

ST25RU3993-EVAL board

Introduction

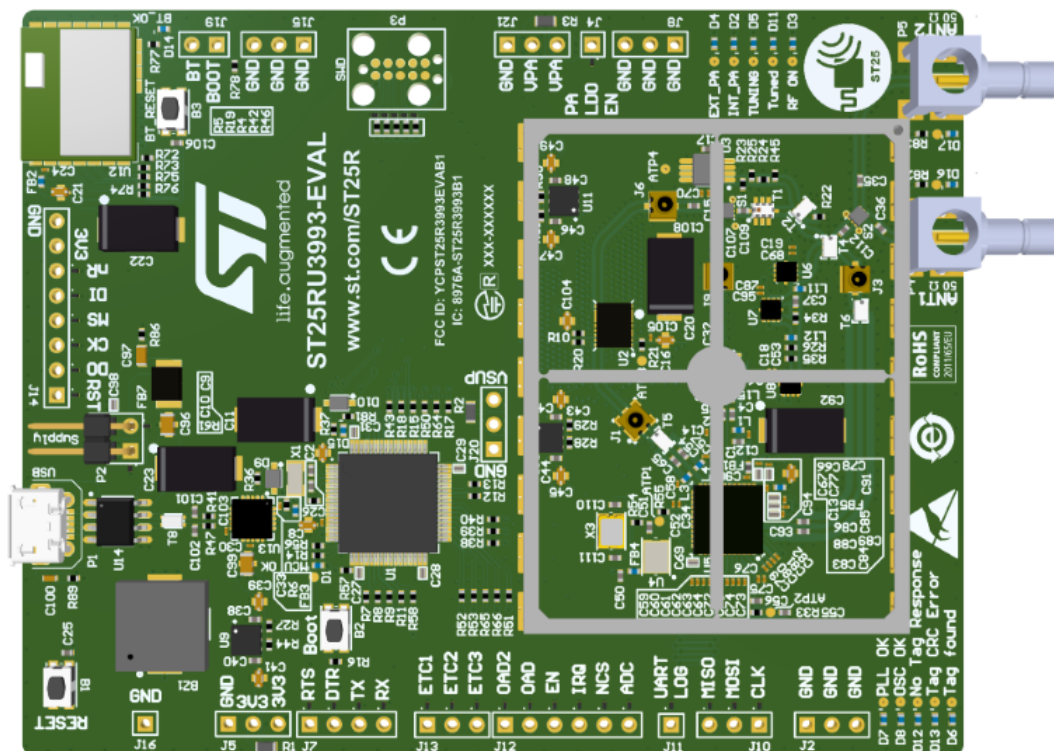
The ST25RU3993-EVAL board is a RAIN® (UHF) RFID reader system based on the integrated reader ST25RU3993 device. The purpose of the ST25RU3993-EVAL board is to provide a comprehensive RAIN® RFID reader system, which allows user to evaluate the properties and features of the ST25RU3993. The ST25RU3993 is a versatile RAIN reader device, which can be deployed in mobile, hand-held and stationary reader applications alike. The architecture of the ST25RU3993-EVAL board combines a long range and a short range reader design. Furthermore the ST25RU3993-EVAL board has been fitted with numerous easy to access test points and measurement possibilities.

The ST25RU3993-EVAL board is controlled via a graphical user interface (GUI) software running on a host PC through an USB/UART bridge (requires COM port driver installation). The GUI can be downloaded from www.st.com.

The ST25RU3993-EVAL is powered through an USB 3.0 port in order to provide sufficient power for the long range configuration of the reader. If an USB 3.0 port is not available an USB 2.0 Y-cable or an external power supply can be used to enable the long range capabilities of the reader. If neither is available only the short range reader configuration with lower RF power is available.

The ST25RU3993-EVAL offers two SMB (female) antenna ports, which can be configured via the GUI as active RF output. To enable scanning for RAIN® RFID transponders connect a suitable 50 Ω UHF antenna for the targeted frequency and RF power range. The ST25RU3993-EVAL board supports 52 frequency channels ranging from 840 MHz to 960 MHz. In the reader settings the appropriate frequency profile has to be selected.

