, geostationary) satellite signals

Acquired information is transmitted over an LPWAN network to a geolocation server. The geolocation server analyzes the signal information and calculates the LR1120's position with data from a geolocation database, enabling a valuable balance between low power and performance.

Disclaimer

Long Range-Frequency Hopping Spread Spectrum (LR-FHSS) is a high link-budget, high-performance technology combining the benefits of a modulation employing low energy per bit and advanced frequency hopping schemes to achieve improved coexistence, spectral efficiency and sensitivity. Semtech Corp. holds patents directed to aspects of the LR-FHSS technology.

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Ordering Information

Part Number	Delivery	Minimum Order Quantity
LR1120IMLTRT	Tape & Reel	3000 pieces

QFN32 Package, Pb-free, Halogen free, RoHS/WEEE compliant product.

Revision History

Version	ECO	Date	Applicable to[1]	Changes
1.0	060460	Feb 2022	Use Case: 01 FW version: 01.00 or later	First Release
1.1	061060	Apr 2022	Use Case: 01 FW version: 01.00 or later	Modification of ETSI and FCC compliance and other minor changes.

1. Use Case and Version concepts are defined in the LR1120 User Manual, see the *GetVersion* command.

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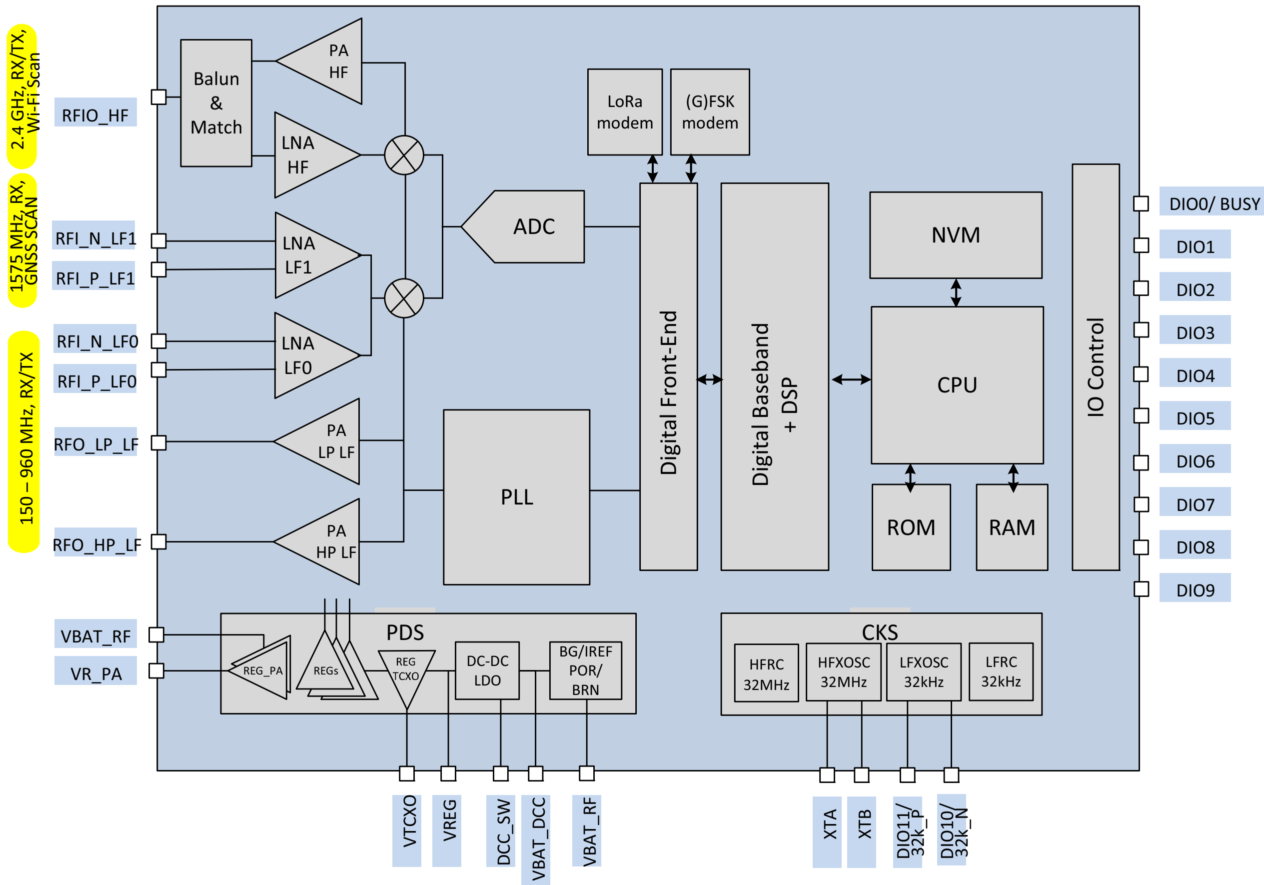
1. System Description

1.1 Simplified Block Diagram

Figure 1-1: LR1120 Simplified Block Diagram



1.2 Overview

1.2.1 Low-Power High-Sensitivity LoRa®/(G)FSK Half-Duplex RF Transceiver

- Worldwide frequency bands support in the range 150 - 960 MHz (sub-GHz) and 2.4 GHz ISM band
- Low Noise Figure modes for enhanced LoRa/ (G) FSK sensitivity (differential input pins RFI_P/N_LF0)
- High power PA path +22 dBm (pin RFO_HP_LF) and High efficiency PA path +15 dBm (pin RFO_LP_LF) for sub-GHz
- High frequency PA path +13 dBm (pin RFIO_HF) for 2.4 GHz ISM band, matched to 50 Ohm impedance, reducing the overall Bill Of Materials cost
- Integrated PA regulator supply selector to simplify dual power +15/+22 dBm with a single board implementation
- Able to support world-wide multi-region BOM, the circuit adapts to satisfy regulatory limits
- Fully compatible with the SX1261/2/8 family and the LoRaWAN® standard, defined by the LoRa Alliance
- LR-FHSS Transmitter, with intra-packet hopping capability

1.2.2 Multi-Purpose Radio Front-End

- 150 - 2600 MHz continuous frequency synthesizer range (2400 MHz - 2500 MHz operation on input/output pin RFIO_HF)
- GPS/ BeiDou scanning (differential input pins RFI_P/N_LF1)
- Wi-Fi® passive scanning (using input/output pin RFIO_HF)
- Digital baseband

1.2.3 Power Management

- Two forms of voltage regulation (DC-DC or linear regulator, LDO) are available depending upon the design priorities of the application. DC-DC usage is recommended for power efficient operation at the cost of an extra inductor.
- Power On Reset (POR), Brown-out detection and Low Battery indication are supported
- Battery voltage measurement

1.2.4 Clock Sources

- 32.768 kHz Low Frequency (LF) internal RC oscillator, optionally used by the circuit Real Time Clock (RTC)
- 32.768 kHz LF crystal oscillator (XOSC), used for the RTC. An external 32.768 kHz reference from a host, applied to pin DIO11, is also possible.
- 32 MHz HF RC (HFRC) oscillator allowing configuration of the device without the need to start the main crystal oscillator
- 32 MHz HF crystal oscillator, HFXOSC, used for radio operation and to calibrate the frequency error of the internal RC oscillators
- 32 MHz TCXO can be used to supply the main clock to the circuit, its power supply being integrated on-chip by REG_TCXO, on pin VTCXO. The circuit is able to boot when a TCXO is connected instead of a 32 MHz crystal, however all start-up (POR) calibrations are skipped. The host processor should program the TCXO configuration and re-launch the calibrations before further usage of the chip. The use of a TCXO is mandatory for GNSS scanning operations.

1.2.5 Digital Subsystem

The circuit on-boards power-efficient functionalities, with sufficient hardware resources to implement a wide range of applications:

- Logic to control chip modes, radio front-end, power management and digital interfaces
- RAM partially retained during sleep mode
- Non-volatile memory (NVM)
- Slave serial peripheral interface (SPI)
- DIO0 used as "BUSY" indicator, indicating that the internal MCU cannot receive any commands from the host controller
- Hardware de-bounce and event detection (IOCD)
- Low-power real-time counter (RTC) and watch-dog timer (WDG)
- LoRa, (G)FSK, modems compatible with the SX126x and SX127x product families in sub-GHz bands
- LoRa, (G)FSK, modems compatible with the SX128x product families in the 2.4 GHz ISM band
- Long Range FHSS in transmit mode, with intra-packet hopping capability

