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## Atmel AVR10004: RCB256RFR2 – Hardware User Manual

**8-bit Atmel Microcontrollers**

### Features

- Stand-alone operable radio controller board (RCB)
- Design based on the single-chip Atmel® ATmega256RFR2 to support IEEE® 802.15.4, ZigBee®, 6LoWPAN, RF4CE, SP100, WirelessHART®, and ISM applications
- FCC-ID: VW4A091786
- SMA RF connector
- Simple user interface with button and LEDs
- Board information EEPROM containing
    - MAC address
    - Board identification, features, and serial number
    - Crystal calibration values
- 2 × AAA batteries for stand-alone operation
- 60-pin extension connector to interface with application-specific hardware

### Introduction

The RCB256RFR2 user manual describes the usage, design, and layout of the Atmel ATmega256RFR2 radio controller board.
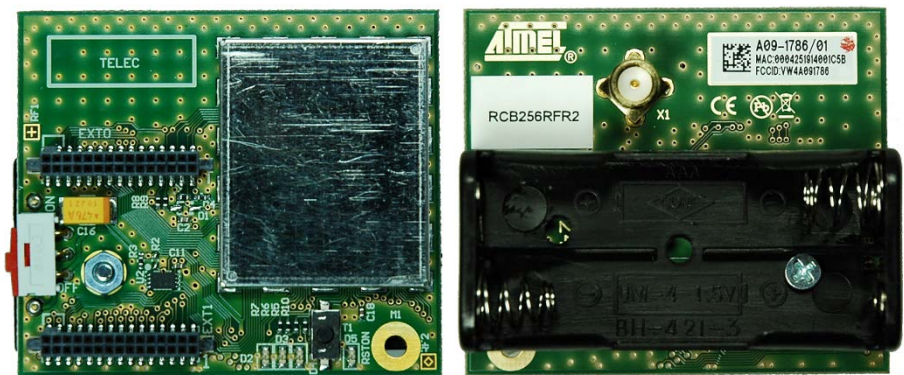
**Figure 1.    RCB256RFR2 PCBA photo.**

# Table of Contents

# 1. Disclaimer

Typical values contained in this application note are based on simulations and testing of individual examples.

Any information about third-party materials or parts was included in this document for convenience. The vendor may have changed the information that has been published. Check the individual vendor information for the latest changes.

# 2. Overview

The RCB256RFR2 is designed to provide a reference design for the Atmel ATmega256RFR2 [1] single-chip microcontroller and radio transceiver. The IC integrates a powerful, 8-bit AVR® RISC microcontroller, an IEEE 802.15.4™-compliant transceiver, and additional peripheral features. The built-in radio transceiver supports the worldwide accessible 2.4GHz ISM band.

The system is designed to demonstrate standard-based applications such as ZigBee/IEEE 802.15.4, ZigBee RF4CE, and 6LoWPAN, as well as high data rate ISM applications. The SMA antenna connector allows either operation with the antenna provided with the RCB or conducted RF performance measurements.

The RF section has been shielded to eliminate interference from sources external to the ATmega256RFR2. To investigate the reference design area, the shield can be opened by removing the snap-in cover while the RCB is not in operation.

Most peripheral features of the ATmega256RFR2 are made available through two expansion connectors (EXT0/1). There are a variety of base boards available for the RCB family.

**Table 2-1.    RCB base boards.**

| Board name | Comment |
|---|---|
| RCB Sensor Terminal Board | Available with Atmel evaluation kit AT256RFR2-EK; [8] |
| RCB Breakout Board | Purchasable on https://shop.dresden-elektronik.de |
| RCB Breakout Board Light | Purchasable on https://shop.dresden-elektronik.de |


**Figure 2-1.    RCB256RFR2 with snap-in cover removed.**
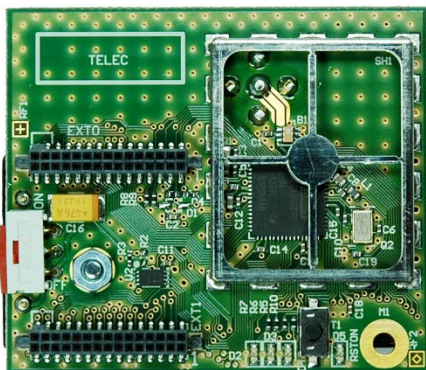
## 3. Mechanical Description

RCBs demonstrating radio transceiver and microcontroller capabilities are equipped with two 50mil, 30-pin connectors (ETX0/1), separated by 22mm from each other, to interface to various port extension boards (base boards).

The RCB256RFR2 has no on-board antenna, and so it is not required to separate the board into an electronics section and an antenna section. When used with a quarter-wave antenna mounted at the SMA connector, the board will act as a ground plane for the antenna.

The other mounting hole is reserved for a battery holder. If battery operation is required, base boards should not make use of this mount.

### 3.1 Mechanical dimensions

Figure 3-1 shows the EXT0/1 interface connector positions referenced to pin 1, as most CAD tools use this pin as a placement reference. Pay attention to the connector key location at pin 30 and the mirrored placement of a male counterpart connector when designing a new base board. The connector pin 1 is marked using a rectangular pad. See Figure 3-2 and Figure A-5.

The PCB is made of standard 1.5mm FR4 material with two copper layers. Due to the panelization and cutting process, the dimension of the outer board edge may vary up to ±0.1mm.

**Figure 3-1. RCB256RFR2 – mechanical drawing (dimensions in mm).**
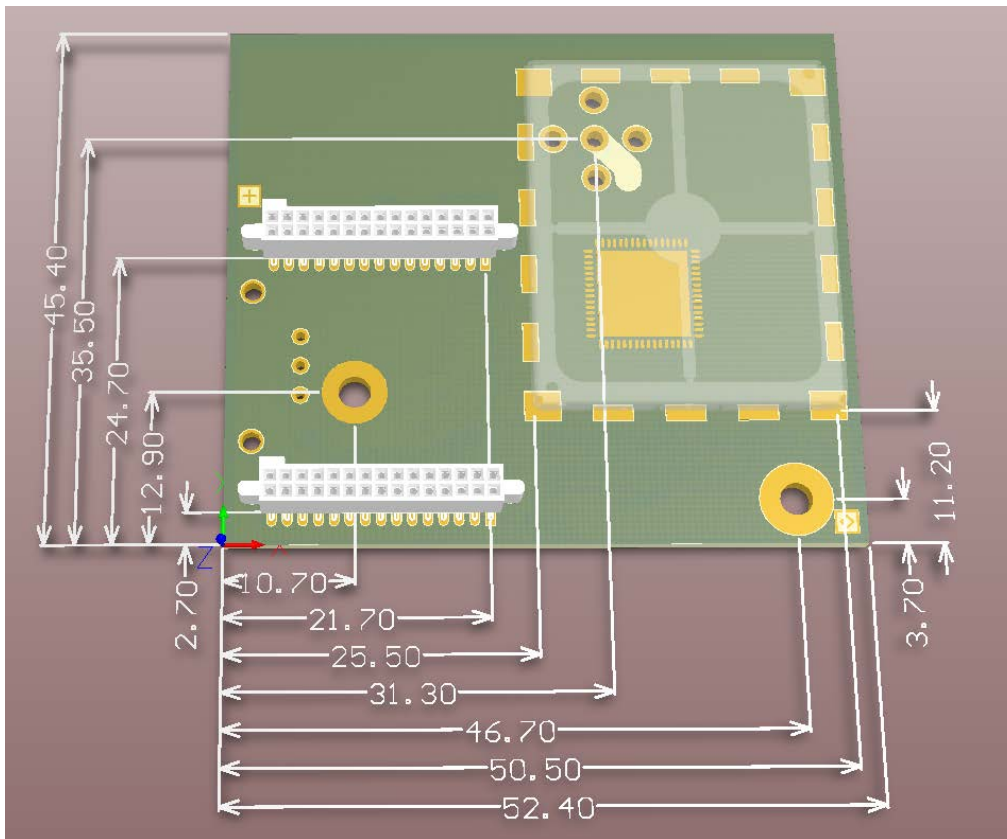
## 3.2 Interface connector specification

