

# AN1200.19

## SX127x Reference Design Overview

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## 1 Introduction

This purpose of this document is to assist the engineer with both the selection of the optimum reference design module and the associated development tool for the SX127x family of LoRa™ long-range, ultra-low power transceivers, and providing information relating to circuit optimization for single antenna port OEM designs.

It is recommended that this application note is read in conjunction with the following documents:

1. SX1272 Datasheet
2. SX1276 Datasheet
3. SX1272 Document and Resources Design Pack:
4. SX1276 Document and Resources Design Pack:
5. SX1232 Datasheet:
6. SX1232 Documentation and Resources Design Pack:
7. Semtech Application Note AN1200.6, "SX1232 LNA and PA Impedance Matching Techniques"

## LoRa™ Modulation

LoRa™, Semtech's proprietary modulation is a spread-spectrum technique that uses wideband linear frequency modulated pulses to encode information, whose frequency increases or decreases over a certain amount of time.

As with other spread-spectrum modulation techniques LoRa™ uses the entire channel bandwidth to broadcast a signal, making it robust to channel noise. In addition, because LoRa modulation uses a broad band of the spectrum it is also resistant to long term relative frequency error, multi-path, fading and Doppler effects.

## 2 Semtech LoRa Module Reference Designs

### 2.1 SX1272

The SX1272RF1xAS reference design module schematic is illustrated below in Figure 1. From the schematic it can be observed that the split RX/TX path as referenced in the specification section of the datasheet [1] has been employed.