1.2.6 Cryptographic Engine

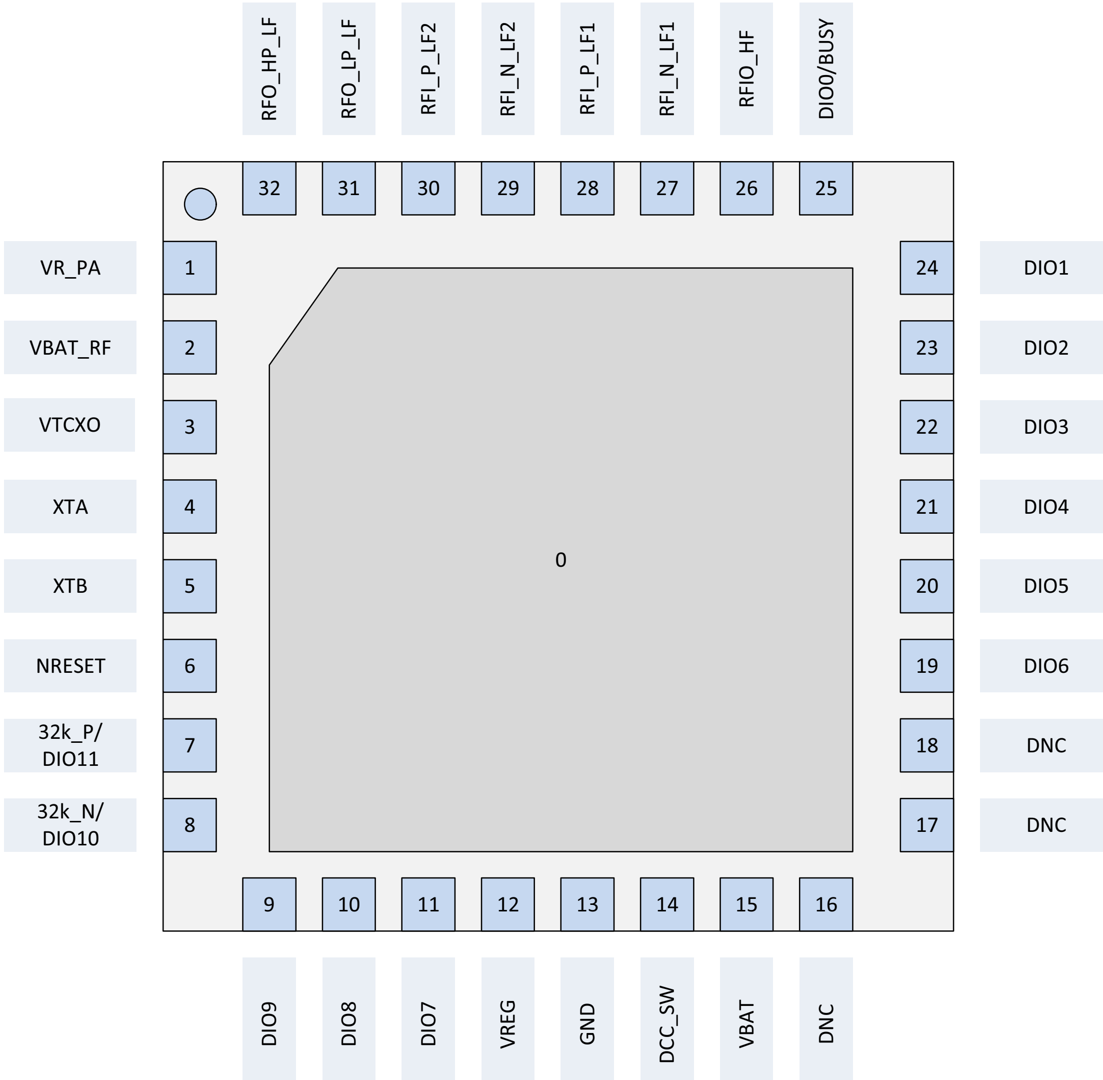
- Hardware support for AES-128 encryption/decryption based algorithms
- Handling device parameters such as DevEUI and JoinEUI, as defined by the LoRa Alliance®
- Protects confidential information such as encryption keys against unauthorized access
- Stores NwkKey, AppKey, as defined in the LoRaWAN® standard

2. Pin Connection

Table 2-1: LR1120 Pinout

Pin	Name	Type	Description
0	GND	-	Exposed Ground pad
1	VR_PA	O	Regulated power amplifier supply, for all power amplifiers
2	VBAT_RF	I	Battery supply
3	VTCXO	O	Internally generated supply for external TCXO frequency reference
4	XTA	-	32 MHz crystal connection, or external TCXO frequency reference input
5	XTB	-	32 MHz crystal connection, or NC in case of external TCXO usage
6	NRESET	I	Reset signal, active low
7	32k_P/ DIO11	I/O	32 kHz crystal connection, or input for 32 kHz reference clock/ Multi-purpose digital I/O
8	32k_N/ DIO10	I/O	32 kHz crystal oscillator connection/ Multi-purpose digital I/O
9	DIO9	I/O	Multi-purpose digital I/O
10	DIO8	I/O	Multi-purpose digital I/O
11	DIO7	I/O	Multi-purpose digital I/O
12	VREG	O	Regulated output voltage from the internal regulator LDO/ DC-DC
13	GND	-	Ground
14	DCC_SW	-	DC-DC Switcher Output
15	VBAT	I	Battery supply
16	DNC	-	Do not connect
17	DNC	-	Do not connect
18	DNC	-	Do not connect
19	DIO6	I/O	Multi-purpose digital I/O
20	DIO5	I/O	Multi-purpose digital I/O
21	DIO4	I/O	Multi-purpose digital I/O
22	DIO3	I/O	Multi-purpose digital I/O
23	DIO2	I/O	Multi-purpose digital I/O
24	DIO1	I/O	Multi-purpose digital I/O
25	DIO0/BUSY	I/O	Multi-purpose digital I/O
26	RFIO_HF	I/O	Receiver input for Wi-Fi passive scanning and 2.4-2.5 GHz input/output
27	RFI_N_LF1	I	RF LF receiver input for GNSS scanning
28	RFI_P_LF1	I	RF LF receiver input for GNSS scanning
29	RFI_N_LF0	I	RF LF receiver input, sub-GHz operation
30	RFI_P_LF0	I	RF LF receiver input, sub-GHz operation
31	RFO_LP_LF	O	RF transmitter output for the low power PA, sub-GHz operation
32	RFO_HP_LF	O	RF transmitter output for the high power PA, sub-GHz operation

Figure 2-1: LR1120 Pinout



3. Specifications

3.1 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, reducing product life time.

Table 3-1: Absolute Maximum Ratings

Symbol	Description	Min	Typ	Max	Unit
VDDmr	Supply voltage	-0.5	-	3.9	V
Tmr	Temperature	-55	-	125	°C
Pmr	RF Input level	-	-	10	dBm

3.2 Operating Range

Operating ranges define the limits for functional operation and parametric characteristics of the device as described in this section. Functionality outside these limits is not guaranteed.

Table 3-2: Operating Range

Symbol	Description		Min	Typ	Max	Unit
VDDop	Supply voltage		1.8	-	3.7	V
Top	Temperature under bias (ambient)		-40	-	85	°C
Clop	Load capacitance on digital ports		-	-	20	pF
ML	Maximum Input power	Sub-GHz path	-	-	0	dBm
		RFIO_HF path	-	-	0	dBm
		GNSS path	-	-	0	dBm
		Wi-Fi path, Wi-Fi b mode	-	-	-10	dBm
		Wi-Fi path, Wi-Fi g mode	-	-	-30	dBm
VSWR	Voltage Standing Wave Ratio	Sub-GHz and RFIO_HF path	-	-	10:1	-

3.3 ESD and Latch-up

The LR1120 is a high performance radio frequency device presenting high ESD and latch-up robustness on all pins. The chip should be handled with all the necessary ESD precautions to avoid any permanent damage.

Table 3-3: ESD and Latch-up

Symbol	Description	Min	Typ	Max	Unit
ESD_HBM	Human Body Model, JEDEC standard JESD22-A114, class II	-	-	2.0	kV
ESD_CDM	ESD Charged Device Model, JEDEC standard JESD22-C101, class II	-	-	500	V
LU	Latch-up, JEDEC standard JESD78, class II level A	-	-	100	mA

3.4 Electrical Specifications

The tables below give the electrical specifications of the LR1120 transceiver under the following conditions, unless otherwise specified:

- VBAT_RF = VBAT = 3.3 V, Temperature = 25 °C, FXOSC = 32 MHz, crystal oscillator,
- FRF = 915/869 MHz for sub-GHz path FSK and LoRa®,
- FRF = 1.57542 GHz for the GNSS path,
- FRF = 2.45 GHz for the RFIO_HF path,
- All RF impedances on sub-GHz and RFIO_HF path matched using multi-band reference design, transmit mode output power defined in 50 Ω load, RxBoosted = 1 for LoRa and FSK, differential use of the LNAs (receiver gain levels are referenced in the device's User Guide),
- FSK Bit Error Rate (BER) = 0.1%, 2-level FSK modulation without pre-filtering, BR = 4.8 kb/s, FDA = 5 kHz, BWF = 20 kHz,
- LoRa Packet Error Rate (PER) = 1%, BWL= 125 kHz, packet of 64 bytes, preamble of 8 symbols, error correction code CR=4/5, CRC on payload enabled, explicit header, sub-GHz frequency range,
- GNSS and Wi-Fi sensitivity given for 10% PER,
  - Wi-Fi b, MPDU size of 272 bits, or 34 Bytes
  - Wi-Fi g/n, MPDU size of 288 bits, or 36 Bytes
- Blocking Immunity, ACR, and co-channel rejection are given for a single tone interferer and referenced to sensitivity +3 dB, blocking tests are performed with unmodulated interferer,
- All power consumption numbers are given with XTAL mode used, the consumption of the TCXO has to be added,
- All power consumption numbers are given without considering the external LNA on the GPS path,
- All receiver BW are expressed as **Double SideBand (DSB)** throughout this document.

3.4.1 Power Consumption

The below tables give the total consumptions of all blocks in the specified modes of the circuit.

Table 3-4: Basic Modes Power Consumption

Symbol	Description	Conditions	Min	Typ	Max	Unit
IDDPDN	Supply current in power down mode		-	0.8	-	µA
IDDSL3	Supply current in SLEEP mode, no RTC	8 kB RAM retained	-	1.6	-	µA
IDDSL1 IDDSL3A	Supply current in SLEEP mode LFRC (32 kHz) based RTC	no RAM retained 8 kB RAM retained	- -	1.6 1.85	- -	µA µA
IDDSL2 IDDSL4A	Supply current in SLEEP mode LFXOSC (32 kHz) based RTC	No RAM retained 8 kB RAM retained	- -	1.5 1.75	- -	µA µA
IDDSBRLD	Supply current in STBY_RC	HFRC (32 MHz) ON, LDO, System clock 16 MHz	-	1.25	-	mA
IDDSBXLD IDDSBXDC	Supply current in STBY_XOSC	HFXOSC ON, LDO HFXOSC ON, DC-DC	- -	1.3 1.1	- -	mA mA
IDDFSDC	Supply current in Synthesizer mode	DC-DC, system clock 32 MHz	-	2.85	-	mA

Table 3-5: Receive Mode Power Consumption, DC-DC mode used

Symbol	Description	Conditions	Min	Typ	Max	Unit
IDDRXF1	Supply current in Receive mode	FSK 4.8 kb/s sub-GHz with RxBoosted = 1	- -	5.4 7.5	- -	mA mA
IDDRXF2		FSK 4.8 kb/s 2.4 GHz with RxBoosted = 1 FSK 1 Mb/s 2.4 GHz with RxBoosted = 1	- - - -	5.9 6.6 6.7 7.4	- - - -	mA mA mA mA
IDDRXL1		LoRa® SF12 125 kHz sub-GHz with RxBoosted = 1	- -	5.7 7.8	- -	mA mA
IDDRXL2		LoRa® SF12 125 kHz 2.4 GHz with RxBoosted = 1 LoRa® SF12 406kHz 2.4 GHz with RxBoosted = 1 LoRa® SF12 812 kHz 2.4 GHz with RxBoosted = 1	- - - - - -	6 6.7 7.6 8.3 6.8 7.5	- - - - - -	mA mA mA mA mA mA
IDDRXWIFI1 IDDRXWIFI2 IDDRXWIFI3	Supply current in Wi-Fi scan mode	Preamble detect phase Capture phase Processing phase	- - -	11 10 3	- - -	mA mA mA
IDDRXGPS1 IDDRXGPS2	Supply current in GNSS scan mode	Capture phase Processing phase	- -	10 5	- -	mA mA

