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nRF8001

Single-chip *Bluetooth*® low energy solution

Product Specification 1.3

Key Features

- *Bluetooth* low energy peripheral device
- Stack features:
  - Low energy PHY layer
  - Low energy link layer slave
  - Low energy host for devices in the peripheral role
  - Proprietary Application Controller Interface (ACI)
- Hardware features:
  - 16 MHz crystal oscillator
  - Low power 32 kHz ± 250 ppm RC oscillator
  - 32.768 kHz crystal oscillator
  - DC/DC converter
  - Temperature sensor
  - Battery monitor
  - Direct Test Mode interface
- Ultra-low power consumption
- Single 1.9 - 3.6 V power supply
- Temperature range -40 to 85°C
- Compact 5x5 mm QFN32 package
- RoHS compliant

Applications

- Sport and fitness sensors
- Health care sensors
- Proximity
- Watches
- Personal User Interface Devices (PUID)
- Remote controls

2015-03-12

Liability disclaimer

Life support applications

Datasheet 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
March 2015	1.3	• Removed B017566 and added QDID for the nRF8001 qualification using the new *Bluetooth* qualification regime in Chapter 2 on page 9. • Minor modification in the introduction to Table 31 on page 92. • Updated Section 24.4.1 on page 100
August 2013	1.2	• Updated Chapter 3 on page 11, Section 4.1 on page 13, Table 1 on page 15, Section 6.2 on page 16, Figure 10. on page 23, Figure 11. on page 24, Section 7.1.5 on page 24, Section 7.1.6 on page 24, Table 5 on page 30, Table 9 on page 34, Table 14 on page 36, Table 15 on page 37, Chapter 17 on page 51, Figure 45. on page 80 and Section 24.23.3 on page 128. • Added Section 14.4 on page 48, Section 20.6 on page 72 and Section 20.7 on page 74. • Fixed minor issues throughout the document
October 2012	1.1	• Fixed C/I values in Table 12. on page 35. • Added Section 7.1.4 on page 23. • Updated Figure 28. on page 62 through Figure 42. on page 73. • Updated figures in Section 20.5 on page 66 to highlight location of GATT server and client. • Added additional information about the command response event to each section in Chapter 24 on page 96 and Chapter 25 on page 133. • Re-ordered the sections in Chapter 24 on page 96 by OpCode.
January 17th 2012	1.0	• First release of the Product Specification • Fixed minor issues throughout the document • Updated the schematics, Figure 21. on page 51 and Figure 22. on page 53

Contents

1 Introduction

nRF8001 is a *Bluetooth*® low energy solution designed for operation in the peripheral role. By integrating a *Bluetooth* low energy compliant radio (PHY), slave mode link controller, and host, nRF8001 offers you an easy way to add *Bluetooth* low energy connectivity to your application.

nRF8001 offers a serial interface (ACI) for configuration and control from your microcontroller. This microcontroller will in the remainder of this document be referred to as the application controller.

This document is divided into two parts:

- **Part A** defines the nRF8001 hardware and electrical specifications as well as operating procedures.
- **Part B** describes the Application Controller Interface (ACI); the logical interface between the nRF8001 and your application

1.1 Prerequisites

To fully understand this document, knowledge of electronic and software engineering is required.

Knowledge of *Bluetooth Core specification* v4.0, Volumes 1, 3, 4, and 6 is required to operate nRF8001 correctly and to understand the terminology used within this document.

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

1.3 *Bluetooth* specification releases

This document is valid based on *Bluetooth Core specification* v4.0 for a low energy device operating in the peripheral role.

2 *Bluetooth* Qualification ID

nRF8001 is listed as an EP-QDL on the Qualified listings page of the *Bluetooth* Special Interest Group website (https://www.bluetooth.org/tpg/listings.cfm).

For details on the design qualifications, please refer to the following qualification ID:

- B019756: QDID - 39051: nRF8001 end product containing core PICS.

Part A: nRF8001 Physical description

This section defines the physical features of nRF8001 and its electrical and mechanical specifications. It also defines the nRF8001 hardware, specifications, and provides information on operating procedures.

3 Product overview

nRF8001's main physical features are the *Bluetooth* low energy PHY and the *Bluetooth* low energy stack that handles the link controller and host stack. It also includes additional analog sub-systems needed for the *Bluetooth* low energy operation, such as power management and several oscillator options.