Figure 1. ST25RU3993-EVAL board (top view)



1 General information

The ST25RU3993-EVAL supports Arm®-based devices.

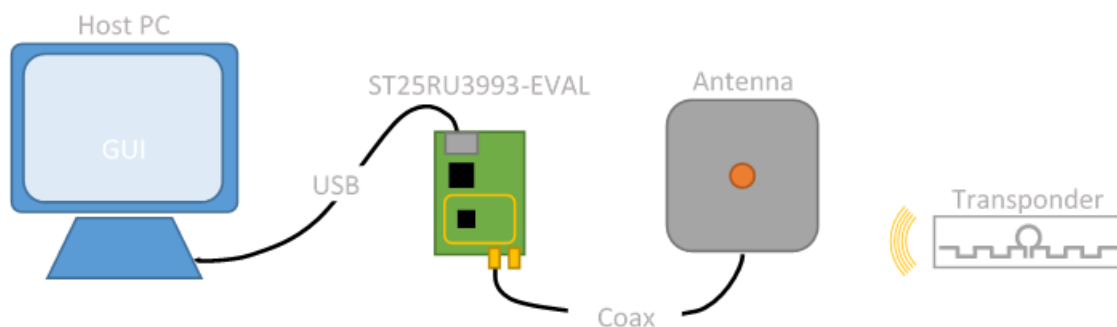
Note: Arm is a registered trademark of Arm Limited (or its subsidiaries) in the US and/or elsewhere.



2 Standard connection setup

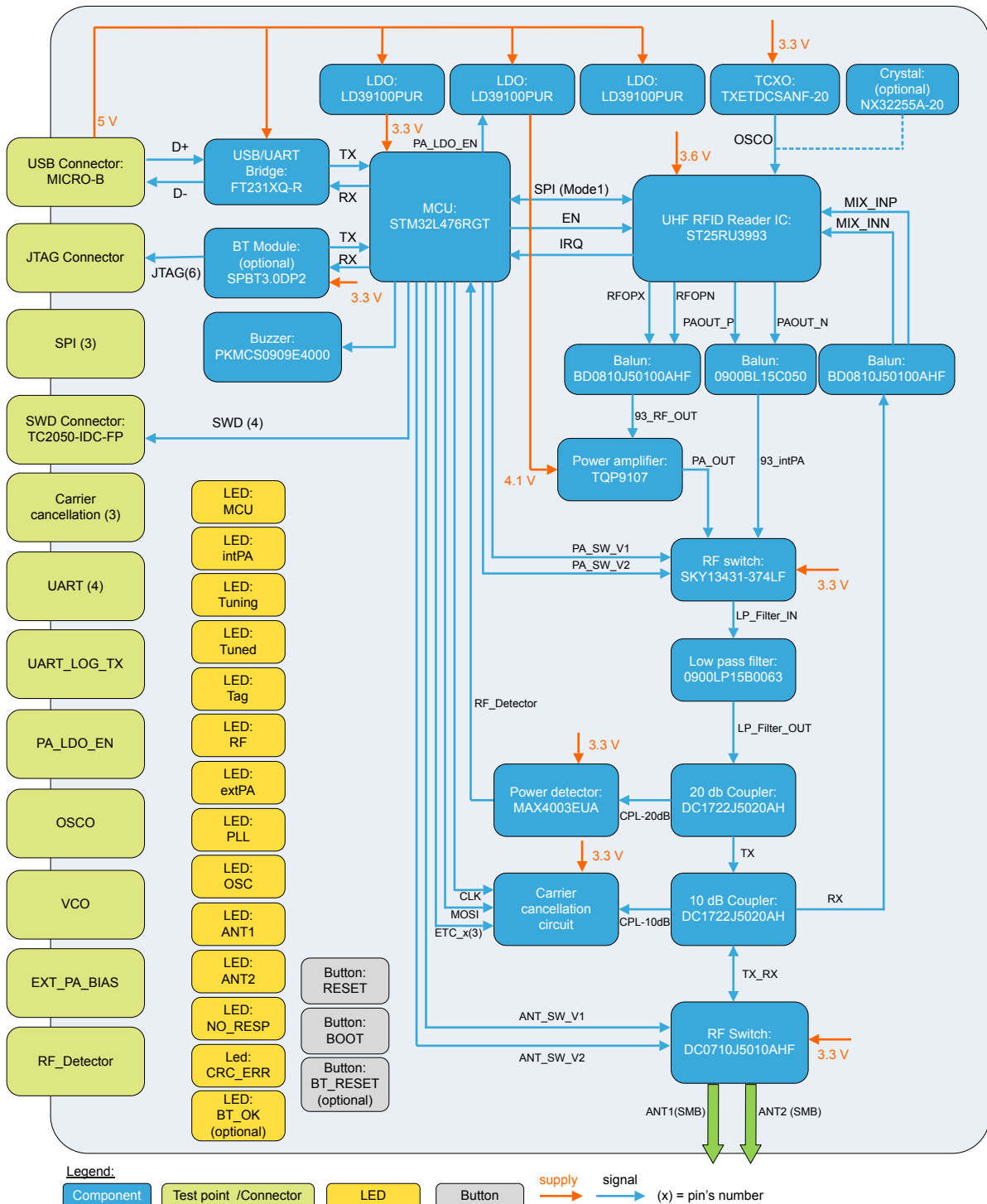
The typical reader setup is shown in Figure 2. The host PC running the GUI is connected to the ST25RU3993-EVAL board via a micro USB cable. The antenna is connected to the active antenna port using a 50 Ω coax cable. An UHF transponder is within range of the antenna reader.

