Nordic VLSI ASA

nRF904 RF and antenna layout **nAN900-03**

1. General

Gerber files for RF layouts have been made for Nordic VLSI's **nRF904** Single Chip 915MHz RF Transmitter [1]. A loop antenna for 915MHz has also been made available.

The Gerber files for each layout are compressed into the Zip archive format. The Zip archive files includes a file named **readme.wri** that must be read before importing the Gerber files into the PCB editor.

All described layouts should be fabricated on standard 1.6mm double-sided FR4 printed circuit board.

2. RF layout for nRF904

The RF layouts include all necessary circuitry to design the radio frequency part of a short range communication system based on **nRF904**. The transmitter data and control lines DIN, XO8, $\overline{\text{PWR\_DOWN}}$, and $\overline{\text{CLOCK}}$/ASK, are available at the perimeter of the RF layout and should be connected to the digital part of a customer's application. +3V and GND are also available at the perimeter of the RF layout. The +3V for the RF part of the application circuit should be filtered separately from the supply voltages of any digital circuitry. Star routing is strictly recommended from the +3V supply source to the RF, digital or other parts of the application circuit.

All RF layouts presented below are equal except for the antenna connection circuitry. Solutions for differential connection to loop antenna and single ended connection to 50Ω antenna are presented.

2.1. Differential connection to loop antenna

Figure 1 shows the schematics for RF layout with differential connection to a loop antenna. The PCB layout is shown in Figure 2. The loop antenna layout described in chapter 3 can easily be placed together with this RF layout. The connection points numbered 1, 2 and 3 on the loop antenna layout must be connected exactly to the corresponding connection points numbered 1, 2 and 3 on the RF layout.

The Gerber files Zip archive filename is **PCB_nRF904_diff.zip**.

The recommended external components are as given in Table 1.

Component	Description	Size	Value	Tolerance	Units
C1	NP0 ceramic chip capacitor (REXT pin decoupling)	0603	33		pF
C2	X7R ceramic chip capacitor (REXT pin decoupling)	0603	4.7		nF
C3	X7R ceramic chip capacitor (Supply decoupling)	0603	4.7		nF
C4	NP0 ceramic chip capacitor (Supply decoupling)	0603	33		pF
C5	NP0 ceramic chip capacitor (Supply decoupling)	0603	33		pF
C6	Tantalum chip capacitor (Supply decoupling)	3216	4.7		µF
C7	X7R ceramic chip capacitor (Data bit stream filter)	0603	680		pF
R1	0.1W chip resistor (Crystal oscillator bias)	0603	150		kΩ
R2	0.1W chip resistor (Transmitter power setting)	0603	56 1)		kΩ
R3	0.1W chip resistor (XO8 output level setting)	0603	15 2)		kΩ
R4	0.1W chip resistor (Data bit stream filter/Frequency deviation setting)	0603	22 3)		kΩ
R5	0.1W chip resistor (Data bit stream filter/Frequency deviation setting)	0603	3.9 4)		kΩ
X1	Crystal	-	14.2992	5)	MHz

Table 1 Recommended External Components.

1), 2), 3), 4), 5) See [1].

2.2. Single ended connection to 50Ω antenna by using a differential to single ended matching network

Figure 3 shows the schematics for RF layout with single ended connection to 50Ω antenna by using a differential to single ended matching network. The PCB layout is shown in Figure 4.

The antenna connection point should be as close as possible to the output of the matching network. If this is not possible of practical reasons, the PCB track between the output of the matching network and the antenna connection should be carried out as a 50Ω microstrip line. In such a case, the length of the microstrip line is limited to a few centimetres. For a standard FR4 printed circuit board with 1.54mm substrate thickness and relative dielectric constant $\varepsilon_r \approx 4.25$ at 915MHz, the width of the microstrip line should be 3mm.

The Gerber files Zip archive filename is **PCB_nRF904_single_netw.zip**.

The recommended external components are as given in Table 1, with addition of the components in the differential to single ended matching network as given in Table 2.

Component	Description	Size	Value	Tolerance	Units
C8	NP0 ceramic chip capacitor (Impedance matching)	0603	3.3	<±0.1	pF
C9	NP0 ceramic chip capacitor (Impedance matching)	0603	3.3	<±0.1	pF
R6	0.1W chip resistor (Impedance matching)	0603	1		kΩ
L1	Chip inductor, SRF>915 MHz 6) (Impedance matching)	0603	68	±5%	nH
L2	Chip inductor, SRF>915 MHz 7) (Impedance matching)	0603	15	±2%	nH

Table 2 Recommended components in the differential to single ended matching network

6), 7) See [1].