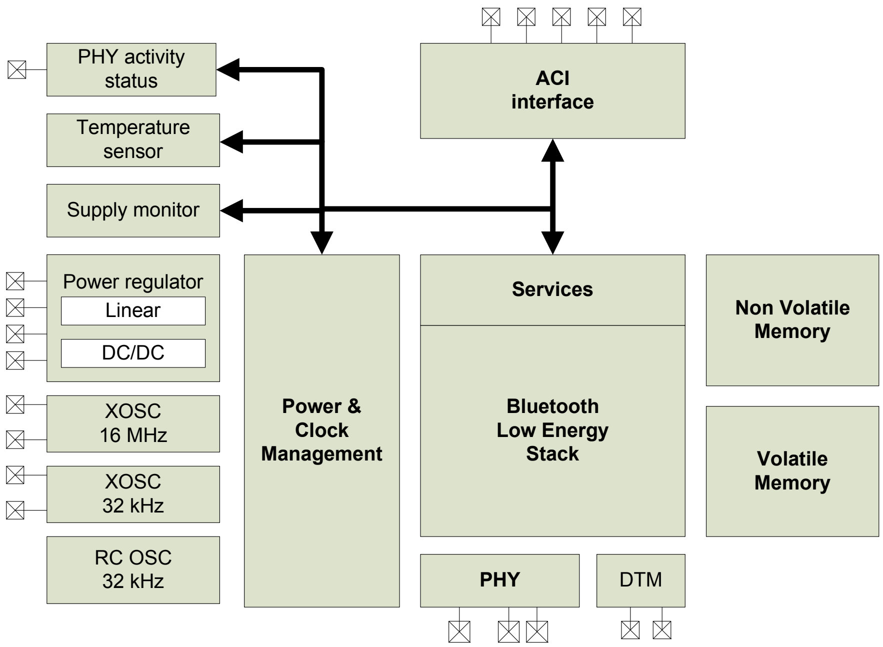

Figure 1. nRF8001 block diagram

nRF8001 has on-chip non-volatile memory for storing service configurations. This on-chip storage lets you select and combine the necessary services for your application, reducing the requirements on your application controller for handling all real-time operations related to the *Bluetooth* low energy communication protocol.

nRF8001 includes a power supply voltage monitor and a temperature sensor that further reduces the requirements to the application controller. These features are accessible through the Application Controller Interface (ACI).

nRF8001 also offers an optional output signal (**ACTIVE**) that is activated before the radio becomes active. This timing signal enables you to control the peak current drain of your application, avoiding overload of your power supply (for most applications this is usually a small battery). You can also use this timing signal to control the application circuitry, avoiding noise interference when the nRF8001 radio is operating.

A separate serial interface (UART) gives you access to the *Bluetooth* low energy Direct Test Mode (DTM). This interface is used to control the *Bluetooth* low energy radio (RF PHY) and is supported by commercially available *Bluetooth* test equipment used for *Bluetooth* qualification. This serial interface also enables you to test radio performance and to optimize your antenna.

4 *Bluetooth* low energy features

nRF8001 includes *Bluetooth* low energy protocols and profiles (see Figure 2.) that are defined in the *Bluetooth Core specification* v4.0 in the following volumes:

- Volume 2 Part D: Error Codes
- Volume 3: Core System Package [Host Volume]
    - Part A: Logical Link Control and Protocol
    - Part C: Generic Access Profile (GAP)
    - Part F: Attribute Protocol (ATT)
    - Part G: Generic Attribute Profile (GATT)
    - Part H: Security Manager (SM)
- Volume 6: Core System Package [Low Energy Controller Volume]

nRF8001 supports the peripheral role as defined in the *Bluetooth low energy specification* Volume 3, Part C, 2.2.2.3 Peripheral Role. All mandatory features for a device operating in the peripheral role are supported. In addition to the mandatory features, a subset of optional features are available for use. Access to these features is specified in Part B of this document. Detailed information of the *Bluetooth* low energy features supported in nRF8001 can be found in the *Bluetooth* design listings as specified in Chapter 2 on page 9.

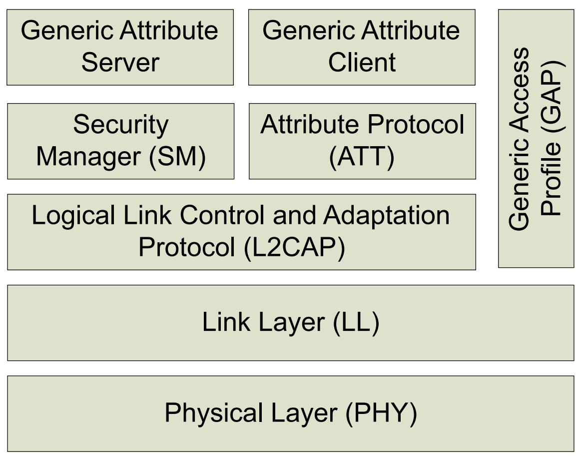

Figure 2. Bluetooth low energy layers implemented in nRF8001

4.1 Features

nRF8001 features

- Radio features
  - *Bluetooth* low energy RF transceiver
  - Ultra-low peak current consumption <14 mA
  - Common TX/RX terminals
  - Low current for connection oriented profiles, typically 2 µA
  - Ultra-low current for connectionless oriented profiles, typically 500 nA
- Auxiliary features
  - Integrated low frequency reference oscillator
  - Power management
  - Battery monitor
  - Temperature monitor
  - DC/DC converter that reduces current by up to 20% if enabled
  - Integrated 16 MHz crystal oscillator
  - OTP for customer configuration
- Interfaces
  - UART Test Interface for Direct Test Mode
  - Application Controller Interface (ACI)
  - Radio Active signal

Bluetooth low energy features

- *Bluetooth* low energy stack
  - All layers up to GATT included in core software stack
- Link Layer Features
  - Slave role
  - Control PDUs in the slave role
  - 27 byte MTU
  - Encryption
- L2CAP
  - 27 byte MTU
  - Slave connection update
  - Attribute Channel
  - Security Channel
- General Access Profile (GAP) features
  - Discoverable modes
  - Dedicated bonding
  - GAP attributes
- Attribute Protocol
  - Mandatory client protocol
  - Mandatory server protocol
- Security Manager
  - Generation of keys for encryption
  - Just works security
  - Passkey entry
- Generic Attribute Profile (GATT)
  - Mandatory client profile features
  - Mandatory server profile features
- Direct Test Mode (DTM)
  - DTM for RF qualification

5 Physical product overview

This section describes the physical properties of nRF8001.

