

# Single chip 2.4 GHz Transceiver with Embedded ANT protocol

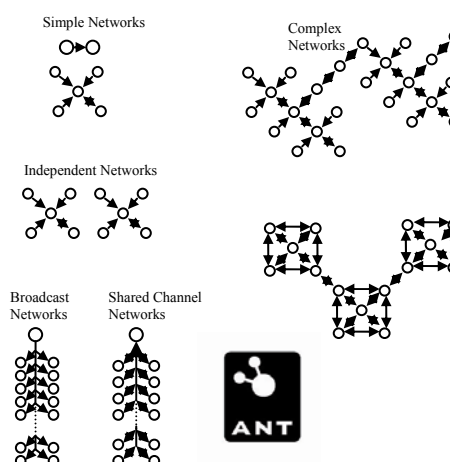
## nRF24AP1

### FEATURES

- Integrated PAN (Personal Area Network)
- Drop in wireless networking with simple serial interface
- 2.4GHz Worldwide ISM Band
- Ultra-low power (coin cell battery)
- Fully scaleable
- Broadcast, Acknowledged or Burst Data
- Message rates 0.5Hz -> 200Hz (8byte data payload)
- Burst transfer rates up to 20kbps (true data throughput)
- Public and private networks
- 1 Mbps RF data rate
- 125 RF channels

### APPLICATIONS

- Sensor Networks
- Industrial Automation
- Home Automation
- Sports Monitoring



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### GENERAL DESCRIPTION

The nRF24AP1 is an ultra-low power single-chip radio transceiver with embedded ANT protocol for personal area networks. The transceiver's RF operating frequency range falls within the world-wide 2.4 - 2.5 GHz RF ISM band, allowing for regulatory compliance and product sales into global markets.

### QUICK REFERENCE DATA

| Parameter                                                             | Value            | Unit              |
|-----------------------------------------------------------------------|------------------|-------------------|
| Minimum supply voltage                                                | 1.9              | V                 |
| Maximum output power                                                  | 0                | dBm               |
| Maximum data rate (over the air)                                      | 1000             | kbps              |
| Temperature range                                                     | -40 to +85       | °C                |
| Sensitivity                                                           | -80              | dBm               |
| Average current consumption as low as                                 | 30               | µA                |
| Peak current consumption TX @-5dBm                                    | 13.5mA for 350us | mA                |
| Peak current consumption RX                                           | 22mA for 600us   | mA                |
| Max # of simultaneous connections <sup>1</sup>                        | >65000           | connections       |
| Max # of simultaneous independent 2-way connections                   | 4                | 2-way connections |
| Maximum sustained transfer rate (all data – no overhead) <sup>2</sup> | 20               | kbps              |
| CR2032 Battery life in a typical sensor application <sup>3</sup>      | 5                | years             |

Table 1: nRF24AP1 quick reference data

<sup>1</sup> Using Shared Channel Network

<sup>2</sup> Transfer rate refers to data rate of the end application's message payload

<sup>3</sup> Message interval of 2s, 1 hour/day usage



The transceiver consists of the ANT fully integrated protocol engine, frequency synthesizer, power amplifier, crystal oscillator and modulator, and can be interfaced to a host micro controller over either a synchronous or asynchronous serial interface. Designed to run on a wrist-watch coin cell battery, current consumption of the device is extremely low - a typical sensor application can operate on approximately 30µA average current consumption. Short, low peak current transitions are battery friendly.

The embedded ANT protocol makes for easy, low cost integration. Eliminating the need for 3<sup>rd</sup> party RF protocol implementation, the on-chip ANT protocol combined with the 2.4GHz transceiver enables system and application developers to interact with the nRF24AP1 as a black box wireless solution. The simple serial interface (asynchronous or synchronous) to the device allows for flexibility and scalability from ultra-low power sensors (30µA) through to higher data rate (20kbps) applications implemented in a multitude of network configurations. Networks can be scaled from as little as two nodes to thousands. With 2<sup>32</sup> unique IDs, multiple radio frequencies, public and private network management and scalable data rates, an unlimited number of network configurations and applications are possible.

Prior to reading this document, the “ANT Message Protocol and Usage” document should be read to gain understanding of the ANT protocol capabilities.

## REFERENCES

| Ref. No. | Doc. No.  | Revision | Title                                                                                        |
|----------|-----------|----------|----------------------------------------------------------------------------------------------|
| 1        | D00000794 | 1.0      | Interfacing with ANT General Purpose Chipset and Modules<br>(Part of nRF24AP1 Specification) |
| 2        | D00000652 | 1.36     | ANT Message Protocol and Usage                                                               |

Table 2 nRF24AP1 referenced documents

For more information see: [www.nordicsemi.no](http://www.nordicsemi.no)



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### 1. BLOCK DIAGRAM

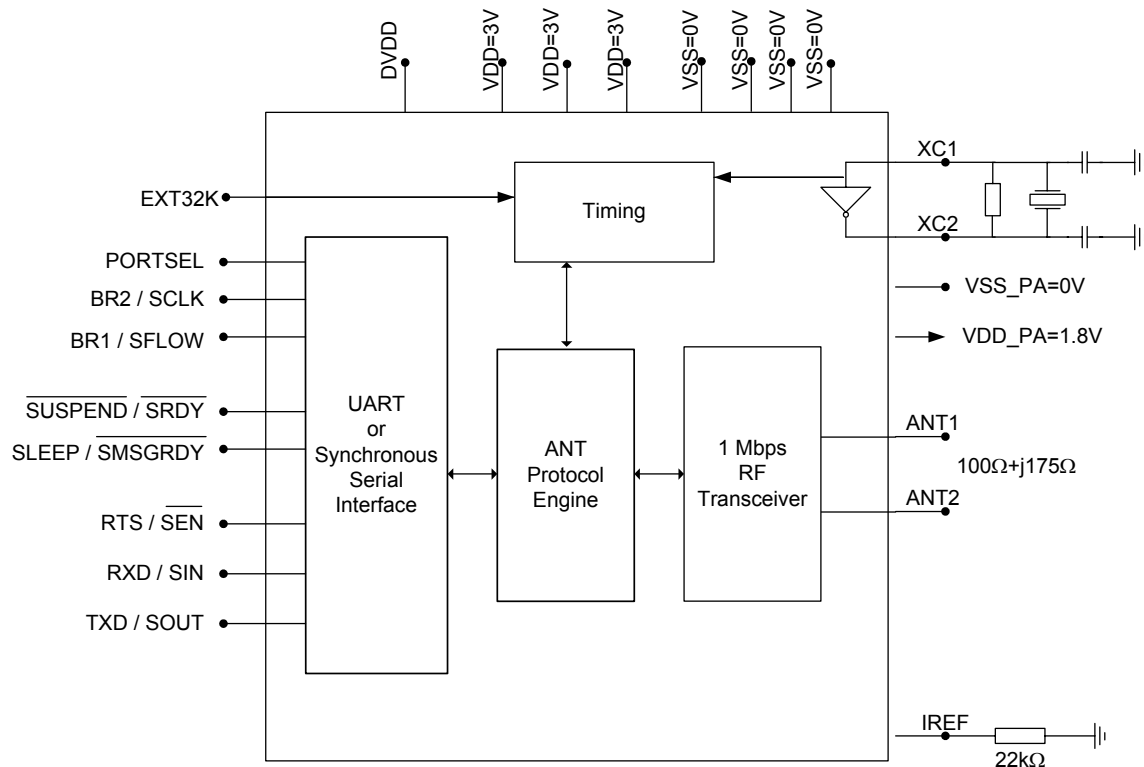


Figure 1: nRF24AP1 with external components.

