SX1257

Low Power Digital I and Q RF Multi-PHY Mode Transceiver

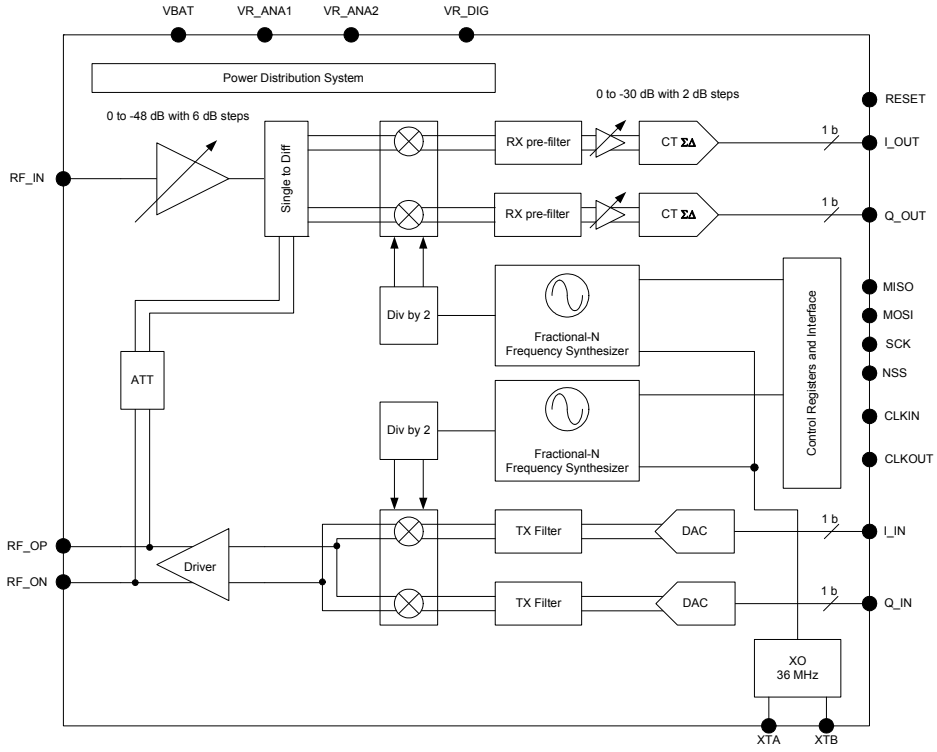

Figure A: SX1257 Block Diagram

General Description

The SX1257 is a highly integrated RF front-end to digital I and Q modulator/demodulator Multi-PHY mode transceiver capable of supporting multiple constant and non-constant envelope modulation schemes. It is designed to operate over the 862 to 960 MHz European, North American and Japanese ISM (Industrial, Scientific and Medical) license-exempt frequency bands. Its highly integrated architecture allows for a minimum of external components whilst maintaining maximum design flexibility. All major RF communication parameters are programmable and most of them can be dynamically set. The SX1257 offers support for both narrow-band and wide-band communication modes without the need to modify external components. The SX1257 is optimized for low power consumption while offering the provision for high RF output power and channelized operation. TrueRF™ technology enables a low-cost external component count whilst still satisfying ETSI, FCC and ARIB regulations.

Applications

- IEEE 802.15.4g SUN Multi-PHY Mode Smartgrid
- Cognitive / Software Defined Radio (SDR)

Key Product Features

- Fully flexible I and Q modulator and demodulator
- Half or full-duplex operation
- Bullet proof RX LNA
- Analog TX and RX pre-filtering
- Programmable tap TX FIR-DAC filter
- Linear TX amplifier for both constant and non-constant envelope modulation schemes

Ordering Information

Part Number	Delivery	Minimum Order Quantity
SX1257IWLTRT	MLPQW-32	3'000 pieces

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

Document Revision History

Version	ECO	Date	Modifications
1.0	005895	February 2012	First Final datasheet revision
1.1	040837	February 2018	Migration to new data sheet template Correction of Data Hold and Set-Up Time Correction of minor typographical errors
1.2	041328	March 2018	Correction of NSS Hold Time to 50 ns

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1. General Description

The SX1257 is a single-chip Zero-IF RF-to-digital front-end transceiver integrated circuit ideally suited for today's high performance multi-PHY mode or SDR ISM band RF applications. The SX1257 has a maximum signal bandwidth of 500 kHz in both transmission and reception and is intended as a high performance, low-cost RF-to-digital converter and provides a generic RF front-end that allows several constant and non-constant envelope modulation schemes to be handled, such as LoRa®, the MR-FSK, MR-OFDM and MR-O-QPSK PHYs of the IEEE 802.15.4g standard for Smart Utility Networks (SUN) and Smartgrid applications in the 862 - 960 MHz license-exempt frequency bands.

The SX1257's advanced features set greatly simplifies system design whilst the high level of integration reduces the external BOM to an optional RF power amplifier, and a handful of passive decoupling and matching components. A simple 4-wire 1-bit digital serial interface is provided for the baseband I and Q data streams to a baseband processor.

The SX1257 can operate in both half and full-duplex mode and is compliant with ETSI, FCC and ARIB regulatory requirements. It is available in a MLPQ-W 5 x 5 mm 32 lead package.

1.1 Simplified Block Diagram

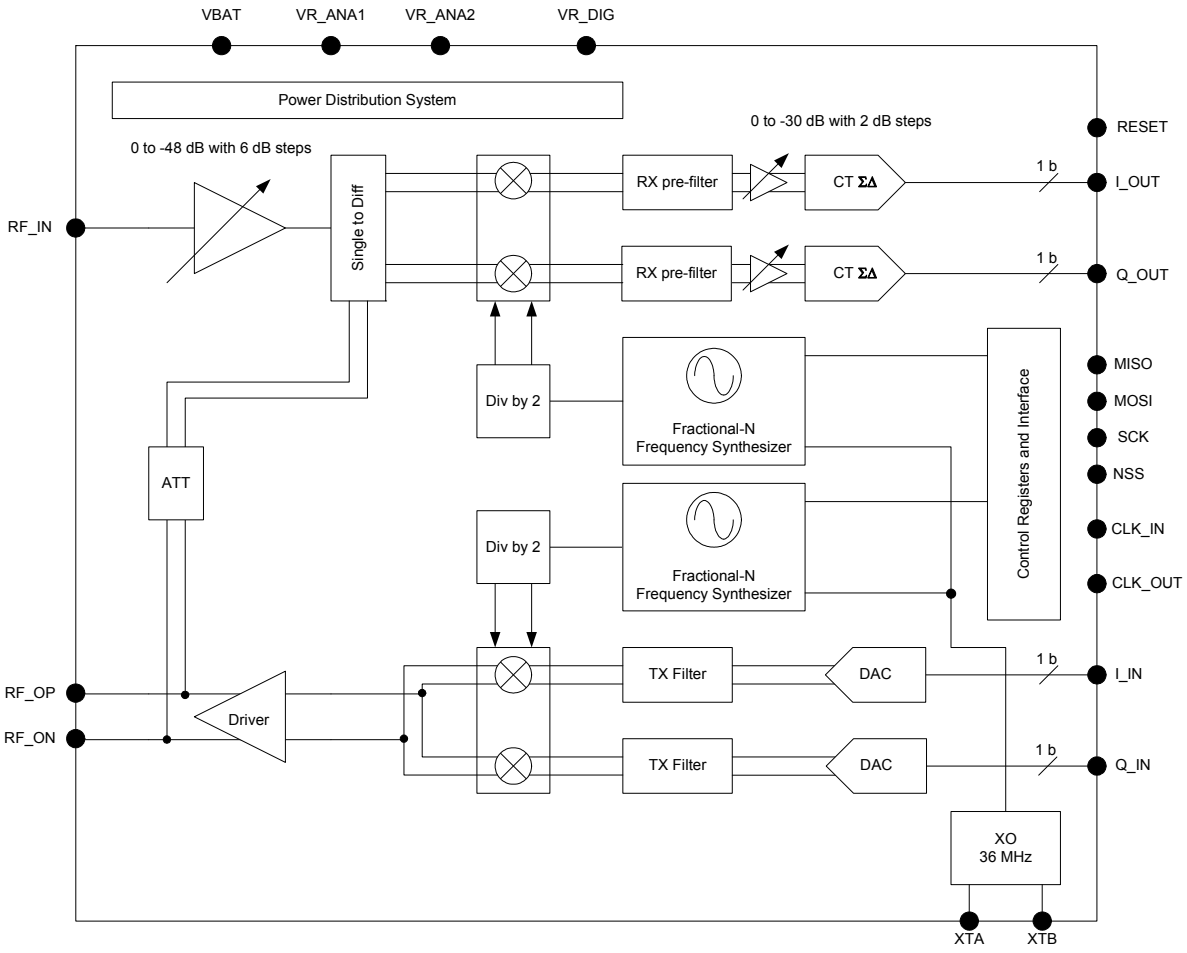


Figure 1-1: SX1257 Block Diagram

1.2 I/O Description

Table 1-1: SX1257 Pinout

Pin Number	Pin Name	Type (I = input O = Ouptut)	Description
0	Ground	-	Exposed Ground pad
1	VR_PA	-	Regulated supply for TX amplifier
2	VBAT1	-	VBAT Supply voltage
3	VR_ANA1	-	Regulated supply for analog TX circuit
4	GND	-	Ground
5	VR_DIG	-	Regulated supply for digital circuit
6	XTA	I/O	Crystal pad
7	GND	-	Ground
8	XTB	I/O	Crystal pad / input for external clock
9	Reset	I/O	Reset
10	CLK_OUT	O	36 MHz digital clock output
11	CLK_IN	I	36 MHz digital clock input
12	Q_IN	I	Digital baseband data input for I (inphase) channel DAC
13	I_IN	I	Digital baseband data input for Q (quadrature) channel DAC
14	Q_OUT	O	Digital baseband data output from I (inphase) channel ADC
15	I_OUT	O	Digital baseband data output from Q (quadrature) channel ADC
16	VBAT2	-	VBAT supply voltage
17	SCK	I	SPI clock
18	MISO	O	Master In Slave Output SPI output
19	MOSI	I	Master Out Slave Input SPI input
20	NSS	I	SPI chip select
21	DIO0	O	Digital I/O, software configured
22	DIO1	O	Digital I/O, software configured
23	DIO2	O	Digital I/O, software configured
24	DIO3	O	Digital I/O, software configured
25	VR_ANA2	-	Regulated supply for analog RX circuit
26	GND	-	Ground
27	RF_IN	I	RX LNA input
28	GND	-	Ground