Figure 2. Standard connection setup



3 ST25RU3993 block diagram

Figure 3. Functional block diagram



4 ST25RU3993-EVAL board features

- ST25RU3993 RAIN® (UHF) RFID reader IC
- Two power amplifier (internal/external) options - software-controlled
- External PA: 29 dBm max TX power
- Internal PA: 18 dBm max TX power
- Configurable TX power level
- Power detector to monitor TX power level
- Carrier cancellation circuitry
- Differential RX input
- Maximum sensitivity: -80 dBm
- External 20 MHz TCXO, clipped sine wave
- External reference: 20 MHz crystal
- Usable frequency range: 840 MHz – 960 MHz
- Two antenna connectors: SMB (female)
- USB receptacle: Micro, B-Type
- USB/UART bridge
- Main supply: 5V USB powered (1 A)
- STM32L476RGT6 (Arm® 32-bit Cortex®-M4):
 - 64 MHz
 - 128-Kbyte RAM
 - 1-Mbyte Flash
 - SPI (mode 4MHz)
- SWD debug interface
- LED indicators:
 - Carrier cancellation tuning activity
 - Carrier cancellation tuning OK
 - OSC OK (20 MHz external reference)
 - PLL OK
 - RF ON
 - No tag response
 - Tag CRC error
 - Tag found
 - Active antenna port
 - Power amplifier option
 - BT OK (not installed)
- Test points:
 - RF power levels of TX and RX signals
 - UART signal lines
 - SPI signal lines
 - UART_LOG for debugging purposes
 - Control voltage of internal VCO
 - RF power detector output voltage
 - 20 MHz reference signal
 - External PA BIAS voltage
 - LDO output voltages
 - Enable line of LDO for power amplifier
- Jumper for current consumption measurements:

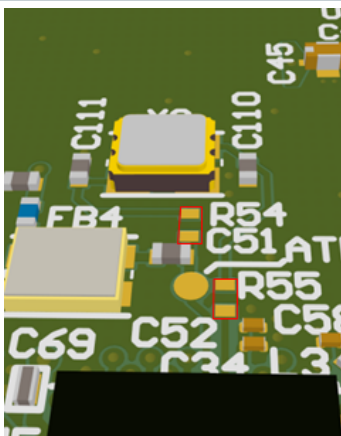
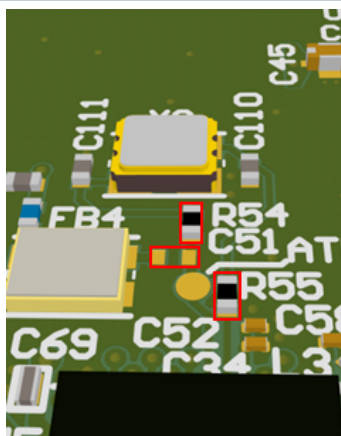
- Main supply
- Buttons:
 - MCU Reset
 - MCU Boot Mode
 - BT module reset button (not installed)
- Buzzer
- Wireless Interface (not installed):
 - BT 4.0 - SPP Profile
 - JTAG interface: for BT module programming
 - BT module boot mode jumper

5 Hardware description

5.1 RF circuit

The core component of the RF circuit is the ST25RU3993 chip. It receives digital base-band transmit data and commands from the MCU via the SPI interface. ST25RU3993 frames this transmit data accordingly and automatically encodes it into PIE symbols. Based on the PIE encoded symbols ST25RU3993 creates a sinusoidal shaped modulation signal. The modulation signal can either be ASK or PR-ASK. ST25RU3993 synthesizes an RF carrier frequency with a VCO / integer-n phase locked loop (PLL). The frequency reference for the PLL can either be a 20 MHz crystal oscillator or a temperature compensated crystal oscillator (TCXO). The ST25RU3993-EVAL board includes both options. The default configuration is the TCXO with a clipped sine wave output wave form and an amplitude of 0.8 Vpp. With a minor modification it is possible to connect the existing crystal to ST25RU3993 instead.

Table 1. TCXO/Crystal Configuration

Default configuration	Alternate configuration (user configuration)
TCXO connected to ST25RU3993	Crystal connected to ST25RU3993
R54 and R55 not populated	C51 removed and populate R54 and R55
	

The output of the internal PLL- charge pump is connected to LF_CEXT (pin 45) at which the external part of the loop filter is placed in close proximity. An additional low pass filter stage is integrated in ST25RU3993 and is part of the loop filter circuit. The loop filter output is the control voltage of the internal VCO. The carrier frequency is modulated by the ASK or PR-ASK shaped modulation signal.

ST25RU3993 has two differential output port pairs:

- The 0-dBm (linear) output
- The internal power amplifier output

Depending on which differential output port pair is activated the modulated carrier frequency will be amplified accordingly.

The 0-dBm output is used for the long-range configuration of the ST25RU3993-EVAL reader. The 0-dBm output with its differential output pin pairs RFONX (23) and RFOPX (24) is connected to a 2:1 Balun at which point the transmit signal is transformed from a 100 differential to a 50 Ω single-ended signal. The output stage of the 0-dBm output is supplied by the VDD_B voltage that is generated and regulated by ST25RU3993. L3 and L4 act as a RF choke, C57 and C58 as bypass capacitors and C65 and C54 as DC blocking capacitors. The signal then proceeds to the external power amplifier to generate a high power output signal with approximately 31 dBm in default configuration of ST25RU3993-EVAL board.

The internal power amplifier is used for the short-range configuration of the ST25RU3993-EVAL reader. The output pins for the internal power amplifier are PAOUT_N (16, 17) and PAOUT_P (20, 21). A matching network

and an 1:1 Balun transform the output of the internal power amplifier to a 50 Ω single-ended signal. The internal power amplifier is supplied by the on-chip generated and regulated voltage VDD_PA.