**Figure 3-2. RCB256RFR2 – interface connector drawing.**
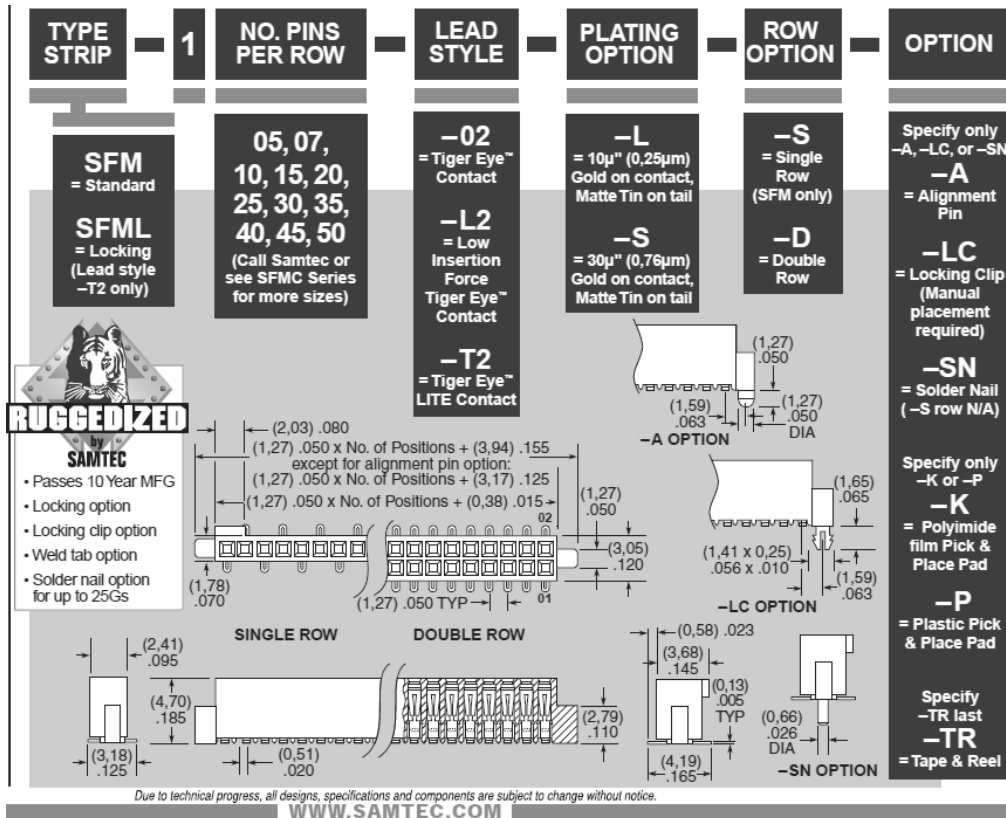


The base board interface connector, EXT0/1, mounted on the RCB, is a 50mil, 30-pin type from SAMTEC.

The detailed part number is: SFM-115-L2-S-D-LC.

The L2 in the part number indicates the low insertion force (LIF) variant to allow easy mounting.

The drawing shown in Figure 3-2 is from a SAMTEC datasheet. Check the latest datasheet for possible updates and changes.

## 3.3 Application (base) board connectors

**Figure 3-3.** Application board connector drawing.
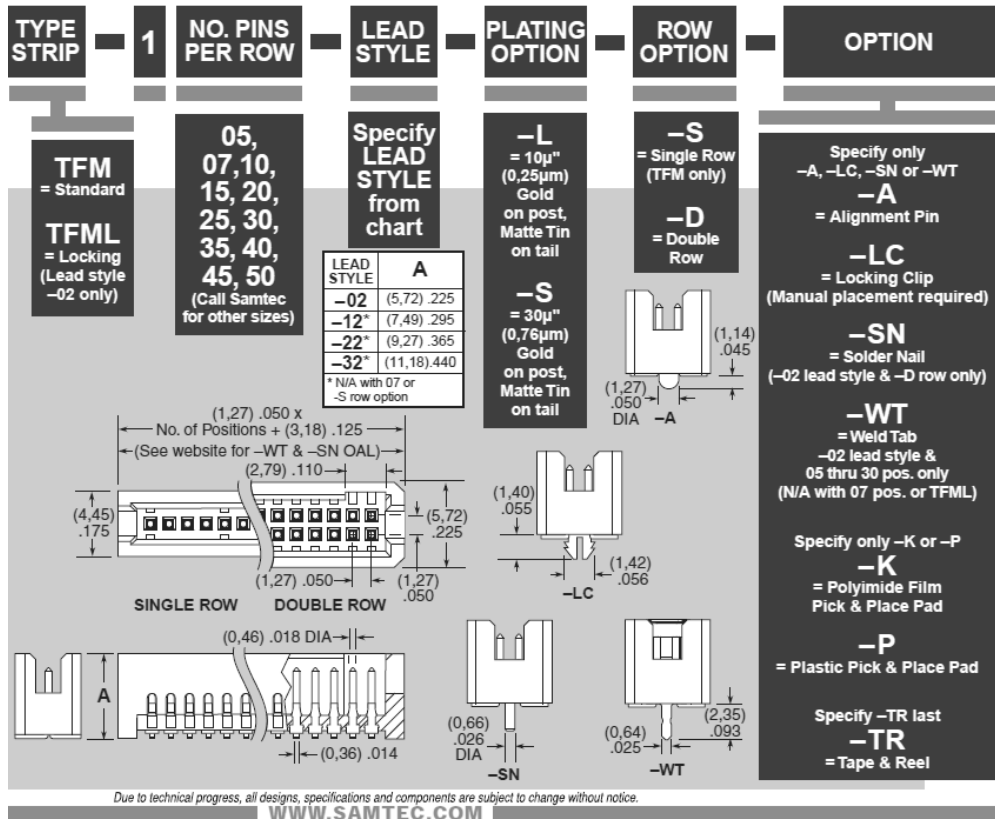


The drawing in Figure 3-3 shows the connector to be used on a base board to interface the RCB EXT0/1 connectors.

The detailed part number is: TFM-115-02-S-D.

Alternatively, a Tyco part can be used: Tyco 5-104655-4.

Note: The Tyco part requires a different footprint design!

The drawing shown in Figure 3-3 is from a SAMTEC datasheet. Check the latest datasheet for possible updates and changes.

# 4. Functional Description

Figure 4-1 illustrates the RCB setup in general. It mainly consists of an Atmel ATmega256RFR2 and some peripheral circuitry. An ID EEPROM stores MAC address and additional board information. This information is stored in a separate EEPROM to avoid accidental data erasure during microcontroller firmware development.

