Remote Control Reference Design

nRD24H1

User Guide

December 2006

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Revision History

Date	Version	Description
December 2006	1.0	

Contents

1 Introduction

nRD24H1 is a reference design for the nRF24L01 general purpose radio chip. The purpose of this document is to help with the design of RF based remote controls operating in the worldwide 2.4GHz ISM band. Based on this reference design you will be able to design one-way and two-way remote controls that are not limited by line-of-sight conditions. This reference design also provides valuable design suggestions for other applications with comparable data rates.

2 System Overview

The reference design consists of complete design files (schematics, layout, Gerber, BOM data and source code) for a USB receive dongle, an RF module and, an application board. The remote control unit consists of the RF module and application board. The RF module contains all critical parts and the application board is easily redesigned for the form factor of the finished product.

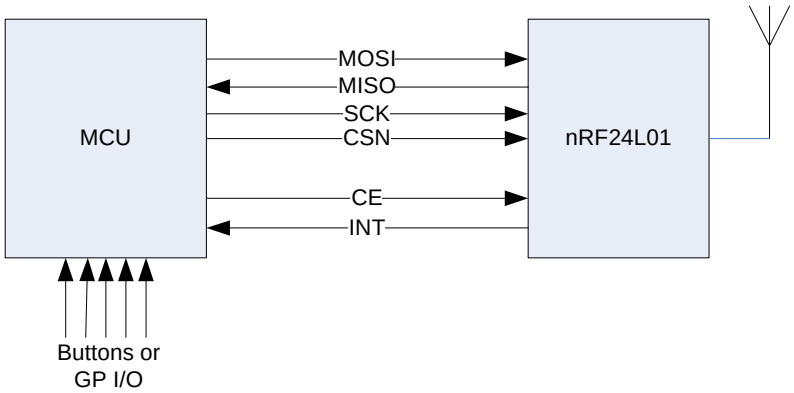


Figure 1. Block diagram of the remote control unit

The USB receive dongle may be used as-is with no hardware changes. The USB receive dongle and remote control unit are not supplied with plastic housing.

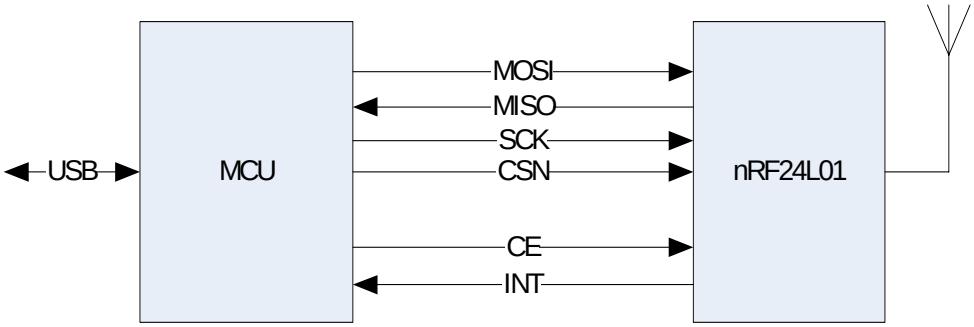


Figure 2. Block diagram of the USB receive dongle

You can download the design files from Nordic Semiconductor at www.nordicsemi.no.

It is assumed that the USB receive dongle is permanently on while the PC it is plugged into is on. The USB receive dongle goes to a low power mode when the PC is in standby. Only the remote control unit is optimized for long battery life.

3 Hardware Description

This section describes the hardware units that are supplied with the nRD24H1.

3.1 RF Module

In most applications, redesigning the RF module is not required. The RF module includes the nRF24L01 radio IC and all its supporting components, that is, antenna, matching network and crystal. The RF module also contains a microcontroller. The circumference of the RF module holds GPIO pins of the MCU. The choice of pins enables the RF module to support several different IO standards:

- 14 pins for matrix scan of 49 keyboard buttons + 1 LED output.
- SPI master interface + 14 GPIO pins.
- Two GPIO pins may alternatively be used for a 2-wire interface (master or slave).
- Two GPIO pins may alternatively be used for a UART interface.

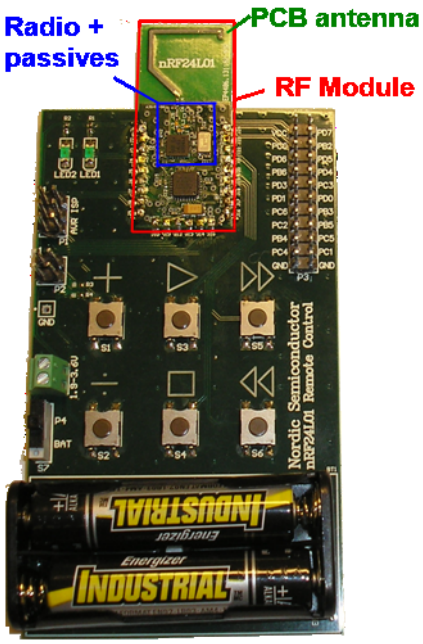


Figure 3. RF module

The nRF24L01 radio IC uses a differential antenna interface for both receive and transmit. Connected to this interface are a balun (balanced/unbalanced) and a matching network.

