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nRF24LU1+

Single Chip 2.4 GHz Transceiver with USB Microcontroller and Flash Memory

Product Specification v1.1

Key Features

- nRF24L01+ compatible RF transceiver
- Worldwide 2.4 GHz ISM band operation
- Up to 2 Mbps on air data rate
- Enhanced ShockBurst™ hardware link layer
- Air compatible with nRF24LU1, nRF24LE1, nRF24L01+, nRF24L01, nRF2401A, nRF2402, nRF24E1 and nRF24E2
- Low cost external ±60 ppm 16 MHz crystal
- Full speed USB 2.0 compliant device controller
- Up to 12 Mbps USB transfer rate
- 2 control, 10 bulk/interrupt and 2 ISO endpoints
- Dedicated 512 bytes endpoint buffer RAM
- Software controlled pull-up resistor for D+
- PLL for full-speed USB operation
- Voltage regulator, 4.0 to 5.25V supply range
- Enhanced 8-bit 8051 compatible microcontroller
- Drop-in compatibility with nRF24LU1
- Reduced instruction cycle time
- 32-bit multiplication-division unit
- 16 or 32 kbytes of on-chip flash memory
- 2 kbytes of on-chip SRAM
- 6 general purpose digital input/output pins
- Hardware SPI slave and master, UART
- 3 16-bit timers/counters
- AES encryption/decryption co-processor
- Supports firmware upgrade over USB
- Supports FS2 hardware debugger
- Compact 32-pin 5x5mm QFN package

Applications

- Compact USB dongles for wireless peripherals
- USB dongles for mouse, keyboards and remotes
- USB dongle 3-in-1 desktop bundles
- USB dongle for advanced media center remote controls
- USB dongle for game controllers
- Toys

April 2010

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Data sheet status	
Objective product specification	This product specification contains target specifications for product development.
Preliminary product specification	This product specification contains preliminary data; supplementary data may be published from Nordic Semiconductor ASA later.
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RoHS statement

nRF24LU1+ where explicitly stated in this product specification meets the requirements of Directive 2002/95/EC of the European Parliament and of the Council on the Restriction of Hazardous Substances (RoHS). Complete hazardous substance reports as well as material composition reports for all active Nordic products can be found on our web site www.nordicsemi.com.

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1 Introduction

The nRF24LU1+ is a unique single chip solution for compact USB dongles. The internal nRF24L01+ 2.4 GHz RF transceiver supports a wide range of applications including PC peripherals, sports accessories and game peripherals.

With an air data rate of 2 Mbps combined with full speed USB, supporting up to 12 Mbps, the nRF24LU1+ meets the stringent performance requirements of applications such as wireless mouse, game controllers and media center remote controls with displays.

The nRF24LU1+ integrates:

- A nRF24L01+ 2.4 GHz RF transceiver
- A full speed USB 2.0 compliant device controller
- An 8-bit microcontroller
- 16 or 32 kbytes of flash memory

All this is packaged on a compact 5x5mm package, low cost external BOM.

With an internal voltage regulator that enables the chip to be powered directly from the USB bus, it does not require an external voltage regulator, saving cost and board space. With a fully integrated RF synthesizer and PLL for the USB no external loop filters, resonators or VCO varactor diodes are required. All that is needed is a low cost ±60ppm 16 MHz crystal, matching circuitry and the antenna.

The main benefits of nRF24LU1+ are:

- Very compact USB dongle
- Low cost external BOM
- No need for an external voltage regulator
- Single low cost ±60ppm 16 MHz crystal
- Flash memory for firmware upgrades

1.1 Prerequisites

In order to fully understand the product specification, a good knowledge of electronic and software engineering is necessary.

1.2 Writing conventions

This product specification follows a set of typographic rules that makes the document consistent and easy to read. The following writing conventions are used:

- Commands, bit state conditions, and register names are written in `Courier`.
- Pin names and pin signal conditions are written in **`Courier bold`**.
- Cross references are underlined and highlighted in blue.