**Figure 4-1.** Radio controller board - block diagram.



The radio transceiver incorporates MAC hardware accelerators to handle all RF modulation/demodulation, signal processing, and frame reception and transmission actions. Further information about the radio transceiver and the microcontroller are provided in the datasheet (see reference [1]).

The RF front-end implementation was kept minimal by using a balun with integrated filter. An antenna, provided with the RCB, has to be connected to the SMA connector.

All components are placed on one PCB side to demonstrate a low-cost manufacturing solution.

## 4.1 Power supply

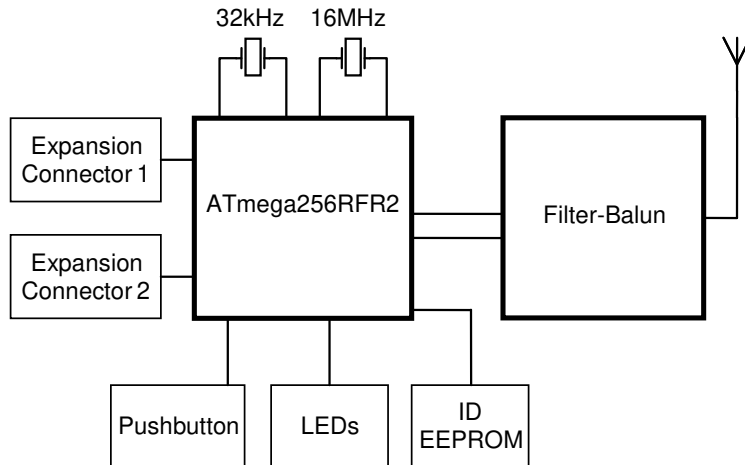The RCB is powered by a single supply voltage in the range of 1.8V to 3.6V, which makes it possible to use 1.5V alkaline cells. Optionally, the power can be supplied from a base board. In this case, the power switch, SW1, must be in the off position or the battery must be removed from the battery holder.

All PCB components are powered by this single supply to minimize the bill of materials (BOM) and maximize the power efficiency.

### 4.1.1 Battery power

For autonomous operation, the RCB can be powered by two AAA batteries inserted in the battery clip on the back side of the RCB. Use power switch SW1 to manually switch on/off the board.

Note:   A power cycle may not be detected if the radio transceiver and microcontroller are in sleep mode with all peripheries disabled.

### 4.1.2 External power

An RCB mounted on a base board may be powered via the expansion connectors (see Table 4-2). In this case, the power switch, SW1, has to be in the off position to avoid unintentionally charging the batteries, if present.

## 4.2 Microcontroller

The Atmel ATmega256RFR2 integrates a low-power 8-bit microcontroller based on the AVR enhanced RISC architecture. The 256KB non-volatile flash program memory and 32KB internal SRAM, supported by a rich set of peripheral units, makes it suitable for a full-function sensor network node.

The microcontroller is capable of operating as a PAN-coordinator, a full-function device (FFD), or a reduced function device (RFD), as defined by IEEE 802.15.4 [2]. However, the RCB is not limited to these, and can be programmed to operate in other standards or ISM applications, too.

All spare I/O pins are accessible via the expansion connectors for external use.

The Atmel ATmega256RFR2 is designed to operate at full 16MHz speed over the complete supply voltage range from 1.8V to 3.6V.

## 4.3 On-chip radio transceiver

Besides an 8-bit AVR microcontroller, the ATmega256RFR2 also integrates an IEEE 802.15.4-compliant radio transceiver. RF and baseband critical components are integrated to transmit and receive signals according to IEEE 802.15.4 or proprietary ISM data rates.

The RCB illustrates a minimal component count implementation. Filter-balun B1 [6] operates as a differential to single-ended converter connecting the ATmega256RFR2 to a standard SMA connector. An integrated harmonic filter ensures sufficient harmonic rejection.

A 2.45GHz ISM antenna must be connected to the SMA connector for proper operation.

Any modification of components, PCB layout, or shielding may influence the performance of the circuitry and cause existing certifications to be invalid.

## 4.4 Clock sources

### 4.4.1 Radio transceiver clock

The integrated radio transceiver is clocked by a highly accurate 16MHz reference crystal, Q2. Operating the node according to IEEE 802.15.4, the reference frequency deviation must be within ±40ppm (see [2]). The absolute clock frequency is mainly determined by the external load capacitance of the crystal, which depends on the crystal type and is given in its datasheet.

The radio transceiver reference crystal, Q2, must be isolated from fast switching digital signals and surrounded by a grounded guard trace to minimize disturbance of the oscillation.

The RCB uses a SIWARD SX4025 crystal with two load capacitors of 10pF each. To compensate for fabrication and environment variations, the frequency can be tuned with the transceiver register, XOSC_CTRL (0x12) (see [1]). An initial tuning is done during fabrication, and the correction value has been stored in the onboard ID EEPROM (see Section 4.5.2.

By setting the fuses accordingly, the microcontroller can also be clocked by the 16MHz radio reference crystal.

### 4.4.2 Microcontroller clock

The Atmel ATmega256RFR2 provides several clock source options for the internal microcontroller:

- 16MHz calibrated internal RC oscillator
- 128kHz internal RC oscillator
- 16MHz radio reference crystal

The calibrated internal RC oscillator, pre-scaled to 8MHz, is used as the default clocking. It is recommended to use the MAC symbol counter (see [1]) clocked from the 16MHz radio reference crystal as a reference to calibrate the RC oscillator for higher accuracy.

The symbol counter replaces and enhances the CLKM-driven timer1 function originally available in ATmega1281V-based solutions.

A 32kHz crystal, Q1, is connected to the related Atmel ATmega256RFR2 pins (17-TOSC2; 18-TOSC1) to be used as a low-power, real-time clock. This time base can also run in sleep mode and create timer-based system wake-up events.

## 4.5 On-board peripherals

### 4.5.1 Key and LEDs

For simple applications and debugging purposes, or just to deliver status information, a basic user interface is provided directly on board, and consists of four LEDs and a pushbutton. Three LEDs (D2…D4) are connected to PE2…PE4 for active-low operation. One LED (D5) signals the single-chip reset state. The pushbutton, T1, pulls PE5 to GND, and is intended to be used in combination with the internal pull-up resistor.

When mounted on a base board, I/O ports PE4 and PE5 are used to emulate #WR and #RD lines handling a memory interface. Therefore, the pushbutton and LED D4 are not functional. On RCB256RFR2, the port G I/O lines cannot be used because they are shared with dedicated radio transceiver functionality.

In sleep mode, when the signals are supposed to be inactive, no additional current occurs.

