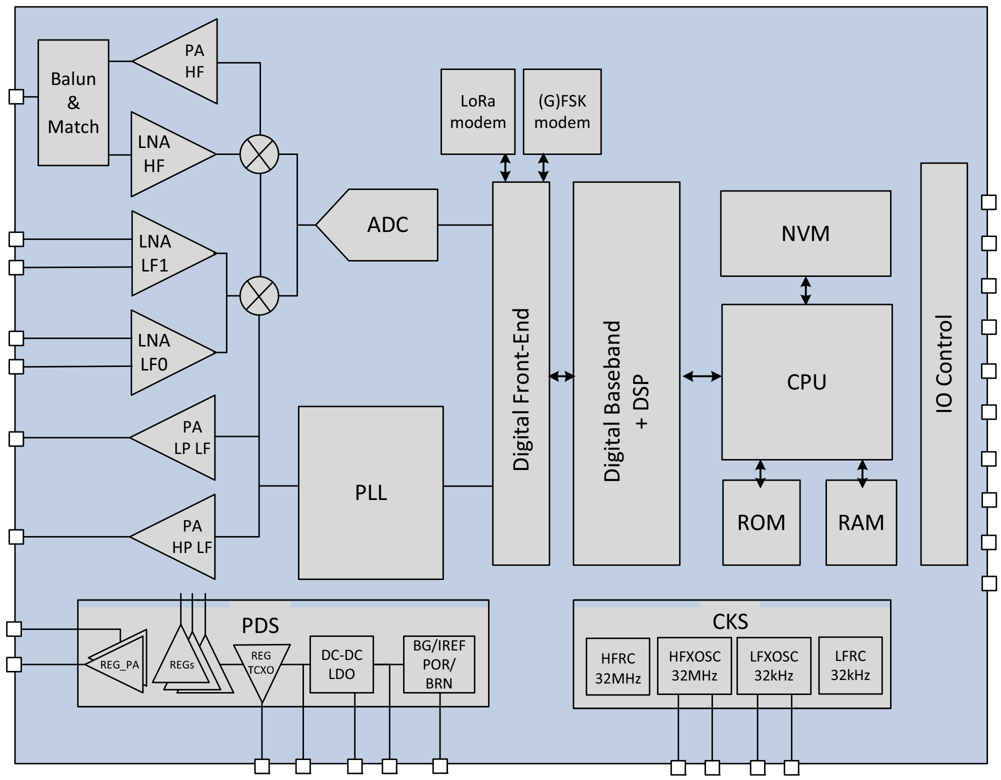
LR1110 Datasheet

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



The LR1110 is an ultra-low power platform targeting geolocation applications. It integrates a long range LoRa® transceiver, a multi-constellation global navigation satellite system (GNSS) scanner, and a passive Wi-Fi® Access Point MAC address scanner.

For LPWAN use cases, the LR1110 supports LoRa and (G)FSK modulation on sub-GHz bands, as well as Sigfox® modulation on sub-GHz bands, and Long Range Frequency Hopping Spread Spectrum (LR-FHSS) on sub-GHz bands.

The LR1110 complies with the physical layer requirements of the LoRaWAN® specification released by LoRa Alliance®, while remaining highly configurable to meet different application requirements and proprietary protocols.

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

Besides world-wide sub-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 analyses the signal information and calculates the LR1110's position with data from a geolocation database, enabling a valuable balance between low power and performance.

The LR1110 geolocation capability is further increased by Bluetooth® Low Energy beaconing compatibility to allow indoor and outdoor geolocation use cases, as well as a powerful sub-GHz ranging engine for localization and recovery of lost assets in logistics applications.

Disclaimers

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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Semtech's products are designed to be used in connection with qualified Bluetooth® products and applications but are not certified or qualified Bluetooth® products.

Ordering Information

Part Number	Delivery	Minimum Order Quantity
LR1110IMLTRT	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	050748	Feb 2020	Use Case: 01 FW version: 03.02 or later	First Final Release
1.1	050926	Mar 2020	Use Case: 01 FW version: 03.02 or later	Correction of typos Table 3.4 (IDDTXHP3 and IDDTXHP4) Addition of IDDSL3. Modification of section 4.1.2.3 description
1.2	058921	Oct 2021	Use Case: 01 FW version: 03.07 or later	Modified GNSS Scanning Tables 3.9 and 3.10
1.3	059757	Dec 2021	Use Case: 01 FW version: 03.07 or later	Add relevant information for support of Long Range FHSS modulation
1.4	066803	May 2023	Use Case: 01 FW version: 03.07 or later	Table 3-5 Added Note 1 Table 3-11 FRSYNTH max changed to 2500MHz Table 3-12 FERR: removed "no sensi degradation" Added section 3.6.2 Flash Memory Specifications Section 4.6 Added “A 32.768kHz clock source is necessary for the GNSS Advanced scan.” & “A 32.768kHz clock source is necessary for usage of LoRa Basics Modem-E firmware of the LR1110” Improved Fig 4.4 Modified section 1.2.1: air interface Section 1.2.4 rewritten Add reference to AN1200.74 in section 4.6 Added IDDSL4B parameter Added section 5.6 Tape and Reel Information Other minor improvements

Version	ECO	Date	Applicable to[1]	Changes
1.5	067385	Jun 2023	Use Case: 01 FW version: 03.08 or later	Added support of Sigfox Transceiver, Bluetooth® Low Energy Beaconing Compatibility and Round Trip Time of Flight (RTToF) Ranging Added Note 2 on GNSS Table 3-9 & Table 3-10 Modified Table 2-1 Pin 26 pinout description Modified Figure 4-4: pin 26 and 2.4GHz ANT Table 3-11 Removed FDAFSK condition
2.0	069610	Dec 2023	Use Case: 01 FW version: 04.01 or later	Modified Section 3.4 for DER, Modified Figure 4-4 pins 7,8,10,11 Section 4.1.2 for new FW Section 4.4 Sub-GHz Ranging became RTToF Section 4.9 advise to update FW Added extra rows to Table 3-9, Table 3-10, Table 3-13 Added Section 4.1.2.3, 4.6 Chip Wakeup Sequence

