

Headset Reference Design nRD24V1

User Guide v1.0

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1 Introduction

This user guide is for the nRD24V1 headset reference design, a voice quality wireless headset for Voice over IP (VoIP) applications. The quality of the audio in this design is the same as the audio quality in telephony.

This user guide describes the nRD24V1 system, HW modules and gives guidelines on how to take this reference design and build it into a headset application for a finished product.

The nRD24V1 consists of a USB dongle and two application boards with a radio module mounted. You can establish a full duplex voice link between one application board and the USB dongle or between the two application boards.

Target applications for the nRD24V1 are:

- Voice over IP headsets
- Short range intercom applications
- Toys

2 System Description

The headset unit can be used to communicate with either a USB dongle or an audio dongle.

Note: The audio dongle is simply a headset unit with different firmware and jumper settings.

Figure 1. "Headset unit with a USB configuration" and Figure 2. "System diagram of headset unit with USB configuration" illustrate the headset unit with a USB configuration.

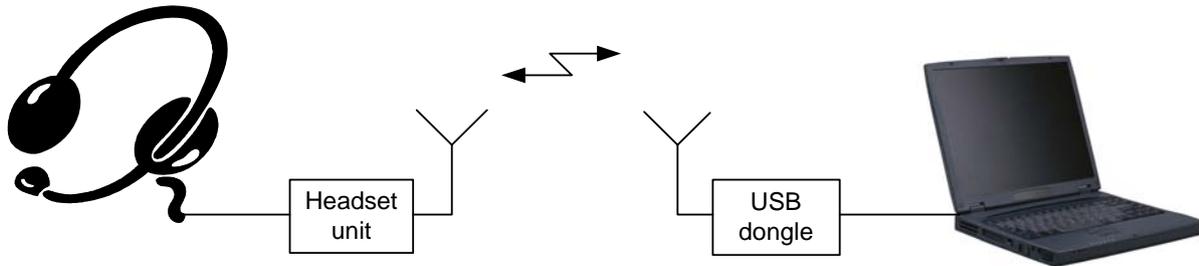


Figure 1. Headset unit with a USB configuration

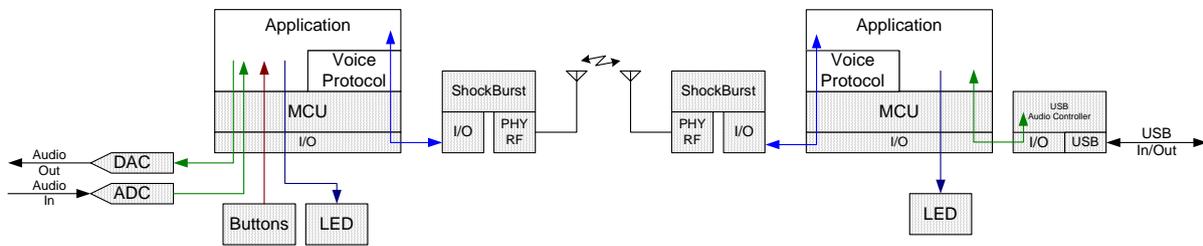


Figure 2. System diagram of headset unit with USB configuration

Figure 3. "Headset unit with an audio dongle configuration" and Figure 4. "System diagram of headset unit with audio dongle configuration" illustrate the headset unit with audio dongle configuration.

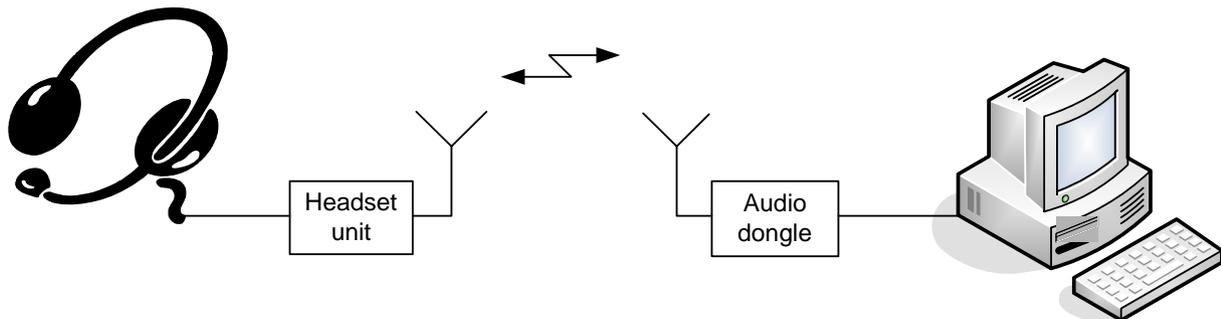


Figure 3. Headset unit with an audio dongle configuration

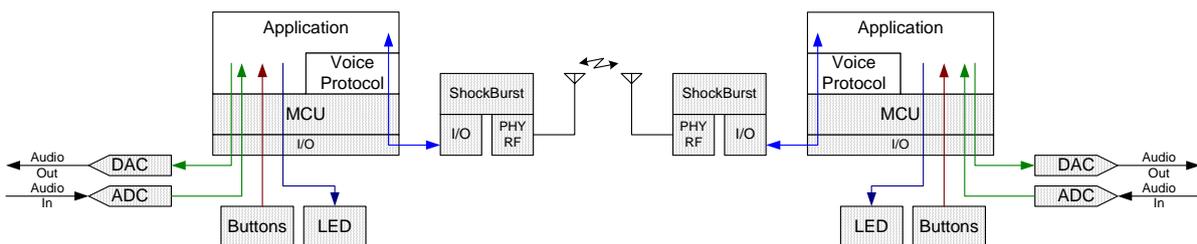


Figure 4. System diagram of headset unit with audio dongle configuration

The headset unit and the audio dongle are based on the same hardware. Both use an audio codec to provide coding and decoding of the analog audio signals to 16-bit linear PCM code. This bit stream is processed by the micro controller to an 8-bit a-law bit stream, which is sent to the nRF24L01 for wireless transmission. The nRF24L01 uses the ShockBurst feature to transmit and receive the RF packets in a time multiplexed scheme. The micro controller fetches received 8-bit a-law samples from the nRF24L01, converts to 16-bit linear PCM, and outputs to the audio codec. Button status is read by the MCU and embedded in the RF packets.