Table 1-1: SX1257 Pinout

Pin Number	Pin Name	Type (I = input O = Ouptut)	Description
29	RF_ON	O	Differential TX Output, negative node
30	RF_OP	O	Differential TX Output, positive node
31	GND	-	Ground
32	VBAT3	-	VBAT supply for TX amplifier

1.3 Package View

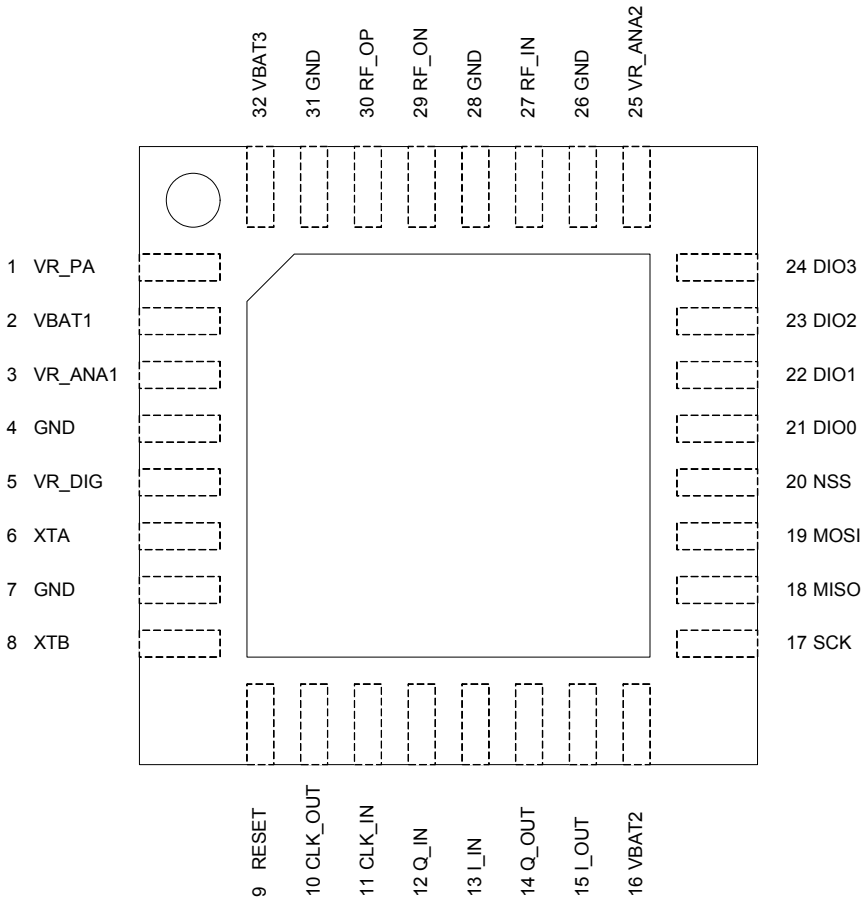


Figure 1-2: SX1257 Top View Pin Location

2. Specifications

2.1 ESD Notice

The SX1257 is a high performance radio frequency device.

- Class 3A of the JEDEC standard JESD22-A114-C (Human Body Model) on all pins
- Class B of the JEDEC standard JESD22-A115-A (Machine Model) on all pins
- Class III of the JEDEC standard JESD22-C101-C (Charged Device Model) on all pins

The chip should be handled with all the necessary ESD precautions to avoid any permanent damage.

2.2 Absolute Maximum Ratings

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

Table 2-1: Absolute Maximum Ratings

Symbol	Description	Min	Typ	Max	Unit
VDDmr	Supply voltage	-0.5	-	3.9	V
Tmr	Temperature	-55	-	115	°C
Tj	Junction temperature	-	-	125	°C
Pmr	RF input level	-	-	+6	dBm

2.3 Operating Range

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

Table 2-2: Operating Range

Symbol	Description	Min	Typ	Max	Unit
VDDop	Supply voltage	2.7	-	3.6	V
Top	Temperature under bias	-40	-	85	°C
Clop	Load capacitance on digital ports	-	-	25	pF
ML	RF Input power	-	-	0	dBm

2.4 Electrical Specifications

The electrical specifications are given with the following conditions unless otherwise specified:

- VBAT_IO = VBAT = 3.3 V, all current consumptions are given for VBAT connected to VBAT_IO
- Temperature = 25 °C
- FXOSC = 36 MHz
- F_{RF} = 915 MHz
- OFDM with 16-QAM
- 3/4 rate coded with 26 active tones (IEEE 802.15.4g MR-OFDM Option 3)
- Output power = -5 dBm (100 ohm differential transmission)
- TXBWANA = 250 kHz
- RXBWANA = 250 kHz
- External baseband RX filter = 150 kHz

2.4.1 Power Consumption Specifications

Table 2-3: Power Consumption Specifications

Symbol	Description	Conditions	Min	Typ	Max	Unit
IDDSL	Supply current in sleep mode		-	0.5	1	µA
IDDST	Supply current in standby mode	Crystal oscillator enabled	-	1.15	1.5	mA
IDDRX	Supply current in receive mode	-		20	25	mA
IDDTX	Supply current in transmit mode	RFOutput Power = -5 dBm	-	58	85	mA

2.4.2 Frequency Synthesis Specifications

Table 2-4: Frequency Synthesis Specifications

Symbol	Description	Conditions	Min	Typ	Max	Unit
FR	Synthesizer frequency range	Programmable	862	-	1020	MHz
FXOSC	Crystal oscillator frequency	See Section 5. "Configuration and Status Registers" on page 29	32	36	36	MHz
TS_OS	Crystal oscillator wake-up time	from sleep mode	-	300	500	µs
TS_FS	Synthesizer wake-up time	Crystal oscillator enabled	-	100	150	µs
FSTEP	Frequency synthesizer step size	FSTEP = FXOSC / 2^{19}	61	68.7	68.7	Hz

2.4.3 Transmitter Front-End Specifications

Table 2-5: Transmitter Front-End Specifications

Symbol	Description	Conditions	Min	Typ	Max	Unit
FCLK_IN	External clock frequency for TX synthesizer or DAC input clock	SX1257 slave mode	32	-	36	MHz
TXPmax	TX maximum output power	Saturated Power	+5	+8	-	dBm
TXP1dB	TX 1 dB compression point	Peak value	+3	+6	-	dBm
TXOIP3	TX output IP3	-5 dBm average output power	+13	+16	-	dBm
PHN	Transmitter phase noise	100 kHz offset from carrier	-	-98	-	dBc/Hz
PHNF	Transmitter output noise floor	10 MHz offset from carrier	-131	-128	-	dBc/Hz
PHNID	Transmitter integrated DSB phase noise	Integrated bandwidth from 500 Hz to 125 kHz	-	0.6	1.5	°RMS
TXGM	Transmitter IQ gain mismatch	-	-	0.5	1	dB
TXPM	Transmitter IQ phase mismatch	-	-	1	3	°
TXBWANA	Transmitter analog prefilter BW (SSB)	Programmable	210	-	850	kHz
XBWANAPrc	Transmitter analog prefilter BW precision	-	-30	-	+30	%
TXBWDIFG	Transmitter FIR-DAC taps	Programmable	24	-	64	-
TXLO	TX LO leakage (before DC offset calibration)	ADC rms input: -10 dBFS	-	-8	-	dBc
TS_TR	Transmitter wake-up time	Frequency synthesizer enabled	-	120	-	µs

2.4.4 Receiver Front-End Specifications

Table 2-6: Receiver Front-End Specifications

Symbol	Description	Conditions	Min	Typ	Max	Unit
FCLK_IN	External clock frequency for TX synthesizer or DAC input clock	SX1257 slave mode	32	-	36	MHz
CLK_INJ	External clock jitter specification	External clock, white noise	-	-	0.01	%
RXNF	Receiver noise figure	Maximum LNA gain	-	7	10	dB
RXGR	RX gain range	Adjustable in 2 dB steps	-	70	-	dB
IIP3	3rd order input intercept point Unwanted tones are 2 MHz and 3.8 MHz above the LO	Lowest LNA gain Highest LNA gain	+10 -28	- -25	- -	dBm dBm
RXGM	Receiver IQ gain mismatch	-	-	0.5	1	dB
RXPM	Receiver IQ phase mismatch	-	-	1	3	°
RXBWANA	Receiver analog prefilter BW (SSB)	Programmable	250	-	750	kHz

2.4.5 SPI Bus Digital Specifications

Table 2-7: Digital I/O Specifications

Symbol	Description	Conditions	Min	Typ	Max	Unit
V_{IH}	Input high voltage	-	0.8	-	-	VDD
V_{IL}	Input low voltage	-	-	-	0.2	VDD
V_{OH}	Output high voltage	I_{max} = 1 mA	0.9	-	-	VDD
V_{OL}	Output low voltage	I_{max} = -1 mA	-	-	0.1	MHz
F_{SCK}	SCK frequency	-	-	-	10	ns
t_{ch}	SCK high time	-	50	-	-	ns
t_{cl}	SCK low time	-	50	-	-	ns
t_{rise}	SCK rise time	-	-	5	-	ns
t_{fall}	SCK fall time	-	-	5	-	ns
t_{setup}	MOSI set-up time	From MOSI change to SCK rising edge	30	-	-	ns
t_{hold}	MOSI hold time	From SCK rising edge to MOSI change	60	-	-	ns
t_{nsetup}	NSS set-up time	From NSS falling edge to SCK rising edge	30	-	-	ns
t_{nhold}	NSS hold time	From SCK falling edge to NSS rising edge	50	-	-	ns
t_{nhigh}	NSS high time between SPI access	-	20	-	-	ns
t_{data}	Data hold and set-up time	-	25	-	-	ns

3. Circuit Description

3.1 Power Supply Strategy

The SX1257 employs an advanced power distribution scheme (PDS), which provides stable operating characteristics over the full temperature and voltage range of operation.