Table 3-6: Transmit Mode Power Consumption[1]

Symbol	Frequency Band	PA Match	Output Power	Min	Typ	Max	Unit
IDDTXLP1	868/915 MHz	+14 dBm, LP PA[2]	+15dBm	-	36	-	mA
IDDTXLP2			+14 dBm	-	28	-	mA
IDDTXLP3			+10 dBm	-	18.5	-	mA
IDDTXLP4	434/490 MHz		+15dBm	-	35	-	mA
IDDTXLP5			+14 dBm	-	28	-	mA
IDDTXLP6			+10 dBm	-	19	-	mA
IDDTXHP1	868/915 MHz	+22 dBm, HP PA[3]	+22 dBm	-	118	-	mA
IDDTXHP2			+20 dBm	-	96	-	mA
IDDTXHP3			+17 dBm	-	73	-	mA
IDDTXHP4			+14 dBm	-	50	-	mA
IDDTXHP5	434/490 MHz		+22 dBm	-	100	-	mA
IDDTXHP6			+20 dBm	-	86	-	mA
IDDTXHP7			+17 dBm	-	70	-	mA
IDDTXHP8			+14 dBm	-	45	-	mA
IDDTXHF1	2.4 GHz	+13 dBm, HF PA	+13 dBm	-	26	-	mA
IDDTXHF2			+10 dBm	-	23	-	mA

1. Using optimized settings described in the LR1120 User Manual.
2. DC-DC mode of the LDO/DC-DC combo is used to supply the entire circuit.
3. Battery used to supply the PA, and DC-DC used to supply the rest of the circuit.

Table 3-7: Wi-Fi Passive Scanning Duration[1]

Symbol	Description	Conditions	Min	Typ	Max	Unit
TWFBA	Average scanner time to capture 6 MAC addresses by scanning 3 Wi-Fi channels	Wi-Fi 802.11 b, DSSS, DBPSK	-	65-75	-	ms
TWFBP	Wi-Fi 802.11 b	Preamble search phase	-	10[2]	-	ms
TWFB1	Wi-Fi 802.11 b DBPSK, DR = 1 Mb/s	Capture phase MAC search	-	0.5	-	ms
TWFB2		Demodulation phase MAC search	-	1.3	-	ms
TWFB3		Capture phase country code	-	3.0	-	ms
TWFB4		Demodulation phase MAC country code	-	6.2[3]	-	ms
TWFB5	Wi-Fi 802.11 b DQPSK, DR = 2 Mb/s	Capture phase MAC search	-	0.5	-	ms
TWFB6		Demodulation phase MAC search	-	1.8	-	ms
TWFB7		Capture phase country code	-	3.0	-	ms
TWFB8		Demodulation phase MAC country code	-	6.87[4]	-	ms
TWGNC	Wi-Fi 802.11 g and n	Capture phase	-	0.1	-	ms

Table 3-7: Wi-Fi Passive Scanning Duration[1] (Continued)

Symbol	Description	Conditions	Min	Typ	Max	Unit
TWFGD1	Wi-Fi 802.11 g demodulation phase	BPSK, CR = 1/2	-	42.7	-	ms
TWFGD2		BPSK, CR = 3/4		49.8		ms
TWFGD3		QPSK, CR = 1/2		39.4		ms
TWFGD4		QPSK, CR = 3/4		47.8		ms
TWFGD5		16-QAM, CR = 1/2		38.8		ms
TWFGD6		16-QAM, CR = 3/4		47.2		ms
TWNLD1	Wi-Fi 802.11 n, long guard interval demodulation phase	BPSK, CR = 1/2	-	49.4	-	ms
TWNLD2		QPSK, CR = 1/2	-	47.3	-	ms
TWNLD3		QPSK, CR = 3/4	-	56.4	-	ms
TWNLD4		16-QAM, CR = 1/2	-	46.6	-	ms
TWNLD5		16-QAM, CR = 3/4	-	55.7	-	ms
TWNSD1	Wi-Fi 802.11 n, short guard interval demodulation phase	BPSK, CR = 1/2	-	48.4	-	ms
TWNSD2		QPSK, CR = 1/2	-	47.3	-	ms
TWNSD3		QPSK, CR = 3/4	-	56.4	-	ms
TWNSD4		16-QAM, CR = 1/2	-	46.6	-	ms
TWNSD5		16-QAM, CR = 3/4	-	55.7	-	ms

1. Demodulation time given as the calculated average time over 100 packets
2. Preamble detection phase depends significantly on the traffic in the scanner channel, beacon are sent every 102.4 ms
3. Time depends on beacon size
4. Time depends on beacon size

Table 3-8: Wi-Fi Passive Scanning Average Energy Consumption, DC-DC mode used

Symbol	Description	Conditions	Min	Typ	Max	Unit
ENWFB1	Average scanner time to capture 6 MAC addresses by scanning 3 Wi-Fi channels	Wi-Fi 802.11 b, DSSS, DBPSK	-	0.5-0.7	-	µWh

Table 3-9: GNSS Scanning Duration

Symbol	Description	Conditions	Min	Typ	Max	Unit
TGPSATIC	Indoor detection[1], GPS	Autonomous mode	-	1.25	-	s
TGPSASIC		Assisted mode	-	0.7	-	s
TGPSAS1	SV scan, GPS, assisted mode	Best assistance information	-	3	-	s
TGPSAS2		Good assistance information	-	3.8	-	s
TGPSBEIAS1	GPS+Beidou, assisted mode	Best assistance information	-	6.8	-	s
TGPSBEIAS2		Good assistance information	-	7.8	-	s

1. Indoor conditions, 0 SV detected

Table 3-10: GNSS Scanning Energy Consumption, DC-DC mode Used[1]

Symbol	Description	Conditions	Min	Typ	Max	Unit
ENGATIC	Indoor detection, GPS	Autonomous mode	-	5.4	-	µWh
ENGASIC		Assisted mode	-	4.1	-	µWh
ENGPSAS1	SV scan, GPS, assisted mode	Best assistance information	-	11.4	-	µWh
ENGPSAS2		Good assistance information	-	13.8	-	µWh
ENGPSBEIAS1	SV scan, GPS+Beidou, assisted mode	Best assistance information	-	24.8	-	µWh
ENGPSBEIAS2		Good assistance information	-	27.7	-	µWh

1. It takes into account only the energy needed by the LR1120 to acquire the signals of opportunity and does not include any uplink/ downlink communication to transmit the information to the servers, or receiver Almanac /Ephemeris data.

3.4.2 General Specifications

Table 3-11: General Specifications

Symbol	Description	Conditions	Min	Typ	Max	Unit
FRSYNTH	Synthesizer frequency range		150	-	2500	MHz
FSTEP	Synthesizer frequency step	FXOSC/ 2^{25}	-	0.9536	-	Hz
HFOSCCP	32 MHz Crystal oscillator supported off-chip capacitance	Single ended on XTA and XTB	0.2	1	3	pF
OSCTRM1	HF Crystal oscillator trimming step		-	1	-	ppm
LFCLKFR	Frequency of external LF clock applied on pin DIO11		-	32.768	-	kHz
LFCLKRF	Rise/fall time for external LF clock applied on pin DIO11		-	-	5	ns
BRFSK	Bit rate, FSK Minimum modulation index is 0.5	Programmable, lowest setting Programmable, highest setting	- -	0.6 300[1]	- -	kb/s kb/s
FDAFSK	Frequency deviation, FSK	Programmable FDA + BRF / 2 = < 250 kHz	- -	0.6 200	- -	kHz kHz
BRLORA	Raw data rate, LoRa®, sub-GHz	SF12, BWL = 62.5 kHz, CR = 1/2 SF5, BWL = 500 kHz, CR = 4/5	- -	91 62.5	- -	b/s kb/s
	Raw data rate, LoRa, RFIO_HF 2.4 GHz	SF12, BWL=203 kHz, CR=4/5 SF7, BWL=812 kHz, CR=4/5	- -	0.476 35.53	- -	kb/s kb/s
BWL	Signal BW, LoRa	Programmable, lowest setting Programmable, highest setting	- -	62.5 500[2]	- -	kHz kHz
	Signal BW, LoRa, RFIO_HF 2.4 GHz	Programmable, lowest setting Programmable, highest setting	- -	203 812	- -	kHz kHz
SF	Spreading factor coefficient, LoRa chips/symbol = 2^SF	Programmable, lowest setting Programmable, highest setting	- -	5 12	- -	- -
BWF	DSB channel filter BW, FSK, sub-GHz path	Programmable, lowest setting Programmable, highest setting	- -	4.8 467	- -	kHz kHz

1. Maximum bit rate is assumed to scale with the RF frequency; example 300 kb/s in the 869/915 MHz frequency bands and only 50 kb/s @150 MHz
2. For RF frequencies below 300 MHz, the LoRa signal BW is limited to maximum 250 kHz, the data rate being reduced accordingly