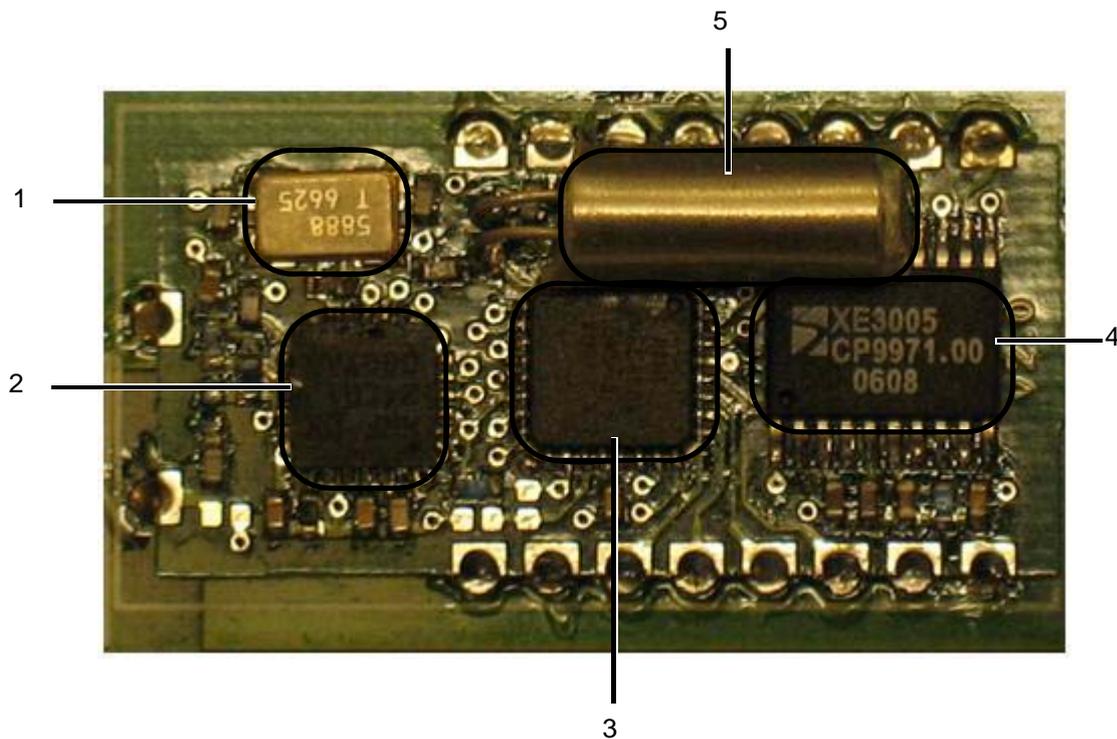
The USB Dongle uses a USB Audio Controller to handle the USB interface. The audio samples are 16 bit linear PCM between the USB Audio Controller and the micro controller, where the micro controller acts as a bus master. The audio frame signals are derived from clock output from the USB Audio Controller to keep the audio frames in sync with the USB audio frames. The micro controller can also access the USB HID interface through the I2C bus, also with the micro controller as the bus master. The USB HID interface is used to upstream button status received from the headset to the USB host. The micro controller converts the 16 bit linear PCM code to an 8-bit a-law bit stream, which is sent to the nRF24L01 for wireless transmission. The nRF24L01 uses the ShockBurst feature to transmit and receive the RF packets in a time multiplexed scheme.

3 Hardware description

3.1 nRD24V1 Radio module

The radio module is a complete system for telephone quality wireless headset applications intended for VoIP. It can be used in a headset, or in an audio module for connection to a PC audio outlet. There are 6 GPIOs for buttons or LEDs on the radio module.

The radio module is mounted on a 25 x 12 x 0.8 mm, 4-layer FR4 circuit board, with components on one side.



- | | | | |
|---|------------|---|-------------|
| 1 | RF crystal | 4 | Audio codec |
| 2 | nRF24L01 | 5 | MCU crystal |
| 3 | MCU | | |

Figure 5. nRD24V1 radio module

3.1.1 Audio Codec

The audio codec is a XE3005 from Semtech that receives a 4.096 MHz master clock from the micro controller. The micro controller configures the codec through the SPI interface. The 8 ksp/s audio samples are transferred on the I2S interface, where the micro controller is the bus master.

The microphone input has a 1.1 VDC bias for driving the microphone.

The loudspeaker outputs are a differential class D output and need some external filtering components.

3.1.2 Micro controller

The micro controller is an AVR, ATmega88 and runs on a 4.096 MHz crystal. The micro controller's main tasks are:

- Setting up codec and RF circuits.
- Converting 16 bit PCB audio samples from the codec to 8 bit a-law samples to the radio circuit.
- Converting 8-bit a-law samples from the radio circuit to 16-bit linear PCM.
- Handling the RF protocol.

