nRF51824

Multiprotocol *Bluetooth*® low energy/2.4 GHz RF System on Chip

Product Specification v1.0

Key Features

- Automotive AEC-Q100 Grade 2 compliance (-40 to +105°C)
- 2.4 GHz transceiver
  - -93 dBm sensitivity in *Bluetooth*® low energy mode
  - 250 kbps, 1 Mbps BLE, 2 Mbps supported data rates
  - TX Power -20 to +4 dBm in 4 dB steps
  - TX Power -30 dBm Whisper mode
  - 13 mA peak RX, 10.5 mA peak TX (0 dBm)
  - 9.7 mA peak RX, 8 mA peak TX (0 dBm) with DC/DC
  - RSSI (1 dB resolution)
- ARM® Cortex™-M0 32 bit processor
  - 275 µA/MHz running from flash memory
  - 150 µA/MHz running from RAM
  - Serial Wire Debug (SWD)
- S100 series SoftDevice ready
- Memory
  - 256 kB embedded flash program memory
  - 16 kB RAM
- On-air compatibility with nRF24L series for 250 kbps and 2 Mbps
- Flexible Power Management
  - Supply voltage range 1.9 V to 3.6 V
  - 4.2 µs wake-up using 16 MHz RCOSC
  - 0.6 µA at 3 V OFF mode
  - 1.2 µA at 3 V in OFF mode + 1 region RAM retention
  - 2.6 µA at 3 V ON mode, all blocks IDLE
- 8/9/10 bit ADC - 8 configurable channels
- 31 General Purpose I/O Pins
- One 32 bit and two 16 bit timers with counter mode
- SPI Master/Slave
- Low power comparator
- Temperature sensor
- Two-wire Master (I2C compatible)
- UART (CTS/RTS)
- CPU independent Programmable Peripheral Interconnect (PPI)
- Quadrature Decoder (QDEC)
- AES HW encryption
- Real Timer Counter (RTC)
- Package: QFN48 6 x 6 mm

Applications

- *Bluetooth* Smart and proprietary 2.4 GHz systems
- Remote keyless entry
- Infotainment and media
- Tire pressure monitoring
- Cable replacement
- Diagnostics
- Sensor nodes
- Wireless charging

Liability disclaimer

Nordic Semiconductor ASA reserves the right to make changes without further notice to the product to improve reliability, function or design. Nordic Semiconductor ASA does not assume any liability arising out of the application or use of any product or circuits described herein.

Life support applications

Nordic Semiconductor's products are not designed for use in life support appliances, devices, or systems where malfunction of these products can reasonably be expected to result in personal injury. Nordic Semiconductor ASA customers using or selling these products for use in such applications do so at their own risk and agree to fully indemnify Nordic Semiconductor ASA for any damages resulting from such improper use or sale.

Contact details

For your nearest distributor, please visit www.nordicsemi.com.
Information regarding product updates, downloads, and technical support can be accessed through your My Page account on our home page.

Main office: Otto Nielsens veg 12
7052 Trondheim
Norway

Phone: +47 72 89 89 00
Fax: +47 72 89 89 89

Mailing address: Nordic Semiconductor
P.O. Box 2336
7004 Trondheim
Norway

RoHS and REACH statement

Nordic Semiconductor's products meet the requirements of Directive 2002/95/EC of the European Parliament and of the Council on the Restriction of Hazardous Substances (RoHS) and the requirements of the REACH regulation (EC 1907/2006) on Registration, Evaluation, Authorization and Restriction of Chemicals. The SVHC (Substances of Very High Concern) candidate list is continually being updated. Complete hazardous substance reports, material composition reports and latest version of Nordic's REACH statement can be found on our website www.nordicsemi.com.

Datasheet Status

Status	Description
Objective Product Specification (OPS)	This product specification contains target specifications for product development.
Preliminary Product Specification (PPS)	This product specification contains preliminary data; supplementary data may be published from Nordic Semiconductor ASA later.
Product Specification (PS)	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.

Revision History

Date	Version	Description
September 2016	1.0	Upgraded to Product Specification (PS).
August 2016	0.9	Added extended temperature range (+105°C instead of +85°C) for Automotive AEC-Q100 Grade 2 compliance.
November 2015	0.7	First release.

Table of contents

1 Introduction

The nRF51824 chip is an ultra-low power 2.4 GHz wireless System on Chip (SoC) integrating the nRF51 Series 2.4 GHz transceiver, a 32 bit ARM® Cortex™-M0 CPU, flash memory, and analog and digital peripherals. nRF51824 can support *Bluetooth*® low energy and a range of proprietary 2.4 GHz protocols, such as Gazell from Nordic Semiconductor.

The nRF51824 chip is fully qualified in accordance to AEC-Q100 Grade 2 specifications.

Fully qualified *Bluetooth* low energy stacks for nRF51824 are implemented in the S1x0 series of SoftDevices. The S1x0 series of SoftDevices are available for free and can be downloaded and installed on nRF51824 independent of your own application code.

1.1 Required reading

The following documentation is available for download from the Infocenter:

- *nRF51 Series Reference Manual*
- *nRF51824-PAN (Product Anomaly Notification)*

1.2 Writing conventions

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

- Command, event names, and bit state conditions, are written in `Lucida Console`.
- Pin names and pin signal conditions are written in **`Consolas.`**
- File names and User Interface components are written in **bold**.
- Internal cross references are italicized and written in ***semi-bold.***
- Placeholders for parameters are written in italic regular text font. For example, a syntax description of Connect will be written as:
  Connect*(TimeOut, AdvInterval)*.
- Fixed parameters are written in regular text font. For example, a syntax description of Connect will be written as:
  Connect(0x00F0, Interval).

2 Product overview

2.1 Block diagram

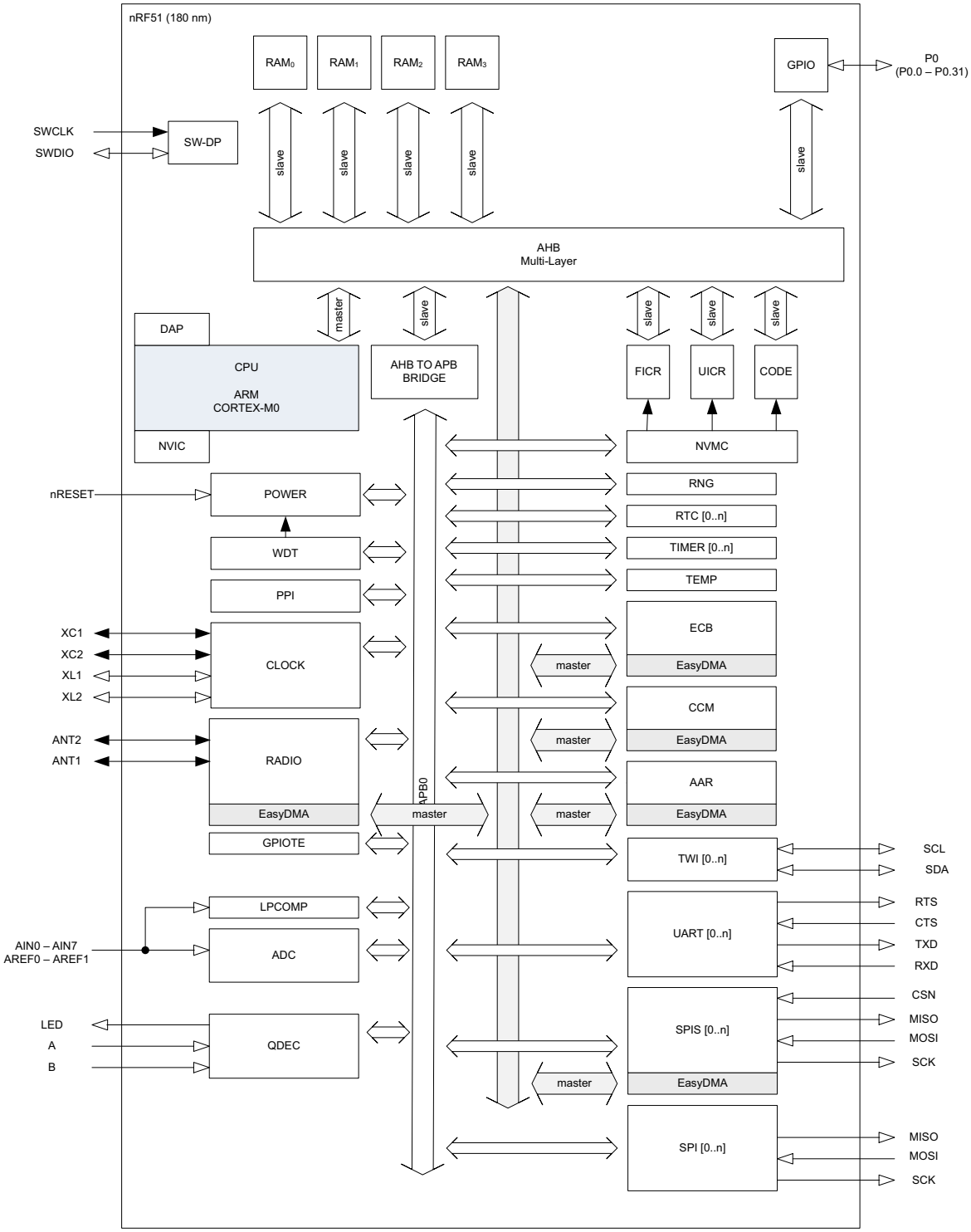

Figure 1 *Block diagram*

2.2 Pin assignments and functions

This section describes the pin assignment and the pin functions.

2.2.1 Pin assignment QFN48

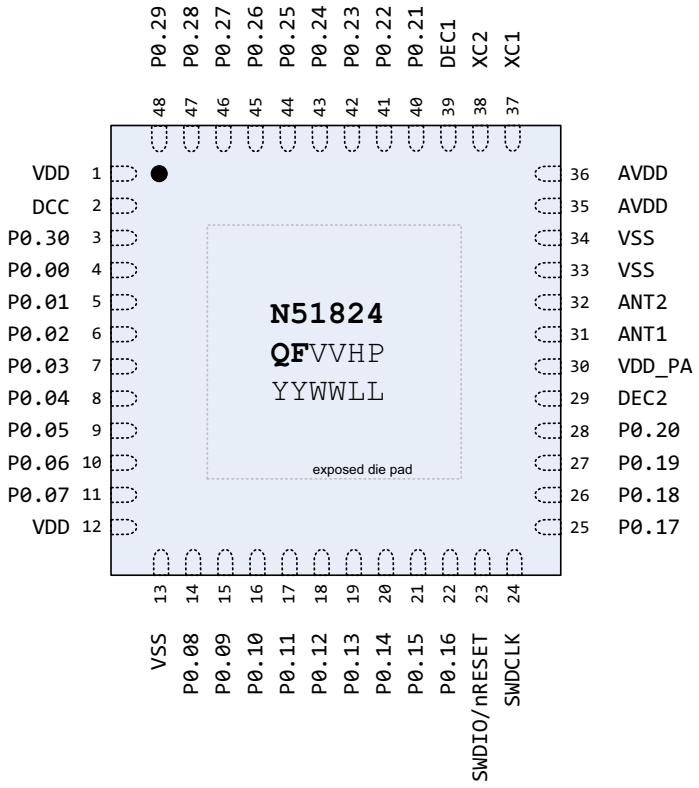

Figure 2 *Pin assignment - QFN48 packet*

Note: VV = Variant code, HP = Build code, YYWWLL = Tracking code.
For more information, see ***Section 10.6 "Code ranges and values"*** on page 61.

2.2.1.1 Pin functions QFN48

Pin	Pin name	Pin function	Description
1	VDD	Power	Power supply.
2	DCC	Power	DC/DC output voltage to external LC filter.
3	P0.30	Digital I/O	General purpose I/O pin.
4	P0.00 AREF0	Digital I/O Analog input	General purpose I/O pin. ADC/LPCOMP reference input 0.
5	P0.01 AIN2	Digital I/O Analog input	General purpose I/O pin. ADC/LPCOMP input 2.
6	P0.02 AIN3	Digital I/O Analog input	General purpose I/O pin. ADC/LPCOMP input 3.
7	P0.03 AIN4	Digital I/O Analog input	General purpose I/O pin. ADC/LPCOMP input 4.
8	P0.04 AIN5	Digital I/O Analog input	General purpose I/O pin. ADC/LPCOMP input 5.
9	P0.05 AIN6	Digital I/O Analog input	General purpose I/O pin. ADC/LPCOMP input 6.
10	P0.06 AIN7 AREF1	Digital I/O Analog input Analog input	General purpose I/O pin. ADC/LPCOMP input 7. ADC/LPCOMP reference input 1.
11	P0.07	Digital I/O	General purpose I/O pin.
12	VDD	Power	Power supply.
13	VSS	Power	Ground (0 V)[1].
14 to 22	P0.08 to P0.16	Digital I/O	General purpose I/O pin.
23	SWDIO/nRESET	Digital I/O	System reset (active low). Hardware debug and flash programming I/O.
24	SWDCLK	Digital input	Hardware debug and flash programming I/O.
25 to 28	P0.17 to P0.20	Digital I/O	General purpose I/O pin.
29	DEC2	Power	Power supply decoupling.
30	VDD_PA	Power output	Power supply output (+1.6 V) for on-chip RF power amp.
31	ANT1	RF	Differential antenna connection (TX and RX).
32	ANT2	RF	Differential antenna connection (TX and RX).
33, 34	VSS	Power	Ground (0 V).
35, 36	AVDD	Power	Analog power supply (Radio).
37	XC1	Analog input	Connection for 16/32 MHz crystal or external 16 MHz clock reference.
38	XC2	Analog output	Connection for 16/32 MHz crystal.
39	DEC1	Power	Power supply decoupling.

Pin	Pin name	Pin function	Description
40 to 44	P0.21 to P0.25	Digital I/O	General purpose I/O pin.
45	P0.26 AIN0 XL2	Digital I/O Analog input Analog output	General purpose I/O pin. ADC/LPCOMP input 0. Connection for 32.768 kHz crystal.
46	P0.27 AIN1 XL1	Digital I/O Analog input Analog input	General purpose I/O pin. ADC/LPCOMP input 1. Connection for 32.768 kHz crystal or external 32.768 kHz clock reference.
47, 48	P0.28 and P0.29	Digital I/O	General purpose I/O pin.

1. The exposed center pad of the QFN48 package must be connected to ground for proper device operation.

Table 1 *Pin functions QFN48 packet*

3 System blocks

The chip contains system-level features common to all nRF51 Series devices including clock control, power and reset, interrupt system, Programmable Peripheral Interconnect (PPI), watchdog, and GPIO.

System blocks which have a register interface and/or interrupt vector assigned are instantiated in the device address space. The instances of system blocks, their associated ID (for those with interrupt vectors), and base addresses are found in ***Table 15*** on page 28. Detailed functional descriptions, configuration options, and register interfaces can be found in the *nRF51 Series Reference Manual*.