1.3 Features

Features of the nRF24LU1+ include:

- Fast 8-bit MCU:
  - Intel MCS 51 compliant instruction set
  - Reduced instruction cycle time, up to 12x compared to legacy 8051
  - 32 bit multiplication – division unit
- Memory:
  - 16 or 32 kbytes of on-chip flash memory with security features
  - 2 kbytes of on-chip RAM memory
  - Pre-programmed USB bootloader in the on-chip flash memory.
- 6 programmable digital input/output pins configurable as:
  - GPIO
  - SPI master
  - SPI slave
  - External interrupts
  - Timer inputs
  - Full duplex serial port
  - Debug interface
- High performance 2.4 GHz RF-transceiver
  - True single chip GFSK transceiver
  - Enhanced ShockBurst™ link layer support in HW:
    - Packet assembly/disassembly
    - Address and CRC computation
    - Auto ACK and retransmit
  - On the air data rate 250 kbps, 1 Mbps or 2 Mbps
  - Digital interface (SPI) speed 0-8 Mbps
  - 125 RF channel option, with 79 (2.402 GHz-2.480 GHz) channels within 2.400 - 2.4835 GHz
  - Short switching time enable frequency hopping
  - Fully RF compatible with nRF24LXX
  - RF compatible with nRF2401A, nRF2402, nRF24E1, nRF24E2 in 250 kbps and 1 Mbps mode
- AES encryption/decryption HW-block with 128 bits key length
  - ECB – Electronic Code Book mode
  - CBC – Cipher Block Chaining
  - CFB – Cipher FeedBack mode
  - OFB – Output FeedBack mode
  - CTR – Counter mode
- Full speed USB 2.0 compliant device controller supporting:
  - Data transfer rates up to 12 Mbit/s
  - Control, Interrupt, Bulk and ISO data transfer
  - Endpoint 0 for control
  - 5 input and 5 output Bulk/Interrupt endpoints
  - 1 input and 1 output iso-synchronous endpoints
  - Total 512 bytes of USB buffer endpoint memory sharable between endpoints
  - On-chip USB transceiver PHY
  - On-chip pull-up resistor on D+ line with software controlled disconnect
- Power management function:
  - Low power design supporting fully static stop/ standby/ suspend modes
  - Programmable MCU clock frequency from 64 kHz to 16 MHz
  - On-chip voltage regulators supporting low power mode (supplied from USB power)
  - Watchdog and wakeup functionality running in low power mode

- On-chip oscillator and PLL to obtain full speed USB operation and to reduce the need for external components
- On-chip power on reset generator and brown-out detector
- On-chip support for FS2 and nRFprobe™ HW debugger, supported by Keil development tools.
- Complete firmware platform available:
  - Hardware abstraction layer (HAL) Functions
  - USB library Functions
  - Standard and HID specific USB Requests and Descriptors
  - nRF24LU1+ Library functions
  - AES HAL
  - Application examples
  - Device Firmware Upgrade