1. Use Case and Version concepts are defined in the LR1110 User Manual, see the `GetVersion` command.

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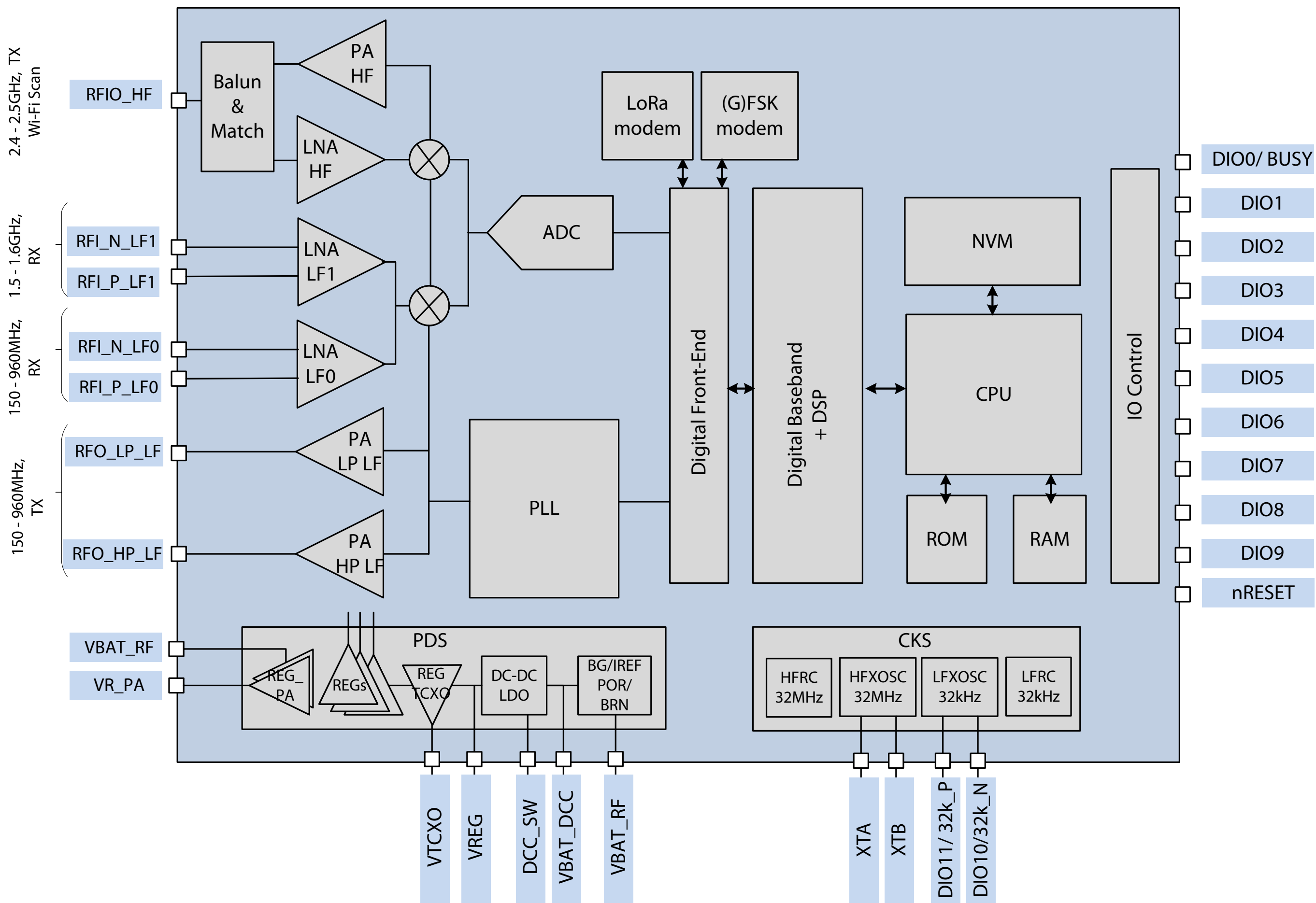


1.2 Overview

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

- Worldwide frequency bands support in the range 150 - 960MHz (sub-GHz).
- Low Noise Figure modes for enhanced LoRa/ (G) FSK sensitivity (differential input pins RFI_P/N_LF0)
- High power PA path +22dBm (pin RFO_HP_LF) and High efficiency PA path +15dBm (pin RFO_LP_LF) for sub-GHz
- High frequency PA path +13dBm (pin RFIO_HF) for 2.4GHz ISM band, matched to 50Ohm impedance, reducing the overall Bill Of Materials cost
- Integrated PA regulator supply selector to simplify dual power +15/+22dBm with a single board implementation
- Able to support world-wide multi-region BOM, the circuit adapts to satisfy regulatory limits
- Air interface 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
- Sigfox transceiver, all Sigfox Radio Configurations (RC1 to RC7) supported. Downlink capability

1.2.2 Multi-Purpose Radio Front-End

- 150 - 2500MHz continuous frequency synthesizer range
- GPS/ BeiDou scanning (differential input pins RFI_P/N_LF1)
- Bluetooth Low Energy beaconing compatibility (on input/output pin RFIO_HF)
- Round Trip Time Of Flight Ranging (on output pins RFO_HP/LP_LF and on 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

- 32.768kHz Low Frequency (LF) internal RC oscillator, optionally used by the circuit Real Time Clock (RTC)
- 32.768kHz LF crystal oscillator (XOSC), used for the RTC. An external 32.768kHz reference from a host, applied to pin DIO11, is also possible.
- 32MHz HF RC (HFRC) oscillator allows configuration of the device without the need to start the main crystal oscillator
- 32MHz HF crystal oscillator (HFXOSC) for radio operations and to calibrate frequency error of internal RC oscillators
- 32MHz 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 32MHz 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.
- For additional guidance on external clock sources (crystal and TCXO), refer to Section 4.10.

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
- Long Range FHSS in transmit mode, with intra-packet hopping capability

1.2.6 Cryptographic Engine

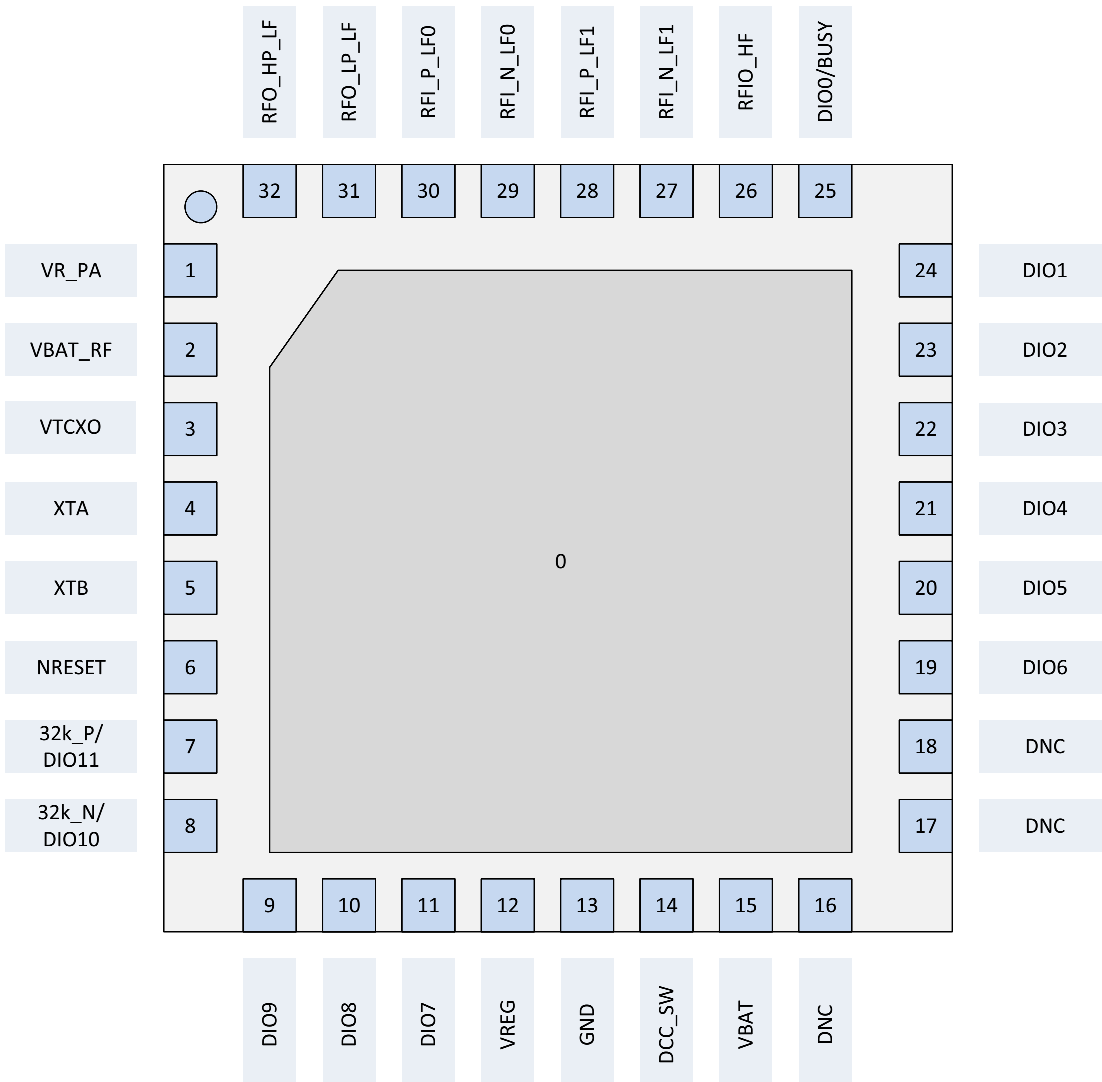
- Hardware support for AES-128 encryption/decryption based algorithms
- Handling device parameters such as DevEUI and JoinEUI, as defined by the LoRa Alliance
- Protects confidential information such as encryption keys against unauthorized access
- Stores NwkKey, AppKey, as defined in the LoRaWAN standard

