AVR2044: RCB128RFA1 - Hardware User Manual

Application Note

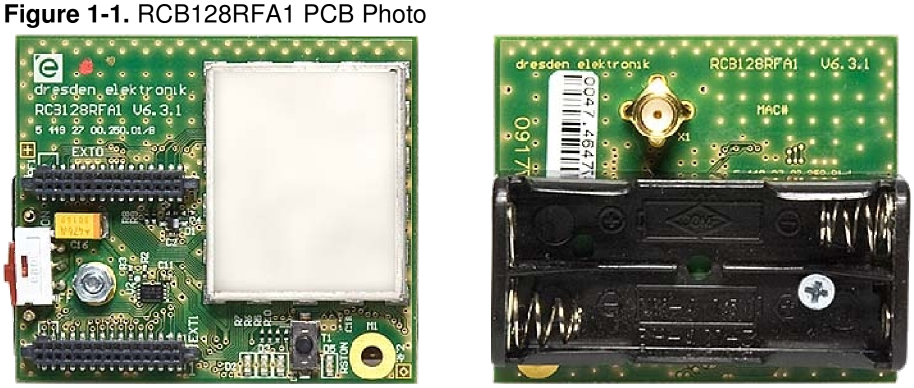
Features

- Stand alone operable Radio Controller Board (RCB)
- The design is based on the single chip ATmega128RFA1 to support IEEE 802.15.4™, ZigBee™, 6LoWPAN, RF4CE, SP100, WirelessHART™ and ISM Applications
- FCC-ID: VNR-S31SM-V4-00
- Japan TELEC: 005WWCA0425
- SMA RF connector
- Simple user interface with button and LED's
- Board Information EEPROM containing
  - MAC Address
  - Board identification, features and serial number
  - Crystal calibration values
- 2xAAA batteries for stand alone operation
- 60 pin extension connector to interface with application specific hardware

1 Introduction

The RCB128RFA1 user manual describes the usage, design, and layout of the ATmega128RFA1 radio controller board.

Figure 1-1. RCB128RFA1 PCB Photo



Rev. 8339A-AVR-09/10

2 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 is included into this document for convenience. The vendor may have changed the information in between. Check the individual part information for latest changes.

3 Overview

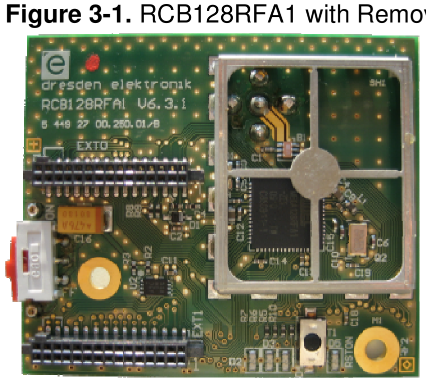
The RCB128RFA1 is designed to provide a reference design for the single chip microcontroller and radio transceiver ATmega128RFA1 [1]. The IC integrates a powerful 8-bit AVR RISC microcontroller, an IEEE802.15.4-compliant transceiver and additional periphery. The built-in radio transceiver supports the worldwide accessible 2.4 GHz ISM band.

The system is designed to demonstrate standard based applications like 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 together with the RCB or to perform conducted RF performance measurements.

The RF section has been shielded to eliminate interference from external sources to the ATmega128RFA1. 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 ATmega128RFA1 where made available through two expansion connectors (EXT0/1). There is a variety of base boards available for the RCB family.

Figure 3-1. RCB128RFA1 with Removed Snap-In Cover



4 Mechanical Description

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

The RCB128RFA1 has no on-board antenna, so that a board separation into an electronic and an antenna section is not required. When used with a quarter wave antenna, mounted at the SMA connector, the board will act as a ground plane for this antenna.

This design with RF shield is implementing one M2.5 mounting hole (see Figure 4-1). In consequence, one mounting bolt has to be removed on several base boards types to mount the RCB128RFA1 in a correct position.

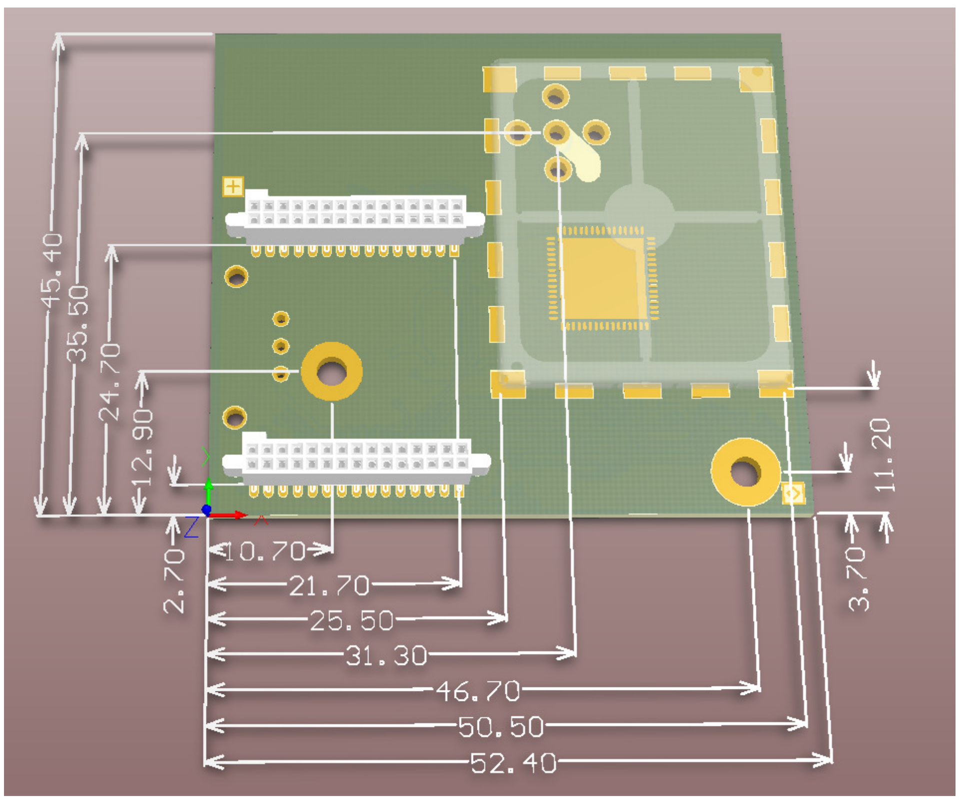
The other mounting hole is reserved for a battery holder. If battery operation is required, base boards should not make use of this mount.

4.1.1 Mechanical Dimensions

Figure 4-1 shows the EXT0/1 interface connector position referred to pin1, since most of the CAD tools using this pin as a placement reference. Please 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 4-2 and Figure 8-5 also.