Additionally, five button inputs are scanned and one output is provided for driving. For example, this can be used for an LED.

3.1.3 Radio circuit

The radio circuit (nRF24L01) is a complete radio transceiver for use in the unlicensed 2.4 GHz band. A 16 MHz crystal is used as a frequency reference for the RF. The RF output is matched to approximately 50 ohm at the antenna port. See section 3.1.4 "Antenna matching network" below.

3.1.4 Antenna matching network

The RF output of the radio module is matched to approximately 50 ohm. An antenna is needed to set up the RF link. There is a variety of different antenna types, please see section 4.1.1 "Antenna" for more information.

3.1.5 Power supply

The module needs a power supply in the range of 1.9 to 3.3 Volts. The module has been tested with a supply consisting of two ZinkAir cells (type 675) in series. Check the current consumption values shown in Table 1. "Electrical Specifications" below.

Note: Not all battery types are capable of handling the peak and average currents, even if the battery capacity is sufficient.

3.1.6 Programming

The module can be programmed using the ISP connector on the application board (see section 3.2 "Application board"), by connecting the appropriate pins on the module, or by using test probes on the corresponding exposed vias on the back of the board.

3.1.7 Specifications

Operating conditions	Status	Value
Supply voltage		1.9 - 3.6 V
Current consumption	Idle	< 1 mA average (15 mA peak) at 2.5 V supply
	Connected	< 7 mA average (15 mA peak) at 2.5 V supply
Radio frequency		2402-2478 MHz
Output power		0 dBm

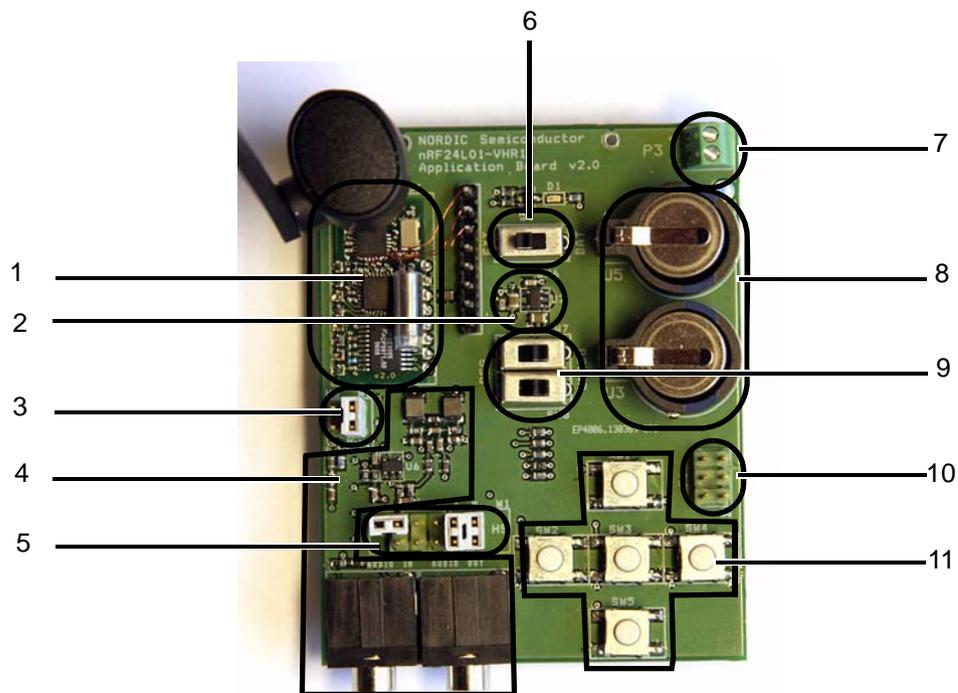
Table 1. Electrical Specifications

PCB attributes	Description
PCB type	0.8 mm 4 layer FR4
PCB dimension (length x width x height)	25 mm x 12 mm x 0.8 mm

Table 2. Physical Specifications

3.2 Application board

The nRF24L01-VHR1 application board contains all peripherals necessary to build a complete audio module from the nRF24L01-VHR1 radio module.



- | | | | |
|---|------------------|----|-------------------|
| 1 | Radio module | 7 | P3 external power |
| 2 | Linear regulator | 8 | Batteries |
| 3 | Jumpers | 9 | Switches 7 and 8 |
| 4 | Audio interface | 10 | ISP programming |
| 5 | Jumpers | 11 | Buttons |
| 6 | Switch 6 | | |

Figure 6. Application board components

3.2.1 Audio interface

This module can be used to set up a wireless audio link, for example, from a PC to a headset. The radio module is the same for both sides of the link, but needs some external components to interface with either the PC audio connections, or a microphone/loudspeaker for a headset.

3.2.1.1 Headset interface

The loudspeaker(s) are driven differentially, and need some filtering due to the class D output amplifier of the audio codec. Figure 7. "Loudspeaker interface" shows a typical filter network that can be used for driving a headset loudspeaker. The filter depends on the chosen loudspeaker.

The microphone can be connected directly to the codec input. The codec input has a 1.1 V supply that can power a typical headset microphone.