3.4.3 Receiver

Table 3-12: Receiver Specifications, Sub-GHz Bands

Symbol	Description	Conditions	Min	Typ	Max	Unit
FRRXLF	RX input frequency	Sub-GHz frequency range, LoRa® and FSK[1]	150	-	960	MHz
ZINRXLF	RX input impedance	Impedance across RFI_N_LF0 / RFI_P_LF0[2]				
		433 MHz	-	29 - j289	-	Ohm
		868 MHz	-	9.4 - j141	-	Ohm
		920 MHz	-	9.5 - j131	-	Ohm
PHNLF1	Synthesizer phase noise[3,4] sub-GHz band	100 kHz offset	-	-102	-	dBc/Hz
PHNLF2		1 MHz offset	-	-120	-	dBc/Hz
PHNLF3		10 MHz offset	-	-129	-	dBc/Hz
RXS2F1	Sensitivity 2-FSK	BRF = 0.6 kb/s, FDA = 0.8 kHz, BWF = 4 kHz	-	-123	-	dBm
RXS2F2		BRF = 1.2 kb/s, FDA = 5 kHz, BWF = 20 kHz	-	-122	-	dBm
RXS2F3		BRF = 4.8 kb/s, FDA = 5 kHz, BWF = 20 kHz	-	-117.5	-	dBm
RXS2F4		BRF = 38.4 kb/s, FDA = 40 kHz, BWF = 160 kHz	-	-109	-	dBm
RXS2F5		BRF = 250 kb/s, FDA = 125 kHz, BWF = 500 kHz	-	-103.5	-	dBm
RXS2F1HP3	Sensitivity 2-FSK, RxBoosted = 1	BRF = 0.6 kb/s, FDA = 0.8 kHz, BWF = 4 kHz	-	-125	-	dBm
RXS2F2HP3		BRF = 1.2 kb/s, FDA = 5 kHz, BWF = 20 kHz	-	-124	-	dBm
RXS2F3HP3		BRF = 4.8 kb/s, FDA = 5 kHz, BWF = 20 kHz	-	-119	-	dBm
RXS2F4HP3		BRF = 38.4 kb/s, FDA = 40 kHz, BWF = 160 kHz	-	-111	-	dBm
RXS2F5HP3		BRF = 250 kb/s, FDA = 125 kHz, BWF = 500 kHz	-	-105	-	dBm
CCRFSK	Co-channel rejection, FSK		-	-8	-	dB
ACRFSK	Adjacent channel rejection, FSK	Offset = +/- 50 kHz	-	47	-	dB
BIFSK1	Blocking immunity, FSK	BRF = 4.8 kb/s, FDA = 5 kHz, BWF = 20 kHz Offset = +/- 1 MHz	-	67	-	dB
BIFSK2		Offset = +/- 2 MHz	-	70	-	dB
BIFSK3		Offset = +/- 10 MHz	-	80	-	dB
IIP3FSK	3rd order input intercept point, FSK	Unwanted tones @1 MHz and 1.96 MHz	-	-12	-	dBm
IMRFSK	Image attenuation, sub-GHz path	Without IQ calibration	-	40	-	dB
		With IQ calibration	-	50	-	dB
RXSL1	Sensitivity LoRa®	BWL = 62.5 kHz, SF = 7	-	-128	-	dBm
RXSL2		BWL = 62.5kHz, SF = 12	-	-142	-	dBm
RXSL3		BWL = 125 kHz, SF = 7	-	-125	-	dBm
RXSL4		BWL = 125 kHz, SF = 12	-	-139	-	dBm
RXSL5		BWL = 250 kHz, SF = 7	-	-122	-	dBm
RXSL6		BWL = 250 kHz, SF = 12	-	-136	-	dBm
RXSL7		BWL = 500 kHz, SF = 7	-	-118	-	dBm
RXSL8		BWL = 500 kHz, SF = 12	-	-132	-	dBm

Table 3-12: Receiver Specifications, Sub-GHz Bands (Continued)

Symbol	Description	Conditions	Min	Typ	Max	Unit
RXSL1HP7	Sensitivity LoRa®, RxBoosted = 1	BWL = 62.5 kHz, SF = 7	-	-130	-	dBm
RXSL2HP7		BWL = 62.5kHz, SF = 12	-	-144	-	dBm
RXSL3HP7		BWL = 125 kHz, SF = 7	-	-127	-	dBm
RXSL4HP7		BWL = 125 kHz, SF = 12	-	-141	-	dBm
RXSL5HP7		BWL = 250 kHz, SF = 7	-	-124	-	dBm
RXSL6HP7		BWL = 250 kHz, SF = 12	-	-138	-	dBm
RXSL7HP7		BWL = 500 kHz, SF = 7	-	-121	-	dBm
RXSL8HP7		BWL = 500 kHz, SF = 12	-	-134	-	dBm
CCRLORA1	Co-channel rejection, LoRa®	SF = 7	-	5	-	dB
CCRLORA2		SF = 12	-	19	-	dB
	Adjacent channel rejection, LoRa®	Offset = +/- 1.5 x BW_L				
ACRLORA1		BW_L = 125 kHz, SF = 7	-	60	-	dB
ACRLORA2		BW_L = 125 kHz, SF = 12	-	73	-	dB
BILORA1	Blocking immunity, LoRa®, BW_L = 125kHz	SF =12, offset = +/- 1MHz	-	88	-	dB
BILORA2		SF =12, offset = +/- 2 MHz	-	91	-	dB
BILORA3		SF =12, offset = +/- 10 MHz	-	103	-	dB
BILORA4		SF =7, offset = +/- 1MHz	-	74	-	dB
BILORA5		SF =7, offset = +/- 2 MHz	-	77	-	dB
BILORA6		SF =7, offset = +/- 10 MHz	-	90	-	dB
FERR	Max. tolerated frequency offset between Tx and Rx	SF5 to SF12 All bandwidths, ±25% of BW. The tighter limit applies (see below)	-	+/- 25%	-	BW_L
	Max. tolerated frequency offset between Tx and Rx	SF12	-50	-	50	ppm
		SF11	-100	-	100	ppm
		SF10	-200	-	200	ppm
FDRIFT	LoRa frequency drift tolerance	For sensitivity degradation below 3 dB BW_L=125kHz, SF12, LowDataRateOptimize = 1	-	-	120	Hz/s

1. LoRa operation is on the 150 - 960MHz band
2. Single ended impedance
3. Phase Noise specifications are given for the recommended PLL bandwidth to be used for the specific modulation/ bit rate
4. Phase Noise is not constant over frequency, the topology of VCO + DIV used, for two frequencies close to each other, the phase noise could change significantly; the specification covers the worse value

Table 3-13: Receiver Specifications, RFIO-HF Path

Symbol	Description	Conditions	Min	Typ	Max	Unit
FRRXHF	RX input frequency	2.4 GHz frequency range, LoRa and FSK	2400	-	2500	MHz
ZINRXHF	RX input impedance	Impedance across RFIP_HF, 2.4 GHz	-	50 + j 0	-	Ohm
RXS2FHF2	Sensitivity 2-FSK	BRF = 1.2 kb/s, FDA = 5 kHz, BWF = 20 kHz	-	-117	-	dBm
RXS2FHF3		BRF = 4.8 kb/s, FDA = 5 kHz, BWF = 20 kHz	-	-112	-	dBm
RXS2FHF4		BRF = 38.4 kb/s, FDA = 40 kHz, BWF = 160 kHz	-	-103	-	dBm
RXS2FHF5		BRF = 250 kb/s, FDA = 125 kHz, BWF = 500 kHz	-	-97.5	-	dBm
CCRFSKHF	Co-channel rejection, FSK		-	-8	-	dB
ACRFSKHF1	Adjacent channel rejection, FSK	Offset= = +/- 50 kHz	-	33	-	dB
ACRFSKHF2		Offset= = +/- 1 MHz	-	58	-	dB
BIFSKHF1	Blocking Immunity, FSK	Offset= = +/- 2 MHz	-	63	-	dB
BIFSKHF2		Offset= = +/- 10 MHz	-	77	-	dB
IMRFSKHF	Image attenuation, FSK	Without IQ calibration	-	23	-	dB
RXSLHF7	Sensitivity LoRa Signal2.4 GHz band RxBoosted = 1	BWL = 406 kHz, SF = 7	-	-115	-	dBm
RXSLHF8		BWL = 406 kHz, SF = 12	-	-129	-	dBm
RXSLHF9		BWL = 812 kHz, SF = 7	-	-112	-	dBm
RXSLHF10		BWL = 812 kHz, SF = 12	-	-125	-	dBm
CCRLORAHF1	Co-channel rejection, LoRa®	BWL = 406 kHz, SF = 7	-	5	-	dB
CCRLORAHF2		BWL = 406 kHz, SF = 12	-	19	-	dB
CCRLORAHF3		BWL = 812 kHz, SF = 7	-	5	-	dB
CCRLORAHF4		BWL = 812 kHz, SF = 12	-	19	-	dB

Table 3-13: Receiver Specifications, RFIO-HF Path (Continued)

Symbol	Description	Conditions	Min	Typ	Max	Unit
ACRLORAHF1	Adjacent channel rejection, LoRa®	BWL = 406 kHz, SF=7, Offset = +1.5 x BW_L	-	53	-	dB
ACRLORAHF2		BWL = 406 kHz, SF=7, Offset = -1.5 x BW_L	-	34	-	dB
ACRLORAHF3		BWL = 406 kHz, SF=12, Offset = +1.5 x BW_L	-	68	-	dB
ACRLORAHF4		BWL = 406 kHz, SF=12, Offset = -1.5 x BW_L	-	49	-	dB
ACRLORAHF5		BWL = 812 kHz, SF=7, Offset = +1.5 x BW_L	-	59	-	dB
ACRLORAHF6		BWL = 812 kHz, SF=7, Offset = -1.5 x BW_L	-	59	-	dB
ACRLORAHF7		BWL = 812 kHz, SF=12, Offset = +1.5 x BW_L	-	72	-	dB
ACRLORAHF8		BWL = 812 kHz, SF=12, Offset = -1.5 x BW_L	-	72	-	dB
BILORAHF1	Blocking Immunity, LoRa®	BWL = 406 kHz, SF=7, Offset= +/- 1 MHz	-	59	-	dB
BILORAHF2		BWL = 406 kHz, SF=7, Offset= +/- 2MHz	-	64	-	dB
BILORAHF3		BWL = 406 kHz, SF=7, Offset= +/- 10 MHz	-	80	-	dB
BILORAHF4		BWL = 406 kHz, SF=12, Offset= +/- 1 MHz	-	73	-	dB
BILORAHF5		BWL = 406 kHz, SF=12, Offset= +/- 2MHz	-	79	-	dB
BILORAHF6		BWL = 406 kHz, SF=12 Offset= +/- 10 MHz	-	94	-	dB
BILORAHF7		BWL = 812 kHz, SF=7, Offset= +/- 1 MHz	-	57	-	dB
BILORAHF8		BWL = 812 kHz, SF=7, Offset= +/- 2MHz	-	61	-	dB
BILORAHF9		BWL = 812 kHz, SF=7, Offset= +/- 10 MHz	-	78	-	dB
BILORAHF10		BWL = 812 kHz, SF=12, Offset= +/- 1 MHz	-	70	-	dB
BILORAHF11		BWL = 812 kHz, SF=12, Offset= +/- 2MHz	-	76	-	dB
BILORAHF12		BWL = 812 kHz, SF=12 Offset= +/- 10 MHz	-	91	-	dB