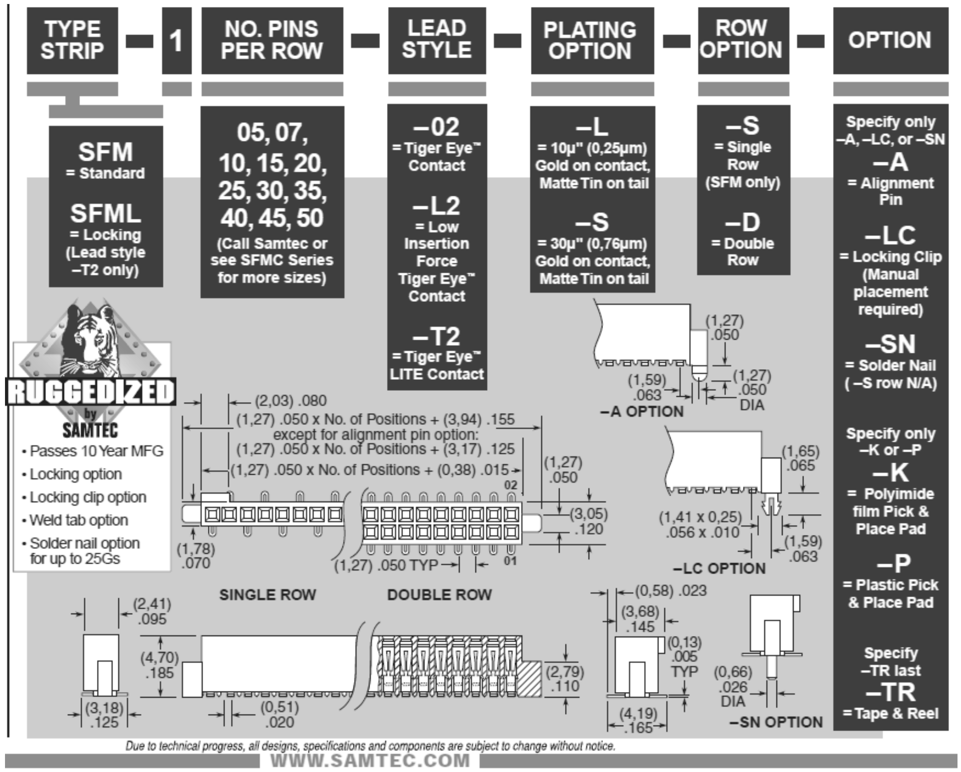
The PCB is standard 1.5 mm FR4 material with 2 copper layers. Due to panelization and cutting process, the dimension of the outer board edge may vary up to +0,1mm.

Figure 4-1. RCB128RFA1 – Mechanical Drawing (Dimensions in mm)



4.1.2 Interface Connector Specification

Figure 4-2. RCB128RFA1 – Interface Connector Drawing



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

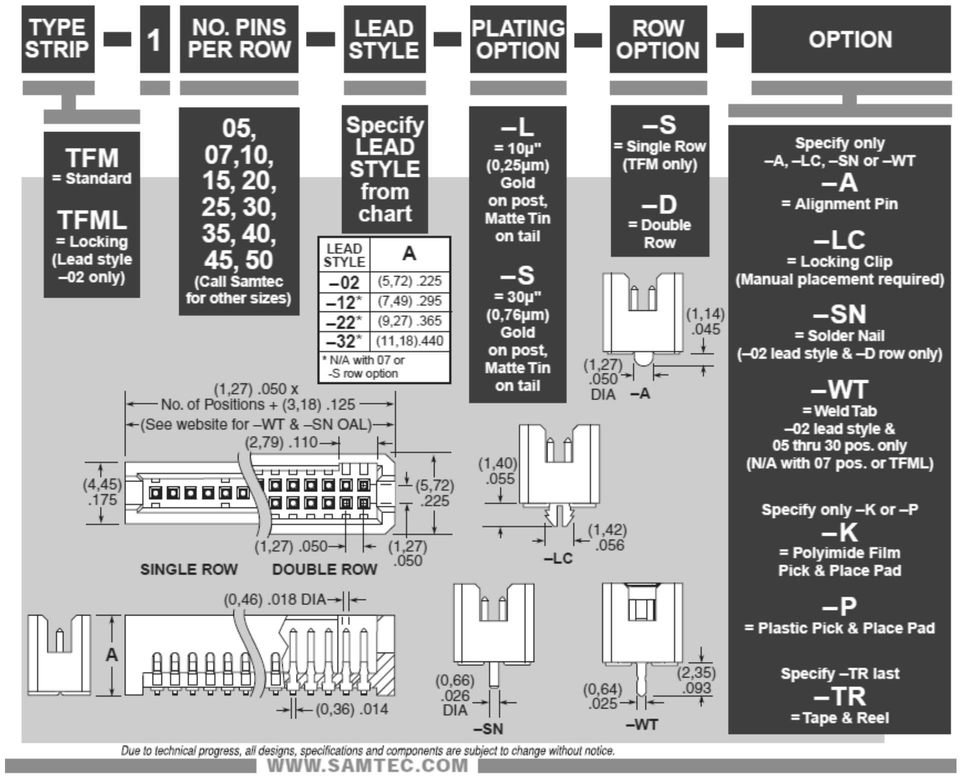
The detailed part number is: SFM-115-L2-S-D-LC.

L2 is the low insertion force (LIF) variant to allow easy mounting.

The drawing shown in Figure 4-2 is a copy taken from a SAMTEC datasheet. Check the latest datasheet for possible updates and changes.

4.1.3 Application (Base) Board Connectors

Figure 4-3. Application Board Connector Drawing



The drawing in Figure 4-3 shows the connector to be used on a base board to interface the RCB EXT0/1 connectors.

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

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

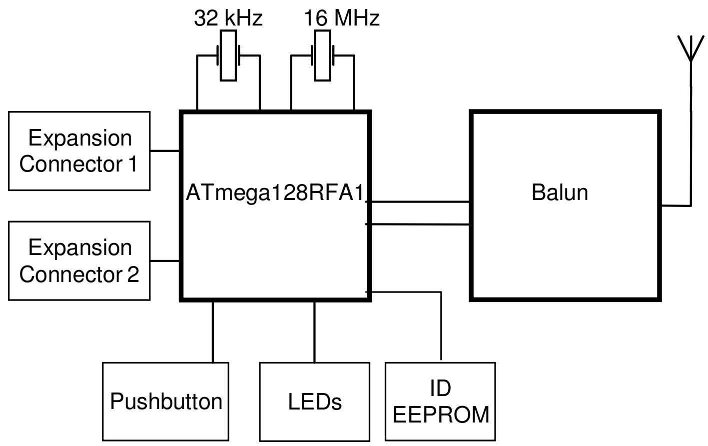
Note: The Tyco part requires a different footprint design!

The drawing shown in Figure 4-3 is a copy taken from a SAMTEC datasheet. Check the latest datasheet for possible updates and changes.

5 Functional Description

Figure 5-1 illustrates the RCB setup in general. It mainly consists of an ATmega128RFA1 and some periphery. An ID-EEPROM stores MAC address and additional board information. This information is stored in a separate EEPROM to avoid accidental data erase during microcontroller firmware development.

Figure 5-1. Radio Controller Board - Block Diagram



The radio transceiver incorporates MAC hardware accelerators to handle all actions concerning RF modulation/demodulation, signal processing, frame reception and transmission. 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.

5.1 Power Supply

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

All PCB components are supplied by this single supply to minimize the bill of material (BoM) and maximize the power efficiency.

