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nRF24LU1+ OTP

Single Chip 2.4 GHz Transceiver with USB Microcontroller and OTP Memory

Product Specification v1.0

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, nRF24LU1+, nRF24LE1 OTP, 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 and nRF24LU1+ except for programming
- Reduced instruction cycle time
- 32-bit multiplication-division unit
- 16 + 1 kbytes of on-chip OTP 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
- 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

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October 2009

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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.
Product specification	This product specification contains final product specifications. Nordic Semiconductor ASA reserves the right to make changes at any time without notice in order to improve design and supply the best possible product.

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Revision History

Date	Version	Description
October 2009	1.0	Product specification

RoHS statement

nRF24LU1+ OTP 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.

Contents

1 Introduction

The nRF24LU1+ OTP 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+ OTP meets the stringent performance requirements of applications such as wireless mice, game controllers and media center remote controls with displays.

The nRF24LU1+ OTP integrates:

- A nRF24L01+ 2.4 GHz RF transceiver
- A full speed USB 2.0 compliant device controller
- An 8-bit microcontroller
- 17 kbytes of OTP 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 ±60 ppm 16 MHz crystal, matching circuitry and the antenna.

The main benefits of nRF24LU1+ OTP are:

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

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+ OTP 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 + 1 kbytes of on-chip OTP memory with security features
  - 2 kbytes of on-chip RAM memory
- 6 programmable digital input/output pins configurable as:
  - GPIO
  - SPI master
  - SPI slave
  - External interrupts
  - Timer inputs
  - Full duplex serial port
- 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 operation, 79 (2.402-2.81 GHz) channels within 2.400 - 2.4853 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 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

- Complete firmware platform available:
  - Hardware abstraction layer (HAL) Functions
  - USB library Functions
  - Standard and HID specific USB Requests and Descriptors
  - nRF24LU1+ OTP Library functions
  - AES HAL
  - Application examples

1.4 Block diagram

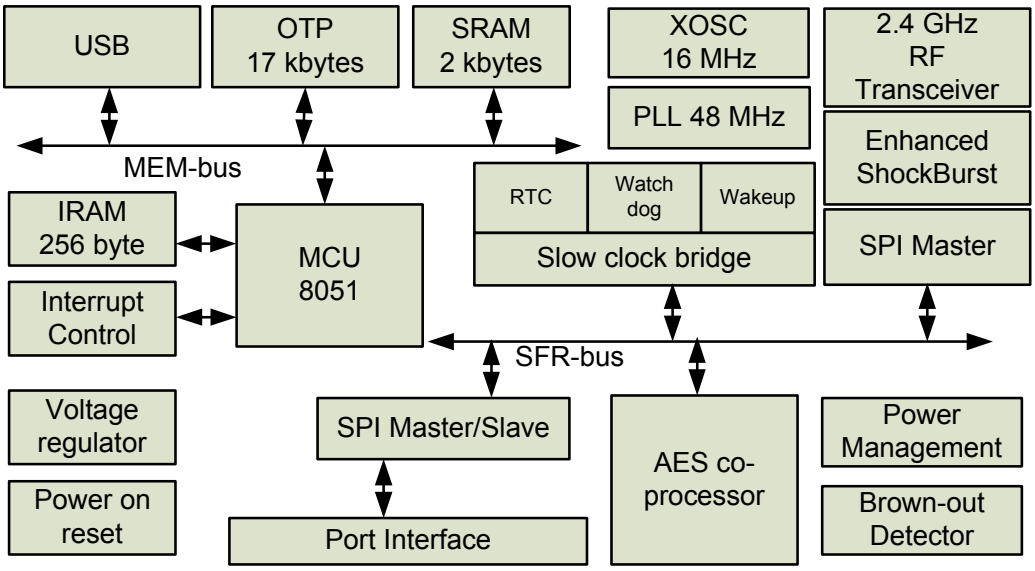

Figure 1. nRF24LU1+ OTP block diagram

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

Name	Reference
USB	chapter 7 on page 63
OTP	chapter 17 on page 135
SRAM	chapter 15 on page 127
2.4 GHz RF transceiver	chapter 6 on page 26
XOSC	section 23.2 on page 168
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 153
SPI Master	chapter 9 on page 98
Interrupt control	chapter 21 on page 163
SPI master/slave	chapter 9 on page 98 and chapter 10 on page 100
AES co-processor	chapter 8 on page 93
Power management	chapter 20 on page 158
Brown-out detector	section 17.4 on page 139

Table 1. Block diagram cross references

1.5 Typical system usage

Figure 2. shows an nRF24LU1+ OTP device designed for use as a single-chip USB dongle, with optional ESD (electrostatic discharge) protection.