The nRF24L01 needs very few external components. A resistor is used for biasing while two small capacitors are sufficient for decoupling. The nRF24L01 also needs an external 16MHz crystal for time reference. The radio is tolerant of ±60ppm crystals, but the RF module is equipped with a ±10ppm crystal because this is the most common tolerance for a crystal of this size.

The Atmel ATmega88 MCU is rich in hardware IO features while consuming little power. The MCU on the RF module is programmed from a header on the Application board. The MCU has a 4kbyte program memory and an internal RC oscillator running on 1MHz. Tools from Atmel are necessary to reprogram the MCU.

Pin	Name	Alternate function
1	GND	
2	PD7	LED2
3	PC0	RX data
4	PC1	
5	PC4	VOL - / SDA
6	PC5	VOL UP / SCL
7	PB4	MISO
8	PB5	SCK
9	GND	
10	PC2	
11	PB3	MOSI
12	VCC	
13	PC6	RESET
14	PD0	
15	PD1	TX data
16	GND	
17	PC3	
18	PD3	STOP
19	PD4	PLAY
20	PB6	FORWARD
21	PD5	BACK
22	PD6	LED1
23	PB2	
24	GND	

Table 1. RF module pinout

Note: The PB2 pin of the Atmel ATmega88 MCU has special functionality. This pin may not be used as a general purpose input pin in the current design. We recomend that you limit its use to one of the following:

- Not connected (as is the case with the present Application Board)
- General-purpose output pin for a LED etc.
- SPI slave select for devices on your custom Application Board
- SPI slave select for the MCU in case devices on your custom Application Board need this communication mode with the MCU.

For more information, please consult the Atmel datasheet.

The RF module has an operating range from 1.9 to 3.6V.

3.1.1 Specifications

Operating conditions	Status	Range
Supply voltage		1.9 - 3.6 V
Current consumption	Idle	20µA with brownout detection at 3 V supply. 1.2µA without brownout detection.
	Peak current	15 mA peak at 3 V supply
Radio frequency		2402-2478 MHz
Output power		0 dBm

Table 2. Electrical Specifications

PCB type		1.6 mm 2 layer FR4
PCB dimension	Length x width x height	39 mm x 17 mm x 1.6 mm

Table 3. Physical Specifications

3.2 Application Board

While the RF module can be used as-is in a vast number of applications, the application board is made with redesign in mind. It is hard to anticipate all the different form factors that end products based on nRD24H1 may have. But, the most likely hardware differences will be in casing, button placement, display design and power management. We have not considered the casing design at all, but the rest of the application board should be very easy to redesign.

The Application board that ships with nRD24H1 contains the following units:

- Footprint for the RF module
- Six buttons
- Batteries
- External power connector
- Programming header for the MCU on the RF module
- Two LEDs
- Debug pins for application development

The power switch S7 can be used in conjunction with the batteries or the external power connector. You should use *either* batteries *or* external power. External power on (batteries off) is selected with the switch pointing down while batteries on (external power off) is selected with the switch pointing up.

Note: It is important to keep the voltage supply within the 1.9 to 3.6V limits. There is no over voltage protection circuitry on the Application board.

P1 is the ISP6PIN connector used to reprogram Atmel MCUs and has the standard Atmel 6-pin ISP pinout. P2 contains the GPIO pins that may also work as UART and 2-wire interface. The pin names on the debug connector P3 are according to Atmel ATmega88 IO pin names. The pins on P1 and P2 are also available on P3.

Pin	Function
1	MISO
2	VCC
3	SCK

Pin	Function
4	MOSI
5	RST
6	GND

Table 4. ISP connector, P1

The ATmega88 can be programmed with any ISP capable programmer for the Atmel MCUs. The ISP connector, P1, has the same pin out as Atmel uses on its programmers, that is, the STK500. The programming details are explained in the software guide.