1.4 Block diagram

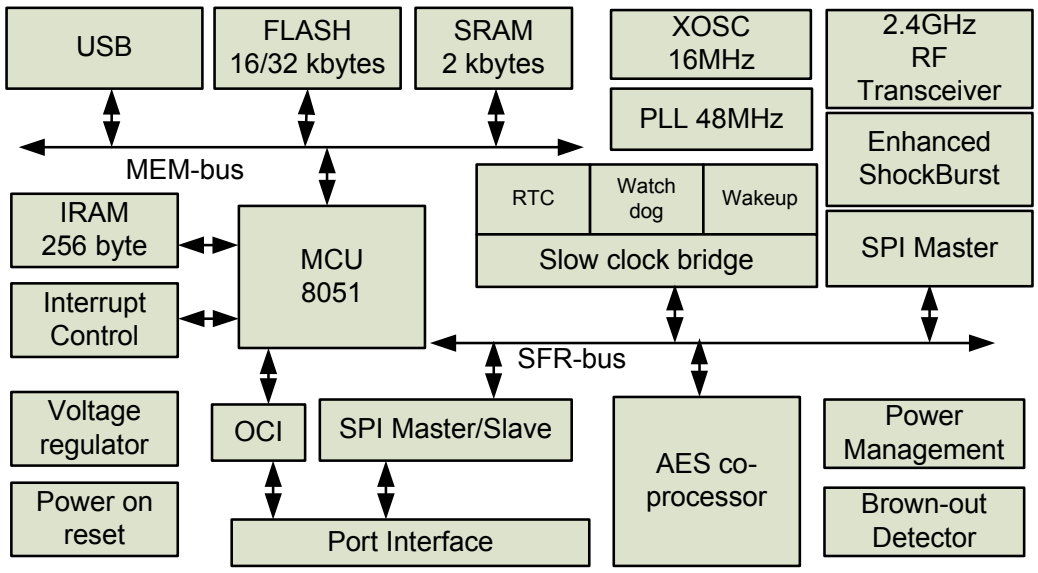

Figure 1. nRF24LU1+ block diagram

To find more information on the block diagram, see Table 1.

Name	Reference
USB	chapter 7 on page 63
FLASH	chapter 17 on page 135
SRAM	chapter 15 on page 127
2.4 GHz RF transceiver	chapter 6 on page 26
XOSC	section 24.2 on page 176
Enhanced ShockBurst™	section 6.4 on page 32
IRAM	chapter 16 on page 134
MCU	chapter 14 on page 119
RTC, Watchdog and Wakeup	chapter 19 on page 160
SPI Master	chapter 9 on page 99
Interrupt control	chapter 21 on page 170
SPI master/slave	chapter 9 on page 99 and chapter 10 on page 101
AES co-processor	chapter 8 on page 94
Power management	chapter 20 on page 165
Brown-out detector	section 17.4 on page 139

