

# deRFsamR21E -23S00/-23S20

dresden elektronik



## Datasheet

### General description

The deRFsamR21E is a 2.4GHz ZigBee 3.0 radio module series which integrates the SoC ATSAMR21E18 from Microchip / Atmel together with a 4 Mbit data flash on a tiny size of 21 mm x 13 mm. The microcontroller ATSAMR21E18 integrates a powerful and energy efficient 32-Bit ARM Cortex-M0+ core together with a 2.4 GHz IEEE 802.15.4 radio transceiver. The module comes with 16 I/O's, 256 kbit internal program flash and 4 Mbit data flash for firmware updates over the air and data storage. For reliable assembly the module offers SMD solderable side contacts in 50 mil / 1.27 mm grid. The module offers ZigBee 3.0 support for smart devices.

Two radio module variants are available:

- deRFsamR21E-23S00: integrated RF-design with chip antenna
- deRFsamR21E-23S20: coaxial u.FL-connector for external antenna applications as well as a RF-pad for custom RF-designs e.g. external frontend or antenna diversity



deRFsamR21E-23S00



deRFsamR21E-23S20

### Features

- ATSAMR21E18 Single-chip ARM Cortex-M0+ based 32-bit Microcontroller with Low Power 2.4 GHz Transceiver for IEEE 802.15.4 and ZigBee Applications with 256 KB Flash and 16 I/O's - all accessible outside the module (four occupied by data flash)
  - Maximum operating frequency 48 MHz
  - 128-bit AES crypto engine
  - 32-bit MAC symbol counter
  - Temperature sensor
  - Automatic transmission modes
- 4 Mbit data flash for firmware updates over the air and data storage
- Ready-to-use RF design
- Radio module with a link budget of up to 103 dBm
- CE compliant according to RED 2014/53/EU and FCC certified
- Single 2.5 V - 3.6 V supply
- Industrial temperature range -40°C to 85°C
- 1.27 mm / 50 mil pin header with several alternative functions:
  - Analog input (12-bit, 350ksps Analog-to-Digital Converter)
  - PWM output
  - TWI (I2C up to 3.4MHz)
  - SPI
  - UART
  - USB
  - GPIO
  - SWD programming interface
- High precision 16 MHz crystal oscillator



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## Document history

Date	Version	Description
2017-10-20	1.00	Initial version
2018-01-15	1.01	Corrections Figure 8-1 and 8-2
2018-10-29	1.02	Correction Table 8-1



## Abbreviations

Abbreviation	Description
IEEE 802.15.4	Communication standard, applicable to low-rate Wireless Personal Area Networks (WPAN)
6LoWPAN	IPv6 over Low Power Wireless Personal Area Networks
ADC	Analog to Digital Converter
ASF	Atmel Software Framework
EMI	Electromagnetic Interference
ETSI	European Telecommunications Standards Institute
FCC	Federal Communications Commission
GPIO	Generals Purpose Input Output
LNA	Low Noise Amplifier
MAC	Medium (Media) Access Control
MCU, $\mu$ C	Microcontroller Unit
OTAU	Over the air update
PA	Power Amplifier
PCB	Printed Circuit Board
PWM	Pulse Width Modulation
RED	Radio Equipment Directive
RF	Radio Frequency
R&TTE	Radio and Telecommunications Terminal Equipment (Directive of the European Union)
SoC	System On Chip
SPI	Serial Peripheral Interface
SWD	Serial Wire Debug
TWI	Two-Wire Serial Interface
U[S]ART	Universal [Synchronous/]Asynchronous Receiver Transmitter
USB	Universal Serial Bus
ZigBee	Low-cost, low-power wireless mesh network standard. The ZigBee Alliance is a group of companies that maintain and publish the ZigBee standard.



## 1. Overview

The deRFsamR21E series is the second generation of small, ready-to-use radio modules that provides a fully integrated solution for wireless applications, using the IEEE 802.15.4 standard in the 2.4 GHz ISM frequency band. All required RF components are already integrated on the module, therefore no expensive RF design is needed. Features can be added by simply connecting sensors and output stages to the module. The deRFsamR21E module series reduces time to market, effort and cost significantly for wireless applications.

The deRFsamR21E series is based on the SoC ATSAMR21E18 from Microchip / Atmel which features an ARM Cortex-M0+ core and a 2.4 GHz IEEE 802.15.4 transceiver. It enables use of ZigBee 3.0 for smart devices in a wide field of applications. For this tiny series, dresden elektronik is using a footprint, which offers SMD solderable side contacts in a 50 mil / 1.27 mm grid for easy assembly and inspection. The module offers 256 KB internal flash as program memory as well as 4 Mbit data flash for firmware updates over the air and data storage.

Two radio module variants are available:

- deRFsamR21E-23S00: integrated RF-design with chip antenna for easy and fast integration with no need for custom RF design and low BOM cost since all necessary components are integrated on the module
- deRFsamR21E-23S20: coaxial u.FL-connector for external antenna applications as well as a RF-pad which enables custom RF-design e.g. use of external frontend with power amplifier/ low noise amplifier or antenna diversity

Both modules are full compliant to all EU and FCC regulatory requirements.

## 2. Applications

The main applications for the radio modules are:

- ZigBee 3.0
- Smart Home
- Lighting Application
- Home Automation
- Wireless Sensor Networks
- Industrial Controlling
- Smart Metering
- 6LoWPAN

### 3. Block diagram

Figure 3-1 shows the block diagram of the radio module deRFsamR21E-23S00.

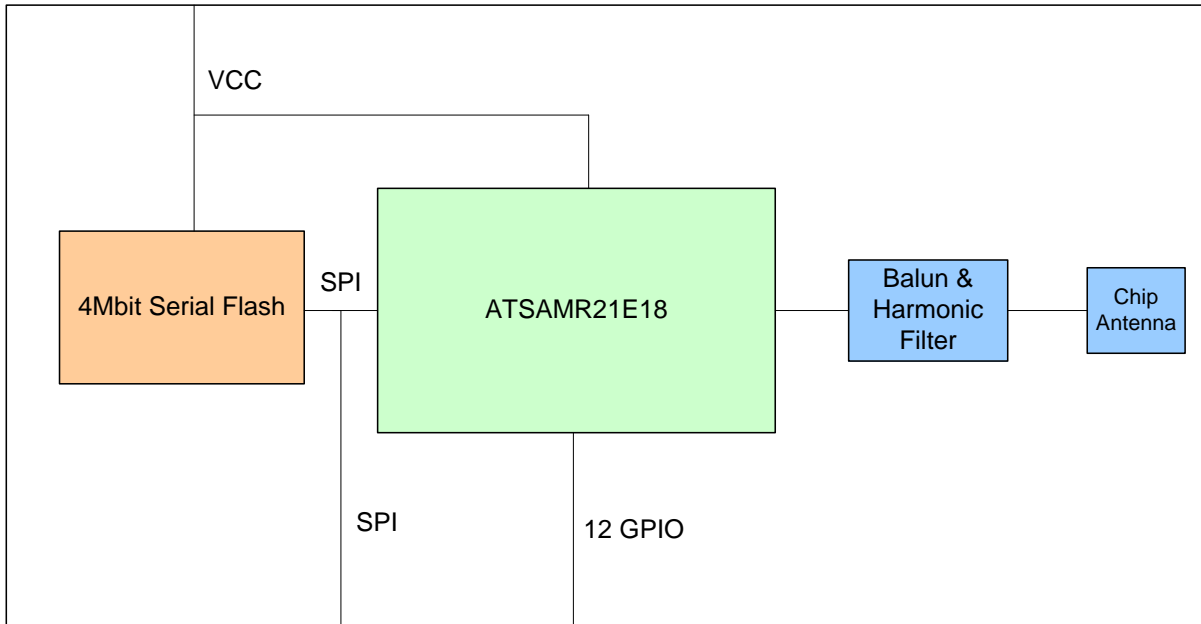


Figure 3-1: Block diagram deRFsamR21E-23S00

Figure 3-2 shows the block diagram of the radio module deRFsamR21E-23S20 with u.FL connector.