The “ANT Protocol Engine” shown in Figure 1 is described in the “ANT Message Protocol and Usage” document.



## 2. PIN FUNCTIONS

| Pin | Name                                                   | Pin function   | Description                                                    |
|-----|--------------------------------------------------------|----------------|----------------------------------------------------------------|
| 1   | BR2 / SCLK                                             | Digital IO     | Asynchronous baud rate select / Synchronous clock signal       |
| 2   | BR1 / SFLOW                                            | Digital Input  | Asynchronous baud rate select / Synch. Bit or byte flow select |
| 3   | EXT32K                                                 | Digital Input  | Optional External 32kHz clock, tied to GND when not used       |
| 4   | RXD / SIN                                              | Digital Input  | Asynchronous UART receive data / Synchronous receive data      |
| 5   | TXD / SOUT                                             | Digital Output | Asynchronous UART transmit data / Synchronous transmit data    |
| 6   | SLEEP / $\overline{\text{SMSGRDY}}$                    | Digital Input  | Asynchronous sleep enable / Synchronous message ready signal   |
| 7   | $\overline{\text{SUSPEND}}$ / $\overline{\text{SRDY}}$ | Digital Input  | Asynchronous suspend control / Synchronous port ready signal   |
| 8   | RTS / $\overline{\text{SEN}}$                          | Digital Output | Asynchronous flow control RTS / Synchronous serial enable      |
| 9   | DVDD                                                   | Power Output   | Positive Digital Supply output for de-coupling purposes        |
| 10  | VSS                                                    | Power          | Ground (0V)                                                    |
| 11  | XC2                                                    | Analog Output  | Crystal Pin 2                                                  |
| 12  | XC1                                                    | Analog Input   | Crystal Pin 1                                                  |
| 13  | VDD_PA                                                 | Power Output   | Power Supply (+1.8V) to Power Amplifier                        |
| 14  | ANT1                                                   | RF             | Antenna interface 1                                            |
| 15  | ANT2                                                   | RF             | Antenna interface 2                                            |
| 16  | VSS_PA                                                 | Power          | Ground (0V)                                                    |
| 17  | VDD                                                    | Power          | Power Supply (+3V DC)                                          |
| 18  | VSS                                                    | Power          | Ground (0V)                                                    |
| 19  | IREF                                                   | Analog Input   | Reference current                                              |
| 20  | VSS                                                    | Power          | Ground (0V)                                                    |
| 21  | VDD                                                    | Power          | Power Supply (+3V DC)                                          |
| 22  | VSS                                                    | Power          | Ground (0V)                                                    |
| 23  | PORTSEL                                                | Digital Input  | Asynchronous / Synchronous port selection                      |
| 24  | VDD                                                    | Power          | Power Supply (+3V DC)                                          |

Table 3: nRF24AP1 pin function

## 3. PIN ASSIGNMENT

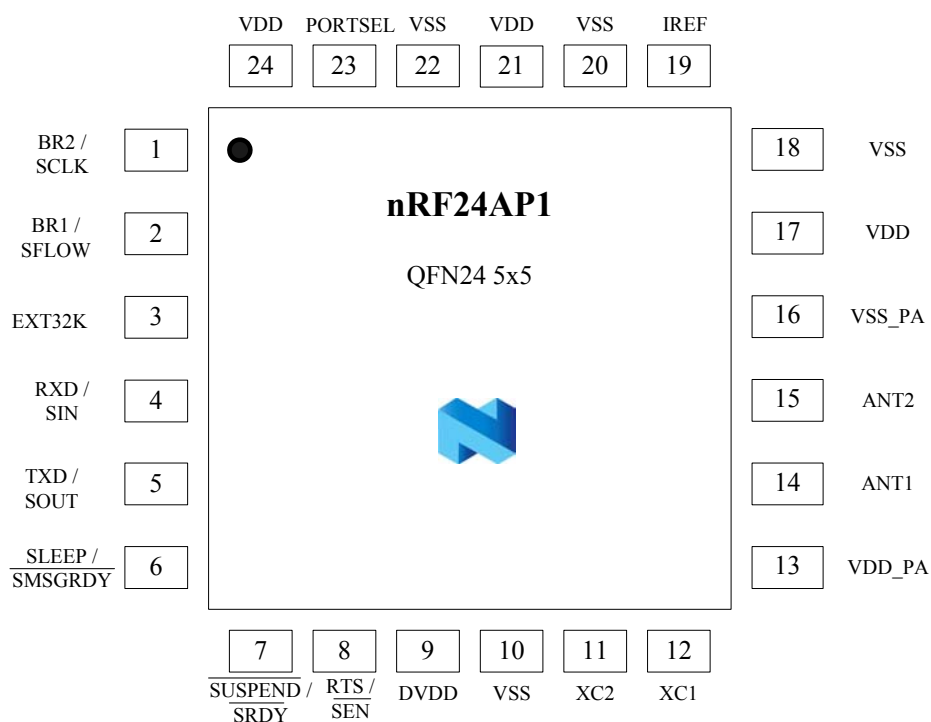


Figure 2: nRF24AP1 pin assignment (top view) for a QFN24 5x5 package.