**Figure 4-2. RCB256RFR2 key and LED connection.**
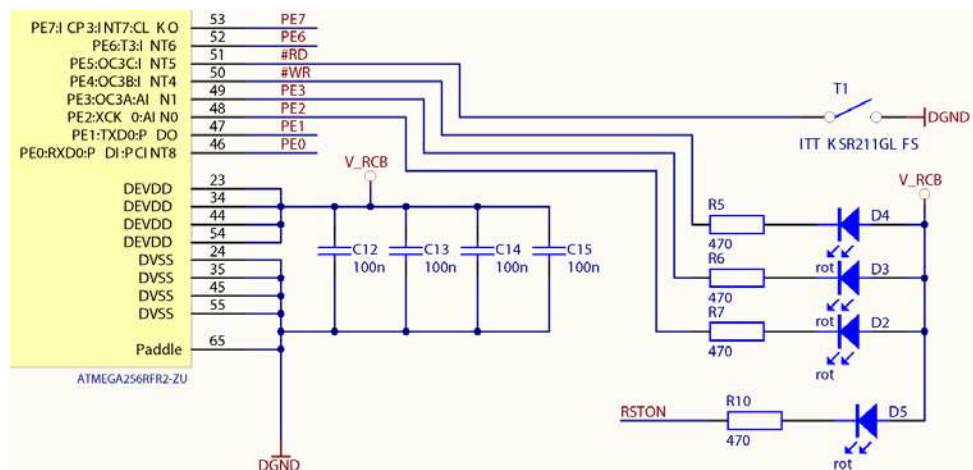


### 4.5.2 ID EEPROM

Firmware-based board type identification is supported by an optional identification EEPROM. Information about the RCB itself, MAC addresses, and production calibration data are stored there. An Atmel AT25010A EEPROM [7] with 128 × 8-bit organization and SPI interface is used because of its small package, low voltage, and low-power operation.

Compared to Atmel Atmega1281V-based RCBs, the ID EEPROM interface has been designed in a different way. Accessing the ID EEPROM requires PG5 set to logic low. This pin is not used on Atmega1281V-based RCBs (see Figure 4-3 for details).

**Figure 4-3.   ID EEPROM access decoding logic.**
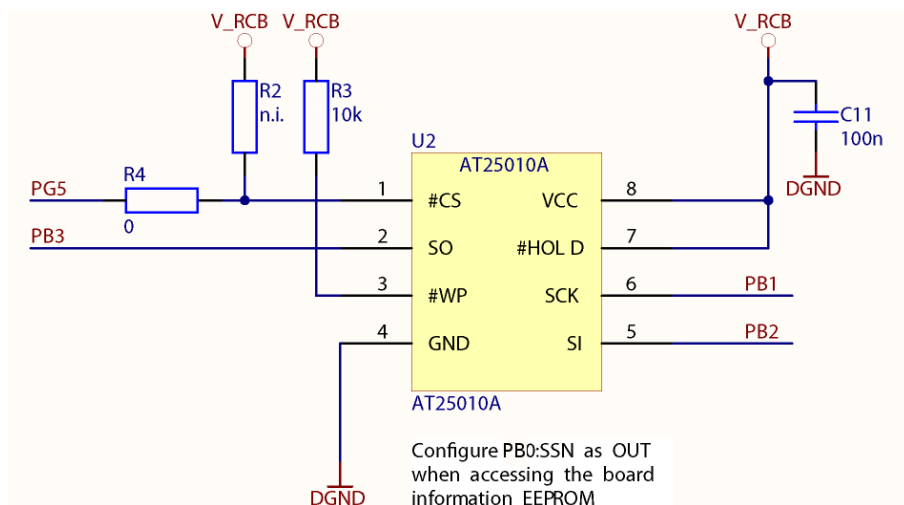


The ID EEPROM is written during board production testing with:

- A unique serial number
- MAC address
- Calibration values

Calibration values are used to optimize radio transceiver performance.

Final products do not require this external ID EEPROM functionality. All data can be stored directly in the Atmel Atmega256RFR2 internal EEPROM. The ID EEPROM is there for convenience to simplify microcontroller firmware development. Table 4-1 shows the data structure of the ID EEPROM. The Cal RC values can be used as start values for the RC calibration algorithm. The Cal OSC 16MHz value can simply be copied to the corresponding radio transceiver register to reduce the frequency deviation. However, the 16MHz crystal is guaranteed to deviate less than 20ppm from the actual 16MHz value at room temperature without any calibration adjustment. When the Cal OSC 16MHz value is applied, the deviation is less than 5ppm at room temperature.

**Table 4-1.   ID EEPROM mapping.**

| Address | Name | Type | Description |
|---------|------|------|-------------|
| 0x00 | MAC address | uint64 | MAC address [1] for the 802.15.4 node, little endian byte order |
| 0x08 | Serial number | uint64 | Board serial number, little endian byte order |
| 0x10 | Board family | uint8 | Internal board family identifier |
| 0x11 | Revision | uint8 | Board revision number, for example 06 03 02 |
| 0x14 | Feature | uint8 | Board features, coded into seven bits<br>7  Reserved<br>6  Reserved<br>5  External LNA<br>4  External PA<br>3  Reserved<br>2  Diversity<br>1  Antenna<br>0  SMA connector |
| 0x15 | Cal OSC 16MHz | uint8 | RF231 XTAL calibration value, register XTAL_TRIM |
| 0x16 | Cal RC 3.6V | uint8 | AVR internal RC oscillator calibration value @ 3.6V, register OSCCAL |
| 0x17 | Cal RC 2.0V | uint8 | AVR internal RC oscillator calibration value @ 2.0V, register OSCCAL |

| Address | Name | Type | Description |
|---------|------|------|-------------|
| 0x18 | Antenna gain | int8 | Antenna gain [1/10dBi]<br>e.g.: 0x0A = 10d will indicate a gain of 1.0dBi. The values 00h and FFh are per definition invalid. Zero or -0.1dBi has to be indicated as 0x01 or 0xFE |
| 0x20 | Board name | char[30] | Textual board description |
| 0x3E | CRC | uint16 | 16 bit CRC checksum, standard ITU-T generator polynomial $G_{16}(x) = x^{16} + x^{12} + x^5 + 1$ |

Note:      1. MAC addresses used for this package are Atmel property. The use of these MAC addresses for development purposes is permitted.

**Example ID EEPROM dump:**
```
0000  FF 1C 00 14 19 25 04 00 00 00 00 00 7D 00 00 00   .....%......}...
0010  01 06 03 02 02 00 A9 A9 00 FF FF FF FF FF FF FF   ................
0020  52 43 42 32 35 36 52 46 52 32 00 00 00 00 00 00   RCB256RFR2......
0030  00 00 00 00 00 00 00 00 00 00 00 00 00 00 28 D9   ..............(.
0040  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF   ................
0050  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF   ................
0060  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF   ................
0070  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF   ................
```

## 4.6 External peripherals

The RCB is equipped with two 50mil connectors (EXT0/1) to mount the RCB on a variety of expansion boards (base boards). The connectors provide access to all spare Atmel Atmega256RFR2 pins, including USART, TWI, ADC, and PWM.

Make sure that any RCB base board that is used together with the RCB256RFR2 will not drive the TST signal (EXT1, pin5) high during operation. The only occasion to drive the TST signal high is during parallel programming. Refer to [1] for detailed information. For normal operation, this signal must be left open or pulled to ground. For the unconnected case, R9 will drive the pin low.

The Atmega256RFR2 does not integrate a memory controller like the Atmel Atmega1281V. A memory controller function is to be emulated by hardware (ports A, B, and C) and software. This results in an I/O mapping if this functionality is needed:

- A memory data bus is emulated using port B
- For the memory address bus emulation, only the upper four address lines can be controlled via port D. To achieve that, the PD4..7 signals are routed to both connections, port D and C
- #RD and #WR, if needed, are emulated by PE5 and PE4

The detailed pin mapping is shown in Table 4-2). This table also provides mapping of existing Atmega1281V-based RCBs.

