

# Zolertia Zoul Revision A Internet of Things hardware wireless module, for 2.4-GHz and 863-950MHz IEEE 802.15.4, 6LoWPAN and ZigBee® Applications

## 1. Device overview

### 1.1. Features

- Module
  - Two on-board IEEE 802.15.4-compliant transceivers: 2.4GHz and 863-950MHz
  - Individual power inputs for the CC2538 and CC1200 on-board chips
  - 2.0-3.3VDC input voltage
  - USB 2.0 Full-Speed device (12Mbps)
- Microcontroller
  - CC2538SF53RTQT ARM® Cortex®-M3 with Code Prefetch
  - Up to 32-MHz Clock Speed
  - 512KB Programmable Flash
  - 32KB RAM (16KB with retention in all Power Modes)
  - JTAG Debugging
  - Low-Power
    - Active Mode: 20mA
    - Power Mode 1 (4µs wake-up): 0.6mA
    - Power Mode 2 (sleep timer running and 16KB RAM retention): 1.3µA
    - Power Mode 3 (external interrupt and 16KB RAM retention): 0.4 µA
- Radio
  - ISM 2.4GHz IEEE 802.15.4 Compliant transceiver
    - Receiver sensitivity -97dBm
    - Robustness to interference with ACR 44dB
    - Programmable output power up to 7dBm
  - ISM 863-950MHz IEEE 802.15.4 Compliant transceiver
    - 250Kbps data rate with DSSS modulation
    - Reception (CPU Idle): 20mA peak
    - Transmission (CPU Idle, @ 0dBm): 24mA peak
    - Receiver sensitivity -123dBm @1.2kbps, -109dBm @ 50kbps
    - Blocking 86dB at 10MHz
    - Adjacent channel selectivity: up to 60dB at 12.5KHz offset
    - Programmable output power up to 16dBm
    - Modulation formats: 2-FSK, 2-GFSK, 4-FSK, 4-GFSK, MSK, OOK
    - Data rate up to 1.25Mbps
    - Power down: 0.12 µA, 0.5 µA with Wake-On radio (eWOR)
    - Reception: 19mA, 0.5mA in RX Sniff Mode
    - Transmission (@10-14dBm): 35-46mA
- Security Hardware Acceleration
  - AES-128/256, SHA2 Hardware Encryption Engine
  - ECC-128/256 RSA Hardware Acceleration Engine for secure key exchange
- Layout
  - 16.78 x 30.89 mm
  - RF shield included

## 1.2. Description

The Zoul is a core module developed by Zolertia to target most IoT applications, providing a flexible and affordable module solution to integrate to most existing products and solutions.

The Zoul ecosystem comprises both hardware development platforms and commercial products, bridging the gap between prototyping to production, with a fast time to market.

## 1.3. Applications

- Internet of Things products
- Wireless Sensor Networks
- Smart Grid and Home Area Network
- Home and Building Automation
- Intelligent Lighting System
- Smart Metering

## 1.4. Development Tools

- Code Composer Studio™
- IAR Embedded Workbench® for ARM
- SmartRF™ Studio
- SmartRF™ Flash Programmer
- BSL programming over USB (cc2538-bsl)
- Sensniff 6LoWPAN packet sniffer

## 1.5. Operating Systems & Software

- Contiki OS
- RIOT OS
- OpenWSN
- OpenThread
- Texas Instruments ZigBee Z-Stack
- Texas Instruments CC2538 Foundation Firmware
- Texas Instruments IEEE 802.15.4 MAC software Stack (TIMAC)

## 2. Revision history

Version	Author	Date	Description
1.0.0	Antonio Liñán Colina	28/09/2016	Initial Release