5.1 Package and pin assignment

nRF8001 is available in a 5 x 5 mm QFN32 package. The backplate of the QFN32 capsule must be grounded to the application PCB in order to achieve optimal performance. The physical dimensions of nRF8001 are presented in Chapter 15 on page 49.

Figure 3. shows the pin assignment for nRF8001 and Table 1. on page 15 describes the pin functionality.

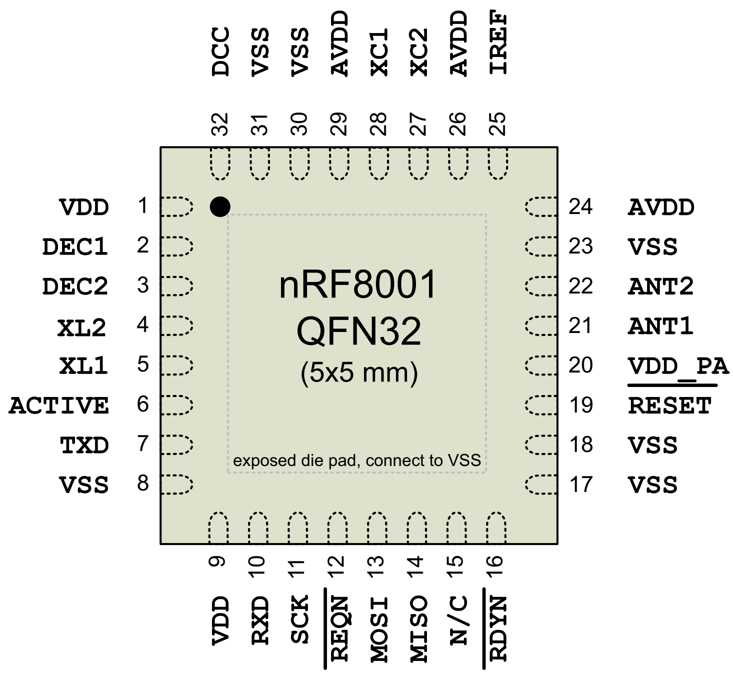

Figure 3. nRF8001 pin assignment (top view)

5.2 Pin functions

Pin	Pin name	Pin function	Description
1	**VDD**	Power	Power supply (1.9 – 3.6 V)
2	**DEC1**	Power	Regulated power supply output for decoupling purposes only. Connect 100 nF capacitor to ground
3	**DEC2**	Power	Regulated power supply output for decoupling purposes only. Connect 33 nF capacitor to ground
4	**XL2**	Analog output	Connect to 32.768 kHz crystal oscillator. If internal RC oscillator is enabled, this pin shall not be connected.
5	**XL1**	Analog input	Connect to 32.768 kHz crystal oscillator or external 32.768 kHz clock reference. If internal RC oscillator is enabled, this pin shall not be connected. If using a digital clock, this pin must be defined when entering sleep mode.
6	**ACTIVE**	Digital output	Device RF front end activity indicator
7	**TXD**	Digital output	UART (transmit) for *Bluetooth* low energy Direct Test Mode Interface. Leave unconnected if not in use.
8	**VSS**	Power	Ground (0 V)
9	**VDD**	Power	Power supply (1.9 – 3.6 V)
10	**RXD**	Digital input	UART (receive) for *Bluetooth* low energy Direct Test Mode Interface. Leave unconnected if not in use.
11	**SCK**	Digital input	ACI clock input. Must be high or low and not floating.
12	**REQN**	Digital input	ACI request pin (handshaking, active low). Must be high or low and not floating.
13	**MOSI**	Digital input	ACI Master Out Slave In. Must be high or low and not floating.
14	**MISO**	Digital output	ACI Master In Slave Out
15	**N/C**	Digital input	Not connected
16	**RDYN**	Digital output	ACI device ready indication (handshaking, active low)
17	**VSS**	Power	Ground (0 V)
18	**VSS**	Power	Ground (0 V)
19	**RESET**	Digital input	Reset (active low)
20	**VDD_PA**	Power output	Regulated power supply output for on-chip RF Power amplifier
21	**ANT1**	RF	Differential antenna connection (TX and RX)
22	**ANT2**	RF	Differential antenna connection (TX and RX)
23	**VSS**	Power	Ground (0 V)
24	**AVDD**	Power	Analog power supply (1.9 – 3.6 V DC)
25	**IREF**	Analog output	Current reference terminal. Connect a 22 kΩ 1% resistor to ground
26	**AVDD**	Power	Analog power Supply (1.9 – 3.6 V)
27	**XC2**	Analog output	Connection for 16 MHz crystal oscillator. Leave unconnected if not in use.
28	**XC1**	Analog input	Connection for 16 MHz crystal or external 16 MHz reference
29	**AVDD**	Power	Analog power supply (1.9 – 3.6 V DC)
30	**VSS**	Power	Ground (0 V)
31	**VSS**	Power	Ground (0 V)
32	**DCC**	Power	Pulse Width Modulated (PWM) driver for the external LC filter if the DC/DC converter is enabled. If the DC/DC converter is disabled this pin shall be not connected.
Exposed die pad	**VSS**	Power	Ground (0 V)

Table 1.nRF8001 pin functions

6 Analog and physical features

This chapter describes the analog and physical features of nRF8001.