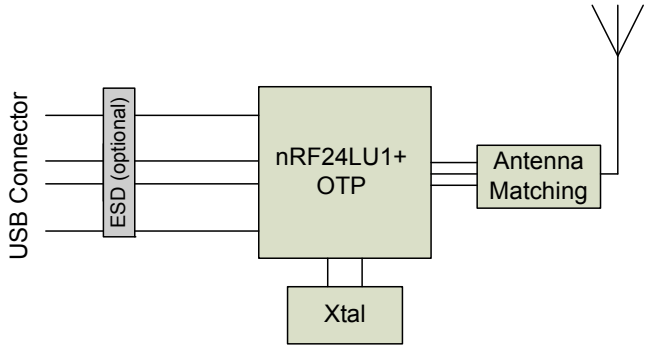

Figure 2. Typical system usage

2 Pin Information

2.1 Pin Assignments

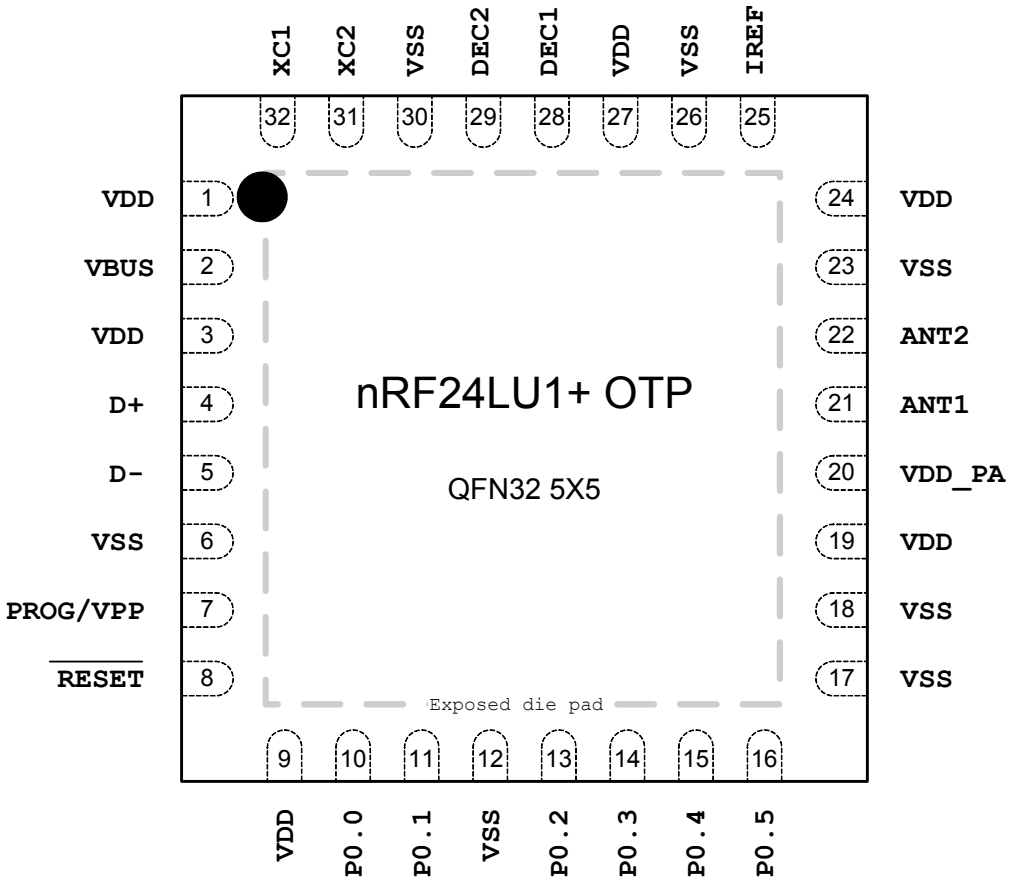

Figure 3. nRF24LU1+ OTP pin assignment (top view) for a QFN32 5x5 mm package.