3.1 CPU

The ARM® Cortex™-M0 CPU has a 16 bit instruction set with 32 bit extensions (Thumb-2® technology) that delivers high-density code with a small-memory-footprint. By using a single-cycle 32 bit multiplier, a 3-stage pipeline, and a Nested Vector Interrupt Controller (NVIC), the ARM Cortex-M0 CPU makes program execution simple and highly efficient.

The ARM Cortex Microcontroller Software Interface Standard (CMSIS) hardware abstraction layer for the ARM Cortex-M processor series is implemented and available for M0 CPU. Code is forward compatible with ARM Cortex M3 based devices.

3.2 Memory

All memory and registers are found in the same address space as shown in the Device Memory Map, see ***Figure 3***. Devices in the nRF51 Series use flash based memory in the code, FICR, and UICR regions. The RAM region is SRAM.

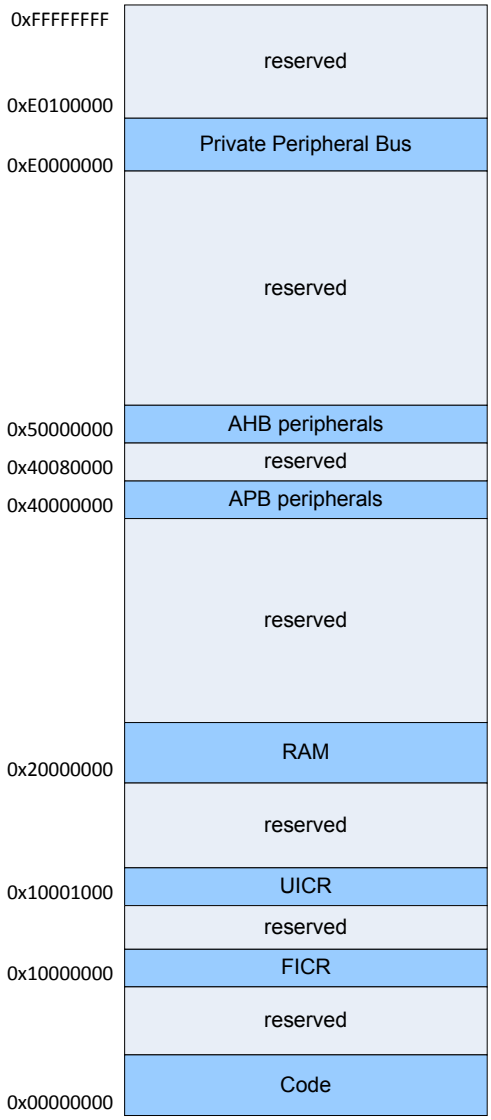

Figure 3 *Memory Map*

The embedded flash memory for program and static data can be programmed using In Application Programming (IAP) routines from RAM through the SWD interface, or in-system from a program executing from code area. The Non-Volatile Memory Controller (NVMC) is used for program/erase operations. Regions of flash memory can be protected from read, write, and erase by the Memory Protection Unit (MPU). A User Information Configuration Register (UICR) contains the lock byte for enabling readback protection to secure the IP, while individual block protection is controlled using registers which can only be cleared on chip reset.

3.2.1 Code organization

Chip variant	Code size	Page size	No of pages
nRF51824-QFAA	256 kB	1024 byte	256

Table 2 *Code organization*

3.2.2 RAM organization

RAM is divided into blocks for separate power management which is controlled by the POWER System Block. Each block is divided into two 4 kByte RAM sections with separate RAM AHB slaves.
Please see the *nRF51 Series Reference Manual* for more information.

Chip variant	RAM size	Block	Size
nRF51824-QFAA	16 kB	Block0 Block1	8 kB 8 kB

Table 3 *RAM organization*

How to organize the use of the RAM

For the best performance we recommend the following use of the RAM AHB slaves (Note that the Crypto consists of CCM, ECB, and AAR modules):

- If the Radio and Crypto buffers together are larger in size than one RAM section, the buffers should be separated so the memory used by the Radio is in one RAM section while the memory used by the Crypto is in another RAM section.
- The sections used by CODE should not be combined with sections used by the Radio, Crypto, or SPI.
- The Stack and Heap should be placed at the top section and should not be combined with sections used by the Radio, Crypto, or SPI.

Table 4 shows how memory allocated to different functions can be distributed between RAM sections for parallel access.

RAM Blocks/Sections		Radio buffers	Crypto buffers	SPIS buffers	CPU Stack/Heap	CODE	Global variables
Block0	RAM0	x	x				x
	RAM1					x	x
Block1	RAM2			x			x
	RAM3				x	x	x

Table 4 *RAM parallel access*

3.3 Memory Protection Unit (MPU)

The memory protection unit can be configured to protect all flash memory on the device from readback, or to protect blocks of flash from over-write or erase.

Chip variant	Flash block size	Number of protectable Flash blocks
nRF51824-QFAA	4 kB	64

Table 5 *MPU flash blocks*

3.4 Power management (POWER)

3.4.1 Power supply

nRF51824 supports two different power supply alternatives:

- Internal LDO setup
- DC/DC converter setup

See ***Table 17*** on page 30 for the voltage range on the different alternatives. See ***Chapter 11 "Reference circuitry"*** on page 64 for details on the schematic used for the different power supply alternatives.

3.4.1.1 Internal LDO setup

In internal LDO mode the DC/DC converter is bypassed (disabled) and the system power is generated directly from the supply voltage VDD. This mode could be used as the only option or in combination with the DC/DC converter setup. See ***Section 3.4.1.2 "DC/DC converter setup"*** for more details.

3.4.1.2 DC/DC converter setup

The nRF51 DC/DC buck converter transforms battery voltage to lower internal voltage with minimal power loss. The converted voltage is then available for the linear regulator input. The DC/DC converter can be disabled when the supply voltage drops to the lower limit of the voltage range so the LDO can be used for low supply voltages. When enabled, the DC/DC converter operation is automatically suspended between radio events when only the low current regulator is needed internally.

This feature is particularly useful for applications using battery technologies with nominal cell voltages higher than the minimum supply voltage with DC/DC enabled. The reduction in supply voltage level from a high voltage to a low voltage reduces the peak power drain from the battery. Used with a 3 V coin-cell battery, the peak current drawn from the battery is reduced by approximately 25%.

3.4.2 Power management

The power management system is highly flexible with functional blocks such as the CPU, Radio Transceiver, and peripherals having separate power state control in addition to the global System ON and OFF modes. In System OFF mode, RAM can be retained and the device state can be changed to System ON through Reset, GPIO DETECT signal, or LPCOMP ANADETECT signal. When in System ON mode, all functional blocks will independently be in IDLE or RUN mode depending on needed functionality.

Power management features:

- Supervisor HW to manage
  - Power on reset
  - Brownout reset
  - Power fail comparator
- System ON/OFF modes
- Pin wake-up from System OFF
  - Reset
  - GPIO DETECT signal
  - LPCOMP ANADETECT signal
- Functional block RUN/IDLE modes
- RAM retention in System OFF mode (8 kB blocks)

3.4.2.1 System OFF mode

In system OFF mode the chip is in the deepest power saving mode. The system's core functionality is powered down and all ongoing tasks are terminated. The only functionality that can be set up to be responsive is the Pin wake-up mechanism.

One or more blocks of RAM can be retained while in System OFF mode.

3.4.2.2 System ON mode

In system ON mode the system is fully operational and the CPU and selected peripherals can be brought into a state where they are functional and more or less responsive depending on the sub-power mode selected.

There are two sub-power modes:

- Low power
- Constant latency

Low Power

In Low Power mode the automatic power management system is optimized to save power. This is done by keeping as much as possible of the system powered down. The cost of this is that you will have varying CPU wakeup latency and PPI task response.

The CPU wakeup latency will be affected by the startup time of the 1V7 regulator. The PPI task response will vary depending on the resources required by the peripheral where the task originated.

The resources that could be involved are:

- 1V7 with the startup time $\mathbf{t_{1V7}}$
- 1V2 with the startup time $\mathbf{t_{1V2}}$
- One of the following clock sources
  - RC16 with the startup time $\mathbf{t_{START,RC16}}$
  - XO16M/XO32M with the startup time the clock management system $\mathbf{t_{XO}}$[1]

Constant Latency

In Constant Latency mode the system is optimized for keeping the CPU latency and the PPI task response constant and at a minimum. This is secured by forcing a set of base resources on while in sleep mode. The cost is that the system will have higher power consumption.

The following resources are kept active while in sleep mode:

- 1V7 regulator with the standby current of I_{1V7}
- 1V2 regulator. Here the current consumption is specified in combination with the clock source.
- One of the following clock sources:
  - RC16 with the standby current of $I_{1V2RC16}$
  - XO16M with the standby current of $I_{1V2XO16}$
  - XO32M with the standby current of $I_{1V2XO32}$

1. For the clock source XO16M and XO32M we assume that the crystal is already running (standby). This will give an increase of the power consumption in sleep mode given by $\mathbf{I_{STBY,X16M}}$ / $\mathbf{I_{STBY,X32M}}$.

3.5 Programmable Peripheral Interconnect (PPI)

The Programmable Peripheral Interconnect (PPI) enables peripherals to interact autonomously with each other using tasks and events independent of the CPU. The PPI allows precise synchronization between peripherals when real-time application constraints exist and eliminates the need for CPU activity to implement behavior which can be predefined using PPI.

Instance	Channel	Number of channels	Number of groups
PPI	0 - 15	16	4

Table 6 *PPI properties*

The PPI system has in addition to the fully programmable peripheral interconnections, a set of channels where the event (EEP) and task (TEP) endpoints are set in hardware. These fixed channels can be individually enabled, disabled, or added to PPI channel groups in the same way as ordinary PPI channels. See the *nRF51 Series Reference Manual* for more information.

Instance	Channel	Number of channels	Number of groups
PPI	20 - 31	12	4

Table 7 *Pre-programmed PPI channels*

3.6 Clock management (CLOCK)

The advanced clock management system can source the system clocks from a range of internal or external high and low frequency oscillators and distribute them to modules based upon a module's individual requirements. This prevents large clock trees from being active and drawing power when system modules needing this clock reference are not active.

If an application enables a module that needs a clock reference without the corresponding oscillator running, the clock management system will automatically enable the RC oscillator option and provide the clock. When the module goes back to idle, the clock management will automatically set the oscillator to idle. To avoid delays involved in starting a given oscillator, or if a specific oscillator is required, the application can override the automatic oscillator management so it keeps oscillators active when no system modules require the clock reference.

Clocks are only available in System ON mode and can be generated by the sources listed in ***Table 8***.

Clock	Source	Frequency options
High Frequency Clock (HFCLK)[1]	External Crystal (XOSC)	16/32 MHz[2]
	External clock reference[3]	16 MHz
	Internal RC Oscillator (RCOSC)	16 MHz
Low Frequency Clock (LFCLK)	External Crystal (XOSC)	32.768 kHz
	External clock reference[3]	32.768 kHz
	Synthesized from HFCLK	32.768 kHz
	Internal RC Oscillator (RCOSC)	32.768 kHz

1. External Crystal must be used for Radio operation.
2. The HFCLK will be 16 MHz for both the 16 and 32 MHz crystal option.
3. See the *nRF51 Series Reference Manual* for more details on external clock reference.

Table 8 *Clock properties*

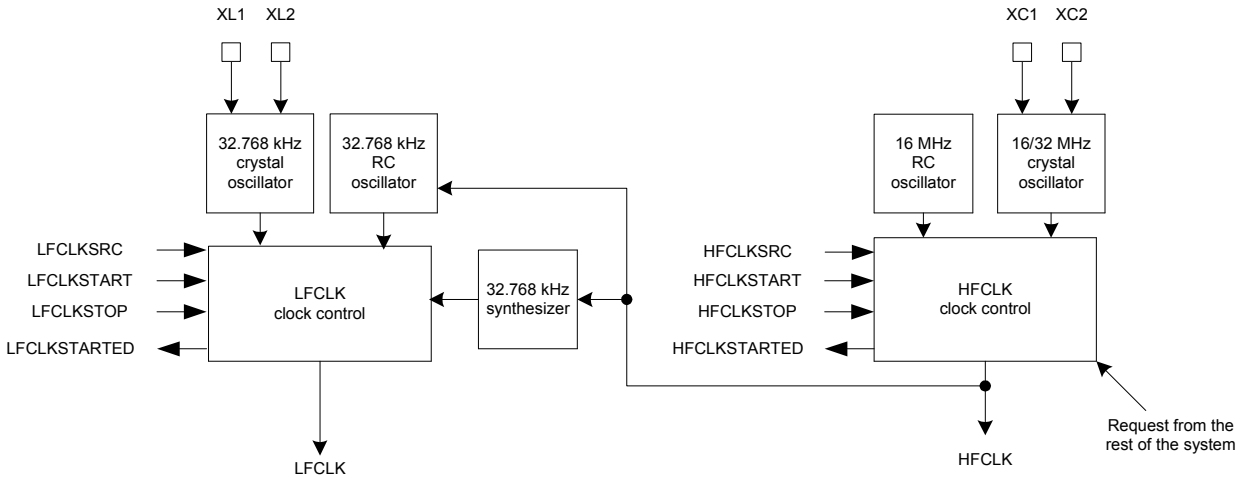

Figure 4 *Clock management*

3.6.1 16/32 MHz crystal oscillator

The crystal oscillator can be controlled either by a 16 MHz or a 32 MHz external crystal. However, the system clock is always 16 MHz, see the *nRF51 Series Reference Manual* for more details. The crystal oscillator is designed for use with an AT-cut quartz crystal in parallel resonant mode. To achieve correct oscillation frequency, the load capacitance must match the specification in the crystal data sheet. ***Figure 5*** shows how the crystal is connected to the 16/32 MHz crystal oscillator.

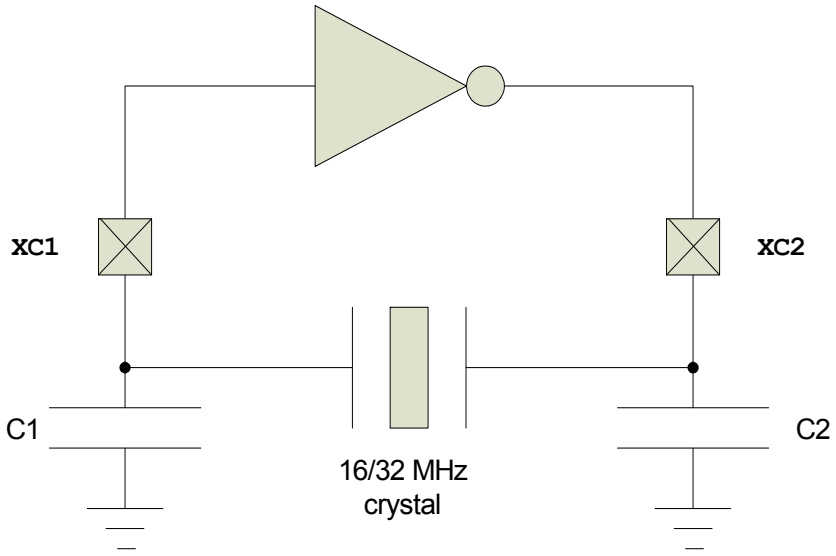

Figure 5 *Circuit diagram of the 16/32 MHz crystal oscillator*

The load capacitance (CL) is the total capacitance seen by the crystal across its terminals and is given by:

$$CL = \frac{(C1' \cdot C2')}{(C1' + C2')}$$

$$C1' = C1 + C\_pcb1 + C\_pin$$

$$C2' = C2 + C\_pcb2 + C\_pin$$

C1 and C2 are ceramic SMD capacitors connected between each crystal terminal and ground. C_pcb1 and C_pcb2 are stray capacitances on the PCB. C_pin is the pin input capacitance on the XC1 and XC2 pins, see ***Table 18*** on page 32 (16 MHz) and ***Table 19*** on page 33 (32 MHz). The load capacitors C1 and C2 should have the same value. See ***Chapter 11 "Reference circuitry"*** on page 64 for the capacitance value used for C_pcb1 and C_pcb2 in reference circuitry.