The SX1257 can be powered from any low-noise voltage source via pins VBAT1, VBAT2 and VBAT3. Decoupling capacitors should be connected, as suggested in the reference design, on VR_PA, VR_DIG, VR_ANA1 and VR_ANA2 pins to ensure a correct operation of the built-in voltage regulators.

3.2 Low Battery Detector

A low battery detector is also included allowing the generation of an interrupt signal in response to passing a programmable threshold adjustable through the register RegLowBat. The interrupt signal can be mapped to the DIO0 pin, through the programmation of RegDioMapping.

3.3 Frequency Synthesizer

The SX1257 incorporates two separate state of the art fractional-N PLLs for the TX and RX circuit blocks.

3.3.1 Reference Oscillator

The crystal oscillator is the main timing reference of the SX1257. It provides the reference source for the transmit and receive frequency synthesizers and as a clock for digital processing.

The XO startup time, TS_OSC, depends on the actual XTAL being connected on pins XTA and XTB. When using the built-in sequencer, the SX1257 optimizes the startup time and automatically triggers the PLL when the XO signal is stable. To manually control the startup time, the user should monitor the signal CLK_OUT which will only be made available on the output buffer when a stable XO oscillation is achieved.

An external crystal controlled source, such as a clipped-sinewave TCXO, clock can be used to replace the crystal oscillator, This external source should be provided on XTB (pin 8) and XTA (pin 6) should be left open, as illustrated in the following figure.

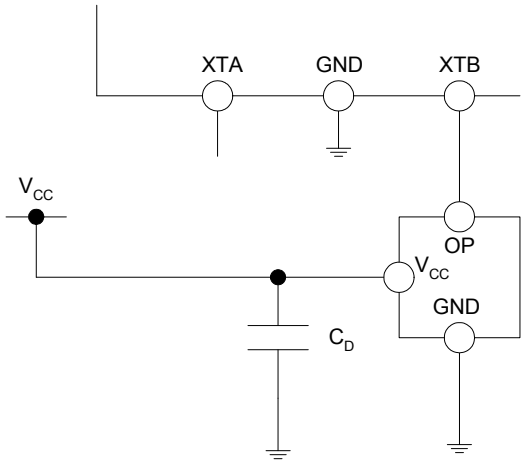


Figure 3-1: TCXO Connection

The peak-peak amplitude of the input signal must never exceed 1.8 V. Please consult your TCXO supplier for an appropriate value of decoupling capacitor, CD. Due to the low jitter requirements required by the receiver digital block it is recommended that only a crystal controlled external frequency source is used.

3.3.2 CLK_OUT Output

For master mode operation the SX1257 provides a system clock output made available at pin CLK_OUT.

3.3.3 PLL Architecture

The SX1257 incorporates two fourth-order type fractional-N sigma-delta PLLs. The PLLs include integrated VCO and programmable bandwidth loop filter, removing the need for any external components. The PLLs are autocalibrating and are capable of fast switching and settling times.

3.3.3.1 VCO

Both TX and RX VCOs operate at twice the RF frequency, with the oscillators centered at 1.9 GHz. This reduces any LO leakage in receive mode, to improve the quadrature precision of the receiver, and to reduce the pulling effects on the VCO during transmission.

The VCO calibration is fully automated, calibration times are fully transparent to the end-user as the processing time is included in the TS_TR and TS_RE specifications.

3.3.3.2 PLL Bandwidth

The bandwidth of the PLL loop filters are independently configurable via the configuration registers TxPllBw and RxPllBw for the modulation schemes supported, as well as fast channel switching and lock times to support FHSS and frequency agile applications, such as AFA.

3.3.3.3 Carrier Frequency and Resolution

Both the TX and RX embed a 19-bit sigma-delta modulator and the frequency resolution, constant over the entire frequency range, is calculated using the following formula:

$$F_{STEP} = \frac{F_{XOSC}}{2^{19}}$$

The RX and RX carrier frequencies are programmed through registers RegFrfRx and RegFrfTx, split across register addresses 0x01 to 0x03 and 0x04 to 0x06, respectively, and are calculated by:

$$F_{RF} = F_{STEP} \times F_{RFXX}(23, 0)$$

where: F_{rfxx} is the integer value of the RegFrfRx or RegFrfTx as defined above.

Note:
As stated above, the F_{rfxx} settings are split across 3 bytes for both the transmitter and receiver frequency synthesizers. A change in the center frequency will only be taken into account when the least significant byte FrfxxLsb in RegFrfxxLsb is written and when exiting SLEEP mode

3.3.3.4 PLL Lock Time

RX and TX PLL lock times are a function of a number of technical factors, such as synthesized frequency, frequency step, etc. The SX1257 includes an auto-sequencer that manages the start-up sequence of the PLL.

3.3.3.5 Lock Detect Indicator

A lock indication signal for both RX and TX PLLs can be accessed via DIO pins, and is toggled high when the PLL reaches its locking range. Please refer to Table 4-1: "DIO Mapping" on page 28 to map this interrupt to the desired DIO pins.

3.4 Transmitter Analog Front-End Description

The analog front-end of the SX1257 transmitter stage comprises the TX frequency synthesizer, I and Q channel filters, the I/Q mixer and RF amplifier blocks.

3.4.1 Architectural Description

The block diagram of the transmitter front-end block is illustrated below.

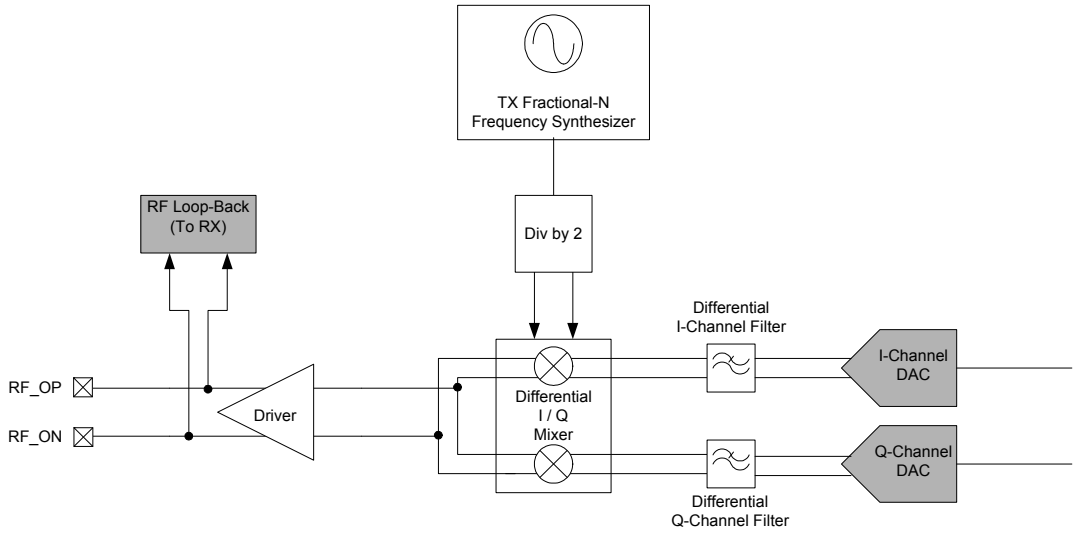


Figure 3-2: SX1257 Transmitter Analog Front-End Block Diagram

3.4.2 TX I / Q Channel Filters

Differential analog I and Q signals input to the TX front-end from the TX FIR DAC are filtered by I and Q channel filters. These filters smooth the reconstructed analog waveforms and remove quantization noise generated by the I and Q channel TX FIR DACs. The filters are unity gain third-order low-pass Butterworth types with programmable bandwidth configured via TxAnaBw.

The 3 dB BW of the analog TX filter BW can be calculated from:

$$BW_{3dB} = \frac{17.15}{(41 - RegTxBWAna(4,0))}$$

The analog filter bandwidth should be set to greater than the signal bandwidth so as to reduce any group delay variations.

The range of programmable TX analog filter bandwidths is tabulated below.

TxAnaBw [Dec]	TxAnaBw [Bin]	SSB Filter BW [kHz]
0	00000	209
1	00001	214
2	00010	220
3	00011	226
4	00100	232
5	00101	238
6	00110	245
7	00111	252
8	01000	260
9	01001	268
10	01010	277
11	01011	286
12	01100	296
13	01101	306
14	01110	318
15	01111	330
16	10000	343
17	10001	357
18	10010	373
19	10011	390
20	10100	408
21	10101	429
22	10110	451
23	10111	476
24	11000	504
25	11001	536
26	11010	572
27	11011	613
28	11100	660
29	11101	715

TxAnaBw [Dec]	TxAnaBw [Bin]	SSB Filter BW [kHz]
30	11110	780
31	11111	858

3.4.3 TX I / Q Up-Conversion Mixers

The TX I / Q mixer block mixes the baseband analog I and Q signals with that from the PLL frequency synthesizer and up converts to the RF carrier frequency. The mixer block includes a highly linear I/ Q mixer stage with programmable gain configurable via configuration register RegTxGain. The modulated RF signal is input to the TX RF amplifier stage.