Pin	Name	Alternate function
1	VCC	
2	PD7	LED2
3	PC0	
4	PB2	
5	PD6	LED1
6	PD5	BACK
7	PB6	FORWARD
8	PD4	PLAY
9	PD3	STOP
10	PC3	
11	PD1	TX data
12	PD0	RX data
13	PC6	RESET
14	PB3	MOSI
15	PC2	
16	PB5	SCK
17	PB4	MISO
18	PC5	VOL UP / SCL
19	PC4	VOL DOWN / SDA
20	PC1	
21	GND	
22	GND	

Table 5. P3 pinout

Pin	Name	Alternate function
1	PD0	RX data
2	PC5	SCL
3	PD1	TX data
4	PC4	SDA

Table 6. P2 pinout

3.3 USB Receive Dongle

The USB receive dongle should not need hardware redesign in most applications. The USB receive dongle features the nRF24L01 with the same supporting components as on the RF module. The USB interface is provided by a Silicon Laboratories C8051F321 IC. This IC also acts as an MCU running the remote control signal reception application.

Figure 4. USB receive dongle

The nRF24L01 requires a supply voltage of between 1.9 and 3.6V. The C8051F321 features a voltage regulator that takes 5V from the USB connector and provides 3V to the rest of the USB receive dongle.

The bottom side of the USB receive dongle has one button and the top side has one LED. These two components are not important in nRD24H1 but have been included in case your application needs them.

The C8051F321 uses an internal timer for waking up the MCU when the PC is in a suspended mode. The frequency of this timer is controlled by the value of the cap, C12, connected to pin P0.2 of the MCU.

Programming the C8051F321 is done with a ISP programmer from SiLabs. The programming details for this are explained in the software guide.

3.3.1 Specifications

Operating conditions		
Supply voltage		4.5 - 5.5 V
Current consumption	Suspend	450 µA
	Connected	25.5 mA
Radio frequency		2402-2478 MHz
Output power		0 dBm

Table 7. Electrical Specifications

PCB type		1.6mm 2 layer FR4
PCB dimension	Length x width x height	42mm x 15mm x 1.6mm

Table 8. Physical Specifications

3.4 nRF24L01 Samples

The samples that are supplied with the nRD24H1 are provided so that you can easily start a design using this part. The nRD24L01 is a general purpose radio IC operating with very low power consumption. More information about this chip can be found on www.nordicsemi.no.

4 Hardware Design Guidelines

This chapter describes important issues that might affect you when developing the remote control reference design for a finished product.

4.1 RF Module

The RF module is designed to cover most remote control and keyboard applications. The most likely change to the RF module is that the antenna may need some retuning for your finished application. The form factor of the Application board in the end product may influence the radiation pattern.

The matching network for the nRF24L01 has the same layout as in the reference design from the datasheet with only some small component changes to compensate for the smaller PCB. The 50 ohm reference point will be between C5 and C14, where C14 is used to match the antenna to this 50 ohm impedance.

Note: Changing the thickness of the PCB will require a retuning of the antenna matching network.

In a mass produced product it is likely that the components on the RF module will be merged with the rest of the electronics. Also, the component cost may be optimized depending on your volumes and needs. In such cases, we recommend that you use the design files for the RF module and keep the RF portion of the design. This includes:

- The nRF24L01 radio and its decoupling.
- The antenna matching network.
- The ground plane pattern between the radio and the antenna.
- The ground vias.

4.2 Application Board

As stated above, the application board is made with redesign in mind and you can redesign it for your product with minimal effort.

We have identified three likely scenarios:

1. For demonstrators, a one-off application board can be combined with the RF modules sold in the nRD24H1 box.
2. For low to mid quantity production, you may produce the RF module yourself and mount it on your custom application board.
3. For high quantity production, merging the electronics on the Application board and RF module will cut production cost.

For the first two scenarios the modified application board must contain the following basic features in addition to your choice of buttons and display:

- The U-shaped footprint for the RF module with all the IO pads placed on the nRD24H1 Application board.
- A voltage supply to the RF module in the range between 1.9 to 3.6V.
- A programming header for the Atmel AVR MCU on the RF module.

4.3 USB Receive Dongle

The USB dongle contains all the components that are necessary for a finished product.

The matching network for the nRF24L01 has the same layout as in the reference design from the datasheet with only some small component changes to compensate for the smaller PCB. The 50 ohm reference point will be between C5 and L4, where L4 is used to match the antenna to this 50 ohm impedance.

The following design alterations are likely to the USB receive dongle:

- Tools from Silicon Laboratories are required to reprogram the USB receive dongle with your software. The top side of the USB receive dongle has a 4-pin programming interface for Silicon Laboratories ISP tools. The 4-pin connector will likely be omitted from the BOM of a production model.
- The LED and button are placed on the the USB receive dongle. If your application does not need these functions, it is easy to disregard the components without having to alter the PCB layout.

  Note: If you need the button and/or LED and find it inconvenient that they are on the bottom side, the simplest modification is to turn the USB connector upside down.