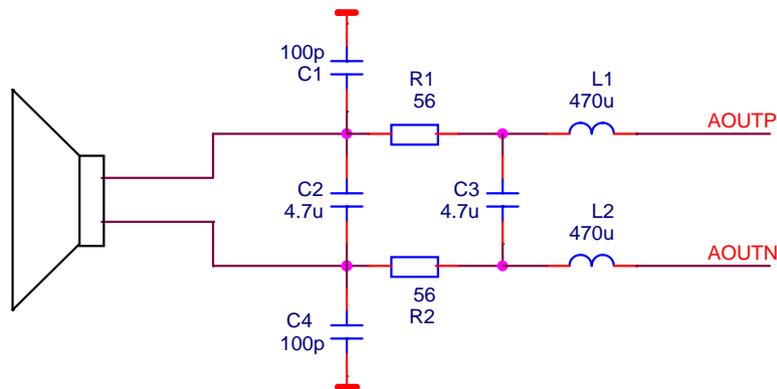


Figure 7. Loudspeaker interface

3.2.1.2 PC interface

The differential loudspeaker output from the codec must be connected single ended to the PC microphone input and the PC loudspeaker output must be connected to the codec microphone input to interface with a PC audio port. Figure 8. "PC input interface" shows the networks that accommodate this. The loudspeaker output from the PC must be level adjusted and a network as shown in Figure 9. "PC output interface" used.

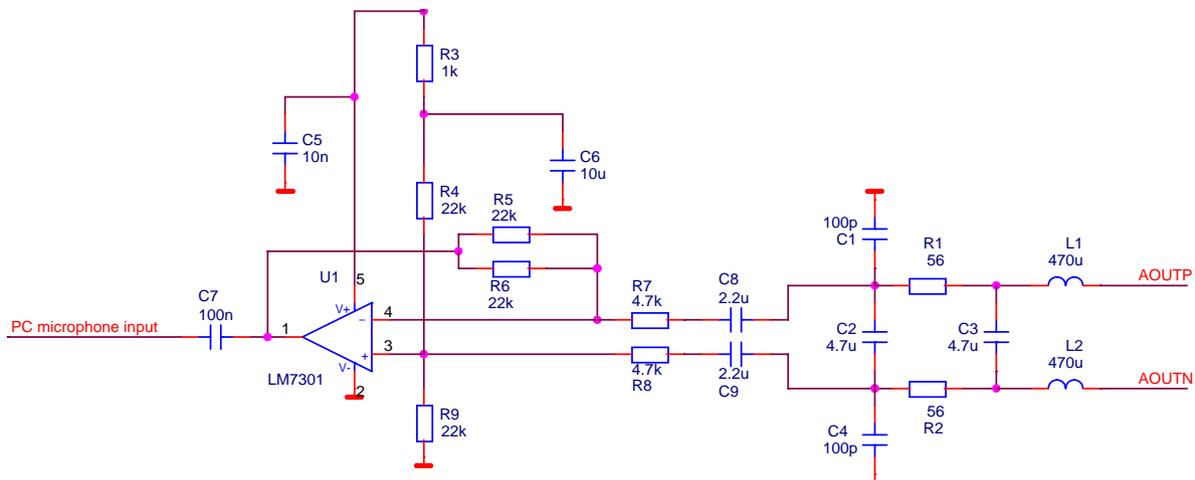


Figure 8. PC input interface

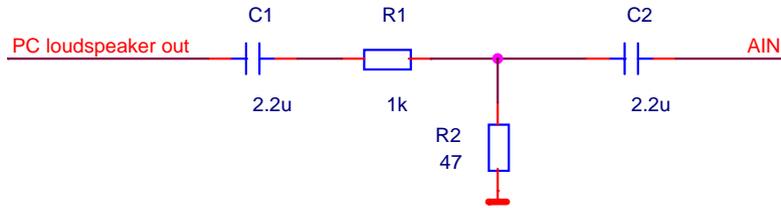


Figure 9. PC output interface

3.2.2 Jumpers

The application board can be set up to interface a headset microphone and loudspeaker, or a PC audio outlet by placing the jumpers as shown in Table 3. "Audio filter settings" below. The filter components mounted should be appropriate for most headset loudspeakers.

	CJ2	CJ3	W1	W2
Connecting to headset	Connect to headset microphone.	Connect to headset loudspeaker	Mount jumpers 4 and 5	Mount jumper 2.
Connecting to PC	Connect to PC microphone input	Connect to PC loudspeaker output	Mount jumpers 1, 2 and 3	Mount jumper 1.

Table 3. Audio filter settings

3.2.3 Antenna

The RF output of the radio module is matched to approximately 50 ohm. An antenna must be connected to the SMA connector to set up an RF link.

3.2.4 Power supply

The application board is fitted with two coin-cell battery holders, connected in series, for use with ZinkAir (type 675) batteries. The board also contains a footprint for a CR2 Li battery holder (1/2 AA, Bulgin BX0031). Alternatively, an external power supply can be connected to P3. You select battery or external voltage with SW6.

The voltage supply to the RF module should be between 1.9 and 3.6 V. If the onboard 2.5 V linear regulator is used, the input voltage should be between 3 and 15 V. The linear regulator can be switched on or bypassed with SW7 and SW8 (both switches should have the same position).

Note: Do not exceed 3.6 V when using external voltage unless the linear regulator is used, as this can damage the radio module.

3.2.5 Buttons

There are five buttons on the application board and these are connected to the AVR micro controller on the radio module as shown in Figure 10. "Button mapping".