2. Pin Connection

Table 2-1: LR1110 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	-	32MHz crystal connection, or external TCXO frequency reference input
5	XTB	-	32MHz crystal connection, or NC in case of external TCXO usage
6	NRESET	I	Reset signal, active low
7	32k_P/ DIO11	I/O	32.768kHz crystal connection, or input for 32.768kHz reference clock/ Multi-purpose digital I/O
8	32k_N/ DIO10	I/O	32.768kHz 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 2.4-2.5GHz transmitter 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: LR1110 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	Conditions	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
		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 LR1110 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 following tables give the electrical specifications of the LR1110 transceiver under the following conditions, unless otherwise specified:

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

3.4.1 Power Consumption

The tables below 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	8kB RAM retained	-	1.6	-	µA
IDDSL1 IDDSL3A	Supply current in SLEEP mode LFRC (32kHz) based RTC	No RAM retained 8kB RAM retained	- -	1.6 1.85	- -	µA µA
IDDSL2 IDDSL4A	Supply current in SLEEP mode LFXOSC (32kHz) based RTC	No RAM retained 8kB RAM retained	- -	1.5 1.75	- -	µA µA
IDDSL4B[1]	Supply current in SLEEP mode 32.768kHz RTC	16kB RAM retention	-	2	-	µA
IDDSBRLD	Supply current in STBY_RC	HFRC (32MHz) ON, LDO, System clock 16MHz	-	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 32MHz	-	2.85	-	mA

1. Only for LoRa Basics Modem-E firmware of the LR1110

Table 3-5: Receive Mode Power Consumption, DC-DC Mode Used

Symbol	Description	Conditions	Min	Typ	Max	Unit
IDDRXF1	Supply current in Receive mode[1]	FSK 4.8kb/s sub-GHz with RxBoosted = 1	- -	5.4 7.5	- -	mA mA
IDDRXL1	Supply current in Receive mode[1]	LoRa® SF12 125kHz sub-GHz with RxBoosted = 1	- -	5.7 7.8	- -	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

1. Add 1mA additional consumption for Modem-E use case because application specific timers are running.

Table 3-6: Transmit Mode Power Consumption[1,2]

Symbol	Frequency Band	PA Match	Output Power	Min	Typ	Max	Unit
IDDTXLP1	868/915MHz	+14dBm, LP PA[3]	+15dBm	-	36	-	mA
IDDTXLP2			+14dBm	-	28	-	mA
IDDTXLP3			+10dBm	-	18.5	-	mA
IDDTXLP4	434/490MHz		+15dBm	-	35	-	mA
IDDTXLP5			+14dBm	-	28	-	mA
IDDTXLP6			+10dBm	-	19	-	mA
IDDTXHP1	868/915MHz	+22dBm, HP PA[4]	+22dBm	-	118	-	mA
IDDTXHP2			+20dBm	-	96	-	mA
IDDTXHP3			+17dBm	-	73	-	mA
IDDTXHP4			+14dBm	-	50	-	mA
IDDTXHP5	434/490MHz		+22dBm	-	100	-	mA
IDDTXHP6			+20dBm	-	86	-	mA
IDDTXHP7			+17dBm	-	70	-	mA
IDDTXHP8			+14dBm	-	45	-	mA

1. Using optimized settings described in the LR1110 User Manual.
2. Add 1mA additional consumption for Modem-E use case because application specific timers are running.
3. DC-DC mode of the LDO/DC-DC combo is used to supply the entire circuit.
4. 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	-	-	(3*102) =306	ms
TWFBP	Wi-Fi 802.11 b	Preamble search phase	-	-	102 [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 [3]	-	ms
TWGNC	Wi-Fi 802.11 g and n	Capture phase	-	0.1	-	ms
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, beacons are sent every 102.4ms.
3. 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	-		(3*102)/75 *0.7 = 2.86	µWh

Table 3-9: GNSS Scanning Duration

Symbol	Description	Conditions	Min	Typ	Max	Unit
TGPSATIC TGPSASIC	Indoor detection[1], GPS	Autonomous mode Assisted mode	- -	1.25 0.7	- -	s s
TGPSAS1 TGPSAS2	SV scan, GPS, assisted mode, scan mode 0[2]	Best assistance information Good assistance information	- -	3 3.8	- -	s s
TGPSBEIAS1 TGPSBEIAS2	SV scan, GPS+Beidou, assisted mode, scan mode 0[2]	Best assistance information Good assistance information	- -	6.8 7.8	- -	s s
TGPSAS3	SV Scan, GPS, assisted scan mode 3, effort=0[3]	Best / Good Assistance Position	-	4.2 [4]	-	s
TGPSAS4	SV Scan, GPS, assisted scan mode 3, effort=1[3]	Best / Good Assistance Position	-	4.2 [5, 4]	-	s
TGPSCS1	SV Scan, GPS, cold start, scan mode 3,effort 0[3]	Best / Good Assistance Position	-	4 [6]	-	s
TGPSCS2	SV Scan, GPS, cold start, scan mode 3,effort=1[3]	Best / Good Assistance Position	-	32.5 [6]	-	s
TBEIAS3	SV Scan, Beidou, assisted scan mode 3, effort=0[3]	Best / Good Assistance Position	-	5.5 [4]	-	s
TBEIAS4	SV Scan, Beidou, assisted scan mode 3, effort=1[3]	Best / Good Assistance Position	-	5.5 [5, 4]	-	s
TBEICS1	SV Scan, Beidou, cold start, scan mode 3,effort 0[3]	Best / Good Assistance Position	-	5.9 [6]	-	s
TBEICS2	SV Scan, Beidou, cold start, scan mode 3,effort=1[3]	Best / Good Assistance Position	-	37.8 [6]	-	s

1. Indoor conditions, 0 SV detected.
2. Scan mode 0, Optimum 32.768kHz clock configuration (frequency accuracy + low jitter).
3. FW 04.01 and beyond.
4. Total duration = Typical value + (3s sleep +1.4s signal demodulation) avg.
5. If the LR1110 has a good sky view, the assisted scan effort, 0 or 1, is the same.
6. Total duration = 18s demodulation (avg).