For reliable operation, the crystal load capacitance, shunt capacitance, equivalent series resistance ($R_{S,X16M}$/$R_{S,X32M}$), and drive level must comply with the specifications in ***Table 18*** on page 32 (16 MHz) and ***Table 19*** on page 33 (32 MHz). It is recommended to use a crystal with lower than maximum $R_{S,X16M}$/$R_{S,X32M}$ if the load capacitance and/or shunt capacitance is high. This will give faster startup and lower current consumption. A low load capacitance will reduce both startup time and current consumption.

3.6.2 32.768 kHz crystal oscillator

The 32.768 kHz crystal oscillator is designed for use with a quartz crystal in parallel resonant mode. To achieve correct oscillation frequency, the load capacitance must match the specification in the crystal data sheet. ***Figure 6*** shows how the crystal is connected to the 32.768 kHz crystal oscillator.

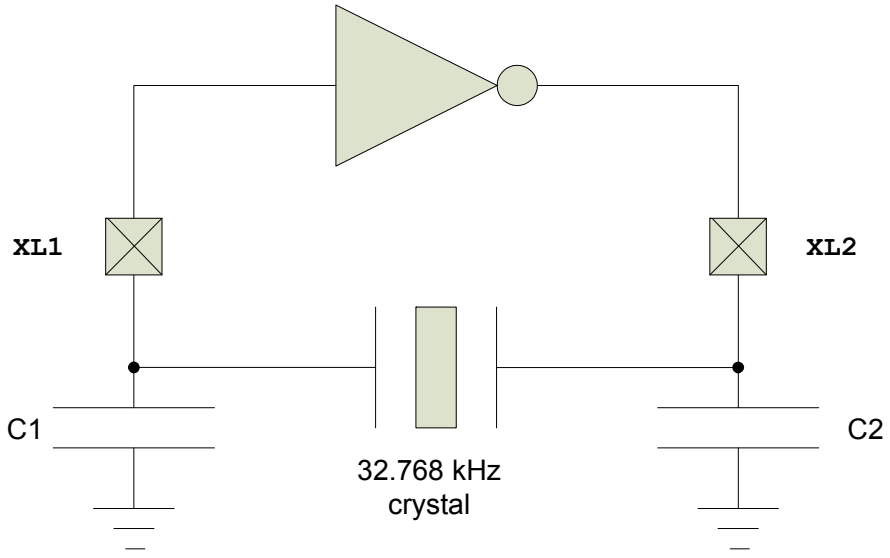

Figure 6 *Circuit diagram of the 32.768 kHz crystal oscillator*

The load capacitance (CL) is the total capacitance seen by the crystal across its terminals and is given by:

$$CL = \frac{(C1' \cdot C2')}{(C1' + C2')}$$

$$C1' = C1 + C\_pcb1 + C\_pin$$

$$C2' = C2 + C\_pcb2 + C\_pin$$

C1 and C2 are ceramic SMD capacitors connected between each crystal terminal and ground. C_pcb1 and C_pcb2 are stray capacitances on the PCB. C_pin is the pin input capacitance on the XC1 and XC2 pins, see ***Section 8.1.5 "32.768 kHz crystal oscillator (32k XOSC)"*** on page 34. The load capacitors C1 and C2 should have the same value. See ***Chapter 11 "Reference circuitry"*** on page 64 for the capacitance value used for C_pcb1 and C_pcb2 in reference circuitry.

3.6.3 32.768 kHz RC oscillator

The 32.768 kHz RC low frequency oscillator may be used as an alternative to the 32.768 kHz crystal oscillator. It has a frequency accuracy of less than ± 250 ppm in a stable temperature environment or when calibration is periodically performed in changing temperature environments. The 32.768 kHz RC oscillator does not require external components.

3.6.4 Synthesized 32.768 kHz clock

The low frequency clock can be synthesized from the high frequency clock. This saves the cost of a crystal but increases average power consumption as the high frequency clock source will have to be active.

3.7 GPIO

The general purpose I/O is organized as one port with up to 32 I/Os (dependent on package) enabling access and control of up to 32 pins through one port. Each GPIO can be accessed individually with the following user configurable features:

- Input/output direction
- Output drive strength
- Internal pull-up and pull-down resistors
- Wake-up from high or low level triggers on all pins
- Trigger interrupt on all pins
- All pins can be used by the PPI task/event system. The maximum number of pins that can be interfaced through the PPI at the same time is limited by the number of GPIOTE channels.
- All pins can be individually configured to carry serial interface or quadrature demodulator signals.

3.8 Debugger support

The two pin Serial Wire Debug (SWD) interface provided as a part of the Debug Access Port (DAP) offers a flexible and powerful mechanism for non-intrusive debugging of program code. Breakpoints and single stepping are part of this support.

4 Peripheral blocks

Peripheral blocks which have a register interface and/or interrupt vector assigned are instantiated, one or more times, in the device address space. The instances, associated ID (for those with interrupt vectors), and base address of features are found in ***Table 15*** on page 28**.** Detailed functional descriptions, configuration options, and register interfaces can be found in the *nRF51 Series Reference Manual*.

4.1 2.4 GHz radio (RADIO)

The nRF51824 2.4 GHz RF transceiver is designed and optimized to operate in the worldwide ISM frequency band at 2.400 to 2.4835 GHz. Radio modulation modes and configurable packet structure enable interoperability with *Bluetooth*® low energy (BLE), ANT™, Enhanced ShockBurst™, and other 2.4 GHz protocol implementations.

The transceiver receives and transmits data directly to and from system memory for flexible and efficient packet data management. The nRF51824 transceiver has the following features:

- General modulation features
  - GFSK modulation
  - Data whitening
  - On-air data rates
    - 250 kbps
    - 1 Mbps BLE
    - 2 Mbps
- Transmitter with programmable output power of +4 dBm to -20 dBm, in 4 dB steps
- Transmitter whisper mode -30 dBm
- RSSI function (1 dB resolution)
- Receiver with integrated channel filters achieving maximum sensitivity
  - -96 dBm at 250 kbps
  - -93 dBm at 1 Mbps BLE
  - -85 dBm at 2 Mbps
- RF Synthesizer
  - 1 MHz frequency programming resolution
  - 1 MHz non-overlapping channel spacing at 250 kbps
  - 2 MHz non-overlapping channel spacing at 2 Mbps
  - Works with low-cost ± 60 ppm 16 MHz crystal oscillators
- Baseband controller
  - EasyDMA RX and TX packet transfer directly to and from RAM
  - Dynamic payload length
  - On-the-fly packet assembly/disassembly and AES CCM payload encryption
  - 8 bit, 16 bit, and 24 bit CRC check (programmable polynomial and initial value)

Note: EasyDMA is an integrated DMA implementation requiring no configuration to take advantage of flexible data management and avoids copying operations to and from RAM.

4.2 Timer/counters (TIMER)

The timer/counter runs on the high-frequency clock source (HFCLK) and includes a 4 bit ($1/2^X$) prescaler that can divide the HFCLK.

The TIMER will start requesting the 1 MHz mode of the HFCLK for values of the prescaler that gives f_{TIMER} less or equal to 1 MHz. If the timer module is the only one requesting the HFCLK, the system will automatically switch to using the 1 MHz mode resulting in a decrease in the current consumption. See the parameters $I_{1v2XO16,1M}$, $I_{1v2XO32,1M}$, $I_{1v2RC16,1M}$ in ***Table 28*** on page 39 and $I_{TIMER0/1/2,1M}$ in ***Table 48*** on page 52.

The task/event and interrupt features make it possible to use the PPI system for timing and counting tasks between any system peripheral including any GPIO of the device. The PPI system also enables the TIMER task/event features to generate periodic output and PWM signals to any GPIO. The number of input/outputs used at the same time is limited by the number of GPIOTE channels.

Instance	Bit-width	Capture/Compare registers
TIMER0	8/16/24/32	4
TIMER1	8/16	4
TIMER2	8/16	4

Table 9 *Timer/counter properties*

4.3 Real Time Counter (RTC)

The Real Time Counter (RTC) module provides a generic, low power timer on the low-frequency clock source (LFCLK). The RTC features a 24 bit COUNTER, 12 bit (1/X) prescaler, capture/compare registers, and a tick event generator for low power, tickless RTOS implementation.

Instance	Capture/Compare registers
RTC0	3
RTC1	4

Table 10 *RTC properties*

4.4 AES Electronic Codebook Mode Encryption (ECB)

The ECB encryption block supports 128 bit AES block encryption. It can be used for a range of cryptographic functions like hash generation, digital signatures, and keystream generation for data encryption/decryption. ECB encryption uses EasyDMA to access system RAM for in-place operations on cleartext and ciphertext during encryption.

4.5 AES CCM Mode Encryption (CCM)

Cipher Block Chaining - Message Authentication Code (CCM) Mode is an authenticated encryption algorithm designed to provide both authentication and confidentiality during data transfer. CCM combines counter mode encryption and CBC-MAC authentication.

Note: The CCM terminology "Message Authentication Code (MAC)" is called the "Message Integrity Check (MIC)" in *Bluetooth* terminology and this document and the *nRF51 Series Reference Manual* are consistent with *Bluetooth* terminology.

The CCM block generates an encrypted keystream, applies it to the input data using the XOR operation, and generates the 4 byte MIC field in one operation. The CCM and radio can be configured to work synchronously, as described in the *nRF51 Series Reference Manual*. The CCM will encrypt in time for transmission and decrypt after receiving bytes into memory from the Radio. All operations can complete within the packet RX or TX time.

CCM on this device is implemented according to *Bluetooth* requirements and the algorithm as defined in IETF RFC3610, and depends on the AES-128 block cipher. A description of the CCM algorithm can also be found in the NIST Special Publication 800-38C. The *Bluetooth* Core Specification v4.0 describes the configuration of counter mode blocks and encryption blocks to implement compliant encryption for BLE.

The CCM block uses EasyDMA to load key, counter mode blocks (including the nonce required), and to read/write plain text and cipher text.

4.6 Accelerated Address Resolver (AAR)

Accelerated Address Resolver is a cryptographic support function to implement the "Resolvable Private Address Resolution Procedure" described in the *Bluetooth Core Specification* v4.1. "Resolvable Private Address Generation" should be achieved using ECB and is not supported by AAR. The procedure allows two devices that share a secret key to generate and resolve a hash based on their device address.

The AAR block enables real-time address resolution on incoming packets when configured according to the description in the *nRF51 Series Reference Manual*. This allows real-time packet filtering (whitelisting) using a list of known shared secrets (Identity Resolving Keys (IRK) in *Bluetooth*).

The following table outlines the properties of the AAR.

Instance	Number of IRKs supported for simultaneous resolution
AAR	8

Table 11 *AAR properties*

4.7 Random Number Generator (RNG)

The Random Number Generator (RNG) generates true non-deterministic random numbers derived from thermal noise that are suitable for cryptographic purposes. The RNG does not require a seed value.

4.8 Watchdog Timer (WDT)

A countdown watchdog timer using the low-frequency clock source (LFCLK) offers configurable and robust protection against application lock-up. The watchdog can be paused during long CPU sleep periods for low power applications and when the debugger has halted the CPU.

4.9 Temperature sensor (TEMP)

The temperature sensor measures die temperature over the temperature range of the device with 0.25° C resolution.

4.10 Serial Peripheral Interface (SPI/SPIS)

The SPI interfaces enable full duplex synchronous communication between devices. They support a three-wire (SCK, MISO, MOSI) bi-directional bus with fast data transfers. The SPI Master can communicate with multiple slaves using individual chip select signals for each of the slave devices attached to a bus. Control of chip select signals is left to the application through use of GPIO signals. SPI Master has double buffered I/O data. The SPI Slave includes EasyDMA for data transfer directly to and from RAM allowing Slave data transfers to occur while the CPU is IDLE.

The GPIOs used for each SPI interface line can be chosen from any GPIO on the device and are independently configurable. This enables great flexibility in device pinout and efficient use of printed circuit board space and signal routing.

The SPI peripheral supports SPI mode 0, 1, 2, and 3.

Instance	Master/Slave
SPI0	Master
SPI1	Master
SPIS1	Slave

Table 12 *SPI properties*

4.10.1 Enable 4 Mbps SPIS bit rate

In order to utilize 4 Mbps bit rate for SPIS, the SPIS must be the only peripheral using a specific RAM section. Construction of RAM sections are described in ***Section 3.2.2 "RAM organization"*** on page 14. If other peripherals than SPIS use a specific RAM section, only 2 Mbps bit rate is possible.

4.11 Two-wire interface (TWI)

The two-wire interface can communicate with a bi-directional wired-AND bus with two lines (SCL, SDA). The protocol makes it possible to interconnect up to 127 individually addressable devices. The interface is capable of clock stretching, supporting data rates of 100 kbps and 400 kbps.

The GPIOs used for each two-wire interface line can be chosen from any GPIO on the device and are independently configurable. This enables great flexibility in device pinout and efficient use of board space and signal routing.

Instance	Master/Slave
TWI0	Master
TWI1	Master

Table 13 *Two-wire properties*

4.12 Universal Asynchronous Receiver/Transmitter (UART)

The Universal Asynchronous Receiver/Transmitter offers fast, full-duplex, asynchronous serial communication with built-in flow control (CTS, RTS) support in hardware up to 1 Mbps baud. Parity checking is supported.

The GPIOs used for each UART interface line can be chosen from any GPIO on the device and are independently configurable. This enables great flexibility in device pinout and efficient use of board space and signal routing.

4.13 Quadrature Decoder (QDEC)

The quadrature decoder provides buffered decoding of quadrature-encoded sensor signals. It is suitable for mechanical and optical sensors with an optional LED output signal and input debounce filters. The sample period and accumulation are configurable to match application requirements.

4.14 Analog to Digital Converter (ADC)

The 10 bit incremental Analog to Digital Converter (ADC) enables sampling of up to 8 external signals through a front-end multiplexer. The ADC has configurable input, reference prescaling, and sample resolution (8, 9, and 10 bit).

Note: The ADC module uses the same analog inputs as the LPCOMP module (AIN0 - AIN7 and AREF0 - AREF1). Only one of the modules can be enabled at the same time.