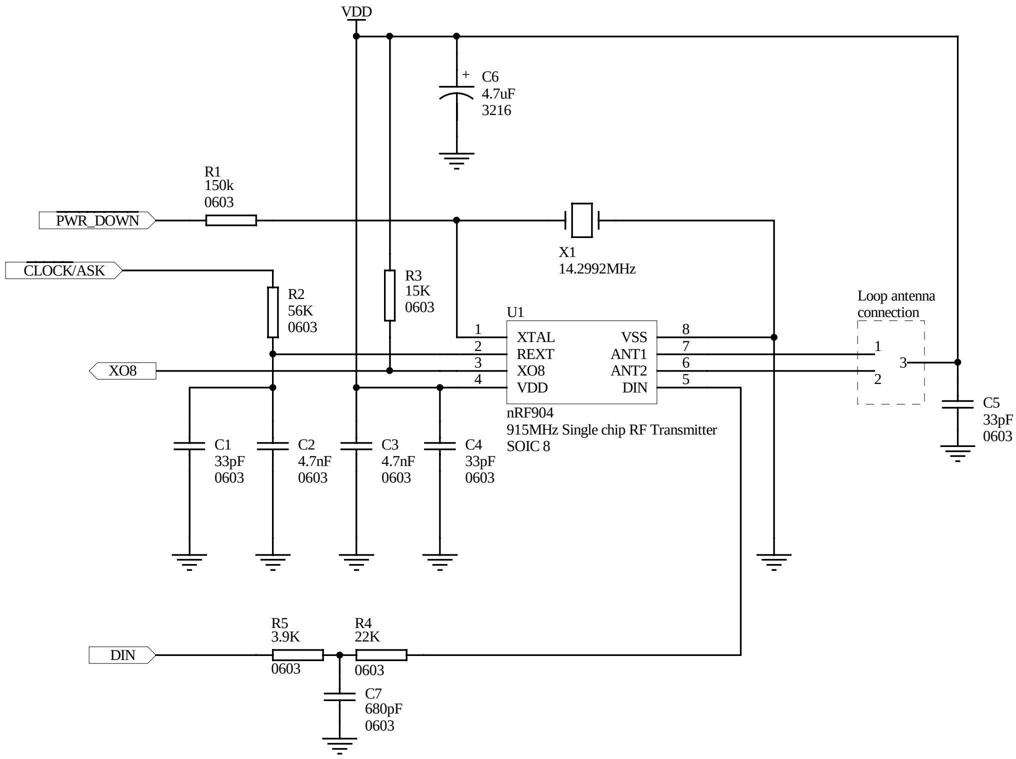
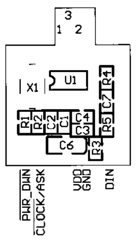
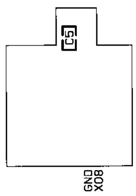


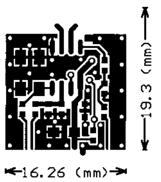
Figure 1. Schematics for RF layout with differential connection to a loop antenna



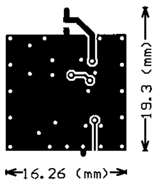
Top silk screen



Bottom silk screen



Top view



Bottom view

Figure 2. RF layout with differential connection to a loop antenna

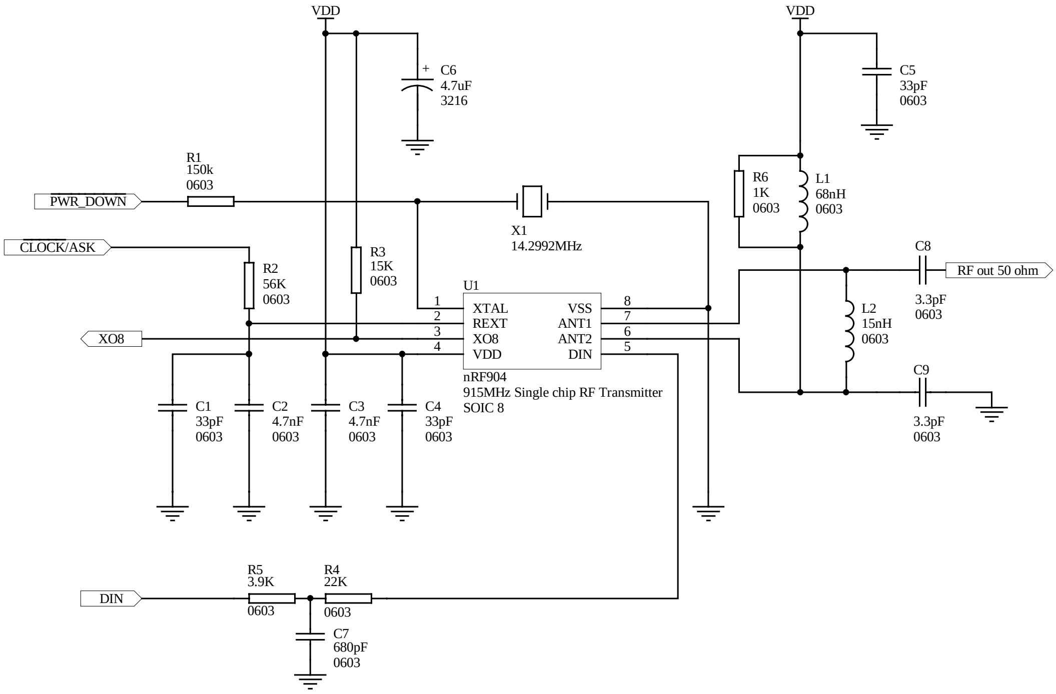
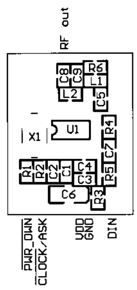
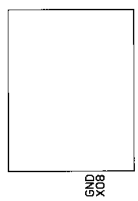