## 3. Compliances

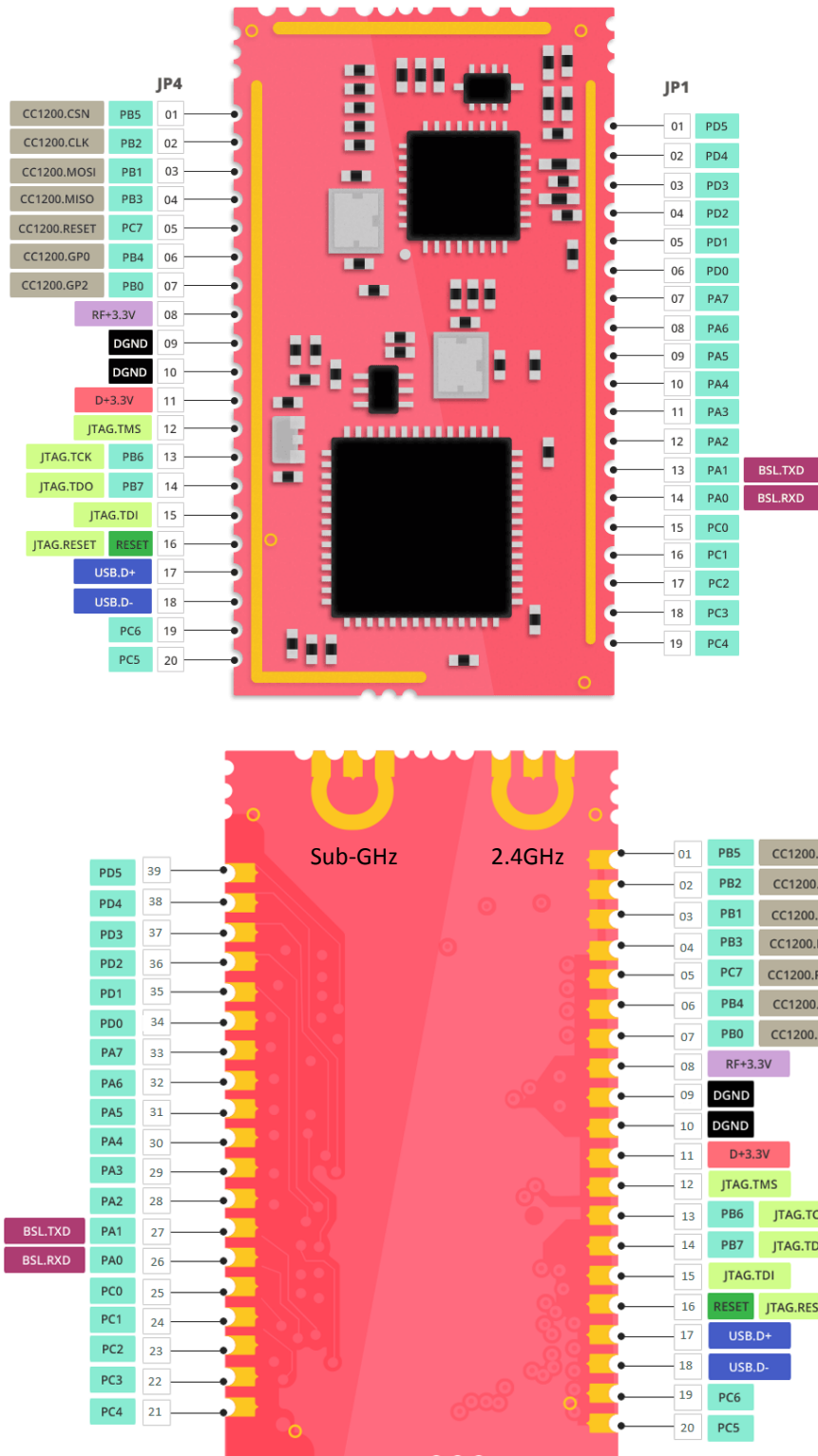
- Europe: ETSI EN 300 220, ETSI EN 300 328, ETSI EN 300 440, EN 54-25
  - US: FCC CFR47 Part 15, FCC CFR47 Part 90
- Certification for CE/FCC 2016 Q4

## 4. Ordering information and documentation

- Online Purchases: <http://zolertia.io/store>
- Sales department: [sales@zolertia.com](mailto:sales@zolertia.com)
- Website: <http://zolertia.io/product/hardware/zoul-module>
- Technical resources: <https://github.com/Zolertia/Resources/wiki/The-Zoul-module>
- Schematics and design resources: <https://github.com/Zolertia/Resources>
- Texas Instruments CC2538: <http://www.ti.com/product/CC2538>
- Texas Instruments CC1200: <http://www.ti.com/product/CC1200>

## 5. Device Information

### 5.1. Block description and pin-out



The 2.4GHz RF pad (top right) and 820-950MHz RF pad (top left right) are shown in the image above. The RF pads are 50Ω.