Table 3-14: Receiver Specifications, GNSS Scanner[1]

Symbol	Description	Conditions	Min	Typ	Max	Unit
FRRXGPS	RX input frequency	GPS	-	1.57542	-	GHz
		BeiDou	-	1.5611	-	
ZINRXGPS	RX input impedance	impedance across RFI_N_LF1 / RFI_P_LF1[2]	-	17.6 - j76.5	-	Ohm
RXSGPS1E	GNSS sensitivity	GPS, indoor classification, and strong signal SV capture	-	-134	-	dBm
RXSGPS2E		GPS, weak signal SV capture	-	-141	-	dBm
RXSBEI1E		BeiDou, strong signal SV capture	-	-131	-	dBm
RXSBEI2E		BeiDou, weak signal SV capture	-	-138	-	dBm

1. All sensitivity numbers are given using the external LNA listed in the reference design.
2. Single ended impedance

Table 3-15: Receiver Specifications, Wi-Fi Passive Scanner

Symbol	Description	Conditions	Min	Typ	Max	Unit
FRRXWF	RX input frequency	Wi-Fi channels	2412	-	2484	MHz
RXSWFB1	Wi-Fi sensitivity for Wi-Fi 802.11 b, DSSS	DBPSK, DR = 1Mb/s	-	-94	-	dBm
RXSWFB2		DQPSK, DR = 2 Mb/s	-	-91	-	dBm
RXSWFG1	Wi-Fi sensitivity for Wi-Fi 802.11 g, OFDM, 20MHz channel spacing	BPSK, CR = 1/2, DR = 6 Mb/s	-	-88	-	dBm
RXSWFG2		BPSK, CR = 3/4, DR = 9 Mb/s	-	-85	-	dBm
RXSWFG3		QPSK, CR = 1/2, DR = 12 Mb/s	-	-87	-	dBm
RXSWFG4		QPSK, CR = 3/4, DR = 18 Mb/s	-	-84	-	dBm
RXSWFG5		16-QAM, CR = 1/2, DR = 24 Mb/s	-	-82	-	dBm
RXSWFG6		16-QAM, CR = 3/4, DR = 36 Mb/s	-	-78	-	dBm
RXSWFG7	Wi-Fi sensitivity for Wi-Fi 802.11 n[1], OFDM, 20MHz channel spacing, long guard interval	BPSK, CR = 1/2, DR = 6.5 Mb/s	-	-87	-	dBm
RXSWFG8		QPSK, CR = 1/2, DR = 13 Mb/s	-	-85	-	dBm
RXSWFG9		QPSK, CR = 3/4, DR = 19.5 Mb/s	-	-81	-	dBm
RXSWFG10		16-QAM, CR = 1/2, DR = 26 Mb/s	-	-80	-	dBm
RXSWFG11		16-QAM, CR = 3/4, DR = 39 Mb/s	-	-75	-	dBm
RXSWFG12	Wi-Fi sensitivity for Wi-Fi 802.11 n[1], OFDM, 20MHz channel spacing, short guard interval	BPSK, CR = 1/2, DR = 7.2 Mb/s	-	-87	-	dBm
RXSWFG13		QPSK, CR = 1/2, DR = 14.4 Mb/s	-	-85	-	dBm
RXSWFG14		QPSK, CR = 3/4, DR = 21.7 Mb/s	-	-82	-	dBm
RXSWFG15		16-QAM, CR = 1/2, DR = 28.9 Mb/s	-	-80	-	dBm
RXSWFG16		16-QAM, CR = 3/4, DR = 43.3 Mb/s	-	-76	-	dBm
IIP3WF	3rd order input intercept point	Unwanted tones @22 MHz and 24 MHz offsets	-	-28	-	dBm
		Unwanted tones @25 MHz and 48 MHz offsets	-	-15	-	dBm
ACRWFB	Selectivity, at sensitivity + 3dB, for 50% PER	Wi-Fi b 1Mb/s, 25 MHz offset	-	51	-	dB
ACRWFG		Wi-Fi g 6 Mb/s, 25 MHz offset	-	24	-	dB

1. 2.4 GHz Wi-Fi n only, mixed mode

3.4.4 Transmitter

Table 3-16: Transmitter Specifications, sub-GHz Path

Symbol	Description	Conditions	Min	Typ	Max	Unit
TXOPLP TXOPHP	Maximum TX power	LP PA HP PA	+12 +19	+15 +22	- -	dBm dBm
TXDRPLF1 TXDRPLF2	Drop in maximum TX power vs. VDD (1.8 to 3.7V)	LP PA operating under DC-DC or LDO HP PA, operating under battery	- -	0.5 6	- -	dB dB
TXPRNGLF	TX power range	Programmable in steps of -1dB from maximum TX power	-	31	-	steps
TXACCLF	TX output power step accuracy		-	+/- 2	-	dB
TXRMPLF	Power amplifier ramping time	Programmable, lowest step Programmable, highest step	- -	16 304	- -	µs µs
TXEVM	EVM for LR-FHSS	GMSK 488 b/s	-	-	-20	dB

Table 3-17: Transmitter Specifications, RFIO_HF Path

Symbol	Description	Conditions	Min	Typ	Max	Unit
TXOPHF	Maximum TX power	HF PA	9	+11.5	-	dBm
TXDRPHF	Drop in maximum TX power vs. VDD (1.8 to 3.7V)	LP PA operating under DC-DC or LDO	-	0.5	-	dB
TXPRNGHF	TX power range	Programmable in steps of -1dB from maximum TX power	-	31	-	steps
TXACCHF	TX output power step accuracy		-	+/- 2	-	dB
TXRMPHF	Power amplifier ramping time	Programmable, lowest step Programmable, highest step	- -	16 304	- -	µs µs
TXEVMHF	EVM for LR-FHSS	GMSK 488 b/s	-	-	-20	dB

3.5 Reference Oscillator

Table 3-18: 32 MHz Crystal Specifications

Symbol	Description	Conditions	Min	Typ	Max	Unit
FXOSCHF	Crystal oscillator frequency		-	32	-	MHz
CLOADHF	Crystal loading capacitance	Differential	9.5	10	10.5	pF
C0XTALHF	Crystal shunt capacitance		0.3	0.6	2	pF
RSXTALHF	Crystal series resistance		-	30	60	Ω
CMXTALHF	Crystal motional capacitance		1.3	1.89	2.5	fF
DRIVEHF	Drive level		-	-	100	µW
FRTOLHF	Crystal frequency accuracy	Initial Over temperature (-20 to 70 °C) Aging over 10 years	- - -	- - -	+/- 10 +/- 10 +/- 10	ppm ppm ppm

Table 3-19: 32 MHz TCXO Regulator Specifications

Symbol	Description	Conditions	Min	Typ	Max	Unit
CVTCXO	External decoupling capacitor for REG_TCXO	X5R type recommended	70	100	130	nF
RVTCXO	Equivalent series resistance for CVTCXO		0.1	-	1	Ohm
VTCXO	Regulated voltage range for TCXO voltage supply, VDDop > VTCXO + 200 mV	RegTcxoTune = 000 RegTcxoTune = 001 RegTcxoTune = 111	- - -	1.6 1.7 3.3	- - -	V V V
ILTCXO	Load current for TCXO regulator		-	1.5	4	mA
ATCXO	Amplitude voltage for external TCXO applied to XTA pin	AC coupled through 10 pF DC-cut series with 220 Ohm	0.4	0.6	1.2	Vpk-pk

Table 3-20: 32 kHz Crystal Specifications

Symbol	Description	Conditions	Min	Typ	Max	Unit
FXOSCLF	Crystal oscillator frequency		32400	32768	33100	Hz
CLOADLF	Crystal loading capacitance	Differential	-	9.0	-	pF
C0XTALLF	Crystal shunt capacitance		0.7	1.1	2	pF
RSXTALLF	Crystal series resistance		25	45	100	kΩ
CMXTALLF	Crystal motional capacitance		1.5	4.7	8	fF
DRIVELF	Drive level		0.5			µW
FRTOLLF	Crystal frequency accuracy	Initial Over temperature (-20 to 70 °C) Aging over 10 years	- - -	- - -	+/-20 +/-180 +/-3	ppm ppm ppm

3.6 Digital I/O and Interface Specifications

3.6.1 Digital I/O Specifications

Table 3-21: Digital I/O and NRESET Specifications

Symbol	Description	Conditions	Min	Typ	Max	Unit
VIH	Input High Voltage		0.7*VBAT	-	VBAT+0.3	V
VIL	Input Low Voltage		-0.3		0.3*VBAT	V
VOH	Output High Voltage	I_{max} = 2.5 mA	0.9*VBAT		VBAT	V
VOL	Output Low Voltage	I_{max} = -2.5mA	0		0.1*VBAT	V

3.6.2 SPI Interface

The SPI interface gives access to the configuration register via a synchronous full-duplex protocol corresponding to CPOL = 0 and CPHA = 0 in Motorola/Freescale nomenclature. Only the slave side is implemented. A transfer is always started by a falling edge of NSS. MISO is high impedance when NSS is high. The SPI runs on the external SCK signal to allow high speed operation up to 16 MHz.

All timings in the following table are given for a maximum load capatitance of 10 pF.