- It is possible to reduce the size of the USB receive dongle by using a chip antenna or another antenna configuration, choosing a more compact USB connector or, altering the layout. If you choose to do so, the antenna matching network must be redesigned.
- The antenna is matched for best reception when the dongle is placed in a USB slot of a computer, and without a plastic housing. Adding housing can affect the antenna resulting in the antenna matching needing changed.

5 Appendix

5.1 Bill Of Materials (BOM)

Part	Designator	Footprint	Description
LED Green	LED1, LED2	1206	Led Green 1206
Header 2x6	P1	Header 2x6	Pin Header 2x6
Header 2x2	P2	Header 2x2	Pin Header 2X2
Header 2x11	P3	Header 2x11	Pin Header 2x11
Screw terminal	P4		Phoenix MPT 0,5/2-2,54
	P5		NA
100R	R1, R2	0402	100R
NA	R3, R4	0402	NA
Switch	S1, S2, S3, S4, S5, S6	SKHJAD	Alps SKHUAD
Switch	S7		EAO, type 1K2 straigh pins
Battery	BT1		2xAAA Battery box

Figure 5. Application board BOM

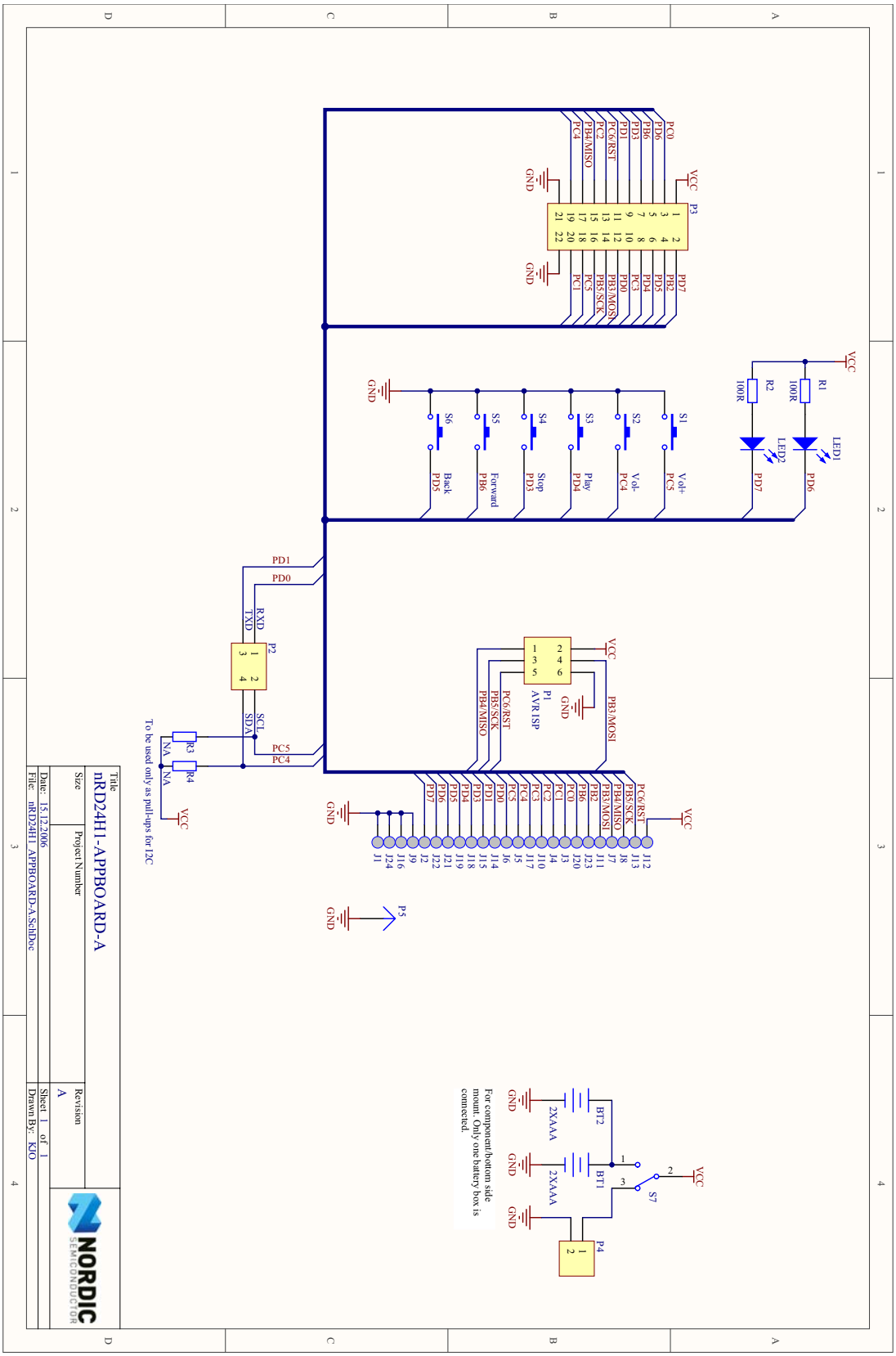
Part	Designator	Footprint	Description
15pF	C1, C2	0402s	15pF NP0 +/-2%
2.2nF	C3	0402s	2.2nF X7R +/-10%
4.7pF	C4	0402s	4.7pF NP0 +/-0.25pF
1.5pF	C5	0402s	1.5pF NP0 +/-0.1pF
1.0pF	C6, C14	0402s	1.0pF NP0 +/-0.1pF
33nF	C7	0402s	33nF X7R +/-10%
1nF	C8	0402s	1nF X7R +/-10%
10nF	C9	0402s	10nF X7R +/-10%
100nF	C10, C11	0402s	100nF X7R +/-10%
33pF	C12	0402s	33pF NP0 +/-5%
1uF	C13	0402s	1uF 6.3V X5R
LED GREEN	D1	1.6X0.8X0.4	LED GREEN 0603
8.2nH	L1	0402s	Chip inductor, +/- 5%
2.7nH	L2	0402s	Chip inductor, +/- 5%
3.9nH	L3	0402s	Chip inductor, +/- 5%
USB Type A	P1	USB through hole	Molex 47037-0001
Header 1x4	P2	HDR1X4	
1M	R1	0402s	1M 5%
22k	R2	0402s	22k 1%
1k	R3, R4	0402s	1k 5%
100R	R5	0402s	100R
NA	R6	0402s	NA
ALPS SKHUAD	S1	ALPS SKHUAD	
nRF24L01	U1	QFN20L/4x4	Nordic Semiconductor
C8051F321	U2	MLP-28	SiLabs
16MHz	X1	TSX-4025	16MHz, CL=9pF, < +/- 60ppm