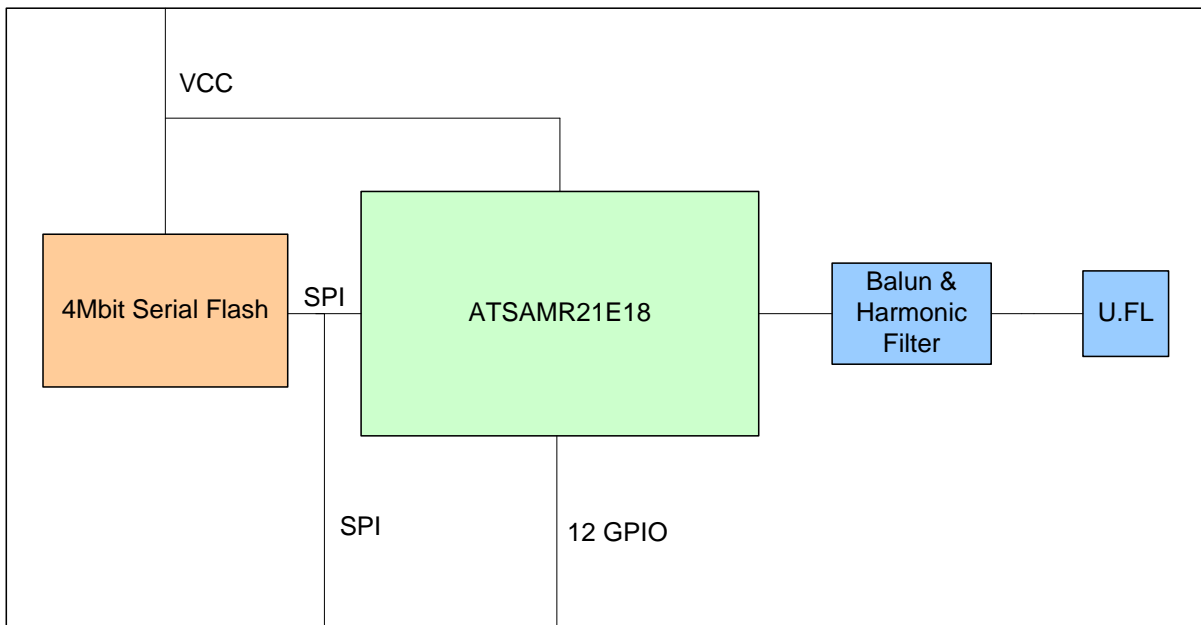
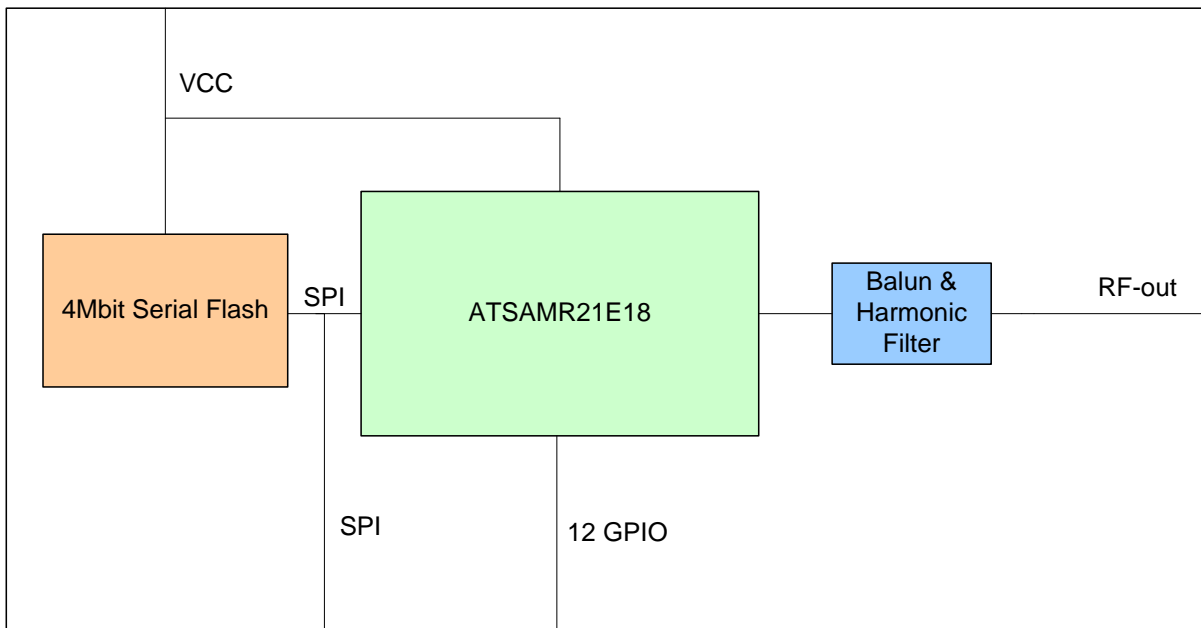


Figure 3-2: Block diagram deRFsamR21E-23S20



**Figure 3-3** shows the block diagram of the radio module deRFsamR21E-23S20 with RF-out pad.



**Figure 3-3: Block diagram deRFsamR21E-23S20 with RF-out pad used**





## 5. Mechanical description

### 5.1. Module dimensions

The mechanical dimensions are described in this chapter. The modules size is 21.0 x 13.0 x 2.5 mm (0,827 x 0,512 x 0,098 inch). **Figure 5-1** shows additional dimensions.

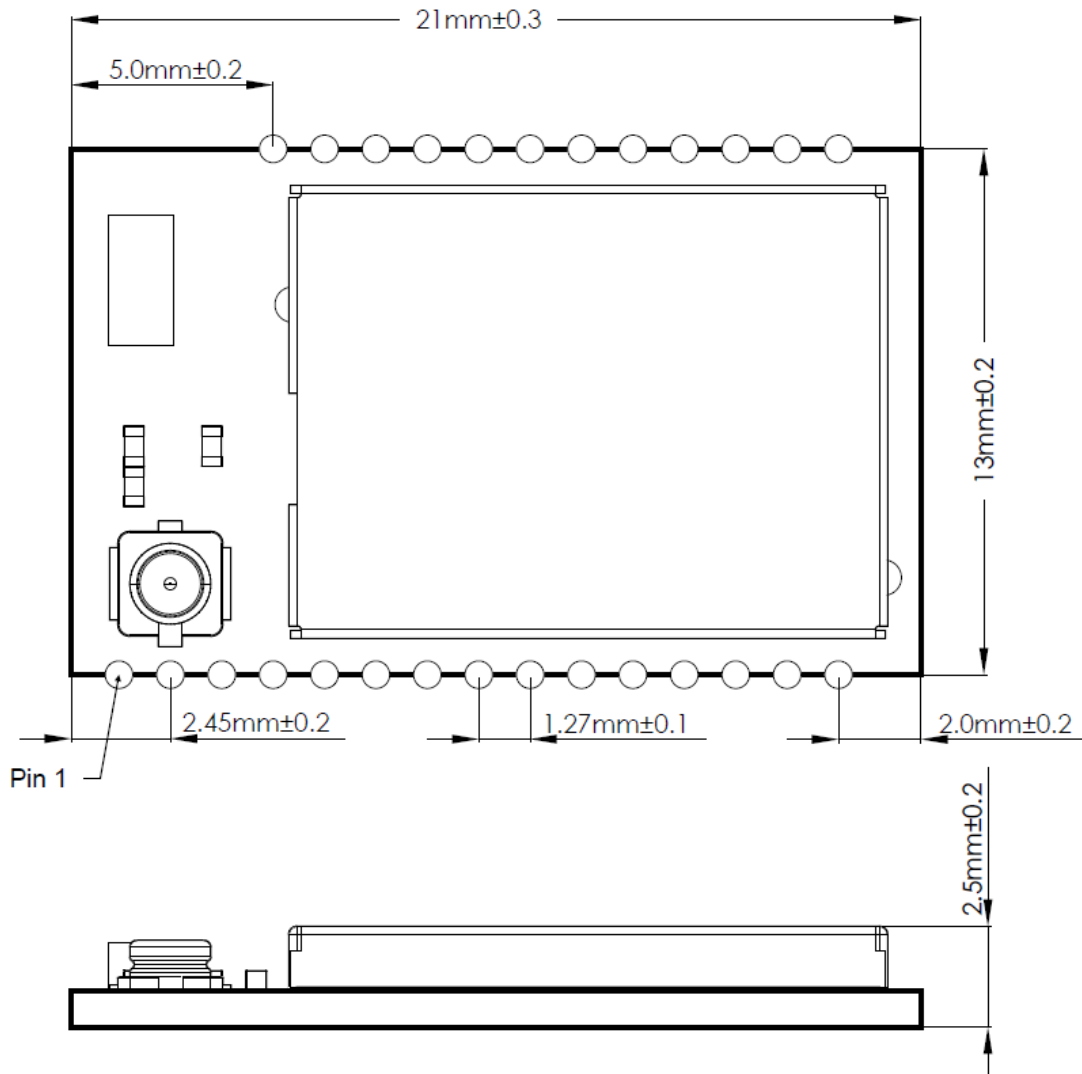


Figure 5-1: mechanical dimensions of the module

## 5.2. Recommended footprint

Both radio module types share the same footprint, only the area which it is not allowed to place copper on is different.