The following analog features are included in nRF8001:

- *Bluetooth* low energy RF transceiver
- Three on-chip reference oscillators
- DC/DC converter for extended battery life with coin-cell batteries
- Temperature sensor
- Battery monitor

6.1 RF transceiver

nRF8001 includes an integrated RF transceiver which is compliant with the *Bluetooth Core specification* v4.0 Volume 6, Part A. The RF transceiver requires the following external components to operate:

- 16 MHz crystal or external 16 MHz reference
- Resistor for setting internal bias currents
- Balun to match an antenna to the receiver/transmitter pins of nRF8001

6.1.1 Enabling the RF transceiver

All RF transceiver functionality and operation is controlled through the ACI. Configuring the GAP parameters and entering a mode of operation through the ACI enables the transceiver to send advertisement events and connect to a peer device. Data transfer is initiated after the negotiated *Bluetooth* low energy setup procedures have been completed.

6.2 On-chip oscillators

nRF8001 includes three integrated oscillators:

- Low power amplitude regulated 16 MHz crystal oscillator
- Ultra-low power amplitude regulated 32.768 kHz crystal oscillator
- Ultra-low power 32.768 kHz RC oscillator with ± 250 ppm frequency accuracy

The 16 MHz crystal oscillator provides the reference frequency for the RF transceiver. The two low frequency 32.768 kHz oscillators provide the protocol timing. Only one low frequency reference can be used at any time. The choice of which reference to use depends on your application and will affect the design cost and current consumption. The low frequency crystal oscillator clock can be driven by either a 32.768 kHz crystal oscillator or a 32.768 kHz external clock source.

6.2.1 Enabling the oscillators

The 16 MHz crystal oscillator is automatically enabled when nRF8001 requires it. The 32.768 kHz oscillator is automatically enabled when nRF8001 is in a connection or advertising state. Both the 32.768 kHz and the 16 MHz reference sources and oscillator settings are set through the ACI, see Part B, section 22.3 on page 81.

6.2.2 16 MHz crystal oscillator

The 16 MHz 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 datasheet. Figure 4. shows how the crystal is connected to the 16 MHz crystal oscillator.

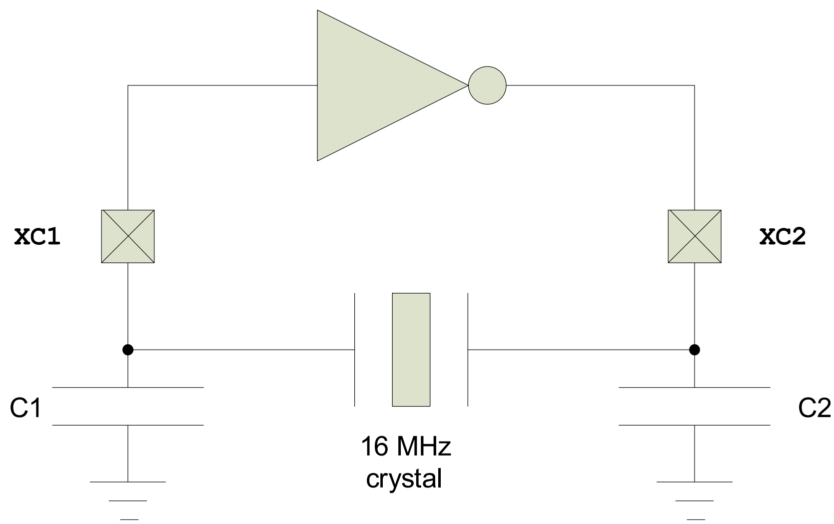

Figure 4. Circuit diagram of the nRF8001 16 MHz crystal oscillator

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

$$C_{load} = \frac{(C1' \times C2')}{(C1' + C2')}$$

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

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

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, typically 1 pF. The load capacitance C1 and C2 should be of the same value.

6.2.3 External 16 MHz clock

nRF8001 may be used with an external 16 MHz reference applied to the **XC1** pin instead of a 16 MHz crystal. An input amplitude of 0.8 V peak-to-peak or higher is recommended to achieve low current consumption. Keep the maximum voltage level so that all peak voltages are under the recommended maximum operating conditions as specified in Chapter 11 on page 33. The external signal must have an accuracy of 40 ppm or better. The **XC1** pin loads the external application's crystal oscillator with approximately 1 pF in addition to PCB routing. Do not connect the **XC2 pin**.

6.2.4 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 datasheet. Figure 5. on page 18 shows how the crystal is connected to the 32.768 kHz crystal oscillator.