3.4.4 RF Amplifier

The TX amplifier receives the input signal from the TX mixer and provides two differential outputs. The first output provides the RF_OP and RF_ON signals in TX mode. The second output is used to provide an internal differential signal to the receiver during RX gain calibration. The amplifier provides good linear performance required to meet the peak to average power level variation of OFDM.

The peak output power is +5 dBm, which allows for an average output power of greater than -5 dBm with 10 dB back-off. The output signal is intended to be amplified through a suitable external RF power amplifier to the maximum permissible level allowed by relevant regulatory standards. The optimum load impedance presented RF amplifier is 100 ohms differential.

3.5 Transmitter Digital Baseband Description

The transmitter digital baseband section contains separate I and Q channel digital-to-analog convertors.

3.5.1 Digital-to-Analog Converters

The TX DAC is the first block of the SX1257 transmitter. It accepts the 1-bit I and Q noise shaped 32 Msample/second or 36 MSample/second bit-stream from the baseband processor and converts into two analog differential signals. Each TX DAC provides 8-bits of resolution in a 500 kHz bandwidth which corresponds to maximum RF transmitted double-sideband bandwidth of 1 MHz.

A programmable Finite Impulse Response (FIR) filter allows the removal of the digital modulator noise from the external baseband processor. The number of taps implemented by the FIR-DAC and subsequent single-side DAC bandwidth is controlled by the parameter TxDacBw.

TxDacBw [Dec]	TxDacBw [Bin]	No. DAC-FIR Taps	SSB Filter BW [kHz]
0	000	24	
1	001	32	450
2	010	40	
3	011	48	
4	100	56	
5	101	64	290

Examples of the FIR DAC normalized magnitude response are illustrated below.

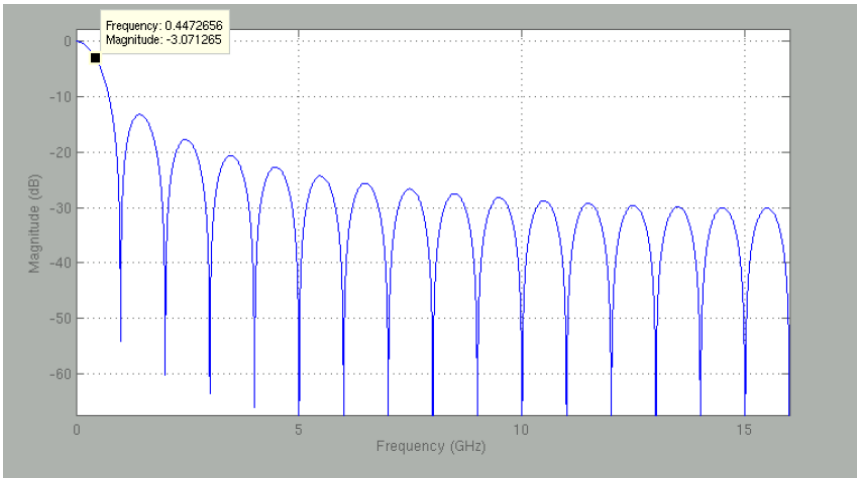


Figure 3-3: FIR-DAC Normalized Magnitude Response with f_S = 32 MHz and N = 32

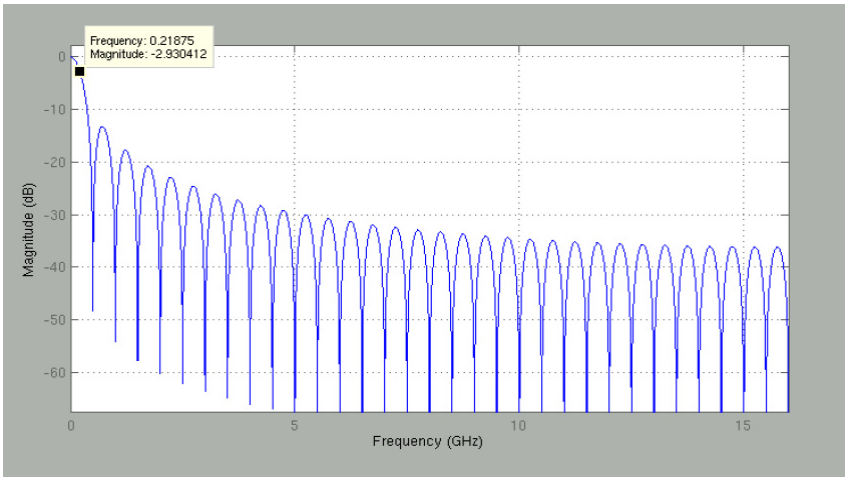


Figure 3-4: FIR-DAC Normalized Magnitude Response with f_S = 32 MHz and N = 64

The DAC 3dB bandwidth is proportional to the sampling frequency fs and inversely proportional to the number of taps N. In the case where f_S = 32 MHz with N = 32 the 3 dB bandwidth is typically 450 kHz. Reducing the bandwidth may be useful to reduce the quantisation noise contribution when the signal bandwidth request is lower, as is illustrated in the case where N = 64, resulting in a 3 dB bandwidth of approximately 290 kHz.

3.5.2 I and Q Serial Interface

I and Q data is input to the DACs on the rising edge of the reference sampling clock and is sampled on a falling edge. The TX DAC can be used either with an external clock CLK_IN or with the internal clock, available on CLK_OUT for data synchronization (recommended mode).

The I and Q channel bit stream timing diagram is illustrated below.

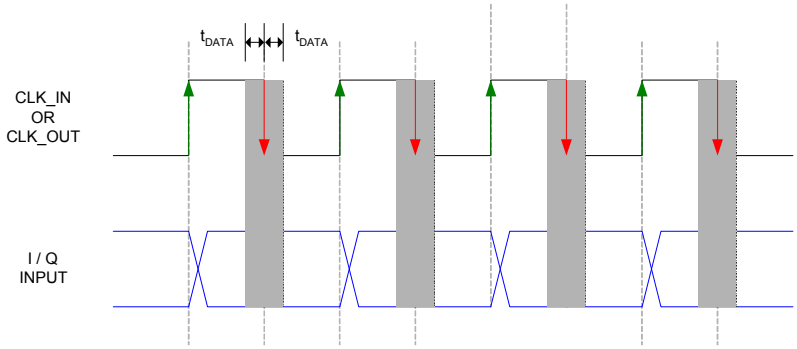


Figure 3-5: Transmitter I and Q Channel Bit-Stream Timing Diagram

3.6 Receiver Analog Front-End Description

The SX1257 receiver front-end is based upon a zero-IF architecture, ideally suited to handle multiple complex modulation schemes. The RX chain incorporates a programmable gain LNA and single to differential buffer, I / Q mixer, separate I and Q channel analog low-pass filters and programmable baseband amplifiers. The amplified differential analog I and Q outputs are input to two 5th order continuous-time sigma-delta Analog to Digital Converters (ADC) for further signal processing in the digital domain.

3.6.1 Architectural Description

The block diagram of the receiver front-end block is illustrated below.

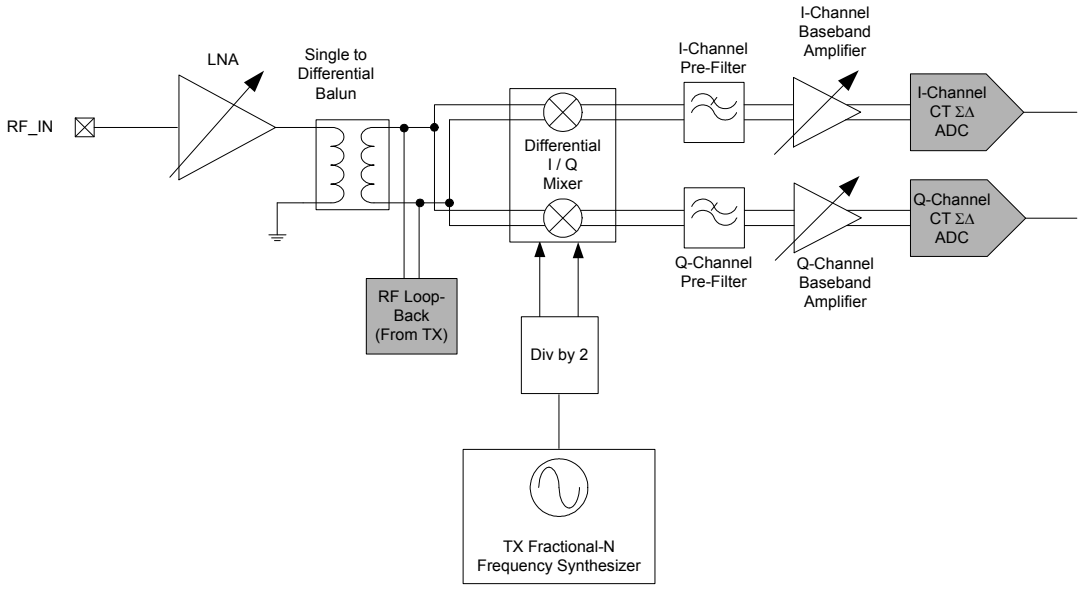


Figure 3-6: SX1257 Receiver Analog Front-End Block Diagram

3.6.2 LNA and Single to Differential Buffer

The LNA uses a common-gate topology, which allows for a flat characteristic over the whole frequency range. It is designed to have an input impedance of 50 Ohms or 200 ohms (as selected with bit LnaZin in RegRxAnaGain). A single to differential buffer is implemented to improve the second order linearity of the receiver.

The LNA gain, including the single-to-differential buffer, is programmable over a 48 dB dynamic range, and gain control can be enabled via an external AGC function.

3.6.3 I /Q Downconversion Quadrature Mixer

The mixer is inserted between output of the RF buffer stage and the input of the I and Q channel analog low-pass filter stages. This block is designed to downconvert the spectrum of the input RF signal to base-band and offers both high IIP2 and IIP3 responses.