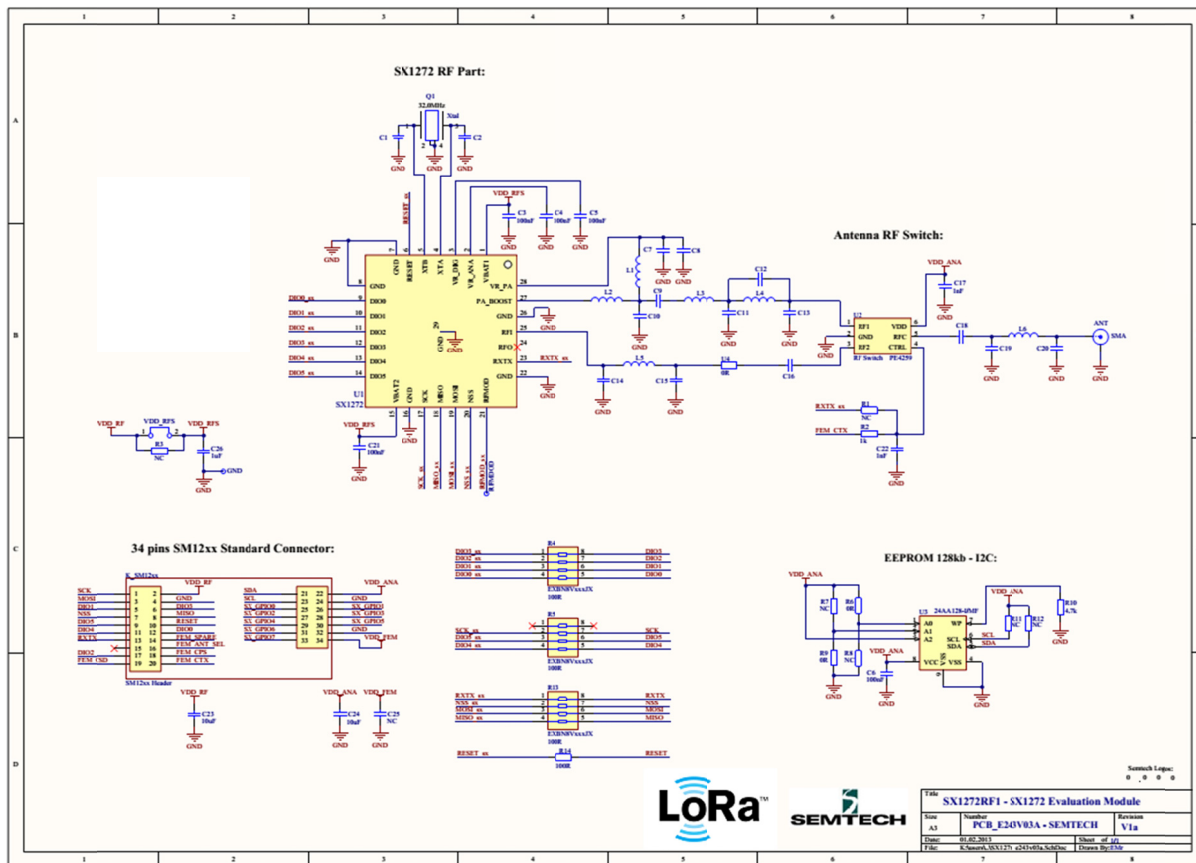


Figure 1: SX1272RF1 Evaluation Module

The split path approach allows for the receiver RFI port to be optimized for sensitivity rather than employing the combined high-efficiency transmitter RFO / RFI lumped-element matching single path network of the SX1232. The high-power PA Boost transmitter port is employed with this design, enabling transmitted output power up to +20 dBm. Note that the high-efficiency RFO port is left open-circuit on this design implementation.

Port combination to a single antenna port is achieved via the single control line RF switch. While the reference module is intended to interface with the appropriate Semtech SX127x Development Kit and

thus the switch control line is via a separate control port, by open-circuiting R2 and placing a 1k resistor at R1, the RF switch may be controlled via the RXTX pin of the SX1272 (Pin 23.)

## 2.2 SX1276

There are three versions of the SX1276 reference design module and these are summarized below:

1. SX1276RF1IAS: 169 MHz / 868 – 915 MHz
2. SX1276RF1JAS: 433 MHz / 868 – 915 MHz
3. SX1276RF1KAS: 470 – 490 MHz / 868 – 915 MHz

All SX1276RF1xAS reference module designs employ the split RX / TX path architecture to ensure optimum performance of both the transmitter and receiver [2].

### 2.2.1 SX1276RF1IAS

The SX1276RF1IAS 169 MHz / 868 – 915 MHz reference design module schematic is illustrated below in Figure 2.