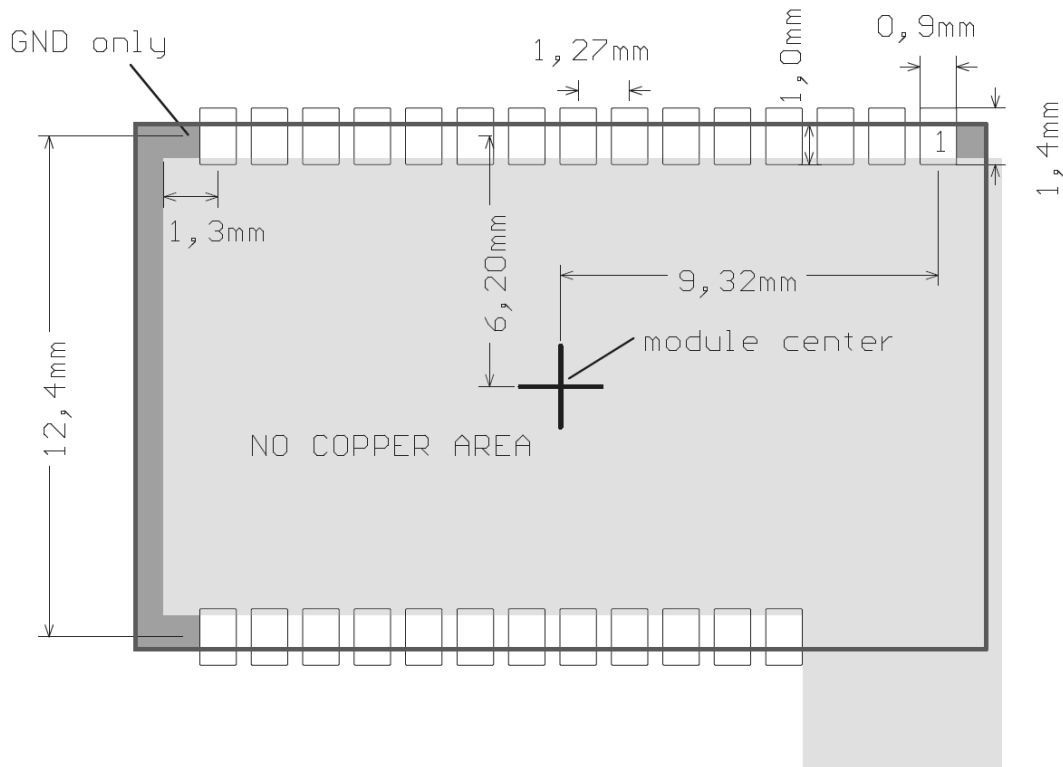


Figure 5-2: Recommended Footprint for deRFsamR21E-23S00

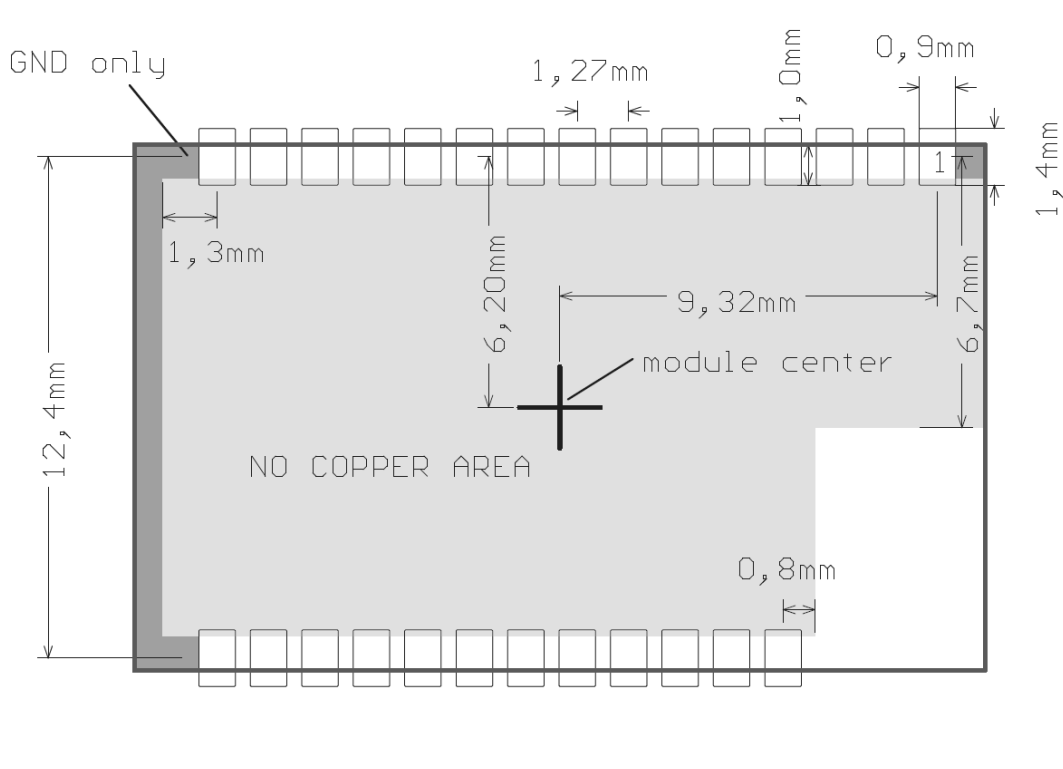


Figure 5-3: Recommended footprint for deRFsamR21E-23S20



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The recommended

- pad size is 0.9 x 1.4 mm,
- solder mask clearance is 75 to 100 µm,
- stencil opening is 0.8 x 1.25 mm with stencil thickness 100 to 150 µm.

The 23S00 with internal antenna requires the user to follow the placement and layout guidelines for best RF performance. For more details see **Section 9.6 and 0**.

With the RF-pad of 23S20 it is possible to implement antenna diversity and front-end design for increased transmit power and receiver sensitivity as well as custom antenna design. More details can be found in chapter **9.8.1 External front end and antenna diversity**.

### 5.3. ECAD libraries

dresden elektronik offers schematic and footprint libraries for all available radio modules for ECAD design software Altium Designer® [6] and Eagle® [9]. This allows a fast design-in of radio modules into a custom product.

The pin-assignment in the schematic library is a suggestion for frequently used functions. A detailed description on this configuration can be found in **Section 8**. The pins can be muxed in many different ways with other functions depending on application needs. For more details on that refer to **Section 4**.

### 5.4. STEP model library

dresden elektronik offers a STEP model library with all available OEM radio modules for CAD design tools [10].



## 6. Electrical specification

This section will outline the main parameters required to build applications. The module characteristics are determined by the implemented parts. See references at the end of this document for required datasheet references.

### 6.1. Absolute maximum ratings

Stresses beyond those listed in **Table 6-1** may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or other conditions beyond those indicated in the operational sections of this specification are not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

**Table 6-1: Absolute maximum ratings**

Symbol	Parameter	Condition	Min	Typ	Max	Unit
T <sub>OP</sub>	Operating temperature		-40		+85	°C
T <sub>storage</sub>	Storage temperature		-40		+125	°C
V <sub>PIN</sub>	Pin voltage with respect to GND and V <sub>CC</sub>		GND -0.3		V <sub>CC</sub> +0.3	V
V <sub>CC</sub>	Maximum V <sub>CC</sub> pin voltage		0		3.8	V
V <sub>ESD</sub>	ESD robustness	Human Body Model Charged Device Model	4 550			kV V
P <sub>RF</sub>	Input RF level				+10	dBm

### 6.2. Electrical characteristics

The data in the following table is measured at a temperature of 25°C with supply voltage of 3.3 V if not otherwise noted.

**Table 6-2: Electrical specification data**

Symbol	Parameter	Condition	Min	Typ	Max	Unit
V <sub>CC</sub>	Power supply voltage	Default Mode for full operation of data flash	2.5	3.3	3.6	V
		For USB interface	3.0	3.3	3.6	V
I <sub>DD1</sub>	Current consumption of parts (data flash in standby mode)	MCU running while(1) loop		3.4		mA
		Transceiver in RXON state		11.8		mA
		Transceiver in TXON state		13.8		mA
I <sub>DD2</sub>	Current consumption	MCU and data flash in deep power down		5	22	µA
I <sub>DD3</sub>	Current consumption (data flash only)	Read		4	12	mA
		Page Program		10	20	
P <sub>RF</sub>	RF transmit power	conducted		4		dBm



Symbol	Parameter	Condition	Min	Typ	Max	Unit
P <sub>Range</sub>	Output power range	16 steps configurable transceiver output power	-17		4	dB
P <sub>emit</sub>	RF transmit power	radiated deRFsamR21E-23S00 (chip antenna) <sup>2</sup>		4		dBm EIRP
		radiated deRFsamR21E-23S20 using antenna Wimo 17013 (+5 dBi)		9		dBm EIRP
D <sub>los</sub>	Maximum line of sight range <sup>3</sup>	deRFsamR21E-23S00 (chip antenna)		200		m
		deRFsamR21E-23S20 (2 dBi Gain antenna)		220		m
RX <sub>sens</sub>	Receiver sensitivity	Data Rate 250 kBit/s Data Rate 500 kBit/s Data Rate 1 MBit/s Data Rate 2 MBit/s		-99 -94 -92 -86		dBm dBm dBm dBm
P <sub>SPUR_TX</sub>	Transmitter spurious emissions according to EN 300328 V2.1.1 (as measured in certification tests)	30 MHz to 1 GHz			-62	dBm
		1 GHz to 4 GHz			-38	dBm
		4 GHz to 12.75 GHz			-58	dBm
E <sub>SPUR_TX</sub>	Transmitter spurious emissions according to FCC 15.247 (as measured in certification tests, peak values)	30 MHz to 200 MHz			35	dBμV/m
		200 MHz to 1 GHz			22	dBμV/m
		1 GHz to 4 GHz			36	dBμV/m
		4 GHz to 26.5 GHz			48	dBμV/m
		2.3 GHz to 2.4 GHz			53	dBμV/m
		2.484 GHz to 2.5 GHz			61	dBμV/m
f <sub>CPU</sub>	Maximum MCU clock			48		MHz
f <sub>TRXosc</sub>	Transceiver oscillator frequency			16		MHz
f <sub>TRXosc,dev</sub>	Transceiver oscillator frequency deviation	At 25°C	-10		+10	ppm
		Drift over temperature -40°C < T <sub>OP</sub> < +85°C	-20		+20	ppm

Note:

1. For FCC band edge compliance with deRFsamR21E-23S20 it is required to operate Ch26 with not more than TX\_PWR=0x7 (0 dBm).
2. Based on RF pattern measurement with USB powered Baseboard
3. Measured at height of 1.5 m above flat land of grass with transmit power 4 dBm.



### 6.3. TX power register settings

The output power of the transceiver can be configured with the TX\_PWR register according to Table 6-3.