4.15 GPIO Task Event blocks (GPIOTE)

A GPIOTE block enables GPIOs on Port 0 to generate events on pin state change which can be used to carry out tasks through the PPI system. A GPIO can also be driven to change state on system events using the PPI system. Low power detection of pin state changes on Port 0 is possible when in System ON or System OFF.

Instance	Number of GPIOTE channels
GPIOTE	4

Table 14 *GPIOTE properties*

4.16 Low Power Comparator (LPCOMP)

In System ON, the block can generate separate events on rising and falling edges of a signal, or sample the current state of the pin as being above or below the threshold. The block can be configured to use any of the analog inputs on the device. Additionally, the low power comparator can be used as an analog wakeup source from System OFF or System ON. The comparator threshold can be programmed to a range of fractions of the supply voltage.

Note: The LPCOMP module uses the same analog inputs as the ADC module (AIN0 - AIN7 and AREF0 - AREF1). Only one of the modules can be enabled at the same time.

5 Instance table

The peripheral instantiation of the chip is shown in the table below.

ID	Base address	Peripheral	Instance	Description
0	0x40000000	POWER	POWER	Power Control.
0	0x40000000	CLOCK	CLOCK	Clock Control.
0	0x40000000	MPU	MPU	Memory Protection Unit.
1	0x40001000	RADIO	RADIO	2.4 GHz Radio.
2	0x40002000	UART	UART0	Universal Asynchronous Receiver/Transmitter.
3	0x40003000	SPI	SPI0	SPI Master.
3	0x40003000	TWI	TWI0	I2C compatible Two-Wire Interface 0.
4	0x40004000	SPIS	SPIS1	SPI Slave.
4	0x40004000	SPI	SPI1	SPI Master.
4	0x40004000	TWI	TWI1	I2C compatible Two-Wire Interface 1.
5				Unused.
6	0x40006000	GPIOTE	GPIOTE	GPIO Task and Events.
7	0x40007000	ADC	ADC	Analog to Digital Converter.
8	0x40008000	TIMER	TIMER0	Timer/Counter 0.
9	0x40009000	TIMER	TIMER1	Timer/Counter 1.
10	0x4000A000	TIMER	TIMER2	Timer/Counter 2.
11	0x4000B000	RTC	RTC0	Real Time Counter 0.
12	0x4000C000	TEMP	TEMP	Temperature Sensor.
13	0x4000D000	RNG	RNG	Random Number Generator.
14	0x4000E000	ECB	ECB	Crypto AES ECB.
15	0x4000F000	CCM	CCM	AES Crypto CCM.
15	0x4000F000	AAR	AAR	Accelerated Address Resolver.
16	0x40010000	WDT	WDT	Watchdog Timer.
17	0x40011000	RTC	RTC1	Real Time Counter 1.
18	0x40012000	QDEC	QDEC	Quadrature Decoder.
19	0x40013000	LPCOMP	LPCOMP	Low Power Comparator.
20 - 25				Reserved as software interrupt.
26 - 29				Unused.
30	0x4001E000	NVMC	NVMC	Non-Volatile Memory Controller.
31	0x4001F000	PPI	PPI	Programmable Peripheral Interconnect.
NA	0x50000000	GPIO	GPIO	General Purpose Input and Output.
NA	0x10000000	FICR	FICR	Factory Information Configuration Registers.
NA	0x10001000	UICR	UICR	User Information Configuration Registers.

Table 15 *Peripheral instance reference*

6 Absolute maximum ratings

Maximum ratings are the extreme limits the chip can be exposed to without causing permanent damage. Exposure to absolute maximum ratings for prolonged periods of time may affect the reliability of the chip. The absolute maximum ratings are shown in ***Table 16***.

Symbol	Parameter	Min.	Max.	Unit
Supply voltages				
VDD		-0.3	+3.9	V
DEC2			2	V
VSS			0	V
I/O pin voltage				
VIO		-0.3	VDD + 0.3	V
Environmental				
Storage temperature		-40	+125	°C
MSL	Moisture Sensitivity Level		3	
ESD HBM	Human Body Model		4	kV
ESD CDM	Charged Device Model		500	V
Flash memory				
Endurance		10 000[1]		write/erase cycles
Number of times an address can be written between erase cycles			2	times

1. Flash endurance is 10,000 erase cycles. The smallest element of flash that can be written is a 32 bit word.

Table 16 *Absolute maximum ratings*

7 Operating conditions

The operating conditions are the physical parameters that the chip can operate within as defined in ***Table 17***.

Symbol	Parameter	Notes	Min.	Typ.	Max.	Units
VDD	Supply voltage, internal LDO setup		1.9	3.0	3.6	V
VDD	Supply voltage, DC/DC converter setup		2.1	3.0	3.6	V
t_{R_VDD}	Supply rise time (0 V to VDD)	1			100	ms
T_A	Operating temperature		-40	25	105	°C

1. The on-chip power-on reset circuitry may not function properly for rise times outside the specified interval.

Table 17 *Operating conditions*

Nominal operating conditions (NOC) - conditions under which the chip is operated and tested are the typical (Typ.) values in ***Table 17***.

Extreme operating conditions (EOC) - conditions under which the chip is operated and tested are the minimum (Min.) and maximum (Max.) values in ***Table 17***.

8 Electrical specifications

This chapter contains electrical specifications for device interfaces and peripherals including radio parameters and current consumption.

8.1 Clock sources

8.1.1 16/32 MHz crystal startup

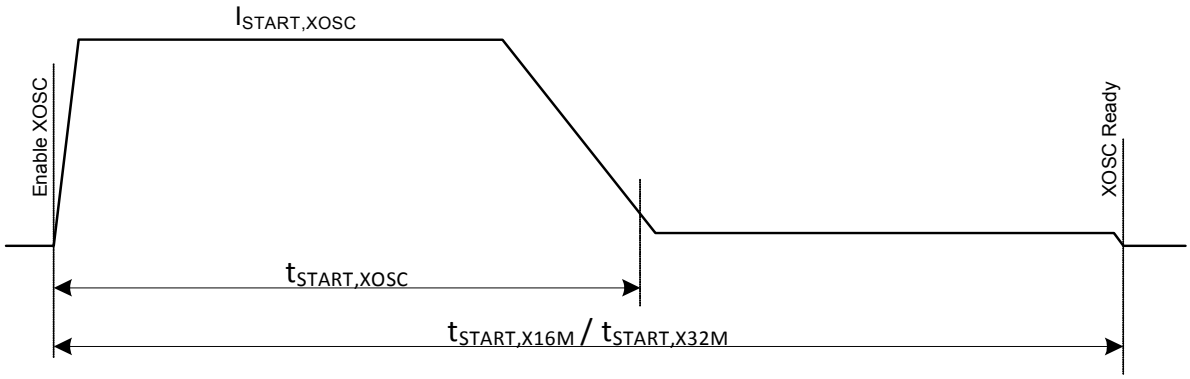

Figure 7 *Current drawn at oscillator startup*

Figure 7 shows the current drawn by the crystal oscillator (XOSC) at startup. The $t_{START,XOSC}$ period is the time needed for the oscillator to start clocking. The length of $t_{START,XOSC}$ is dependent on the crystal specifications.

The period following $t_{START,XOSC}$ to the end of $t_{START,X16M}$ /$t_{START,X32M}$ is fixed. This is the debounce period where the clock stabilizes before it is made available to rest of the system.

8.1.2 16 MHz crystal oscillator (16M XOSC)

Symbol	Description	Note	Min.	Typ.	Max.	Units
$f_{NOM,X16M}$	Crystal frequency.			16		MHz
$f_{TOL,X16M}$	Frequency tolerance.[1]				±50[2]	ppm
$f_{TOL,X16M,BLE}$	Frequency tolerance, *Bluetooth* low energy applications.[1]				±40[2]	ppm
$R_{S,X16M}$	Equivalent series resistance.	C0 ≤ 7 pF, $C_{L,MAX}$ ≤ 16 pF C0 ≤ 5 pF, $C_{L,MAX}$ ≤ 12 pF C0 ≤ 3 pF, $C_{L,MAX}$ ≤ 12 pF		50 75 100	100 150 200	Ω Ω Ω
$P_{D,X16M}$	Drive level.				100	µW
C_{pin}	Input capacitance on XC1 and XC2 pads.			4		pF
I_{X16M}	Run current for 16 MHz crystal oscillator.	SMD 2520 CL = 8 pF		470[3]		µA
$I_{X16M,1M}$	Run current for the 16 MHz crystal oscillator when used only for a Timer at 1 MHz or less.	SMD 2520 CL = 8pF		250[3]		µA
$I_{STBY,X16M}$	Standby current for 16 MHz crystal oscillator.[4]	SMD 2520 CL = 8 pF		25		µA
$I_{START,XOSC}$	Startup current for 16 MHz crystal oscillator.			1.1		mA
$t_{START,XOSC}$	Startup time for 16 MHz crystal oscillator.	SMD 2520 CL = 8 pF		400	500[5]	µs
$t_{START,X16M}$	Total startup time ($t_{START,XOSC}$ + debounce period).[6]	SMD 2520 CL = 8 pF		800		µs
$V_{INEXTCLK}$	Input amplitude if driven by external clock applied to XC1 pin.[7]		800		[8]	mV pp

1. The Frequency tolerance relates to the amount of time the radio can be in transmit mode. See ***Table 34*** on page 42.
2. Includes initial tolerance of the crystal, drift over temperature, aging, and frequency pulling due to incorrect load capacitance.
3. This number includes the current used by the automated power and clock management system.
4. Standby current is the current drawn by the oscillator when there are no resources requesting the 16M, meaning there is no clock management active (see ***Table 29*** on page 40). This value will depend on type of crystal.
5. Crystals with other specification than SMD 2520 may have much longer startup times.
6. This is the time from when the crystal oscillator is powered up until its output becomes available to the system. It includes both the crystal startup time and the debounce period.
7. Leave XC2 pin unconnected.
8. Input signal must not swing outside supply rails.

Table 18 *16 MHz crystal oscillator*

8.1.3 32 MHz crystal oscillator (32M XOSC)

Symbol	Description	Note	Min.	Typ.	Max.	Units
$f_{NOM,X32M}$	Crystal frequency.			32		MHz
$f_{TOL,X32M}$	Frequency tolerance.[1]				±50[2]	ppm
$f_{TOL,X32M,BLE}$	Frequency tolerance, *Bluetooth* low energy applications.[1]				±40[2]	ppm
$R_{S,X32M}$	Equivalent series resistance.	C0 ≤ 7 pF, $C_{L,MAX}$ ≤ 12 pF C0 ≤ 5 pF, $C_{L,MAX}$ ≤ 12 pF C0 ≤ 3 pF, $C_{L,MAX}$ ≤ 9 pF		30 40 50	60 80 100	Ω Ω Ω
$P_{D,X32M}$	Drive level.				100	µW
C_{pin}	Input capacitance on XC1 and XC2 pads.			4		pF
I_{X32M}	Run current for 32 MHz crystal oscillator.	SMD 2520 CL = 8 pF		500[3]		µA
$I_{X32M,1M}$	Run current for the 32 MHz crystal oscillator when used only for a Timer at 1 MHz or less.	SMD 2520 CL = 8 pF		300[3]		µA
$I_{STBY,X32M}$	Standby current for 32 MHz crystal oscillator.[4]	SMD 2520 CL = 8 pF		30		µA
$I_{START,XOSC}$	Startup current for 32 MHz crystal oscillator.			1.1		mA
$t_{START,XOSC}$	Startup time for 32 MHz crystal oscillator.	SMD 2520 CL = 8 pF		300	400[5]	µs
$t_{START,X32M}$	Total startup time ($t_{START,XOSC}$ + debounce period).[6]	SMD 2520 CL = 8 pF		750		µs

1. The Frequency tolerance relates to the amount of time the radio can be in transmit mode. See ***Table 34*** on page 42.
2. Includes initial tolerance of the crystal, drift over temperature, aging and frequency pulling due to incorrect load capacitance.
3. This number includes the current used by the automated power and clock management system.
4. Standby current is the current drawn by the oscillator when there are no resources requesting the 32M, meaning there is no clock management active (see ***Table 29*** on page 40). This value will depend on type of crystal.
5. Crystals with other specification than SMD 2520 may have much longer startup times.
6. This is the time from when the crystal oscillator is powered up until its output becomes available to the system. It includes both the crystal startup time and the debounce period.

Table 19 *32 MHz crystal oscillator*

8.1.4 16 MHz RC oscillator (16M RCOSC)

Symbol	Description	Min.	Typ.	Max.	Units
$f_{NOM,RC16M}$	Nominal frequency.		16		MHz
$f_{TOL,RC16M}$	Frequency tolerance.		±1	±5	%
I_{RC16M}	Run current for 16 MHz RC oscillator.		750[1]		µA
$I_{RC16M,1M}$	Run current for 16 MHz RCOSC when used only for a Timer at 1 MHz or less.		540[1]		µA
$t_{START,RC16M}$	Startup time for 16 MHz RC oscillator.		4.2	5.2	µs
$I_{RC16M, START}$	Startup current for 16 MHz RC oscillator.		400		µA

1. This number includes the current used by the automated power and clock management system.

Table 20 *16 MHz RC oscillator*

8.1.5 32.768 kHz crystal oscillator (32k XOSC)

Symbol	Description	Min.	Typ.	Max.	Units
$f_{NOM,X32k}$	Crystal frequency.		32.768		kHz
$f_{TOL,X32k,BLE}$	Frequency tolerance, *Bluetooth* low energy applications.			±250	ppm
$C_{L,X32k}$	Load capacitance.			12.5	pF
$C_{0,X32k}$	Shunt capacitance.			2	pF
$R_{S,X32k}$	Equivalent series resistance.		50	80	kΩ
$P_{D,X32k}$	Drive level.			1	µW
C_{pin}	Input capacitance on XL1 and XL2 pads.		4		pF
I_{X32k}	Run current for 32.768 kHz crystal oscillator.		0.7		µA
$I_{START,X32k}$	Startup current for 32.768 kHz crystal oscillator.		1.3	1.8	µA
$t_{START,X32k}$	Startup time for 32.768 kHz crystal oscillator.		0.3	1	s
$V_{INEXTCLK}$	Input amplitude if driven by external clock applied to XL1 pin.[1]	200		600[2,3]	mV pp

1. Leave XL2 pin unconnected.
2. The oscillator run current will increase above 1 µA for higher amplitudes.
3. Input signal must not swing outside supply rails.