## 5.2. Pin description

Pins are numbered from JP4 port and then continue from JP1, the numbering starts at JP1 from pin 19 as pin number 21, as shown in the pin-out reverse image in the previous section.

Pin	Default name	Pin Type	MC	Description
1	CC1200.CSN	Digital I/O	PB5	CC1200 SPI CSN. If RF+3.3V=0V is available as GPIO
2	CC1200.CLK	Digital I/O	PB2	CC1200 SPI Clock. If RF+3.3V=0V is available as GPIO
3	CC1200.MOSI	Digital I/O	PB1	CC1200 SPI MOSI. If RF+3.3V=0V is available as GPIO
4	CC1200.MISO	Digital I/O	PB3	CC1200 SPI MISO. If RF+3.3V=0V is available as GPIO
5	CC1200.RESET	Digital I/O	PC7	CC1200 Reset pin. If RF+3.3V=0V is available as GPIO
6	CC1200.GPIO0	Digital I/O	PB4	CC1200 GPIO0 pin. If RF+3.3V=0V is available as GPIO
7	CC1200.GPIO2	Digital I/O	PB0	CC1200 GPIO2 pin. If RF+3.3V=0V is available as GPIO
8	RF+3.3V	Power Input	N/A	CC1200 power supply input (2-3.6VDC)
9	DGND	Ground	N/A	Digital Ground
10	DGND	Ground	N/A	Digital Ground
11	D+3.3V	Power Input	N/A	CC2538 power supply input (2-3.6VDC)
12	JTAG.TMS	Digital Input	TMS	CC2538 JTAG TMS pin
13	JTAG.TCK	Digital I/O	PB6	CC2538 JTAG TCK pin and GPIO
14	JTAG.TDO	Digital I/O	PB7	CC2538 JTAG TDO pin and GPIO
15	JTAG.TDI	Digital Input	TDI	CC2538 JTAG TDI pin
16	JTAG.RESET/RESET	Digital Input	RST	JTAG and CC2538 Reset line
17	USB.D+	USB 2.0 Data	D+	USB 2.0 Data Pin, requires external 1.5KΩ pull-up resistor
18	USB.D-	USB 2.0 Data	D-	USB 2.0 Data Pin
19	PC6	Digital I/O	PC6	GPIO 20 mA output capability
20	PC5	Digital I/O	PC5	GPIO 20 mA output capability
21	PC4	Digital I/O	PC4	GPIO 20 mA output capability
22	PC3	Digital I/O	PC3	GPIO 20 mA output capability
23	PC2	Digital I/O	PC2	GPIO 20 mA output capability
24	PC1	Digital I/O	PC1	GPIO 20 mA output capability
25	PC0	Digital I/O	PC0	GPIO 20 mA output capability
26	BSL.TX/PA0	Digital I/O	PA0	GPIO 4 mA output capability, may be used with a serial to USB converter to flash the CC2538 using serial BSL
27	BSL.RX/PA1	Digital I/O	PA1	GPIO 4 mA output capability, may be used with a serial to USB converter to flash the CC2538 using serial BSL
28	PA2	Digital I/O	PA2	GPIO 4 mA output capability
29	PA3	Digital I/O	PA3	GPIO 4 mA output capability
30	PA4	Digital I/O	PA4	GPIO 4 mA output capability
31	PA5	Digital I/O	PA5	GPIO 4 mA output capability
32	PA6	Digital I/O	PA6	GPIO 4 mA output capability
33	PA7	Digital I/O	PA7	GPIO 4 mA output capability
34	PD0	Digital I/O	PD0	GPIO 4 mA output capability
35	PD1	Digital I/O	PD1	GPIO 4 mA output capability
36	PD2	Digital I/O	PD2	GPIO 4 mA output capability
37	PD3	Digital I/O	PD3	GPIO 4 mA output capability
38	PD4	Digital I/O	PD4	GPIO 4 mA output capability
39	PD5	Digital I/O	PD5	GPIO 4 mA output capability

## 5.3. Parametric and ratings

The Zoul module allows to individually power on-board CC2538 microcontroller and CC1200 transceiver, using D+3.3V and RF+3.3V power inputs respectively.