2.2 Pin Functions

Pin	Name	Type	Description
21, 22	ANT1, ANT2	RF	Differential antenna connection (TX and RX)
5, 4	D-, D+	Digital I/O	Differential USB connection. External ESD protection is recommended.
28, 29	DEC1, DEC2	Power	Power supply outputs for de-coupling purposes
25	IREF	Analog Input	Device reference current output. To be connected to reference resistor on PCB.
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/VPP	Digital Input high voltage	Enable SPI OTP interface
8	RESET	Digital Input	Reset for microcontroller, active low
2	VBUS	Power	USB power supply (+4.0V to +5.25V DC)
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 output (+1.8V) for on-chip RF power amplifier
6, 12, 17, 18, 23, 26, 30	VSS	Power	Ground (0V)
32, 31	XC1, XC2	Analog Input	Connection for 16 MHz crystal
	Exposed die pad	Power/heat relief	Not connected

Table 2. nRF24LU1+ OTP pin functions

2.2.1 Power supply pins

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

The nRF24LU1+ OTP contains an on-chip regulator that produces +3.3V on the VDD pins, from the VBUS supply line (4.0 – 5.25V). 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.

2.2.2 PROG/VPP pin

When set high (>3V) this pin enables external SPI access to the OTP memory, and Port 0 is configured as a slave SPI port. With an external pull-down resistor, the chip can be returned to normal operation.
For SPI programming of the OTP, the PROG pin is also used as a high voltage supply during programming.

For programming the PROG pin must be raised to VPP (6.75V) before the first SPI command is issued. VPP must be held at that level until 0.1 ms after programming is completed. For another SPI command like READ, no VPP high voltage is needed, 3.3V is sufficient.

3 Absolute Maximum Ratings

Maximum ratings are the extreme limits that you can expose the nRF24LU1+ OTP 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 voltages			
PROG/VPP	-0.3	+7.0	V
Other pins	-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

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		22.6		mA
$I_{STANDBY}$	Supply current in standby mode	b		500		µA
	MCU					
$I_{MCU16MPLL}$	Running @ 16 MHz, generated from PLL			6.3		mA
$I_{MCU12MPLL}$	Running @ 12 MHz, generated from PLL			5.7		mA
$I_{MCU8MPLL}$	Running @ 8 MHz, generated from PLL			5.2		mA
$I_{MCU4MPLL}$	Running @ 4 MHz, generated from PLL			4.6		mA
$I_{MCU1.6MPLL}$	Running @ 1.6 MHz, generated from PLL			4.2		mA
$I_{MCU4MXO}$	Running @ 4 MHz, generated from XO			4.0		mA
$I_{MCU1.6MXO}$	Running @ 1.6 MHz, generated from XO			3.7		mA
$I_{MCU.32MXO}$	Running @ 0.32 MHz, generated from XO			3.5		mA
$I_{MCU64KXO}$	Running @ 0.064 MHz, generated from XO			3.5		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			3.0		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 14.
d. Only possible when USB is in suspend mode

Table 4. 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 @ 250kbps			±160		kHz
Δf_{1M}	Frequency deviation @ 1Mbps			±160		kHz
Δf_{2M}	Frequency deviation @ 2Mbps			±320		kHz
R_{GFSK}	Air data rate	b	250		2000	kbps
$F_{CHANNEL\ 1M}$	Non-overlapping channel spacing @ 250kbps/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 (2Mbps)				-20	dBc
$P_{RF2.2}$	2^{nd} Adjacent Channel Transmit Power 4 MHz (2Mbps)				-45	dBc
$P_{RF1.1}$	1^{st} Adjacent Channel Transmit Power 1 MHz (1Mbps)				-20	dBc
$P_{RF2.1}$	2^{nd} Adjacent Channel Transmit Power 2 MHz (1Mbps)				-40	dBc
$P_{RF1.250}$	1^{st} Adjacent Channel Transmit Power 1 MHz (250kbps)				-25	dBc
$P_{RF2.250}$	2^{nd} Adjacent Channel Transmit Power 2 MHz (250kbps)				-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 4MHz (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) @ 2Mbps	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) @ 250kbps	Input power of IM interferers at 3 and 6 MHz distance from wanted signal	g		-36		dBm
P_IM(4) @ 250kbps	Input power of IM interferers at 4 and 8 MHz distance from wanted signal	g		-36		dBm
P_IM(5) @ 250kbps	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 are 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 5. 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	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 6. USB interface characteristics

5.4 OTP memory

Characteristic	Symbol	Conditions	Min.	Typ.	Max	Unit
Programming voltage	VPP	-40 to +85°C	6.6	6.75	7.0	V
Data retention	Tret	85°C	>10			years

Table 7. OTP memory characteristics

Name	Size	Unit
OTP memory MainBlock	17408	bytes
OTP InfoPage	512	bytes

Table 8. OTP memory 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 (e.g. Japan and South Korea max ±50ppm).

Table 9. 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	b			2	mA

a. Also valid for VDD input voltage
b. Total current load from external circuitry on VDD pins

Table 10. 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 11. 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+ OTP 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 12. Digital output pin