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

Symbol	Description	Conditions	Min	Typ	Max	Unit
ENGATIC ENGASIC	Indoor detection, GPS	Autonomous mode Assisted mode	- -	5.4 4.1	- -	µWh µWh
ENGPSAS1 ENGPSAS2	SV scan, GPS, assisted mode, scan mode 0[2]	Best assistance information Good assistance information	- -	11.4 13.8	- -	µWh µWh
ENGPSBEIAS1 ENGPSBEIAS2	SV scan, GPS+Beidou, assisted mode, scan mode 0[2]	Best assistance information Good assistance information	- -	24.8 27.7	- -	µWh µWh
ENGPSAS3	SV Scan, GPS, assisted scan mode 3, effort 0[3]	Best / Good Assistance Position	-	12 [4]	-	µWh
ENGPSCS2	SV Scan, GPS, cold start, scan mode 3, effort=1[3]	Best / Good Assistance Position	-	163 [5]	-	µWh
ENBEIAS3	SV Scan, Beidou, assisted scan mode 3, effort 0[3]	Best / Good Assistance Position	-	16 [4]	-	µWh
ENBEICS2	SV Scan, Beidou, cold start, scan mode 3, effort=1[3]	Best / Good Assistance Position	-	190 [5]	-	µWh

1. Takes into account only the energy needed by the LR1110 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.
2. Scan mode 0, optimum 32.768kHz clock configuration (frequency accuracy + low jitter).
3. FW 04.01 and beyond.
4. Total energy = Typical value + (12.9µWh sleep + demod) avg.
5. Total energy = Typical value + 104.7µWh demod avg.

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	-	0.9536	-	Hz
HFOSCCP	32MHz 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	0.6	-	200	kHz
BRLORA	Raw data rate, LoRa	SF12, BWL = 62.5kHz, CR = 1/2 SF5, BWL = 500kHz, CR = 4/5	- -	76 62.5	- -	b/s kb/s
BWL	Signal BW, LoRa	Programmable, lowest setting Programmable, highest setting	- -	62.5 500[2]	- -	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
BRBLE	Raw data rate Bluetooth Low Energy beaconing compatibility		-	1	-	Mbps

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

3.4.3 Receiver

Table 3-12: Receiver Specifications, Sub-GHz Bands (Sheet 1 of 2)

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

Table 3-12: Receiver Specifications, Sub-GHz Bands (Sheet 2 of 2)

Symbol	Description	Conditions	Min	Typ	Max	Unit
RXSL1HP7	Sensitivity LoRa, RxBoosted = 1	BWL = 62.5kHz, SF = 7	-	-130	-	dBm
RXSL2HP7		BWL = 62.5kHz, SF = 12	-	-144	-	dBm
RXSL3HP7		BWL = 125kHz, SF = 7	-	-127	-	dBm
RXSL4HP7		BWL = 125kHz, SF = 12	-	-141	-	dBm
RXSL5HP7		BWL = 250kHz, SF = 7	-	-124	-	dBm
RXSL6HP7		BWL = 250kHz, SF = 12	-	-138	-	dBm
RXSL7HP7		BWL = 500kHz, SF = 7	-	-121	-	dBm
RXSL8HP7		BWL = 500kHz, 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 = 125kHz, SF = 7	-	60	-	dB
ACRLORA2		BW_L = 125kHz, SF = 12	-	73	-	dB
BILORA1	Blocking immunity, LoRa, BW_L = 125kHz	SF =12, offset = +/- 1MHz	-	88	-	dB
BILORA2		SF =12, offset = +/- 2MHz	-	91	-	dB
BILORA3		SF =12, offset = +/- 10MHz	-	103	-	dB
BILORA4		SF =7, offset = +/- 1MHz	-	74	-	dB
BILORA5		SF =7, offset = +/- 2MHz	-	77	-	dB
BILORA6		SF =7, offset = +/- 10MHz	-	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 3dB BW_L=125kHz, SF12, LowDataRateOptimize = 1	-	-	120	Hz/s

1. LoRa operation is on the 150 - 960MHz band.
2. Single ended impedance presented at the package level, without the effect of the PCB.
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, GNSS Scanner[1]

Symbol	Description	Conditions	Min	Typ	Max	Unit
FRRXGPS	RX input frequency	GPS BeiDou	- -	1.57542 1.5611	- -	GHz
ZINRXGPS	RX input impedance	impedance across RFI_N_LF1 / RFI_P_LF1[2]	-	17.6 - j76.5	-	Ohm
RXSGPS1E RXSGPS2E RXSBEI1E RXSBEI2E	GNSS sensitivity	GPS, indoor classification, and strong signal SV capture GPS, weak signal SV capture BeiDou, strong signal SV capture BeiDou, weak signal SV capture	- - - -	-134 -141 -131 -138	- - - -	dBm dBm dBm dBm
RXSGAD	GNSS Almanac Demodulation Sensitivity[3]	GPS Beidou		-138 -135		dBm dBm
RXSGTD	GNSS Time Demodulation Sensitivity[3]	GPS, TOW demodulation Beidou, TOW demodulation		-138 -135		dBm dBm
RXSG2D	GNSS ON-chip 2D Solve Sensitivity[3]	GPS Beidou		-136 -134		dBm dBm

1. All sensitivity numbers are given using the external LNA listed in the reference design.
2. Single ended impedance presented at the package level, without the effect of the PCB.
3. LR1110 firmware 04.01 and beyond.

Table 3-14: Receiver Specifications, Wi-Fi Passive Scanner

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

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

3.4.4 Transmitter

Table 3-15: 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 488b/s	-	-	-20	dB

3.5 Reference Oscillator

Table 3-16: 32MHz 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 3-17: 32MHz 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 + 200mV	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 10pF DC-cut series with 220Ohm	0.4	0.6	1.2	Vpk-pk

Table 3-18: 32kHz 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, Flash Memory, & Interface Specifications

3.6.1 Digital I/O Specifications

Table 3-19: 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} = 2.5mA	0.9*VBAT		VBAT	V
VOL	Output Low Voltage	I_{max} = -2.5mA	0		0.1*VBAT	V

3.6.2 Flash Memory Specifications

The LR1110 embeds a Flash memory for storing the internal firmware, application configuration data, and security keys.

Table 3-20: Flash Memory Specifications

Symbol	Description	Conditions	Min	Typ	Max	Unit
FEND	Flash Memory Endurance	T_{op}=-40 to 85°C	10.000	-	-	Cycles
FRET	Flash Memory Data Retention	T_{op}=85°C	10	-	-	Years

3.6.3 SPI Interface

The SPI interface gives access to the configuration register via a synchronous full-duplex protocol corresponding to CPOL = 0 and CPHA = 0 (clock polarity and phase in Motorola/NXP® 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 16MHz.