**Table 6-3: TX\_PWR Register settings at 3.0V**

TX_PWR Value	TX Output Power [dBm]	Current Consumption [mA] <sup>1</sup>
0x0	4	13.8
0x1	3.7	
0x2	3.4	
0x3	3	
0x4	2.5	
0x5	2	
0x6	1	
0x7	0	11.8
0x8	-1	
0x9	-2	
0xA	-3	
0xB	-4	
0xC	-6	
0xD	-8	
0xE	-12	
0xF	-17	7.2

Note:

1. Current consumption for transceiver only, MCU and data flash currents have to be considered as well

### 6.4. Fuse setting

Fuses are used to configure the ATSAMR21E18 operation modes and clocks. This is mainly done by internal commands which can be found in [1].

### 6.5. Non-volatile memory user row

The NV Memory contains an area referred to as user row in the ATSAMR21 datasheet. Module specific data is written there during production. The following data in the NV Memory User Row is starting at base address 0x804008. It shall not be erased.



**Table 6-4: NVM area content**

Addr. Offset	Name	Description	Length
+ 0x00	reserved		2 Byte
+ 0x02	MAC_ADDRESS	Module specific IEEE MAC Address	8 Byte
+ 0x0a	BOARD_SERIAL	Module specific serial number	10 Byte
+ 0x14	reserved		10 Byte
+ 0x1e	CRC16	Checksum	2 Byte

The data in MAC\_IEEE\_ADDRESS have to be copied to the registers IEEE\_ADDR\_0 to \_7 in the radio transceiver.

For user data storage the memory starting at 0x804030 can be used.





## 7. Onboard SPI serial flash

The module incorporates a 4 MBit data flash connected to the module by SPI bus. The data flash connects from PA16 to PA19 according to **Table 7-1**.

**Table 7-1: dataflash to microcontroller connection**

Port	Function	Flash pin	Controller settings
PA16	MISO	SO	SERCOM1 PAD0
PA17	SCK	SCK	SERCOM1 PAD1
PA18	CS	SS	SERCOM1 PAD2
PA19	MOSI	SI	SERCOM1 PAD3

Note: The slave select line (SS) is hardware controlled when Master Slave Select Enable (CTRLB.MSSEN) is set to one.

The signals in this table are available at module pins 7-10 as well. The module contains the serial data flash AT25SF041 according to **Table 7-2**. Since the memory market is very difficult at the moment, the module incorporates some alternative flash devices listed in **Table 7-3**. This is done to avoid supply bottlenecks. To avoid problems, no specific flash ID shall be used in the customer firmware. This section outlines basic usage instructions. For a more detailed description refer to the datasheets of the flash devices.

**Table 7-2: default serial data flash**

Partnumber	Manufacturer	JEDEC ID (9Fh)	Datasheet reference
AT25SF041	Adesto	1F-84-01	[11]

**Table 7-3: second source serial data flash list**

Partnumber	Manufacturer	JEDEC ID (9Fh)	Datasheet reference
MX25V4006E	Macronix	C2-20-13	[12]
W25X40CL	Winbond	EF-30-13	[13]
W25Q40CL	Winbond	EF-40-13	[14]

### 7.1. Commands

To erase the implementation of the different flash devices **Table 7-4** lists the commands and their respective opcodes common to all the flash devices listed above.

**Table 7-4: command table common to all flash options**

Command	Opcode	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte n
Write enable	06h						
Write disable	04h						
Read Status Register	05h	(S7-S0)					
Write Status Register	01h	S7-S0	see*				
Page Program	02h	A23-A16	A15-A8	A7-A0	(D7-D0)	(next byte)	Up to 256 bytes
Sector Erase (4kB)	20h	A23-A16	A15-A8	A7-A0			
Block Erase (64kB)	D8h	A23-A16	A15-A8	A7-A0			
Chip Erase	C7h/60h						
Power-down	B9h						
Resume from Deep Power Down	ABh						



Command	Opcode	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte n
Resume from Deep Power Down and read ID	ABh	dummy	dummy	dummy	(IRD7-IRD0)		
Read Data (up to 30 MHz)	03h	A23-A16	A15-A8	A7-A0	(D7-D0)	(next byte)	continuous
Fast Read (up to 70 MHz)	0Bh	A23-A16	A15-A8	A7-A0	dummy	(D7-D0)	continuous
Read Manufacturer and Device ID	9Fh	(M7-M0)	(ID15-ID8)	(ID7-ID0)			
Read ID	90h	dummy	dummy	00h	(M7-M0)	(IRD7-IRD0)	

\*make sure not to send a second byte since it may activate the "One Time Program" mode of AT25SF041 and W25Q40CL, which irreversibly blocks write commands to the device.

## 7.2. Status register

The status register is described in **Table 7-5**.

**Table 7-5: flash status register**

Bit	content	explanation	Type
S7	SRP	Software Protected	R/W
S6	0	Do not use (always set to 0)	R/W
S5	0	Do not use (always set to 0)	R/W
S4	BP2	Block Protection Bit 2	R/W
S3	BP1	Block Protection Bit 1	R/W
S2	BP0	Block Protection Bit 0	R/W
S1	WEL	Write Enable Latch status	R
S0	BUSY	Indicates ready/busy status	R

Status register bit S5 and S6 always have to be programmed to 0 to ensure proper operation of the block protection according to **Table 7-6** for all flash devices. Ignore S5 and S6 during readout.

**Table 7-6: block protection**

BP2	BP1	BP0	Address Range	Portion
0	0	0	None	None
0	0	1	070000h-07FFFFh	Upper 1/8
0	1	0	060000h-07FFFFh	Upper 1/4
0	1	1	040000h-07FFFFh	Upper 1/2
1	X	X	000000h-07FFFFh	All



### 7.3. Flash Timings

**Table 7-7** contains typical and maximum values for timings. Typical values refer to the standard flash AT25SF041 while maximum values apply to all the listed flash devices.

**Table 7-7: timings of onboard flash**

Parameter	Typ	Max	Unit
Page Program	0.7	2.5	ms
Byte Program	5		us
Block erase 4K	60	300	ms
Block erase 64K	500	2200	ms
Chip Erase	4	10	s
$t_{css}$		7	ns
$t_v$ Output Valid time		8	ns



## 8. Recommended configuration

This chapter describes a recommended configuration which enables use of all frequently used interfaces. The schematic symbol used in this chapter as well as a footprint can be found in dresden elektronik Altium and Eagle libraries (see **Section 5.3**). **Figure 8-1** shows the schematic of a sample application. The sample application provides USB and incorporates two sensors, a LED, an analogue input measuring the battery voltage and using the UART interface through a 6-pin header for tracing. This configuration with all common interfaces is shown in **Figure 8-1**.

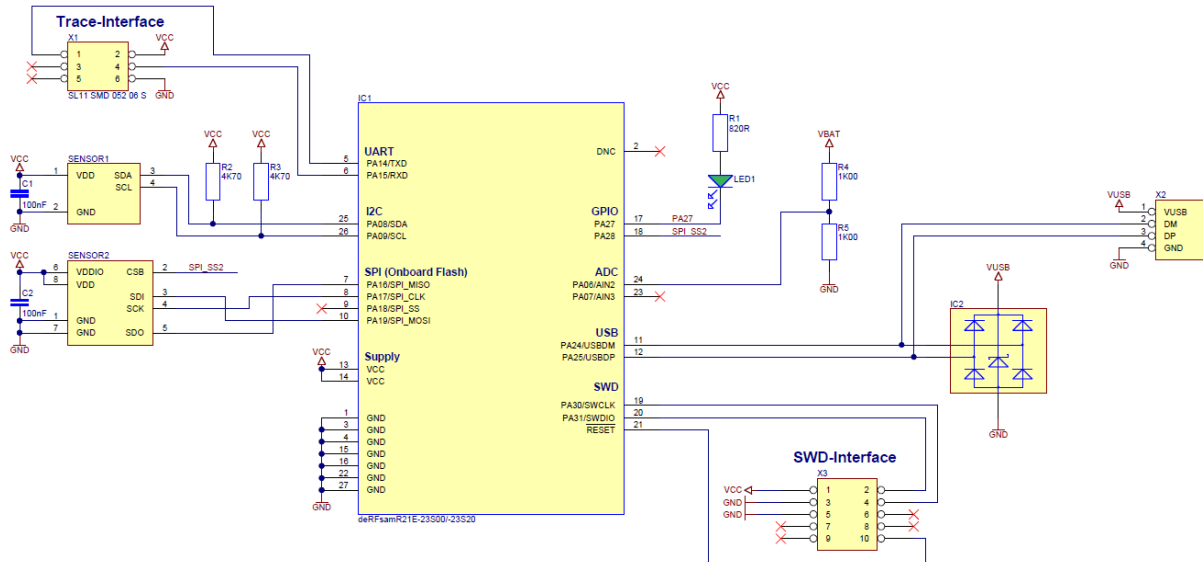


Figure 8-1 configuration with all common interfaces

### 8.1. Signal description

The features of the controller can be mapped to different ports. How to configure the device for the example configuration is described in this chapter. The serial interface functions are organized in SERCOM units (Serial Communication Interface). These units consist of 4 Signals and can be mapped to several ports of the microcontroller. The configuration is shown in **Table 8-1**.

