AN4111
Application note

BAL-NRF01D3 matched balun with integrated harmonics filter for Nordic Semiconductor ultralow power transceivers

Introduction

The nRF24LE1, nRF24AP2, nRF51422 and nRF51822 QFN from Nordic Semiconductor are 2.45 GHz combo chips with an ultralow power transceiver.

The BAL-NRF01D3 from STMicroelectronics is an ultra miniature balun for which the matching impedance has been customized for the nRF24LE1 QFN-32, nRF24AP2-1CH, nRF24AP2-8CH, nRF51422-QFAA, and nRF51822-QFAA Nordic Semiconductor circuits.

The BAL-NRF01D3 integrates matching network and harmonics filters. It uses STMicroelectronics' IPD technology on non-conductive glass substrate which optimizes RF performance.

Compared to traditional discrete solutions (*Figure 3*), STMicroelectronics BAL-NRF01D3 decreases the BOM count by 80%, from 5 components to 1 component (*Figure 4*). This results in a lower system cost solution.

The BAL-NRF01D3 has been tested and approved by Nordic Semiconductor in the nRF2723 nRFgo module (from the nRFgo nRF24LE1 QFN-32 pins development kit) and the nRF2752 nRFgo module (from the nRFgo nRF51x22 Developer Preview kit). The BAL-NRF01D3 demonstrates a higher system performance compared to traditional solutions. This document presents the test and performance results.

1 BAL-NRF01D3 preview

1.1 Features

- 50 Ω nominal input / conjugate match to Nordic Semiconductor chips nRF24LE1 QFN32, nRF24AP2-1CH, nRF24AP2-8CH, nRF51422-QFAA and nRF51822-QFAA
- Low insertion loss
- Low amplitude imbalance
- Low phase imbalance
- Small footprint: < 1.5 mm^2

Benefits

- Very low profile: < 595 µm after reflow
- High RF performance
- RF BOM and area reduction

Applications

- 2.45 GHz impedance matched balun filter
- Optimized for Nordic's chip set nRF24LE1/AP2 and nRF51 series

1.2 Description

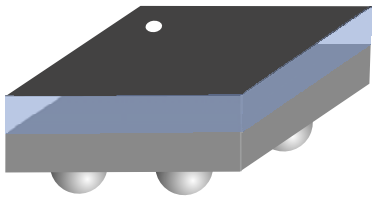
STMicroelectronics BAL-NRF01D3 is an ultra miniature balun. The BAL-NRF01D3 integrates matching network and harmonics filter. Matching impedance has been customized for the following Nordic Semiconductor circuits: nRF24LE1 QFN-32 pins, nRF24AP2-1CH, nRF24AP2-8CH, nRF51422-QFAA and nRF51822-QFAA.

The BAL-NRF01D3 uses STMicroelectronics IPD technology on non-conductive glass substrate which optimize RF performances.

The BAL-NRF01D3 has been tested and approved by Nordic Semiconductor in their nRF2723 and nRF2752 nRFgo modules.

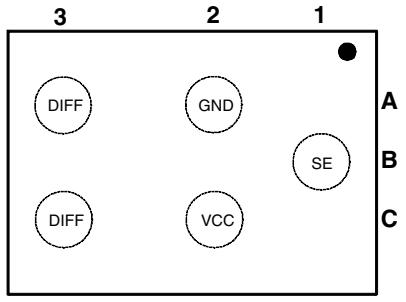
1.3 Flip chip package

Figure 1. Package 5 bumps



Lead-free Flip-Chip package
5 bumps

Figure 2. Pin out diagram (top view)



2 Benefits of BAL-NRF01D3 reference design

Figure 3. Traditional discrete solution for nRF24LE1

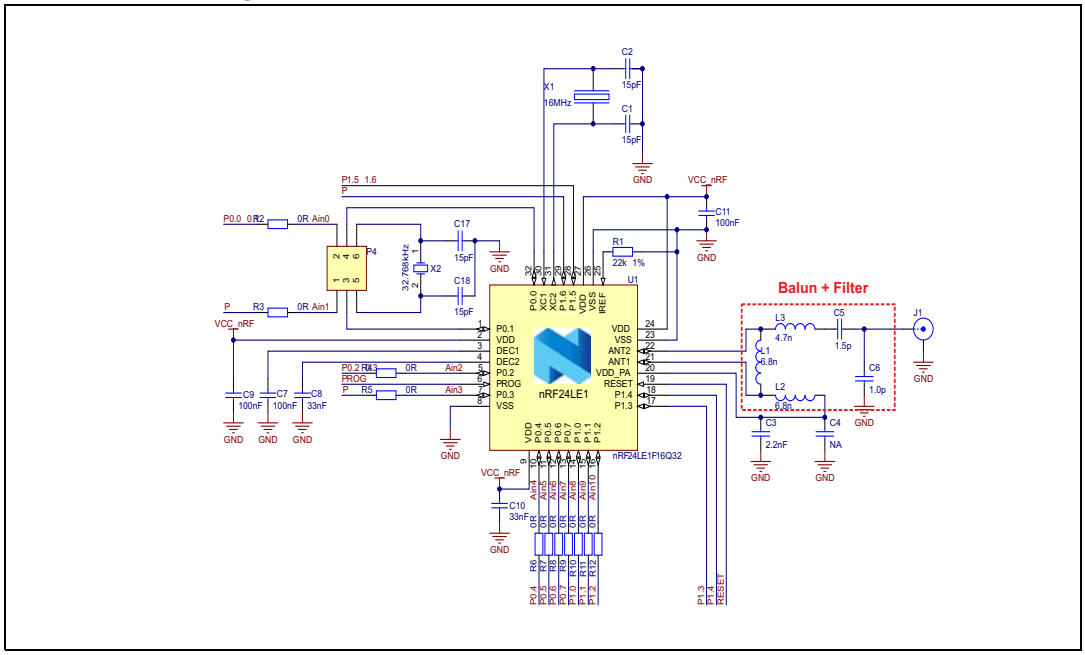
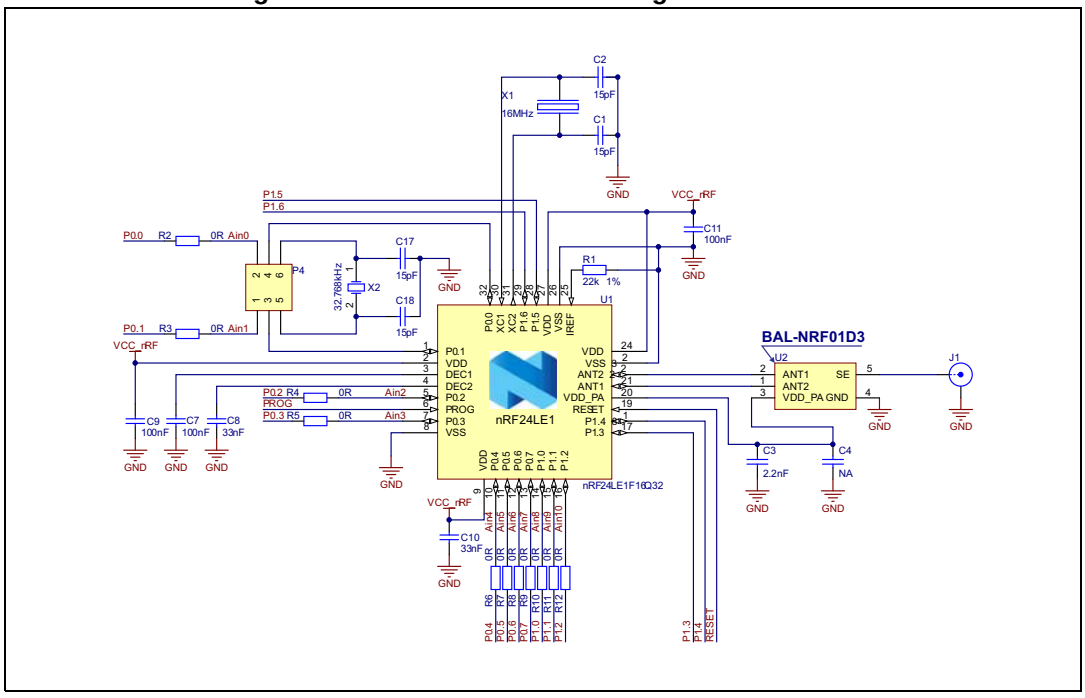