Table 1. Block diagram cross references

1.5 Typical system usage

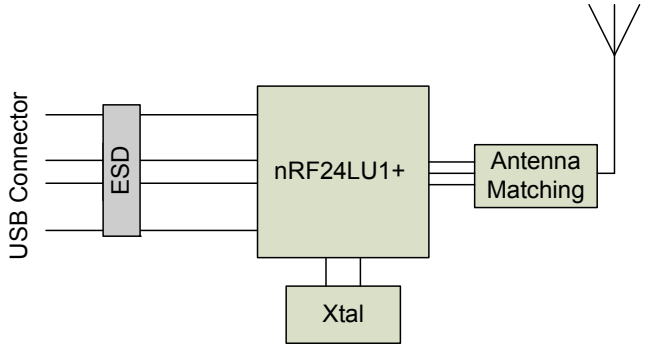

Figure 2. Typical system usage

2 Pin Information

2.1 Pin Assignments

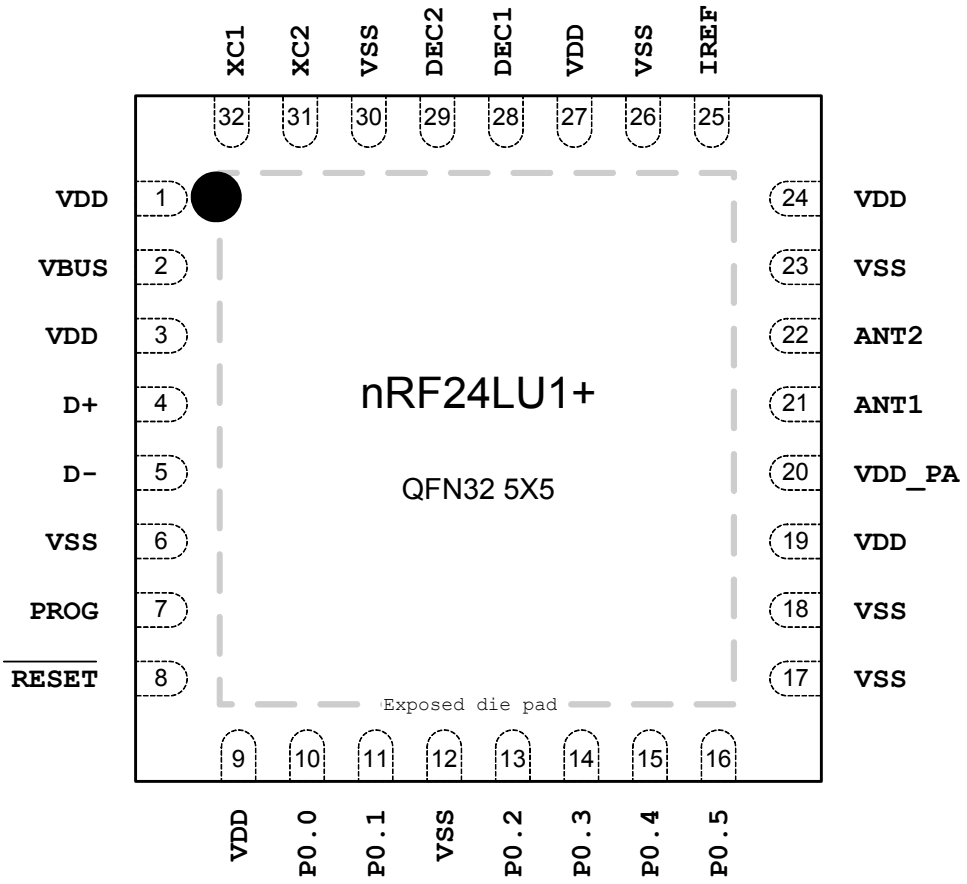

Figure 3. nRF24LU1+ pin assignment (top view) for a QFN32 5x5 mm package.

2.2 Pin Functions

Pin	Name	Type	Description
21, 22	ANT1, ANT2	RF	Antenna connection
5, 4	D-, D+	Digital I/O	USB data
28, 29	DEC1, DEC2	Power	Positive Digital Supply output for de-coupling purposes
25	IREF	Analog Input	Reference current output.
10, 11, 13, 14, 15, 16	P0.0 – P0.5	Digital I/O	General purpose data Port 0, bit 0 - 5. See Table 99. on page 118 for alternative pin functions.
7	PROG	Digital Input	Enables SPI flash programming
8	RESET	Digital Input	Reset for microcontroller, active low
2	VBUS	Power	USB power connection
1, 3, 9, 19, 24, 27	VDD	Power	Alternative power supply pins. The VDD pins must always be connected and de-coupled externally.
20	VDD_PA	Power Output	Power supply (+1.8V) to Power Amplifier
6, 12, 17, 18, 23, 26, 30	VSS	Power	Ground (0V)
32, 31	XC1, XC2	Analog Input	Crystal connection
	Exposed die pad	Power/heat relief	Not connected

Table 2. nRF24LU1+ pin functions

2.2.1 Antenna pins

ANT1 and ANT2 are connections for the external antenna (both receive and transmit).

2.2.2 USB pins

D- and D+ are the connections to the USB data lines. External ESD protection is recommended.

2.2.3 Power supply pins

VBUS and VSS are the power supply and ground pins. The nRF24LU1+ can operate from a single power supply.

The nRF24LU1+ contains an on-chip regulator that produces +3.3V on the VDD pins, from the VBUS supply line (4.0 – 5.25 V). Alternatively, the VBUS pin can be left open and the VDD pins may be fed from an external 3.3V supply. In this case, the on-chip 3.3V regulator is switched off.

Additional on-chip regulators produce voltages for internal analog and digital functions blocks. External decoupling capacitors are required on DEC1 and DEC2.

VDD_PA is a 1.8V output that is used to switch on an external RF Power Amplifier.

2.2.4 PROG pin

When set high this pin enables external SPI flash programming and Port 0 is configured as a slave SPI port.

The PROG pin needs an external pull-down resistor.

2.2.5 Reference current pins

The **IREF** pin must be connected to an external resistor.

2.2.6 Port pins

P0.0 – **P0.5** are six general purpose I/O pins. Their functions are described in chapter 13 on page 116.

2.2.7 External RESET Pin

A logic 0 on the RESET pin forces the nRF24LU1+ to a known start-up state.

2.2.8 Crystal oscillator pins

XC1 and **XC2** are connections to an external crystal.

3 Absolute Maximum Ratings

Maximum ratings are the extreme limits that you can expose the nRF24LU1+ to without permanently damaging it. Exposure to absolute maximum ratings for prolonged periods of time may affect device reliability.