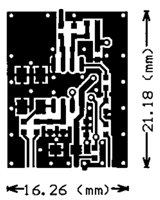
Figure 3. Schematics for RF layout with single ended connection to 50Ω antenna by using a differential to single ended matching network



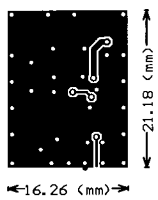
Top silk screen



Bottom silk screen



Top view



Bottom view

Figure 4. RF layout with single ended connection to 50Ω antenna by using a differential to single ended matching network

3. Loop antenna layouts

A loop antenna with T-match [2] is a good solution for low cost and small size radio modules. A layout solution for a small rectangular loop antenna is described below.

Figure 5 shows the basic geometry of the designed rectangular loop antenna.

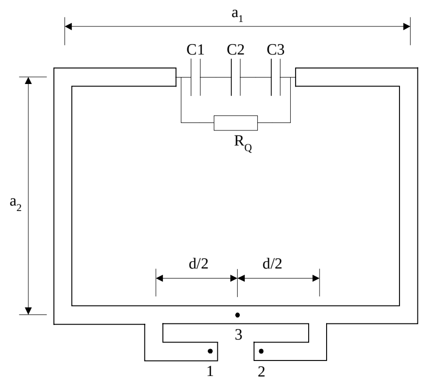


Figure 5. Geometry of rectangular loop antenna

The loop antenna physical parameters are

a_1 = loop antenna length [mm]
a_2 = loop antenna width [mm]
d = feed length [mm]
b = width of loop conductor

The antenna is tuned to a resonance frequency of 915MHz with chip capacitors *C1, C2* and *C3*.

To keep the variations in antenna gain due to capacitor variations lower than 3dB and thus achieve reproducible values of antenna gain in mass production, the total tuning capacitance tolerance should not exceed 5% (that is, ±2.5%). According to [2], the antenna should then be designed for a Q-value of about 40.

For the designed loop antenna, capacitors *C1, C2* and *C3* should have tolerances equal to or better than ±0.1pF. The resistor R_Q controls the *Q*-value of the antenna. The loop antenna is tuned to approximately 300Ω with a T-match. The width of the loop conductor is 1.524mm (60mil). There is no ground plane beneath the antenna.

Table 3 shows a summary of the designed loop antenna.

Loop antenna a_1 x a_2 [mm]	Feed length d [mm]	C1		C2		C3		R_O [8] [kΩ]	Q-value	Zo [Ω]
		Value [pF]	Tolerance [pF]	Value [pF]	Tolerance [pF]	Value [pF]	Tolerance [pF]			
9.5x9.5	13	3.3	±0.1	3.9	±0.1	6.8	±0.1	18	40	300

Table 3 Summary of the loop antenna

[8] Thick film chip resistor with resistance tolerance 5% or better.

The component values given in Table 3 are only valid when the connection points numbered 1, 2 and 3 on the loop antenna layout, as shown in Figure 6, are connected exactly to the corresponding connection points numbered 1, 2 and 3 on the RF layout with differential loop antenna connection. The component footprints used in the loop antenna layout are size 0603.

The layout of the rest of the communication system may influence the antenna tuning and require measurement of the antenna together with the complete system in order to find the values for C1, C2, C3 and R_Q for your system.

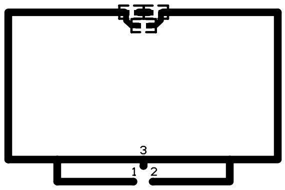


Figure 6. Loop antenna PCB layout (not actual size)

It is recommended that a system should not be designed with a longer communication range than the application requires. Estimations on communication range with the antenna presented in this application note and a receiver with a given sensitivity and antenna gain, can be made based on the theory given in [2]. Initial communication range tests should be carried out with the lowest RF output power setting that, based on the estimations, satisfies the range requirements. If the achieved communication range does not satisfy the requirements, the RF output power should be increased to the required level.

Table 4 lists the Gerber file Zip archive filename for the antenna layout.

Loop antenna a_1xa_2 [mm]	Gerber files Zip archive filename
9.5x9.5	Loop_9.5x9.5mm_915MHz.zip

Table 4 Gerber files Zip archive filenames

Measured loop antenna gain relative to λ/4 dipole antenna mounted on a 40x40cm ground plane is shown in Table 5.

Loop antenna a_1xa_2 [mm]	Gain relative to λ/4 dipole antenna [dB]
9.5x9.5	-15

Table 5 Measured loop antenna gain relative to λ/4 dipole antenna mounted on a 40x40cm ground plane

4. References

1. Product Specification **nRF904**, “Single Chip 915MHz Transmitter”,
   Nordic VLSI ASA.
2. Application note **nAN400-03**, “Small loop antennas”,
   Nordic VLSI ASA.

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