Figure 4. nRF24LE1 solution using BAL-NRF01D3



Using BAL-NRF01D3 **no external components** are required for matching and for harmonic filtering. Only a 2.2 nF external capacitor is required for V_{DD} decoupling. The test board for nRF24LE1 is shown in *Figure 8*.

Figure 5. Traditional discrete solution for nRF51822

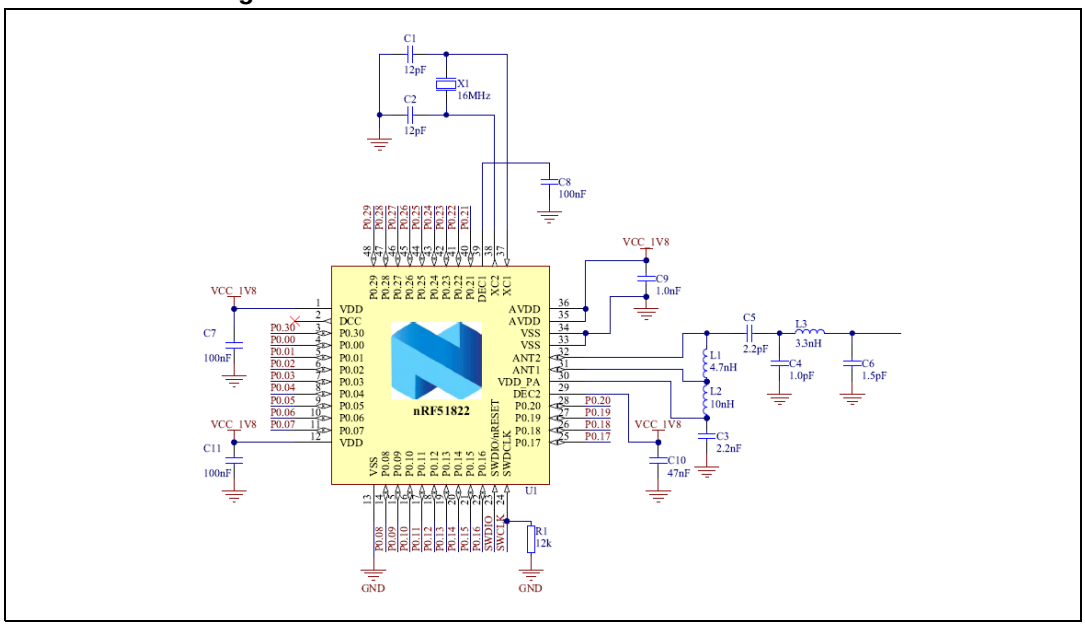
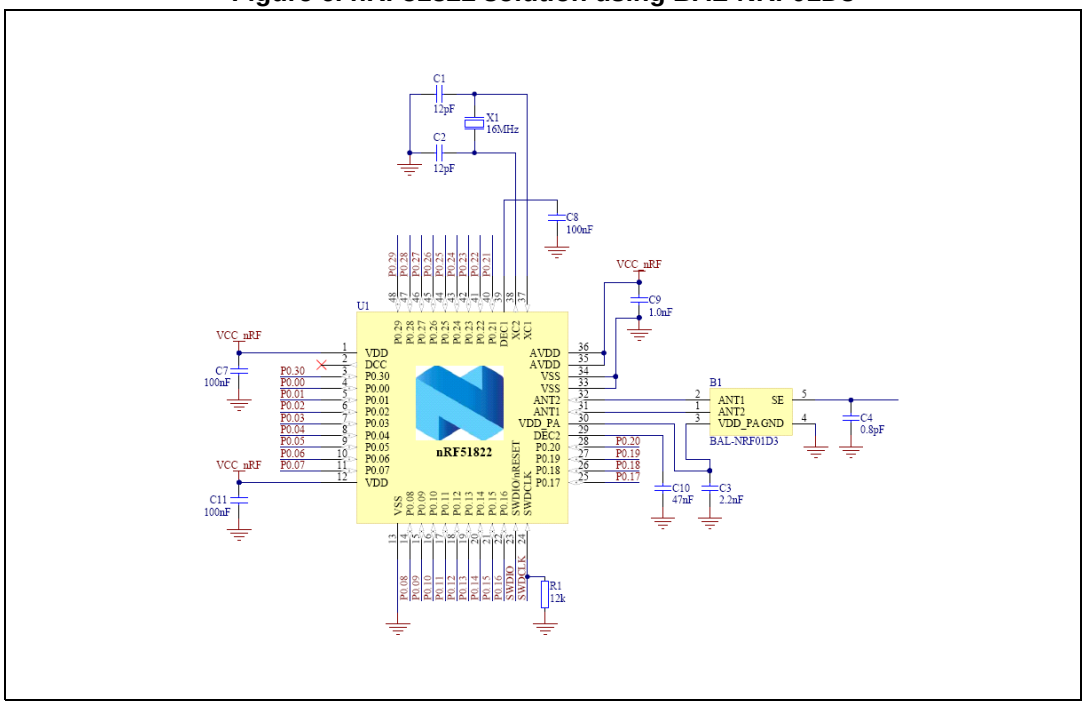