Figure 6. USB receiver dongle BOM

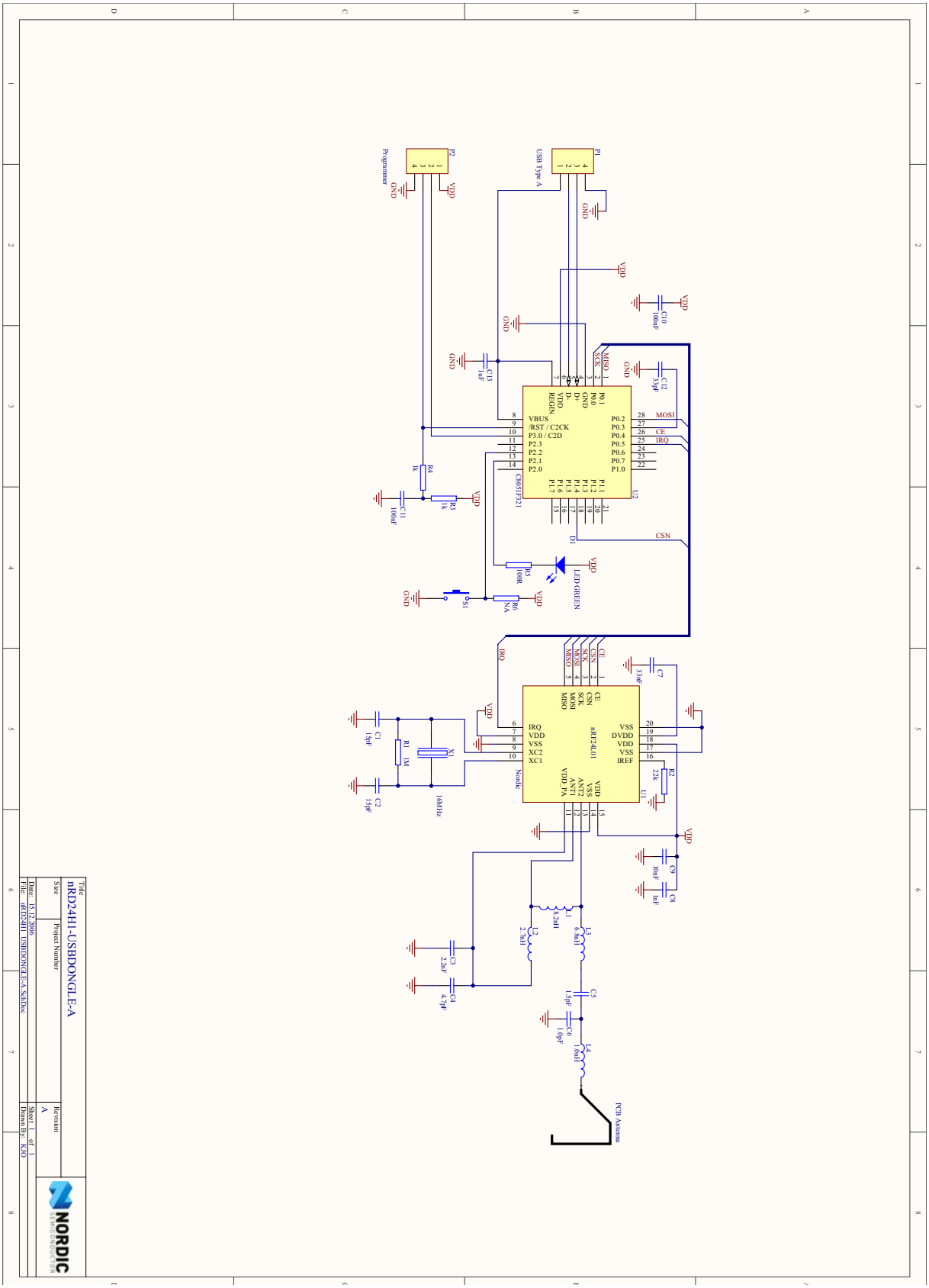
Part	Designator	Footprint	Description
15pF	C1, C2	0402	15pF NP0 +/-2%
2.2nF	C3	0402	2.2nF X7R +/-10%
4.7pF	C4	0402	4.7pF NP0 +/-0.25nF
1.5pF	C5	0402	1.5pF NP0 +/-0.1nF
1.0pF	C6, C14	0402	1.0pF NP0 +/-0.1nF
33nF	C7	0402	33nF X7R +/-10%
1nF	C8	0402	1nF X7R +/-10%
10nF	C9	0402	10nF X7R +/-10%
10uF	C10	1206	10uF 6.3V Tantal
100nF	C11, C12, C13, C15	0402	100nF X7R +/-10%
8.2nH	L1	0402	Chip inductor, +/- 5%
2.7nH	L2	0402	Chip inductor, +/- 5%
6.8nH	L3	0402	Chip inductor, +/- 5%
1M	R1	0402	1M 5%
22k	R2	0402	22K 1%
nRF24L01	U1	QFN20L/4x4	Nordic Semiconductor
atMega88V-10MU	U2	QFN32L/5x5	Atmel
16MHz	X1	TSX-4025	16MHz, CL=9pF, < +/- 60ppm