Table 21 *32.768 kHz crystal oscillator*

8.1.6 32.768 kHz RC oscillator (32k RCOSC)

Symbol	Description	Note	Min.	Typ.	Max.	Units
$f_{NOM,RC32k}$	Nominal frequency.			32.768		kHz
$f_{TOL,RC32k}$	Frequency tolerance.			±2		%
$f_{TOL,CAL,RC32k}$	Frequency tolerance.	Calibration interval 4 s			±250	ppm
I_{RC32k}	Run current.			1.3	1.5	µA
$t_{START,RC32k}$	Startup time.			390	487	µs

Table 22 *32.768 kHz RC oscillator*

8.1.7 32.768 kHz Synthesized oscillator (32k SYNT)

Symbol	Description	Note	Min.	Typ.	Max.	Units
$f_{NOM,SYNT32k}$	Nominal frequency.			32.768		kHz
$f_{TOL,SYNT}$	Frequency tolerance.			$f_{TOL,XO16M}$ ±8 $f_{TOL,XO32M}$ ±8		ppm
$I_{SYNT32k}$	Run and startup current for 32.768 kHz Synthesized clock including the 16M XOSC.			15		µA
$t_{START,SYNT32k}$	Startup time for 32.768 kHz Synthesized clock.			406		µs

Table 23 *32.768 kHz Synthesized oscillator*

8.2 Power management

Symbol	Description	Note	Min.	Typ.	Max.	Units
V_{POF}	Nominal power level warning thresholds (falling supply voltage).	Accuracy as defined by V_{TOL}		2.1 2.3 2.5 2.7		V
V_{TOL}	Threshold voltage tolerance.				±5	%
V_{HYST}	Threshold voltage hysteresis.	V_{POF} = 2.1 V V_{POF} = 2.3 V V_{POF} = 2.5 V V_{POF} = 2.7 V		46 62 79 100		mV

Table 24 *Power Fail Comparator*

Symbol	Description	Min.	Typ.	Max.	Units
$t_{HOLDRESETNORMAL}$	Hold time for reset pin when doing a pin reset.[1]	0.2			µs
$t_{HOLDRESETDEBUG}$	Hold time for reset pin when doing a pin reset during debug.[1,2]	100			µs

1. SWDCLK pin must be kept low during reset.
2. Bit 0 in the RESET register in the power management module must be set to 1 to enable reset during debug.

Table 25 *Pin Reset*

Power on reset time (t_{POR}) is the time from when the supply starts rising to when the device comes out of reset and the CPU starts. The time increases with, and is inclusive of, supply rise time from 0 V to VDD. ***Table 26*** gives t_{POR} for a number of supply rise times, simulated with a linear ramp from 0 V to VDD, over the supply voltage range 1.9 V to 3.6 V.

Symbol	Description	Note	Min.	Typ.	Max.	Units
$t_{POR, 10\ \mu s}$	Power on reset time, 10 µs rise time (0 V to VDD).		0.7	2.4	19	ms
$t_{POR, 1\ ms}$	Power on reset time, 1 ms rise time (0 V to VDD).		1.7	3.4	20	ms
$t_{POR, 10\ ms}$	Power on reset time, 10 ms rise time (0 V to VDD).		11	12	28	ms
$t_{POR, 100\ ms}$	Power on reset time, 100 ms rise time (0 V to VDD).		68	101	115	ms

Table 26 *Power on reset time*

The data in ***Figure 8*** and ***Table 27*** show measured $t_{\_POR}$ data. Measurements were taken using the reference circuit shown in ***Section 11.2.1 "QFAA QFN48 schematic with internal LDO setup"*** on page 66 with the given supply voltage and temperature conditions.

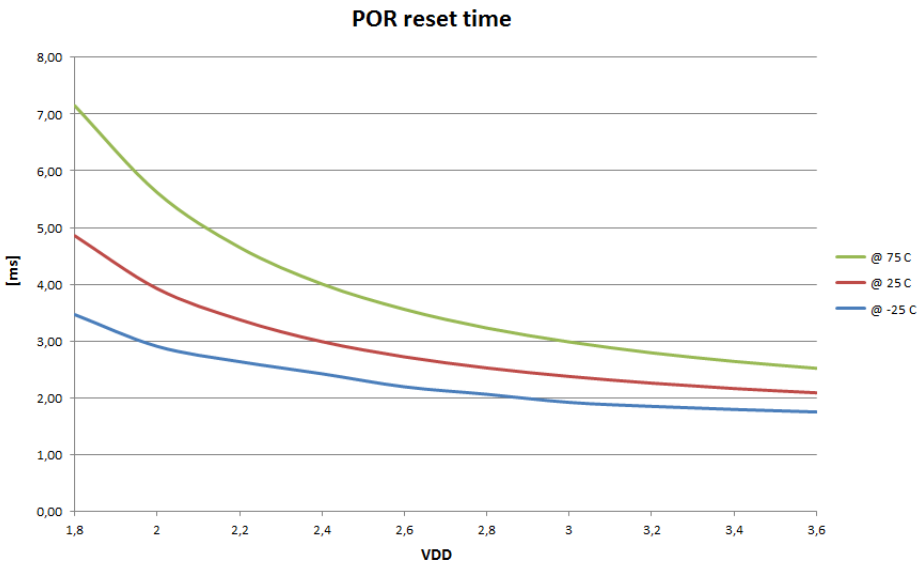

Figure 8 *Power on reset time*

VDD	Rise Time from 10% to 90% of VDD
1.8	570 µs
3.0	605 µs
3.6	635 µs

Table 27 *Supply rise time at sample voltages for the measured data shown in* ***Figure 8****.*

Symbol	Description	Note	Min.	Typ.	Max.	Units
I_{OFF}	Current in SYSTEM OFF, no RAM retention.			0.6		µA
$I_{OFF, RET, 8k}$	Additional current in SYSTEM OFF per retained RAM block (8 kB).			0.6		µA
I_{OFF2ON}	OFF to CPU execute transition current.			400		µA
t_{OFF2ON}	OFF to CPU execute.			9.6	10.6	µs
$I_{ON,16k}$	SYSTEM-ON base current with 16 kB RAM enabled.			2.6		µA
$I_{ON,32k}$	SYSTEM-ON base current with 32 kB RAM enabled.			3.8		µA
t_{1V2}	Startup time for 1V2 regulator.			2.3		µs
$I_{1V2XO16}$	Current drawn by 1V2 regulator and 16 MHz XOSC when both are on at the same time.	See ***Table 29*** on page 40.		810[1]		µA
$I_{1V2XO32}$	Current drawn by 1V2 regulator and 32 MHz XOSC when both are on at the same time.	See ***Table 29*** on page 40.		840[1]		µA
$I_{1V2RC16}$	Current drawn by 1V2 regulator and 16 MHz RCOSC when both are on at the same time.	See ***Table 29*** on page 40.		880[1]		µA
$I_{1V2XO16,1M}$	For HFCLK in 1 MHz mode[2]. Current drawn by 1V2 regulator and 16 MHz XOSC when both are on at the same time.	See ***Table 29*** on page 40.		520[1]		µA
$I_{1V2XO32,1M}$	For HFCLK in 1 MHz mode[2]. Current drawn by 1V2 regulator and 32 MHz XOSC when both are on at the same time.	See ***Table 29*** on page 40.		560[1]		µA
$I_{1V2RC16,1M}$	For HFCLK in 1 MHz mode[2]. Current drawn by 1V2 regulator and 16 MHz RCOSC when both are on at the same time.	See ***Table 29*** on page 40.		630[1]		µA
t_{XO}	Startup time for the clock management system when the XTAL is in standby.			2.3	5.3	µs

Symbol	Description	Note	Min.	Typ.	Max.	Units
t_{1V7}	Startup time for 1V7 regulator.			2	3.6	µs
I_{1V7}	Current drawn by 1V7 regulator.			105		µA
F_{DCDC}	DC/DC converter current conversion factor.		0.65[3]		1.2[3]	

1. This number includes the current used by the automated power and clock management system.
2. For details on 1 MHz mode, see ***Section 4.2 "Timer/counters (TIMER)"*** on page 24.
3. F_{DCDC} will vary depending on VDD and internal radio current consumption (I_{DD}). Please refer to the *nRF51 Series Reference Manual*, v3.0 or later, for a method to calculate $I_{DD,DCDC}$.

Table 28 *Power management*

8.3 Block resource requirements

Block	ID	Resource requirements				Comment
		1V2	HFCLK[1]	LFCLK	1V7	
Radio	1	x	x			Requires HFCLK XOSC.
UART	2	x	x			When receiver or transmitter are STARTed.
SPIS	4	x	x			Requested when CSN asserts.
SPI	3, 4	x	x			
TWI	3, 4	x	x			
GPIOTE	6	x	x			Only in input mode.
ADC	7	x	x			Requires HFCLK XOSC.
TIMER	8, 9, 10		x			Requires 1V2 when a TIMER EVENT is triggered.
RTC	11, 17			x		HFCLK will be requested if the LFCLK is synthesized from HFCLK.
TEMP	12	x	x			Requires HFCLK XOSC.
RNG	13	x	x			
ECB	14	x	x			
WDT	16			x		HFCLK will be requested if the LFCLK is synthesized from HFCLK.
QDEC	18	x	x			
LPCOMP	19					No resources required.
CPU	--	x	x		x	

1. HFCLK could be one of the following; RC16M, XO16M, or XO32M.

Table 29 *Clock and power requirements for different blocks*

8.4 CPU

Symbol	Description	Min.	Typ.	Max.	Units
$I_{CPU, FLASH}$	Run current at 16 MHz (XOSC). Executing code from flash memory.		4.1[1]		mA
$I_{CPU, RAM}$	Run current at 16 MHz (XOSC). Executing code from RAM.		2.4[2]		mA
$I_{START, CPU}$	CPU startup current.		600		µA
$t_{START, CPU}$	IDLE to CPU execute.	0[3]			µs

1. Includes CPU, flash, 1V2, 1V7, RC16M.
2. Includes CPU, RAM, 1V2, RC16M.
3. t_{1V2} if 1V2 regulator is not running already.

Table 30 *CPU specifications*

8.5 Radio transceiver

8.5.1 General radio characteristics

Symbol	Description	Note	Min.	Typ.	Max.	Units
f_{OP}	Operating frequencies.	1 MHz channel spacing.	2400		2483	MHz
PLL_{res}	PLL programming resolution.			1		MHz
Δf_{250}	Frequency deviation at 250 kbps.			±170		kHz
Δf_{2M}	Frequency deviation at 2 Mbps.			±320		kHz
Δf_{BLE}	Frequency deviation at BLE.		±225	±250	±275	kHz
bps_{FSK}	On-air data rate.		250		2000	kbps

Table 31 *General radio characteristics*

8.5.2 Radio current consumption with DC/DC disabled

Symbol	Description	Note	Min.	Typ.	Max.	Units
$I_{TX,+4dBm}$	TX only run current at P_{OUT} = +4 dBm.	1		16		mA
$I_{TX,0dBm}$	TX only run current at P_{OUT} = 0 dBm.	1		10.5		mA
$I_{TX,-4dBm}$	TX only run current at P_{OUT} = -4 dBm.	1		8		mA
$I_{TX,-8dBm}$	TX only run current at P_{OUT} = -8 dBm.	1		7		mA
$I_{TX,-12dBm}$	TX only run current at P_{OUT} = -12 dBm.	1		6.5		mA
$I_{TX,-16dBm}$	TX only run current at P_{OUT} = -16 dBm.	1		6		mA
$I_{TX,-20dBm}$	TX only run current at P_{OUT} = -20 dBm.	1		5.5		mA
$I_{TX,-30dBm}$	TX only run current at P_{OUT} = -30 dBm.	1		5.5		mA
$I_{START,TX}$	TX startup current.	2		7		mA
$I_{RX,250}$	RX only run current at 250 kbps.			12.6		mA
$I_{RX,1M\ BLE}$	RX only run current at 1 Mbps BLE.			13		mA
$I_{RX,2M}$	RX only run current at 2 Mbps.			13.4		mA
$I_{START,RX}$	RX startup current.	3		8.7		mA

1. Valid for data rates 250 kbps, 1 Mbps BLE, and 2 Mbps.
2. Average current consumption (at 0 dBm TX output power) for TX startup (130 µs), and when changing mode from RX to TX (130 µs).
3. Average current consumption for RX startup (130 µs), and when changing mode from TX to RX (130 µs).

Table 32 *Radio current consumption with DC/DC disabled (NOC, VDD = 3 V)*

8.5.3 Radio current consumption with DC/DC enabled

Symbol	Description	Note	Min.	Typ.	Max.	Units
$I_{TX,+4dBm}$	TX only run current at P_{OUT} = +4 dBm.	1		11.8		mA
$I_{TX,0dBm}$	TX only run current at P_{OUT} = 0 dBm.	1		8.0		mA
$I_{TX,-4dBm}$	TX only run current at P_{OUT} = -4 dBm.	1		6.3		mA
$I_{TX,-8dBm}$	TX only run current at P_{OUT} = -8 dBm.	1		5.6		mA
$I_{TX,-12dBm}$	TX only run current at P_{OUT} = -12 dBm.	1		5.3		mA
$I_{TX,-16dBm}$	TX only run current at P_{OUT} = -16 dBm.	1		5.0		mA
$I_{TX,-20dBm}$	TX only run current at P_{OUT} = -20 dBm.	1		4.7		mA
$I_{TX,-30dBm}$	TX only run current at P_{OUT} = -30 dBm.	1		4.7		mA
$I_{RX,1M\ BLE}$	RX only run current at 1 Mbps BLE.			9.7		mA

1. Valid for data rates 250 kbps, 1 Mbps BLE, and 2 Mbps.

Table 33 *Radio current consumption with DC/DC enabled (NOC, VDD = 3 V)*

8.5.4 Transmitter specifications

Symbol	Description	Min.	Typ.	Max.	Units
P_{RF}	Maximum output power.		4		dBm
P_{RFC}	RF power control range.	20	24		dB
PRFCR	RF power accuracy.			±4	dB
P_{WHISP}	RF power whisper mode.		-30		dBm
P_{BW2}	20 dB bandwidth for modulated carrier (2 Mbps).		1800	2000	kHz
P_{BW250}	20 dB bandwidth for modulated carrier (250 kbps).		700	1300	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
$P_{RF1.250}$	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
$t_{TX,30}$	Maximum consecutive transmission time, f_{TOL} < ±30 ppm.			16	ms
$t_{TX,60}$	Maximum consecutive transmission time, f_{TOL} < ±60 ppm.			4	ms

Table 34 *Transmitter specifications*

8.5.5 Receiver specifications

Symbol	Description	Min.	Typ.	Max.	Units
Receiver operation					
PRX_{MAX}	Maximum received signal strength at < 0.1% PER.		0		dBm
$PRX_{SENS,2M}$	Sensitivity (0.1% BER) at 2 Mbps.		-85		dBm
$PRX_{SENS,250k}$	Sensitivity (0.1% BER) at 250 kbps.		-96		dBm
P_{SENS} IT 1 Mbps BLE	Receiver sensitivity: Ideal transmitter.		-93		dBm
P_{SENS} DT 1 Mbps BLE	Receiver sensitivity: Dirty transmitter.[1]		-91		dBm
RX selectivity - modulated interfering signal[2]					
	2 Mbps				
C/I_{CO}	C/I co-channel.		12		dB
C/I_{1ST}	1^{st} ACS, C/I 2 MHz.		-4		dB
C/I_{2ND}	2^{nd} ACS, C/I 4 MHz.		-24		dB
C/I_{3RD}	3^{rd} ACS, C/I 6 MHz.		-28		dB
C/I_{6th}	6^{th} ACS, C/I 12 MHz.		-44		dB
C/I_{Nth}	N^{th} ACS, C/I f_i > 25 MHz.		-50		dB