5.1.1 Battery power

For autonomous operation, the RCB can be supplied by two AAA batteries to be 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 radio transceiver and microcontroller are in sleep mode, and all periphery disabled.

5.1.2 External power

An RCB mounted on a base board may be powered via the expansion connectors, see Table 5-2. In this case the power switch SW1 has to be in OFF position to avoid unintentionally charging of the batteries, if they are applied.

5.2 Microcontroller

The ATmega128RFA1 integrates a low-power 8-bit microcontroller based on the AVR enhanced RISC architecture. The non-volatile flash program memory of 128 kB and

16 kB of 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) as well as a reduced function device (RFD), as defined by IEEE802.15.4 [2]. However, the RCB is not limited to this 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 ATmega128RFA1 is designed to operate at full 16 MHz speed over the complete supply voltage range from 1.8V to 3.6V.

5.3 On Chip Radio Transceiver

Beside an 8-bit AVR microcontroller, the ATmega128RFA1 further integrates an IEEE802.15.4 compliant radio transceiver. RF and base band critical components are integrated to transmit and receive signals according to IEEE802.15.4, or even 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 ATmega128RFA1 to a standard SMA connector. An integrated harmonic filter ensures sufficient harmonic rejection.

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

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

5.4 Clock Sources

5.4.1 Radio Transceiver clock

The integrated radio transceiver is clocked by a high accurate 16 MHz reference crystal Q2. Operating the node according to IEEE802.15.4, the reference frequency deviation must be within +/-40 ppm, 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 shall be isolated from fast switching digital signals and surrounded by a grounded guard trace to minimize disturbances of the oscillation.

The RCB uses a SIWARD crystal SX4025 with two load capacitors of 10 pF. To compensate fabrication and environment variations the frequency can be tuned with the transceiver register “XOSC_CTRL (0x12)”, refer to [1], section 9.6. An initial tuning is done during fabrication and the correction value has been stored in the onboard ID-EEPROM, see section 5.5.2.

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

5.4.2 Microcontroller

There are various clock source options for the microcontroller inside the ATmega128RFA1:

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

The calibrated internal RC oscillator, prescaled to 8 MHz is used as the default clocking. It is recommended to use the MAC symbol counter, see [1], clocked from the 16 MHz radio 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 32 kHz crystal Q1 is connected to the related ATmega128RFA1 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.

5.5 On-Board Peripherals

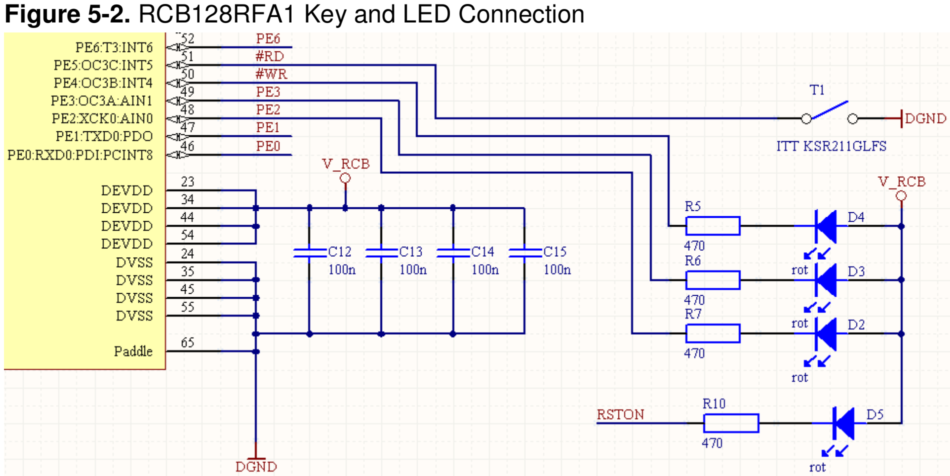
5.5.1 Key & LED's

For simple applications, debugging purposes or just to deliver status information, a basic user interface is provided directly on-board, consisting of four LED's and a pushbutton. Three LED's (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, 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 RCB128RFA1 the port G I/O lines can not be used since they are shared with dedicated radio transceiver functionality.

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

Figure 5-2. RCB128RFA1 Key and LED Connection

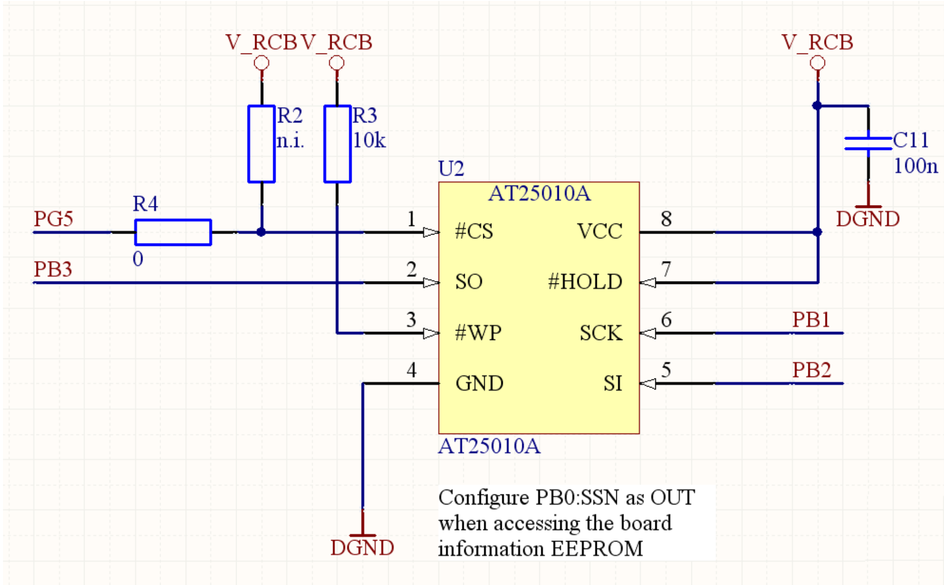


5.5.2 ID-EEPROM

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. An Atmel AT25010A EEPROM [7] with 128x8 bit organization and SPI interface is used because of its small package, low voltage and low power operation.

Compared to Atmega1281V based RCB's, 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 RCB's, refer to Figure 5-3 for details.

Figure 5-3. ID-EEPROM Access Decoding Logic



The ID-EEPROM data is written during board production test with

- A unique serial number,
- MAC address
- Calibration values.

Calibration values are to be used to optimize radio transceiver performance.

Final products do not require this external ID-EEPROM functionality. All data can directly be stored in the Atmega128RFA1 internal EEPROM. The ID-EEPROM is placed for convenience, to simplify microcontroller firmware development.

Table 5-1 shows the data structure of the ID-EEPROM. The Cal RC values can be used as a start value for the RC calibration algorithm. The Cal OSC 16 MHz value can simply be copied to the corresponding radio transceiver register to reduce the frequency deviation. However, the 16 MHz crystal is guarantied to deviate less than 20 ppm at room temperature, from the actual 16 MHz value without any calibration adjustment. When the Cal OSC 16 MHz value is applied, the deviation is less than 5 ppm at room temperature.