Figure 7. RF module BOM

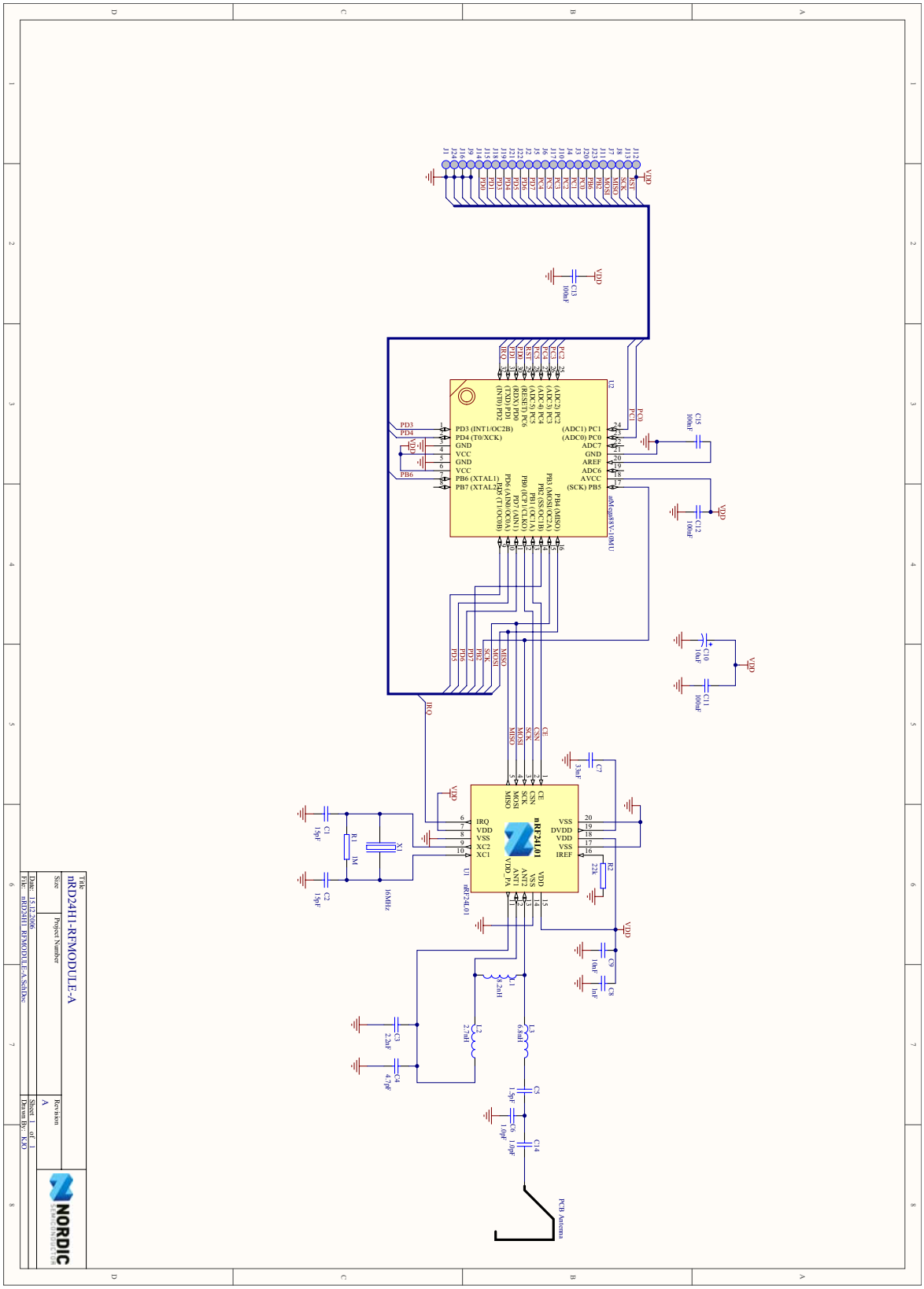
5.2 Application board schematics



5.3 USB receive dongle schematics



5.4 RF module schematics



5.5 Design layout for application board

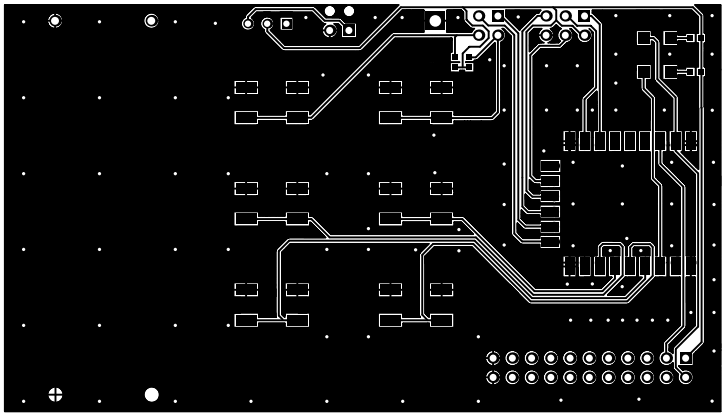


Figure 8. Application board top layer

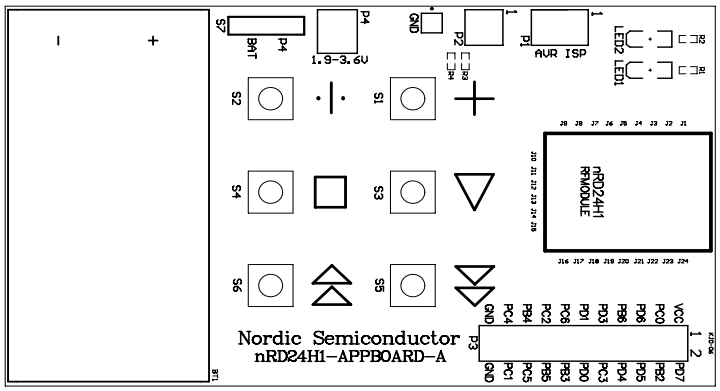