Operating conditions	Minimum	Maximum	Units
Supply voltages			
VBUS	-0.3	+5.75	V
VSS		0	V
VDD	-0.3	+3.6	V
Input voltage			
VI	-0.3	+3.6	V
Temperatures			
Operating Temperature	-40	+85	°C
Storage Temperature	-40	+125	°C

Table 3. Absolute maximum ratings

Attention!
Observe precaution for handling
Electrostatic Sensitive Device.

HBM (Human Body Model): Class 1C

4 Operating Conditions

Symbol	Parameter (condition)	Notes	Min.	Typ.	Max.	Units
VBUS	Supply voltage		4.0	5	5.25	V
VDD	Alternative supply voltage		3.05	3.27	3.5	V
TEMP	Operating Temperature		-40	+27	+85	ºC

Table 4. Operating conditions

5 Electrical Specifications

This section contains electrical and timing specifications.

5.1 Power consumption and timing characteristics

Symbol	Parameter (condition)	Notes	Min.	Typ.	Max.	Units
I_{OP}	Average supply current in operating mode	a		24		mA
$I_{STANDBY}$	Supply current in standby mode	b		480		µA
	MCU					
$I_{MCU16MPLL}$	Running @ 16 MHz, generated from PLL			6.3		mA
$I_{MCU12MPLL}$	Running @ 12 MHz, generated from PLL			5		mA
$I_{MCU8MPLL}$	Running @ 8 MHz, generated from PLL			4		mA
$I_{MCU4MPLL}$	Running @ 4 MHz, generated from PLL			3		mA
$I_{MCU1.6MPLL}$	Running @ 1.6 MHz, generated from PLL			2		mA
$I_{MCU4MXO}$	Running @ 4 MHz, generated from XO			2.4		mA
$I_{MCU1.6MXO}$	Running @ 1.6 MHz, generated from XO			1.75		mA
$I_{MCU.32MXO}$	Running @ 0.32 MHz, generated from XO			1.1		mA
$I_{MCU64KXO}$	Running @ 0.064 MHz MHz, generated from XO			1		mA
Trst_act	From RESET to MCU active				2	ms
Tint_act	From INTERRUPT to MCU active				300	µs
Tact_stby	MCU from active to standby	c			32	µs
	RF Transceiver					
I_{TX}	RF Transceiver TX current @0dBm output power			11.1		mA
	RF Transceiver RX current @ 2 Mbps			13.3		mA
I_{RX}	RF Transceiver RX current @ 1 Mbps			12.9		mA
Tstby2a	RF Transceiver from standby to active	c			130	µs
Trst_radio	From RESET to RF Transceiver power down				50	ms
	USB					
I_{USB}	USB active current			4.4		mA
Tusb_wh	USB wakeup from host				500	µs
Tusb_wmcu	USB wakeup from MCU				300	µs
Tusbact_susp	USB from active to suspend	c			32	µs
	PLL					
Tplloff_on	PLL from off to on time	c d			250	µs
Tpllon_off	PLL from on to off time	c d			32	µs

a. MCU running radio receive at 2 Mbps and USB transmit
b. When MCU is in standby, USB is suspended and the RF Transceiver is in standby
c. Measured from start of the software instruction which executes the change of mode, see also Table 15.
d. Only possible when USB is in suspend mode

