Nordic VLSI ASA

nRF401 RF and antenna layout **nAN400-05**

1. General

Gerber files for RF layouts have been made for Nordic VLSI's **nRF401** Single Chip 433MHz RF Transceiver [1]. Three different loop antennas for 433MHz have 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 nRF401

The RF layouts include all necessary circuitry to design the radio frequency part of a short range communication system based on **nRF401**. The transceiver data and control lines DIN, DOUT, TXEN, CS and PWR_UP 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 layouts 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 layouts should 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_nRF401_diff.zip**.

The recommended external components are as given in Table 1.

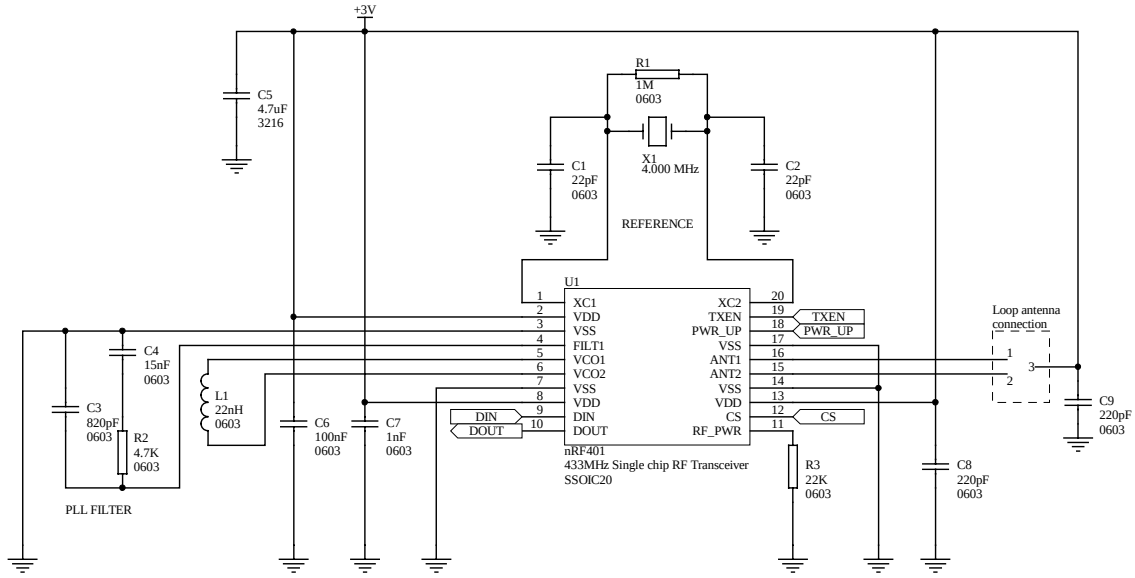
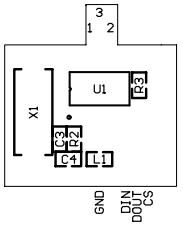
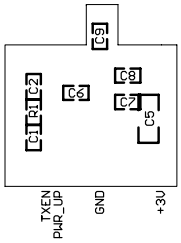


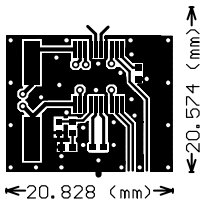
Figure 1. Schematics for RF layout with differential connection to a loop antenna