**Table 4-2.** Extension connector (EXT0/1) mapping.

| EXT0 | | | | | | |
|------|-------------------|------------------|---|------|-------------------|------------------|
| Pin# | RCB256RFR2 function | 1281V RCB function | | Pin# | RCB256RFR2 function | 1281V RCB function |
| 1 | PG0 | PB6 | | 2 | PG1 | PB7 |
| 3 | RSTN | #RESET | | 4 | V_RCB | V_RCB |
| 5 | GND | GND | | 6 | not connected | XTAL2 |
| 7 | CLKI | XTAL1 | | 8 | GND | GND |
| 9 | PD0 | PD0 (SCL) | | 10 | PD1 | PD1 (SDA) |
| 11 | PD2 | PD2 (RXD1) | | 12 | PD3 | PD3 (TXD1) |
| 13 | PD4 | PD4 | | 14 | PD5 | PD5 |
| 15 | PD6 | PD6 (CLKM) | | 16 | PD7 | PD7 |
| 17 | PE4 (#WR) | PG0 (#WR) | | 18 | PE5 (#RD) | PG1 (#RD) |
| 19 | GND | GND | | 20 | GND | GND |
| 21 | GND | PC0 | | 22 | GND | PC1 |
| 23 | GND | PC2 | | 24 | GND | PC3 |
| 25 | PD4 | PC4 | | 26 | PD5 | PC5 |
| 27 | PD6 | PC6 | | 28 | PD7 | PC7 |
| 29 | GND | GND | | 30 | PG2 (ALE) | PG2 (ALE) |

| EXT1 | | | | | | |
|------|-------------------|------------------|---|------|-------------------|------------------|
| Pin# | RCB256RFR2 function | 1281V RCB function | | Pin# | RCB256RFR2 function | 1281V RCB function |
| 1 | PB1 | PB1 (SCK) | | 2 | GND | GND |
| 3 | PE7 | PE7 | | 4 | PE6 | PE6 |
| 5 | TST (connect for parallel programming only) | PE5 | | 6 | RSTON | PE4 |
| 7 | PE3 | PE3 | | 8 | PE2 | PE2 |
| 9 | PE1 | PE1 (PDO) | | 10 | PE0 | PE0 (PDI) |
| 11 | GND | AGND | | 12 | AREF | AREF |
| 13 | PF0 | PF0 | | 14 | PF1 | PF1 |
| 15 | PF2 | PF2 | | 16 | PF3 | PF3 |
| 17 | PF4 | PF4 (TCK) | | 18 | PF5 | PF5 (TMS) |
| 19 | PF6 | PF6 (TDO) | | 20 | PF7 | PF7 (TDI) |
| 21 | V_RCB | V_RCB | | 22 | GND | GND |
| 23 | PB0 | PA0 | | 24 | PB1 | PA1 |
| 25 | PB2 | PA2 | | 26 | PB3 | PA3 |
| 27 | PB4 | PA4 | | 28 | PB5 | PA5 |
| 29 | PB6 | PA6 | | 30 | PB7 | PA7 |

The connector pin-out mapping enables operation with almost all peripheral elements on existing base boards, except external SRAM support.

## 4.7 PCB layout description

This section discusses critical layout details, important for derived PCB designs. A derived design should carefully consider the following details:

- Establish a solid ground plane for the antenna. The PCB area has to be considered as a counterpart of the antenna. The PCB interacts with the radiated electromagnetic wave
- Isolate digital noise from the antenna and the RF and analog radio transceiver sections to ensure maximum possible radio transceiver performance
- Isolate digital noise from the reference crystal to ensure maximum possible transmit signal purity and receiver performance, especially when operating in high data rate ISM modes
- Reduce any kind of spurious emissions well below the limits set by the individual regulatory organizations

Layout details 1 to 9, as shown in Figure 4-4 and Figure 4-5, are described in the following sub-sections.

**Figure 4-4. RCB256RFR2 top layer design details.**
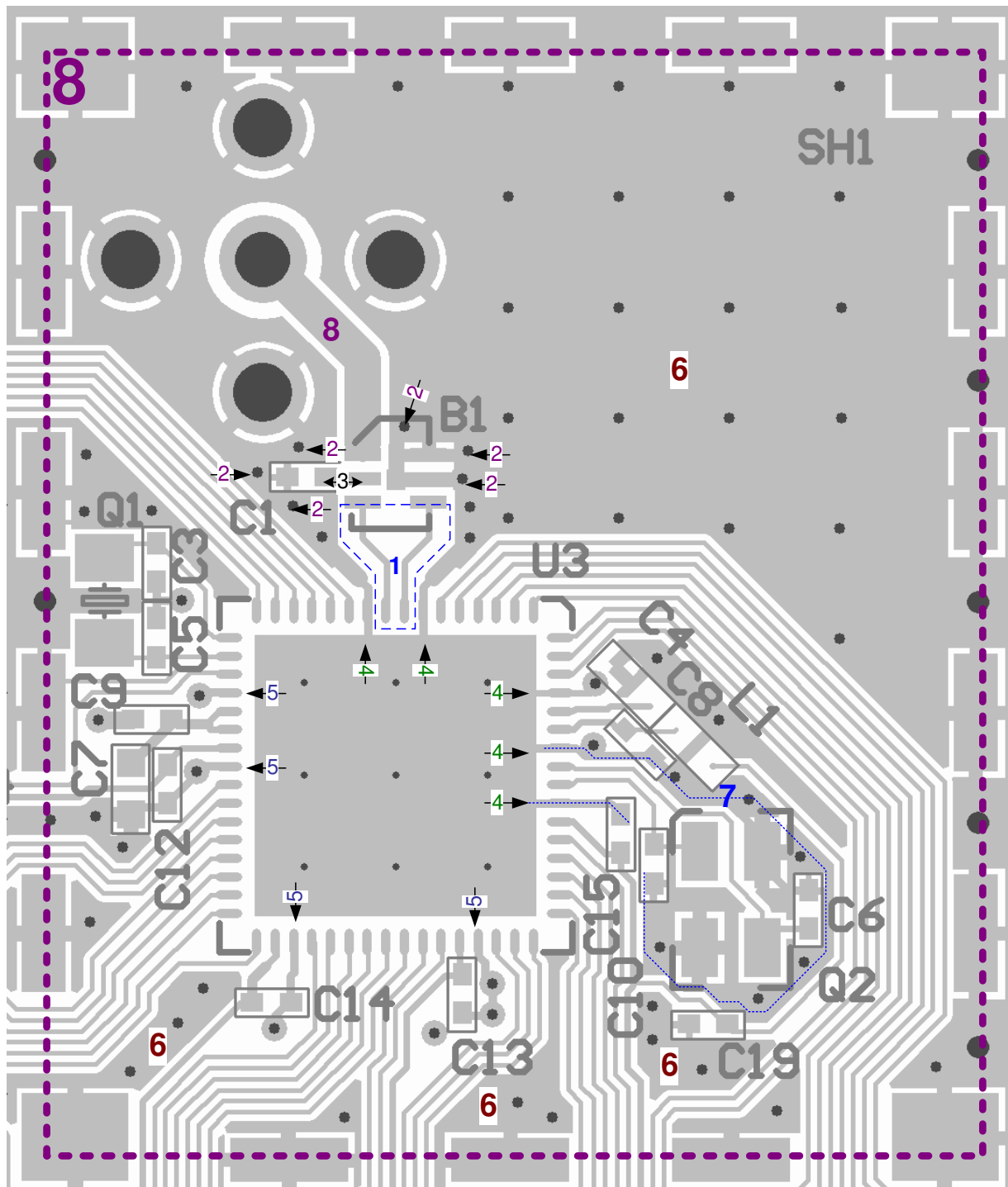
**Figure 4-5.   RCB256RFR2 bottom layer design details.**
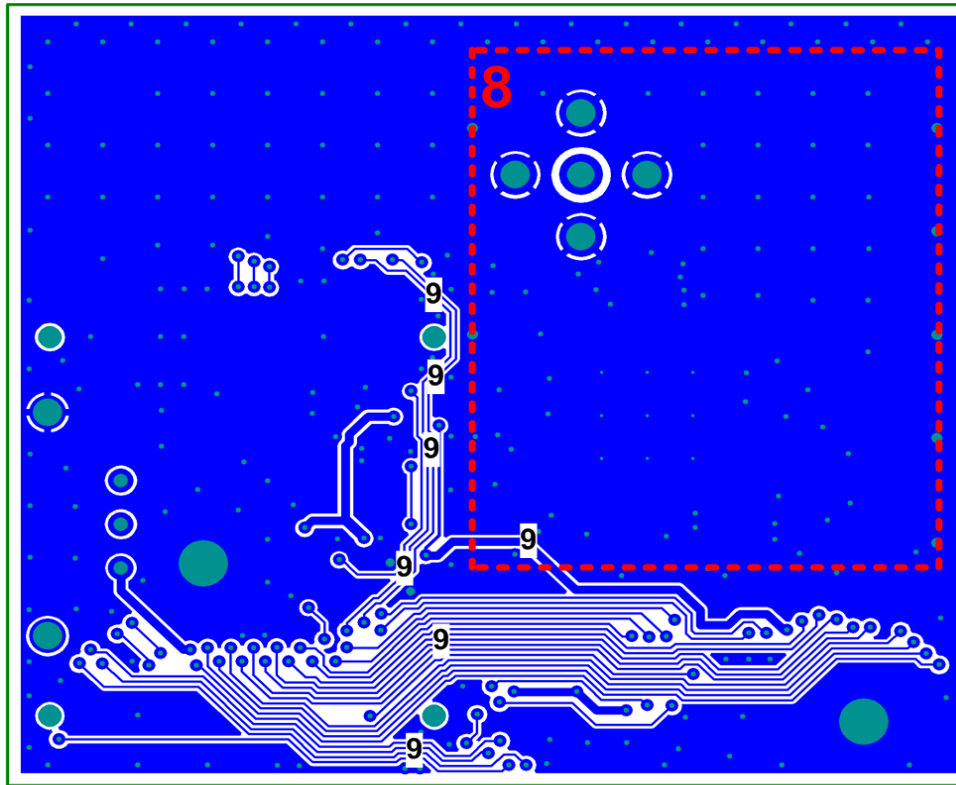