## 4. ELECTRICAL SPECIFICATIONS

Conditions: VDD = +3V, VSS = 0V, TA = - 40°C to + 85°C

| Symbol                           | Parameter (condition)                                                                                | Notes | Min.     | Typ.    | Max.   | Units |
|----------------------------------|------------------------------------------------------------------------------------------------------|-------|----------|---------|--------|-------|
| <b>Operating conditions</b>      |                                                                                                      |       |          |         |        |       |
| VDD                              | Supply voltage                                                                                       |       | 1.9      | 3.0     | 3.6    | V     |
| TEMP                             | Operating Temperature                                                                                |       | -40      | +27     | +85    | °C    |
| <b>Digital input pin</b>         |                                                                                                      |       |          |         |        |       |
| V <sub>IH</sub>                  | HIGH level input voltage                                                                             |       | 0.7VDD   |         | VDD    | V     |
| V <sub>IL</sub>                  | LOW level input voltage                                                                              |       | VSS      |         | 0.3VDD | V     |
| <b>Digital output pin</b>        |                                                                                                      |       |          |         |        |       |
| V <sub>OH</sub>                  | HIGH level output voltage (I <sub>OH</sub> =-0.5mA)                                                  |       | VDD- 0.3 |         | VDD    | V     |
| V <sub>OL</sub>                  | LOW level output voltage (I <sub>OL</sub> =0.5mA)                                                    |       | VSS      |         | 0.3    | V     |
| <b>Crystals and clocks</b>       |                                                                                                      |       |          |         |        |       |
| f <sub>XTAL</sub>                | RF Crystal frequency                                                                                 |       |          | 16      |        | MHz   |
| f <sub>XTAL-OFFSET</sub>         | RF Crystal offset (Initial, Temp & Aging)                                                            |       |          |         | 30     | PPM   |
| f <sub>EXT32K</sub>              | EXT32K – external 32.768kHz clock                                                                    |       |          | 32.768  |        | kHz   |
| f <sub>EXT32K-ERROR</sub>        | Maximum error for 32.768kHz clock                                                                    |       |          |         | 50     | PPM   |
| <b>Synchronous Serial Timing</b> |                                                                                                      |       |          |         |        |       |
| sclk freq.                       | Synchronous clock frequency (byte mode)                                                              |       |          | 150-175 |        | kHz   |
| t <sub>ReadValid</sub>           | Data is valid on read before low to high transition on the clock (byte mode)                         |       | 0.5      |         |        | µs    |
| t <sub>WriteValid</sub>          | Data must be valid on write within this time after a high to low transition on the clock (byte mode) |       |          |         | 2      | µs    |
| t <sub>SRDY_MinLow</sub>         | Minimum $\overline{\text{SRDY}}$ low time                                                            |       | 2.5      |         |        | µs    |
| t <sub>Reset</sub>               | Synchronous Reset. $\overline{\text{SRDY}}$ falling edge to $\overline{\text{SMSGRDY}}$ falling edge |       | 250      |         |        | µs    |
| <b>General RF conditions</b>     |                                                                                                      |       |          |         |        |       |
| f <sub>OP</sub>                  | Operating frequency                                                                                  | 1)    | 2400     |         | 2524   | MHz   |
| F <sub>CHANNEL</sub>             | Channel spacing                                                                                      |       |          | 1       |        | MHz   |
| Δf                               | Frequency deviation                                                                                  |       |          | ±156    |        | kHz   |
| <b>Current Consumption</b>       |                                                                                                      |       |          |         |        |       |
| I <sub>Idle</sub>                | No active channels – No communications                                                               |       |          | 2       |        | µA    |
| I <sub>Peak</sub>                | Peak Current consumption, RX                                                                         | 2)    |          | 22      |        | mA    |
| I <sub>PeakTX</sub>              | Peak Current – TX @ 0dBm                                                                             | 3)    |          | 16      |        | mA    |
| <b>Transmitter operation</b>     |                                                                                                      |       |          |         |        |       |
| P <sub>RF</sub>                  | Maximum Output Power                                                                                 | 4)    |          | 0       | +4     | dBm   |
| P <sub>RFC</sub>                 | RF Power Control Range                                                                               |       | 16       | 20      |        | dB    |
| P <sub>RFCR</sub>                | RF Power Control Range Resolution                                                                    |       |          |         | ±3     | dB    |
| P <sub>BW</sub>                  | 20dB Bandwidth for Modulated Carrier                                                                 |       |          |         | 1000   | kHz   |
| P <sub>RF2</sub>                 | 2 <sup>nd</sup> Adjacent Channel Transmit Power 2MHz                                                 |       |          |         | -20    | dBm   |
| P <sub>RF3</sub>                 | 3 <sup>rd</sup> Adjacent Channel Transmit Power 3MHz                                                 |       |          |         | -40    | dBm   |
| I <sub>VDD</sub>                 | Supply peak current @ 0dBm output power                                                              | 4)    |          | 16      |        | mA    |
| I <sub>VDD</sub>                 | Supply peak current @ -20dBm output power                                                            | 4)    |          | 13      |        | mA    |
| <b>Receiver operation</b>        |                                                                                                      |       |          |         |        |       |
| I <sub>VDD</sub>                 | Supply peak current receive mode                                                                     | 4)    |          | 22      |        | mA    |
| RX <sub>SENS</sub>               | Sensitivity at 0.1%BER (@1000kbps)                                                                   |       |          | -80     |        | dBm   |
| C/I <sub>CO</sub>                | C/I Co-channel                                                                                       |       |          | 10/4    |        | dB    |
| C/I <sub>1ST</sub>               | 1 <sup>st</sup> Adjacent Channel Selectivity C/I 1MHz                                                |       |          | -20/0   |        | dB    |
| C/I <sub>2ND</sub>               | 2 <sup>nd</sup> Adjacent Channel Selectivity C/I 2MHz                                                |       |          | -37/-20 |        | dB    |
| C/I <sub>3RD</sub>               | 3 <sup>rd</sup> Adjacent Channel Selectivity C/I 3MHz                                                |       |          | -43/-30 |        | dB    |

1) Usable band is determined by local regulations

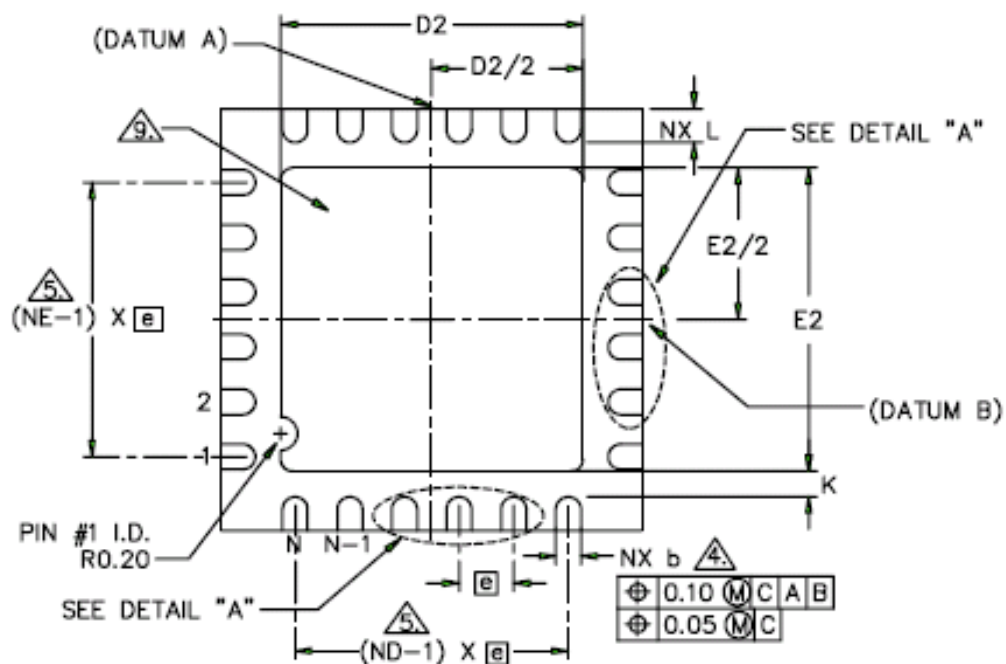
2) Time of Maximum Current consumption in RX is typical 600us and maximum 1ms

3) Time of Maximum TX Only Current is typical 400us and maximum 400us.