Figure 6. nRF51822 solution using BAL-NRF01D3

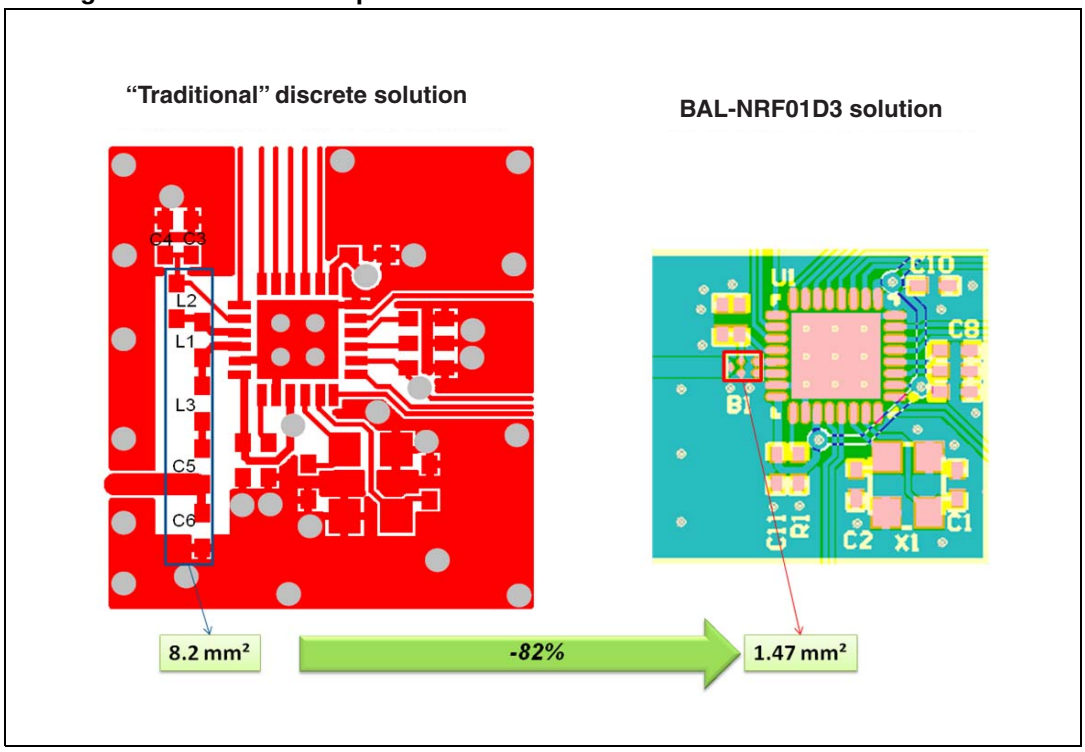


Using BAL-NRF01D3 only a 0.8 pF capacitor is needed for molding and for harmonic filtering. A 2.2 nF external capacitor is required for V_{DD} decoupling. The test board for nRF51822 is shown in *Figure 14*.

Figure 7 demonstrates two essential benefits of the BAL-NRF01D3.

- Decrease in the BOM count by 80%, from 5 components to 1 component
- More than 80% PCB area reduction compared to the traditional discrete solution

Figure 7. PCB area comparison between BAL-NRF01D3 and discrete solution



Compared to discrete solutions, the BAL-NRF01D3 solution is much easier to implement.

Thanks to this smart implementation:

- No RF measurement tools and RF skills are required to design and validate the function.
- Performance is less sensitive to component placement.
- PCB design is symmetrical from differential output to antenna, providing much shorter traces between transceiver outputs to the balun.

As a result, ST BAL-NRF01D3 reduces harmonics generation.

3 Measured performances

3.1 Nordic Semiconductor nRF2723 nRFgo module (nRF24xx)

Figure 8. nRF2723 ST balun reference nRFgo module from Nordic Semiconductor

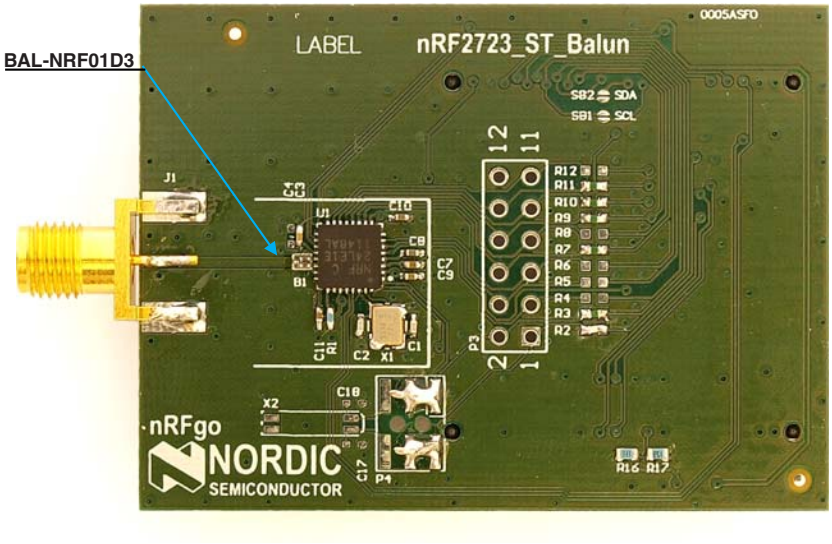
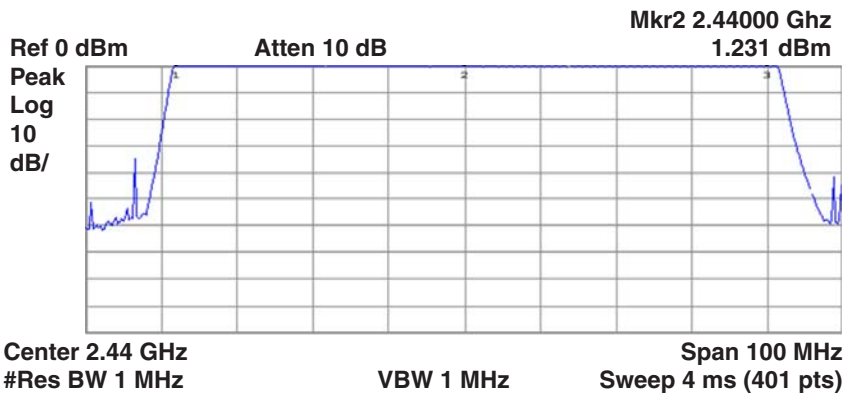


Table 1. Main parameter measurements (2402 to 2480 MHz)

Parameter	Values	Parameter	Values
PA_TX_FUND (-18 dBm)	-17.1	PA_TX_5H (0 dBm)	-53.7
PA_TX_FUND (-12 dBm)	-8.7	2LO (0 dBm)	-72.1
PA_TX_FUND (-6 dBm)	-3.0	LO (0 dBm)	-68.8
PA_TX_FUND (-0 dBm)	1.1	LO/2 (0 dBm)	-67.5
PA_TX_2H (0 dBm)	-39.1	LO/4 (0 dBm)	-79.1
PA_TX_3H (0 dBm)	-47.5	LO/8 (0 dBm)	-80.1
PA_TX_4H (0 dBm)	-47.5	Receiver sensitivity [dBm] @ 1 Mbps	-85.6