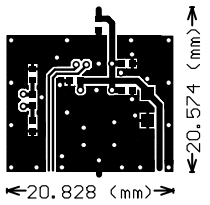
Top silk screen



Bottom silk screen



Top view



Bottom view

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

Component	Description	Size	Value	Tolerance	Units
C1	NP0 ceramic chip capacitor, (Crystal oscillator)	0603	22		pF
C2	NP0 ceramic chip capacitor, (Crystal oscillator)	0603	22		pF
C3	X7R ceramic chip capacitor, (PLL loop filter)	0603	820		pF
C4	X7R ceramic chip capacitor, (PLL loop filter)	0603	15		nF
C5	Tantalum chip capacitor, (Supply decoupling)	3216	4.7		µF
C6	X7R ceramic chip capacitor, (Supply decoupling)	0603	100		nF
C7	X7R ceramic chip capacitor, (Supply decoupling)	0603	1		nF
C8	NP0 ceramic chip capacitor, (Supply decoupling)	0603	220		pF
C9	NP0 ceramic chip capacitor, (Supply decoupling)	0603	220		pF
L1	VCO inductor, Q>45 @ 433 MHz	0603	22	±2%	nH
R1	0.1W chip resistor, (Crystal oscillator)	0603	1.0		MΩ
R2	0.1W chip resistor, (PLL loop filter)	0603	4.7		kΩ
R3	0.1W chip resistor, (Transmitter power setting)	0603	22[1)]		kΩ
X1	Crystal	-	4.000	[2)]	MHz

Table 1 External Component Specification.

[1)] See [1].
[2)] 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 the PCB track between the output of the matching network and the antenna connection point of practical reasons has to exceed about 3cm, this track should be carried out as a 50Ω microstrip line. For a standard FR4 printed circuit board with 1.54mm substrate thickness and relative dielectric constant $\varepsilon_r \approx 4.45$ at 433MHz, the width of the microstrip line should be 3mm.

The Gerber files Zip archive filename is **PCB_nRF401_single_netw-1_2.zip**.

The external component specifications 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
C10	NP0 ceramic chip capacitor, (Impedance matching)	0603	8.2	<±0.1	pF
C11	NP0 ceramic chip capacitor, (Impedance matching)	0603	8.2	<±0.1	pF
C12	NP0 ceramic chip capacitor, (Impedance matching)	0603	1.5	<±0.1	pF
C13	NP0 ceramic chip capacitor, (Impedance matching)	0603	220		pF
L2	Chip inductor, SRF>433 MHz (Impedance matching)	0603	22	±2%	nH
L3	Chip inductor, SRF>433 MHz (Impedance matching)	0603	22	±2%	nH
L4	Chip inductor, SRF>433 MHz (Impedance matching)	0603	22	±2%	nH

Table 2 Component specification for the differential to single ended matching network

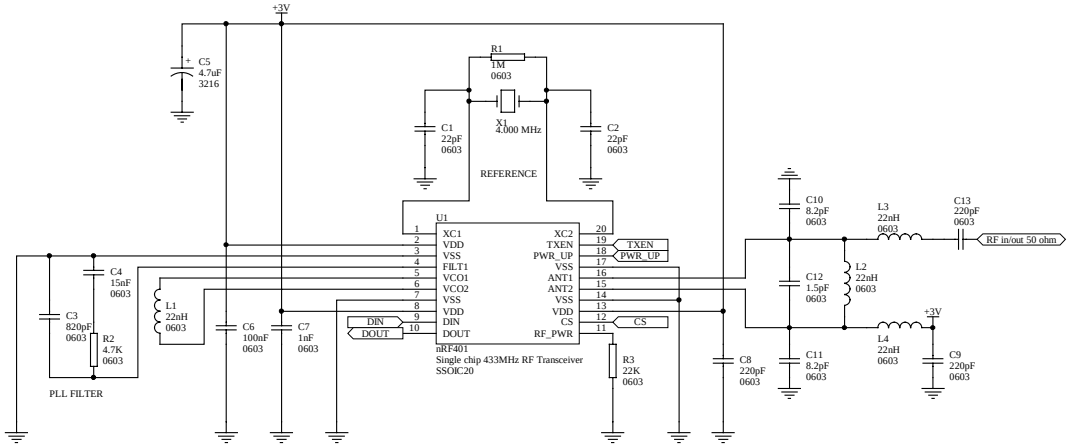
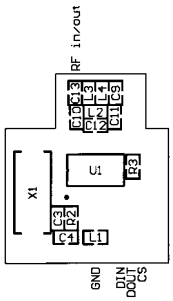
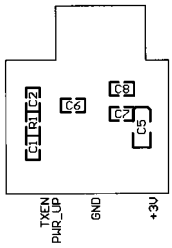