Table 5. Power consumption and timing characteristics

5.2 RF transceiver characteristics

Symbol	Parameter (condition)	Notes	Min.	Typ.	Max.	Units
	General RF conditions					
f_{OP}	Operating frequency	a	2400		2525	MHz
PLL_{res}	PLL Programming resolution			1		MHz
f_{XTAL}	Crystal frequency			16		MHz
Δf_{250}	Frequency deviation @ 250 kbps			±160		kHz
Δf_{1M}	Frequency deviation @ 1 Mbps			±160		kHz
Δf_{2M}	Frequency deviation @ 2 Mbps			±320		kHz
R_{GFSK}	Air data rate	b	250		2000	kbps
$F_{CHANNEL\ 1M}$	Non-overlapping channel spacing @ 250 kbps/1 Mbps)	c		1		MHz
$F_{CHANNEL\ 2M}$	Non-overlapping channel spacing @ 2 Mbps			2		MHz
	Transmitter operation					
P_{RF}	Maximum output power	d		0	+4	dBm
P_{RFC}	RF power control range		16	18	20	dB
P_{RFCR}	RF power accuracy				±4	dB
P_{BW2}	20dB bandwidth for modulated carrier (2 Mbps)			1800	2000	kHz
P_{BW1}	20dB bandwidth for modulated carrier (1 Mbps)			950	1100	kHz
P_{BW250}	20dB bandwidth for modulated carrier (250 kbps)			700	800	kHz
$P_{RF1.2}$	1^{st} Adjacent Channel Transmit Power 2 MHz (2 Mbps)				-20	dBc
$P_{RF2.2}$	2^{nd} Adjacent Channel Transmit Power 4 MHz (2 Mbps)				-45	dBc
$P_{RF1.1}$	1^{st} Adjacent Channel Transmit Power 1 MHz (1 Mbps)				-20	dBc
$P_{RF2.1}$	2^{nd} Adjacent Channel Transmit Power 2 MHz (1 Mbps)				-40	dBc
$P_{RF1.250}$	1^{st} Adjacent Channel Transmit Power 1 MHz (250 kbps)				-25	dBc
$P_{RF2.250}$	2^{nd} Adjacent Channel Transmit Power 2 MHz (250 kbps)				-40	dBc
	Receiver operation					
RX_{MAX}	Maximum received signal at < 0.1% BER			0		dBm
RX_{SENS}	Sensitivity (0.1% BER) @ 2 Mbps			-82		dBm
RX_{SENS}	Sensitivity (0.1% BER) @ 1 Mbps			-85		dBm
RX_{SENS}	Sensitivity (0.1% BER) @ 250 kbps	e		-94		dBm
RX selectivity according to ETSI EN 300 440-1 V1.3.1 (2001-09) page 27						
C/I_{CO}	C/I co-channel (2 Mbps)			7		dBc
C/I_{1ST}	1^{st} ACS (Adjacent Channel Selectivity), C/I 2 MHz (2 Mbps)			3		dBc
C/I_{2ND}	2^{nd} ACS, C/I 4 MHz (2 Mbps)			-17		dBc