3.6.4 Baseband Analog Filters and Amplifiers

The differential I and Q baseband mixer signals are pre-filtered by a programmable 1st order low-pass pre-filter and input to programmable linear baseband amplifiers. The single-sideband 3 dB bandwidth of the pre-filters can be programmed between 250 kHz and 750 kHz. This additional pre-filtering improves the selectivity of the receiver for complex modulation schemes, such as OFDM.

The amplifier stage gain offers 32 dB of programmable gain, in 2 dB steps, from -24 dB to +6 dB via configuration register RegRxAnaGain while the analog filter bandwidth is programmed via the two least significant bits of configuration register RegRxBw.

3.7 Receiver Digital Baseband

The receiver digital baseband section contains separate I and Q channel continuous time Sigma-Delta analog-to-digital converters to digitize and filter the analog bit stream.

3.7.1 Architectural Block Diagram

The block diagram of the receiver digital baseband is illustrated below.

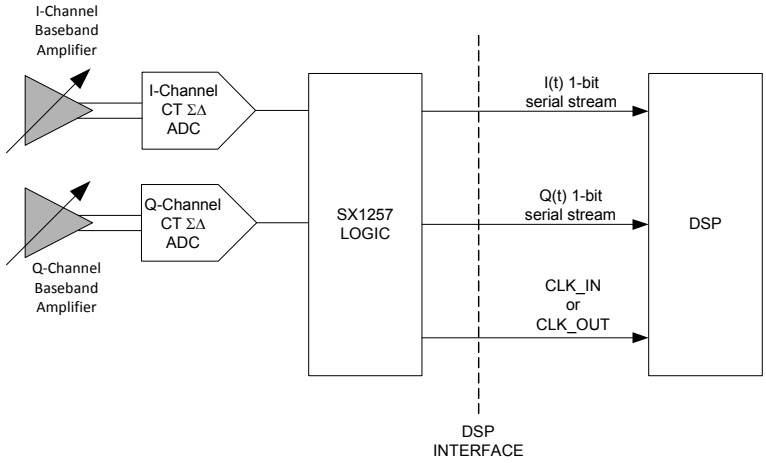


Figure 3-7: SX1257 Digital Receiver Baseband Block Diagram

3.7.2 Analog-to-Digital Converters

The receiver digital baseband consists of separate I and Q channel 5th order continuous-time sigma-delta modulator analog -to-digital converters which sample and digitize the analog baseband I and Q signals output at the analog baseband amplifiers.

The ADC output allows for 13 bits of resolution after decimation and filtering by the external baseband processor within a 500 kHz maximum bandwidth, corresponding to a maximum RF received double sideband bandwidth of 1 MHz.

The ADC output is one bit per channel quadrature bit stream at 32 or 36 MSamples/s.

3.7.3 Temperature Sensor

The receiver ADC can be used to perform a temperature measurement by digitizing the sensor response. The response of the sensor is -1C / Lsb. Since a CMOS temperature sensor is not accurate by nature, the sensor should be calibrated at ambient temperature for a precise reading.

It takes less than 100 µs for the SX1257 to evaluate the temperature (from setting RxAdcTemp = "1"). The AdcTemp value can be read at Q_OUT. Since there is no on-chip decimation or averaging it is recommmended that data on Q_OUT is externally processed, for example using a simple FFT.

The temperature measurement should be performed with the SX1257 in StandbyEnable Mode (RegMode = 0x01)

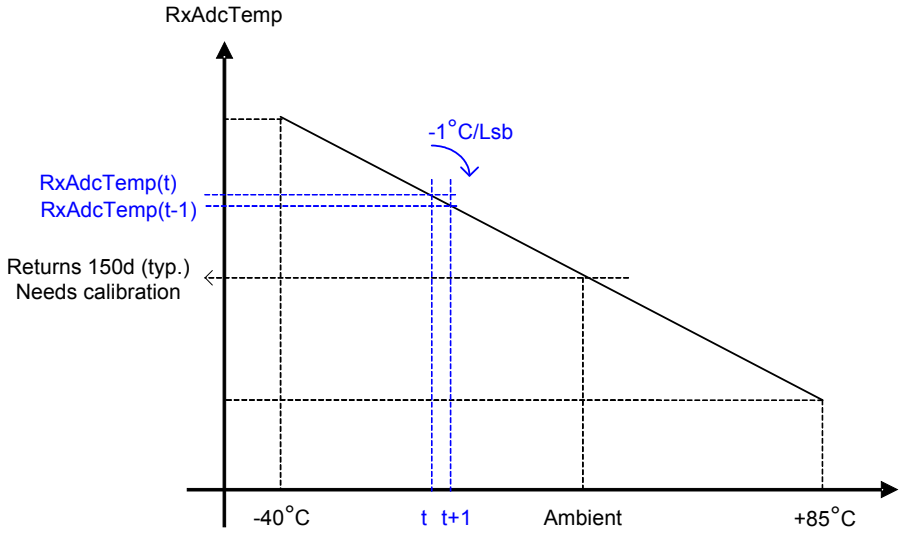


Figure 3-8: Temperature Sensor Response

3.7.4 I and Q Serial Interface

I and Q data is input to the ADCs on the rising edge of the reference sampling clock and is sampled on a falling edge. The RX ADC can be used either with an external clock CLK_IN or with the internal clock, available on CLK_OUT (recommended mode) for data synchronization. The I and Q channel bit stream timing diagram is illustrated below.

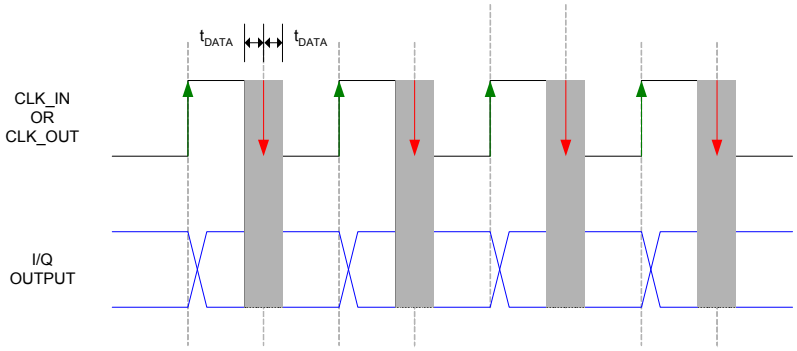


Figure 3-9: Receiver I and Q Channel Bit-Stream Timing Diagram

3.8 Loop-Back

The SX1257 provides mechanisms to both monitor and externally calibrate both the RF transmission path and the I and Q bit streams generated by the external baseband processor.

3.8.1 Digital Loop-Back

The digital loop-back enables the connection of the input and output I and Q baseband bit streams prior to processing by the SX1257. This loop back path enables the validation of the transmitter and receiver baseband processing paths.

3.8.2 RF Loop Back

The RF loop-back path connects the balanced RF output signal of the transmitter driver stage to the output of the differential mixer of the receiver. This path provides a mechanism for the external baseband processor to implement a calibration for the following:

- Receiver I, Q gain mismatch
- Receiver I and Q phase imbalance
- Transmitter I, Q gain mismatch
- Transmitter I and Q phase imbalance
- Transmitter DC offset

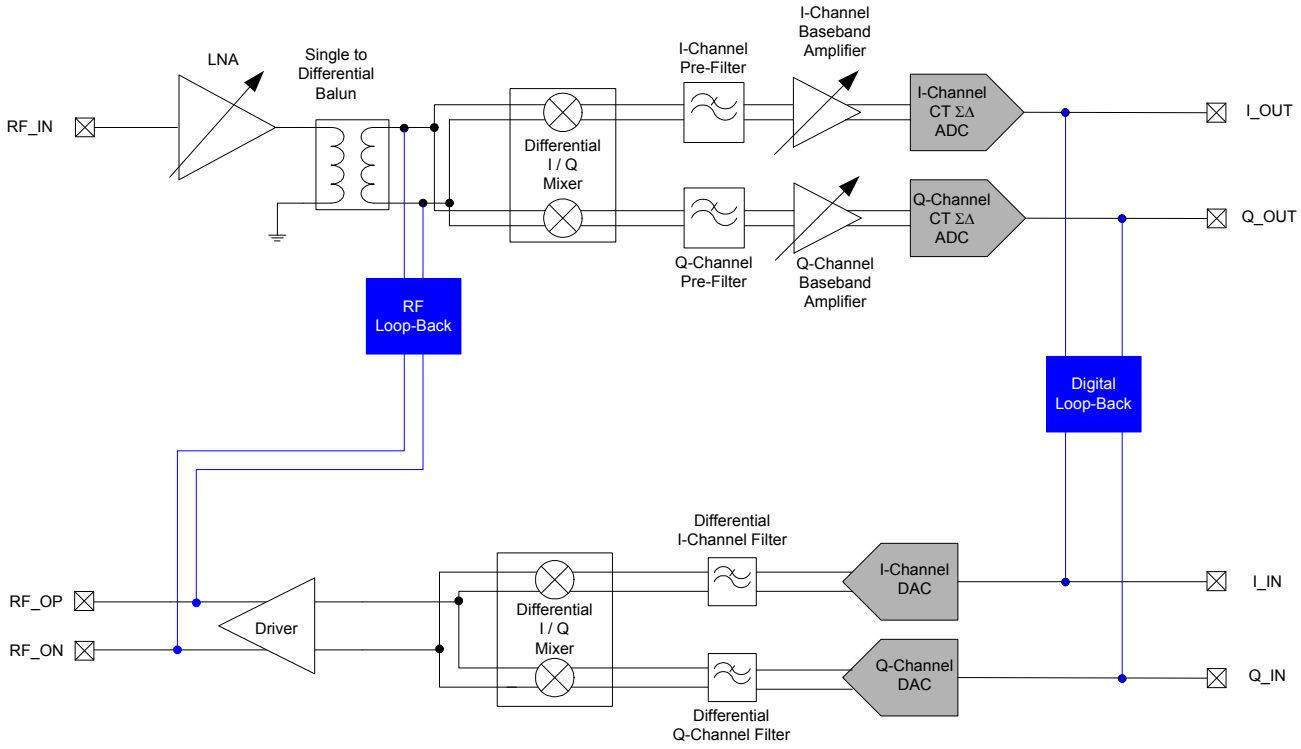


Figure 3-10: Digital and RF Loop-Back Paths

4. Digital Interface

The SX1257 has several operating modes, configuration parameters and internal status indicators. All these operating modes, configuration parameters and status information are stored in internal registers that may be accessed by the external micro-controller via the serial SPI interface.