Table 8-1: Pin configuration

Pin	Pad	Function	Config/	Pin Function
05	PA14	UART/TXD	SERCOM2/PAD2	2
06	PA15	UART/RXD	SERCOM2/PAD3	2
07	PA16	SPI_MISO	SERCOM1/PAD0	3
08	PA17	SPI_CLK	SERCOM1/PAD1	3
09	PA18	SPI_SS	Digital out	
10	PA19	SPI_MOSI	SERCOM1/PAD3	3
11	PA24	USBDM		6
12	PA25	USBDP		6
17	PA27	GPIO	Digital out	
18	PA28	SPI_SS2	Digital out	
19	PA30	SWD/SWCLK		
20	PA31	SWD/SWDIO		
21	-	RESET		



Pin	Pad	Function	Config/	Pin Function
23	PA07	ADC/AIN7		2
24	PA06	ADC/AIN6		2
25	PA08	I2C/SDA	SERCOM0/PAD0	4
26	PA09	I2C/SCL	SERCOM0/PAD1	4

## 8.2. UART

The UART interface is a commonly used bidirectional interface for communication between microcontrollers. The transmit (TXD) and receive (RXD) lines have to be connected directly to the second device. TXD for the host controller is RXD for the client, the other signal works accordingly.

For communication to a host with a different supply voltage domain it is necessary to use a level-shifter part. We recommend the USB level-shifter by dresden elektronik. The level-shifter can be connected to the custom base board via 100 mil 2 x 3 pin header. The pin assignment should be designed as below in **Figure 8-2**. For a UART connection it is sufficient to use only TXD, RXD and GROUND signals.

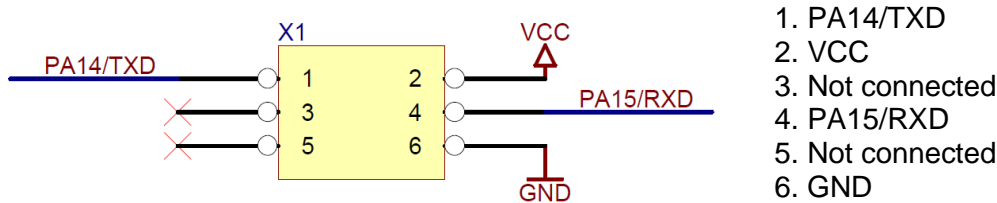


Figure 8-2: 100 mil / 2,54 mm 2 x 3 pin header for UART

## 8.3. I2C (TWI)

The I2C (Inter-Integrated Circuit, also referred to as TWI – two wire interface) is a common interface for sensor connection and it is able to connect several devices at one bus. There is one clock signal (SCL) and a data signal (SDA). It is necessary to place pull-up resistors for both lines externally to the radio module for proper function. We recommend the use of 4.7 kΩ resistors as shown in **Figure 8-3**.

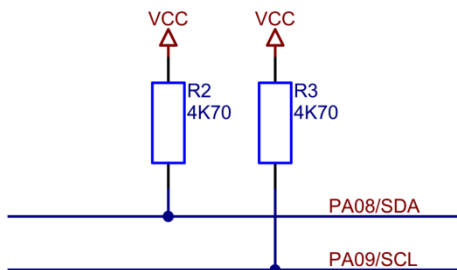


Figure 8-3: Two Wire Interface

## 8.4. USB

The USB (Universal Serial Bus) interface complies with USB 2.1 specification. It supports both device and embedded host modes. PA24 (USBDM) and PA25 (USBDP) are routed as differential lines from the MCU to the radio module side contacts to pins 11 and 12. The module power supply cannot be operated directly from a 5 V USB source. The module base



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board has to implement the required voltage regulator for recommended voltage supply of 3.3 V. For USB operation a minimum supply voltage of 3.0 V is required.

### 8.5. SPI

The SPI (Serial Peripheral Interface) is a synchronous serial communication interface commonly used in embedded systems. The SPI Interface on this module is used by the onboard serial data flash. To add another device to the SPI Bus SCLK, MISO and MOSI can be used, only another chip select signal (SS) is needed for each device. Any GPIO can be used for this purpose, except pin 9 (PA18) since it is connected to the chip select of the onboard data flash. In this example pin 18 (PA28) is used for the SPI Sensor chip select.

### 8.6. ADC

The module contains an ADC (Analog to Digital Converter) with 12-bit resolution. It supports sample rates up to 350 ksps. Pin 23 and 24 (PA07 and PA06) are used in this configuration. The internal reference voltage can be set to 1.0 V,  $VCC/1.48$  and  $VCC/2$ .

### 8.7. SWD

The SWD interface consists of clock signal (SWCLK) and data signal (SWDIO) as well as the RESET signal for programming and debugging the microcontroller. More details on programming can be found in **Section 10**.

### 8.8. GPIO

In this example pin 17 (PA27) and pin 18 (PA28) are reserved for GPIO usage, but nearly every pin can be used as GPIO if not used otherwise.

### 8.9. Reset

The reset pin is low active and has an internal 10k pull-up resistor to power supply VCC.

## 9. Application information

The PCB design of a radio module base board is important for a proper performance of peripherals and the radio. The next subsections give design hints to create a custom base board.

### 9.1. PCB technology

The module is designed for use with standard PCB technology to reduce the costs and cover a wide application range.

### 9.2. Power supply

Power supply pins 13 and 14 have to be connected to a power domain of 2.5 to 3.6 V. No external decoupling components are needed. For noisy environments it is recommended to include a filter consisting of a ferrite or inductor and capacitors to reduce noise on the power domain to the module. An example is shown in **Figure 9-1**. Place all components in near proximity to each other and C2 between Pin 14 and 15 next to the module.

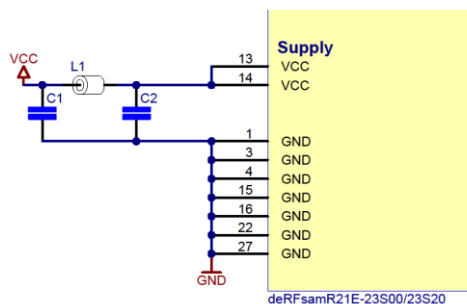


Figure 9-1: Power supply decoupling for noisy environments

### 9.3. Ground plane

The performance of RF applications mainly depends on the ground plane design. The often used chip ceramic antennas are very tiny, but they need a proper ground plane to establish a good radiation pattern. Every board design is different and cannot easily be compared to each other. Some practical notes for the ground plane design are described below:

- Regard to the design guideline of the antenna manufacturer
- Use closed ground planes on the PCB edges on top and bottom layer
- Connect the ground planes with lots of vias. Place it inside the PCB like a chessboard and on the edges very closely.

### 9.4. Layers

The use of 2 or 4 layer PCB boards have advantages and disadvantages for the design of a custom base board.

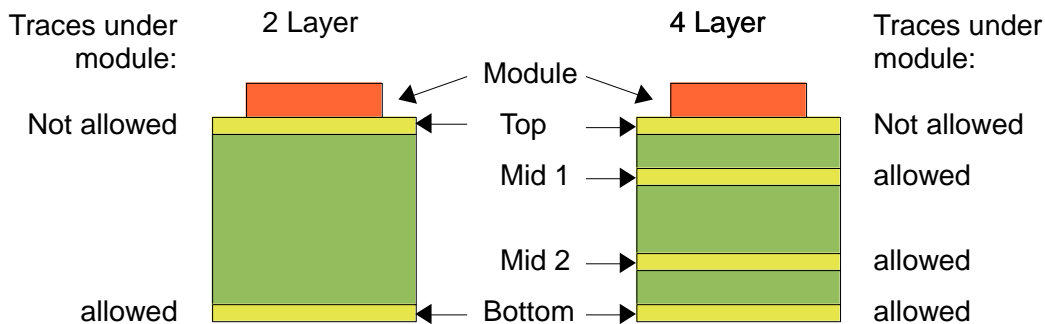
**Table 9-1: 2 and 4 layer board properties in comparison**

2 Layer board	4 Layer board
(-) only 2 layers available for routing traces and design a proper ground area	(+) 4 layers available for routing traces and design a proper ground area
(-) only 1 layer available for routing traces below the module	(+) 3 layers available for routing traces below the module
(-) no separate VCC plane usable	(+) separate VCC plane usable
(+) cheaper than 4 layers	(-) more expensive than 2 layers

### 9.5. Traces below the module

Signal traces should not be placed directly below the module to avoid short circuits:

- Traces on top layer are not allowed under the module (see **Figure 9-2**)
- Traces on mid layers and bottom layers are allowed (see **Figure 9-2**)



**Figure 9-2: Layer design of 2 and 4 layer boards**

### 9.6. Placement on the PCB

The PCB design of the radio module base board and placement affects the radio pattern. For the deRFsamR21E-23S20 with coaxial u.FL connector usage, module placement is not critical, since the radiating part is placed external to the module and can therefore be placed everywhere on the board. If the RF-Pad is used, the placement shall be chosen for proper RF design.

For deRFsamR21E-23S00 with integrated antenna the performance is strongly influenced by the base board design. The module shall be placed at the edge of the base board. The chip antenna has to be placed next to the edge as shown in the figures below. The antenna design is optimized for use on 1.5 mm FR4 PCB baseboard. Best performance is obtained with the module placed at the corner of the PCB with as much ground plane on the board as possible.