Symbol	Description	Min.	Typ.	Max.	Units
	250 kbps				
C/I_{CO}	C/I co-channel.		4		dB
C/I_{1ST}	1st ACS, C/I 1 MHz.		-10		dB
C/I_{2ND}	2nd ACS, C/I 2 MHz.		-34		dB
C/I_{3RD}	3rd ACS, C/I 3 MHz.		-39		dB
C/I_{6th}	6th ACS, C/I f_i > 6 MHz.		-50		dB
C/I_{12th}	12th ACS, C/I 12 MHz.		-55		dB
C/I_{Nth}	Nth ACS, C/I f_i > 25 MHz.		-60		dB
	***Bluetooth* Low Energy RX selectivity**				
C/I_{CO}	C/I co-channel.		10		dB
C/I_{1ST}	1st ACS, C/I 1 MHz.		1		dB
C/I_{2ND}	2nd ACS, C/I 2 MHz.		-25		dB
C/I_{3+N}	ACS, C/I (3+n) MHz offset [n = 0, 1, 2, . . .].		-51		dB
C/I_{Image}	Image blocking level.		-30		dB
$C/I_{Image±1MHz}$	Adjacent channel to image blocking level (±1 MHz).		-31		dB
RX intermodulation[3]					
P_IMD_{2Mbps}	IMD performance, 2 Mbps, 3rd, 4th, and 5th offset channel.		-41		dBm
$P\_IMD_{250kbps}$	IMD performance, 250 kbps, 3rd, 4th, and 5th offset channel.		-36		dBm
P_IMD_{BLE}	IMD performance, 1 Mbps BLE, 3rd, 4th, and 5th offset channel.		-39		dBm

1. As defined in the *Bluetooth Core Specification* v4.0 Volume 6: Core System Package (Low Energy Controller Volume).
2. Wanted signal level at P_{IN} = -67 dBm. One interferer is used, having equal modulation as the wanted signal. The input power of the interferer where the sensitivity equals BER = 0.1% is presented.
3. Wanted signal level at P_{IN} = -64 dBm. Two interferers with equal input power are used. The interferer closest in frequency is not modulated, 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 35 *Receiver specifications*

8.5.6 Radio timing parameters

Symbol	Description	250 k	2 M	BLE	Jitter	Units
t_{TXEN}	Time between TXEN task and READY event.	132	132	140	0	µs
$t_{TXDISABLE}$	Time between DISABLE task and DISABLED event when the radio was in TX.	10	3	4	1	µs
t_{RXEN}	Time between the RXEN task and READY event.	130	130	138	0	µs
$t_{RXDISABLE}$	Time between DISABLE task and DISABLED event when the radio was in RX.	0	0	0	1	µs
$t_{TXCHAIN}$	TX chain delay.	5	0.5	1	0	µs
$t_{RXCHAIN}$	RX chain delay.	12.5	2	3	0	µs

Table 36 *Radio timing*

8.5.7 Antenna matching network requirements

Symbol	Description	Min.	Typ.	Max.	Units
$Z_{QFN48,ANT1,2}$	Optimum differential impedance at 2.4 GHz seen into the matching network from pin ANT1 and ANT2 on the QFN48 packet.		15 + j85		Ω

Table 37 *Optimum differential load impedance*

8.6 Received Signal Strength Indicator (RSSI) specifications

Symbol	Description	Note	Min.	Typ.	Max.	Units
$RSSI_{ACC}$	RSSI accuracy.	Valid range -50 dBm to -80 dBm.			±6	dB
$RSSI_{RESOLUTION}$	RSSI resolution.			1		dB
$RSSI_{PERIOD}$	Sample period.		8.8			µs
$RSSI_{CURRENT}$	Current consumption in addition to I_{RX}.			250		µA

Table 38 *RSSI specifications*

8.7 Universal Asynchronous Receiver/Transmitter (UART) specifications

Symbol	Description	Note	Min.	Typ.	Max.	Units
I_{UART1M}	Run current at max baud rate.			230		µA
$I_{UART115k}$	Run current at 115200 bps.			220		µA
$I_{UART1k2}$	Run current at 1200 bps.			210		µA
f_{UART}	Baud rate for UART.		1.2		1000	kbps
t_{CTSH}	CTS high time.		1			µs

Table 39 *UART specifications*

8.8 Serial Peripheral Interface Slave (SPIS) specifications

Symbol	Description	Min.	Typ.	Max.	Units
$I_{SPIS125K}$	Run current for SPI slave at 125 kbps.[1]		180		µA
I_{SPIS2M}	Run current for SPI slave at 2 Mbps.[1]		183		µA
f_{SPIS}	Bit rates for SPIS.	0.125		4[2]	Mbps

1. CSN asserted.
2. This bit rate is only possible if the instructions are followed in ***Section 4.10.1 "Enable 4 Mbps SPIS bit rate"*** on page 26.

Table 40 *SPIS specifications*

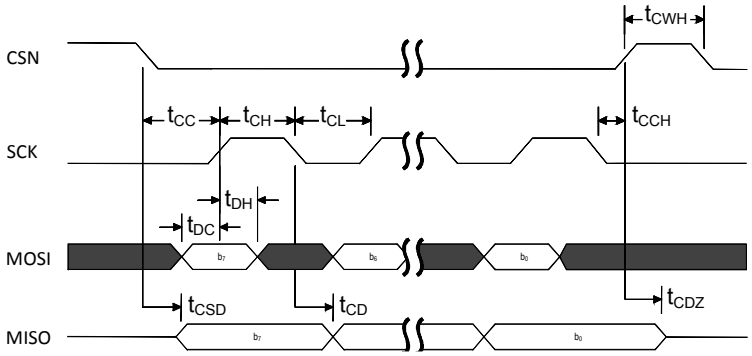

Figure 9 *SPIS timing diagram, one byte transmission, SPI Mode 0*

Symbol	Description	Note	Min.	Typ.	Max.	Units
t_{DC}	Data to SCK setup.		10			ns
t_{DH}	SCK to data hold.		10			ns
t_{CSD}	CSN to data valid.	Low power mode.[1] Constant latency mode.[1]			7100 2100	ns
t_{CD}	SCK to data valid.	C_{LOAD} = 10 pF			97[2]	ns
t_{CL}	SCK low time.		40			ns
t_{CH}	SCK high time.		40			ns
t_{CC}	CSN to SCK setup.	Low power mode.[1] Constant latency mode.[1]	7000 2000			ns
t_{CCH}	Last SCK edge to CSN hold.		2000			ns
t_{CWH}	CSN inactive time.		300			ns
t_{CDZ}	CSN to output high Z.				40	ns
f_{SCK}	SCK frequency.		0.125		2	MHz
$t_{R,}t_{F}$	SCK rise and fall time.				100	ns

1. For more information on how to control the sub power modes, see the *nRF51 Series Reference Manual*.
2. Increases/decreases with 1.2 ns/pF load.

Table 41 *SPIS timing parameters*

8.9 Serial Peripheral Interface (SPI) Master specifications

Symbol	Description	Min.	Typ.	Max.	Units
$I_{SPI125K}$	Run current for SPI master at 125 kbps.		180		µA
I_{SPI4M}	Run current for SPI master at 4 Mbps.		200		µA
f_{SPI}	Bit rates for SPI.	0.125		4	Mbps

Table 42 *SPI specifications*

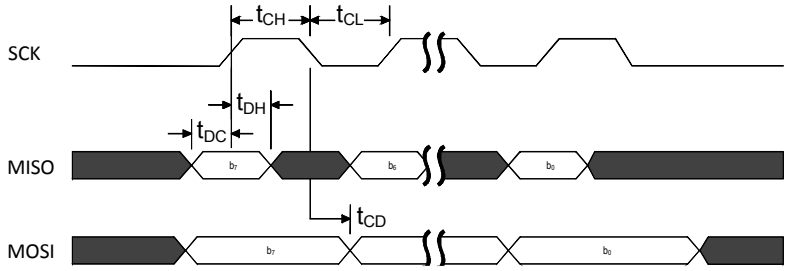

Figure 10 *SPI timing diagram, one byte transmission, SPI mode 0*

Symbol	Description	Note	Min.	Typ.	Max.	Units
t_{DC}	Data to SCK setup.		10			ns
t_{DH}	SCK to data hold.		10			ns
t_{CD}	SCK to data valid.	C_{LOAD} = 10 pF			97[1]	ns
t_{CL}	SCK low time.		40			ns
t_{CH}	SCK high time.		40			ns
f_{SCK}	SCK frequency.		0.125		4	MHz
t_R,t_F	SCK rise and fall time.				100	ns

1. Increases/decreases with 1.2 ns/pF load.

Table 43 *SPI timing parameters*

8.10 I2C compatible Two Wire Interface (TWI) specifications

Symbol	Description	Note	Min.	Typ.	Max.	Units
I_{2W100K}	Run current for TWI at 100 kbps.			380		µA
I_{2W400K}	Run current for TWI at 400 kbps.			400		µA
f_{2W}	Bit rates for TWI.		100		400	kbps
$t_{TWI,START}$	Time from STARTRX/STARTTX task is given until start condition.	Low power mode.[1] Constant latency mode.[1]		3 1	4.4	µs

1. For more information on how to control the sub power modes, see the *nRF51 Series Reference Manual*.

Table 44 *TWI specifications*

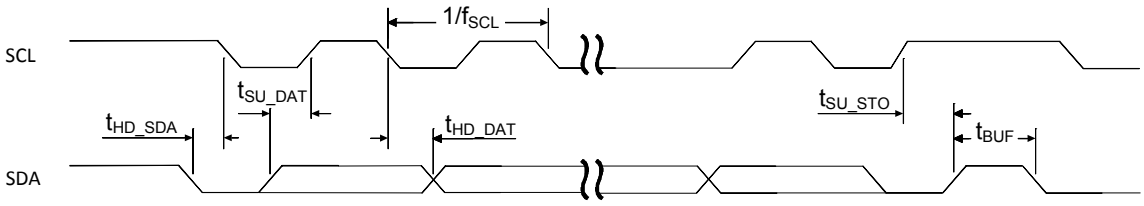

Figure 11 *SCL/SDA timing*

Symbol	Description	Standard Min.	Standard Max.	Fast Min.	Fast Max.	Units
f_{SCL}	SCL clock frequency.		100		400	kHz
t_{HD_STA}	Hold time for START and repeated START condition.	5200		1300		ns
t_{SU_DAT}	Data setup time before positive edge on SCL.	300		300		ns
t_{HD_DAT}	Data hold time after negative edge on SCL.	300		300		ns
t_{SU_STO}	Setup time from SCL goes high to STOP condition.	5200		1300		ns
t_{BUF}	Bus free time between STOP and START conditions.	4700		1300		ns

Table 45 *TWI timing parameters*

8.11 GPIO Tasks and Events (GPIOTE) specifications

Symbol	Description	Min.	Typ.	Max.	Units
$I_{GPIOTE,IN}$	Run current with 1 or more GPIOTE active channels in Input mode.		22		µA
$I_{GPIOTE,OUT}$	Run current with 1 or more GPIOTE active channels in Output mode.		0.1		µA
$I_{GPIOTE,IDLE}$	Run current when all channels are in Idle mode. PORT event can be generated with a delay of up to t_{1V2}.		0.1		µA

***Table 46** GPIOTE specifications*

Note: Setting up one or more GPIO DETECT signals to generate PORT EVENT, which can be used either as a wakeup source or to give an interrupt, will not lead to an increase of the current consumption.

8.12 Analog to Digital Converter (ADC) specifications

Note: HFCLK XOSC is required to get the stated ADC accuracy.

Symbol	Description	Note	Min.	Typ.	Max.	Units
DNL_{10b}	Differential non-linearity (10 bit mode).			< 1		LSB
INL_{10b}	Integral non-linearity (10 bit mode).			2		LSB
V_{OS}	Offset error.		-2		+2	%
e_G	Gain error.	1	-3		+3	%
V_{REF_VBG}	Internal Band Gap reference voltage (VBG).			1.20 V		V
$V_{REF\_VBG\_ERR}$	Internal Band Gap reference voltage error.		-2		+2	%
$TC_{REF\_VBG\_DRIFT}$	Internal Band Gap reference voltage drift.		-200		+200	ppm/°C
V_{REF_EXT}	External reference voltage (AREF0/1).		0.83	1.2	1.3	V
$V_{REF\_VDD\_LIM}$	Limited supply voltage range for ADC using VDD with prescaler as the reference. CONFIG.REFSEL = SupplyOneHalfPrescaling CONFIG.REFSEL = SupplyOneThirdPrescaling		 1.7 2.5		 2.6 3.6	 V V
t_{ADC10b}	Time required to convert a single sample in 10 bit mode.			68		µs
t_{ADC9b}	Time required to convert a single sample in 9 bit mode.			36		µs
t_{ADC8b}	Time required to convert a single sample in 8 bit mode.			20		µs
I_{ADC}	Current drawn by ADC during conversion.			260		µA
ADC_ERR_2V2	Absolute error when used for battery measurement at 2.2 V, 2.6 V, 3.0 V, and 3.4 V.	2		2		LSB
ADC_ERR_2V6				1		LSB
ADC_ERR_3V0				1		LSB
ADC_ERR_3V4				1		LSB

1. Source impedance less than 5 kΩ.
2. Internal reference, input from VDD/3, 10 bit mode.

Table 47 *Analog to Digital Converter (ADC) specifications*

8.13 Timer (TIMER) specifications

Symbol	Description	Note	Min.	Typ.	Max.	Units
$I_{TIMER0/1/2}$	Timer current when running from HFCLK in 16 MHz mode.			30		µA
$I_{TIMER0/1/2,1M}$	Timer current when running from HFCLK in 1 MHz mode.			4		µA
$t_{TIMER,START}$	Time from START task is given until timer starts counting.			0.25		µs

***Table 48** Timer specifications*

8.14 Real Time Counter (RTC)

Symbol	Description	Min.	Typ.	Max.	Units
I_{RTC}	Timer (LFCLK source).		0.1		µA

***Table 49** RTC*

8.15 Temperature sensor (TEMP)

Note: HFCLK XOSC is required to get the stated accuracy.

Symbol	Description	Min.	Typ.	Max.	Units
I_{TEMP}	Run current for Temperature sensor.		185		µA
t_{TEMP}	Time required for temperature measurement.		35		µs
T_{RANGE}	Temperature sensor range.	-40		105	°C
T_{ACC}	Temperature sensor accuracy.[1]	-4		+4	°C
T_{RES}	Temperature sensor resolution.		0.25		°C

1. Stated temperature accuracy is valid in the range 0 to 60°C.
Temperature accuracy outside the 0 to 60°C range is ± 8°C.