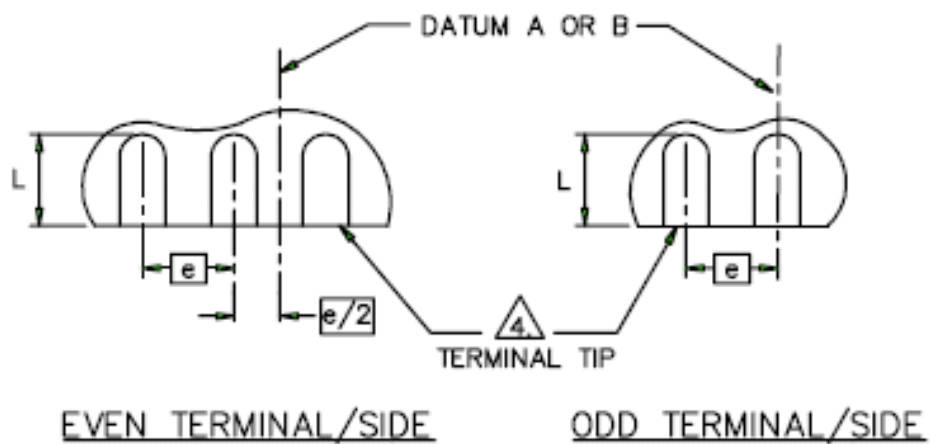
4) Antenna load impedance = 100Ω+j175Ω

Table 4: nRF24AP1 RF specifications





**BOTTOM VIEW**



**DETAIL "A"**

| Package Type       |     | A    | A1   | A3   | K    | D/E | e    | D2/E2 | L    | b    |
|--------------------|-----|------|------|------|------|-----|------|-------|------|------|
| SAW<br>QFN24 (5x5) | Min | 0.8  | 0.00 | 0.20 | 0.20 | 5.0 | 0.65 | 3.50  | 0.35 | 0.25 |
|                    | Typ | 0.85 | 0.02 | REF. | MIN. | BSC | BSC  | 3.60  | 0.40 | 0.30 |
|                    | Max | 0.90 | 0.05 |      |      |     |      | 3.70  | 0.45 | 0.35 |

Figure 3 nRF24AP1 package outline.



## 5.1 Package marking:

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| n | R | F |   | B | X |
| 2 | 4 | A | P | 1 |   |
| Y | Y | W | W | L | L |

### Abbreviations:

- B – Build Code, i.e. unique code for production sites, package type and test platform
- X – "X" grade, i.e. Engineering Samples (optional)
- YY – 2 digit Year number
- WW – 2 digit Week number
- LL – 2 letter wafer lot number code

## 6. ORDERING INFORMATION

| Ordering code  | Description                           | Package        | Container                  | MOQ <sup>4</sup> |
|----------------|---------------------------------------|----------------|----------------------------|------------------|
| nRF24AP1-REEL  | 1 Mbps Transmitter                    | 24 pin QFN 5x5 | Tape and reel <sup>5</sup> | 4000             |
| nRF24AP1-REEL7 | 1 Mbps Transmitter                    | 24 pin QFN 5x5 | Tape and reel <sup>5</sup> | 1500             |
| nRF24AP1       | 1 Mbps Transmitter                    | 24 pin QFN 5x5 | Tray                       | 490              |
| nRF24AP1-EVKIT | 4 node evaluation and development kit | N/A            | N/A                        | 1                |

Table 5 nRF24AP1 ordering information

<sup>4</sup> MOQ = Minimum order quantity

<sup>5</sup> **Moisture Sensitivity Level:** MSL2@260°C, three times reflow



### 7. ABSOLUTE MAXIMUM RATINGS

#### Supply voltages

VDD ..... - 0.3V to + 3.6V

VSS ..... 0V

#### Input voltage

V<sub>I</sub> ..... - 0.3V to VDD + 0.3V

#### Output voltage

V<sub>O</sub> ..... - 0.3V to VDD

#### Total Power Dissipation

P<sub>D</sub> (T<sub>A</sub>=85°C) ..... 90mW

#### Temperatures

Operating Temperature.... - 40°C to + 85°C

Storage Temperature..... - 40°C to + 125°C

*Note: Stress exceeding one or more of the limiting values may cause permanent damage to the device.*

#### ATTENTION!

Electrostatic Sensitive Device

Observe Precaution for handling.





## Glossary of Terms

| Term              | Description                                                                                                              |
|-------------------|--------------------------------------------------------------------------------------------------------------------------|
| Acknowledged Data | Data for which the transmitter receives an acknowledgement from the receiver                                             |
| ANT               | Ultra-low power embedded RF protocol                                                                                     |
| Broadcast Data    | Default transmission type. Data sent on every time slot                                                                  |
| Burst Data        | Bulk data transmission between two nodes                                                                                 |
| Channel           | Basic building block of ANT. Connects two devices together                                                               |
| Device ID         | Device ID – Identifier for the master end of the channel                                                                 |
| Device Number     | Device Number is a subcomponent of Device ID, uniquely identifying this device                                           |
| Device Type       | Device Type is a subcomponent of Device ID, uniquely identifying the type of this device                                 |
| Forward Channel   | Data transmission from Master to Slave on a channel                                                                      |
| GFSK              | Gaussian Frequency Shift Keying                                                                                          |
| HOST MCU          | The MCU which interfaces and controls the nRF24AP1                                                                       |
| ISM               | Industrial-Scientific-Medical                                                                                            |
| ISM Band          | Industrial, Scientific and Medical Band                                                                                  |
| Manufacturer ID   | Manufacturer ID is a subcomponent of Device ID, uniquely identifying the manufacturer of this device                     |
| Master            | Primary transmitter of the ANT network channel                                                                           |
| MCU               | Micro controller unit                                                                                                    |
| Message Data rate | Number of messages per second sent over a channel                                                                        |
| Message Payload   | User portion of a data packet. Each data packet contains a payload of 8 bytes.                                           |
| Message           | Data packet sent over a channel from one device to another                                                               |
| Networks          | A group of ANT nodes connected together via channels forms a network in which the nodes may communicate with one another |
| Node              | An application running on a host controller connected to an nRF24AP1, which communicates with other ANT nodes.           |
| Pairing           | The process in which a Slave obtains the Master's ID in order to establish communications.                               |
| Reverse Channel   | Data transmission from Slave to Master on a channel                                                                      |
| RF data rate      | The on air data rate. This rate is 1Mbps.                                                                                |
| RF Frequency      | RF Frequency used for communications. The nRF24AP1 can be configured to one of 125 different RF frequencies.             |
| RX                | Receive                                                                                                                  |
| Slave             | Primary receiver of the ANT network channel                                                                              |
| TX                | Transmit                                                                                                                 |

Table 6: Glossary



## 8. ARCHITECTURAL OVERVIEW

The nRF24AP1 is a single-chip silicon solution that integrates a 2.4GHz transceiver and the ANT RF protocol stack. The ANT protocol stack is stored on-chip and is executed by the nRF24AP1's internal MCU core.

Functionally, the nRF24AP1 is composed of 4 main building blocks as shown in Figure 1. Together, the 4 blocks enable the drop-in RF and protocol solution. As shown, the 4 main blocks are the serial interface, the timing interface, the ANT protocol engine, and the RF transceiver. Both the ANT protocol engine and the RF transceiver are embedded within the device and interact with the external host environment through a UART or synchronous serial interface. This functional approach allows the nRF24AP1 to be treated as a black box wireless solution from the system application perspective. Integration of an RF protocol with the RF physical layer is not required. Application developers provides channel configuration and message data information to the device through the serial interface, and the nRF24AP1 executes the configuration and sends/receives the message data packets over the air to other waiting devices.