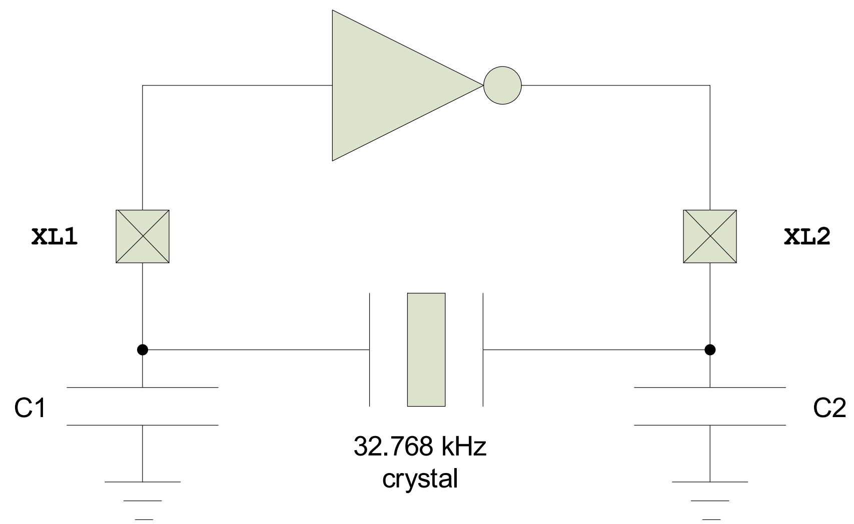

Figure 5. Circuit diagram of the nRF8001 32.768 kHz crystal oscillator

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

$$C_{load} = \frac{(C1' \times C2')}{(C1' + C2')}$$

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

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

C1 and C2 are ceramic SMD capacitors connected between **XC1** and **XC2** and ground. C_pcb1 and C_pcb2 are stray capacitances on the PCB. C_pin is the input capacitance on the **XC1** and **XC2** pins, typically 1 pF. C1 and C2 should be of the same value.

6.2.5 32.768 kHz RC oscillator

The nRF8001 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 ± 250 ppm in a stable temperature environment. The 32.768 kHz RC oscillator does not require external components.

6.2.6 External 32.768 kHz clock

nRF8001 may be used with an external 32.768 kHz clock applied to the **XL1** pin. The application controller sets the reference signal configuration. It can be a rail-to-rail signal or an analog signal. An analog input signal must have an amplitude of 0.2 V peak-to-peak or greater. Keep the maximum and minimum voltage levels so that all peak voltages are under recommended maximum operating conditions as specified in Chapter 11 on page 33. If the external source is derived from the application controller's crystal oscillator, the **XL1** pin will load the application's crystal oscillator with approximately 3 pF in addition to PCB routing.

6.3 DC/DC converter

nRF8001 incorporates linear supply voltage regulators and an optional step-down DC/DC converter. The internal linear regulators are always enabled. When enabled, the step-down DC/DC converter transforms the battery voltage to a lower internal voltage with minimal power loss. The converted voltage is then fed to the input of the linear regulators.

This feature is particularly useful for applications using battery technologies with higher nominal cell voltages. 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 20%.

The DC/DC converter is functional only when operating from the internal 32.768 kHz RC oscillator (see Section 6.2.5 on page 18) or from an external 32.768 kHz digital rail-to-rail clock (see Section 6.2.6 on page 18).

Figure 6. illustrates the peak current reduction in percentage (%) using the values for I_{RX_DC} and I_{TX_DC} in Table 15 on page 37.

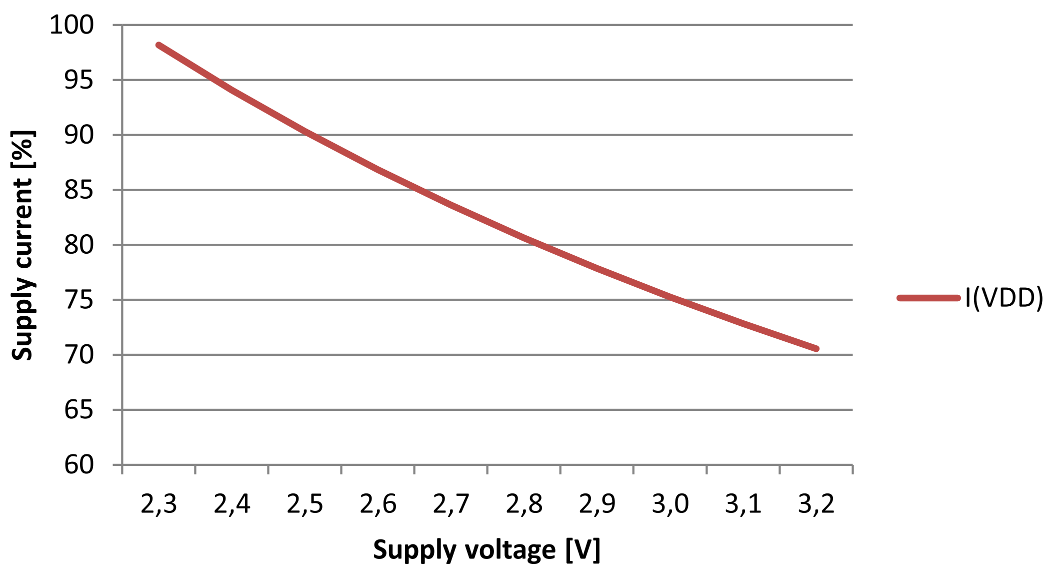

Figure 6. Relative current consumption over supply voltage with DC/DC converter enabled

Note: Three external passive components are required in order to use the step-down converter. See Chapter 17 on page 51 for details on schematics, layout and BOM for the two power supply alternatives.

6.3.1 Enabling the DC/DC converter

You can enable the DC/DC converter through nRFgo Studio, see Part B, section 22.3 on page 81.

6.4 Temperature sensor

nRF8001 incorporates an integrated temperature sensor. The temperature sensor reports the silicon temperature. The temperature sensor's electrical specifications are defined in Chapter 12 on page 34.