4.1 SPI Bus 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.

Two access modes to the registers are provided:

- SINGLE access: an address byte followed by a data byte is sent for a write access whereas an address byte is sent and a read byte is received for the read access. The NSS pin goes low at the begin of the frame and goes high after the data byte.
- BURST access: the address byte is followed by several data bytes. The address is automatically incremented internally between each data byte. This mode is available for both read and write accesses. The NSS pin goes low at the beginning of the frame and stay low between each byte. It goes high only after the last byte transfer.

An example of a typical SPI single access to a register is illustrated below.

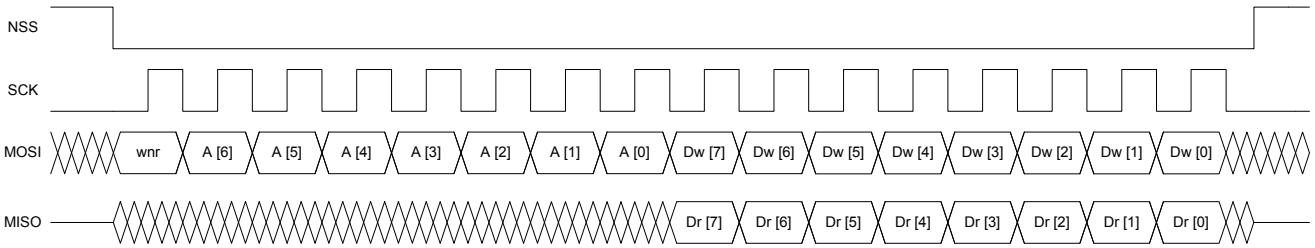


Figure 4-1: SPI Timing Diagram (Single Access)

MOSI is generated by the master on the falling edge of SCK and is sampled by the slave (i.e. this SPI interface) on the rising edge of SCK. MISO is generated by the slave on the falling edge of SCK.

A transfer always starts by the NSS pin going low. MISO is high impedance when NSS is high.

The first byte is the address byte. It is made of:

- wnr bit, which is 1 for write access and 0 for read access
- 7 bits of address, MSB first

The second byte is a data byte, either sent on MOSI by the master in case of a write access, or received by the master on MISO in case of read access. The data byte is transmitted MSB first.

Succeeding bytes may be sent on MOSI (for write access) or received on MISO (for read access) without rising NSS and re-sending the address. The address is then automatically incremented at each new byte received (BURST mode).

The frame ends when NSS goes high. The next frame must start with an address byte. The SINGLE access mode is actually a special case of BURST mode with only 1 data byte transferred. During the write accesses, the byte transferred from the slave to the master on the MISO line is the value of the written register before the write operation.

4.2 Digital IO Pin Mapping

Four general purpose IO pins are available on the SX1257 and their configuration is controlled through the RegDioMapping configuration register.

Table 4-1: DIO Mapping

Mode	DIO MApping	DIO3	DIO2	DIO1	DIO0
Sleep	00	-	-	-	-
	01	-	-	-	-
	10	-	-	-	-
	11	-	-	-	-
Standby	00	-	xosc_ready	-	-
	01	-	-	-	-
	10	-	-	-	-
	11	-	-	-	-
RX	00	pll_lock_rx	-	-	pll_lock_rx
	01	-	-	-	pll_lock_rx
	10	-	-	-	pll_lock_rx
	11	-	-	-	Low Bat
TX	00	pll_lock_tx	-	pll_lock_tx	-
	01	-	-	-	-
	10	-	-	-	-
	11	-	-	-	-

5. Configuration and Status Registers

5.1 General Description

Table 5-1: Configuration Register Summary

Address	Register Name	Reset Value	Description
0x00	RegMode	0x00	Operating modes of the SX1257
0x01	RegFrfRxMsb	0xCB	RX carrier frequency MSB
0x02	RegFrfRxMid	0x55	RX carrier frequency intermediate bits
0x03	RegFrfRxLsb	0x55	RX carrier frequency LSB
0x04	RegFrfTxMsb	0x00	TX carrier frequency MSB
0x05	RegFrfTxxMid	0xCB	TX carrier frequency intermediate bits
0x06	RegFrfTxLsb	0x55	TX carrier frequency LSB
0x08	RegTxGain	0x2E	TX DAC and mixer gain setting
0x0A	RegTxBw	0x30	TX FE PLL and analog filter bandwidths
0x0B	RegTxDacBw	0x02	TX DAC bandwidth
0x0C	RegRxAnaGain	0x3F	RX FE LNA and baseband amplifier gain
0x0D	RegRxBw	0xFD	RX FE ADC and analog filter bandwidths
0x0E	RegRxPLLBw	0x06	RX FE PLL bandwidth
0x0F	RegDioMapping	0x00	Mapping of DIO pins
0x10	RegClkSelect	0x02	Sampling clock congfiguration
0x11	RegMode Status	0x00	SX1257 mode status
0x1A	RegLowBatThres$	0x02	Low battery threshold

Note:

- **The reset values are automatically refreshed at Power on Reset**

5.2 Mode Configuration Registers

Table 5-2: Mode Configuration Registers

Name (Address)	Bits	Variable Name	Mode	Default Value	Description
RegMode (0x00)	7-4	-	r	0000	unused
	3	PADriverEnable	rw	0	Enables the TX PA driver 0 = Disabled 1 = Enabled
	2	TxEnable-	rw	0	Enables the TX front-end and PLL (except the TX PA driver) 0 = Disabled 1 = Enabled
	1	RxEnable	rw	0	Enables the RX front-end and PLL 0 = Disabled 1 = Enabled
	0	StandbyEnable	rw	1	Enables the PDS and the oscillator in Standby Mode 0 = Disabled 1 = Enabled

5.3 Frequency Synthesizer Configuration Registers

Table 5-3: Frequency Synthesizer Configuration Registers

Name (Address)	Bits	Variable Name	Mode	Default Value	Description
RegFrfRxMsb (0x01)	7-0	FrfRx(23:16)	rw	0xCB	MSB of the RX carrier frequency
RefFrfRxMid (0x02)	7-0	FrfRx(15:8)	rw	0x55	Middle byte of the RX carrier frequency
RefFrfRxLsb (0x03)	7-0	FrfRx(7:0)	rw	0x55	LSB of the RX carrier frequency $F_{RF} = F_{STEP} \times F_{rfxx}(23, 0)$ with a 36 MHz XO, value 0xCB5555 F_{rfRx} = 915 MHz and frequency resolution = 68.66455 Hz The RX RF frequency is updated only under the following conditions: - 36 MHz XO is active - RefFrfRxLsb is written - When exiting SLEEP mode
RegFrfTxMsb (0x04)	7-0	FrfTx(23:16)	rw	0xCB	MSB of the TX carrier frequency
RefFrfTxMid (0x05)	7-0	FrfTx(15:8)	rw	0x55	Middle byte of the TX carrier frequency
RefFrfTxLsb (0x06)	7-0	FrfTx(7:0)	rw	0x55	LSB of the TX carrier frequency $F_{RF} = F_{STEP} \times F_{rfxx}(23, 0)$ With a 36 MHz XO, value 0xCB5555 FrfTx = 915 MHz and frequency resolution = 68.66455 Hz The TX RF frequency is updated only under the following conditions: - 36 MHz XO is active - RefFrfTxLsb is written - when exiting SLEEP mode

5.4 Transmitter Front-End Configuration Registers

Table 5-4: Transmitter Front-End Configuration Registers

Name (Address)	Bits	Variable Name	Mode	Default Value	Description
RegTxGain (0x08)	7	-	r	0	Unused
	6-4	TxDacGain	rw	010	DAC gain, programmable in 3 dB steps: 000 = maximum gain - 9 dB 001 = maximum gain - 6 dB 010 = maximum gain - 3 dB 011 = maximum gain (0 dB full scale)
	3-0	TXMixerGain	rw	1110	Mixer gain, programmable in 2 dB steps *Gain ~ -38 +2 x Int(TxMixerGain(3,0))* in dB
RegTxBw (0x0A)	7	-	r	0	unused
	6-5	TxPllBw	rw	11	TX PLL bandwidth, programmable: 00 = 75 kHz 01 = 150 kHz 10 = 225 kHz 11 = 300 kHz
	4-0	TxAnaBw	rw	0000	TX analog filter bandwidth, programmable: $Bandwidth = \frac{17.5}{2 \times (41 - Int(TxBw(4,0)))}$ in MHz
RegTxDacBw (0x0B)	7-3	-	r	00000	unused
	2-0	TxDacBw	rw	010	Number of taps of TX FIR-DAC, programmable: $N = 24 + 8 \times Int(TxDacBw(2,0))$ where $N_{MAX} = 64$