Table 5-1 ID-EEPROM Mapping

Address	Name	Type	Description
0x00	MAC address	uint64	MAC address[1] for the 802.15.4 node, little endian byte order

Address	Name	Type	Description
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 eg. 06 03 01
0x14	Feature	uint8	Board features, coded into 7 Bits 7 – Reserved 6 – Reserved 5 – External LNA 4 – External PA 3 – Reserved 2 – Diversity 1 – Antenna 0 – SMA connector
0x15	Cal OSC 16 MHz	uint8	RF231 XTAL calibration value, register “XTAL_TRIM”
0x16	Cal RC 3.6 V	uint8	AVR internal RC oscillator calibration value @ 3.6 V, register “OSCCAL”
0x17	Cal RC 2.0 V	uint8	AVR internal RC oscillator calibration value @ 2.0 V, register “OSCCAL”
0x18	Antenna Gain	int8	Antenna gain [resolution 1/10 dBi] eg.: 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 $G_{16}(x) = x^{16}+x^{12}+x^5+1$

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

Example ID-EEPROM dump:

```
6D 4D 17 FF FF 25 04 00 86 12 00 00 2F 00 00 00    mM...%....../...
01 06 03 01 02 00 A5 A5 01 FF FF FF FF FF FF FF    ................
52 43 42 31 32 38 52 46 41 31 00 00 00 00 00 00    RCB128RFA1......
00 00 00 00 00 00 00 00 00 00 00 00 00 00 52 F2    ..............R.
FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF    ................
FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF    ................
FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF    ................
FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF    ................
```

5.6 External Peripherals

The RCB is equipped with two 50 mil connectors (EXT0/1) to mount the RCB on a variety of expansion boards (base boards). The connectors providing access to all spare Atmega128RFA1 pins, including USART, TWI, ADC and PWM.

Make sure that any RCB base board that is used together with the RCB128RFA1 will not drive the TST signal (EXT1, pin5) high during operation. The only occasion to drive the TST signal high is during parallel programming. Please 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 Atmega128RFA1 does not integrate a memory controller like Atmega1281V. A memory controller function is to be emulated by hard- (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 5-2. This table further provides mapping of existing, Atmega1281V based RCB’s.

Table 5-2 Extension Connector (EXT0/1) Mapping

EXT0						
Pin#	**RCB128RFA1 Function**	**1281V RCB Function**		**Pin#**	**RCB128RFA1 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#	RCB128RFA1 Function	1281V RCB Function		Pin#	RCB128RFA1 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.

5.7 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 operating high data rate ISM modes.
- Reduce any kind of spurious emissions well below the limits set by the individual regulatory organizations.

The RCB128RFA1 demonstrates a low cost, 2-layer PCB design. Performance is achieved without using additional inner ground and supply planes.

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

Figure 5-4. RCB128RFA1 Top Layer Design Details

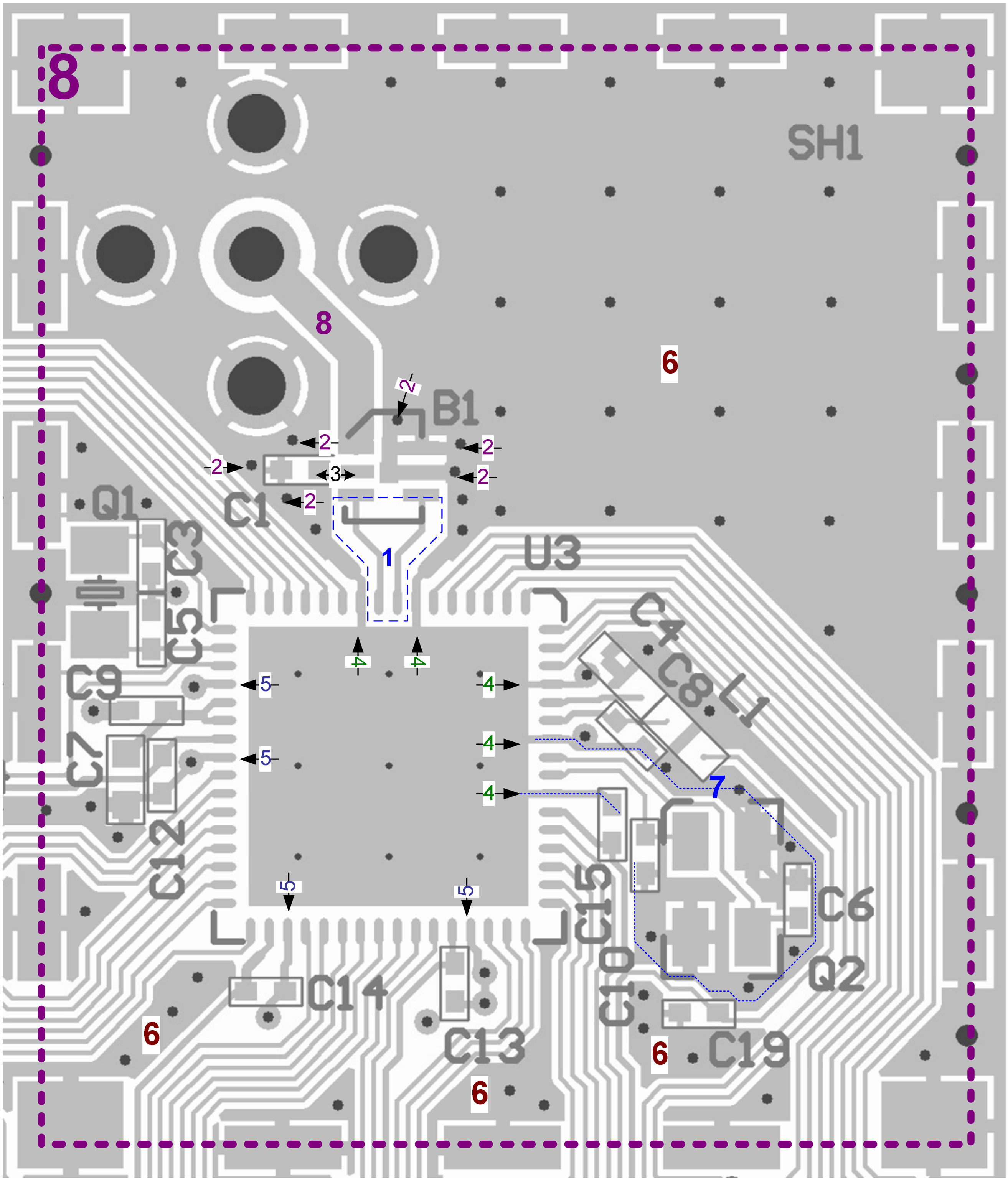
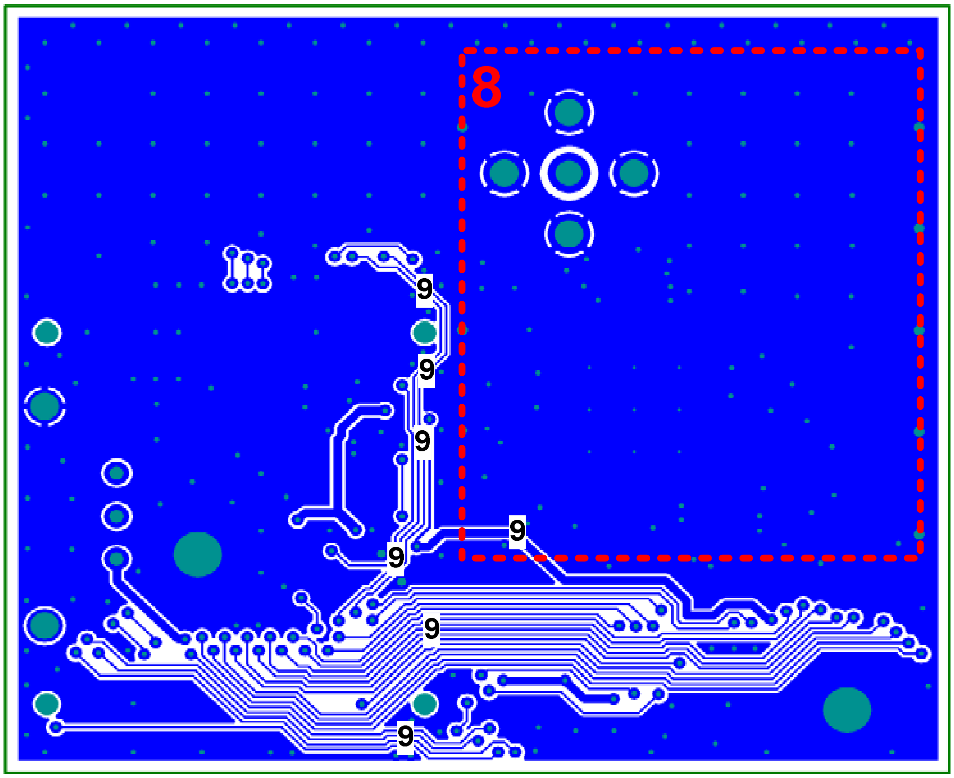