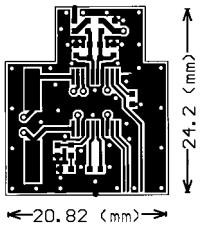
Figure 3. Schematics for RF layout with single ended connection to 50Ω antenna by using a differential to single ended matching network



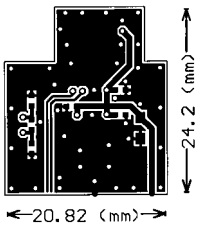
Top silk screen



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. Three different layout solutions for small rectangular loop antennas are described below.

Figure 5 shows the geometry of the designed rectangular loop antennas.

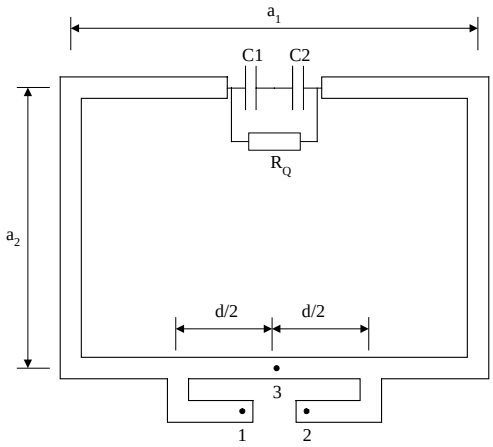


Figure 5. Geometry of rectangular loop antenna

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

Each antenna is tuned to a resonance frequency of 433MHz with chip capacitors *C1* and *C2*. For the designed loop antennas, these capacitors should have tolerances better then 5% (that is, ±2.5%). The resistor R_Q controls the *Q*-value of the antenna. All loop antennas are tuned to approximately 400Ω with a T-match. The width of the loop conductor for all of the loop antennas is 1mm. There is no ground plane beneath the antennas.

Table 3 shows a summary of the designed loop antennas.

Loop antenna a_1 x a_2 [mm]	Feed length d [mm]	C1		C2		R_Q [3)] [kΩ]	Q-value	Zo [Ω]
		Value [pF]	Tolerance [pF]	Value [pF]	Tolerance [pF]			
18x10	22	5.6	±0.1	10	±0.1	18	55	400
25x15	21.5	3.3	±0.1	5.6	±0.1	18	55	400
35x20	22.5	1.8	±0.1	4.7	±0.1	68	68	380

Table 3 Summary of the loop antennas

[3)] 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 layouts 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 and R_Q for your system.

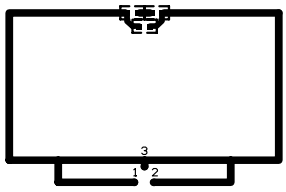


Figure 6. Loop antenna PCB layout (not actual size)

It is recommended that a system should not be designed with a longer communication range than the application requires. Estimations on communication range with combinations of antennas presented in this application note can be made based on the theory given in [2]. Initial communication range tests should be carried out with the combination of the smallest antennas that, based on the estimations, satisfies the range requirements. If the achieved communication range does not satisfy the requirements, one or both of the antennas in the communication link should be exchanged with a larger antenna.

Table 4 lists the Gerber files Zip archive filenames for the three antenna layouts.

Loop antenna a_1xa_2 [mm]	**Gerber files Zip archive filename**
18x10	Loop_18x10mm_400ohm.zip
25x15	Loop_25x15mm_400ohm.zip
35x20	Loop_35x20mm_400ohm.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]**
18x10	-19
25x15	-15
35x20	-11

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

4. References

1. Product Specification **nRF401**, “433MHz Single Chip RF Transceiver”, Nordic VLSI ASA.
2. Application note **nAN400-03**, “Small loop antennas”, Nordic VLSI ASA.

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