The tables above resume the ratings and parametric of the on-board devices, for further references and detailed information please refer to the Texas Instruments product page.

Table 1. Absolute Maximum Ratings

Parameter	Min	Max	Unit
Supply voltage	2.0	3.9	V
Voltage on any digital pin	-0.3 (D+3.3V) -0.3 (RF+3.3V)	3.3 (D+3.3V) 3.3 (RF+3.3V)	V
Supply Current	0.40 (D+3.3V) 0.12 (RF+3.3V)	-	µA
GPIO output current	-	24 GPIO x 4 4 GPIO x 20	mA
Input RF Level	-	10 both RF interfaces	dBm
Storage temperature range	-40	125	°C

Table 2. Recommended Operating Conditions

Parameter	Min	Max	Unit
Operating ambient temperature range	-40	125 (CC2538) 85 (CC1200)	°C
Operating supply voltage	2.1	3.3	V
Current consumption	0.4 µA (D+3.3V) 0.12 µA (RF+3.3V)	34mA (D+3.3V) 46mA (RF+3.3V @ 14dBm – High Performance Mode)	-

Table 3. RF characteristics

Parameter	Min	Max	Unit
Frequency Bands	820 2394	950 2507	MHz
Frequency Resolution	30 (820-950MHz band) 1x10 <sup>6</sup> (5MHz between channels, 2.4GHz band)		Hz
Data Rate	0-1250 (820-950MHz band, packet mode) 0-625 (820-950MHz band, transparent mode) 250 (2.4GHz band)		Kbps
Transmission Output Power	-12 (820-950MHz) -24 (2.4GHz)	15 (868MHz) 16 (RF+3.3V=3.6V, 868MHz) 14 (915-920MHz) 15 (RF+3.3V=3.6V, 915-920MHz) 7 (2.4GHz)	dBm

Table 4. CC2538's 32MHz crystal information

Parameter	Min	Max	Unit
Crystal Frequency	32		MHz
Accuracy	-20	20	ppm
ESR	60		Ω
Crystal Load Capacitance	10		pF

Table 5. CC2538's 32KHz crystal information

Parameter	Min	Max	Unit
Crystal Frequency	32.768		KHz
Accuracy	-20	20	ppm
ESR	90		KΩ
Crystal Load Capacitance	12.5		pF

Table 6. CC1200's 40MHz crystal information

Parameter	Min	Max	Unit
Crystal Frequency	40		MHz
Accuracy	-10	10	ppm
ESR	60		$\Omega$
Crystal Load Capacitance	10		pF

## 5.4. Digital communication and I/O ports

Table 7. Wired Communication information

Bus Name	SPI (x2)	I2C	UART (x2)	USB
Operating Voltage [V]	3.3	3.3	3.3	3.3
Current Consumption [mA]	0.3	0.1	0.7	3.8