The RCB256RFR2 demonstrates a low-cost two-layer PCB design with a total thickness of 1.6mm. The chosen PCB material is FR4 (ISOLA IS400). The top and bottom layer each with 35µm copper are used as ground planes. Performance is achieved without using additional inner ground and supply planes. Figure 4-6 shows the layer stack.

**Figure 4-6.   PCB layer stack.**



### 4.7.2    PCB detail 1 – balanced RF fan out

The radio transceiver RF ports require a small serial inductance in series with the balun or antenna pins. A reasonable inductance value is 1..2nH. With the given 1.5mm RF4 substrate, it is not possible to design a differential 100Ω transmission line. Thus, traces between filter-balun and single chip are kept at a reasonable small width of 0.2mm. With this approach, transmission lines are well routable and create the required inductance at the same time.

### 4.7.3    PCB detail 2 – balun ground connection

The filter-balun requires a solid ground connection (refer to [6]. Because the filter-balun has to drive a single-ended line towards the SMA connector, each current injected into this line creates a counterpart current into the ground plane. A parasitic inductance to ground is, therefore, directly inserted into the signal path and increases the insertion loss.

Further, the integrated harmonic low-pass filter has to perform well at much higher frequencies to reduce harmonics. Any parasitic inductance causes limited harmonic filter performance.

Lowest inductance is achieved with large copper areas on the top and bottom planes. Both planes are to be sewn together with sufficient through holes, especially in close proximity of GND pins of critical RF components. Resulting through-hole inductances are to be considered as parallel connected, resulting in the lowest possible overall inductance.

### 4.7.4    PCB detail 3 – bias DC block, AC ground

The RCB uses an integrated filter-balun (refer to [6]). The component provides pin 2 as a bias port towards the differential pins. To avoid a DC connection of the radio transceiver circuitry (refer to [1]), filter-balun pin 2 requires a DC blocking capacitor, C1, to create an AC GND connection only.

This capacitor is to be placed as close as possible to the filter-balun to ensure a low-impedance AC connection. For the RCB256RFR2, the minimum distance was limited by the minimum width of a solder mask separator in between the balun and the capacitor pad. The actual value is related to the PCB manufacturer capabilities.

The grounded pad of the capacitor is surrounded by three through holes in close proximity to ensure the lowest possible impedance.

The capacitor itself should be of size 0402, or smaller.

### 4.7.5    PCB detail 4 – analog GND routing

It is recommended to design the ground trace as wide as possible to avoid parasitic inductances.

Atmel Atmega256RFR2 analog ground pins are to be routed to the paddle underneath the IC. The GND trace width is recommended to be similar to the pad width.

Each GND pin should be connected to the bottom plane with at least one through hole in direct proximity to the IC.

Soldering technology allows placing small through holes (0.15mm drill) within the ground paddle underneath the Atmega256RFR2. Through holes are filled with solder during reflow soldering; solder paste loss is low, however, due to the small drill size.

For pin 55 an exception should be considered since there are special conditions in its adjacent area:

- In this area a solid GND plane does not exist on top since there are many parts located there (XTAL, load and blocking capacitors). The GND in most cases is limited to one via and maybe some traces. This is not really low inductance, especially on a 1.5mm double layer substrate
- The crystal is right next to it. An increased noise level at this pin may crosstalk into the crystal

Therefore, the rule for pin 55 is that it should be handled like the digital ground pins when a solid grounding is possible next to the package. The term 'solid grounding' shall be understood as a close connection to a ground plane on top and more than one via.

If only one or no via is possible the pin shall also be connected to the paddle.

### 4.7.6    PCB detail 5 – digital GND routing

The digital GND pins are not directly connected to the paddle. This is to avoid dispersion of digital noise from I/O pad cells or other digital processing units.

A direct connection causes a small voltage drop for digital noise due to the limited impedance of the paddle through holes, resulting in an increased noise floor transferred to the analog domain.

Digital ground pins should be connected to the top layer ground fill, and from there with vias to the ground plane below.

### 4.7.7 PCB detail 6 – ground plane

Besides acting as an electrical ground plane, the PCB area creates a counterpart pole for the antenna. Such an antenna base plate is considered as a continuous metal plane.