ANT is a 2.4GHz bidirectional wireless Personal Area Network (PAN) communications technology optimized for transferring low data-rate, low latency data between multiple ANT-enabled devices. The ultra-low power consumption of ANT guarantees an extended battery life even from low capacity supplies such as a coin cell battery, such as are required for heart rate monitors, bicycle computers, and wrist watches. The small size and low-cost implementation of ANT proves essential in allowing effortless integration into the tiny form factor of wrist watches, PDAs, and mobile phones.

The ANT – HOST interface has been designed with utmost simplicity in mind so that it can be easily and quickly implemented into new devices and applications. The encapsulation of the wireless protocol complexity within the ANT chipset vastly reduces the burden on the application host controller, allowing a low-cost 4-bit or 8-bit Microcontroller (MCU) to establish and maintain complex wireless networks with remote devices. Data transfers can be scheduled in a deterministic or ad-hoc fashion, and a burst mode allows for the efficient transfer of large amounts of stored data to and from a PC or other computing device. The ANT system aggressively balances functionality, cost, size, and power consumption within the constraints of a mobile Personal Area Network.

The ANT protocol implements layers 1-4 of the OSI networking stack as well as automatically providing session authentication of network devices. For description of layer 3 and 4, please refer to the “ANT Message Protocol and Usage” document.



## 9. ANT INTERFACE

### 9.1 Physical Layer – Serial Interfacing

The ANT serial interface between host controller and nRF24AP1 can be implemented over either a synchronous or asynchronous connection, which can be selected by the product developer as preferred for a given implementation. The precise details of the physical connections and signaling can be found in the ‘Interfacing with ANT General Purpose Chipsets and Modules’ document.

### 9.2 ANT Message Summary

The table in Section 9.4 summarizes the message types employed between the host controller and the nRF24AP1, which are used to establish and maintain RF connections to remote devices. Further details of the message fields and data contents can be found in the ‘ANT Message Protocol and Usage’ document.

### 9.3 32kHz Clock Signal (EXT32K)

A 32.768kHz clock signal may optionally be provided to the nRF24AP1. If this signal is not used, it must be connected to ground. Please see the electrical specification section for external clock specifications. Use of an external clock is recommended for power sensitive applications. The nRF24AP1 automatically detects the presence of an external clock source upon power up. In order to avoid timing issues between when the external clock source becomes present, and when the nRF24AP1 samples for this signal, it is recommended that a SystemReset (see Message Summary table below) command is issued to the nRF24AP1 upon initial connection. This will ensure that the external clock is properly detected and used. Once the EXT32K signal has been provided on power up it must remain present as long as the nRF24AP1 remains powered up.



### 9.4 Message Summary

| Class                       | Type                     | ANT PC Interface Function                                                | Response | From         | Len | Msg ID | Data 1                      | Data 2           | Data 3           | Data 4           | Data 5 | Data 6 | Data 7 | Data 8 | Data 9 |
|-----------------------------|--------------------------|--------------------------------------------------------------------------|----------|--------------|-----|--------|-----------------------------|------------------|------------------|------------------|--------|--------|--------|--------|--------|
| Channel Event Messages      | Channel Response / Event | ->ChannelEventFunc(Chan, MessageCode) or<br>->ResponseFunc(Chan, MsgID); | -        | ANT          | 3   | 0x40   | Channel Number              | Message ID       | Message Code     |                  |        |        |        |        |        |
| Requested Response Messages | Channel Status           | ->ResponseFunc(Chan,0x52)                                                | -        | ANT          | 2   | 0x52   | Channel Number              | Channel Status   |                  |                  |        |        |        |        |        |
|                             | Channel ID               | ->ResponseFunc(Chan,0x51)                                                | -        | ANT          | 5   | 0x51   | Channel Number              | Device Number    |                  | Device Type ID   | Man ID |        |        |        |        |
|                             | ANT Version              | ->ResponseFunc(-, 0x3D)                                                  | -        | ANT          | 9   | 0x3D   | Ver0                        | Ver1             | Ver2             | Ver3             | Ver4   | Ver5   | Ver6   | Ver7   | Ver8   |
|                             | Capabilities             | ->ResponseFunc(-, 0x54)                                                  | -        | ANT          | 4   | 0x54   | Max Channels                | Max Networks     | Standard Options | Advanced Options |        |        |        |        |        |
| Config. Messages            | Unassign Channel         | ANT_UnAssignChannel()                                                    | Yes      | HOST         | 1   | 0x41   | Channel Number              |                  |                  |                  |        |        |        |        |        |
|                             | Assign Channel           | ANT_AssignChannel()                                                      | Yes      | HOST         | 3   | 0x42   | Channel Number              | Channel Type     | Network Number   |                  |        |        |        |        |        |
|                             | Channel ID               | ANT_SetChannelID()                                                       | Yes      | HOST         | 5   | 0x51   | Channel Number              | Device Number    |                  | Device Type ID   | Man ID |        |        |        |        |
|                             | Channel Period           | ANT_SetChannelPeriod()                                                   | Yes      | HOST         | 3   | 0x43   | Channel Number              | Messaging Period |                  |                  |        |        |        |        |        |
|                             | Search Timeout           | ANT_SetChannelSearchTimeout()                                            | Yes      | HOST         | 2   | 0x44   | Channel Number              | Search Timeout   |                  |                  |        |        |        |        |        |
|                             | Channel RF Frequency     | ANT_SetChannelRFFreq()                                                   | Yes      | HOST         | 2   | 0x45   | Channel Number              | RF Frequency     |                  |                  |        |        |        |        |        |
|                             | Set Network              | ANT_SetNetworkKey()                                                      | Yes      | HOST         | 9   | 0x46   | Net #                       | Key 0            | Key 1            | Key 2            | Key 3  | Key 4  | Key 5  | Key 6  | Key 7  |
|                             | Transmit Power           | ANT_SetTransmitPower()                                                   | Yes      | HOST         | 2   | 0x47   | 0                           | TX Power         |                  |                  |        |        |        |        |        |
| Test Mode                   | CW Init                  | ANT_InitCWTestMode()                                                     | Yes      | HOST         | 1   | 0x53   | 0                           |                  |                  |                  |        |        |        |        |        |
|                             | CW Test                  | ANT_SetCWTestMode()                                                      | Yes      | HOST         | 3   | 0x48   | 0                           | TX Power         | RF Freq          |                  |        |        |        |        |        |
| Control Messages            | SystemReset              | ANT_ResetSystem()                                                        | No       | HOST         | 1   | 0x4A   | 0                           |                  |                  |                  |        |        |        |        |        |
|                             | Open Channel             | ANT_OpenChannel()                                                        | Yes      | HOST         | 1   | 0x4B   | Channel Number              |                  |                  |                  |        |        |        |        |        |
|                             | Close Channel            | ANT_CloseChannel()                                                       | Yes      | HOST         | 1   | 0x4C   | Channel Number              |                  |                  |                  |        |        |        |        |        |
|                             | Request Message          | ANT_RequestMessage()                                                     | Yes      | HOST         | 2   | 0x4D   | Channel Number              | Message ID       |                  |                  |        |        |        |        |        |
| Data Messages               | Broadcast Data           | ANT_SendBroadcastData()<br>->ChannelEventFunc(Chan, EV)                  | No       | ANT/<br>HOST | 9   | 0x4E   | Channel Number              | Data0            | Data1            | Data2            | Data3  | Data4  | Data5  | Data6  | Data7  |
|                             | Acknowledge Data         | ANT_SendAcknowledgedData()<br>->ChannelEventFunc(Chan, EV)               | No       | ANT/<br>HOST | 9   | 0x4F   | Channel Number              | Data0            | Data1            | Data2            | Data3  | Data4  | Data5  | Data6  | Data7  |
|                             | Burst Transfer Data      | ANT_SendBurstTransferPacket()<br>->ChannelEventFunc(Chan, EV)            | No       | ANT/<br>HOST | 9   | 0x50   | Sequence/<br>Channel Number | Data0            | Data1            | Data2            | Data3  | Data4  | Data5  | Data6  | Data7  |