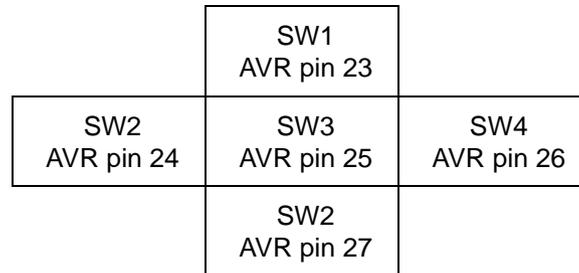


Figure 10. Button mapping

3.2.6 Programming

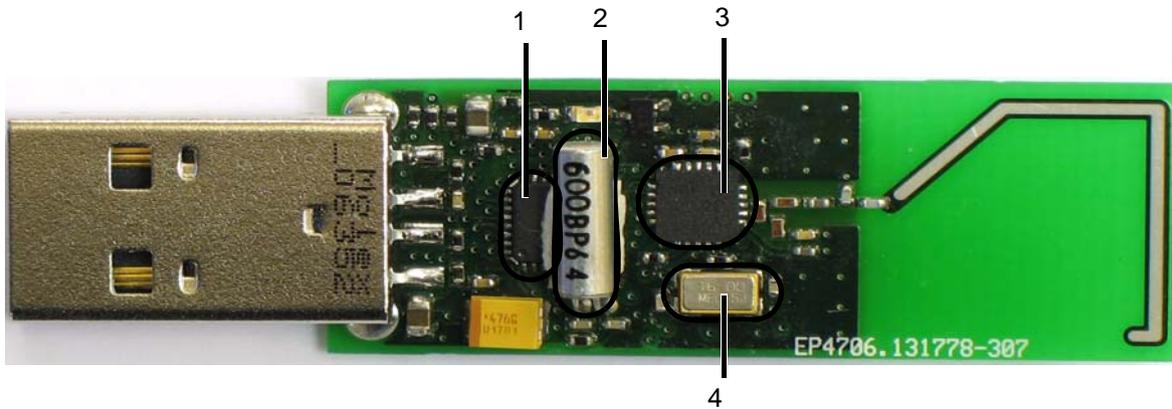
The radio module can be programmed through the 6-pin ISP connector (P1) with an AVR programming tool like the STK500 from Atmel. The programming procedure is as follows:

1. If the unit has never been programmed, set the AVR fuses:
 - Preserve EEPROM memory through chip erase cycle; [EESAVE = 0]
 - Brown-out detection level at Vcc=1.8V; [BODLEVEL=110]
 - Clock output on PORTB0; [CKOUT=0]
 - Ext.Crystal Osc. Frequency 3.0 - 8.0MHz; [CKSEL=1101 SUT=11]
2. Write the SW hex file into the AVR program memory.
3. Write a 3-byte ID into the AVR EEprom. The address should be written with the MSB at address 00.

3.3 USB dongle

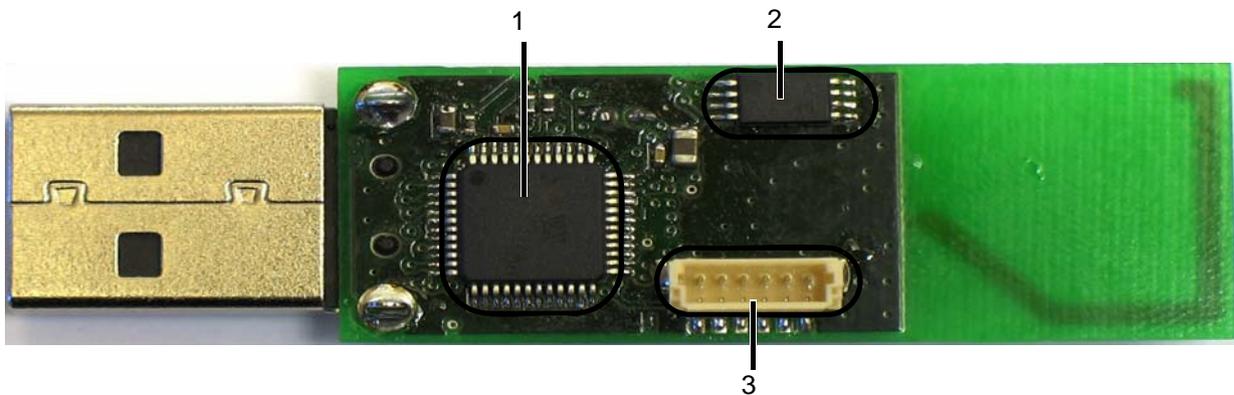
The USB dongle establishes a wireless audio link with the radio module in a headset and is identified as an audio device in the PC operating system.

The USB dongle is mounted on a 0.8 mm, 4-layer FR4 circuit board, with components on both sides of the board.



- | | | | |
|---|-------------|---|------------|
| 1 | MCU | 3 | nRF24L01 |
| 2 | MCU crystal | 4 | RF crystal |

Figure 11. nRD24V1 USB dongle top side



- | | | | |
|---|---------|---|---------------|
| 1 | USB MCU | 3 | ISP connector |
| 2 | EE Prom | | |

Figure 12. nRD24V1 USB dongle bottom side

3.3.1 USB Interface

The USB interface is handled by the Sonix SN11220 USB Audio Controller. All the USB communications are handled by the SN11220. The audio samples are 16 bit linear PCM on the I2S port, where the micro controller acts as a bus master (PADFUN mode 4'1100 in the SN11220ACF data sheet). The audio frame signals are derived from the 2.048 MHz clock output from the USB controller. This synchronizes the audio frames with the USB audio frames. The micro controller can also access the USB HID interface through the I2C bus, also with the micro controller as the bus master.