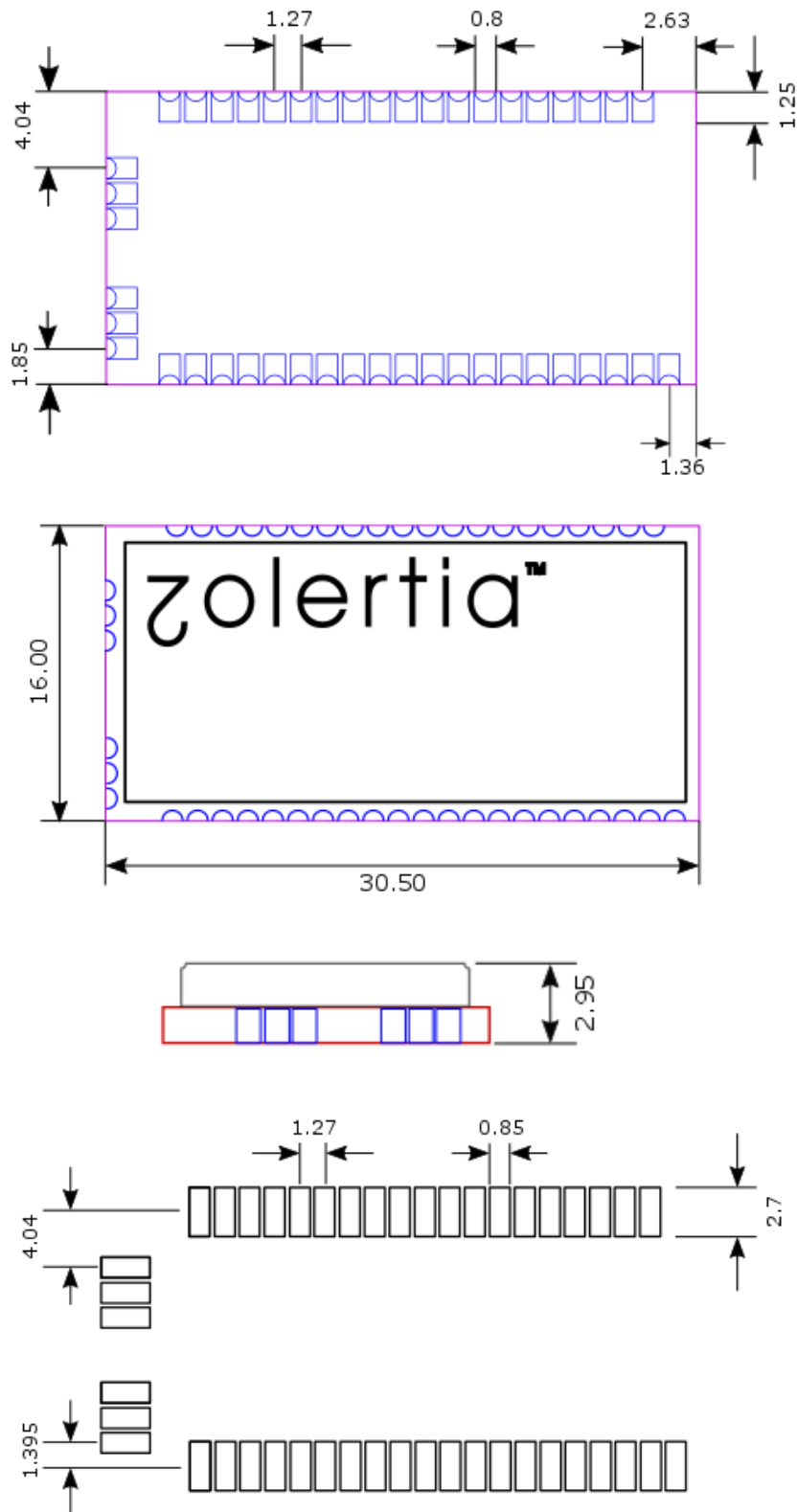
Table 8. Output pins

Parameter	Value	Unit
Logic "low" voltage	0.5	V
Logic "high" voltage	2.6 (D+3.3V=3.3V)	V
Current output	4, 20 (Port C only)	mA
Pull-Up/Down	20 (Port A, B and D only)	K $\Omega$

Table 9. Input pins

Parameter	GPIO	ADC	Unit
Maximum Voltage	D+3.3V + 0.3	D+3.3V	V
Current consumption	$0.3 \times 10^{-3}$	1.2 (measuring)	mA
Input Resistance	197		K $\Omega$