Figure 9. Output power carrier



Marker	Trace	Type	X Axis	Amplitude
1	(1)	Freq	2.40200 GHz	1.275 dBm
2	(1)	Freq	2.44000 GHZ	1.231 dBm
3	(1)	Freq	2.48000 GHz	0.934 dBm

Figure 10. Second harmonic

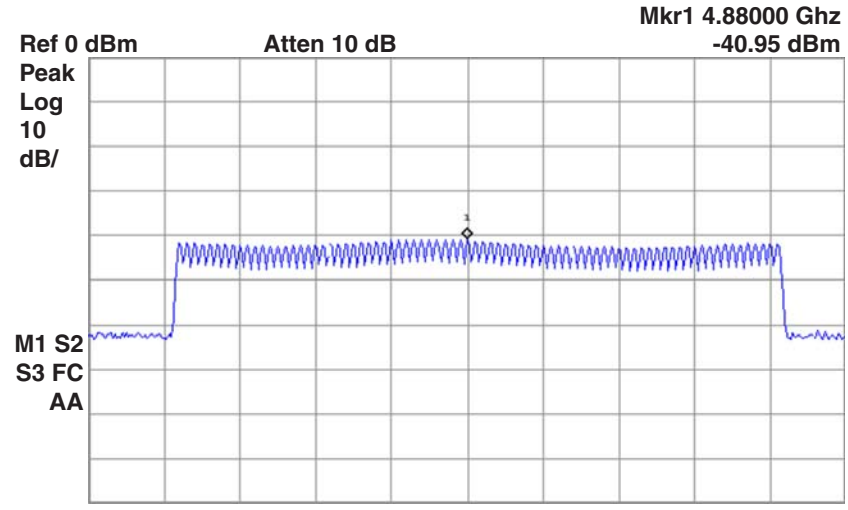


Figure 11. Third harmonic

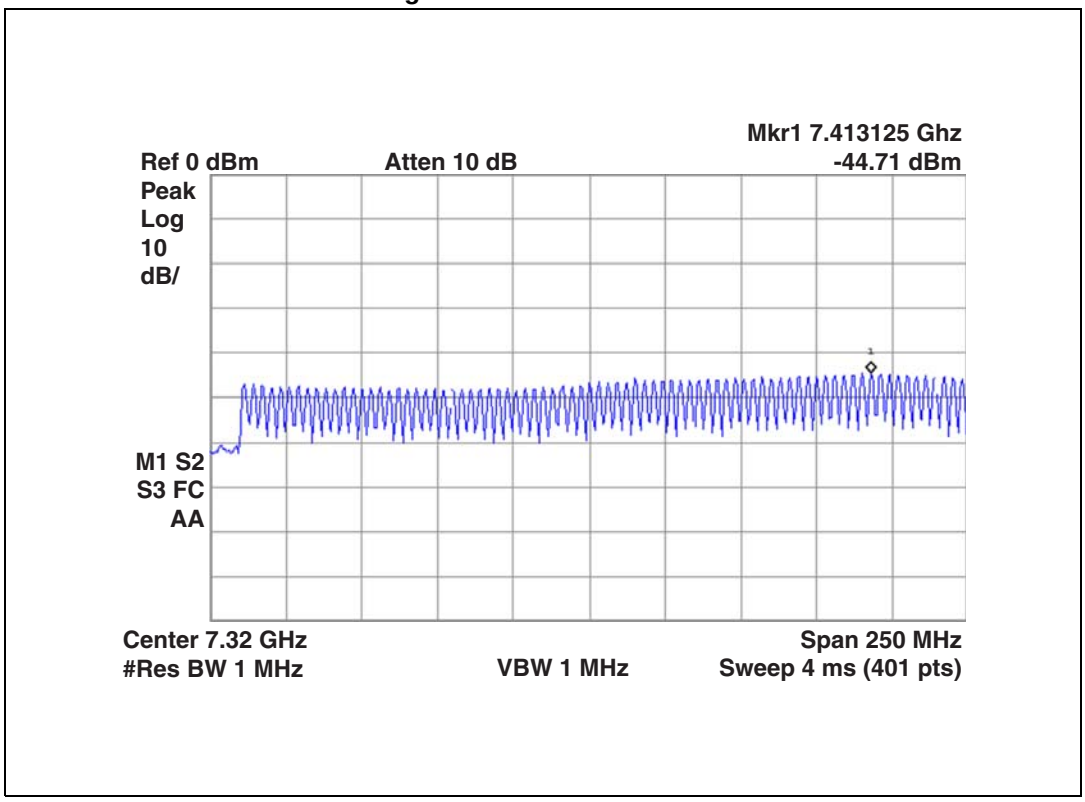


Figure 12. Fourth harmonic

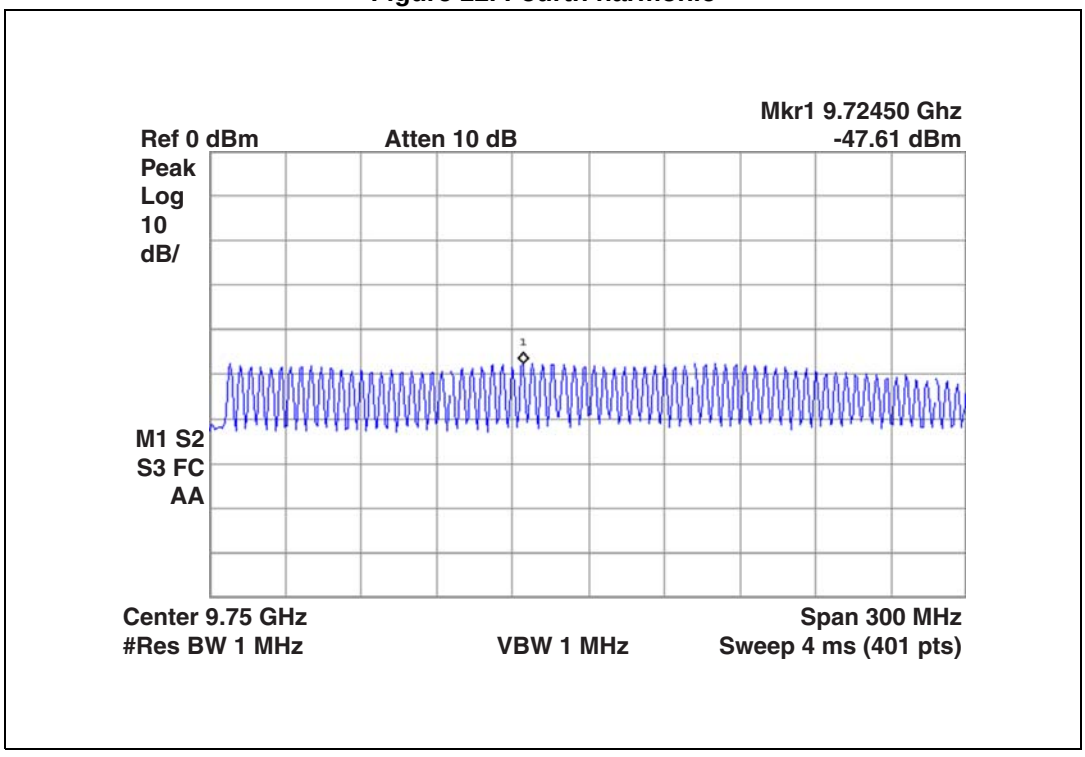
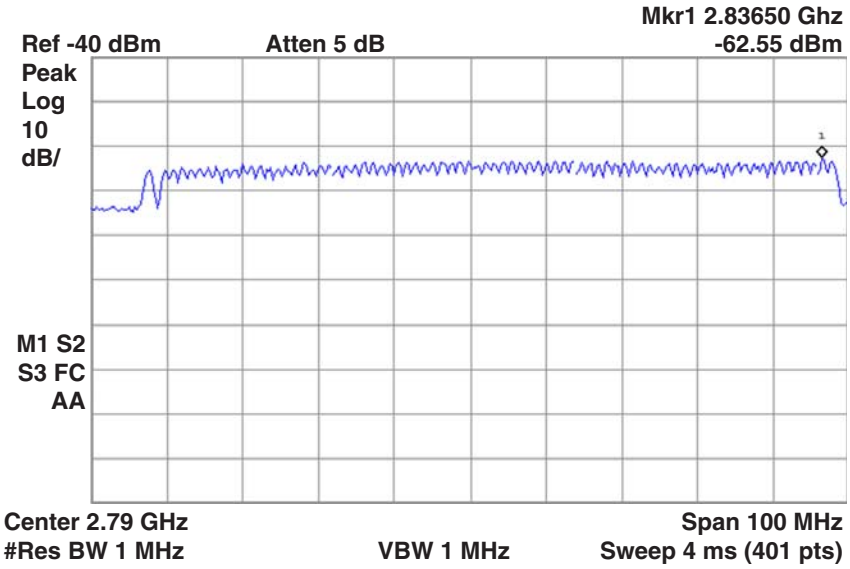