Figure 5-5. RCB128RFA1 Bottom Layer Design Details



5.7.1 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…2 nH. With the given 1.5 mm RF4 substrate, it is not possible to design a differential 100 Ohm 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.

5.7.2 PCB Detail 2 – Balun Ground Connection

The filter balun requires a solid ground connection, refer to [6]. Since 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 top and bottom planes. Both planes are to be sewed 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 lowest possible overall inductance.

5.7.3 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 pin2 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 RCB128RFA1 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 lowest possible impedance.

The capacitor itself should have the size 0402 or smaller.

5.7.4 PCB Detail 4 – Analog GND Routing

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

ATmega128RFA1 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 (0.15 mm drill) within the ground paddle underneath the Atmega128RFA1. Through-holes are filled with solder during reflow soldering, however, solder paste loss is low due to the small drill size.

5.7.5 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 IO 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.

5.7.6 PCB Detail 6 – GND 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's recommended filling 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. Doing this, the PCB behaves like a coherent piece of metal for an external EM field.

5.7.7 PCB Detail 7 – Crystal Guard Routing

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

5.7.8 PCB Detail 8 – RF Section Shielding

A shield covering the Atmega128RFA1 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.

5.7.9 PCB Detail 9 –Board GND Plane Design

A PCB ground plane with openings, small compared to the RF wavelength, can be considered as continuous. Signal lines required for normal operation creating 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 creating a solid antenna ground in spite of the limitations of a cost effective 2-layer board.

6 Programming

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

Base boards with an ISP connector can **not** be used for ISP with the RCB128RFA1. The Atmega128RFA1 has the serial programming function mapped to port B. Please refer to the Atmega128RFA1 data sheet [1] for detailed pin descriptions.

7 Electrical Characteristics

7.1 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.

No.	Parameter	Condition	Min.	Typ.	Max.	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 IO pin voltage	All digital IO signals	-0.3		V_RCB +0.3	V
7.1.5	Analog IO pin voltage	Aref [2] PORTF pins when ADC enabled	-0.3		2.0	V
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 AAA Alkaline Cell[1]			0.5 0	A 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

Note:
1. Note section 5.1.2 if RCB is mounted to a base board.
2. Never drive Aref from an external source, see [1] for further details.

7.2 Recommended Operating Range

No.	Symbol	Parameter	Condition	Min.	Typ.	Max.	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.

7.3 General RF Specifications

For general RF specifications refer to the Atmega128RFA1 datasheet [1]. The RCB schematic follows the application circuit. The filter balun and SMA connector resulting in a typical loss of 1dB in TX output power and sensitivity, compared to the values as shown in the radio transceiver section.

7.4 Current Consumption Specifications

Power consumption figures of the individual Atmega128RFA1 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

No.	Symbol	Parameter	Condition	Min.	Typ.	Max.	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		uA

Note: 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 Atmega128RFA1, I/O ports are set as inputs and are floating. This may result in increased current consumption. It's recommended to either enable internal pull-up resistors or to configure I/O ports as outputs immediately after reset.