## 5.5. Mechanical information and footprint



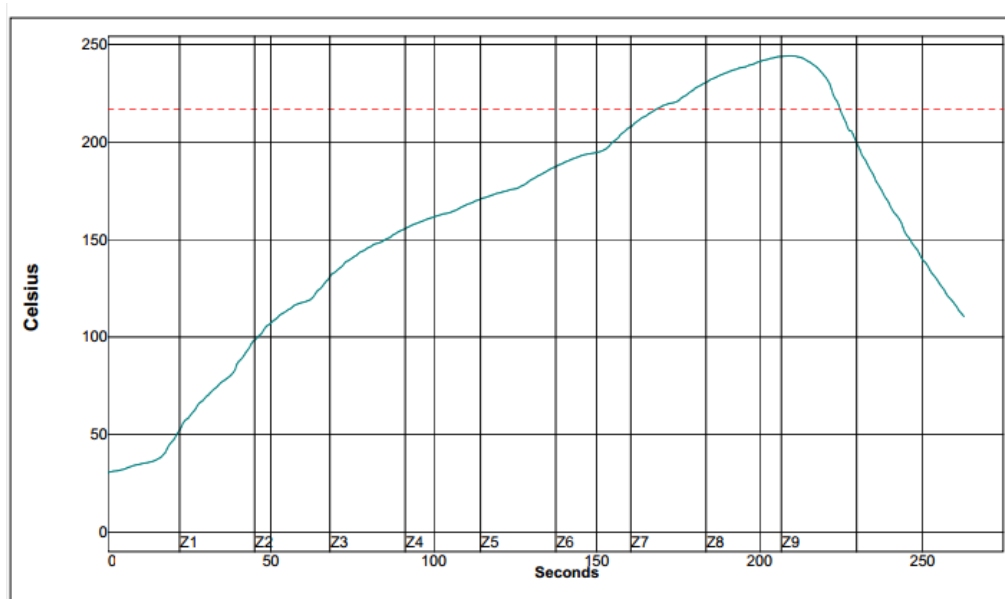
## 6. Soldering information

The Zoul module is designed to be soldered on RoHS reflow mode, based on the IPC/JEDEC joint industry standard J-STD-020D.

### 6.1. Reflow temperature

Table 10. Soldering Set Points

Zone	1	2	3	4	5	6	7	8	9
Top (°C)	110	133	165	174	185	208	238	253	261
Bottom (°C)	110	133	165	174	185	208	238	253	261
Conveyor Speed	71.4 cm/min								



## 7. Reference design

Table 11. Reference design

Designator	Value	Manufacturer	Part Number	Quantity
C1, C3, C5, C6, C7	100nF	Murata Electronics North	GRM188R71H103KA01D	5
C2, C4	1μF	Murata Electronics North	GRM188R61C105KA93D	2
C8	1.5nF	Murata Electronics North	GRM188R71H152KA01D	1
JP1	-	Zolertia	ZOL-ZOUL-A	1
JP2	-	Phoenix Contact	1725656	1
JP3	-	FCI	20021111-00010T4LF	1
L1	51nH	Murata Electronics North	LQW18AN51NG00D	1
L2	-	Johanson Technology	2450AT18A100E	1
L3	-	TDK Corporation	MMZ1608S102ATA00	1
R1	68Ω	Panasonic Electronic	ERJ-3EKF68ROV	2
R2, R3	5.1KΩ	Panasonic Electronic	ERJ-3GEYJ512V	1
S1	-	C&K Components	KMR211GLFS	1
X1	-	Hirose Electric Co Ltd	U.FL-R-SMT(10)	1