## 10. APPLICATION SPECIFIC CURRENT CONSUMPTION

| Symbol                    | Parameter (condition)                                       | Typ. | Units |
|---------------------------|-------------------------------------------------------------|------|-------|
| I <sub>Idle</sub>         | No active channels – No communications                      | 2    | μA    |
| I <sub>Suspend</sub>      | Asynchronous suspend Activated                              | 2    | μA    |
| I <sub>Base-Ext</sub>     | Active base current when EXT32K used                        | 35   | μA    |
| I <sub>Base-Int</sub>     | Active base current with no EXT32K                          | 75   | μA    |
| I <sub>Peak</sub>         | Peak Current consumption, RX                                | 22   | mA    |
| I <sub>PeakTX</sub>       | Peak Current – TX @ 0dBm                                    | 16   | mA    |
| I <sub>RX ByteSync</sub>  | Average Current / RX message byte sync                      | 19   | μA    |
| I <sub>RX BitSync</sub>   | Average Current / RX message bit sync                       | 29   | μA    |
| I <sub>RX 50k</sub>       | Average Current / RX message 50Kbaud async                  | 21   | μA    |
| I <sub>RX 38.4k</sub>     | Average Current / RX message 38.4Kbaud async                | 24   | μA    |
| I <sub>RX 19.2k</sub>     | Average Current / RX message 19.2Kbaud async                | 32   | μA    |
| I <sub>RX 4800</sub>      | Average Current / RX message 4800baud async                 | 85   | μA    |
| I <sub>TX ByteSync</sub>  | Average Current / TX message byte sync                      | 11   | μA    |
| I <sub>TX BitSync</sub>   | Average Current / TX message bit sync                       | 26   | μA    |
| I <sub>TX 50k</sub>       | Average Current / TX message 50Kbaud async                  | 19   | μA    |
| I <sub>TX 38.4k</sub>     | Average Current / TX message 38.4Kbaud async                | 21   | μA    |
| I <sub>TX 19.2k</sub>     | Average Current / TX message 19.2Kbaud async                | 37   | μA    |
| I <sub>TX 4800</sub>      | Average Current / TX message 4800baud async                 | 119  | μA    |
| I <sub>TR ByteSync</sub>  | Average Current / bi-directional TX message byte sync       | 26   | μA    |
| I <sub>TR BitSync</sub>   | Average Current / bi-directional TX message bit sync        | 38   | μA    |
| I <sub>TR 50k</sub>       | Average Current / bi-directional TX message 50Kbaud async   | 33   | μA    |
| I <sub>TR 38.4k</sub>     | Average Current / bi-directional TX message 38.4Kbaud async | 35   | μA    |
| I <sub>TR 19.2k</sub>     | Average Current / bi-directional TX message 19.2Kbaud async | 49   | μA    |
| I <sub>TR 4800</sub>      | Average Current / bi-directional TX message 4800baud async  | 131  | μA    |
| I <sub>ARX ByteSync</sub> | Average Current / Acknowledged RX message byte sync         | 28   | μA    |
| I <sub>ARX BitSync</sub>  | Average Current / Acknowledged RX message bit sync          | 51   | μA    |
| I <sub>ARX 50k</sub>      | Average Current / Acknowledged RX message 50Kbaud async     | 38   | μA    |
| I <sub>ARX 38.4k</sub>    | Average Current / Acknowledged RX message 38.4Kbaud async   | 42   | μA    |
| I <sub>ARX 19.2k</sub>    | Average Current / Acknowledged RX message 19.2Kbaud async   | 48   | μA    |
| I <sub>ARX 4800</sub>     | Average Current / Acknowledged RX message 4800baud async    | 102  | μA    |
| I <sub>ATX ByteSync</sub> | Average Current / Acknowledged TX message byte sync         | 37   | μA    |
| I <sub>ATX BitSync</sub>  | Average Current / Acknowledged TX message bit sync          | 55   | μA    |
| I <sub>ATX 50k</sub>      | Average Current / Acknowledged TX message 50Kbaud async     | 47   | μA    |
| I <sub>ATX 38.4k</sub>    | Average Current / Acknowledged TX message 38.4Kbaud async   | 50   | μA    |
| I <sub>ATX 19.2k</sub>    | Average Current / Acknowledged TX message 19.2Kbaud async   | 70   | μA    |
| I <sub>ATX 4800</sub>     | Average Current / Acknowledged TX message 4800baud async    | 146  | μA    |
| I <sub>Ave</sub>          | Broadcast TX@ 0.5Hz byte sync,EXT32K                        | 30   | μA    |
| I <sub>Ave</sub>          | Broadcast TX @ 2 Hz byte sync,EXT32K                        | 52   | μA    |
| I <sub>Ave</sub>          | Broadcast RX @ 0.5Hz byte sync,EXT32K                       | 34   | μA    |
| I <sub>Ave</sub>          | Acknowledged TX@ 0.5 Hz byte sync,EXT32K                    | 43   | μA    |
| I <sub>Ave</sub>          | Acknowledged RX@ 0.5 Hz byte sync,EXT32K                    | 38   | μA    |
| I <sub>Ave</sub>          | Burst continuous @ 20 kbps, byte synchronous                | 4.92 | mA    |
| I <sub>Ave</sub>          | Burst continuous @ 7.5 kbps, bit synchronous                | 5.7  | mA    |
| I <sub>Ave</sub>          | Burst continuous @ 20 kbps, asynchronous (50k)              | 5.4  | mA    |
| I <sub>Ave</sub>          | Burst continuous @ 13. kbps, asynchronous (38.4k)           | 5.5  | mA    |
| I <sub>Ave</sub>          | Burst continuous @ 8.5 kbps, asynchronous (19.2k)           | 5.85 | mA    |

Table 7: Application specific current consumption



## 11. PERIPHERAL RF INFORMATION

### 11.1 Antenna output

The ANT1 & ANT2 output pins provide a balanced RF output to the antenna. The pins must have a DC path to VDD, either via a RF choke or via the center point in a dipole antenna. A load of  $100\Omega + j175\Omega$  between the ANT1/ANT2 is recommended for maximum output power (0dBm). Lower load impedance (for instance  $50\Omega$ ) can be obtained by fitting a simple matching network.