Therefore it is recommended to fill any unused PCB area with copper electrically connected to GND. Both PCB sides are to be connected using individual or, if possible, grids of through holes. By doing this, the PCB behaves like a coherent piece of metal for an external electromagnetic field.

### 4.7.8 PCB detail 7 – crystal guard routing

The 16MHz radio reference crystal PCB design requires special attention to avoid the influence of external noise sources and to keep the radiation of 16MHz harmonics low.

Any crosstalk from digital lines into the crystal signals increases the phase noise and reduces the radio transceiver performance.

A grounded guard trace is placed around the crystal area to protect the crystal against digital noise.

To investigate the impact of digital noise on the reference crystal, it is recommended to perform packet error rate tests with potential digital noise sources enabled and disabled. The influence of disturbances such as MCLK or SPI activity during transmit or receive can be evaluated by comparing the measurement results.

### 4.7.9 PCB detail 8 – RF section shielding

A shield covering the Atmel Atmega256RFR2 and related parts is used to protect the IC from external noise and strong interferers. The shield is not required to suppress any radiation generated by the IC.

### 4.7.10 board ground plane design

A PCB ground plane with openings that are small compared to the RF wavelength can be considered as continuous. Signal lines required for normal operation create electrically long slots within the ground plane. A PCB design should accommodate ground sections on the opposite PCB side to short the slots. This design technique helps create a solid antenna ground in spite of the limitations of a cost-effective two-layer board.

# 5. Programming

All programming interfaces are available through two 50mil connectors (EXT0/1). Using an appropriate base board, the interfaces are available as 100mil connectors to directly connect programming tools such as JTAGICE mkII.

The Atmel Atmega256RFR2 has the serial programming function mapped to port B. Refer to the Atmega256RFR2 datasheet [1] for detailed pin descriptions. Base boards with an ISP connector cannot be used for ISP with the RCB256RFR2.

# 6.    Electrical characteristics

## 6.1    Absolute maximum ratings

Stresses beyond those listed under "Absolute maximum ratings" may cause permanent damage to the RCB. This is a stress rating only and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of this manual are not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability. For more details about these parameters, refer to individual datasheets of the components used.

Table 6-1.    Absolute maximum ratings.

| No. | Parameter | Condition | Minimum | Typical | Maximum | Units |
|---|---|---|---|---|---|---|
| 7.1.1 | Storage temperature range | | -40 | | +85 | °C |
| 7.1.2 | Humidity | Non-condensing | | | 80 | % |
| 7.1.3 | Supply voltage | | -0.3 | | +3.6 | V |
| 7.1.4 | EXT I/O pin voltage | All digital I/O signals | -0.3 | | V_RCB+0.3 | V |
| 7.1.5 | Analog I/O pin voltage | Aref [1]<br>Port F pins when ADC enabled [2] | -0.3 | | 2.0 | |
| 7.1.6 | Supply current from RCB battery through EXT connectors | Sum over all power pins together | | | -0.5 | A |
| 7.1.7 | Battery charge current | AAA NiMH Accu<br>AAA alkaline cell [3] | | | 0.5<br>0 | A<br>mA |
| 7.1.8 | DC voltage at RF connection | | | | 100 | V |
| 7.1.9 | ESD voltage | HBM | | | 1000 | V |
| 7.1.10 | Input RF level | | | | 14 | dBm |

Notes:    1. Never drive Aref from an external source (see [1] for further details).

2. To measure voltages up V_RCB, see PGA settings in [1].

3. Note Section 4.1.2 if RCB is mounted to a base board.

## 6.2    Recommended operating range

Table 6-2.    Recommended operating range.

| No. | Symbol | Parameter | Condition | Minimum | Typical | Maximum | Units |
|---|---|---|---|---|---|---|---|
| 7.2.1 | $T_{OP}$ | Operating temperature range | 16MHz within ±40ppm | -20 | | +70 | °C |
| 7.2.2 | V_RCB | Supply voltage | $f_{CPU}$ = 16MHz or below | 1.8 [1] | 3.0 | 3.6 | V |
| 7.2.3 | $f_{RF}$ | Operating frequency range | | 2400 | | 2483.5 | MHz |

Note:    1. Minimum value assuming stand-alone operated RCB. If mounted on a base board, value may be increased.

## 6.3    General RF specifications

For general RF specifications, refer to the Atmel Atmega256RFR2 datasheet [1]. The RCB schematic follows the application circuit. The filter-balun and SMA connector result in a typical loss of 1dB in TX output power and sensitivity compared to the values as shown in the radio transceiver section.

## 6.4 Current consumption specifications

Power consumption figures of the individual Atmel Atmega256RFR2 building blocks and operation conditions are listed in the datasheet [1].

To determine the RCB current consumption, the following values are to be taken into account:

Test conditions (unless otherwise stated) [1] [2]:

$V_{DD}$ = 3.0V, $T_{OP}$ = 25°C.

**Table 6-3.    Current consumption.**

| No. | Symbol | Parameter | Condition | Minimum | Typical | Maximum | Units |
|-----|--------|-----------|-----------|---------|---------|---------|-------|
| 7.4.1 | $I_{LED}$ | LED on current | Current per LED when driving port pin is low | | 3 | | mA |
| 7.4.2 | $I_{EE\_SLEEP}$ | ID EEPROM standby current | | | 1.5 | | µA |

Notes:        1. Current consumption figures does not include microcontroller.

2. Current consumption for all operating modes is reduced at lower $V_{DD}$.


The RCB does not provide any external pull-up or pull-down resistors needed to be driven in a static way. However, the software has to ensure proper port settings to avoid floating I/O lines.

After resetting the Atmega256RFR2, I/O ports are set as inputs and are floating. This may result in increased current consumption. It is recommended to either enable internal pull-up resistors or to configure I/O ports as outputs immediately after reset.