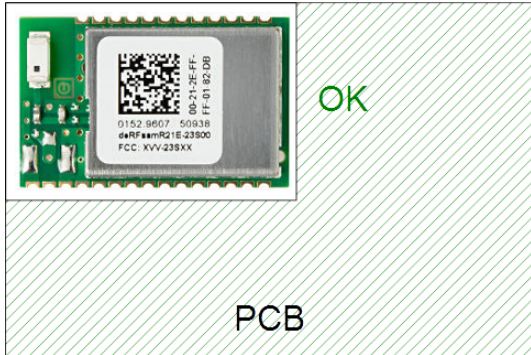


Figure 9-3: Placing at the PCB corner

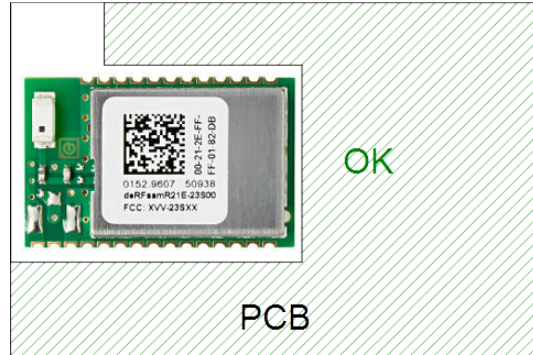


Figure 9-4: Placing at the centre edge

Do not place the chip antenna radio module within the base board. This will cause a very poor radio performance.

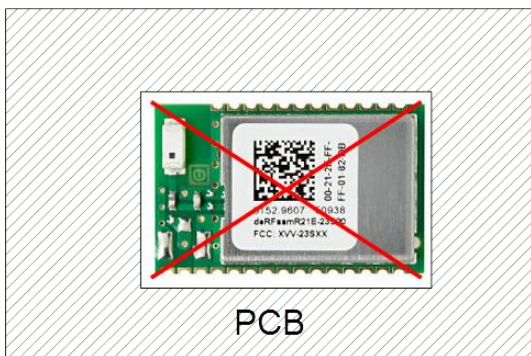


Figure 9-5: Placing in the centre with antenna

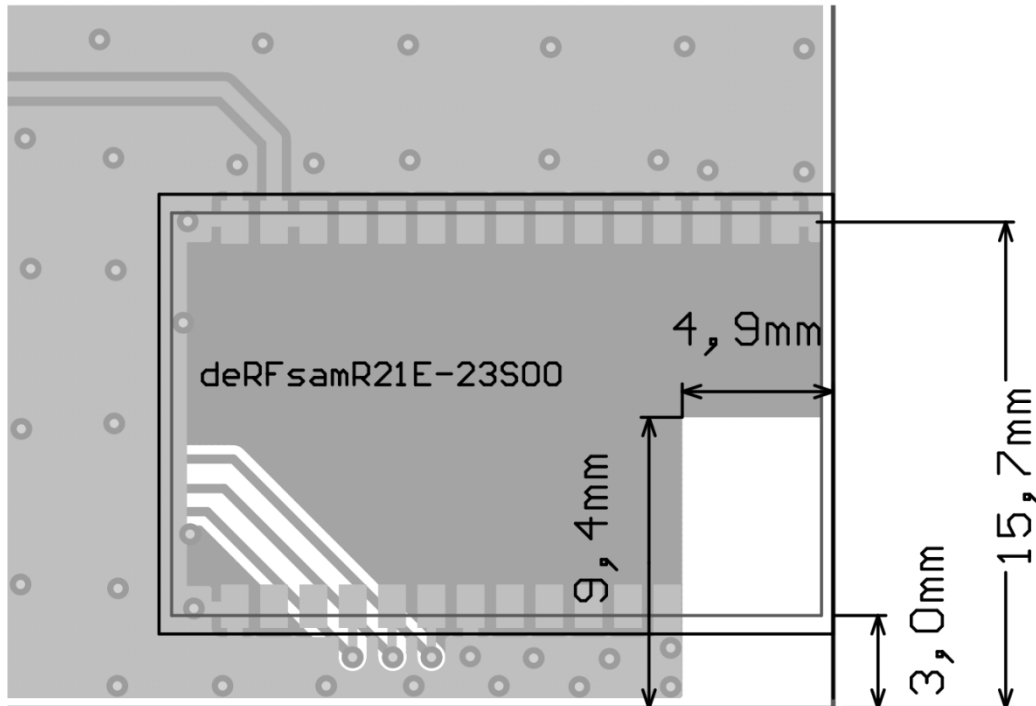


Figure 9-6: Placing in the centre with RF pad antenna

Do not place ground areas below the radio module and near the chip antenna (see **Section 9.5 and 9.7**).

### 9.7. Recommended layout for deRFsamR21E-23S00

For best performance of the deRFsamR21E-23S00 with chip antenna it is recommended to place the module at a corner of the PCB according to **Figure 9-7**.



**Figure 9-7 recommended layout for deRFsamR21E-23S00 module**

The module antenna design of deRFsamR21E-23S00 is optimized for mounting on a standard technology PCB with the following properties:

- Two-layer board
- Board material FR4
- Board thickness of 1.55 mm
- Copper layer thickness of 35  $\mu\text{m}$
- Top and bottom solder

### 9.8. RF design for deRFsamR21E-23S20

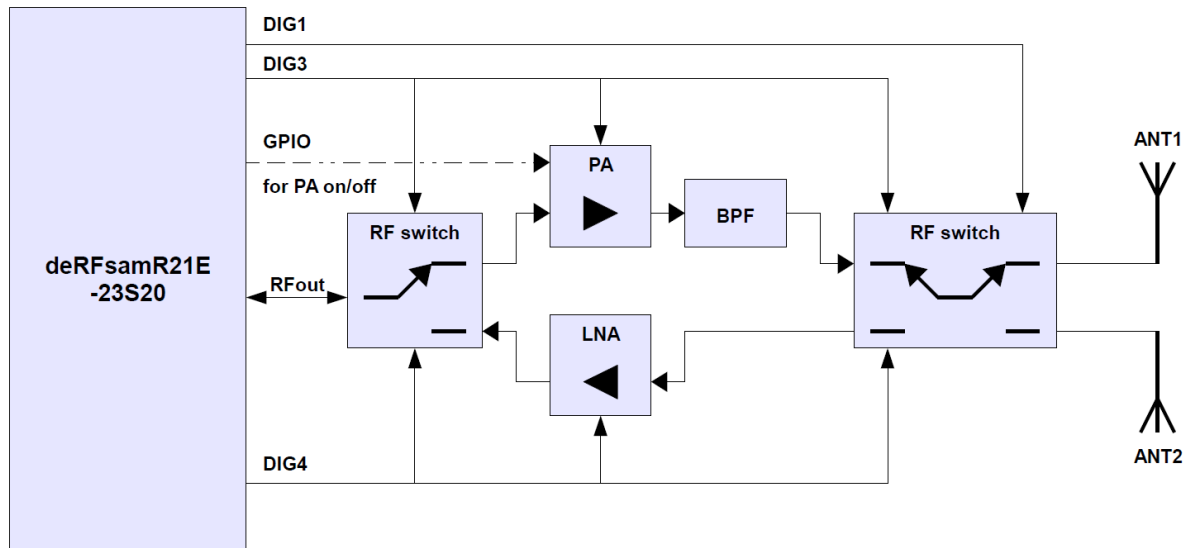
For deRFsamR21E-23S20 two options for the RF signal are available: using the coaxial u.FL connector to connect an external antenna or if needed in the application, custom designed RF circuitry using the RF-out pad.

**Note:** Please get in contact with dresden elektronik to advise for a custom FCC certified design. If necessary dresden elektronik can provide RF part design data. This may require signing a Non-Disclosure Agreement.

When designing RF traces on the base board a line impedance of 50  $\Omega$  shall be used. Depending on the base board layer stack construction a microstrip or grounded coplanar microstrip design can be implemented.

### 9.8.1. External front end and antenna diversity

The radio module deRFsamR21E-23S20 can be used with an external front end, including power amplifier (PA) for transmission and low noise amplifier (LNA) for receiving, and antenna diversity. **Figure 9-8** shows a possible design as block diagram. A custom design can contain a single PA or single LNA or a complete integrated front-end chip. It depends mainly on the application. Furthermore, it is possible to include a RF switch for driving the antenna diversity feature. An example block diagram is shown in **Figure 9-8**.



**Figure 9-8: block diagram for external PA/LNA and antenna diversity control**

The DIG1 to DIG4 signals of the transceiver are connected internally to the microcontroller and have to be muxed on ports PA08, PA09, PA14 and PA15. DIG1 to DIG4 can be activated as alternate pin output functions FECTRL[0..5] by the microcontroller. Please refer to chapter 33 of ATSAMR21 datasheet [1].

#### Unbalanced RF output

The radio module deRFsamR21E-23S20 has a 50  $\Omega$  unbalanced RF output. For designs with external RF power amplifier a RF switch is required to separate the TX and RX path.

#### RF switches to PA, LNA and antenna

The switch must have 50  $\Omega$  inputs and outputs for the RF signal. The switch control can be realized with the DIG3 and DIG4 signal of the radio transceiver.

#### Power amplifier (PA)

The PA has to be placed on the TX path after the RF switch. It is important to regard the PA's manufacturer datasheet and application notes, especially for designing the power supply and ground areas. A poor design could cause a very poor RF performance. For energy efficiency it is useful to activate the PA only during TX signal transmission. In this case the DIG3 signal can be used as switch for (de-)activating the PA. Some PAs have the possibility to set them into sleep state. This application can be realized via a dedicated GPIO pin.

#### Band-pass filter (BPF)

The use of a band-pass filter is optional. It depends on the PA properties. Some PAs have an internal BPF and other do not have. The BPF is necessary to suppress spurious emissions of the harmonics and to be compliant with national EMI limits. It is possible to use an integrated



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BPF part or discrete parts. The advantage of the first variant is that the BPF characteristic is known and published in the manufacturer's datasheet.