6.4.1 Enabling the temperature sensor

The temperature sensor is enabled through the ACI protocol, see Part B, section 24 on page 96. When nRF8001 receives an ACI command initiating the temperature reading it will enable the temperature sensor and start the internal measurement procedure. Upon completion, nRF8001 returns an ACI event reporting the current temperature reading.

6.5 Battery monitor

nRF8001 incorporates an integrated battery monitor. The battery monitor reports the supply voltage (VDD) connected to nRF8001 supply pins. The battery monitor's electrical specifications are defined in Chapter 12 on page 34.

6.5.1 Enabling the battery monitor

The battery monitor sensor is enabled through the ACI protocol see Part B, section 24 on page 96. When nRF8001 receives an ACI command initiating the battery reading it will enable the battery monitor and start the internal measurement procedure. Upon completion, the nRF8001 returns an ACI event reporting the current battery monitor reading.

6.6 Dynamic Window Limiting

Dynamic Window Limiting reduces the average current consumption by reducing the window widening of the receiver, see *Bluetooth Core specification* v4.0, Vol. 6, Part B, section 4.5.7. Dynamic Window Limiting is an optional feature that can be enabled or disabled using nRFgo Studio (see section 22.3 on page 81 for more information on nRFgo Studio). Enabling this feature reduces the overall system ppm to an average of 20 ppm.

> **Note:** Under conditions that cause a major disruption to either the local or peer low frequency clock, the connection may become unstable and terminate.

6.7 Application latency

Application Latency is an optional feature that subrates the slave latency so that nRF8001 listens for the central device's packets at the subrated connection interval. When nRF8001 is in a connection, Application Latency can be enabled or disabled in real time (see Part B, section 24.23 on page 128). When it is enabled, it is used with Slave Latency, see *Bluetooth Core specification* v4.0, Vol. 6, Part B, section 4.5.1.

When Application Latency is enabled, nRF8001 does not turn on its transmitter and acknowledge an empty received packet. This saves nRF8001 current by returning to a low current mode, it also reduces the application latency between a central device and a peripheral device. If the received packet is empty but the MD (More Data) bit in the header is set to 1 then nRF8001 acknowledges the empty packet and listens in the same event for the data indicated by the MD bit.

The average current consumption of the link is significantly reduced compared to a regular continuous connection. But, the application latency of data both for the central and peripheral is significantly lower than for a connection using slave latency only.

7 Interfaces

This chapter defines the physical interfaces for nRF8001:

- Application Controller Interface (ACI)
- Active signal
- *Bluetooth* low energy Direct Test Mode Interface

7.1 Application Controller Interface (ACI)

The Application Controller Interface (ACI) enables an application controller to communicate with nRF8001. The ACI consists of a physical transport which is described in this chapter and a logical interface which is described in Part B of this product specification.

7.1.1 Physical description

The physical ACI interface on nRF8001 consists of five pins. All ACI data exchanges use a standard SPI interface, with nRF8001 using a mode 0 slave interface to the application controller.

However, nRF8001 does not behave as a pure SPI slave device; nRF8001 can receive new data over-the-air at any time or be busy processing a connection event or new data. Consequently, the traditional CSN signal used to initiate an SPI transaction is replaced by two active low hand-shake signals; RDYN and REQN.

These hand shake signals allow nRF8001 to notify the application controller when it has received new data over-the-air and also to hold new data exchanges initiated by the application controller until it is ready to accept and process them. The ACI connections are shown in Figure 7.

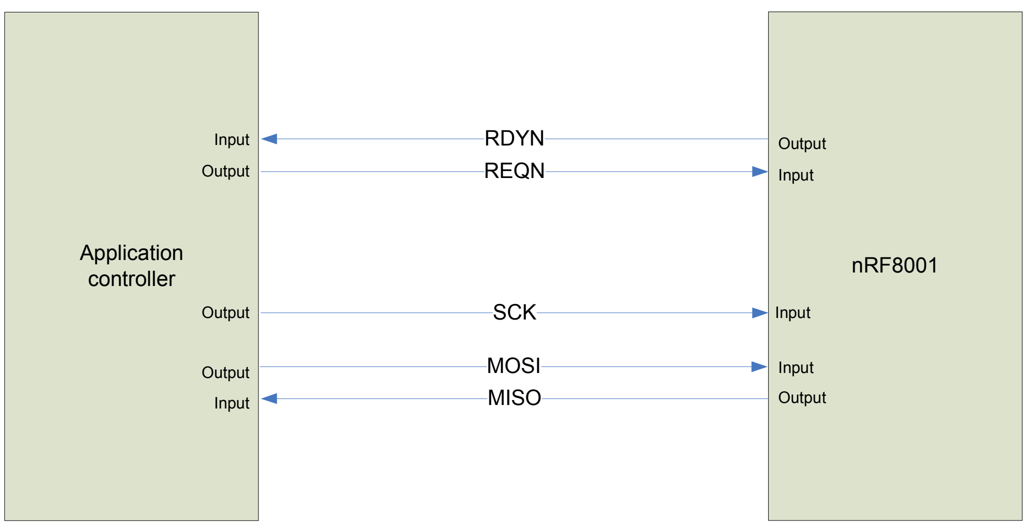

Figure 7. ACI interface between application controller and nRF8001

The data exchanges on the ACI interface are split into two types:

- Commands – Exchanges that are initiated by the application controller, including data that is sent from the application controller to nRF8001.
- Events – Exchanges that are initiated by nRF8001, including data that is sent from nRF8001 to the application controller.