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

Table 3-21: 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

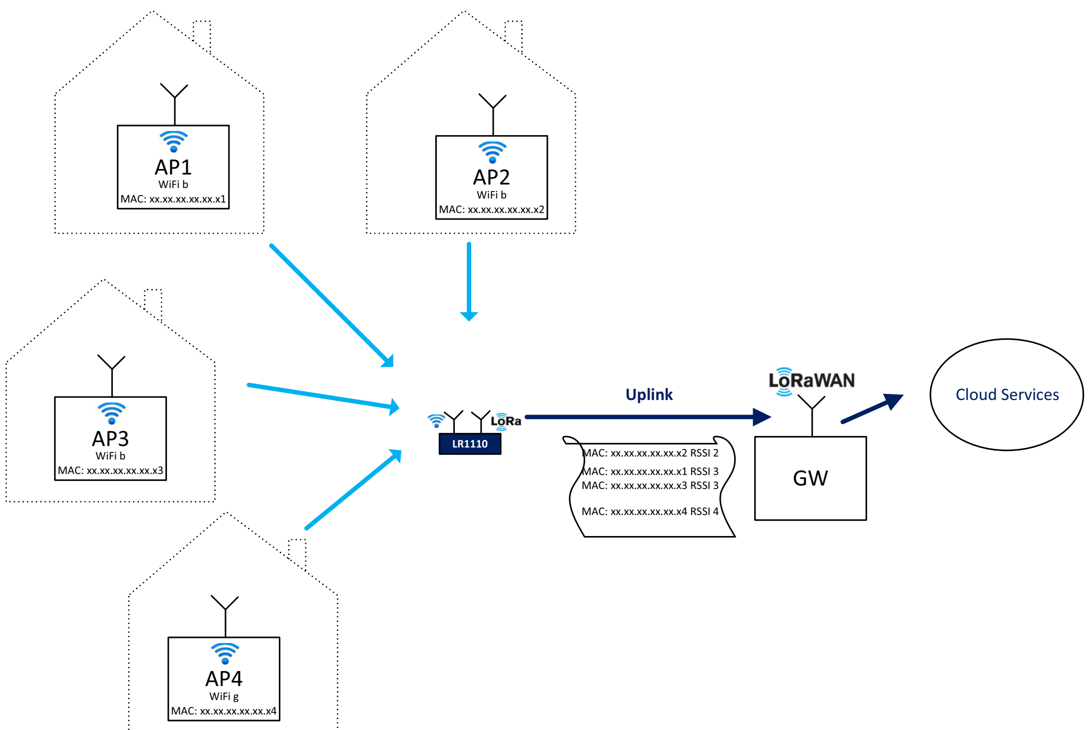
This section gives more insight into the scanning modes available in the LR1110.

4.1.1 Wi-Fi Passive Scanning

The LR1110 can discover the Wi-Fi b/g/n access points available in the vicinity of the device, and extract MAC addresses allowing geolocation of 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

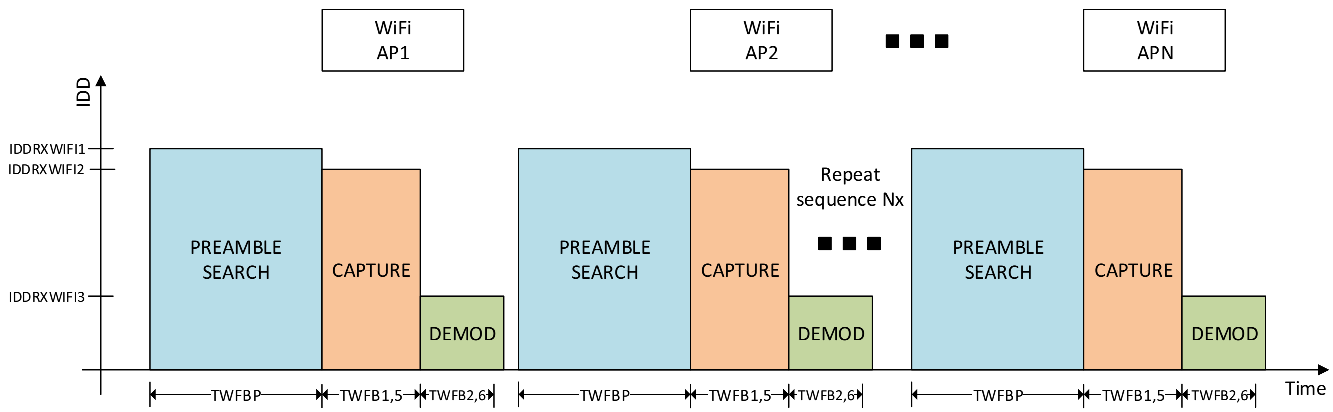


The Wi-Fi passive scanning is composed of a sequence of three phases: preamble search, capture and demodulation, providing one MAC address, if any are found. To obtain additional MAC addresses the three-phase sequence has to be repeated. To preserve power, the RF front-end is turned off during the demodulation 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 LR1110 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



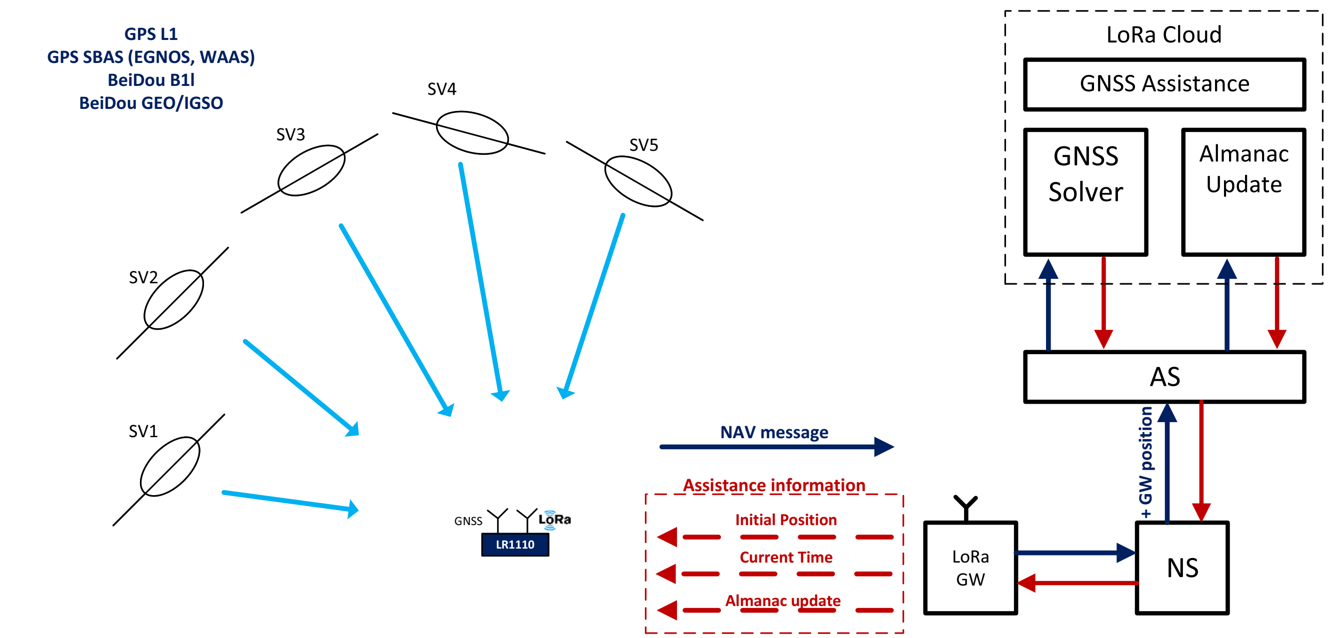
The preamble search duration depends on the traffic in the channel.