#### **Low noise amplifier (LNA)**

The LNA can be used to amplify the received signal. Please refer to the manufacturer's datasheet for a proper design. The control can be done by DIG4 signal.

#### **RF switch for antenna diversity**

The switch must have 50  $\Omega$  inputs and outputs for the RF signal. It is possible to use a separate switch with 2 inputs and 2 outputs or use another (third) switch following the switch required for the PA/LNA. Antenna diversity switching can be controlled via DIG1.

#### **Certification**

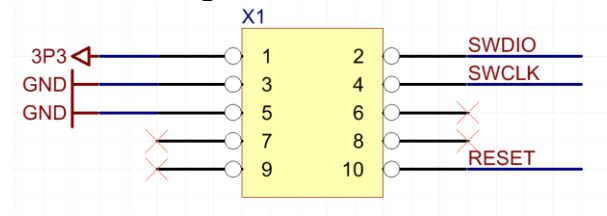
The customer has to ensure, that custom front-end and antenna diversity designs based on the radio module deRFsamR21E-23S20 meet all national regulatory requirements of the assignment location and to have all necessary certifications, device registration or identification numbers.



## 10. Programming

The update process of the radio module, the required software and hardware for programming via SWD interface and the driver installation on different operating systems are described in this chapter. Currently, the SWD interface is supported by several Atmel and third party programmers and debuggers like Atmel ICE and Segger J-Link. Other programmers that support ATSAMR21E18A will work as well.

For the programming the standard SWD header is recommended as 10pin 1.27 mm header as shown in **Figure 10-1**.



**Figure 10-1: Programming header**

### 10.1. Software/Applications

For software development several options are available depending on your needs:

- For ZigBee 3.0 home automation projects Microchip offers the ZigBee 3.0 BitCloud software stack. This stack is platform certified by the ZigBee Alliance. For more information see <http://www.microchip.com/design-centers/wireless-connectivity/embedded-wireless/802-15-4/zigbee-3-0>  
Please contact your local Microchip Sales Representative to get access to the BitCloud Software Development Kit.
- In Atmel Studio the Atmel Software Framework (ASF) offers a big number of examples for ATSAMR21G18A. It is the same controller in a package with more GPIO Pins available for the user. Some minor adjustments are necessary to allow the examples to run on ATSAMR21E18A on this module.

Suitable compilers are GCC (v4.5.2) or IAR Compiler(IAR C/C++ Compiler for ARM v7.80.1) for example.

Dresden elektronik offers software development services with comprehensive experience in ZigBee 3.0 and IEEE 802.15.4 wireless applications.

### 10.2. Clocks

The controller runs on 8 MHz RC-oscillator by default. Since the internal clock generation is not very accurate, it is recommended to use the external transceiver oscillator to avoid problems during communication for example by UART. To change the clock source to the precise transceiver oscillator ( $\pm 10$  ppm at 25°C) the transceiver has to be configured for clock output (CLKM) and the clock source at the controller has to be set to „GLCKIN“/“GCLK\_IO[1]“.

During deep sleep operation the clock source is best set to „OSCULP32K“ for minimized current consumption. Further information can be found in [1].



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### 10.3. Pre-flashed firmware

The radio modules will be delivered without pre-flashed firmware. Dresden elektronik provides development services for industrial or ZigBee 3.0 compatible projects and the modules can be delivered with custom firmware pre-programmed.



## 11. Radio certification

The modules deRFsamR21E-23S00 and deRFsamR21E-23S20 have received regulatory approvals for modular devices in the United States and European countries. The modules were also successfully tested according to IC regulations and are compliant but not certified for Canada.

### 11.1. United States (FCC)

The deRFsamR21E-23S00 with onboard chip antenna and deRFsamR21E-23S20 with coaxial u.FL connector comply with the requirements of FCC part 15.

To fulfil FCC Certification requirements, an OEM manufacturer must comply with the following regulations:

The modular transmitter must be labelled 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.

#### Sample label for radio module deRFsamR21E-23S00 and deRFsamR21E -23S20:

<b>Contains FCC-ID: XVV-23SXX</b>
-----------------------------------

<i>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.</i>
--

The Original Equipment Manufacturer (OEM) must ensure that the OEM modular transmitter must be labelled 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. 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.

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 (FCC 15.19).

Installers must be provided with antenna installation instructions and transmitter operating conditions for satisfying RF exposure compliance. This device is approved as a mobile device with respect to RF exposure compliance, and may only be marketed to OEM installers.

Modifications not expressly approved by this company could void the user's authority to operate this equipment (FCC section 15.21).

This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications.



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## 11.2. European Union (ETSI)

Hereby, dresden elektronik ingenieurtechnik gmbh declares that the radio equipment types deRFsamR21E-23S00 and deRFsamR21E-23S20 are in compliance with the Directive 2014/53/EU. The full text of the EU declaration of conformity is available at the following internet address:

<https://www.dresden-elektronik.de/funktechnik/solutions/wireless-light-control/eu-conformity/?L=1>.

If the deRFsamR21E-23S00 and deRFsamR21E-23S20 modules are 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 VI of the Radio Equipment Directive 2014/53/EU.

The manufacturer must maintain a copy of the deRFsamR21E-23S00 and deRFsamR21E-23S20 modules 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 must be respected.
- The CE marking must have a height of at least 5 mm 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 can be found in [3].





### 11.3. Approved antennas

The deRFsamR21E-23S00 has an integrated chip antenna. The design is fully compliant with all regulations.

The deRFsamR21E-23S20 is compliant with the listed approved antennas in **Table 11-1**.

**Table 11-1: Approved antenna(s) and accessory**

<b>Approved antenna list</b>				
<i>Type</i>	<i>Gain</i>	<i>Mount</i>	<i>Order code</i>	<i>Vendor / Supplier</i>
<i>External antenna</i>				
2400 to 2483.5 MHz Rubber antenna	+5dBi (peak)	RP-SMA	17013.RSMA	WiMo
U.FL-to-RP-SMA pigtail, 15 cm	-0.5dB		BN-023769	dresden elektronik
<i>Integrated antenna</i>				
2400 to 2483.5 MHz Chip antenna	+0.5dBi (peak)	SMT	AMCA31- 2R450G-S1F-T	Abracon LLC

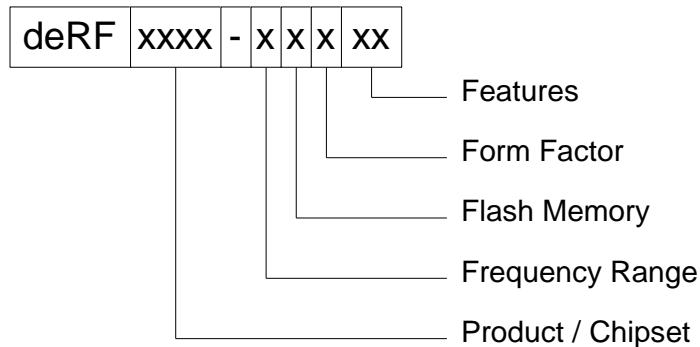
According to FCC KDB 178919 [5] it is allowed to substitute approved antennas through equivalent antennas of the same type with equal or less antenna gain:

'Equivalent antennas must be of the same type (e.g., yagi, dish, etc.), must be of equal or less gain than an antenna previously authorized under the same FCC ID, and must have similar in band and out-of-band characteristics (consult specification sheet for cutoff frequencies).'



## 12. Ordering information

The product name includes the following information:



**Table 12-1: Product name code**

Product name code		
Information	Code	Explanation
Product / Chipset	samR21E	ATSAMR21E18A
Frequency Range	2	2.4 GHz
Flash memory	3	256 kByte
Series	S	OEM module 2 <sup>nd</sup> generation
Features	00	Onboard chip antenna
	20	Coaxial u.FL connector and RF-OUT pad

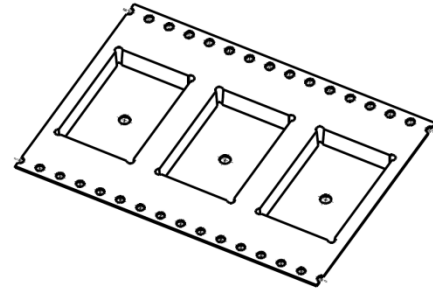
**Table 12-2: Ordering information**

Ordering information		
order number	Product name	Comments
BN-600097	deRFsamR21E-23S00	solderable radio module with onboard chip antenna, no pre-flashed firmware
BN-600098	deRFsamR21E-23S20	solderable radio module with coaxial u.FL-connector and RF-OUT pad, no pre-flashed firmware

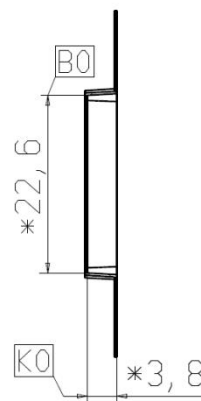
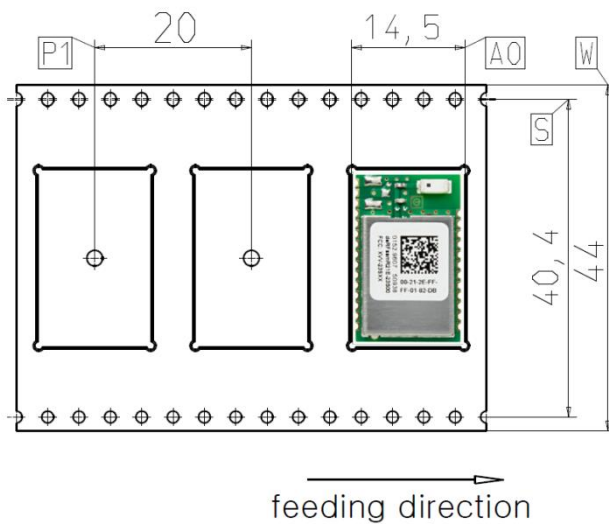
The modules will be delivered in Tape & Reel, for details see section 13.