8 Appendix A – Board Design Information

A.1 – Schematic

Figure 8-1. RCB128RFA1 – RF Section

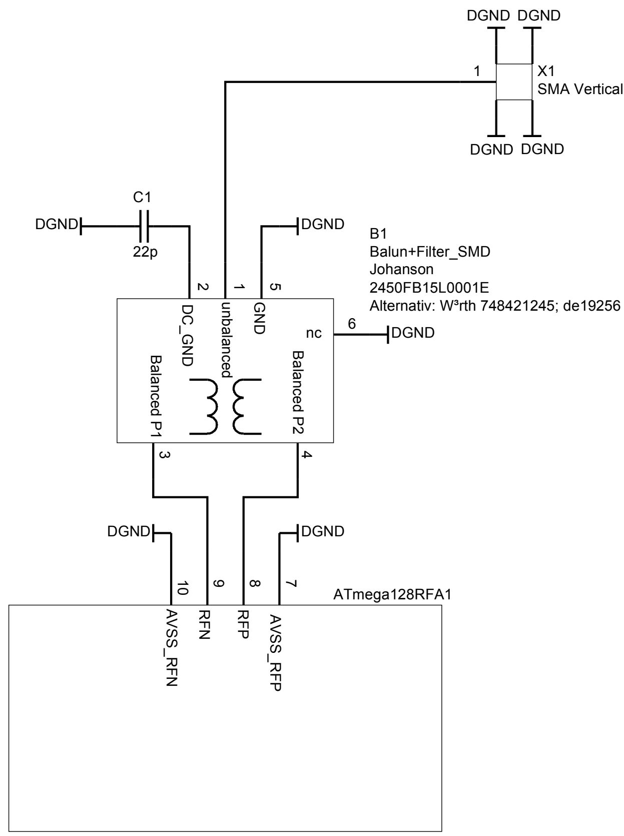
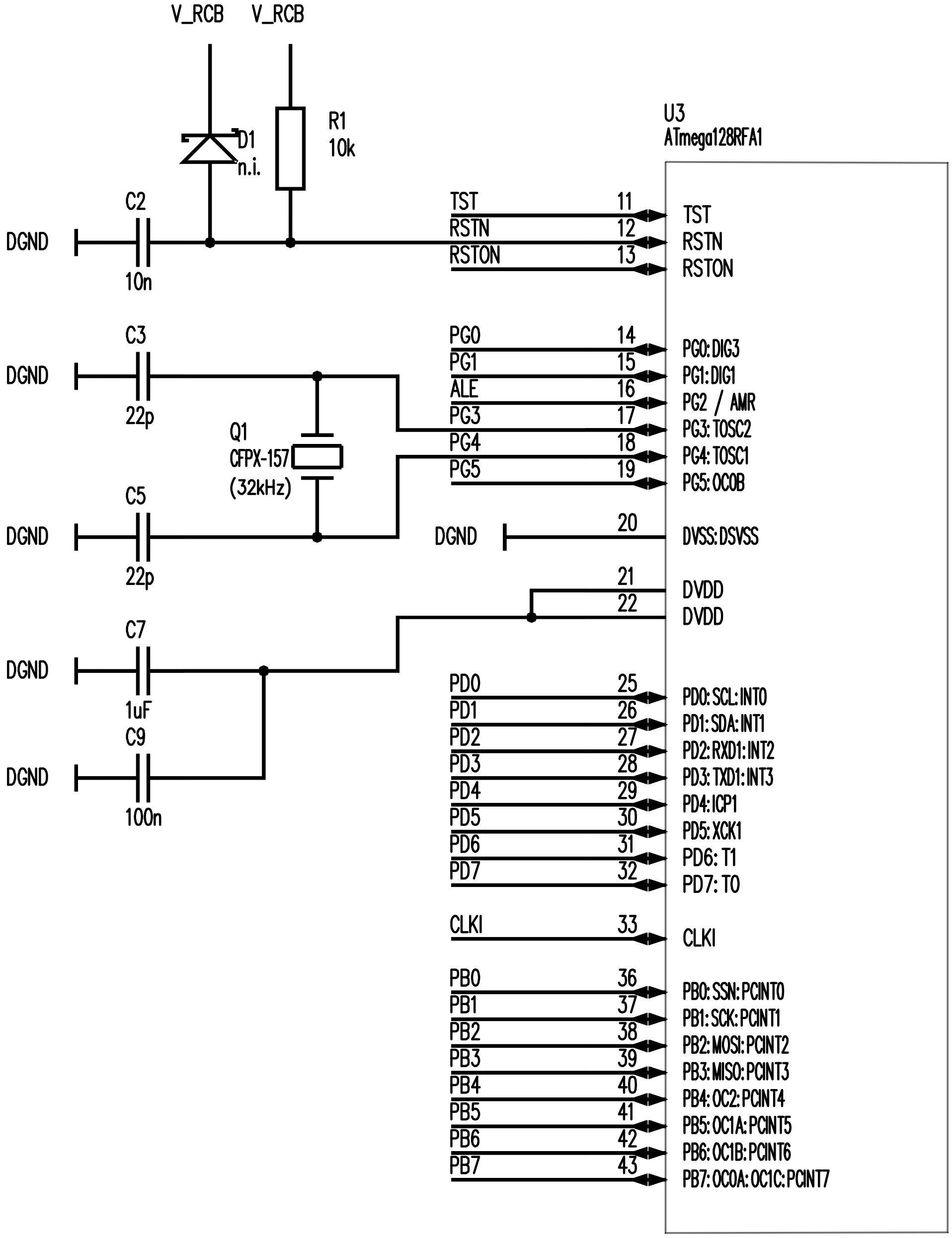


Figure 8-2. RCB128RFA1 – SOC Section 1



Note: Please be aware of the TST and CLKI signal routing on RCB128RFA1. The Connector mapping is visible in Figure 8-4 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. Please refer to [1] for detailed information.