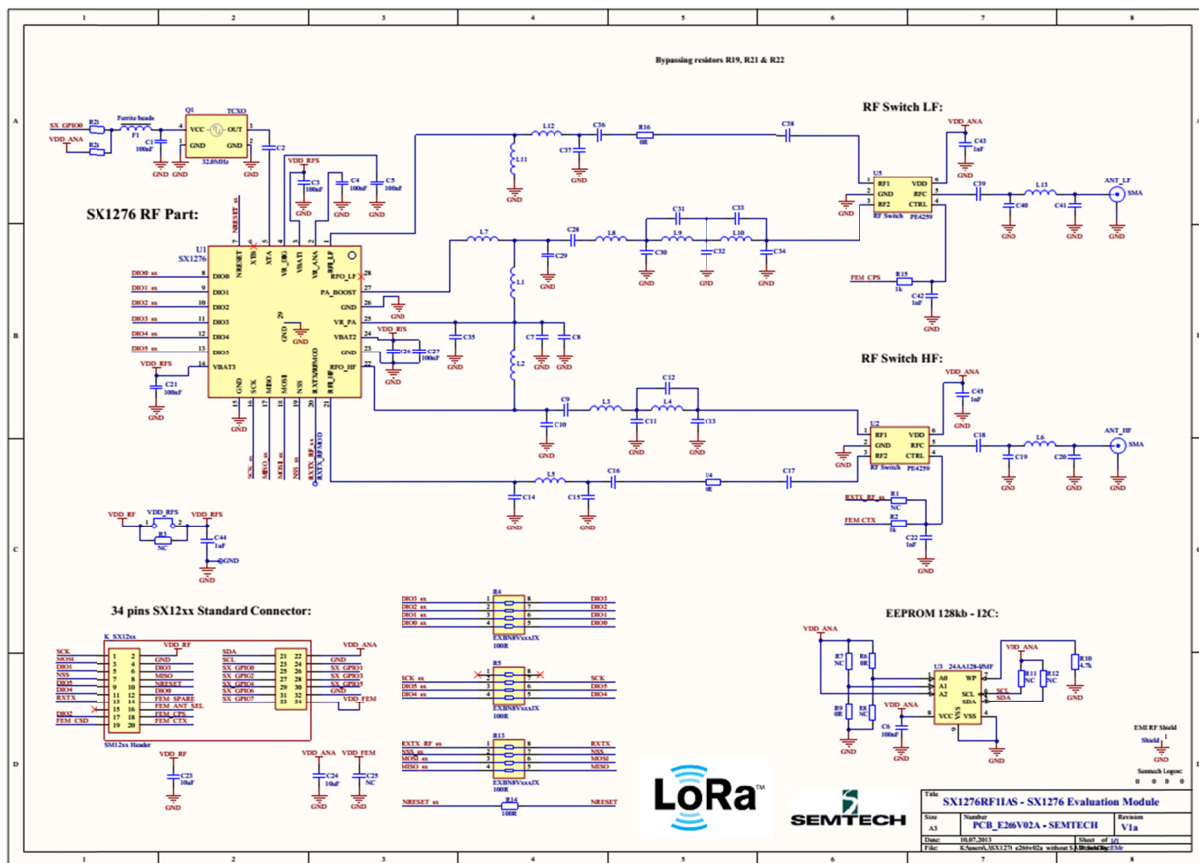


Figure 2: SX1276RF1IAS 169 MHz / 868 – 915 MHz Dual-Band Reference Design

The 868 – 915 MHz band is configured using RFI\_HF and RFO\_HF, while the 169 MHz band utilizes PA\_Boost and RFI\_LF. Note that the RFO\_LF pin is not connected.

This reference design configuration is primarily targeted for ETSI / EU applications. The high-power transmitter PA\_Boost is optimized for the 169 MHz band to take advantage of the 500 mW ERP power limit available in this band. RFO\_HF is optimized for 868 MHz – 915 MHz. The +14 dBm output power available at this port is suitable for the 25 mW ERP permitted in the majority of the European 863 – 870 MHz band as well as the proposed g2, g2.1, g3 and g3.1 band extensions (870 – 876 MHz and 915 – 921 MHz)

### 2.2.2 SX1276RF1JAS

The SX1276RF1JAS 433 MHz / 868 – 915 MHz reference design module schematic is illustrated below in Figure 3:

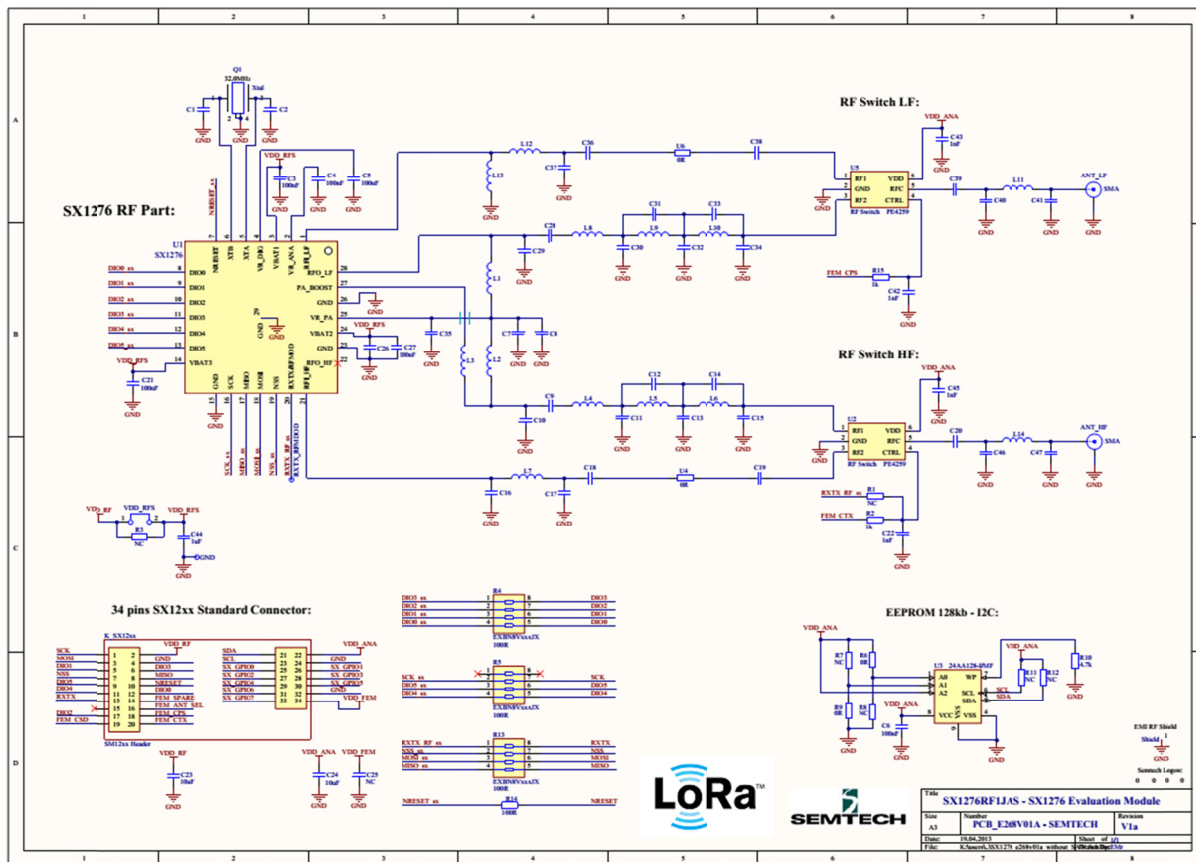


Figure 3: SX1276RF1JAS 433 MHz / 868 – 915 MHz Dual-Band Reference Design

The 433 MHz band is configured with RFI\_LF and RFI\_LF. The high-efficiency transmitter is ideally suited to meet the maximum ERP limits prescribed by both ETSI and the FCC, even when antenna efficiency is reduced due to size constraints.

The 868 / 915 MHz band is configured with PA\_Boost and RFI\_HF. Note that the RFO\_LF pin is not connected.

This reference design module configuration is intended primarily for the North American 902 – 928 MHz ISM band. The high power transmitter available at the PA\_Boost pin can deliver up to +20 dBm output power. The reference design module can also be used to exploit the higher ERP limit available in the European g1.3 band (869.40 – 869.65 MHz) and is also suitable for the 100 mW ERP channels proposed for the European g3.1 band extension.

The high-efficiency, low-power RFO\_LF port is suitable for both the 433 MHz European ISM band as well FCC 15.231 and 15.240 applications, where low transmit power but long-range, robust links may be required.

### 2.2.3 SX1276RF1KAS

The SX1276RF1KAS 490 MHz / 915 MHz reference design module schematic is illustrated below in Figure 4:

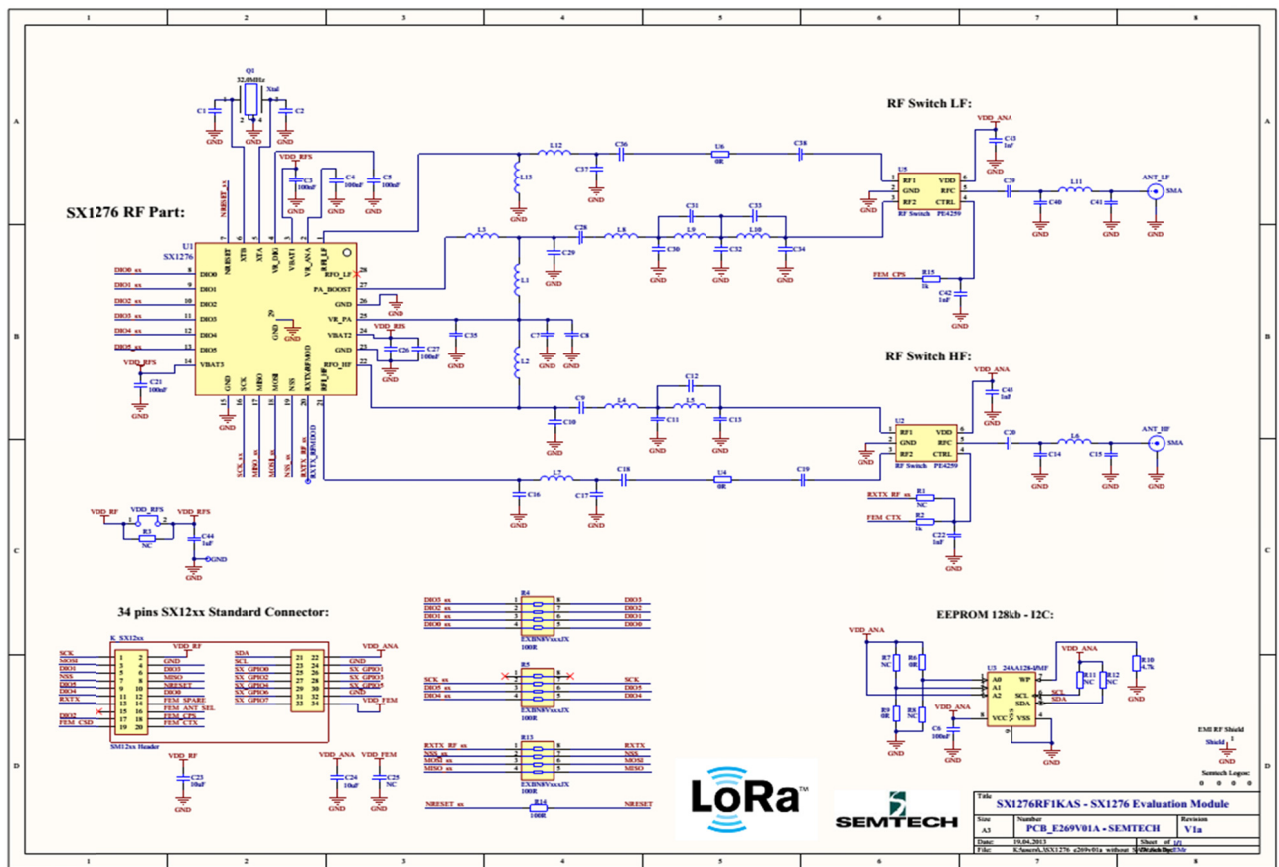


Figure 4: SX1276RF1KAS 490 MHz / 915 MHz Dual-Band Reference Design

The 490 MHz band is configured via PA\_Boost and RFI\_LF. Note that the RFO\_LF pin is left unconnected.

The 915 MHz band is configured via RFO\_HF and RFI\_HF.

This reference module is intended for applications the Chinese 470-510 MHz ISM band, where the high-power PA\_Boost transmitter can output the 50 mW ERP allowed by regulations, even when the antenna efficiency is reduced due to the dimensions of an electrically short antenna. The reference module can also be used for applications in the North American 915 MHz and 920 MHz Japanese ISM band and is fully compliant with the requirements of ARIB Standard T108.