Figure 13. Receiver local oscillator leakage (RX_LO)



3.2 Nordic Semiconductor nRF2752 nRFgo module (nRF51xx)

The results presented in this section are based on measurements performed with the nRF51822 nRFgo module and the BAL-NRF01D3. The BAL-NRF01D3 balun offers high suppression of 2nd to 4th harmonics and simplifies implementation of nRF51822 as regards to FCC and ETSI compliance tests.

Figure 14. nRF2752 ST balun reference nRFgo module from Nordic Semiconductor

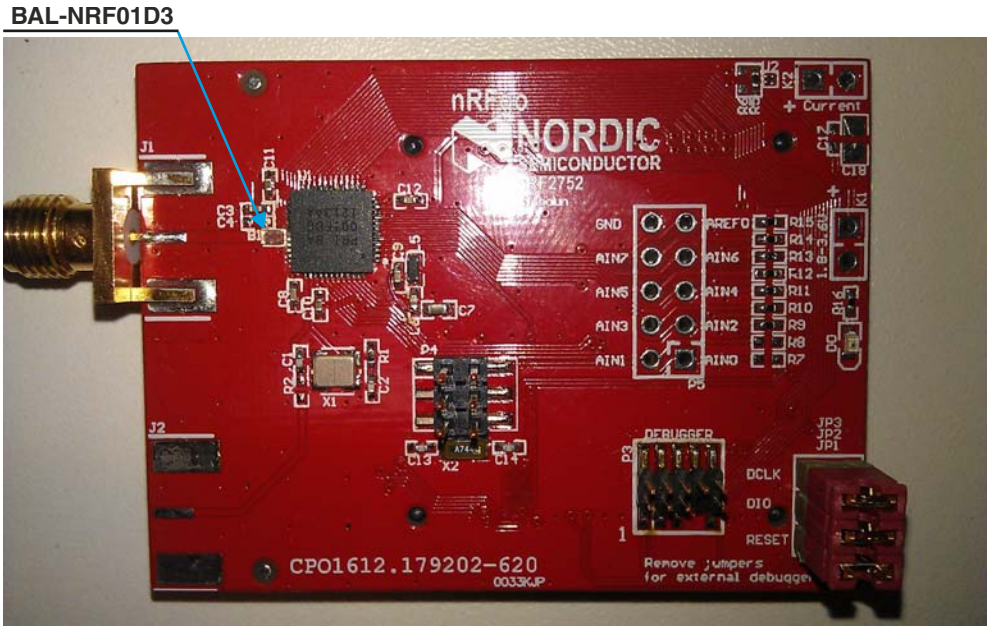


Table 2. Main parameter measurements (2402 to 2480 MHz)

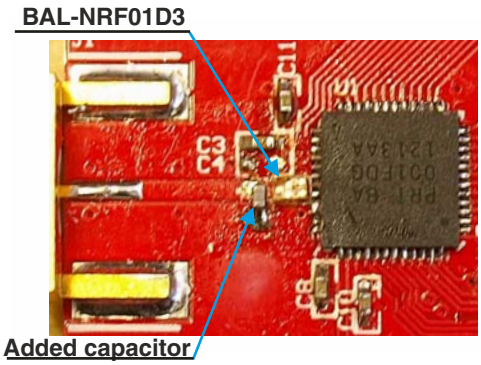
Parameter	Values	Parameter	Values
PA_TX_FUND (0 dBm)	1.3	PA_TX_4H (4 dBm)	-51.1
PA_TX_FUND (4 dBm)	4.5	PA_TX_5H (0 dBm)	-53.7
PA_TX_2H (0 dBm)	-36.8	PA_TX_5H (4 dBm)	-53.7
PA_TX_2H (4 dBm)	-42.8	2LO (0 dBm)	-59.8
PA_TX_3H (0 dBm)	-48.8	LO (0 dBm)	-61.6
PA_TX_3H (4 dBm)	-40.7	LO/2 (0 dBm)	-71.8
PA_TX_4H (0 dBm)	-50.7	Receiver sensitivity [dBm] @ 1 Mbps	-91.02

3.3 High power case

At high power output (4dBm mode), the optimal impedance changes slightly.

To optimize performance and output power on 4dBm mode, adding a 0.8 pF high Q capacitor on the single port of BAL-NRF01D3 is recommended. This capacitor leads to a 1 dB gain on 4 dBm mode without impacting the 0 dBm mode. This capacitor must be added as close as possible to the single port of the BAL-NRF01D3 (see *Section 3.5: Layout recommendations for nRF51xxx*) and must be connected to ground. See *Figure 15*.