5.5 Receiver Front-End Configuration Registers

Table 5-5: Receiver Front-End Configuration Registers

Name (Address)	Bits	Variable Name	Mode	Default Value	Description
RegRxAnaGain (0x0C)	7-5	RxLnaGain	rw	001	RX LNA gain setting: 000 = not used 001 = G1 = highest gain power - 0 dB 010 = G2 = highest gain power - 6 dB 011 = G3 = highest gain power - 12 dB 100 = G4 = highest gain power - 24 dB 101 = G5 = highest gain power - 36 dB 110 = G6 = highest gain power - 48 dB 111 = not used
	4-1	RxBaseband-Gain	rw	1111	RX Baseband amplifier gain, programmable: $Gain = Gain + 2 \times Int(RxBaseBandGain(4, 1))$
	1	LnaZin	rw	1	LNA input impedance 0 = 50 Ω 1 = 200 Ω
RegRxBw (0x0D)	7-5	RxAdcBw	rw	111	RX ADC BW, programmable: 010 = 100 kHz < RxAdcBw < 200 kHz 101 = 200 kHz < RxAdcBw < 400 kHz 111 = 400kHz < RxAdcBw
	4-2	RxAdcTrim	rw	111	RX ADC trim 32 MHz reference crystal: RxAdcTrim = 110 36 MHz reference crystal: RxAdcTrim = 101
	1-0	RxBase-bandBw	rw	01	Bandwidth of RX analog roofing filter, programmable: 00 = 750 kHz 01 = 500 kHz 10 = 375 kHz 11 = 250 kHz
RegRxPLLBw (0x0E)	7-3	-	r	0000	unused
	2-1	RxPllBw	rw	11	RX PLL bandwidth, programmable: 00 = 75 kHz 01 = 150 kHz 10 = 225 kHz 11 = 300 kHz
	0	RxAdcTemp	rw	0	RX ADC temperature measurement mode 0 = Disabled 1 = Enabled

5.6 DIO Mapping Configuration Registers

Table 5-6: DIO Mapping Configuration Registers

Name (Address)	Bits	Variable Name	Mode	Default Value	Description
RegDioMapping (0x0F)	7-6	Dio0Mapping	rw	00	Mapping of pins DIO0 to DIO3. See Table 4-1: "DIO Mapping" on page 28 for further information
	5-4	Dio1Mapping	rw	00	
	3-2	Dio2Mapping	rw	00	
	1-0	Dio3Mapping	rw	00	

5.7 Additional Parameter Configuration Registers

Table 5-7: Additional Parameter Configuration Registers

Name (Address)	Bits	Variable Name	Mode	Default Value	Description
RegClkSelect (0x10)	7-4	-	r	0000	unused
	3	DigitalLoopBack		0	Digital loop back enable 0 = Disabled 1 = Enabled
	2	RfLoopBack	rw	0	RF Loop back enable for RX analog gain calibration 0 = Disabled 1 = Enabled
	1	Clk_out	rw	1	CLK_OUT enable 0 = Disabled 1 = Enabled
	0	TxDacClkSelect	rw	0	Clock select for TX DAC 0 = Internal clock (XTAL) 1 = External clock (CLK_IN)
RegModeStatus (0x11)	7-3	-	r	00000	unused
	2	LowBatEnable	rw	0	LowBat detect flag 0 = VBAT > LowBat threshold 1 = VBAT < LowBat threshold (low battery)
	1	PllLockRx	r	0	Asserted when RX PLL locked
	0	PlllLockTx	r	0	Asserted when TX PLL locked

Table 5-7: Additional Parameter Configuration Registers

Name (Address)	Bits	Variable Name	Mode	Default Value	Description
RegLowBatThres (0x1A)	7-3	-	r	00000	unused
	2-0	LowBatThres	rw	010	LowBat Threshold 000 = 2.516 V 001 = 2.619 V 010 = 2.724 V 011 = 2.829 V 100 = 2.935 V 101 = 3.037 V 110 = 3.143 V 111 = 3.245 V

6. Application Information

6.1 Crystal Resonator Specification

The specification for the crystal resonator of the reference oscillator circuit block is tabulated below.

Table 6-1: Crystal Resonator Specification

Symbol	Description	Conditions	Min	Typ	Max	Unit
FXOSC	XTAL Frequency	-	32	-	36	MHz
RS	XTAL Series Resistance	-	-	30	140	Ω
C0	XTAL Shunt Capacitance	-	-	2.8	7	pF
CLOAD	External Foot Capacitance	On each pin XTA and XTB	8	16	22	pF

Notes:

- **The initial frequency tolerance, temperature stability and ageing performance should be chosen in accordance with the target operating temperature range and the receiver bandwidth selected**
- **The loading capacitance should be applied externally and adapted to the actual Crystal Cload specification**

6.2 Reset of the Chip

A power-on reset of the SX1257 is automatically triggered at power up. Additionally, a manual reset can be issued by controlling the RESET pin (pin 9).

6.2.1 POR

If the application requires the disconnection of VDD from the SX1257, despite the extremely low Sleep Mode current, the user should wait for 10 ms from of the end of the POR cycle before commencing communications over the SPI bus. Pin 9 (RESET) should be left floating during the POR sequence.

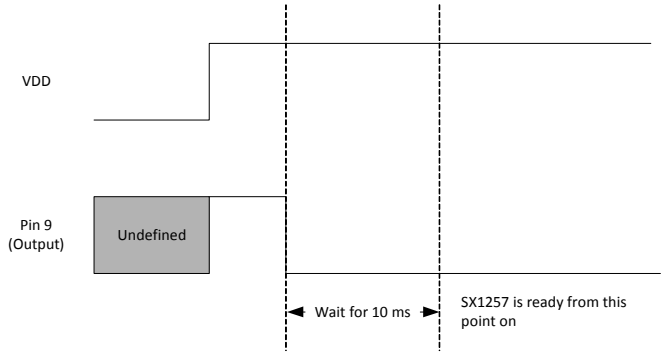


Figure 6-1: POR Timing Diagram

Note that CLK_OUT activity can be used to detect that the chip is ready.

6.2.2 Manual Reset

A manual reset of the SX1257 is possible even for applications in which VDD cannot be physically disconnected. Pin 9 should be pulled high for a hundred microseconds, and then released. The user should then wait for 5 ms before using the chip.

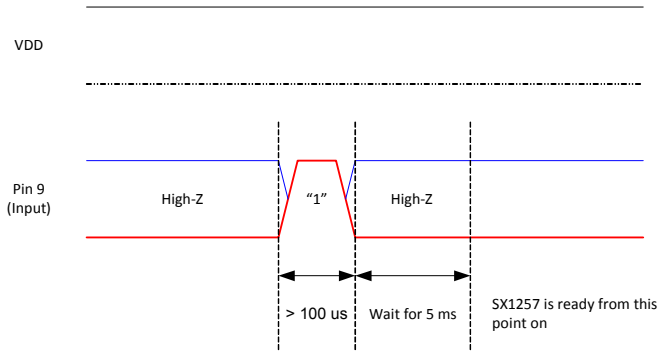


Figure 6-2: Manual Reset Timing Diagram

Note that whilst pin 9 is driven high, an over current consumption of 10 mA may be observed on VDD.

6.2.3 TX Noise Shaper

In order to generate a single TX bit-stream, th 8-bit I and Q signal should be processed by an external third order sigma-delta modulator (implemented within the baseband processor). The noise shaper should be stable for input signals lower than -3dBFS and compatible with SX1257 noise requirements. It is advised that the integrator outputs are saturated to avoid any wraparound of the 2's-complement digital word.

A representative block diagram of a single-bit feed-forward modulator is illustrated below.

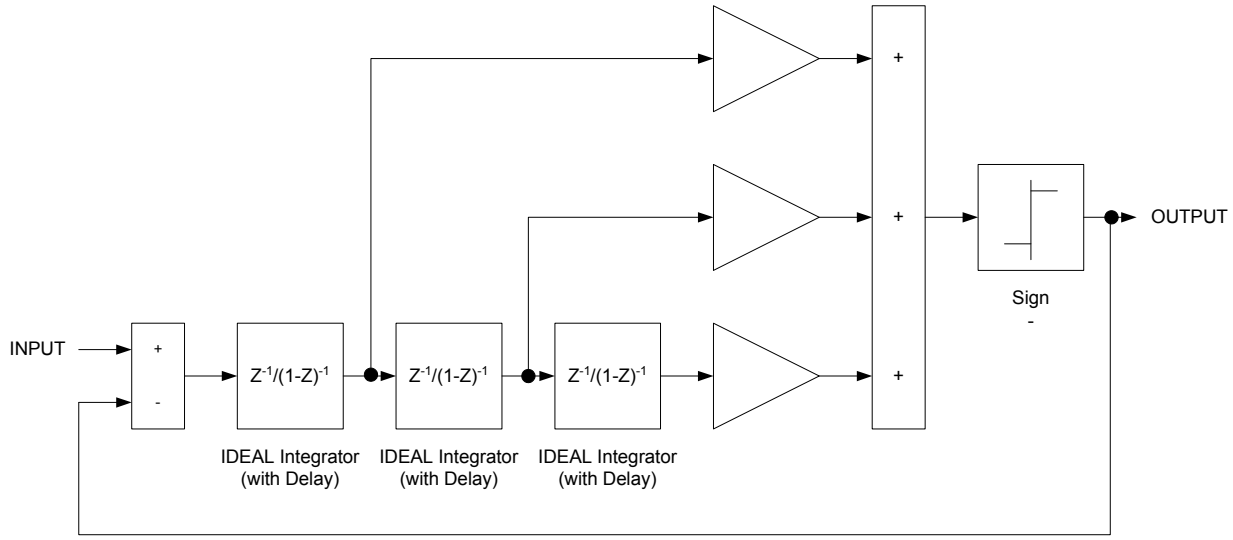


Figure 6-3: Example of a Digital Modulator Implementation

6.3 Application Schematics

Please contact your Semtech representative for evaluation tools, reference designs and design assistance. Note that all schematics shown in this section are full schematics, listing ALL required components, including those required for power supply decoupling.