3.3.2 Micro controller

The micro controller is an AVR, ATmega88 that runs on a 6.00 MHz crystal. The micro controller's main tasks are:

- Setting up USB controller and radio circuits.
- Converting 16 bit PCM audio samples from the USB controller to 8 bit a-law samples for the radio circuit.
- Converting 8-bit a-law samples from the radio circuit to 16-bit linear PCM.
- Handling the RF protocol.
- Optional HID interface for communication with PC application.

In addition, an LED output is available. The LED will light up when USB audio activity is present on the USB port.

3.3.3 Radio circuit

The radio circuit (nRF24L01) is a complete radio transceiver for use in the unlicensed 2.4 GHz band. A 16 MHz crystal is used as frequency reference for the RF and an antenna is included in the layout.

3.3.4 Power supply

The USB dongle is powered from the USB port and needs no extra supply.

3.3.5 Programming

A 6-pin ISP connector is available on the back of the PCB. The included ISP cable can be used to connect this connector to an AVR programming tool like the STK500 from Atmel. The programming procedure is as follows:

1. If the unit has never been programmed, set the AVR fuses:
 - Preserve EEPROM memory through chip erase cycle; [EESAVE = 0]
 - Brown-out detection level at $V_{cc}=2.7V$; [BODLEVEL=101]
 - Ext. Full-swing Crystal; [CKSEL=0111 SUT=01]
2. Write the SW hex file into the AVR program memory.
3. Write a 3-byte ID into the AVR EEprom. The address should be written with the MSB at address 00.

3.3.6 Specifications

Operating conditions	Status	Value
Supply voltage		4.5 - 5.5 V
Current consumption	Idle	< 24 mA
	Connected	< 28 mA
Radio frequency		2402-2478 MHz
Output power		0 dBm

Table 4. Electrical Specifications

PCB attributes	Description
PCB type	0.8mm 4 layer FR4
PCB dimension (length x width x height)	42mm x 16mm x 0.8mm

Table 5. Physical Specifications

4 Hardware design guidelines

This chapter describes important issues that might affect you when developing the headset reference design for a finished product. The USB dongle can be used as-is, but the headset must be redesigned to fit into a headset for a finished product. However, the radio module mounted on the headset can be used as-is together with the audio interfaces from the application board.

Note: Most radio regulations do not allow more than 0dBm output power without doing proper frequency hopping. Adding a PA to this design requires a major re-design of the radio protocol because the headset reference design uses a frequency agility protocol.

4.1 Headset

The radio module is used as-is in the headset design, but it must be interfaced in a way that ensures optimal performance.

4.1.1 Antenna

The radio module is connected to the antenna on the application board. This antenna does not fit into a headset design for a finished product, so using the radio module in a headset application for a finished product will require a different type of antenna.

In a headset application for a finished product, the radio module must be mounted on a PCB with an antenna terminal. On this antenna terminal, any 50 ohm 2.4GHz antenna can be used, from an inexpensive PCB antenna to space saving chip antennas.

There are different types of PCB antennas, from inverted F antennas to simple quarter wave antennas. You must know the characteristics of the chosen antenna and implement it as required. Tuning the antenna will be necessary because an antenna's impedance and performance is affected by the environment the antenna is used in.

Using a chip antenna must only be done according to the chip antenna vendors recommendations.

The radio module is equipped with the recommended antenna matching network layout for the nRF24L01. When operating from the application board, the radio module's antenna matching network is tuned to match the application board antenna impedance.

When using the radio module in a headset application for a finished product it is important to tune the antenna matching network to match the impedance at the antenna's terminal. Another important task of the antenna matching network is to suppress spurious energy. You can achieve this by following our white paper called "Tuning_the_nFR24xx_matching_network" available on our website www.nordicsemi.no.

4.1.2 Interfaces

4.1.2.1 Buttons

Any active closed push buttons referring to ground can be used because the MCU used on the radio module has internal pull-up resistors on the button input signals. The radio module can handle up to five buttons.

4.1.2.2 Audio interface

The audio interfaces from the application board should be used when using the radio module as-is in a design. The audio interfaces are matched to the used audio codec on the radio module. Using a different codec or load on the interfaces requires redesign of the audio interfaces.

4.1.3 Crystals

The crystal used as the RF crystal is a 16 MHz crystal. Any replacement of this crystal must fulfill the crystal requirements found in the nRF24L01 Product Specification.

The MCU crystal fulfills the requirements given by the MCU. The frequency must be 4.096MHz in order to get the timing correct. Any replacements must follow these requirements.

4.1.4 MCU

It is important that the MCU has a double buffered SPI in both the TX and RX direction because the MCU handles the audio stream and requires it to be continuous.

A replacement of the MCU must fulfill these requirements:

- 8-bit MCU
- 4.096 MHz clock frequency
- 1 to 2 cycles per instruction
- 4bytes E2PROM Memory (can be external)
- 1kbyte of IRAM (can maybe work with 512kbytes)
- 8kbyte program memory (possible to get down to 5 to 6kbytes)
- One Double buffered, synchronous hardware SPI both on RX and TX -or- Ideally I2S interface
- One SPI port for RF and codec
- Watchdog times for power management
- One 16-bit timer (Master sync clock)
- One 8-bit timer (hardware sync clock)
- 1.9 to 3.6V supply voltage

4.1.5 Battery

The batteries included in the reference design kit are of the type Zink-Air (Zn), size 675. Two batteries of this size are connected in series to achieve the supply voltage needed.

Any battery that can supply a voltage between 1.9V and 3.6V and sustain the peak current of 15mA can be used in this application.