Figure 15. Capacitor placement for high power case



3.4 Layout recommendations for nRF24LE1

Figure 16. PCB overview

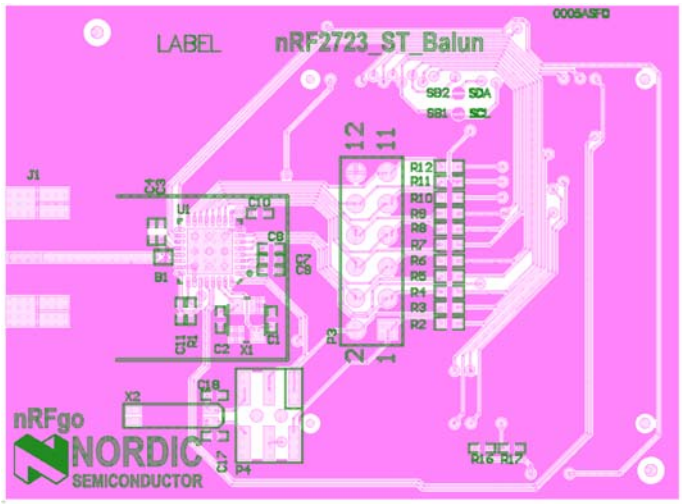


Figure 17. nRF24LE1 exposed pads

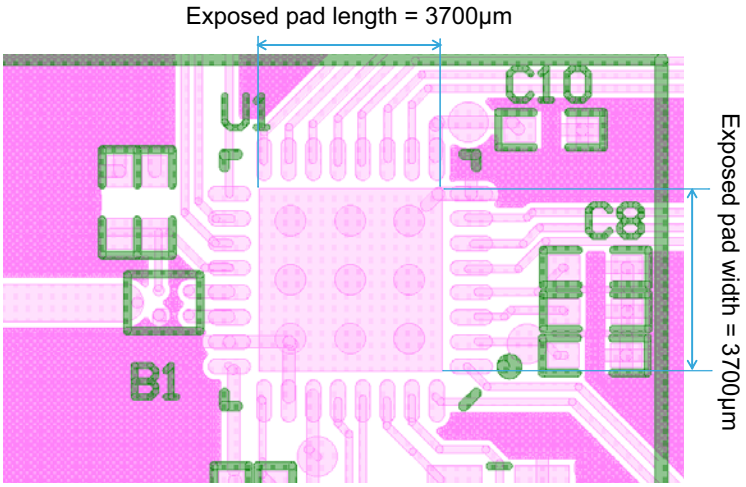


Figure 18. nRF24LE1 land pattern metrics

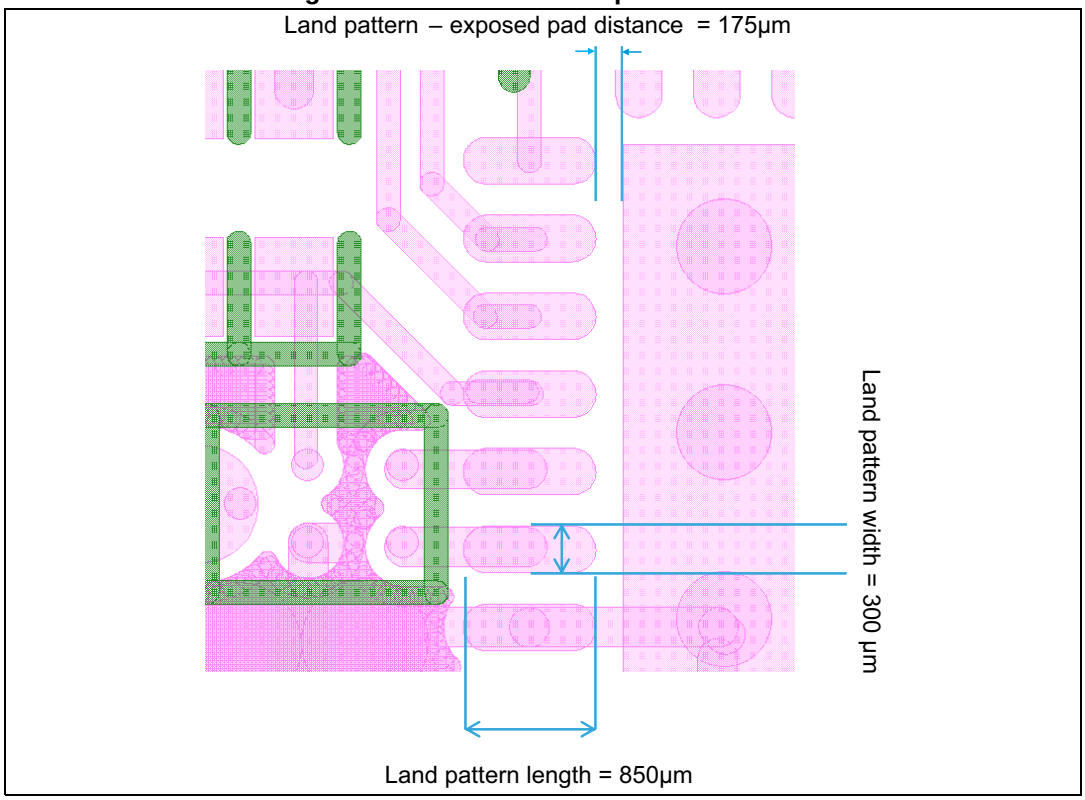
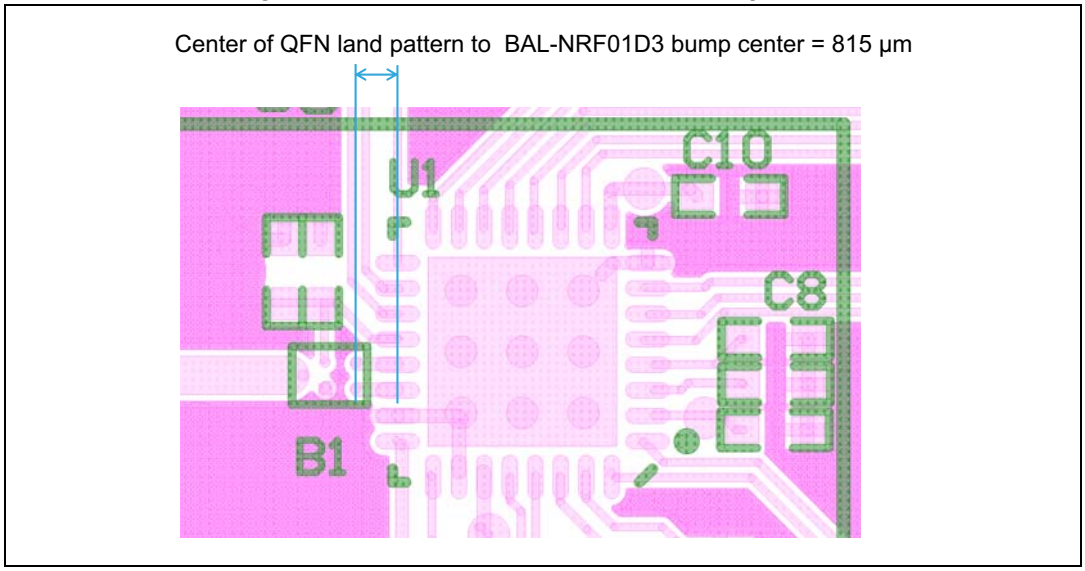