### 2.3 SX127x Reference Designs

The Semtech reference designs for both SX1272 and SX1276 can be downloaded from the product pages of the Semtech website [3, 4]. The reference designs are available in Gerber format or as Altium Design packages.

### 2.4 SX127x Development Kits

The following development kits are available for Semtech's SX127x family of LoRa™ long-range, ultra-low power transceivers:

#### 2.4.1 SX1272 / SX1273

- SX1272DVK1BAS (868 MHz)
- SX1272DVK1CAS (915 MHz)

#### 2.4.2 SX1276 / SX1277 / SX1278

- SX1276DVK1IAS (169 MHz / 868 MHz)
- SX1276DVK1JAS (433 MHz / 868 MHz)
- SX1276DVK1KAS (490 MHz / 915 MHz)

### 3 Design Optimization

#### 3.1 Single Path (Combined RFI / RFO)

Single path optimization allows the designer to remove the need for the RF switch through a lumped-element matching network between RFI and RFO pins.

##### 3.1.1 SX1272

The SX1272 single path RF design is identical to that of the SX1232 reference design [6], as the two devices share a similar front-end architecture.

The recommended schematic layout is illustrated below in Figure 5:

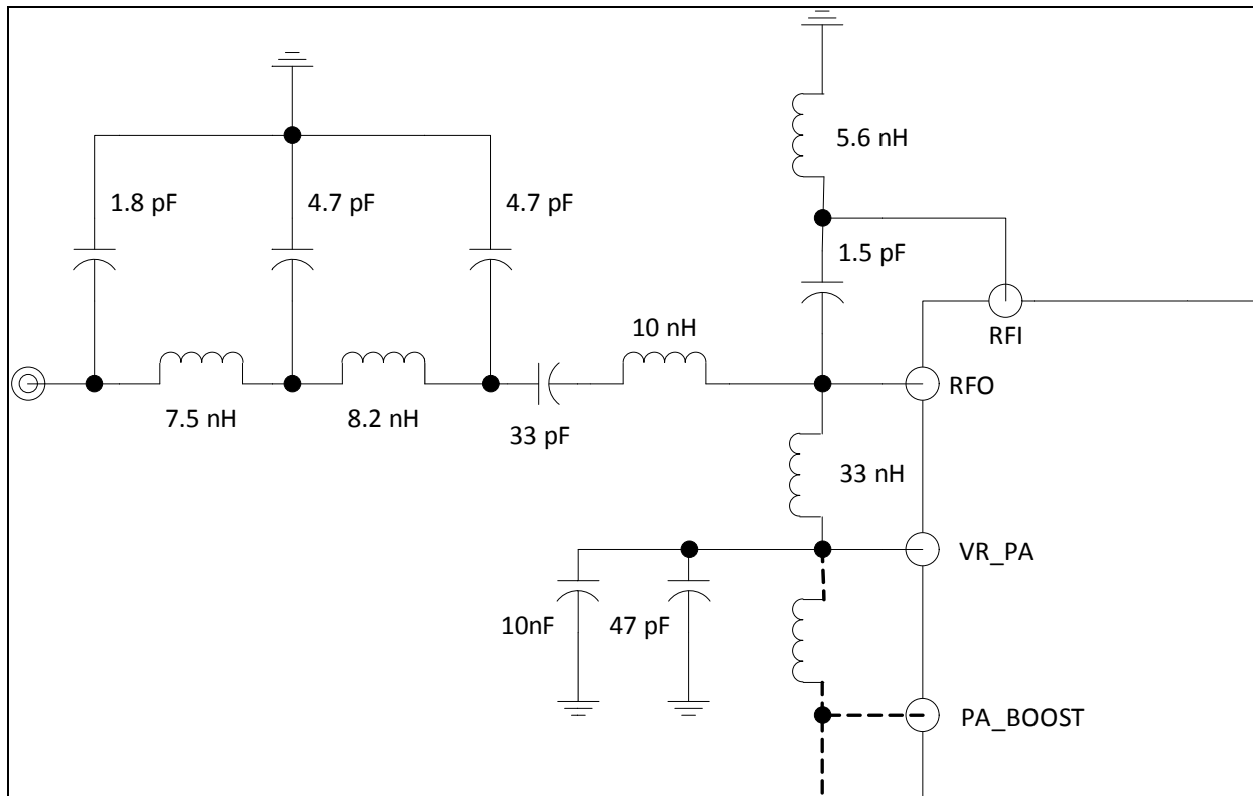


Figure 5: SX1272 Single RF\_IO Path Schematic

Note that it is recommended that PA\_Boost is not combined with the RFI port via a lumped-element matching network.



### 3.1.2 SX1276

The recommended SX1276 single path reference design is illustrated in Figure 6 and the corresponding BOMs for the three low-frequency bands in Table 1, below:

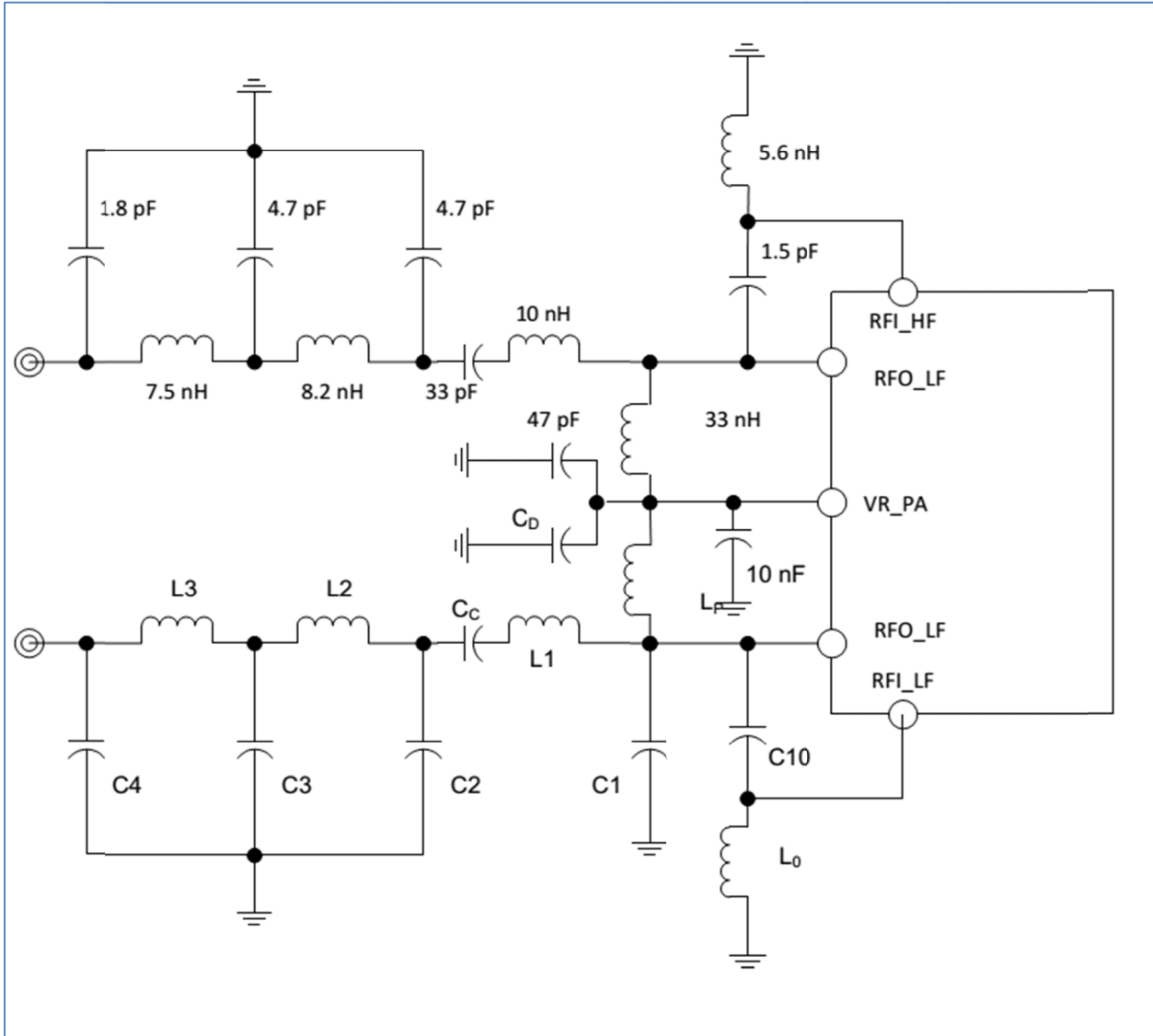


Figure 6: SX1276 Single RF\_IO Path Schematic

COMPONENT IDENTIFIER	FREQUENCY BAND	
	169 MHz	433 MHz
C <sub>C</sub>	220 pF	47 pF
C <sub>D</sub>	220 pF	100 pF
C1	15 pF	6.8 pF
C2	33 pF	15 pF
C3	33 pF	12 pF
C4	8.2 pF	4.7 pF
C10	5.6 pF	2.2 pF
L <sub>0</sub>	82 nH	18 nH
L <sub>P</sub>	100 nH	47 nH
L1	56 nH	22 nH
L2	47 nH	12 nH
L3	33 nH	18 nH

**Table 1: RF\_LF Matching Network BOM**

Again it is recommended that PA\_Boost is not combined with the RFI port via a lumped-element matching network.

### 3.2 Load-Pull and Matching

It may not be possible to replicate the topology and layout of the Semtech reference design due to design constraints or PCB stack definition. In this case the customer will require details of the optimum port impedances to enable both optimum noise matching for the receiver RFI ports and optimum load-impedance for the transmitter RFO and PA\_Boost ports.

Details of the matching network and recommended optimization procedure for SX1272, the high frequency RF ports (RFI\_HF and RFO\_HF) of the SX1276 as well as PA\_Boost when the high-frequency band is selected, can be found in [7].