You can calculate the battery lifetime in both “talk time” and “standby time” from the average current consumption. At $V_{dd}=3V$ the average current consumption in connect mode is 7mA and the average current consumption in idle mode is 250 μA . (At $V_{dd}=2V$ they are 5.7V and 230 μA , respectively.) A battery with capacity 630mAh, like the Zn 675, will have the following battery lifetime:

- Talk time: $630mAh/7mA = 90h$.
- Standby time: $630mAh/250\mu A=2520h$.

The figures for $V_{dd}=3V$ are used because the two batteries in series have a nominal output voltage of 2.8V.

4.2 USB dongle

4.2.1 Antenna

The USB Dongle uses a PCB quarter wave antenna. The USB Dongle is production ready, and any modifications to the antenna are only required as part of the antenna tuning process to compensate for plastic housing, and so on.

If you want an antenna redesign, any 50 ohm 2.4GHz antenna can be used, from an inexpensive PCB antenna to space saving chip antennas.

There are different types of PCB antennas, from inverted F antennas to simple quarter wave antennas. You must know the characteristics of the chosen antenna and implement it as required. Tuning the antenna will be necessary because an antenna's impedance and performance are affected by the environment the antenna is used in.

Using a chip antenna must only be done according to the chip antenna vendors recommendations.

The USB Dongle is equipped with the recommended antenna matching network layout for the nRF24L01 and a PCB quarter wave antenna. If a different antenna is going to be used it is important to tune the antenna matching network to match the impedance at the antenna's terminal. Another important task of the antenna matching network is to suppress spurious energy. This can be achieved by following our White Paper named "Tuning_the_nFR24xx_matching_network" available on our website www.nordicsemi.no

4.2.2 MCU

A replacement of the MCU must fulfill these requirements:

- 8-bit MCU
- 6 MHz clock frequency
- 1 to 2 cycles per instruction
- 4bytes E2PROM Memory (can be external)
- 1kbyte of IRAM (can maybe work with 512kbytes)
- 8kbyte program memory (possible to get down to 5 to 6kbytes)
- One Double buffered, synchronous hardware SPI both on RX and TX -or- Ideally I2S interface
- One SPI port for RF and codec
- One two wire interface to USB Audio Controller for call control (open drain type)
- Watchdog times for power management
- One 16-bit timer (Master sync clock)
- One 8-bit timer (hardware sync clock)
- 1.9 to 3.6V supply voltage

4.2.3 Crystals

The crystal used as the RF crystal is a 16 MHz crystal. Any replacement of this crystal must fulfill the crystal requirements found in the nRF24L01 Product Specification.

The MCU crystal fulfills the requirements given by the MCU. The frequency must be 6.0 MHz in order to get the timing correct. Any replacements must follow these requirements.

5 Appendix

5.1 Bill Of Materials (BOM)

Part	Designator	Footprint	Description
10u	C1 C3 C22 C27	SM/0805	Capacitor 0805/X5R/6V3/15%
10n	C2 C4 C23	SM/0603	Capacitor 0603/X7R/50V/10%
4.7u	C11 C14	SM/0603	Capacitor 0603/X5R/6.3V/10%
100p	C16 C17	SM/0603	Capacitor 0603/NP0/50V/5%
2.2u	C20 C21 C25 C26	SM/0603	Capacitor 0603/X5R/6.3V/10%
100n	C24	SM/0603	Capacitor 0603/X7R/16V/10%
SMA	CJ1	TH/SMA	Coax connector 85 SMA-50-0-101
3.5mm	CJ2 CJ3	TH/CON/KLBR4	Audio Jack, 3.5mm KLBR 4
R	D1	0603_D	LED, Red EL19-21VRC
470u	L1 L5	SM/1210	Inductor, Power LQH32MN471J23L
6PIN2ROW	P1	6PIN/2ROW	Pin row 825457-3
PH2	P3	PHOENIX/2.54/2P	Connector, screw MPT0.5/2-2.54
nRF24L01 VoIP Application Board	PCB1		PCB
BC847BL	Q1	SM/SOT23	NPN BC847BL
470	R3	SM/0603	Resistor, 0.1W 0603/1%
100k	R4 R5	SM/0603	Resistor, 0.1W 0603/1%
56	R6 R7	SM/0603	Resistor, 0.1W 0603/1%
0	R8 R9 R12	SM/0603	Resistor, 0.1W 0603/1%
1k	R13 R16 R17 R18 R25	SM/0603	Resistor, 0.1W 0603/1%
47	R14	SM/0603	Resistor, 0.1W 0603/1%
220	R15	SM/0603	Resistor, 0.1W 0603/1%
22k	R19 R20 R21 R24	SM/0603	Resistor, 0.1W 0603/1%
4.7k	R22 R23	SM/0603	Resistor, 0.1W 0603/1%
SW6x6	SW1 SW2 SW3 SW4 SW5	SM/SW/6x6	Switch, TACT B3S1000
SPDT	SW6 SW7 SW8	TH/SW/OS1020	Switch, Mechanical OS102011MS2QN1
nRF24L01-VHR1-RM	U1	WHS-nRF24L01	Radio Module nRF24L01-VHR1-RM
LP2985AIM5-2.5	U2	SM/SOT23-5	Linear Regulator LP2985AIM5-2.5
12MM	U3 U5	BAT/12MM	Battery holder 12 mm 501
LM7301	U6	SM/SOT23-5	OpAmp LM7301IM5
5LUS	W1	10PIN/2ROW/LUS	Pin Row 825457-5
2LUS	W2	4PIN/2ROW/LUS	Pin row 825457-2
Jumper 2.54 mm	WJ1 WJ2 WJ3 WJ4		Jumper, 2.54mm M7565-05
	One in each corner under the board		Rubber Feet