### 11.2 Output Power adjustment

| RF output power    | Peak current consumption |
|--------------------|--------------------------|
| 0 dBm $\pm 3$ dB   | 16.0 mA                  |
| -5 dBm $\pm 3$ dB  | 13.5 mA                  |
| -10 dBm $\pm 3$ dB | 12.5 mA                  |
| -20 dBm $\pm 3$ dB | 12 mA                    |

Conditions: VDD = 3.0V, VSS = 0V,  $T_A = 27^\circ\text{C}$ , Load impedance =  $100\Omega + j175\Omega$ .

Table 8: RF output power setting for the nRF24AP1

### 11.3 Crystal Specification

Tolerance includes initially accuracy and tolerance over temperature and aging.

| Frequency | $C_L$ | ESR          | $C_{0\text{max}}$ | Tolerance          |
|-----------|-------|--------------|-------------------|--------------------|
| 16        | 12pF  | 100 $\Omega$ | 7.0pF             | $\pm 50\text{ppm}$ |

Table 9: Crystal specification of the nRF24AP1

To achieve a crystal oscillator solution with low power consumption and fast start-up time, it is recommended to specify the crystal with a low value of crystal load capacitance. Specifying  $C_L = 12\text{pF}$  is OK, but it is possible to use up to 16pF. Specifying a lower value of crystal parallel equivalent capacitance,  $C_0$  will also work, but this can increase the price of the crystal itself. Typically  $C_0 = 1.5\text{pF}$  at a crystal specified for  $C_{0\text{max}} = 7.0\text{pF}$ .



#### 11.4 Sharing crystal with micro controller

When using a micro controller to drive the crystal reference input XC1 of the nRF24AP1 transceiver some rules must be followed.

#### 11.5 Crystal parameters:

When the micro controller drives the nRF24AP1 clock input, the requirement of load capacitance  $C_L$  is set by the micro controller only. The frequency accuracy of  $\pm 50$  ppm is still required to get a functional radio link. The nRF24AP1 will load the crystal by 0.5pF at XC1 in addition to the PBC routing.

#### 11.6 Input crystal amplitude & Current consumption

The input signal should not have amplitudes exceeding any rail voltage, but any DC-voltage within this is OK. Exceeding rail voltage will excite the ESD structure and the radio performance is degraded below specification. If testing the nRF24AP1 with a RF source with no DC offset as the reference source, the input signal will go below the ground level, which is not acceptable.

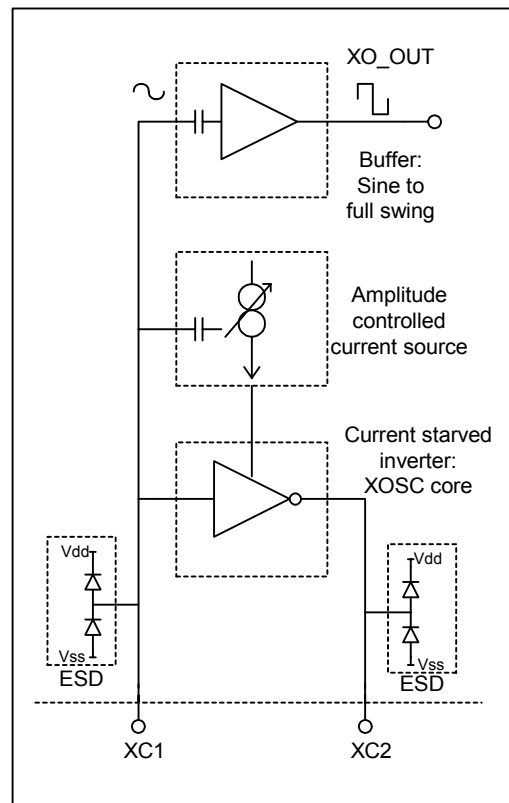


Figure 4: Principle of crystal oscillator

It is recommended to use a DC-block before the XC1 pin so that the internal ESD structures will self bias the XC1 voltage.

The nRF24AP1 crystal oscillator is amplitude regulated. To achieve low current consumption and also good signal-to-noise ratio, it is recommended to use an input signal larger than 0.4 V-peak. The needed input swing is independent of the crystal frequency. When clocking the nRF24AP1 externally, XC2 is not used and can be left as an open pin.



### 11.7 PCB layout and de-coupling guidelines

A well-designed PCB is necessary to achieve good RF performance. Keep in mind that a poor layout may lead to loss of performance, or even functionality, if due care is not taken. A fully qualified RF-layout for the nRF24AP1 and its surrounding components, including matching networks, can be downloaded from **[www.nordicsemi.no](http://www.nordicsemi.no)**.

A PCB with a minimum of two layers including a ground plane is recommended for optimum performance. The nRF24AP1 DC supply voltage should be de-coupled as close as possible to the VDD pins with high performance RF capacitors, see Table 10. It is preferable to mount a large surface mount capacitor (e.g. 4.7 $\mu$ F tantalum) in parallel with the smaller value capacitors. The nRF24AP1 supply voltage 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 nRF24AP1 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. 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.



### 11.8 Reflow information

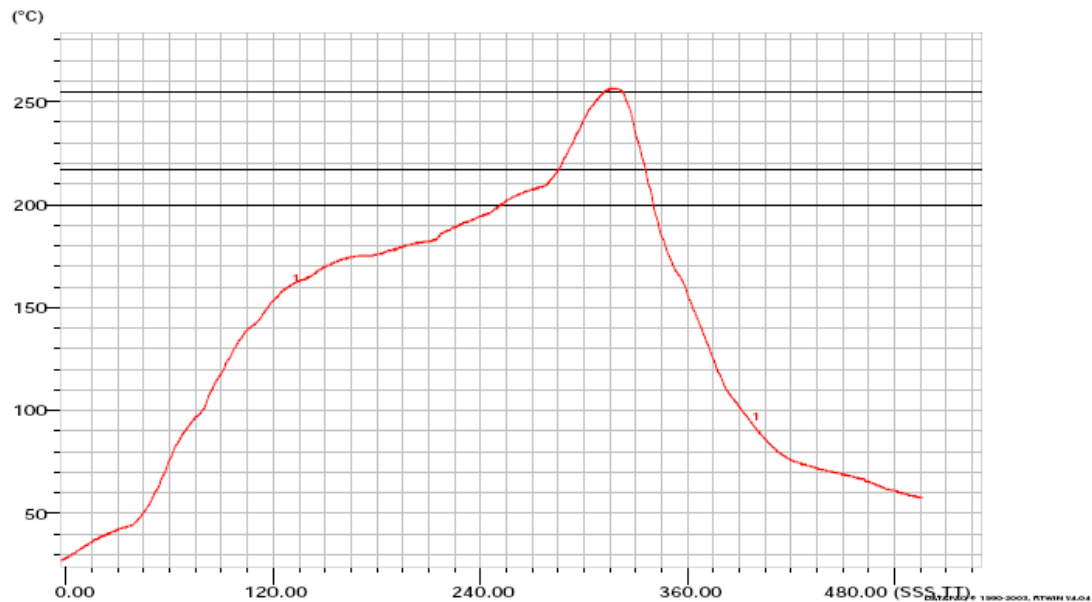


Figure 5 Reflow Soldering profile, GREEN

|                      |           |
|----------------------|-----------|
| Ramp rate (RT-150°C) | 1.38 °C/s |
| Pre-heat (150-200°C) | 134 s     |
| Dwell @217°C         | 50 s      |
| Dwell @245°C         | 10 s      |
| Ramp up              | 1.42 °C/s |
| Ramp down            | 2.59 °C/s |
| Peak temperature     | 257 °C    |
| Time from RT to PT   | 320 s     |