If nRF8001 has event data ready for the application controller when the processor requests a command exchange, the command and event will be combined in a full duplex exchange. nRF8001 sends out the event data at the same time as it receives command data. To accommodate this, the application controller must always monitor the incoming data when issuing a command.

7.1.2 SPI mode

The ACI transport layer uses the SPI in the following mode (SPI mode 0):

Type	Value
Data order	Least significant bit first
Clock polarity	Zero (base value for the clock is zero)
Clock phase	Zero (data is read on the clock's rising edge)

Table 2. SPI signal description

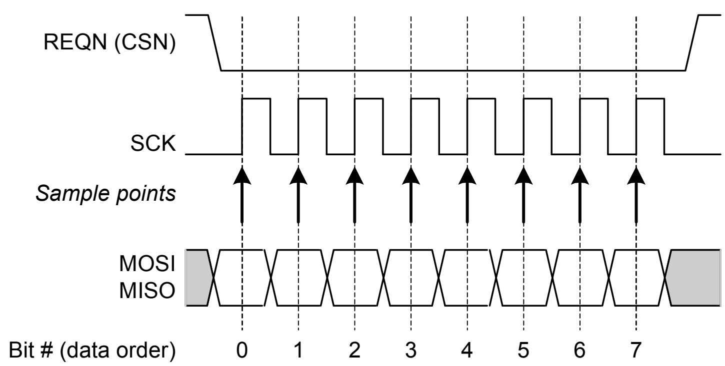

Figure 8. SPI mode 0 description

7.1.3 ACI connections

The required I/O pins needed on the application controller and nRF8001 for the ACI interface are listed in Table 3.

Signal	Application controller	nRF8001	Description
MISO	Input	Output	SPI: Master In Slave Out
MOSI	Output	Input	SPI: Master Out Slave In
SCK	Output	Input	SPI: Serial data Clock
REQN	Output	Input	Application controller to nRF8001 handshake signal
RDYN	Input	Output	nRF8001 to application controller handshake signal

Table 3. ACI I/O signals for an application controller and nRF8001

7.1.3.1 RDYn line

The application controller must, at all times, have the RDYn line configured as input with pull-up drivers. At power on reset and wake up from sleep scenarios, the RDYn level is valid after 62 ms from reset or wake up.

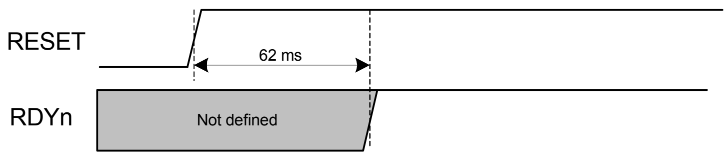

Figure 9. RDYn line functionality

Note: The supply rise time is not included in the power up sequence shown in Figure 9.

7.1.4 ACI command exchange

Figure 10. shows the signaling in an ACI command sent from the application controller to nRF8001.

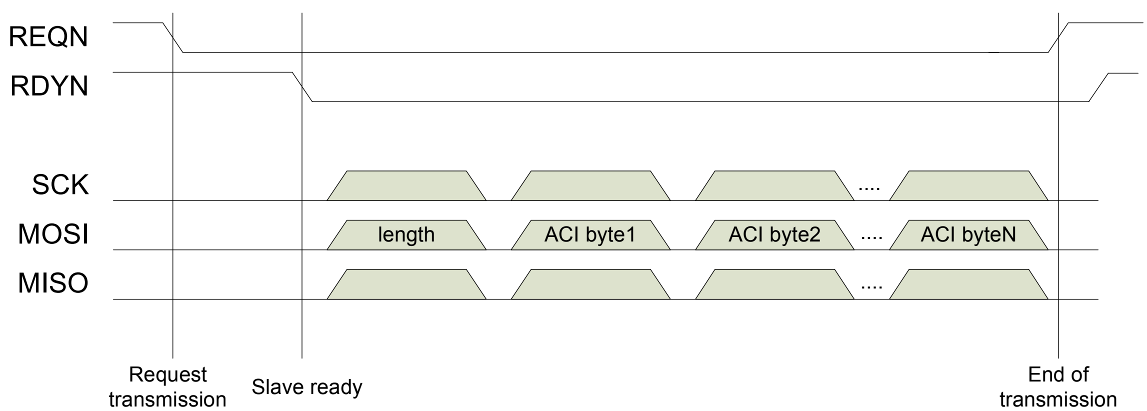

Figure 10. Data exchange from an application controller to nRF8001

The following procedure is performed when the application controller sends a command to nRF8001:

1. The application controller requests the right to send data by setting the **REQN** pin to ground.
2. nRF8001 sets the **RDYN** pin to ground when it is ready to receive data.
3. The application controller starts sending data on the **MOSI** pin:
   - Byte 1 (length byte) from the application controller defines the length of the message.
   - Byte 2 (ACI byte1) is the first byte of the ACI data.
   - Byte N is the last byte of the ACI data.
   - The application controller sets the **REQN** pin high to terminate the data transaction.

Note: The maximum length of a command packet is 32 bytes, including the length byte. **MOSI** shall be held low if the application controller receives an event and has no message to send to the nRF8001.

7.1.5 ACI event exchange

Figure 11. shows the signaling in an ACI event exchange from nRF8001 to the application controller.