Figure 19. nRF24LE1 and BAL-NRF01D3 position



3.5 Layout recommendations for nRF51xxx

Figure 20. nRF51xxx exposed pad dimensions

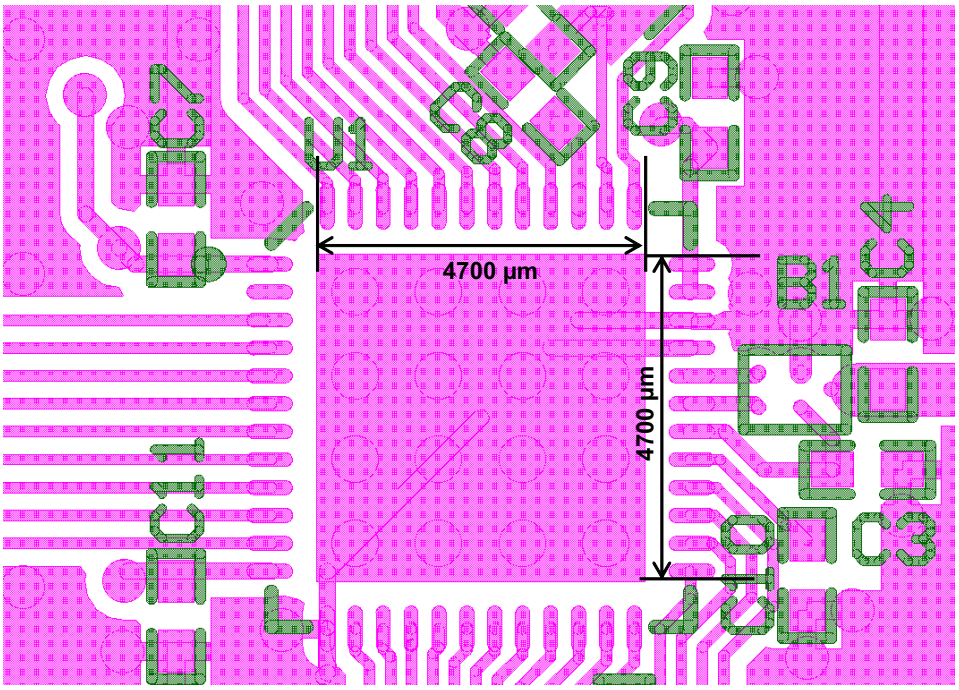


Figure 21. nRF51xxx land pattern metrics

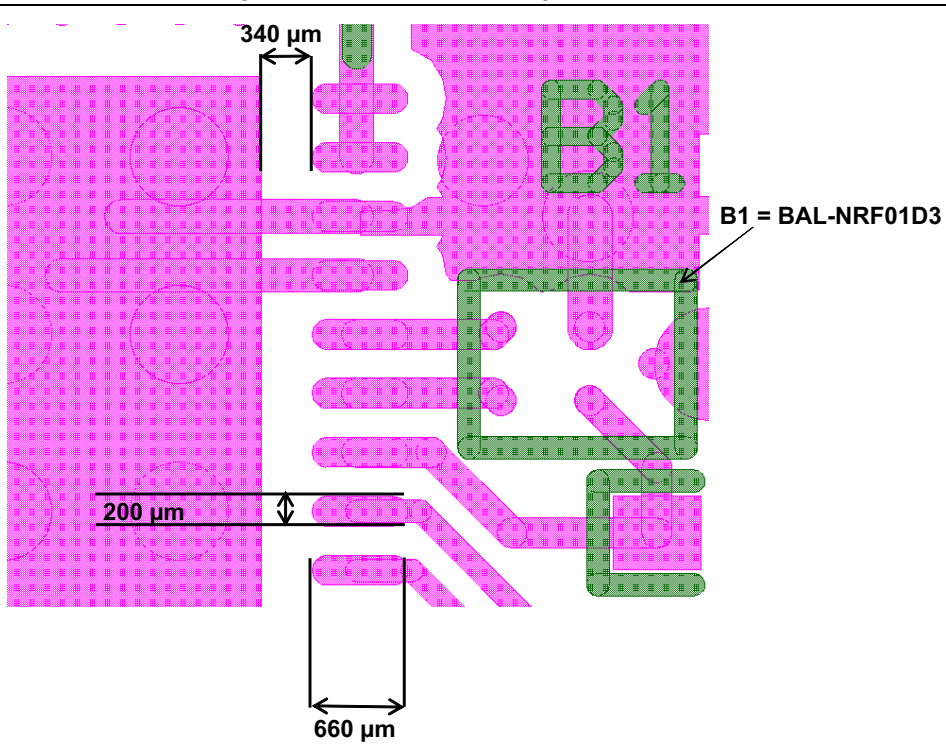


Figure 22. BAL-NRF01D3 position

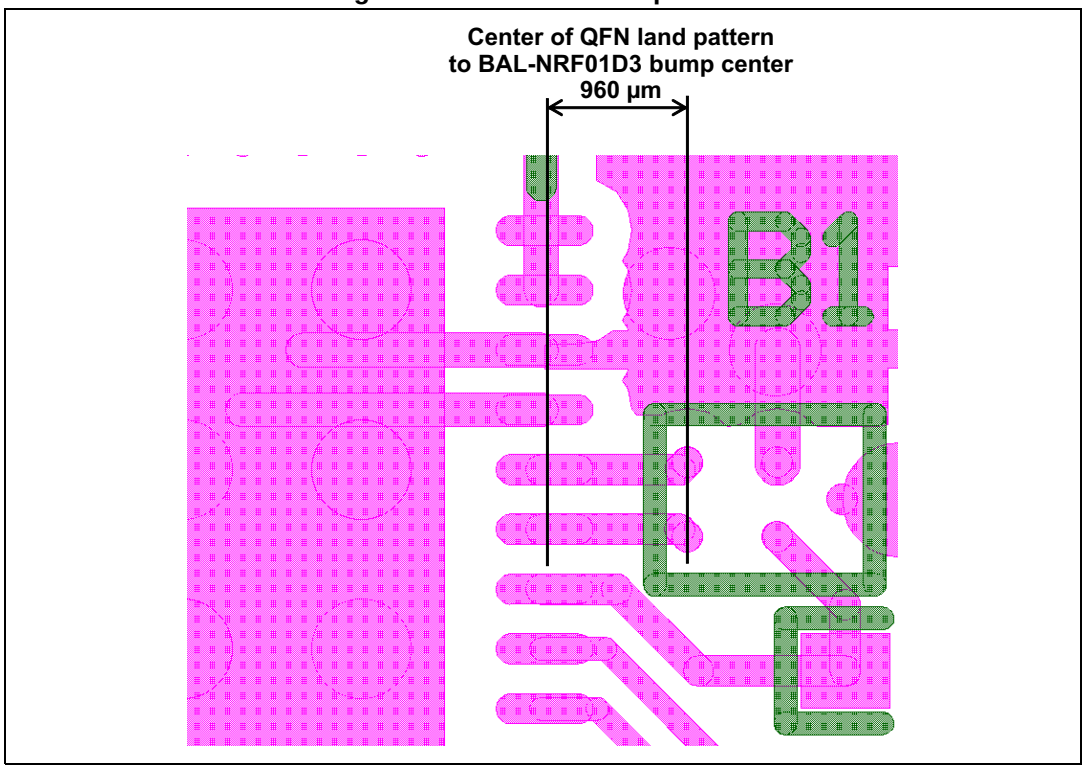


Figure 23. 0.8 pF high Q capacitance position

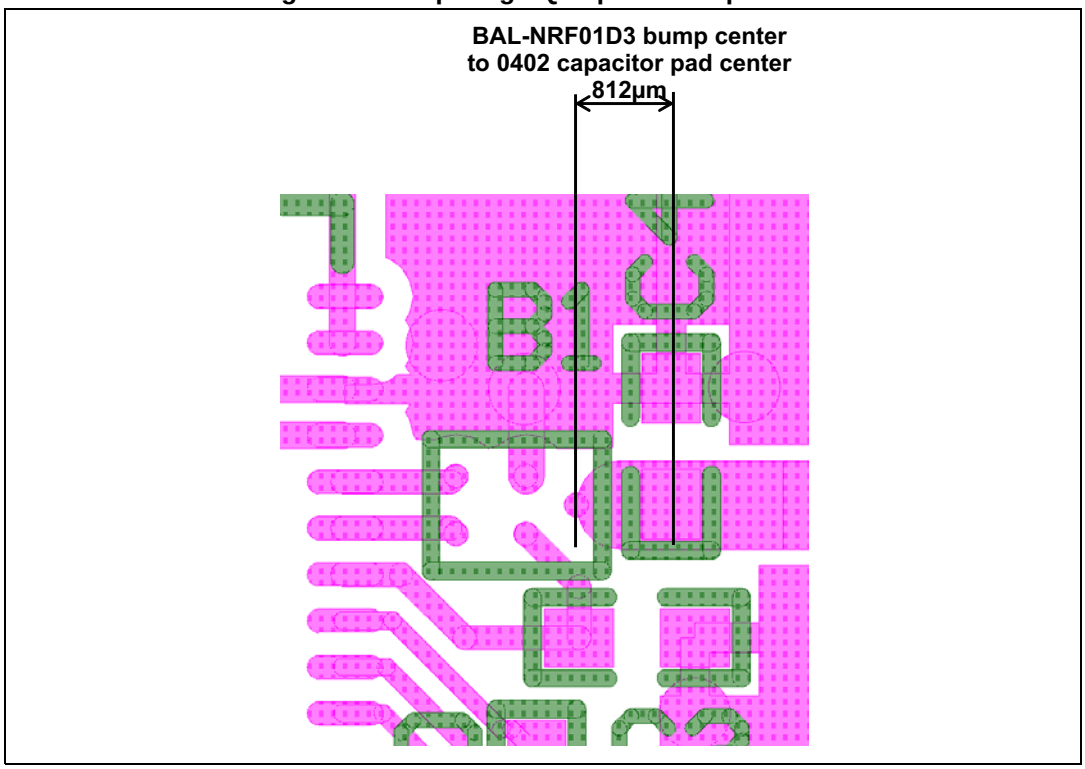


Figure 24. PCB stack-up recommendation

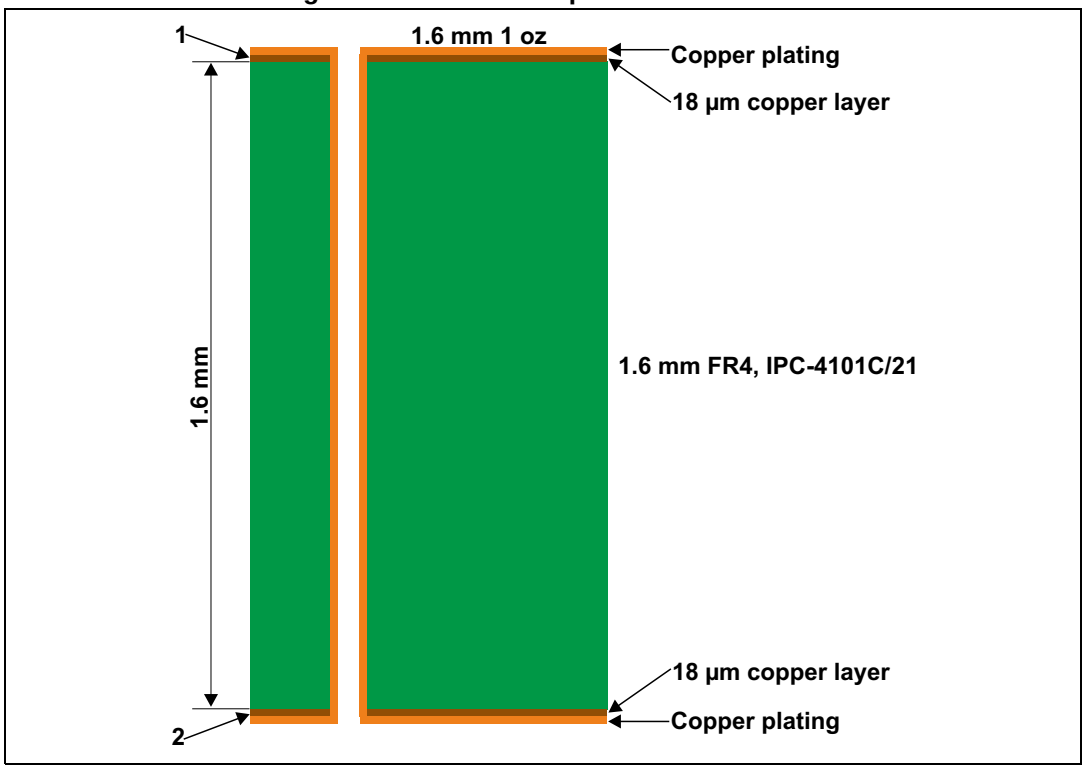


Figure 25. More layout information at Nordic Semiconductor's web site

4 Ordering information

Table 3. Ordering information

Part number	Marking	Weight	Base Qty	Delivery mode
BAL-NRF01D3	SC	1.82 mg	5000	Tape and reel

5 Revision history

Table 4. Document revision history

Date	Revision	Changes
13-July-2012	1	Initial release.
12-Nov-2012	2	Added *Figure 14* and *Figure 15*. Updated text after *Figure 7*. Added *Section 3.2: Nordic Semiconductor nRF2752 nRFgo module (nRF51xx)* and *Section 3.3: High power case*.
04-Mar-2013	3	Updated name of Developer Preview kit in the *Introduction*. Updated last parameter name *Table 1* and *Table 2*. Added *Section 3.4: Layout recommendations for nRF24LE1*.
28-Jun-2013	4	Added *Section 1: BAL-NRF01D3 preview* and *Section 3.4: Layout recommendations for nRF24LE1*.

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