- 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 102.4ms).

4.1.2 GNSS Scanning

The LR1110 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 LR1110's GNSS scanner hardware can support the following constellations:

- GPS L1 + GPS geostationary
- BeiDou B1 + BeiDou geostationary GEO/IGSO

The search for space vehicles (SV) 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 LR1110 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 LR1110:

- A rough estimate of the initial position of the device (Assistance Position)
- The current time
- 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:

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

Once a short period of the satellite broadcast signal is captured, the detection of space vehicles on the LR1110 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 125Hz. With an assistance information less precise, for instance if the Almanac data is out of date, the search window is extended in steps of +/- 125Hz, increasing the search time and the energy consumption. See Table 3-9 and Table 3-10 for details.

The LR1110 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 LR1110 is tailored for an LPWAN use-case, which mean low-throughput and low-power.

Starting from LR1110 FW 04.01, the device may run GNSS Scanning without needing assistance information provided to the LR1110:

- An integrated 2D solver determines locally the Assistance Position
- The GNSS time can be directly demodulated from the satellite signal, thus improving positioning accuracy through knowledge of a precise time base
- The LR1110 can also demodulate the Almanac data from the satellites

This offers two usage modes of the GNSS Scanning feature:

- Assistance information transferred from the network allows to achieve lower power implementations
- Determining assistance information autonomously allows continuous GNSS Scanning operation in case of scarce access to the network. In such cases, the GNSS scan results can also be stored by the host MCU for further geolocation resolution, and forwarded to the solver when network access is available, allowing to reconstruct the whole device's itinerary.

The GNSS scanner of the LR1110 has two modes of operations: autonomous and assisted. Starting from LR1110 firmware version 04.01, the GNSS search mode does not have to be configured by the user, it is determined by the LR1110 firmware, based on the availability of the assistance information and on the actual detection of the visible satellites.

4.1.2.1 Autonomous GNSS Scanning

The LR1110 does 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 those that have a signal better than RXSGPS1E are detected.
This mode can be used to determine if the device is indoor or outdoor; if no SV with strong signal is detected, the application concludes that the device is indoor. Therefore the search for weak signals, which is more time and energy consuming, can be discarded; the search for other signals of opportunity, like Wi-Fi, might be launched instead.

4.1.2.2 Assisted GNSS Scanning

Based on the assistance information, the LR1110 will build a list of 10 to12 SVs per constellation 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 Cold Start Mode

If the time or Assistance Position is not known by the LR1110, the device automatically searches for all the satellites in the selected constellations, then determines assistance information is missing. This Cold Start Mode allows a GNSS scan even without any assistance information, at the expense of a longer execution time. The assistance information will be then known and used by the device for the following scans.

This mode is implemented in the LR1110 device starting from rev. 04.01.

4.1.2.4 GNSS Geolocation System Overview

The LR1110 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 LR1110's GNSS Geolocation System uses the following three back-end system components:

- GNSS Position Solving Component: the LR1110 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 back-end component for final position calculation. This component is required in all operation modes.
- GNSS Almanac Update Component (required in assisted mode): the LR1110 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 LR1110 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 LR1110. 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 Sigfox Transceiver

The LR1110 supports the transmission of Sigfox packets at both 100 and 600bps, allowing compatibility with Sigfox Radio Configurations RC1 to RC7. The LR1110 can also receive Sigfox downlinks.

No Sigfox protocol stack is embedded inside the LR1110, packet transmission has to be handled directly by the host MCU.

4.3 Bluetooth® Low Energy Beaconing Compatibility

The LR1110 embeds a transmitter that is compatible with Bluetooth® technology, to address indoor/outdoor localization use cases based on Bluetooth Low Energy beaconing.

- The Bluetooth Low Energy beaconing compatible data is detected by Bluetooth Low Energy receivers to determine the device's location.
- The Bluetooth Low Energy beaconing compatible parameters are fully configurable to permit transmission of any type of Bluetooth Low Energy beacon.

No Bluetooth Low Energy beaconing compatible stack or state machine is implemented inside the LR1110, the user must handle transmission of the Bluetooth Low Energy compatible beacons.

4.4 Round Trip Time of Flight (RTToF) Ranging

The LR1110 features a Round Trip Time of Flight ranging engine operating on the sub-GHz bands to allow localization of assets.

- This ranging feature is based on time-of-flight measurements between a pair of LR1110 chips.
- It uses the LoRa modulation scheme, and therefore benefits from all the advantages of long range operations.

4.5 LR-FHSS Modulation

The LR1110 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 LR1110 is able to generate LR-FHSS modulated packets on all sub-GHz bands.

LR-FHSS implementation in the LR1110 is transmit only.

4.6 Chip Wakeup Sequence

The supported wakeup sequence is as follows:

1. Bring NSS low.
2. Wait 100µs.
3. Bring NSS high.
4. Wait until the BUSY signal falls before executing the next command.

4.7 Exiting Sleep Mode

The LR1110 exits the lowest-power Sleep mode with:

- A falling edge on the NSS signal
- An RTC Timeout configured in the *SleepConfig* parameter of the `SetSleep()` command

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

4.8 Digital Inputs/Outputs

The LR1110 features 12 digital input/output (DIO) pins, dedicated to host or sensors/peripherals communication, interruption handling and external RF switches or LNA control.

4.8.1 DIO Configuration

The LR1110 features a DIO switch matrix (SWM), allowing a reconfiguration of the DIOs depending on the application requirements. For a transceiver use case, the LR1110 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: LR1110 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

4.8.2 RF Switch Control

The LR1110 can control up to 5 external RF switches or LNAs on the RFIO_HF and GNSS, and Sub-GHz RF paths, reducing the number of host controller IOs required for the application. This allows you to select application MCUs with a reduced pin count or a smaller footprint and therefore design highly integrated solutions. Controlling the external GNSS LNA from the LR1110 allows also to optimize the GNSS scan power consumption. 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.

4.8.3 Reset

A complete restart of the LR1110 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 100µs for the reset to occur.

4.8.4 Host Interrupts

The LR1110 offers 24 interrupt sources, allowing the host to react to special events in the LR1110 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.