# 7. Abbreviations

AAA       -    Battery size, also known as IEC R03 or JIS UM 4

ADC       -    Analog-to-digital converter

EEPROM    -    Erasable electrical programmable read-only memory

FCC       -    Federal Communication Commission

FFD       -    Full functional device

HBM       -    Human body model

ISM       -    Industrial, scientific, and medical

ISP       -    In system programming

LNA       -    Low-noise amplifier

MAC       -    Medium access control

PA       -    Power amplifier

PAN       -    Personal area network

PCB       -    Printed circuit board

PCBA      -    Printed circuit board assembled

RCB       -    Radio controller board

RF       -    Radio frequency

RX       -    Receive

SMA       -    Subminiature version A

SOC       -    System on chip

TWI       -    Two-wire serial interface

TX       -    Transmit

USART      -    Universal synchronous/asynchronous receiver/transmitter

XTAL       -    (Reference) crystal

# Appendix A.  PCB design data

## A.1  Schematic

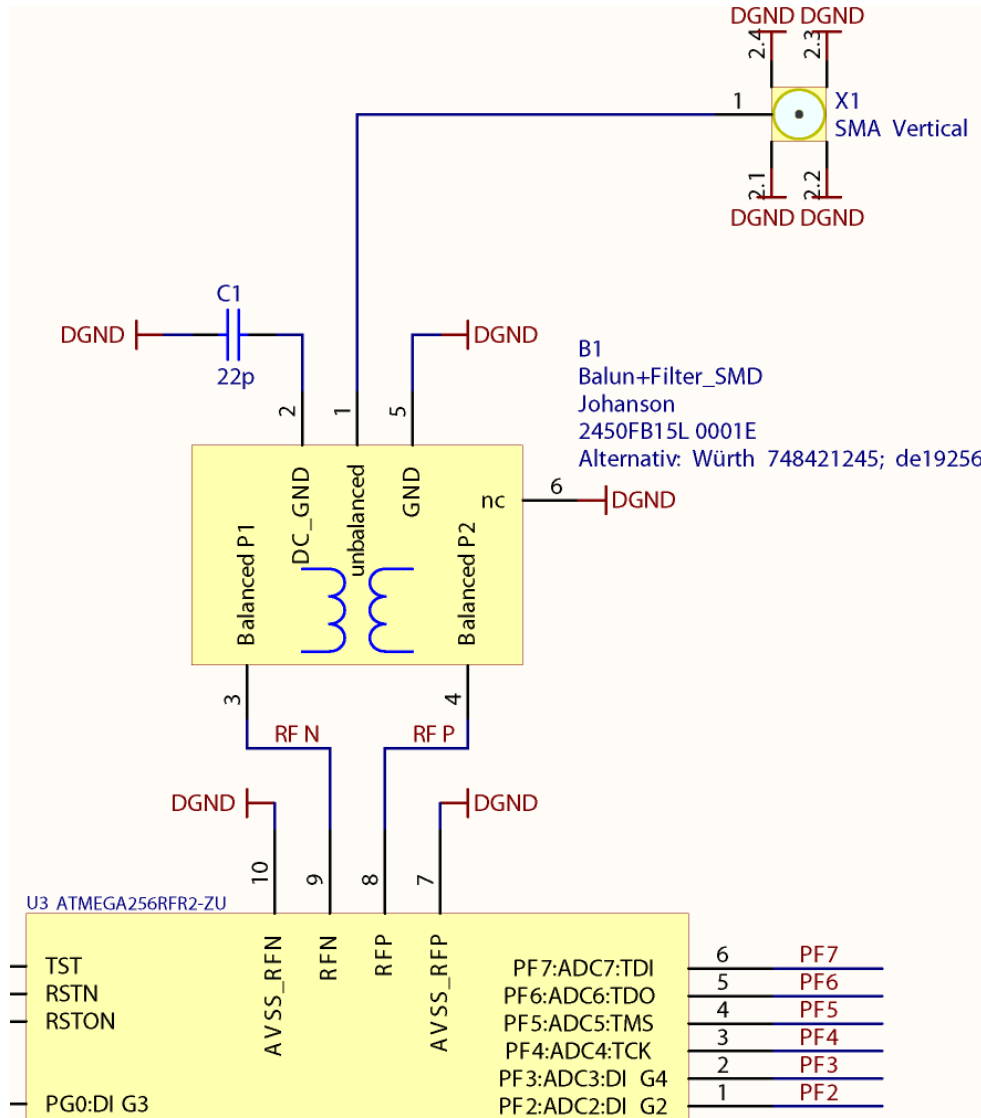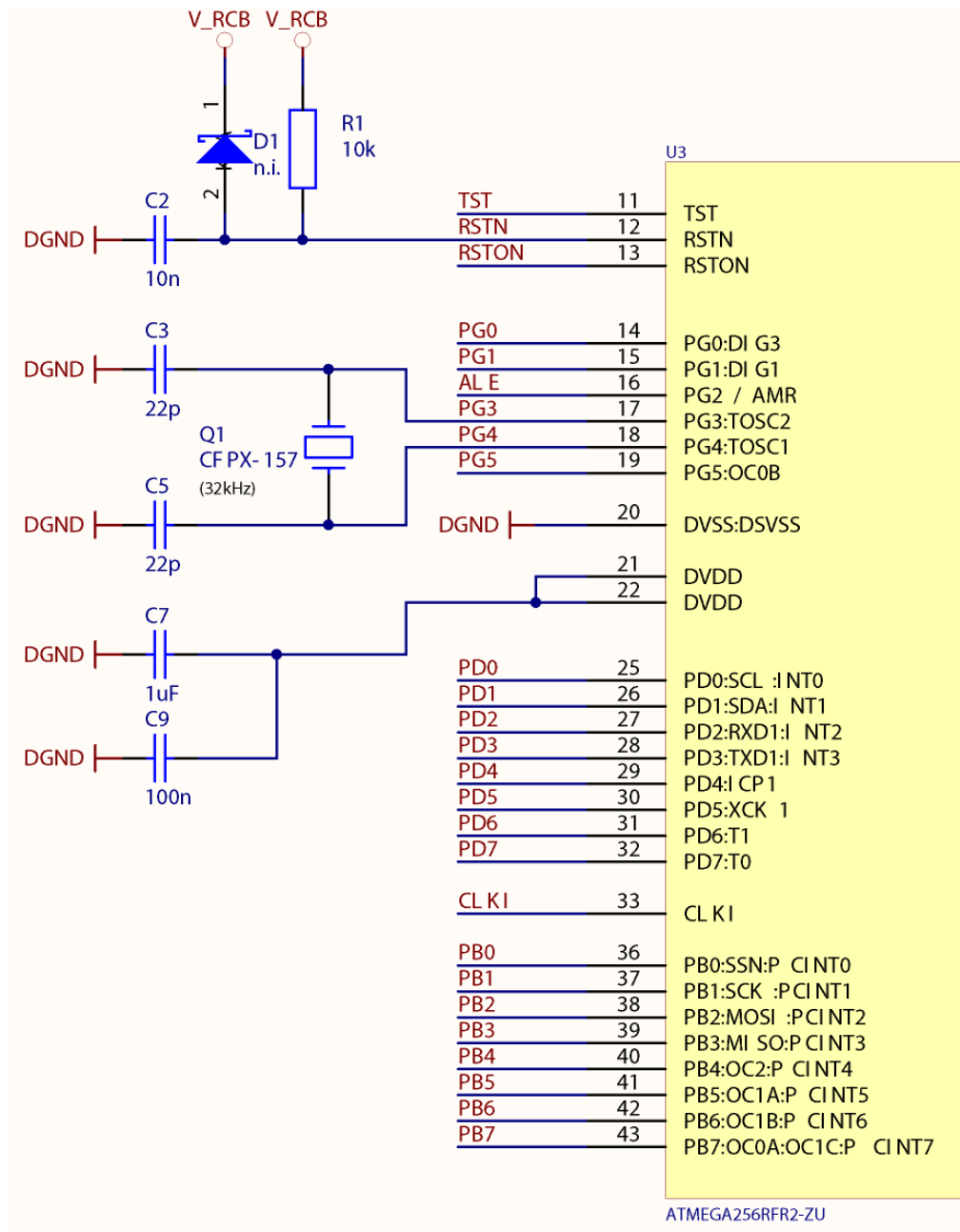**Figure A-1.**  RCB256RFR2 – RF section.

**Figure A-2. RCB256RFR2 – SOC section 1.**



Note: Be aware of the TST and CLKI signal routing on RCB256RFR2. The connector mapping is visible in Figure A-4, as well as pull-down resistors (R8, R9) for both signals. For normal operation, the TST signal must be pulled to ground all the time. The only occasion to drive the TST signal high is during parallel programming. Refer to [1] for detailed information.

Figure A-3.  RCB256RFR2 – SOC section 2.