## 12. APPLICATION EXAMPLE

### 12.1 nRF24AP1 with single ended matching network

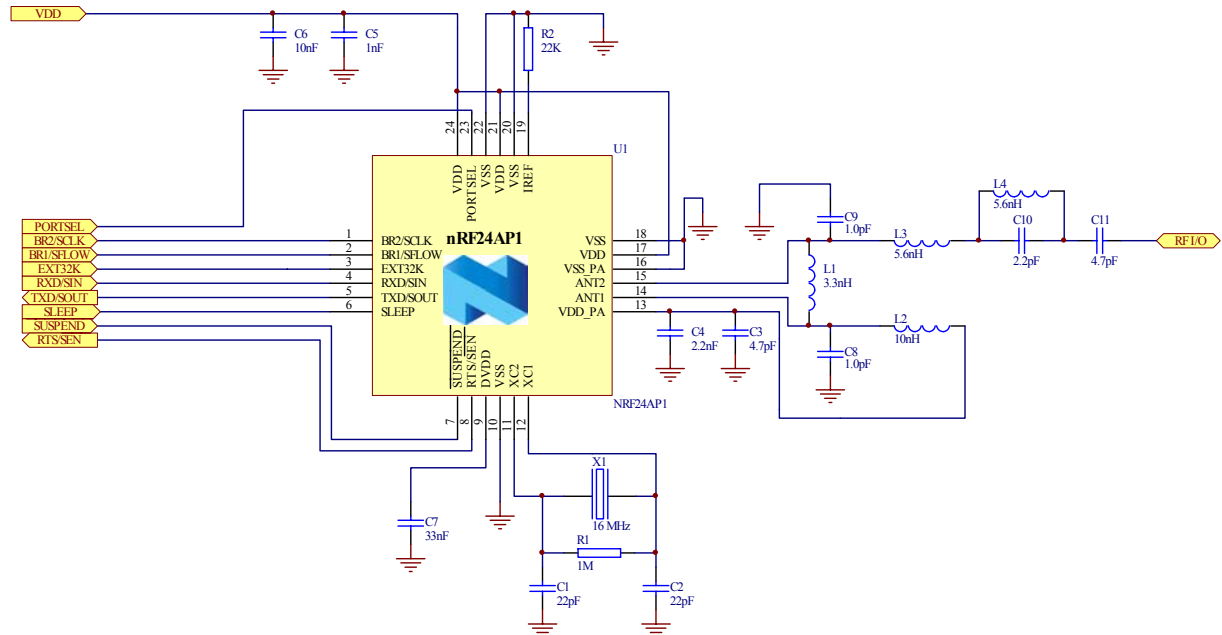


Figure 6: nRF24AP1 schematic for RF layouts with single end 50Ω antenna



| Component | Description                          | Size                   | Value    | Tolerance  | Units |
|-----------|--------------------------------------|------------------------|----------|------------|-------|
| C1        | Capacitor ceramic, 50V, NPO          | 0603                   | 22       | ±5%        | pF    |
| C2        | Capacitor ceramic, 50V, NPO          | 0603                   | 22       | ±5%        | pF    |
| C3        | Capacitor ceramic, 50V, NPO          | 0603                   | 4.7      | ±5%        | pF    |
| C4        | Capacitor ceramic, 50V, X7R          | 0603                   | 2.2      | ±10%       | nF    |
| C5        | Capacitor ceramic, 50V, X7R          | 0603                   | 1.0      | ±10%       | nF    |
| C6        | Capacitor ceramic, 50V, X7R          | 0603                   | 10       | ±10%       | nF    |
| C7        | Capacitor ceramic, 50V, X7R          | 0603                   | 33       | ±10%       | nF    |
| R1        | Resistor                             | 0603                   | 1.0      | ±10%       | MΩ    |
| R2        | Resistor                             | 0603                   | 22       | ±1%        | kΩ    |
| U1        | nRF24AP1 transceiver                 | QFN24 / 5x5            | nRF24AP1 |            |       |
| X1        | Crystal, CL = 12pF,<br>ESR < 100 ohm | LxWxH =<br>4.0x2.5x0.8 | 16       | +/- 50 ppm | MHz   |
| L1        | Inductor                             | 0603                   | 3.3      | ± 5%       | nH    |
| L2        | Inductor                             | 0603                   | 10       | ± 5%       | nH    |
| L3        | Inductor                             | 0603                   | 5.6      | ± 5%       | nH    |
| L4        | Inductor                             | 0603                   | 5.6      | ± 5%       | nH    |
| C8        | Ceramic capacitor, 50V, NP0          | 0603                   | 1.0      | ± 0.1 pF   | pF    |
| C9        | Ceramic capacitor, 50V, NP0          | 0603                   | 1.0      | ± 0.1 pF   | pF    |
| C10       | Ceramic capacitor, 50V, NP0          | 0603                   | 2.2      | ± 0.25 pF  | pF    |
| C11       | Ceramic capacitor, 50V, NP0          | 0603                   | 4.7      | ± 0.25 pF  | pF    |

Table 10: Recommended components (BOM) in nRF24AP1 with antenna matching network



## 12.2 PCB layout example

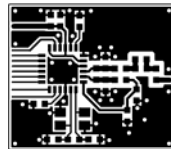
Figure 7 shows a PCB layout example for the application schematic in Figure 6.

A double-sided FR-4 board of 1.6mm thickness is used. This PCB has a ground plane on the bottom layer. Additionally, there are ground areas on the component side of the board to ensure sufficient grounding of critical components. A large number of via holes connect the top layer ground areas to the bottom layer ground plane.

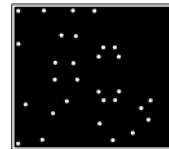


Top silk screen

No components in bottom layer



Top view



Bottom view

Figure 7: nRF24AP1 RF layout with single ended connection to 50Ω antenna and 0603 size passive components



### 13. DEFINITIONS

| Data sheet status                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Objective product specification                                                                                                                                                                                                                                                                                                                               | This data sheet contains target specifications for product development.                                                                                                                                        |
| Preliminary product specification                                                                                                                                                                                                                                                                                                                             | This data sheet contains preliminary data; supplementary data may be published from Nordic Semiconductor ASA later.                                                                                            |
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| Where application information is given, it is advisory and does not form part of the specification.                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                |

Table 11: Definitions

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Preliminary Product Specification: Revision Date: 05.09.2006.

Data sheet order code: 050906-nRF24AP1

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