4.9 Firmware Upgrade/ Update

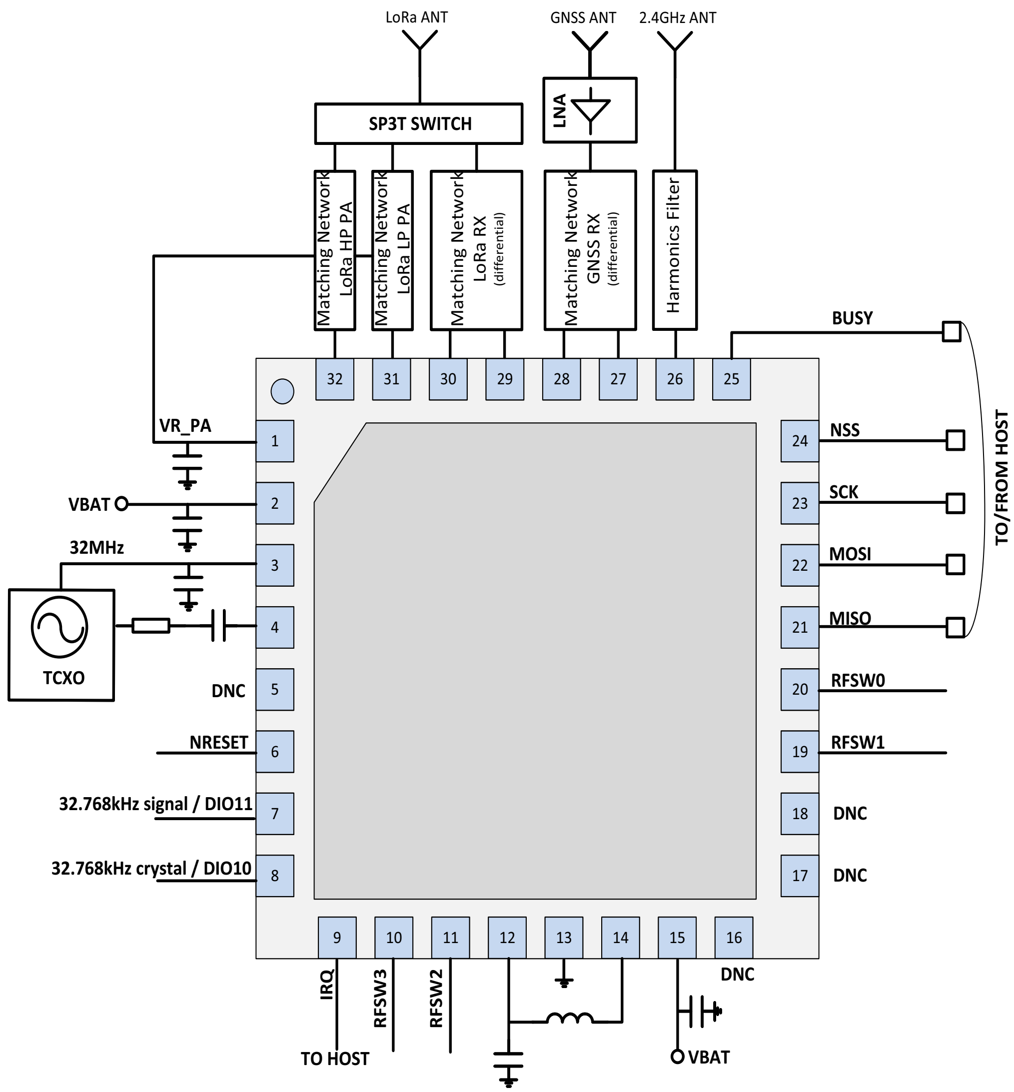
During the manufacturing process, the LR1110 will be provisioned and contain the embedded firmware image.

During the product assembly process, the customer will be able to upgrade the full embedded firmware image running on the LR1110 via the SPI interface. The bootloader of the LR1110 will authenticate the firmware and will allow further execution. Only firmware images provided by Semtech can run on the LR1110. It is advised to flash the device with the latest firmware available.

The LR1110 can also support patch updates, typically for maintenance in the field. Refer to AN1200.57 for additional information.

4.10 Simplified Reference Schematic

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

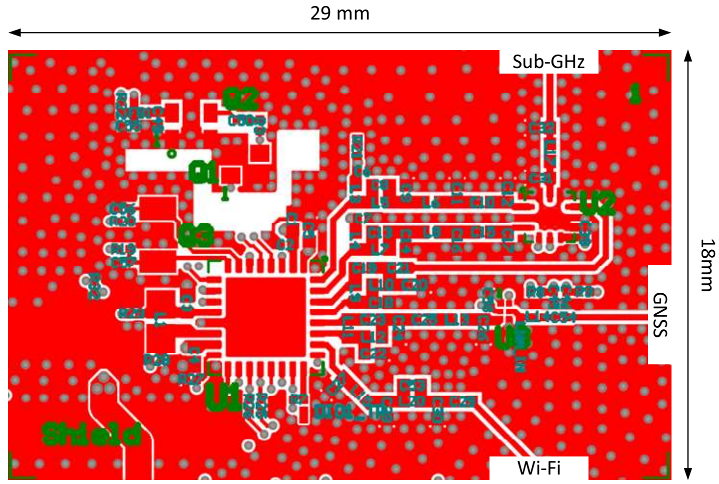


This section provides a reference schematic example using the LR1110.

- A 32MHz TCXO is mandatory for GNSS scan.
- For products that only perform Wi-Fi scans, the TCXO can be replaced by an XTAL, between pins 4 and 5.
- An external LNA is required on the GNSS receive path for GNSS scanning. The LNA is controlled using RFSWx signals.
- A 32.768kHz clock source is necessary for the GNSS Advanced scan and dual constellation scans.
- A 32.768kHz clock source is necessary for usage of LoRa Basics Modem-E firmware of the LR1110.
- For additional guidance about 32MHz and 32kHz clock sources, refer to AN1200.74 LoRa Edge™ Clock Requirements.