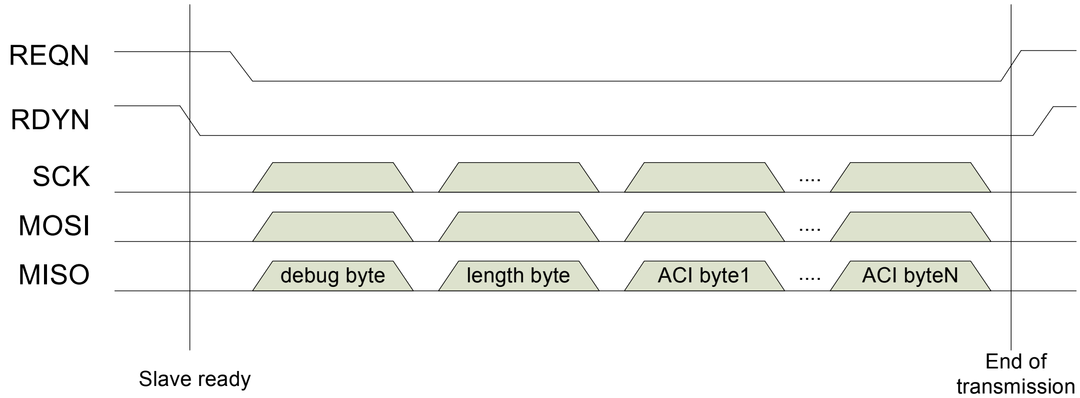

Figure 11. Receiving an ACI event from nRF8001

The application controller receives the ACI event by performing the following procedure:

1. nRF8001 sets the **RDYN** pin to ground.
2. The application controller sets the **REQN** pin to ground and starts clocking on the **SCK** pin.
   - Byte 1 (debug byte) from nRF8001 is an internal debug byte and the application controller discards it.
   - Byte 2 (length byte) from nRF8001 defines the length of the message.
   - Byte 3 (ACI byte1) is the first byte of the ACI data.
   - Byte N is the last byte of the ACI data.
3. The application controller sets the **REQN** pin high to close the event.

Note: The maximum length of an event packet is 31 bytes, including the length byte.

7.1.6 ACI full-duplex transaction

nRF8001 is capable of receiving an ACI command simultaneously as it sends an ACI event to the application controller.

The application controller shall always read the length byte from nRF8001 and check if the length is greater than 0. If the length is greater than 0 the data on the MISO line shall be read as described in section 7.1.5.

An ACI event received from the nRF8001 processor is never a reply to a command being simultaneously transmitted. For all commands, the corresponding event will always be received in a subsequent ACI transaction.

7.1.7 SPI timing

The signaling and timing of each byte transaction for the nRF8001 SPI interface are shown in Figure 12. and Figure 13. on page 26. Critical timing parameters are listed in Table 4. on page 26

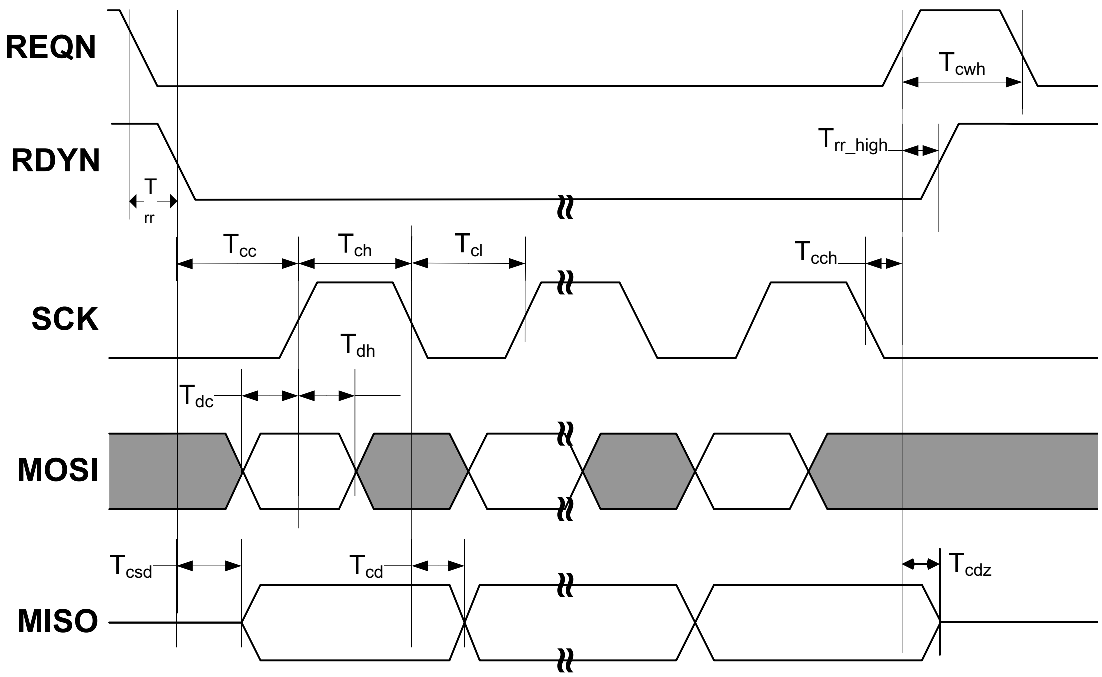

Figure 12. Application controller initiated packet SPI timing