This procedure can also be used for matching the SX1276 ports for operation in the lower-frequency bands. The optimum port impedances measured for the TX ports are tabulated below:

PORT	FREQUENCY (MHz)	Zopt (Ω)
RFO_LF	169	47.8 + j28.9
	434	65.2 – j1.7
	490	61.3 – j7.8
PA_Boost	169	13.2 + j6.7
	434	13.7 + j2,6
	490	14.0 + j1.1

Table 2: Optimum SX1276 Port impedance

## 4 References

- [1]. SX1272 Datasheet - <http://www.semtech.com/apps/filedown/down.php?file=sx1272.pdf>
- [2]. SX1276 Datasheet - <http://www.semtech.com/apps/filedown/down.php?file=sx1276.pdf>
- [3]. SX1272 Document and Resources Design Pack - <http://www.semtech.com/wireless-rf/rf-transceivers/sx1272/>
- [4]. SX1276 Document and Resources Design Pack - <http://www.semtech.com/wireless-rf/rf-transceivers/sx1276/>
- [5]. SX1232 Datasheet - <http://www.semtech.com/apps/filedown/down.php?file=sx1232.pdf>
- [6]. SX1232 Documentation and Resources Design Pack - <http://www.semtech.com/wireless-rf/rf-transceivers/sx1232/>
- [7]. Semtech Application Note AN1200.6, "SX1232 LNA and PA Impedance Matching Techniques" - [http://www.semtech.com/apps/filedown/down.php?file=AN1200-16\\_SX1232\\_API\\_RF\\_ST.pdf](http://www.semtech.com/apps/filedown/down.php?file=AN1200-16_SX1232_API_RF_ST.pdf)

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