Figure 9. Application board top overlay

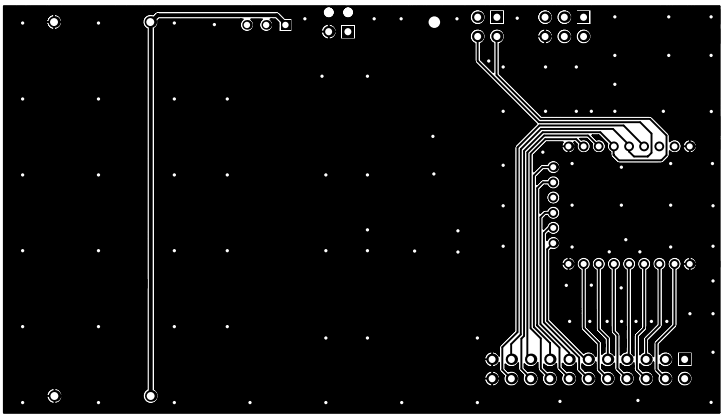


Figure 10. Application board bottom layer

5.6 Design layout for USB receive dongle

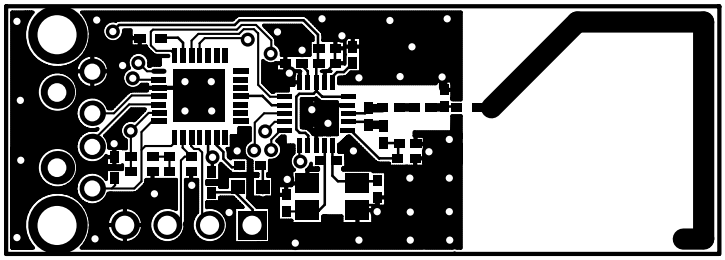


Figure 11. USB receive dongle top layer

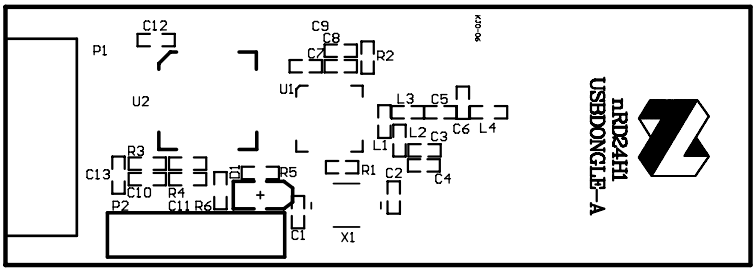


Figure 12. USB receive dongle top overlay