4.11 Example Reference Layout

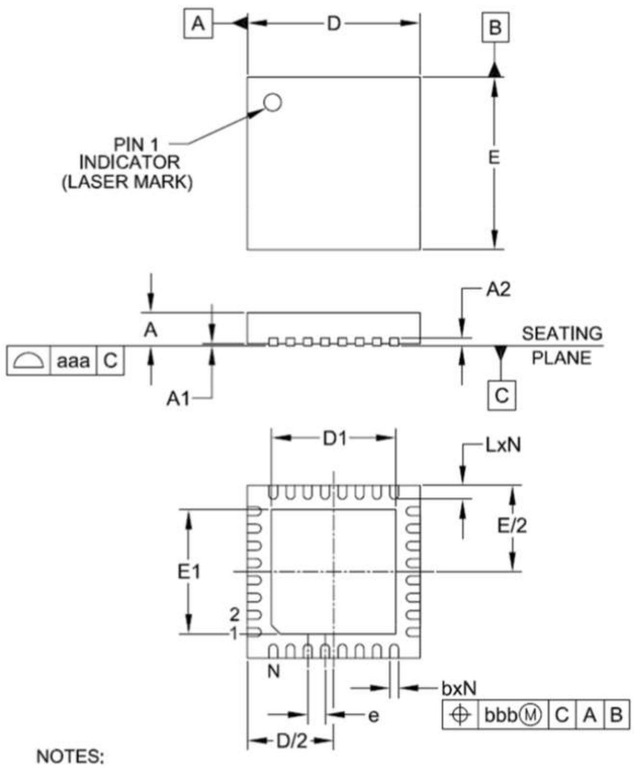
Figure 4-5: Reference Design Layout



5. Package Information

5.1 Package Outline Drawing

Figure 5-1: Package Outline Drawing



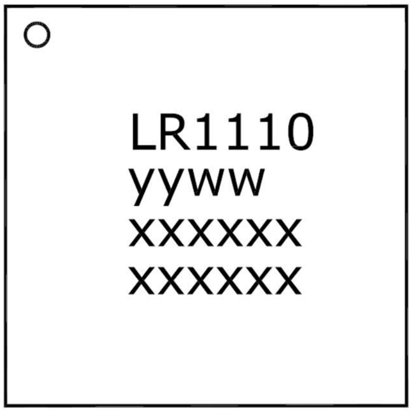
DIMENSIONS						
DIM	INCHES			MILLIMETERS		
	MIN	NOM	MAX	MIN	NOM	MAX
A	.031	-	.039	0.80	-	1.00
A1	.000	-	.002	0.00	-	0.05
A2	-	(.008)	-	-	(0.20)	-
b	.007	.010	.012	0.18	0.25	0.30
D	.193	.197	.201	4.90	5.00	5.10
D1	.140	.146	.150	3.30	3.70	3.80
E	.193	.197	.201	4.90	5.00	5.10
E1	.140	.146	.150	3.30	3.70	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



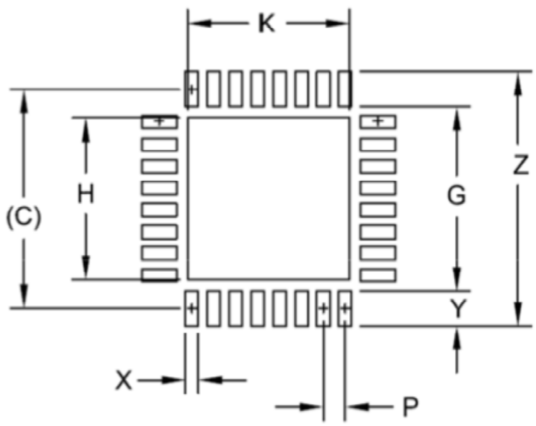
TOP MARK	
CHAR	ROWS
6/6/6/6	4

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

nnnnnn = Part Number (Example: LR1110)
yyww = Date Code (Example: 1852)
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 5x5mm package, also named MLP package.

5.5 Thermal Information

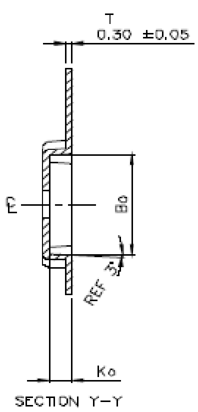
Table 5-1: Package Thermal Information

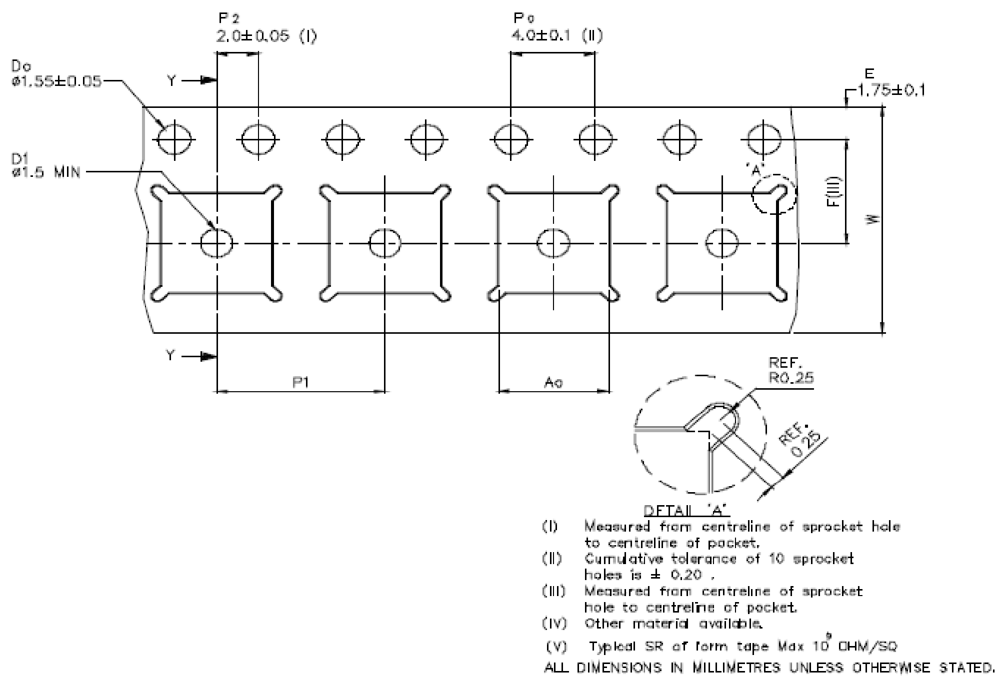
Name	Value[1]	Unit
Theta j-a, Junction to Ambient	26.7	°C/W

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

5.6 Tape & Reel Information

Figure 5-4: Tape & Reel Information





Ao	5.25 +/– 0.1
Bo	5.25 +/– 0.1
Ko	1.10 +/– 0.1
F	5.50 +/– 0.05
P1	8.00 +/– 0.1
W	12.00 +/– 0.3

Glossary

List of Acronyms and their Meaning (Sheet 1 of 2)

Acronym	Meaning
ACR	Adjacent Channel Rejection
ADC	Analog-to-Digital Converter
AP	Access Point
β	Modulation Index
BER	Bit Error Rate
BR	Bit Rate
BW	BandWidth
BWF	FSK BandWidth
BWL	LoRa BandWidth
CPOL	Clock Polarity
CPHA	Clock Phase
CR	Coding Rate
CRC	Cyclical Redundancy Check
DC-DC	Direct Current to Direct Current Converter
DER	Detection Error Rate
DIO	Digital Input / Output
DSB	Double Side Band
ECO	Engineering Change Order
FDA	Frequency Deviation
FSK	Frequency Shift Keying
GFSK	Gaussian Frequency Shift Keying
GMSK	Gaussian Minimum Shift Keying
IRQ	Interrupt Request
ISM	Industrial, Scientific and Medical (radio spectrum)
LDO	Low-Dropout
LNA	Low-Noise Amplifier
LoRa®	Long Range Communication The LoRa® Mark is a registered trademark of the Semtech Corporation

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

Acronym	Meaning
LR-FHSS	Long Range Frequency Hopping Spread Spectrum
MISO	Master Input Slave Output
MOSI	Master Output Slave Input
MSK	Minimum-Shift Keying
NSS	Slave Select active low
PA	Power Amplifier
PER	Packet Error Rate
PLL	Phase-Locked Loop
POR	Power On Reset
RC13M	13MHz Resistance-Capacitance Oscillator
RC64k	64kHz Resistance-Capacitance Oscillator
RFO	Radio Frequency Output
RTC	Real-Time Clock
SCK	Serial Clock
SF	Spreading Factor
SPI	Serial Peripheral Interface
TCXO	Temperature-Compensated Crystal Oscillator
XOSC	Crystal Oscillator

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