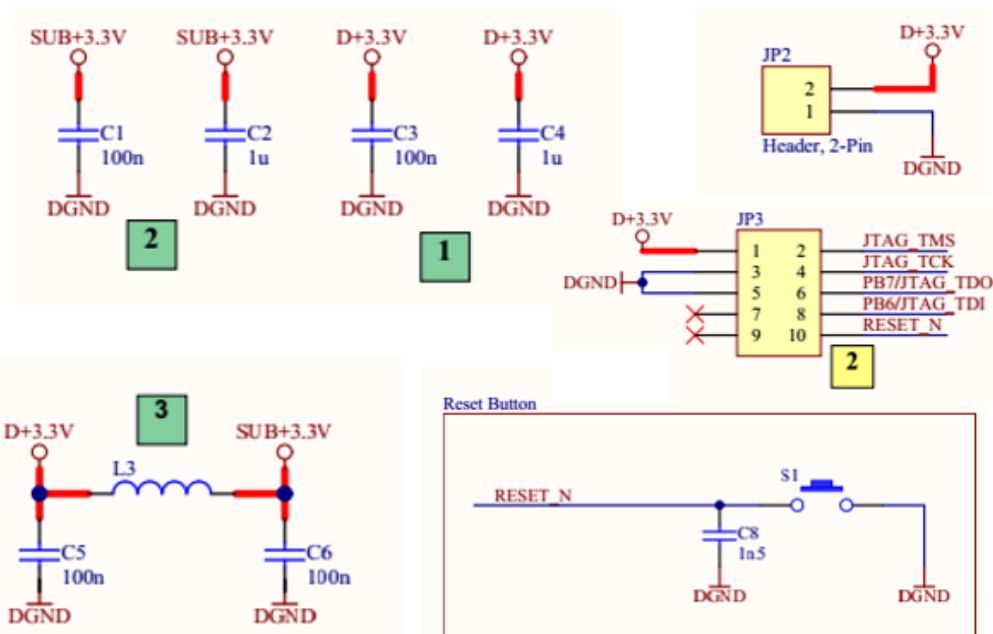
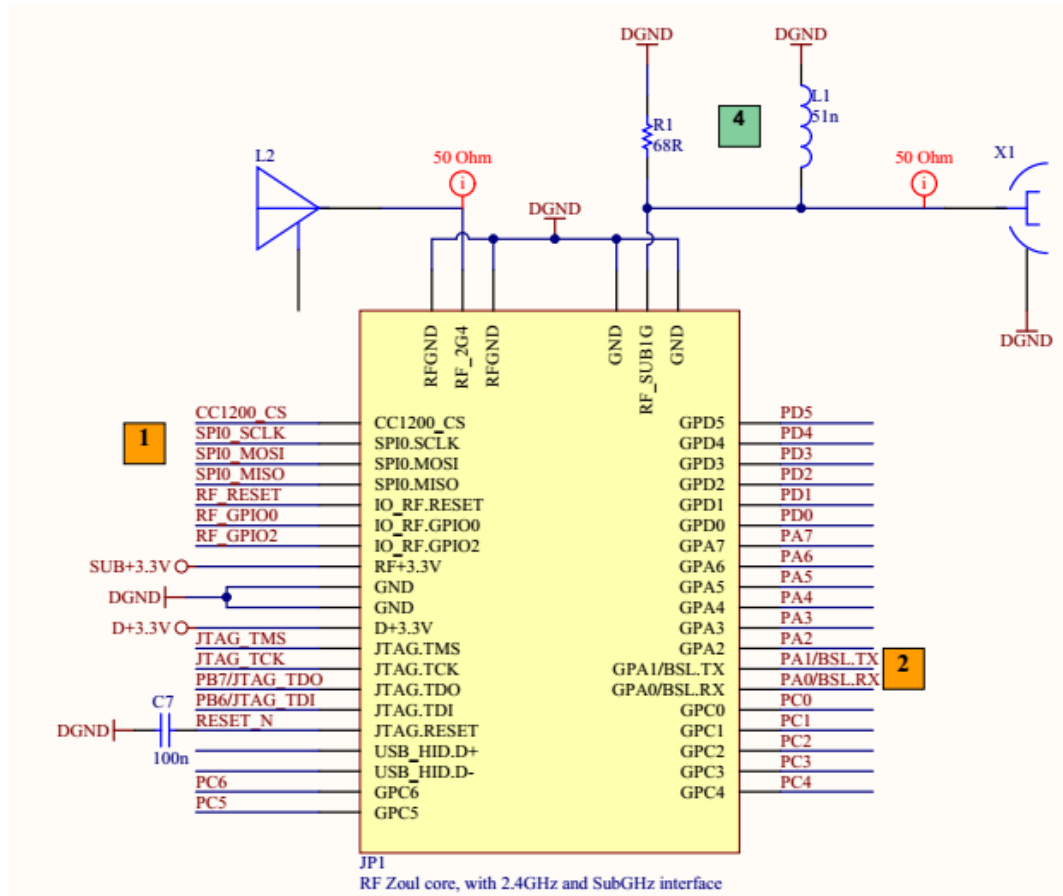


Table 12. Reference design comments

1. Fiducials 2. JTAG programmer to CC2538
1. Pins used for CC1200 as default but also traced for external connections. 2. BSL configuration as default UART0 - RXD: GPA0 - TXD: GPA1
1. Place close to Zoul D+3.3V input 2. Place close to Zoul RF+3.3V 3. Place close to Zoul VDD inputs 4. Place close to Zoul RF output