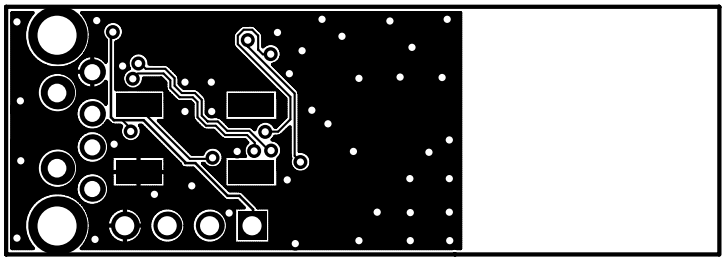


Figure 13. USB receive dongle bottom layer

5.7 Design layout for the RF module

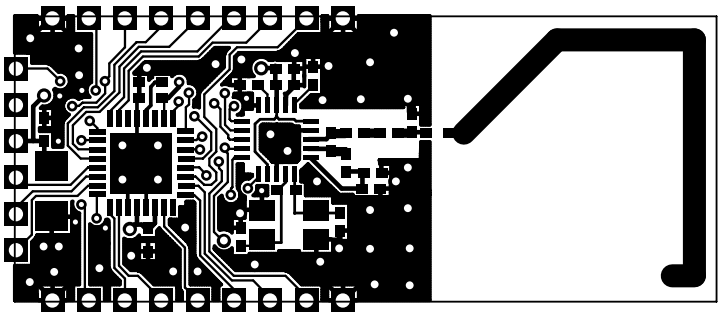


Figure 14. RF module top layer

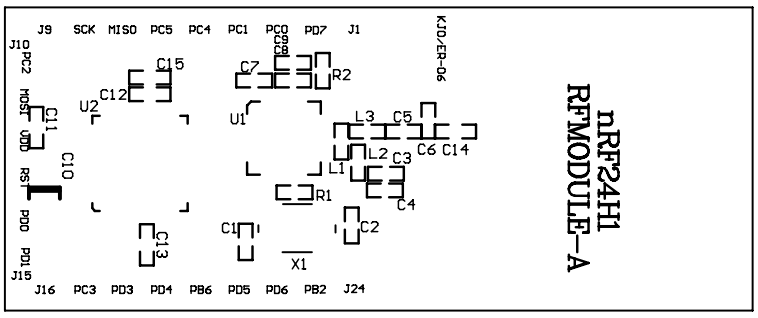


Figure 15. RF module top overlay

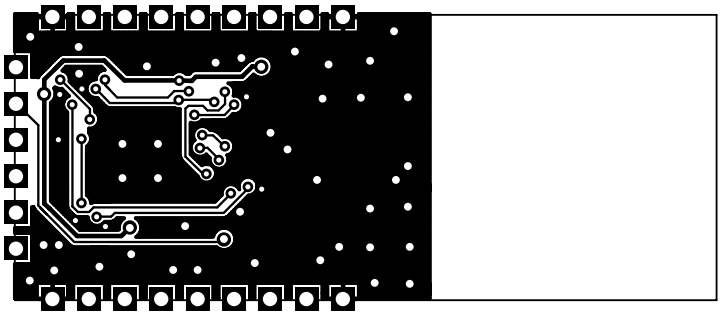


Figure 16. RF module bottom layer