Table 3-22: SPI Timing Requirements

Symbol	Description	Min.	Typ.	Max.	
t1	NSS falling edge to SCK setup time	31.25	-	-	ns
t2	SCK period	61.5	-	-	ns
t3	SCK high time	31.25	-	-	ns
t4	MOSI to SCK hold time	5	-	-	ns
t5	MOSI to SCK setup time	15	-	-	ns
t6	NSS falling to MISO delay	0	-	15	ns
t7	SCK falling to MISO delay,	0	-	15	ns

4. Application Information

4.1 Signals of Opportunity Scanning Modes

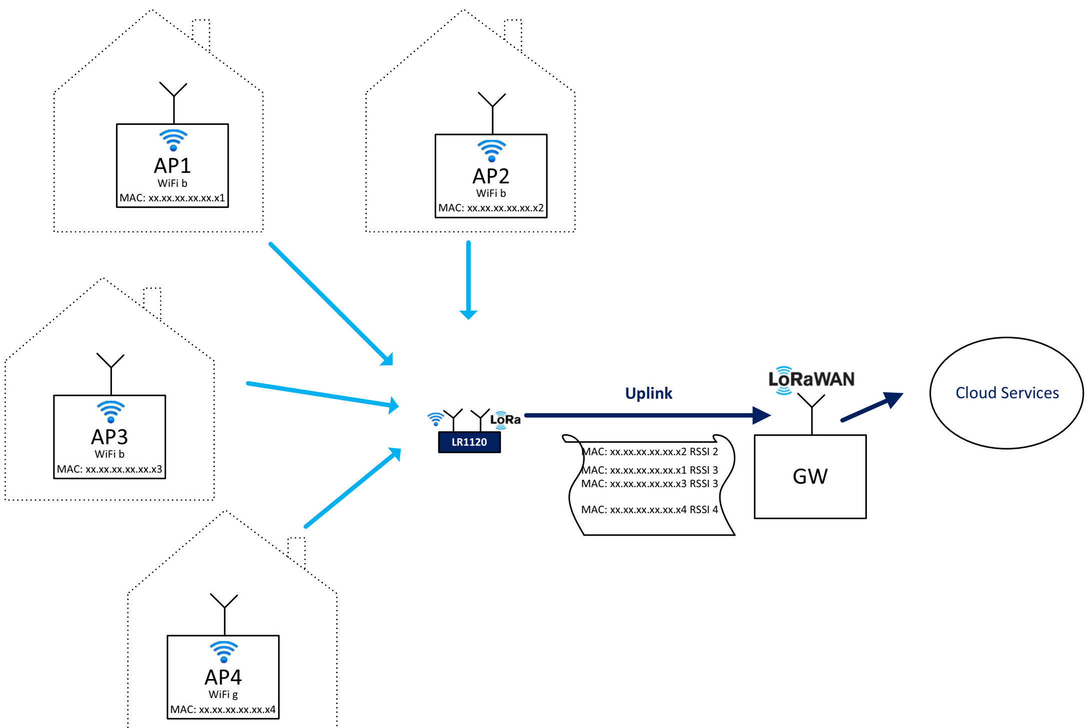
This section gives more insight into the scanning modes available in the LR1120.

4.1.1 Wi-Fi Passive Scanning

The LR1120 is able to discover the Wi-Fi b/g/n access points available in the vicinity of the device, and extract MAC addresses allowing to geolocate the device. The objective is to obtain at least 2 MAC addresses, which are sent to an online Wi-Fi lookup service that determines the position of the device.

To be power efficient, only a small portion of the Wi-Fi packets containing the MAC address information are captured and demodulated.

Figure 4-1: Wi-Fi Passive Scanning Principle

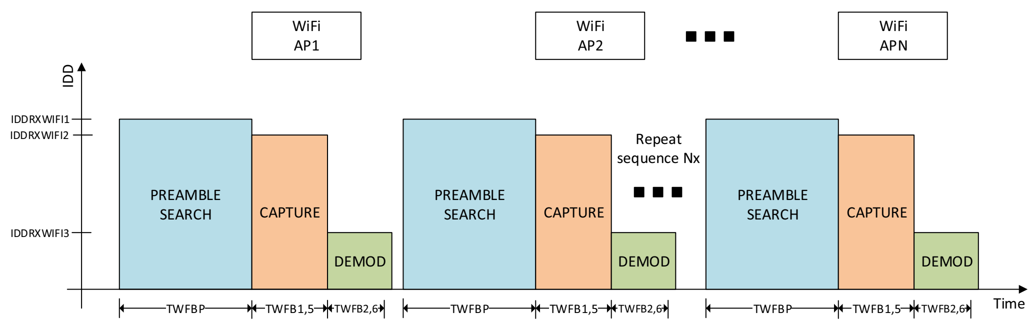


The Wi-Fi passive scanning is composed of a sequence of three phases: preamble search, capture and demodulation, providing one MAC address, if any are found. To obtain additional MAC addresses the three-phase sequence has to be repeated. To preserve power, the RF front-end is turned off during the demodulation phase. The MAC address is the only mandatory information required to find the location of the device. The associated signal level, RSSI, is also extracted and can be sent optionally to the solver to enhance the accuracy. The Wi-Fi passive scanning implemented in the LR1120 can also extract the country code information of an access point, contained in the beacon or probe response.

A single Wi-Fi passive scan spans three phases:

1. The preamble search phase, the device stays in RX mode until the start of a preamble is detected
2. The capture phase, the device captures the part of the packet containing the required information
3. The demodulation phase, the required information is demodulated

Figure 4-2: Wi-Fi b Passive Scanning Sequence



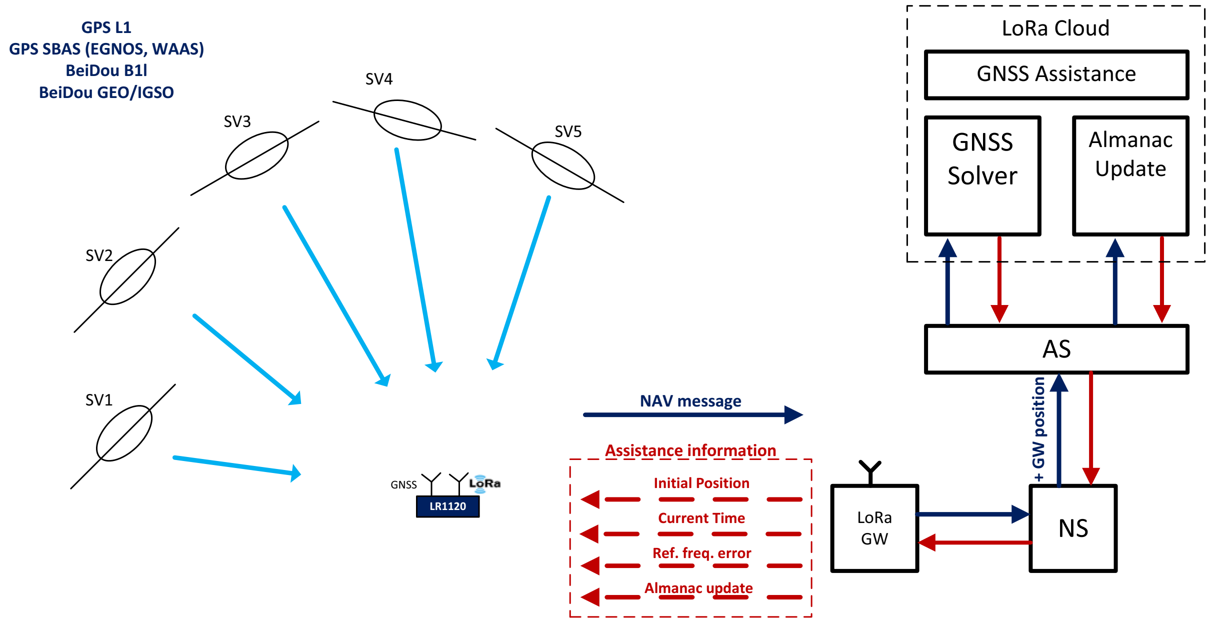
The preamble search duration depends on the traffic in the channel.

- For busy channels, a preamble will quickly be detected.
- For channels where only an AP signal is present, and little traffic is generated, the preamble search can be as long as the beacon interval set for that specific AP (nominally set to 102.4 ms).

4.1.2 GNSS Scanning

The LR1120 features a fast and low-power GNSS scanner. The device captures a short portion of the signal broadcast by the GNSS satellites and extracts the information required to calculate the device position - the pseudo-ranges. This information is aggregated into a NAV message which can be sent to a solver to compute the device position.

Figure 4-3: GNSS Scanning Principle, Assisted Mode



The LR1120's GNSS scanner hardware can support the following constellations:

- GPS L1 + GPS geostationary SBAS: EGNOS and WAAS
- BeiDou B1 + BeiDou geostationary GEO/IGSO

The search for space vehicles is a three-dimensional search challenge: the satellite ID, the frequency offset due to Doppler shift, and the code phase are unknown. Providing assistance information to the LR1120 will minimize the search space, reducing the capture time and the energy spent. To accelerate the detection of SVs, the following assistance parameters can be provided to the LR1120:

- A rough estimate of the initial position of the device
- The current time
- The frequency reference error to be compensated
- A recent version of the Almanac, required to estimate the position of the visible SVs, at the time and location of the scan

All these parameters contribute to the total error of the Doppler estimation for each satellite:

- 200 km error on the initial position is equivalent to 200 Hz increase of the frequency search space
- +/-30 seconds of error on the time estimation are equivalent to 20 Hz increase of the frequency search space
- 0.1 ppm frequency reference error is equivalent to 150 Hz increase of the frequency search space
- Every month of age of the Almanac contributes to 62 Hz increase of the frequency search space

Once a short period of the satellite broadcast signal is captured, the detection of space vehicles on the LR1120 is done in two main phases:

- a faster search of the available SVs received by the device with a strong signal
- a more in-depth search of the available SVs received by the device with a weak signal

Besides providing the pseudo-ranges of those satellites received with strong signal, the first phase also estimates the device's frequency offset and defines the frequency search space for the second phase.

The second phase implies a search centred on the frequency offset resulting from the Doppler error and the frequency reference error on the device. With the best assistance information, the search can be limited to a window of only 125 Hz. With an assistance information less precise, for instance if the ephemeris data is out of date, the search window is extended in steps of +/- 125 Hz, increasing the search time and the energy consumption. See Table 3-9 and Table 3-10 for details.

The LR1120 can take into account Almanac information to speed up the GNSS signal processing step. The Almanac parameters contain coarse orbital parameters which describe the Space Vehicles motion in space. Together with a coarse estimate of time and position, the Almanac can be used to exclude irrelevant space vehicles and reduce the search window for the Doppler error search.

All assistance information transferred to the LR1120 is tailored for an LPWAN use-case, which mean low-throughput and low-power.

The GNSS scanner of the LR1120 has two modes of operations: autonomous and assisted.

4.1.2.1 Autonomous GNSS Scanning

The LR1120 will not require any assistance information in this mode. A fast search of all SVs with strong signals in the selected constellation is performed, and all the SVs received with a signal better than RXSGPS1E are detected.
This mode can be used to determine if the device stands indoor or outdoor; in case no SV with strong signal is detected, the application concludes that the device is indoor. Therefore the search of weak signals, which is more time and energy consuming, can be discarded; the search of other signals of opportunity, like Wi-Fi, might be launched instead.