Figure 8-3. RCB128RFA1 – SOC Section 2

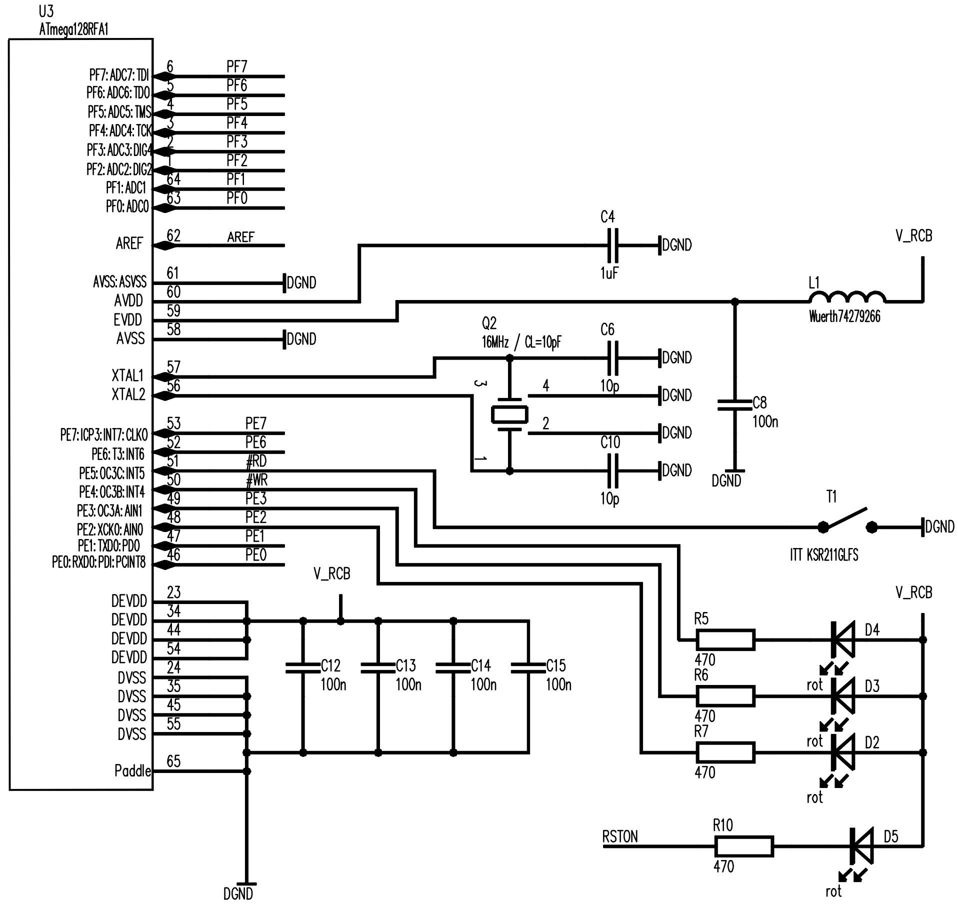
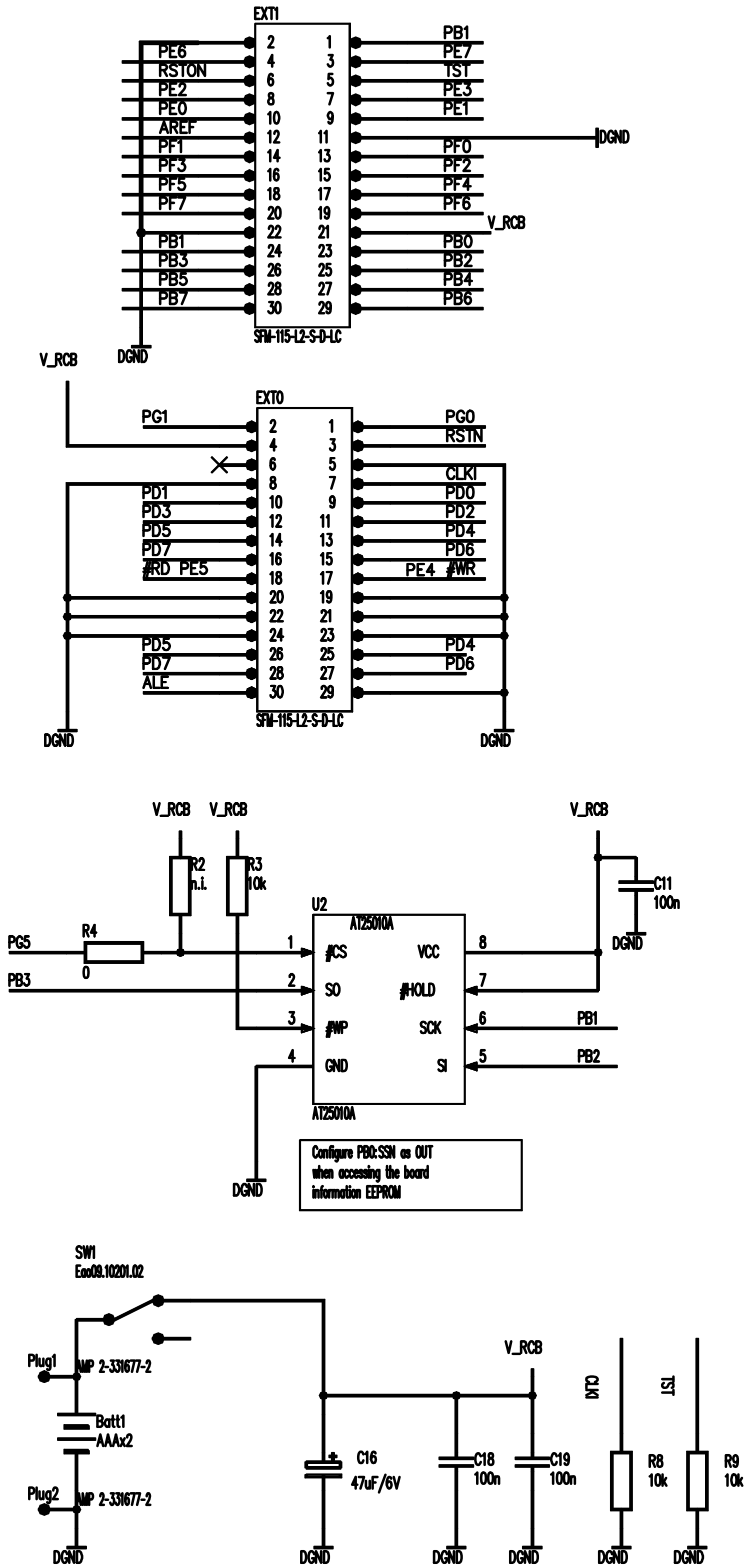
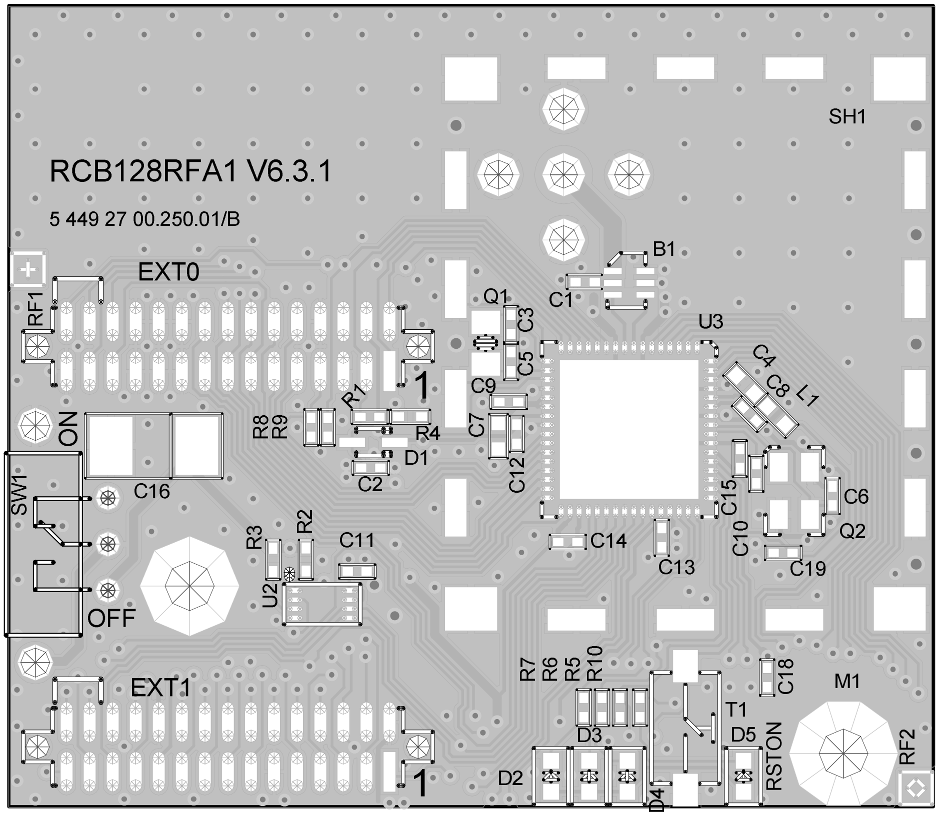


Figure 8-4. RCB128RFA1 – Power, IO and ID-EEPROM



A.2 – Assembly Drawing

Figure 8-5. RCB128RFA1 – Assembly Drawing



A.3 – Bill of Material (BoM)

Table 8-1 Bill of Material

Designator	Description	Comment	Quantity	Manufacturer	P/N
B1		Balun+Filter_SMD	1	Johanson	2450FB15L0001 E
Batt1	Battery	AAAx2	1	COMF	BH-421-3
C1, C3, C5	Capacitor	22p	3		generic 0402
C2	Capacitor	10n	1		generic 0402
C4, C7	Capacitor	1uF	2		generic 0603
C6, C10	Capacitor	10p	2		generic 0402
C8, C9, C11, C12, C13, C14, C15, C18, C19	Capacitor	100n	9		generic 0402
C16	Electrolytic Capacitor	47uF/6V	1	AVX	47uF/6V
D1	Schottky Diode	n.i.	1		
D2, D3, D4, D5		red	4	Vishay	TLMS1000-GS08
EXT0, EXT1	15x2-pin.	SFM-115-L2-S-D-LC	2	SAMTEC	SFM-115-L2-S-D-LC
L1		Wuerth74279266	1	Wuerth	74279266
Plug1, Plug2		AMP 2-331677-2	2	AMP	2-331677-2
Q1	Crystal	CFPX-157	1	Farnell	CFPX-157
Q2	Crystal	16MHz / CL=10pF	1	Siward	A207-011
R1, R8, R9	Resistor	10k	3		generic 0402
R2	Resistor	n.i.	1		
R3	Resistor	10k	1		generic 0402
R4	Resistor	0	1		generic 0402
R5, R6, R7, R10	Resistor	470	4		generic 0402
SH1		Shield_BMIS	1	LairdTech	LT08AD4303
SW1	SPDT	Eao09.10201.02	1	EAO	09.10201.02
T1	Button SPST	ITT KSR211GLFS	1	ITT	KSR211GLFS
U2	EEPROM	AT25010A	1	ATMEL	AT25010A
U3	AVR & Transceiver	Atmega128RFA1	1	ATMEL	Atmega128RFA1
X1	RF Conn	SMA Vertical	1	Multicomp	19-46-1-TGG
PSTG0-2400HS	Antenna	SMA	1	Mobile Mark	

A.4 – Radio Certification

The RCB128RFA1 has received regulatory approvals for modular devices in the United States, European countries and Japan.