Conductor Impedance

Conductor Width (W)  
**0,785 mm**

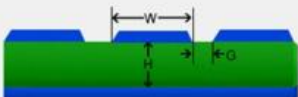
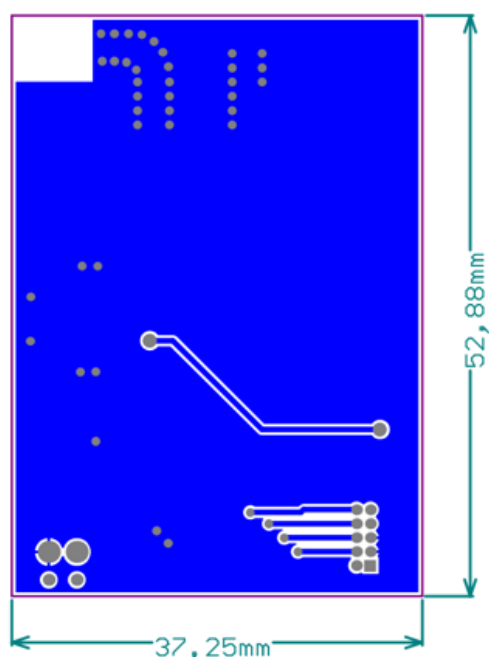
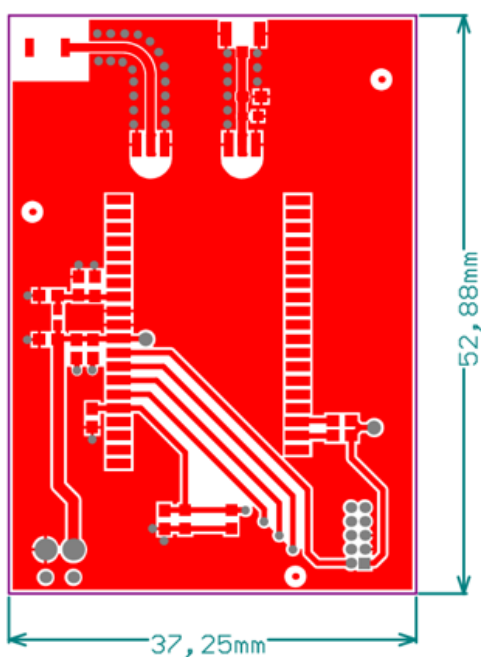
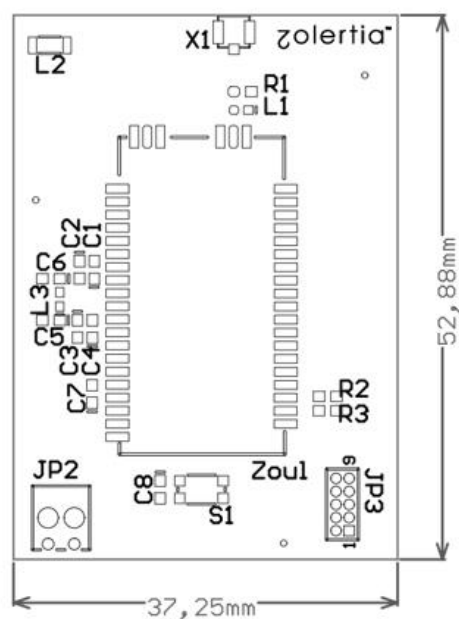
Conductor Height (H)  
**0,8 mm**

Conductor Gap (G)  
**0,15 mm**

**W/H = 0.981**

Formula Restrictions:  
0.1 < W/H < 2.0  
T = 53um

Zo  
**50.0050 Ohms**

## 8. Component and Design libraries

The Zoul module can be imported to a CAD programs:

- Altium: <https://github.com/Zolertia/Resources/tree/master/Zoul/Design/Footprints/Altium>
- Eagle: <https://github.com/Zolertia/Resources/tree/master/Zoul/Design/Footprints/Eagle>
- Fritzing: <https://github.com/Zolertia/Resources/tree/master/Zoul/Design/Footprints/Fritzing>

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