***Table 50** Temperature sensor*

8.16 Random Number Generator (RNG) specifications

Symbol	Description	Note	Min.	Typ.	Max.	Units
I_{RNG}	Run current at 16 MHz.			60		µA
$t_{RNG,RAW}$	Run time per byte in RAW mode.	Uniform distribution of 0 and 1 is not guaranteed.		167		µs
$t_{RNG,UNI}$	Run time per byte in Uniform mode.	Uniform distribution of 0 and 1 is guaranteed. Time to generate a byte cannot be guaranteed.		677		µs

Table 51 *Random Number Generator (RNG) specifications*

8.17 AES Electronic Codebook Mode Encryption (ECB) specifications

Symbol	Description	Min.	Typ.	Max.	Units
I_{ECB}	Run current for ECB.		550		µA
$t_{STARTECB, ENDECB}$	Time for a 16 byte AES block encrypt.		8.5	17	µs

Table 52 *ECB specifications*

8.18 AES CCM Mode Encryption (CCM) specifications

Symbol	Description	Min.	Typ.	Max.	Units
I_{CCM}	Run current for CCM.		550		µA

Table 53 *CCM specifications*

8.19 Accelerated Address Resolver (AAR) specifications

Symbol	Description	Min.	Typ.	Max.	Units
I_{AAR}	Run current for AAR.		550		µA
$t_{START,RESOLVED}$	Time for address resolution of 8 IRKs.		68		µs

Table 54 *AAR specifications*

8.20 Watchdog Timer (WDT) specifications

Symbol	Description	Min.	Typ.	Max.	Units
I_{WDT}	Run current for watchdog timer.		0.1		µA
t_{WDT}	Time out interval, watchdog timer.	30 µs		36 hrs	

Table 55 *Watchdog Timer specifications*

8.21 Quadrature Decoder (QDEC) specifications

Symbol	Description	Note	Min.	Typ.	Max.	Units
I_{QDEC}				12		µA
t_{SAMPLE}	Time between sampling signals from Quadrature Decoder.		128		16384	µs
t_{LED}	Time from LED is turned on to signals are sampled.	Only valid for optical sensors.	0		511	µs

Table 56 *Quadrature Decoder specifications*

8.22 Non-Volatile Memory Controller (NVMC) specifications

Flash write is performed by executing a program that writes one word (32 bit) consecutively after the other to the flash memory.

The program performing the flash write operation could be set up to run from flash or from RAM. The timing of one flash write operation depends on whether the next instructions following the flash write will be fetched from flash or from RAM. Any fetch from flash before the write operation is finished will give $t_{WRITE,FLASH}$ timing.

The flash memory is organized in 256 byte rows starting at CODE and UICR start addresses. Crossing from one row to another will affect the flash write timing when running from RAM.

The time it takes to program the flash memory will depend on different parameters:

- Whether the program doing the flash write is running from RAM or running from flash.
- When running from RAM we will have different timing for:
  - First write operation.
  - Repeated write operations within the same row.
  - Repeated write operation that are crossing from one row to another.

Symbol	Description	Note	Min.	Typ.	Max.	Units
$t_{ERASEALL}$	Erase flash memory.	1, 2			22.3	ms
$t_{PAGEERASEALL}$	Erase page in flash memory.	1, 2			22.3	ms
$t_{WRITE,FLASH}$	Program running from flash. Write one word to flash memory.	1, 3			46.3	µs
$t_{WRITE,RAM,1st}$	Program running from RAM. Write the first word to flash memory.	1			39.3	µs
$t_{WRITE,RAM,2nd}$	Program running from RAM. Repeated writes operations following the first, within the same row.	1			22.3	µs
$t_{WRITE,RAM,3rd}$	Program running from RAM. Repeated write operation, new word is located on a different row compare to the previous write.	1			46.3	µs

1. Max timing is assuming using RC16M, worst case tolerance.
2. The CPU will be halted for the duration of NVMC operations if the CPU tries to fetch data/code from the flash memory.
3. The CPU will be halted for the duration of NVMC operations.

Table 57 *NVMC specifications*

8.23 General Purpose I/O (GPIO) specifications

Symbol	Parameter (condition)	Note	Min.	Typ.	Max.	Units
V_{IH}	Input high voltage.		0.7 VDD		VDD	V
V_{IL}	Input low voltage.		VSS		0.3 VDD	V
V_{OH}	Output high voltage (std. drive, 0.5 mA).		VDD-0.3		VDD	V
V_{OH}	Output high voltage (high-drive, 5 mA).	1	VDD-0.3		VDD	V
V_{OL}	Output low voltage (std. drive, 0.5 mA).		VSS		0.3	V
V_{OL}	Output low voltage (high-drive, 5 mA).		VSS		0.3	V
R_{PU}	Pull-up resistance.		11	13	16	kΩ
R_{PD}	Pull-down resistance.		11	13	16	kΩ

1. Maximum number of pins with 5 mA high drive is 3.

Table 58 *General Purpose I/O (GPIO) specifications*

8.24 Low Power Comparator (LPCOMP) specifications

Symbol	Description	Min.	Typ.	Max.	Units
I_{LPC}	Run current for LPCOMP.		0.5		µA
$t_{LPCANADETOFF}$	Time from VIN crossing to ANADETECT signal generated when in System OFF.			15[1]	µs
$t_{LPCANADETON}$	Time from VIN crossing to ANADETECT signal generated when in System ON.			15[1]	µs
$t_{LPCOMPSTARTUP}$	Startup time for the Low Power Comparator.			40	µs

1. For 50 mV overdrive

Table 59 *Low power comparator specifications*

9 Mechanical specifications

This chapter covers the mechanical specifications for the nRF51824 chip.

9.1 QFN48 package

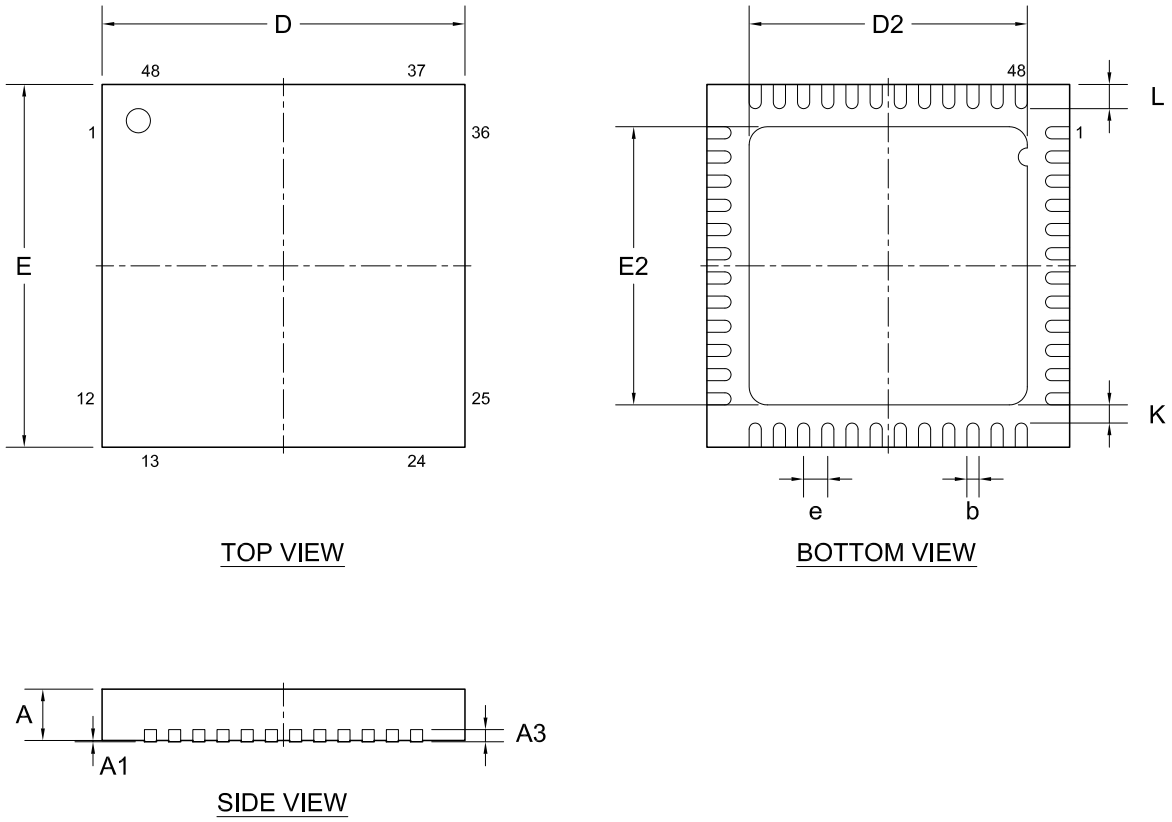

Figure 12 *QFN48 6 x 6 mm package*

Package	A	A1	A3	b	D, E	D2, E2	e	K	L	
QFN48 (6 x 6)	0.80	0.00	0.2	0.15	6.0	4.50	0.4	0.20	0.35	**Min.**
	0.85	0.02		0.20		4.60			0.40	**Nom.**
	0.90	0.05		0.25		4.70			0.45	**Max.**

Table 60 *QFN48 dimensions in millimeters*

10 Ordering information

10.1 Chip marking

N	5	1	8	2	4
<P	P>	<V	V>	<H>	<P>
<Y	Y>	<W	W>	<L	L>

Table 61 *Package marking*

10.2 Inner box label

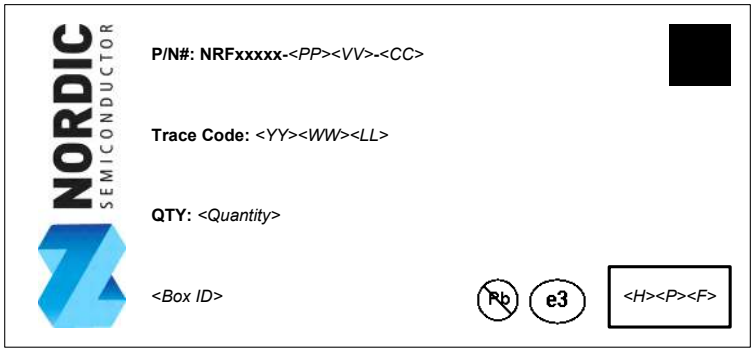

Figure 13 *Inner box label*

10.3 Outer box label

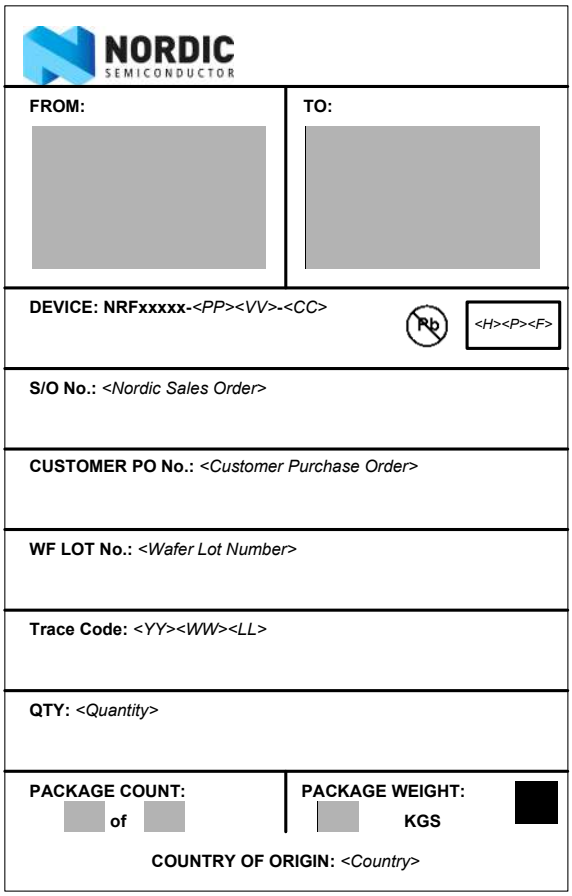

Figure 14 *Outer box label*

10.4 Order code

n	R	F	5	1	8	2	4	-	<P	P>	<V	V>	-	<C	C>

Table 62 *Order code*

10.5 Abbreviations

Abbreviation	Definition and implemented codes
N51/nRF51	nRF51 Series product
824	Part code
<PP>	Package code
<VV>	Variant code
<H><P><F>	Build code H - Hardware version code P - Production configuration code (production site, etc.) F - Firmware version (Only visible on shipping container label)
<YY><WW><LL>	Tracking code YY - Year code WW - Assembly week number LL - Wafer lot code
<CC>	Container code

Table 63 *Abbreviations*

10.6 Code ranges and values

<PP>	Packet	Size (mm)	Pin Count	Pitch (mm)
QF	QFN	6 x 6	48	0.4

Table 64 *Package codes*

<VV>	Flash (kB)	RAM (kB)	DC/DC Bond-out
AA	256	16	YES

Table 65 *Variant codes*

<H>	Description
[A. .Z]	Hardware version/revision identifier (incremental).

Table 66 *Hardware version codes*

<P>	Description
[0. .9]	Production device identifier (incremental).
[A. .Z]	Engineering device identifier (incremental).

Table 67 *Production version codes*

<F>	Description
[A. .N, P. .Z]	Version of programmed firmware
[0]	Delivered without preprogrammed firmware

Table 68 *Firmware version codes*

<YY>	Description
[16. .99]	Production year: 2016 to 2099

Table 69 *Year codes*

<WW>	Description
[1. .52]	Week of production

Table 70 *Week codes*

<LL>	Description
[AA. .ZZ]	Wafer production lot identifier

Table 71 *Lot codes*

<CC>	Description
R7	7" Reel
R	13" Reel
T	Tray

Table 72 *Container codes*

10.7 Product options

10.7.1 nRF ICs

Order code	MOQ[1]
nRF51824-QFAA-R7	1000
nRF51824-QFAA-R	3000
nRF51824-QFAA-T	490

1. Minimum Order Quantity.

Table 73 *Order code*

10.7.2 Development tools

Order code	Description
nRF51-DK[1]	nRF51 *Bluetooth* Smart/ANT/2.4 GHz RF Development Kit
nRF51-Dongle[1]	nRF51 USB dongle for emulator, sniffer, firmware development

1. Uses the nRF51422-QFAC version of the chip (capable of running both *Bluetooth* low energy and ANT).

Table 74 *Development tools*

11 Reference circuitry

For the following reference layouts, C_pcb1 and C_pcb2, between X1 and XC1/XC2, is estimated to 0.5 pF each.

The exposed center pad of the QFN48 package must be connected to supply ground for proper device operation.

11.1 PCB guidelines

A well designed PCB is necessary to achieve good RF performance. A poor layout can lead to loss in performance or functionality. A qualified RF layout for the IC and its surrounding components, including matching networks, can be downloaded from the Infocenter.

Follow the schematics and layout references closely for optimal performance. In the case of the antenna matching circuitry (components between device pins **ANT1**,**ANT2**, **VDD_PA** and the antenna), any changes to the layout can change the behavior, resulting in degradation of RF performance or a need to change component values. All the reference circuits are designed for use with a 50 Ω single end antenna.