Symbol	Parameter (condition)	Notes	Min.	Typ.	Max.	Units
C/I_{3RD}	3^{rd} ACS, C/I 6 MHz (2 Mbps)			-21		dBc
C/I_{Nth}	N^{th} ACS, C/I f_i > 12 MHz (2 Mbps)	f		-40		dBc
C/I_{Nth}	N^{th} ACS, C/I f_i > 36 MHz (2 Mbps)			-48		dBc
C/I_{CO}	C/I co-channel (1 Mbps)			9		dBc
C/I_{1ST}	1^{st} ACS, C/I 1 MHz (1 Mbps)			8		dBc
C/I_{2ND}	2^{nd} ACS, C/I 2 MHz (1 Mbps)			-20		dBc
C/I_{3RD}	3^{rd} ACS, C/I 3 MHz (1 Mbps)			-30		dBc
C/I_{Nth}	N^{th} ACS, C/I f_i > 6 MHz (1 Mbps)			-40		dBc
C/I_{Nth}	N^{th} ACS, C/I f_i > 25 MHz (1 Mbps)	f		-47		dBc
C/I_{CO}	C/I co-channel (250 kbps)			12		dBc
C/I_{1ST}	1^{st} ACS, C/I 1 MHz (250 kbps)			-12		dBc
C/I_{2ND}	2^{nd} ACS, C/I 2 MHz (250 kbps)			-33		dBc
C/I_{3RD}	3^{rd} ACS, C/I 3 MHz (250 kbps)			-38		dBc
C/I_{Nth}	N^{th} ACS, C/I f_i > 6 MHz (250 kbps)			-50		dBc
C/I_{Nth}	N^{th} ACS, C/I f_i > 25 MHz (250 kbps)	f		-60		dBc
RX selectivity with nRF24L01 equal modulation on interfering signal (Pin = -67dBm for wanted signal)						
C/I_{CO}	C/I co-channel (2 Mbps) (modulated carrier)			11		dBc
C/I_{1ST}	1^{st} ACS (Adjacent Channel Selectivity), C/I 2 MHz (2 Mbps)			4		dBc
C/I_{2ND}	2^{nd} ACS, C/I 4 MHz (2 Mbps)			-18		dBc
C/I_{3RD}	3^{rd} ACS, C/I 6 MHz (2 Mbps)			-24		dBc
C/I_{Nth}	N^{th} ACS, C/I f_i > 12 MHz (2 Mbps)			-40		dBc
C/I_{Nth}	N^{th} ACS, C/I f_i > 36 MHz (2 Mbps)			-48		dBc
C/I_{CO}	C/I co-channel (1 Mbps)			12		dBc
C/I_{1ST}	1^{st} ACS, C/I 1 MHz (1 Mbps)			8		dBc
C/I_{2ND}	2^{nd} ACS, C/I 2 MHz (1 Mbps)			-21		dBc
C/I_{3RD}	3^{rd} ACS, C/I 3 MHz (1 Mbps)			-30		dBc
C/I_{Nth}	N^{th} ACS, C/I f_i > 6 MHz (1 Mbps)			-40		dBc
C/I_{Nth}	N^{th} ACS, C/I f_i > 25 MHz (1 Mbps)			-50		dBc
C/I_{CO}	C/I co-channel (250 kbps)			7		dBc
C/I_{1ST}	1^{st} ACS, C/I 1 MHz (250 kbps)			-12		dBc
C/I_{2ND}	2^{nd} ACS, C/I 2 MHz (250 kbps)			-34		dBc
C/I_{3RD}	3^{rd} ACS, C/I 3 MHz (250 kbps)			-39		dBc
C/I_{Nth}	N^{th} ACS, C/I f_i > 6 MHz (250 kbps)			-50		dBc
C/I_{Nth}	N^{th} ACS, C/I f_i > 25 MHz (250 kbps)			-60		dBc
RX intermodulation performance according to Bluetooth specification version 2.0, 4^{th} November 2004, page 42						
P_IM(6) @ 2 Mbps	Input power of IM interferers at 6 and 12 MHz distance from wanted signal	g		-42		dBm
P_IM(8) @ 2Mbps	Input power of IM interferers at 8 and 16 MHz distance from wanted signal	g		-38		dBm

Symbol	Parameter (condition)	Notes	Min.	Typ.	Max.	Units
P_IM(10) @ 2Mbps	Input power of IM interferers at 10 and 20 MHz distance from wanted signal	g		-37		dBm
P_IM(3) @ 1Mbps	Input power of IM interferers at 3 and 6 MHz distance from wanted signal	g		-36		dBm
P_IM(4) @ 1Mbps	Input power of IM interferers at 4 and 8 MHz distance from wanted signal	g		-36		dBm
P_IM(5) @ 1Mbps	Input power of IM interferers at 5 and 10 MHz distance from wanted signal	g		-36		dBm
P_IM(3) @ 250 kbps	Input power of IM interferers at 3 and 6 MHz distance from wanted signal	g		-36		dBm
P_IM(4) @ 250 kbps	Input power of IM interferers at 4 and 8 MHz distance from wanted signal	g		-36		dBm
P_IM(5) @ 250 kbps	Input power of IM interferers at 5 and 10 MHz distance from wanted signal	g		-36		dBm

a. Usable band is determined by local regulations.
b. Data rate in each burst on-air.
c. The minimum channel spacing is 1 MHz.
d. Antenna load impedance = 15Ω + j88Ω.
e. For 250 kpbs sensitivity, frequencies which are integer multiples of 16 MHz (2400, 2416 and so on,) sensitivity is reduced.
f. Narrow Band (In Band) Blocking measurements:
0 to ±40 MHz; 1 MHz step size
For Interferer frequency offsets n*2*fxtal, blocking performance is degraded by approximately 5dB compared to adjacent figures.
g. Wanted signal level at Pin = -64dBm. Two interferers with equal input power are used. The interferer closest in frequency is unmodulated, the other interferer is modulated equal with the wanted signal. The input power of interferers where the sensitivity equals BER = 0.1% is presented.