4.1.2.2 Assisted GNSS Scanning

Based on the assistance information, the LR1120 will build a list of 10 to12 SVs that it should look for at the position of the device and the actual time.

Two different assisted GNSS scanning modes are implemented:

- "Low power": A first search of strong signal satellites within the list of visible ones will be made. If at least one satellite is found in this step, the search will continue for satellites with weaker signals. Otherwise the search will stop. This mode minimizes the energy consumption and can also be used also as indoor/ outdoor detection method, in a more efficient way than the autonomous GNSS scanning mode. The indoor classification is decided after searching 10-12 SVs, versus 32-35 in Autonomous scanning mode.
- "Best effort": A first search of SVs with strong signals, within the list of visible satellites, is made. Even if no satellite is found in the first phase, the search continues for satellites with weaker signals. This mode is to be used in difficult environments where is may be possible to find SVs, at the expense of a longer search phase.

The scanner uses a sequence of capture and processing phases. To preserve power, the RF front-end will be turned off during the processing phases.

4.1.2.3 GNSS Geolocation System Overview

The LR1120 features a GNSS receiver that allows a fast and energy efficient outdoor geolocation. This GNSS Geolocation System achieves low energy geolocation by offloading time- and compute- intensive operations to back-end system components. In particular, the LR1120's GNSS Geolocation System uses the following three back-end system components:

- GNSS Position Solving Component: the LR1120 does not resolve the full position on-device. Instead, the measurements from GNSS signals are combined into a binary message (the NAV message) and expected to be sent via any communication channel to the GNSS Position Solver backend component for final position calculation. This component is required in all operation modes.

- GNSS Almanac Update Component (required in assisted mode): the LR1120 is able to reduce the GNSS scanning time by taking into account coarse orbital parameters for different GNSS constellations (the Almanac parameters). In conjunction with a coarse time and position estimate, the LR1120 uses this information to optimize the search an acquisition of GNSS signals. Over time, the true satellite positions diverge from the fixed Almanac parameters, which requires them to be updated. This can be achieved by a back-end component which estimates the quality of the almanac image on device and issues updates when needed. This component is required if GNSS assisted mode is used.
- GNSS Assistance Component (required in assisted mode): in order to operate GNSS Geolocation System in assisted mode, coarse estimates of time and position must be provided to the LR1120. This information can be obtained in a variety of ways including application-level knowledge. In LoRaWAN the Clock Synchronization protocol can retrieve assistance time information. The assistance position information can generally be derived from past position solutions.

LoRa Cloud™ offers these components in a single, easy to use, managed service as part of the Modem & Geolocation Services. Visit www.loracloud.com for more information.

4.2 LR-FHSS Modulation

The LR1120 supports LR-FHSS modulation (compliant with the LoRaWAN™ specification released by the LoRa Alliance™), which modulates the packet content across several pseudo-random frequencies, providing the following benefits:

- In FCC regions, the LR-FHSS can eliminate the dwell-time limitation by intra-packet hopping. It thus allows to use slower data rates, which increases the communication range, and to carry a longer payload.
- In ETSI regions, the LR-FHSS can provide improved capacity and an even longer range than LoRa for lower data rate devices where the spectrum is limited such as Europe or India.
- The LR-FHSS modulation provides even better robustness in the presence of interferences than LoRa.

The LR1120 is able to generate LR-FHSS modulated packets on sub-GHz and 2.4 GHz ISM bands.

LR-FHSS implementation in the LR1120 is transmit only.

4.3 Exiting Sleep Mode

The LR1120 exits the lowest-power Sleep mode with:

- A falling edge on the NSS signal
- A RTC Timeout configured in the *SetSleep()* command, as an option

Implementation options are detailed in the User Guide, and both can be combined.

4.4 Digital Inputs/Outputs

The LR1120 features 12 DIO pins, dedicated to host or sensors/peripherals communication, interruption handling and external RF switches or LNA control.

4.4.1 DIO Configuration

The LR1120 features a DIO switch matrix (SWM), allowing a reconfiguration of the DIOs depending on the application requirements. For a transceiver use case, the LR1120 is controlled by a host MCU, hence the DIOs are dedicated to host communication. In order to reduce the constraints on the MCU pin count, five DIOs can be used to control external RF switches or LNAs.

Table 4-1: LR1120 DIO Mapping

Pin	I/O Name	Function
6	NRESET	NRESET
7	32k_P/ DIO11	32k_P/ NC
8	32k_N/ DIO10	32k_N/ RFSW4
9	DIO9	IRQ
10	DIO8	RFSW3
11	DIO7	RFSW2
19	DIO6	RFSW1
20	DIO5	RFSW0
21	DIO4	SPI MISO
22	DIO3	SPI MOSI
23	DIO2	SPI SCK
24	DIO1	SPI NSS
25	DIO0/ BUSY	BUSY

4.4.2 RF Switch Control

The LR1120 is able to control up to 5 external RF switches or LNAs on the RFIO_HF, GNSS, and Sub-GHz RF paths, reducing the number of host controller IOs required for the application. This allows selecting application MCUs with a reduced pin count or a smaller footprint, and therefore designing highly integrated solutions. The polarity of the RF switch control signals can be set in each radio mode. By default no DIO is used as RF switch control line, all RF switch outputs are kept in High-Z state.

4.4.3 Reset

A complete restart of the LR1120 internal firmware can be issued on request by toggling the NRESET pin. It will be automatically followed by the standard calibration procedure and any previous context will be lost. The pin should be held low for more than 100 µs for the reset to occur.

4.4.4 Host Interrupts

The LR1120 offers 24 interrupt sources, allowing the host to react to special events in the LR1120 system without the need to poll registers, in order to design power optimized applications.

Interrupts to the host are signalled through one (or more) IRQ lines configured on the DIOs, and can be masked or cleared using dedicated commands.

The interrupt status can be read by the host through the 32-bit interrupt status register. They can be cleared by writing a 1 to the respective bit.

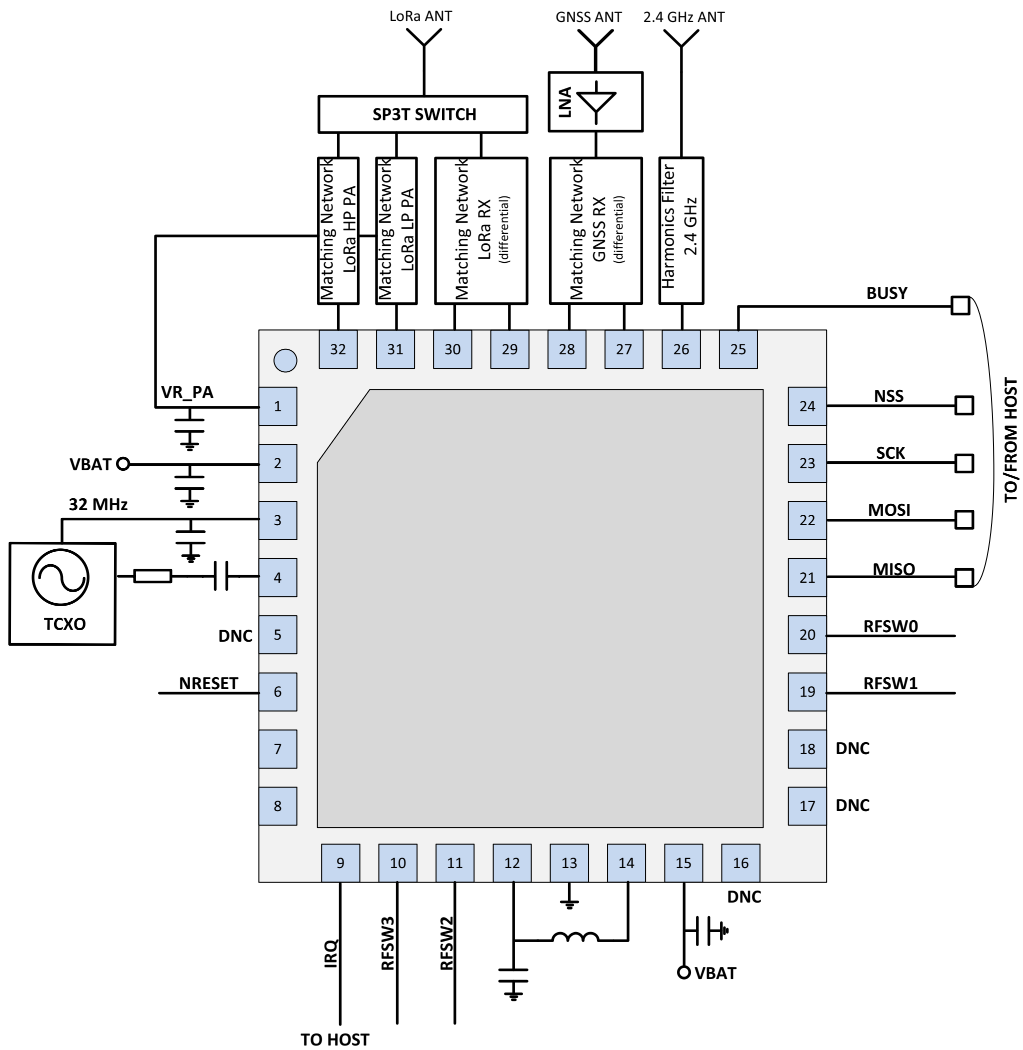
4.5 Firmware Upgrade/ Update

During the manufacturing process, the LR1120 will be provisioned and contain the embedded firmware image. During the product assembly process, the customer will be able to upgrade the full embedded firmware image running on the LR1120 via the SPI interface. The bootloader of the LR1120 will authenticate the firmware and will allow further execution. Only firmware images provided by Semtech can run on the LR1120. The LR1120 can also support patch updates, typically for maintenance in the field.

4.6 Simplified Reference Schematic

This section provides reference schematic examples using the LR1120.

Figure 4-4: Multi-band EU/US LoRaWAN Using Both sub-GHz PAs + GNSS + Wi-Fi Passive Scanner



A TCXO is mandatory for GNSS scan.