### 13. Packaging dimension

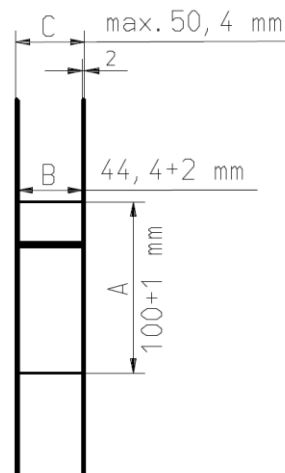
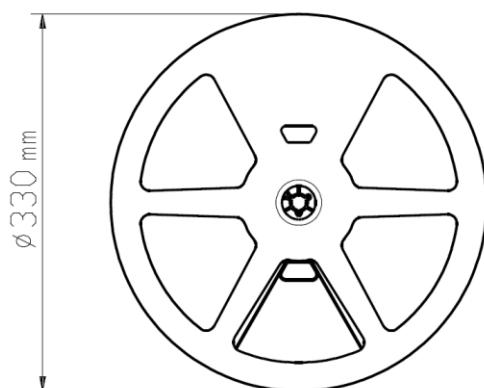
The modules will be delivered in Tape & Reel. The reel quantity is 800 pcs, lower quantities will be delivered in cut tape.



#### Tape dimensions



#### Reel dimensions



Dimensions are nominal and measured in mm.



## 14. Soldering profile

Table 14-1 shows the recommended soldering profile for the radio modules.

Table 14-1: Soldering Profile

Profile Feature	Values
Average-Ramp-up Rate (217°C to Peak)	3°C/s max
Preheat Temperature 175°C ±25°C	180 s max
Temperature Maintained Above 217°C	60 s to 150 s
Time within 5°C of Actual Peak Temperature	20 s to 40 s
Peak Temperature Range	260°C
Ramp-down Rate	6°C/s max
Time 25°C to Peak Temperature	8 min max

Figure 14-1 shows a recorded soldering profile for a radio module. The blue colored line illustrates a temperature sensor placed next to the soldering contacts of the radio module. The pink line shows the set temperatures depending on the zone within the reflow soldering machine.

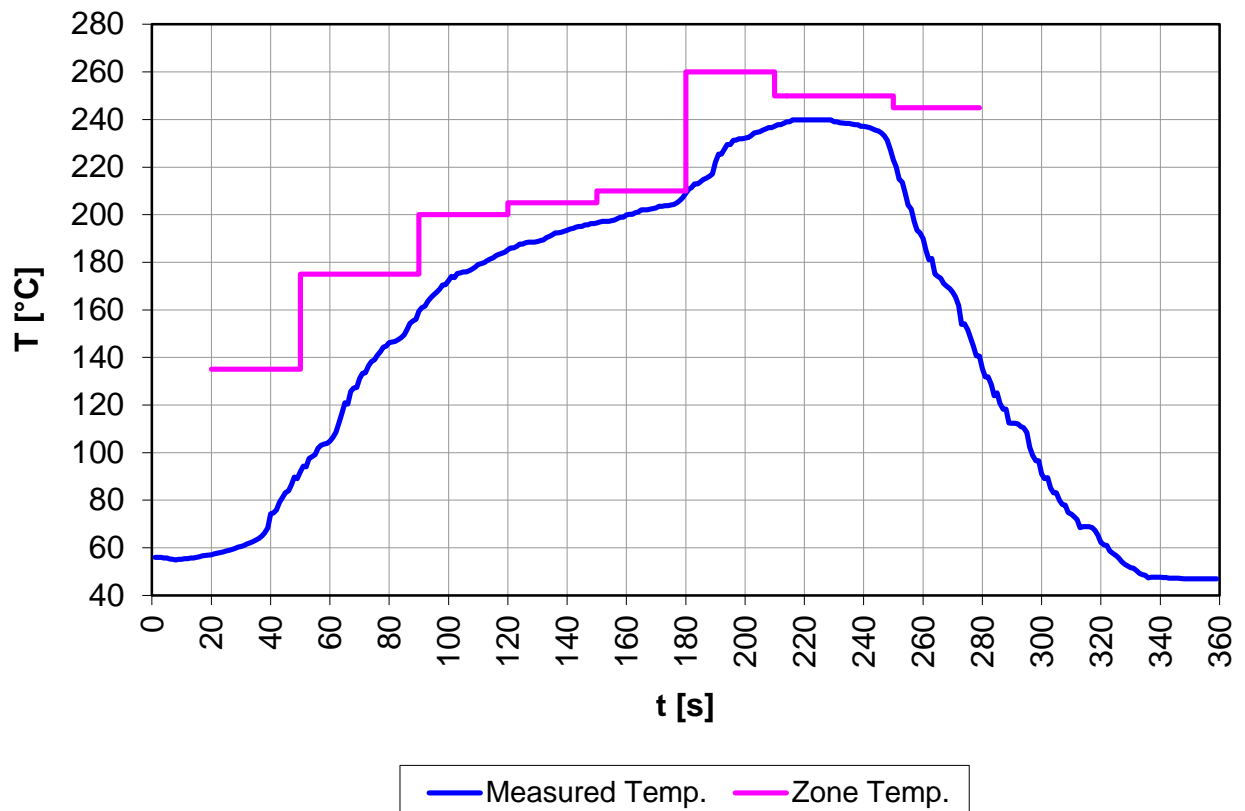


Figure 14-1: Recorded soldering profile

A solder process without supply of nitrogen causes a discoloration of the metal RF-shielding. It is possible that the placed label shrinks due the reflow process.



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## 15. Revision notes

Actually, no design issues of the radio modules are known.

All errata of the ATSAMR21E18A are described in the datasheet [1].



## 16. References

- [1] ATSAMR21E18A: Atmel SAM R21E / SAM R21G, SMART ARM-Based Wireless Microcontroller; Datasheet, URL: <http://www.microchip.com/wwwproducts/en/ATSAMR21E18A>
- [2] AT86RF233: Low Power, 2.4GHz Transceiver for ZigBee, RF4CE, IEEE 802.15.4, 6LoWPAN, and ISM Applications; Datasheet, URL: <http://www.microchip.com/wwwproducts/en/at86rf233>
- [3] Directive 2014/53/EU, European Parliament and the Council, 16 April 2014, URL: <http://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX:32014L0053>
- [4] Transmitter Module Equipment Authorization Guide; 996369 D01 Module Certification Guide; FCC OET; URL: <https://apps.fcc.gov/oetcf/kdb/forms/FTSSearchResultPage.cfm?id=44637&switch=P>
- [5] Permissive Change Policy; 178919 D01 Permissive Change Policy; FCC OET; URL: <https://apps.fcc.gov/oetcf/kdb/forms/FTSSearchResultPage.cfm?id=33013&switch=P>
- [6] 2.4GHz Chip-Antenna AMCA31-2R450G-S1F-T by Abracon LLC; Datasheet; URL: <http://www.abracon.com/chip-antenna/AMCA31-2R450G-S1F-T.pdf>
- [7] 2.4GHz Rubber antenna 17013.xx by WiMo Antennen und Elektronik GmbH; Datasheet; URL: <http://www.wimo.com/download/17013.pdf>
- [8] Schematic and footprint library for Altium Designer®; URL: [http://www.dresden-elektronik.de/funktechnik/service/downloads/documentation/?eID=dam\\_frontend\\_push&ocID=2024](http://www.dresden-elektronik.de/funktechnik/service/downloads/documentation/?eID=dam_frontend_push&ocID=2024)
- [9] Schematic and footprint library for EAGLE®; URL: [http://www.dresden-elektronik.de/funktechnik/service/downloads/documentation/?eID=dam\\_frontend\\_push&ocID=2023](http://www.dresden-elektronik.de/funktechnik/service/downloads/documentation/?eID=dam_frontend_push&ocID=2023)
- [10] STEP model library for CAD tools; URL: [http://www.dresden-elektronik.de/funktechnik/service/downloads/documentation/?eID=dam\\_frontend\\_push&ocID=2022](http://www.dresden-elektronik.de/funktechnik/service/downloads/documentation/?eID=dam_frontend_push&ocID=2022)
- [11] Flash AT25SF041 by Adesto; Datasheet; URL: [https://www.adestotech.com/wp-content/uploads/DS-AT25SF041\\_044.pdf](https://www.adestotech.com/wp-content/uploads/DS-AT25SF041_044.pdf)
- [12] Flash MX25V4006E by Macronix; Datasheet; URL: <http://www.macronix.com/Lists/Datasheet/Attachments/6217/MX25V4006E,%202.5V,%2004Mb,%20v1.9.pdf>
- [13] Flash W25X40CL by Winbond; Datasheet; URL: [http://www.winbond.com/resource-files/w25x40cl\\_f%2020140325.pdf](http://www.winbond.com/resource-files/w25x40cl_f%2020140325.pdf)
- [14] Flash W25X40CL by Winbond; Datasheet; URL: <http://www.winbond.com/resource-files/da00-w25q40cle1.pdf>



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