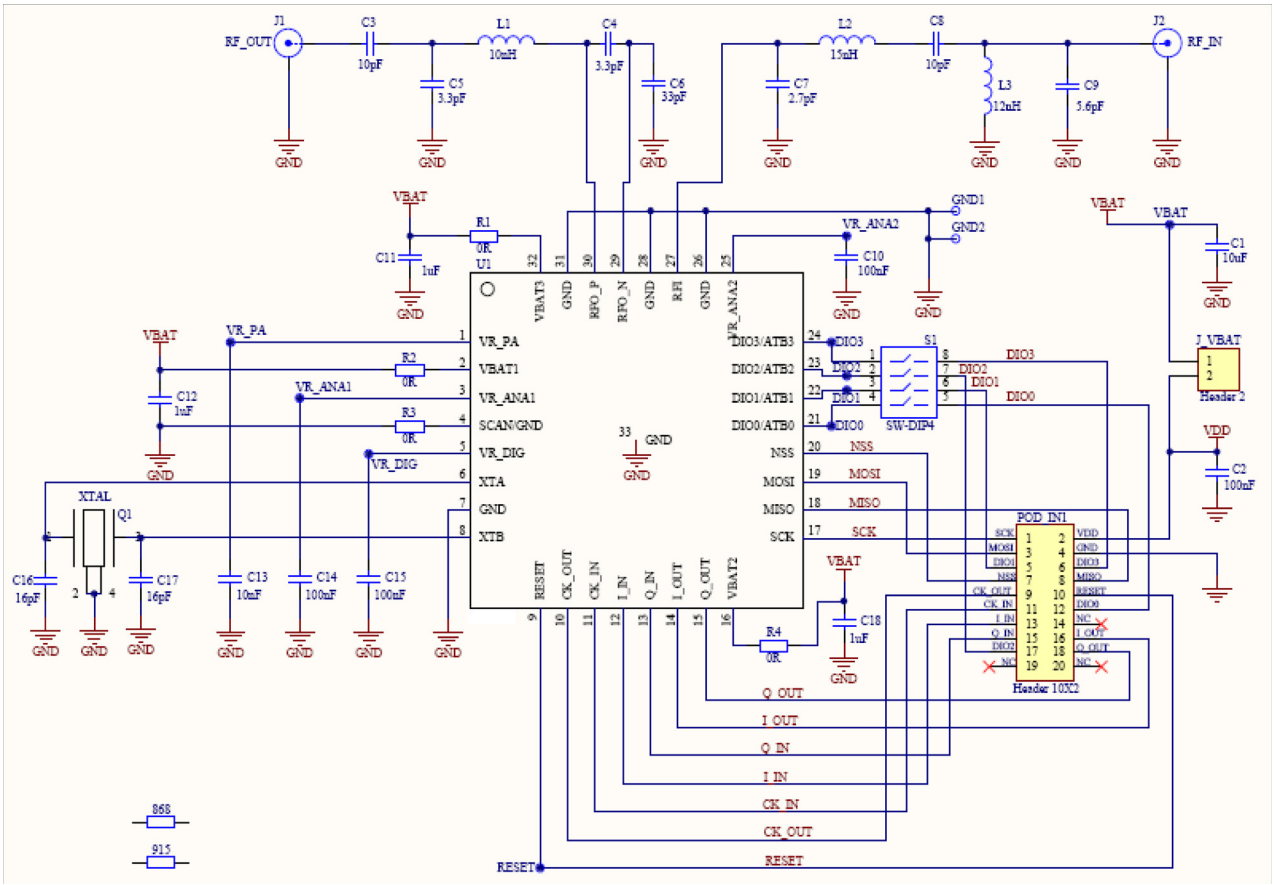


Figure 6-4: Application Schematic of the SX1257

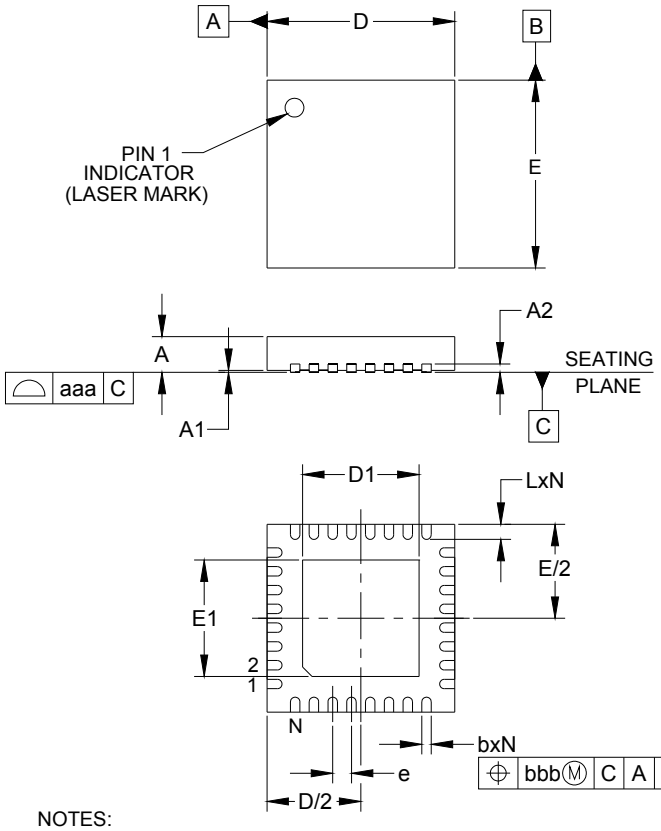
Note:

The application schematic presented here is for information only.

Always refer to the latest reference designs posted on *www.semtech.com*.

7. Packaging Information

7.1 Package Outline Drawing



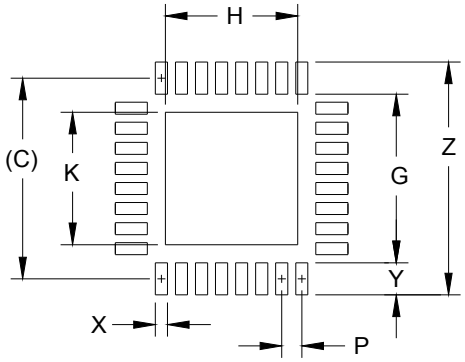
DIMENSIONS						
DIM	INCHES			MILLIMETERS		
	MIN	NOM	MAX	MIN	NOM	MAX
A	.028	.030	.031	0.70	0.75	0.80
A1	.000	-	.002	0.00	-	0.05
A2	-	(.008)	-	-	(0.20)	-
b	.008	.010	.012	0.18	0.25	0.30
D	.193	.197	.201	4.90	5.00	5.10
D1	.118	.122	.126	3.00	3.10	3.20
E	.193	.197	.201	4.90	5.00	5.10
E1	.118	.122	.126	3.00	3.10	3.20
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.

Figure 7-1: Package Outline Drawing

7.2 Recommended Land Pattern



DIMENSIONS		
DIM	INCHES	MILLIMETERS
C	(.193)	(4.90)
G	.161	4.10
H	.130	3.30
K	.130	3.30
P	.020	0.50
X	.012	0.30
Y	.031	0.80
Z	.224	5.70

NOTES:

1. CONTROLLING DIMENSIONS ARE IN MILLIMETERS (ANGLES IN DEGREES).
2. THIS LAND PATTERN IS FOR REFERENCE PURPOSES ONLY.
   CONSULT YOUR MANUFACTURING GROUP TO ENSURE YOUR
   COMPANY'S MANUFACTURING GUIDELINES ARE MET.
3. 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.
4. SQUARE PACKAGE-DIMENSIONS APPLY IN BOTH X AND Y DIRECTIONS.

Figure 7-2: Recommended Land Pattern

7.3 Package Marking

Figure 7-3: SX1257 Marking Diagram

Notes:

- yyww refers to the data code
- xxxxxx refers to the lot number

7.4 Thermal Impedance

The thermal impedance of this package is: **Theta ja = 23.8° C/W typ**., calculated from a package in still air, on a 4-layer FR4 JEDEC PCB.

7.5 Tape and Reel Specification

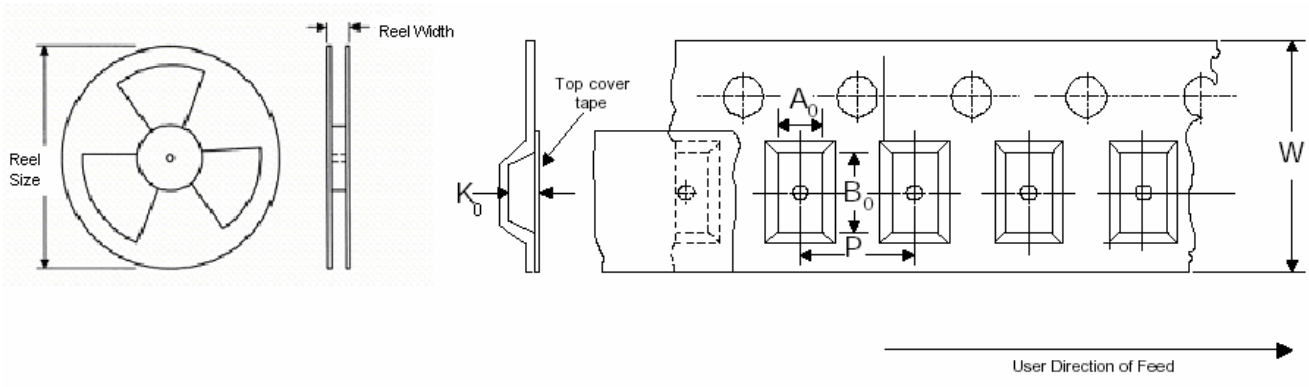


Figure 7-4: Tape and Reel Specification

Table 7-1: Tape and Reel Specification

Carrier Tape (mm)				Reel (mm)				
Tape Width (W)	**Pocket Pitch (P)**	**A_O / B_O**	**K_O**	**Reel Size**	**Reel Width**	**Min. Trailer Length (mm)**	**Min. Leader Length (mm)**	**QTY per Reel**
12 +/- 0.30	8 +/- 0.20	5.25 +/- 0.20	1.10 +/- 0.10	330.2	12.4	400	400	3000

Note: Single sprocket holes

Contact Information

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