A.4.1 United States (FCC)

Compliance Statement (Part 15.19)

The device complies with Part 15 of the FCC rules. To fulfill FCC Certification requirements, an Original Equipment Manufacturer (OEM) must comply with the following regulations:

- The modular transmitter must be labeled with its own FCC ID number, and, if the FCC ID is not visible when the module is installed inside another device, then the outside of the device into which the module is installed must also display a label referring to the enclosed module.
- This exterior label can use wording such as the following. Any similar wording that expresses the same meaning may be used.

Contains FCC-ID: VNR-S31SM-V4-00
This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

The device has been tested and approved with an external antenna as declared in the test report and manual. The device may be integrated with other custom design antennas, which OEM manufacturer must authorize following the FCC 15.21 requirements.

In this case, the OEM manufacturer must ensure that the OEM modular transmitter must be labeled with its own FCC ID number. This includes a clearly visible label on the outside of the final product enclosure that displays the contents shown below.

FCC-ID: <own FCC ID number>
This equipment complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation. The internal / external antenna(s) used for this mobile transmitter must provide a separation distance of at least 20 cm from all persons and must not be co-located or operating in conjunction with any other antenna or transmitter.

If the FCC ID is not visible when the equipment is installed inside another device, then the outside of the device into which the equipment is installed must also display a label referring to the enclosed equipment.

Installers must be provided with antenna installation instructions and transmitter operating conditions for satisfying RF exposure compliance.

Use in portable exposure conditions (FCC 2.1093) requires separate equipment authorization.

Compliance Statement (Part 15.105(b))

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

Warning (Part 15.21)

Changes or modifications not expressly approved by this company could void the user's authority to operate the equipment.

A.4.2 Europe (ETSI)

If the device is incorporated into a product, the manufacturer must ensure compliance of the final product to the European harmonized EMC and low-voltage/safety standards. A Declaration of Conformity must be issued for each of these standards and kept on file as described in Annex II of the R&TTE Directive.

The manufacturer must maintain a copy of the device documentation and ensure the final product does not exceed the specified power ratings, antenna specifications, and/or installation requirements as specified in the user manual. If any of these specifications are exceeded in the final product, a submission must be made to a notified body for compliance testing to all required standards. The "CE" marking must be affixed to a visible location on the OEM product. The CE mark shall consist of the initials "CE" taking the following form:

- If the CE marking is reduced or enlarged, the proportions given in the above graduated drawing must be respected.
- The CE marking must have a height of at least 5mm except where this is not possible on account of the nature of the apparatus.
- The CE marking must be affixed visibly, legibly, and indelibly.

More detailed information about CE marking requirements you can find at "DIRECTIVE 1999/5/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL" on 9 March 1999 at section 12.

A.4.2 Japan

The RCB128RFA1, classified as radio equipment specified in the Certification Ordinance Article 2-1-19, has received type-based certificate for all PSDU rates under the provisions of Article 38-24 of the Radio Law.

The certificate number is **005WWCA0425**.

A.4.3 Approved Antenna

The device has been tested and approved for use with the antenna listed below. The device may be integrated with other custom design antennas which OEM installer must authorize with respective regulatory agencies. The used antenna is connected to the radio module via an SMA connection.

Table 8-2 Approved Antenna

Manufacturer	Description	Model	Frequency	Connector
Mobile Mark	¼ Wave Stub Antenna	PSTG0-2400HS	2400-2490 MHz	Male SMA

9 Abbreviations

AAA		Battery size, also known as IEC R03 or JIS UM 4
ADC	-	Analog-to-digital converter
BOD		Brown-Out Detection (power outage detection)
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
PCB	-	Printed Circuit Board
RCB	-	Radio Controller Board
RF	-	Radio Frequency
RX	-	Receiver
SMA		SubMiniature version A ()
SOC		System On Chip
TWI	-	2-wire Serial Interface
TX	-	Transmitter
USART	-	Universal Asynchronous Receiver Transmitter

Appendix B – EVALUATION BOARD/KIT IMPORTANT NOTICE

This evaluation board/kit is intended for use for **FURTHER ENGINEERING, DEVELOPMENT, DEMONSTRATION, OR EVALUATION PURPOSES ONLY.** It is not a finished product and may not (yet) comply with some or any technical or legal requirements that are applicable to finished products, including, without limitation, directives regarding electromagnetic compatibility, recycling (WEEE), FCC, CE or UL (except as may be otherwise noted on the board/kit). Atmel supplied this board/kit "AS IS," without any warranties, with all faults, at the buyer's and further users' sole risk. The user assumes all responsibility and liability for proper and safe handling of the goods. Further, the user indemnifies Atmel from all claims arising from the handling or use of the goods. Due to the open construction of the product, it is the user's responsibility to take any and all appropriate precautions with regard to electrostatic discharge and any other technical or legal concerns.

EXCEPT TO THE EXTENT OF THE INDEMNITY SET FORTH ABOVE, NEITHER USER NOR ATMEL SHALL BE LIABLE TO EACH OTHER FOR ANY INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES.

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References

[1] AVR2044; 8-bit AVR Microcontroller with Low Power 2.4 GHz Transceiver for ZigBee, IEEE 802.15.4, 6LoWPAN, RF4CE, SP100, WirelessHART and ISM Applications; Preliminary Datasheet; Rev. 8266AB-MCU Wireless-12/09; Atmel Corporation

[2] IEEE Std 802.15.4™-2006: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Networks (LR-WPANs)

[3] FCC Code of Federal Register (CFR); Part 47; Section 15.35, Section 15.205, Section 15.209, Section 15.231, Section 15.247, and Section 15.249. United States.

[4] ETSI EN 300 328, Electromagnetic Compatibility and Radio Spectrum Matters (ERM); Wideband Transmission Systems; Data transmission equipment operating in the 2,4 GHz ISM band and using spread spectrum modulation techniques; Part 1-3.

[5] ARIB STD-T66, Second Generation Low Power Data Communication System/Wireless LAN System 1999.12.14 (H11.12.14) Version 1.0.

[6] Johanson Technology, Inc.; Datasheet 2450FB15L0001

[7] ATMEL Corporation, Datasheet AT25010A 07/2009

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