Table 6. Application board BOM

Part	Designator	Footprint	Description
10n	C1 C3 C4 C5 C6 C11	SM/0402	Capacitor 0402/X7R/16V/10%
10u	C2 C13 C22	SM/0805	Capacitor 0805/X5R/6V3/15%
1.0n	C7	SM/0402	Capacitor 0402/X7R/50V/10%
33n	C8	SM/0402	Capacitor 0402/X7R/16V/10%
4.7p	C9	SM/0402	Capacitor 0402/NP0/50V/5%
2.2n	C10	SM/0402	Capacitor 0402/X7R/50V/10%
4.7p	C12	SM/0402	Capacitor 0402/NP0/50V/5%
1.0p	C14 C26	SM/0402	Capacitor 0402/NP0/50V/5%
15p	C15 C16	SM/0402	Capacitor 0402/NP0/50V/5%
22p	C17 C18	SM/0402	Capacitor 0402/NP0/50V/5%
47u	C23	CAPMP3528X210L	Capacitor,Tant, B TAJB476K004R
470n	C24	SM/0402	Capacitor 0402/X5R/6.3V/10%
2.2u	C25	SM/0603	Capacitor 0603/X5R/6.3V/10%
G	D1	0603_D	LED, Green EL19-21UGC
4.7n	L1	SM/0402	Inductor, RF LQP15MN4N7B02D
8.2n	L2	SM/0402	Inductor, RF LQP15MN8N2B02D
5.6n	L3	SM/0402	Inductor, RF LQP15MN5N6B02D
USB-A	P1	CON/USB-A/PLUG	USB connector 48037-2100
nRF24L01 VoIP USB Dongle Board	PCB1		PCB
PDTC115TU	Q1	SM/SOT323	NPN with resistors PDTC115TU
22k	R1	SM/0402	Resistor, 0.1W 0402/1%
22	R2 R3	SM/0402	Resistor, 0.1W 0402/1%
1M	R4	SM/0402	Resistor, 0.1W 0402/1%
100K	R5	SM/0402	Resistor, 0.1W 0402/1%
0	R8 R9 R21 R26	SM/0402	Resistor, 0.1W 0402/1%
10	R10	SM/0402	Resistor, 0.1W 0402/1%
2.2k	R11	SM/0402	Resistor, 0.1W 0402/1%
3.3k	R12	SM/0402	Resistor, 0.1W 0402/1%
470	R20	SM/0402	Resistor, 0.1W 0402/1%
10k	R23 R24	SM/0402	Resistor, 0.1W 0402/1%
1.5k	R25	SM/0402	Resistor, 0.1W 0402/1%
SN11220ACF	U1	TSQFP50P900X900X16 0-48L	USB Audio Controller SN11220ACF
nRF24L01	U2	QFN20-4x4	RF Transceiver nRF24L01
ATMega88	U3	QFN50P500X500X100- 33AL	Microcontroller ATmega88V- 10MU
93C46	U4	TSSOP-8	EEPROM, 1k AT93C46-10TU- 2.7
16MHz	Y1	XW4*2.5	Crystal TSX-10 16MHz
6.0MHz	Y2	TH/XO/CA-301	Crystal CA-301 6.000M-C
Connector	P3	0	ISP Connector BM06B-SRSS- TB(LF)(SN)

Table 7. USB dongle BOM

Part	Designator	Footprint	Description
100n	C1 C13	SM/0402	Capacitor 0402/X7R/16V/10%
22p	C2 C5	SM/0402	Capacitor 0402/NP0/50V/5%
15p	C3 C4	SM/0402	Capacitor 0402/NP0/50V/5%
4.7p	C6	SM/0402	Capacitor 0402/NP0/50V/5%
2.2n	C7	SM/0402	Capacitor 0402/X7R/50V/10%
1.0p	C9	SM/0402	Capacitor 0402/NP0/50V/5%
10n	C10 C14 C16	SM/0402	Capacitor 0402/X7R/16V/10%
1u	C11 C12	SM/0402	Capacitor 0402/X5R/6.3V/10%
33n	C15	SM/0402	Capacitor 0402/X7R/16V/10%
1.0n	C17	SM/0402	Capacitor 0402/X7R/50V/10%
0.8p	C18	SM/0402	Capacitor 0402/NP0/50V/5%
4.7n	L1	SM/0402	Inductor, RF LQP15MN4N7B02D
8.2n	L2	SM/0402	Inductor, RF LQP15MN8N2B02D
4.7n	L3	SM/0402	Inductor, RF LQP15MN4N7B02D
nRF24L01 VoIP RF Module Board	PCB1		PCB
10	R1 R3	SM/0402	Resistor, 0.1W 0402/1%
100k	R2 R9	SM/0402	Resistor, 0.1W 0402/1%
1M	R4	SM/0402	Resistor, 0.1W 0402/1%
390k	R5	SM/0402	Resistor, 0.1W 0402/1%
22k	R8	SM/0402	Resistor, 0.1W 0402/1%
XE3005	U1	TSSOP-20	Audio Codec XE3005I033TRLF
ATMega88	U3	QFN50P500X500X 100-33AL	Microcontroller ATmega88V- 10MU
nRF24L01	U4	QFN20-4X4	RF Transceiver nRF24L01
4.096MHz	Y1	TH/XO/CA-301	Crystal CSA309-4.096MABJ-UB
16MHz	Y2	XW4*2.5	Crystal TSX-10 16MHz

Table 8. Radio module BOM

5.2 Application board schematics