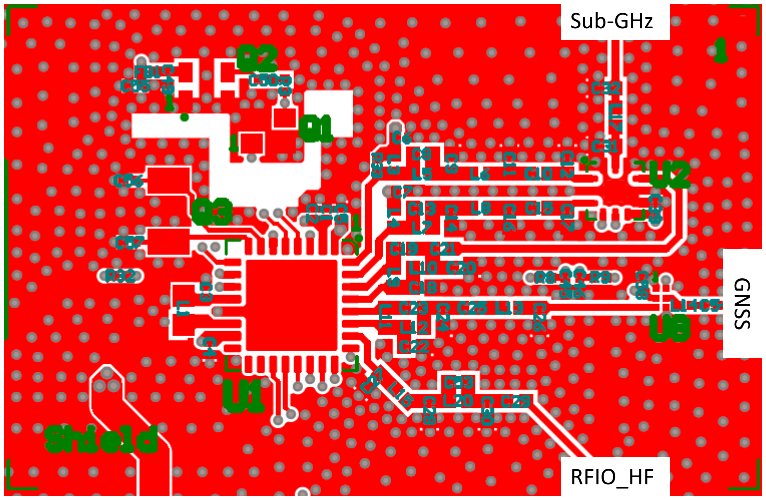
For Wi-Fi scan only products, the TCXO can be replaced by an XTAL, between pin 4 and pin 5.

An external LNA is required on the GNSS receive path for GNSS scanning. The LNA is controlled using the RFSWx signals.

For LoRa® operating in lower frequency bands, 2 SPST switches might be needed to isolate the GNSS and Wi-Fi paths.

4.7 Example Reference Layout

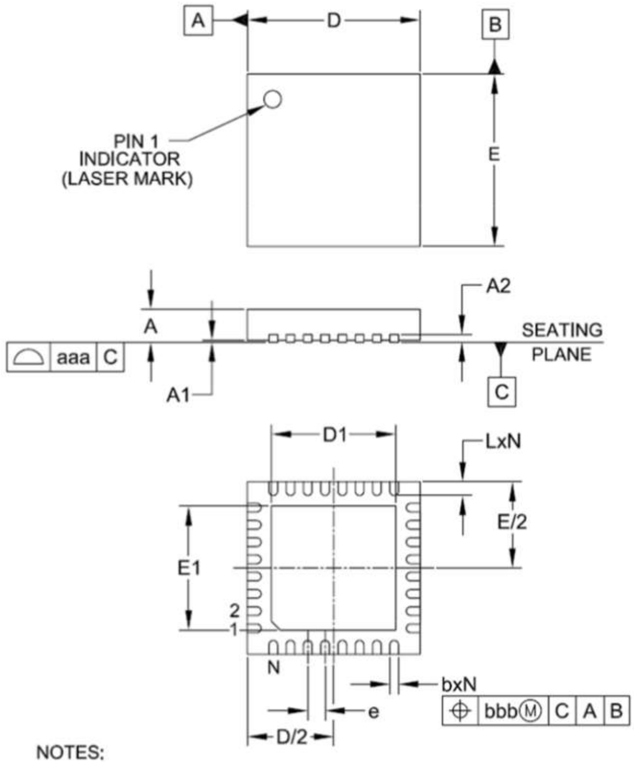
Figure 4-5: Reference Design Layout



5. Package Information

5.1 Package Outline Drawing

Figure 5-1: Package Outline Drawing



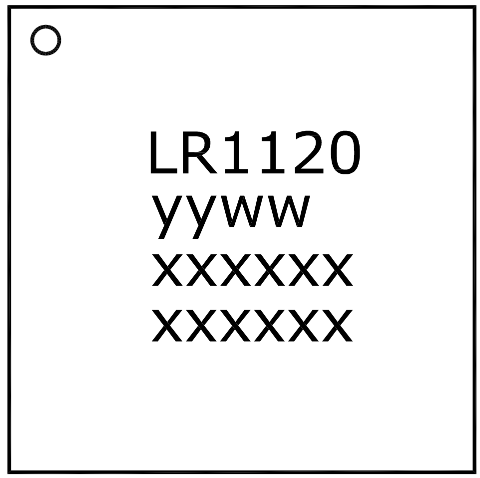
DIMENSIONS						
DIM	INCHES			MILLIMETERS		
	MIN	NOM	MAX	MIN	NOM	MAX
A	.031	-	.039	0.80	-	1.00
A1	.000	-	.002	0.00	-	0.05
A2	-	(.008)	-	-	(0.20)	-
b	.007	.010	.012	0.18	0.25	0.30
D	.193	.197	.201	4.90	5.00	5.10
D1	.140	.146	.150	3.30	3.70	3.80
E	.193	.197	.201	4.90	5.00	5.10
E1	.140	.146	.150	3.30	3.70	3.80
e	.020 BSC			0.50 BSC		
L	.012	.016	.020	0.30	0.40	0.50
N	32			32		
aaa	.003			0.08		
bbb	.004			0.10		

NOTES:

1. CONTROLLING DIMENSIONS ARE IN MILLIMETERS (ANGLES IN DEGREES).
2. COPLANARITY APPLIES TO THE EXPOSED PAD AS WELL AS THE TERMINALS.

5.2 Package Marking

Figure 5-2: Package Marking



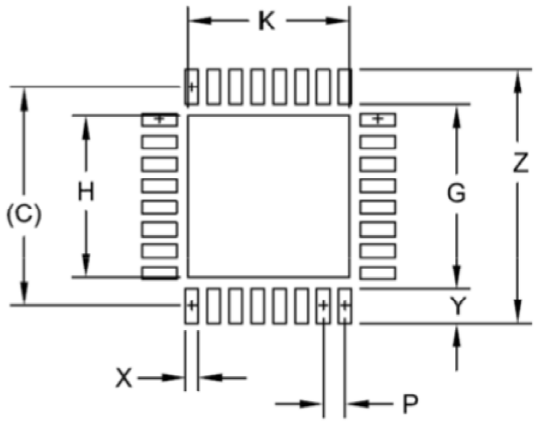
TOP MARK	
CHAR	ROWS
6/6/6/6	4

Marking for the 5 x 5 mm MLPQ 32 Lead package:

nnnnnn = Part Number (Example: LR1120)
yyww = Date Code (Example: 2052)
xxxxxx = Semtech Lot No. (Example: E90101
xxxxxx 0101-1)

5.3 Land Pattern

Figure 5-3: Land Pattern



DIMENSIONS		
DIM	INCHES	MILLIMETERS
C	(.197)	(5.00)
G	.165	4.20
H	.146	3.70
K	.146	3.70
P	.020	0.50
X	.012	0.30
Y	.031	0.80
Z	.228	5.80

NOTES:

1. THIS LAND PATTERN IS FOR REFERENCE PURPOSES ONLY. CONSULT YOUR MANUFACTURING GROUP TO ENSURE YOUR COMPANY'S MANUFACTURING GUIDELINES ARE MET.
2. THERMAL VIAS IN THE LAND PATTERN OF THE EXPOSED PAD SHALL BE CONNECTED TO A SYSTEM GROUND PLANE. FAILURE TO DO SO MAY COMPROMISE THE THERMAL AND/OR FUNCTIONAL PERFORMANCE OF THE DEVICE.
3. SQUARE PACKAGE - DIMENSIONS APPLY IN BOTH " X " AND " Y " DIRECTIONS.

5.4 Reflow Profiles

Reflow process instructions are available from the Semtech website, at the following address:
http://www.semtech.com/quality/ir_reflow_profiles.html

The device uses a QFN32 5x5 mm package, also named MLP package.

5.5 Thermal Information

Table 5-1: Package Thermal Information

Name	Value[1]	Unit
Theta j-a, Junction to Ambient	26.7	°C/W

1. As measured on a 4-layer test board with 9 thermal vias, per the Jedec standard

Glossary

List of Acronyms and their Meaning (Sheet 1 of 3)

Acronym	Meaning
ACR	Adjacent Channel Rejection
ADC	Analog-to-Digital Converter
AP	Access Point
API	Application Programming Interface
β	Modulation Index
BER	Bit Error Rate
BR	Bit Rate
BT	Bandwidth-Time bit period product
BW	BandWidth
CAD	Channel Activity Detection
CPOL	Clock Polarity
CPHA	Clock Phase
CR	Coding Rate
CRC	Cyclical Redundancy Check
CW	Continuous Wave
DC-DC	Direct Current to Direct Current Converter
DIO	Digital Input / Output
DSB	Double Side Band
ECO	Engineering Change Order
FDA	Frequency Deviation
FEC	Forward Error Correction
FIFO	First In First Out
FSK	Frequency Shift Keying
GFSK	Gaussian Frequency Shift Keying
GMSK	Gaussian Minimum Shift Keying
GDPW	Gross Die Per Wafer
IF	Intermediate Frequencies
IRQ	Interrupt Request
ISM	Industrial, Scientific and Medical (radio spectrum)

List of Acronyms and their Meaning (Sheet 2 of 3)

Acronym	Meaning
LDO	Low-Dropout
LDRO	Low Data Rate Optimization
LFSR	Linear-Feedback Shift Register
LNA	Low-Noise Amplifier
LO	Local Oscillator
LoRa®	Long Range Communication *The LoRa® Mark is a registered trademark of the Semtech Corporation*
LR-FHSS	Long Range Frequency Hopping Spread Spectrum
LSB	Least Significant Bit
MISO	Master Input Slave Output
MOSI	Master Output Slave Input
MSB	Most Significant Bit
MSK	Minimum-Shift Keying
NOP	No Operation (0x00)
NRZ	Non-Return-to-Zero
NSS	Slave Select active low
OCP	Over Current Protection
PA	Power Amplifier
PER	Packet Error Rate
PHY	Physical Layer
PID	Product Identification
PLL	Phase-Locked Loop
POR	Power On Reset
RC13M	13 MHz Resistance-Capacitance Oscillator
RC64k	64 kHz Resistance-Capacitance Oscillator
RFO	Radio Frequency Output
RFU	Reserved for Future Use
RTC	Real-Time Clock
SCK	Serial Clock
SF	Spreading Factor
SN	Sequence Number
SNR	Signal to Noise Ratio

List of Acronyms and their Meaning (Sheet 3 of 3)

Acronym	Meaning
SPI	Serial Peripheral Interface
SSB	Single Side Bandwidth
STDBY	Standby
TCXO	Temperature-Compensated Crystal Oscillator
XOSC	Crystal Oscillator

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