Table 6. RF Transceiver specifications

5.3 USB interface

The USB interface electrical performance is compliant with the USB specification 2.0.

Characteristic	Symbol	Conditions	Min.	Typ.	Max	Unit
Electrical characteristics						
Input high voltage (driven)	VIH		2.0			V
Input low voltage	VIL				0.8	V
Differential input sensitivity	VDI	|(D+) – (D-)|	0.2			V
Differential common mode range	VCM	Includes VDI range	0.8		2.5	V
Single ended receiver threshold	VSE		0.8		2.0	V
Single ended receiver hysteresis	VSEH			200		mV
Output low voltage	VOL		0		0.3	V
Output high voltage	VOH		2.8		3.6	V
Differential output signal cross-point voltage	VCRS		1.3		2.0	V
Internal pull-up resistor (Standby mode)	R_{PU1}		900	1100	1575	Ω
Internal pull-up resistor (Active mode)	R_{PU2}		1425	2100	3090	Ω
Termination voltage connected to R_{PU}	VTRM		3.05		3.5	V
Output driver resistance (does not include the series resistance)	ZDRV	Steady state drive		15		Ω
Timing characteristics						
Driver rise time	TFR	CL=50pF	4		20	ns
Driver fall time	TFF	CL=50pF	4		20	ns
Rise/fall time matching	TFRFF	TRF / TFF	90		111	%
Transceiver pad capacitance	CIN	Pad to ground			20	pF

Table 7. USB interface characteristics

5.4 Flash memory

Characteristic	Symbol	Conditions	Min.	Typ.	Max	Unit
Endurance	Nendur		1000			cycles
Data retention	Tret	25°C	100			years

Table 8. Flash memory characteristics

Name	Size	Unit
Flash memory MainBlock	32768	bytes
Flash InfoPage	512	bytes
Flash page size	512	bytes

Table 9. Flash memory and page size

5.5 Crystal specifications

Symbol	Parameter (condition)	Notes	Min.	Typ.	Max.	Units
f_{NOM}	Nominal frequency (parallel resonant)			16.000		MHz
f_{TOL}	Frequency tolerance	a b			±60	ppm
C_L	Load capacitance			9	16	pF
C_0	Shunt capacitance			3	7	pF
ESR	Equivalent series resistance			50	100	Ω
P_D	Drive level				100	µW

a. Includes initial accuracy, stability over temperature, aging and frequency pulling due to incorrect load capacitance.
b. Frequency regulations in certain regions set tighter requirements on frequency tolerance (for example Japan and South Korea max ±50ppm).

Table 10. Crystal specifications

5.6 DC Electrical Characteristics

Symbol	Parameter (condition)	Notes	Min.	Typ.	Max.	Units
	Operating conditions					
VBUS	Supply voltage		4.0	5.0	5.25	V
TEMP	Operating Temperature		-40	+27	+85	ºC
	On-chip voltage regulators					
VDD	Output voltage	a	3.05	3.27	3.5	V
IVDD	External load current				2	mA

a. Also valid for VDD input voltage.

Table 11. DC characteristics

Symbol	Parameter (condition)	Notes	Min.	Typ.	Max.	Units
VIH	HIGH level input voltage		0.7 VDD		VDD	V
VIL	LOW level input voltage		VSS		0.3 VDD	V

Table 12. Digital input pin

Symbol	Parameter (condition)	Notes	Min.	Typ.	Max.	Units
VOH	HIGH level output voltage (IOH= -1.0mA)	a	VDD-0.3		VDD	V
VOL	LOW level output voltage (IOL= 1.0mA))		VSS		0.3	V

a. When the nRF24LU1+ is supplied from VBUS, there is a limit (IVDD) on the current that can be drawn from VDD by external devices. Current sourced by high outputs are supplied to external devices for this purpose.

Table 13. Digital output pin