A PCB with a minimum of two layers, including a ground plane, is recommended for optimal performance. On PCBs with more than two layers, put a keep-out area on the inner layers directly below the antenna matching circuitry (components between device pins **ANT1**, **ANT2**, **VDD_PA**, and the antenna) to reduce the stray capacitances that influence RF performance.

A matching network is needed between the differential RF pins **ANT1** and **ANT2** and the antenna, to match the antenna impedance (normally 50 Ω) to the optimum RF load impedance for the chip. For optimum performance, the impedance for the matching network should be set as described in ***Section 8.5.7 "Antenna matching network requirements"*** on page 45 along with the recommended QFN48 package reference circuitry from ***Section 11.2 "Reference design schematics"*** on page 66.

The DC supply voltage should be decoupled as close as possible to the VDD pins with high performance RF capacitors. See the schematics for recommended decoupling capacitor values. The supply voltage for the chip should be filtered and routed separately from the supply voltages of any digital circuitry.

Long power supply lines on the PCB should be avoided. All device grounds, VDD connections, and VDD bypass capacitors must be connected as close as possible to the IC. For a PCB with a topside RF ground plane, the VSS pins should be connected directly to the ground plane. For a PCB with a bottom ground plane, the best technique is to have via holes as close as possible to the VSS pads. A minimum of one via hole should be used for each VSS pin.

Full-swing digital data or control signals should not be routed close to the crystal or the power supply lines. Capacitive loading of full-swing digital output lines should be minimized in order to avoid radio interference.

11.1.1 PCB layout example

The PCB layout shown in ***Figure 15*** is a reference layout for the QFN package with internal LDO setup. For all available reference layouts, see the Reference Layout page in our Infocenter.

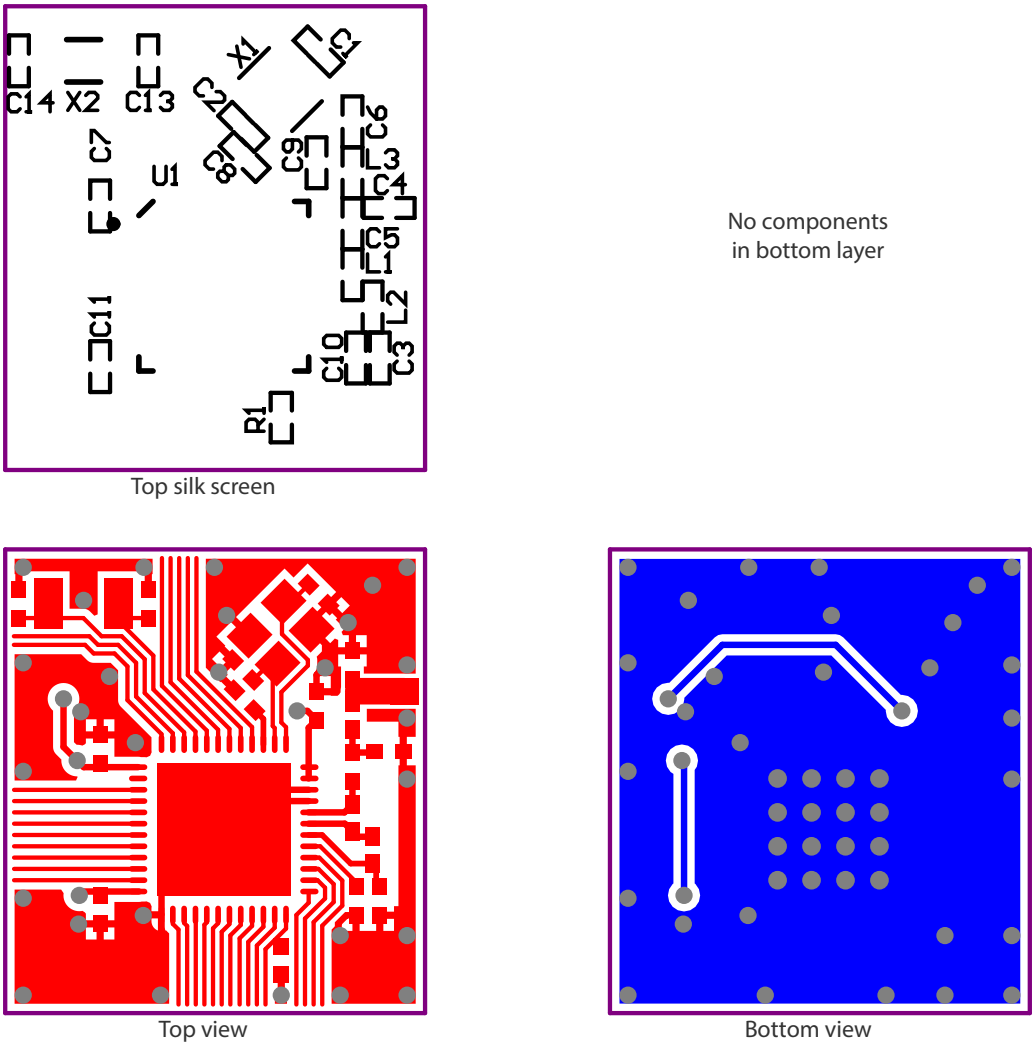

Figure 15 *PCB layout for QFN48 package with internal LDO setup*

11.2 Reference design schematics

The following sections include the reference design schematics for the nRF51824 QFAA QFN48 package.

Documentation for the QFAA QFN48 package reference circuit, including Altium Designer files, PCB layout files, and PCB production files can be downloaded from Infocenter.

11.2.1 QFAA QFN48 schematic with internal LDO setup

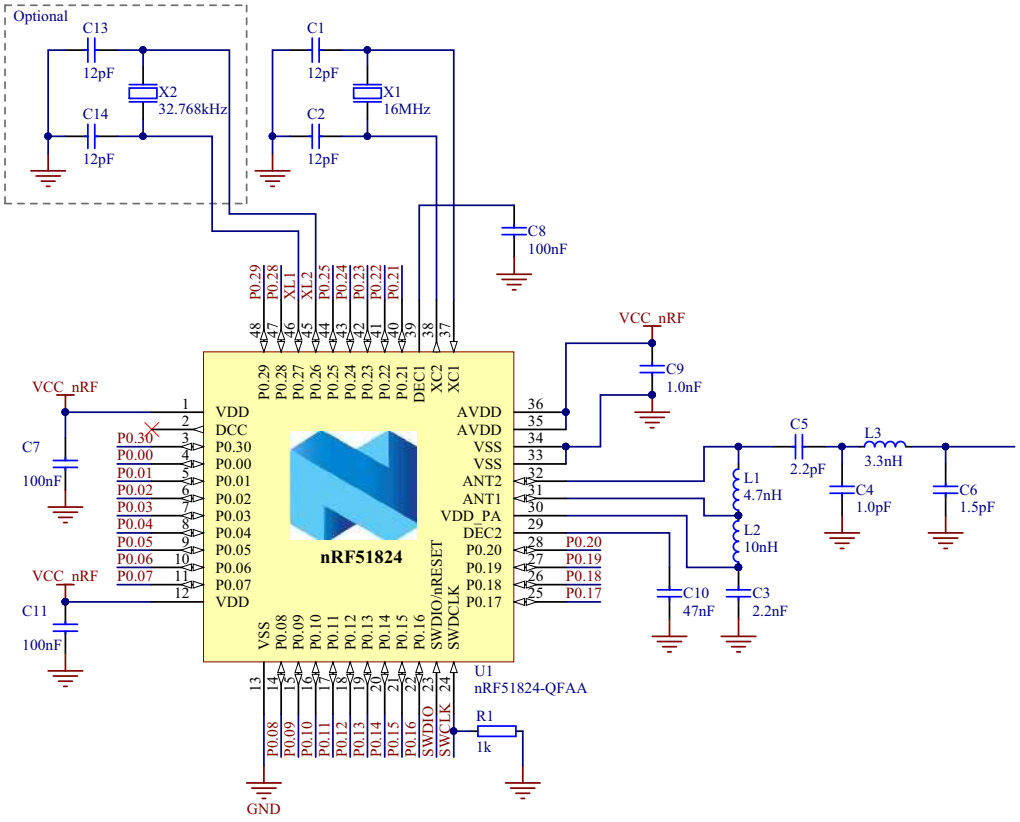

Figure 16 *QFAA QFN48 with internal LDO setup*

Note: For PCB reference layouts, see the Reference Layout page in our Infocenter.

11.2.1.1 Bill of Materials

Designator	Value	Description	Footprint
C1, C2, C13, C14	12 pF	Capacitor, NP0, ±2%	0402
C3	2.2 nF	Capacitor, X7R, ±10%	0402
C4	1.0 pF	Capacitor, NP0, ±0.1 pF	0402
C5	2.2 pF	Capacitor, NP0, ±0.1 pF	0402
C6	1.5 pF	Capacitor, NP0, ±0.1 pF	0402
C7, C8, C11	100 nF	Capacitor, X7R, ±10%	0402
C9	1.0 nF	Capacitor, X7R, ±10%	0402
C10	47 nF	Capacitor, X7R, ±10%	0402
L1	4.7 nH	High frequency chip inductor ±5%	0402
L2	10 nH	High frequency chip inductor ±5%	0402
L3	3.3 nH	High frequency chip inductor ±5%	0402
R1	1 kΩ	Resistor ±1%, 0.063 W	0402
U1	nRF51824-QFAA	RF SoC	QFN48
X1	16 MHz	Crystal SMD 2520, 16 MHz, 8 pF, ±40 ppm	SMD 2520
X2	32.768 kHz	Crystal SMD 3215, 32.768 kHz, 9 pF, ±50 ppm	SMD 3215

Table 75 *QFAA QFN48 with internal LDO setup*

11.2.2 QFAA QFN48 schematic with DC/DC converter setup

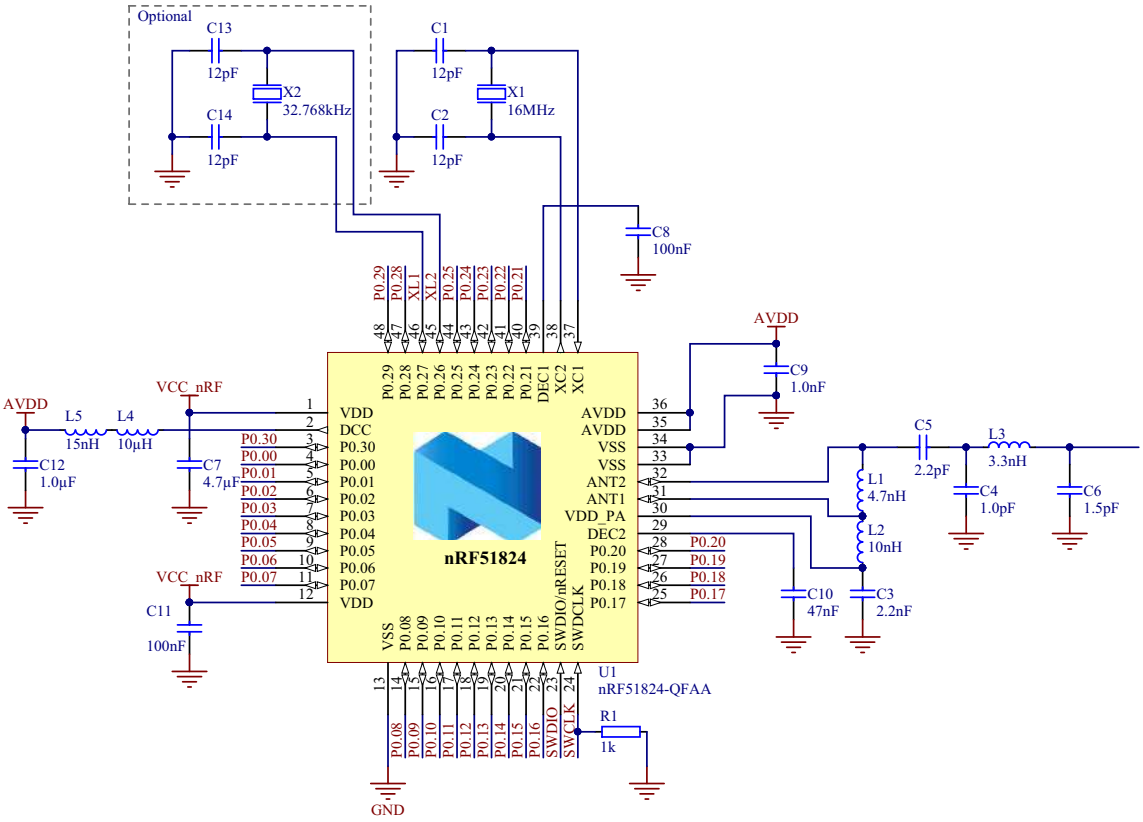

Figure 17 *QFAA QFN48 with DC/DC converter setup*

Note: For PCB reference layouts, see the Reference Layout page in our Infocenter.

11.2.2.1 Bill of Materials

Designator	Value	Description	Footprint
C1, C2, C13, C14	12 pF	Capacitor, NP0, ±2%	0402
C3	2.2 nF	Capacitor, X7R, ±10%	0402
C4	1.0 pF	Capacitor, NP0, ±0.1 pF	0402
C5	2.2 pF	Capacitor, NP0, ±0.1 pF	0402
C6	1.5 pF	Capacitor, NP0, ±0.1 pF	0402
C7	4.7 µF	Capacitor, X5R, ±10%	0603
C8, C11	100 nF	Capacitor, X7R, ±10%	0402
C9	1.0 nF	Capacitor, X7R, ±10%	0402
C10	47 nF	Capacitor, X7R, ±10%	0402
C12	1.0 µF	Capacitor, X7R, ±10%	0603
L1	4.7 nH	High frequency chip inductor ±5%	0402
L2	10 nH	High frequency chip inductor ±5%	0402
L3	3.3 nH	High frequency chip inductor ±5%	0402
L4	10 µH	Chip inductor, $I_{DC,min}$ = 50 mA, ±20%	0603
L5	15 nH	High frequency chip inductor ±10%	0402
R1	1 kΩ	Resistor ±1%, 0.063 W	0402
U1	nRF51824-QFAA	RF SoC	QFN48
X1	16 MHz	Crystal SMD 2520, 16 MHz, 8 pF, ±40 ppm	SMD 2520
X2	32.768 kHz	Crystal SMD 3215, 32.768 kHz, 9 pF, ±50 ppm	SMD 3215

Table 76 *QFAA QFN48 with DC/DC converter setup*

12 Glossary

Term	Description
EOC	Extreme Operating Conditions
GFSK	Gaussian Frequency-Shift Keying
GPIO	General Purpose Input Output
ISM	Industrial Scientific Medical
MOQ	Minimum Order Quantity
NOC	Nominal Operating Conditions
NVMC	Non-Volatile Memory Controller
QDEC	Quadrature Decoder
RF	Radio Frequency
RoHS	Restriction of Hazardous Substances
RSSI	Radio Signal Strength Indicator
SPI	Serial Peripheral Interface
TWI	Two-Wire Interface
UART	Universal Asynchronous Receiver Transmitter

Table 77 *Glossary*