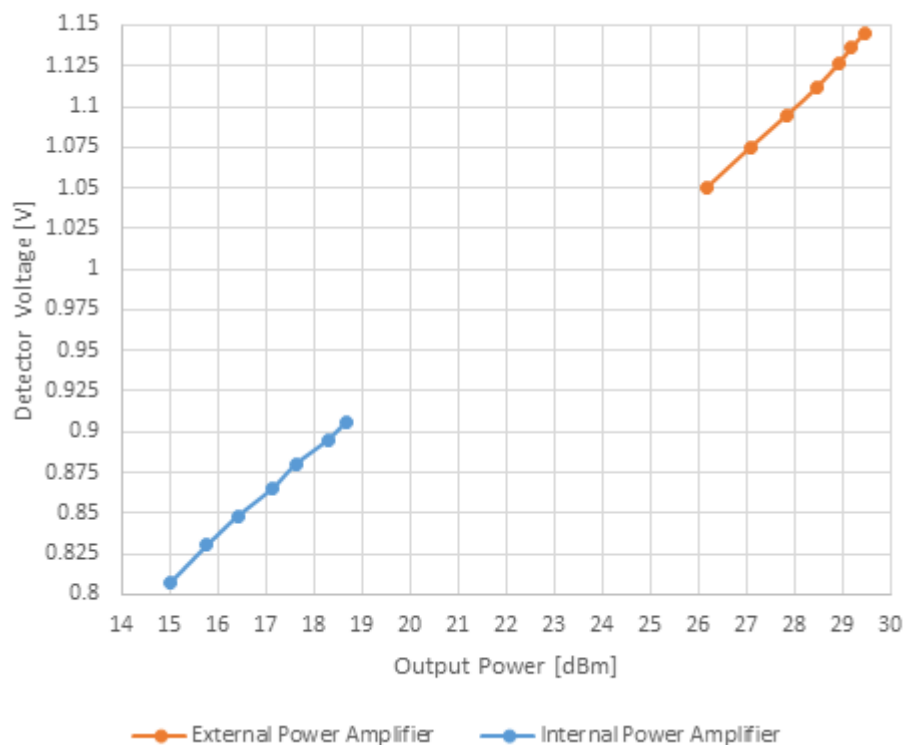
L1, L2 act as RF chokes, C12 and C14 are bypass capacitors. After the Balun the output power of the internal power amplifier can be measured as being approximately 21 dBm when switched to the short range configuration. The output of the external power amplifier and the output of the internal power amplifier are connected to an RF-switch, which can be controlled via the GUI of the ST25RU3993-EVAL reader. Only one power amplifier option can be active at a time.

Note that in a typical reader design only one power amplifier option will be used depending on the application and read range requirements. So for a commercial reader design the RF-switch will be removed and so it's introduced insertion loss of ~0.5 dB.

The RF-switch requires DC blocking capacitors on all its RF terminal. The output of the RF-switch is connected to a low pass filter, which should attenuate the second and third harmonic of the carrier frequency.

The filtered transmit signal is then connected to a 20 dB directional coupler, which takes a portion of the transmit power (<10 mW). This sample power is further attenuated by a pi-pad attenuator to limit the input power of the logarithmic power detector. The power detector generates a DC voltage, which corresponds to the transmit power. The characteristic of output DC voltage of the power detector versus the generated RF power is shown in the chart below.

Figure 6. Power detector voltage characteristic



The DC output of the power detector is connected to an ADC (PA1) of the microcontroller.

After the 20 dB directional coupler the main directional coupler is placed, which has a coupling factor of 10 dB. The purpose of this device is to isolate the transmit signal from the receiving inputs of ST25RU3993 and has thereby a major influence on the sensitivity of the reader.

The output port of the main directional coupler is connected to a second RF-switch that allows to direct the transmit power to either antenna port 1 or antenna port 2. The RF-switch again requires DC blocking capacitors on all its RF terminal. The antenna ports both are of SMB (female) type.

In order to maintain the sensitivity of the reader the self-jamming signal reaching the receive inputs of ST25RU3993 need to be minimized. The self-jamming signal comprises of reflections from the antenna (S11) and

the leakage across the main directional coupler. To minimize the self-jamming signal a carrier cancellation circuit is connected to the coupled port of the main directional coupler.

The carrier cancellation circuit is able to change its impedance and thereby is able to reflect a certain amount of the coupled power back into the directional coupler again. This reflected signal will combine at the isolated port of the main directional coupler with the self-jamming signal. The isolated port of the main directional coupler is connected to the receive pins of ST25RU3993. In theory, if the signal reflected by the carrier cancellation circuit has the same amplitude and the opposite phase then the self-jamming signal would cancel-out and vanishes.

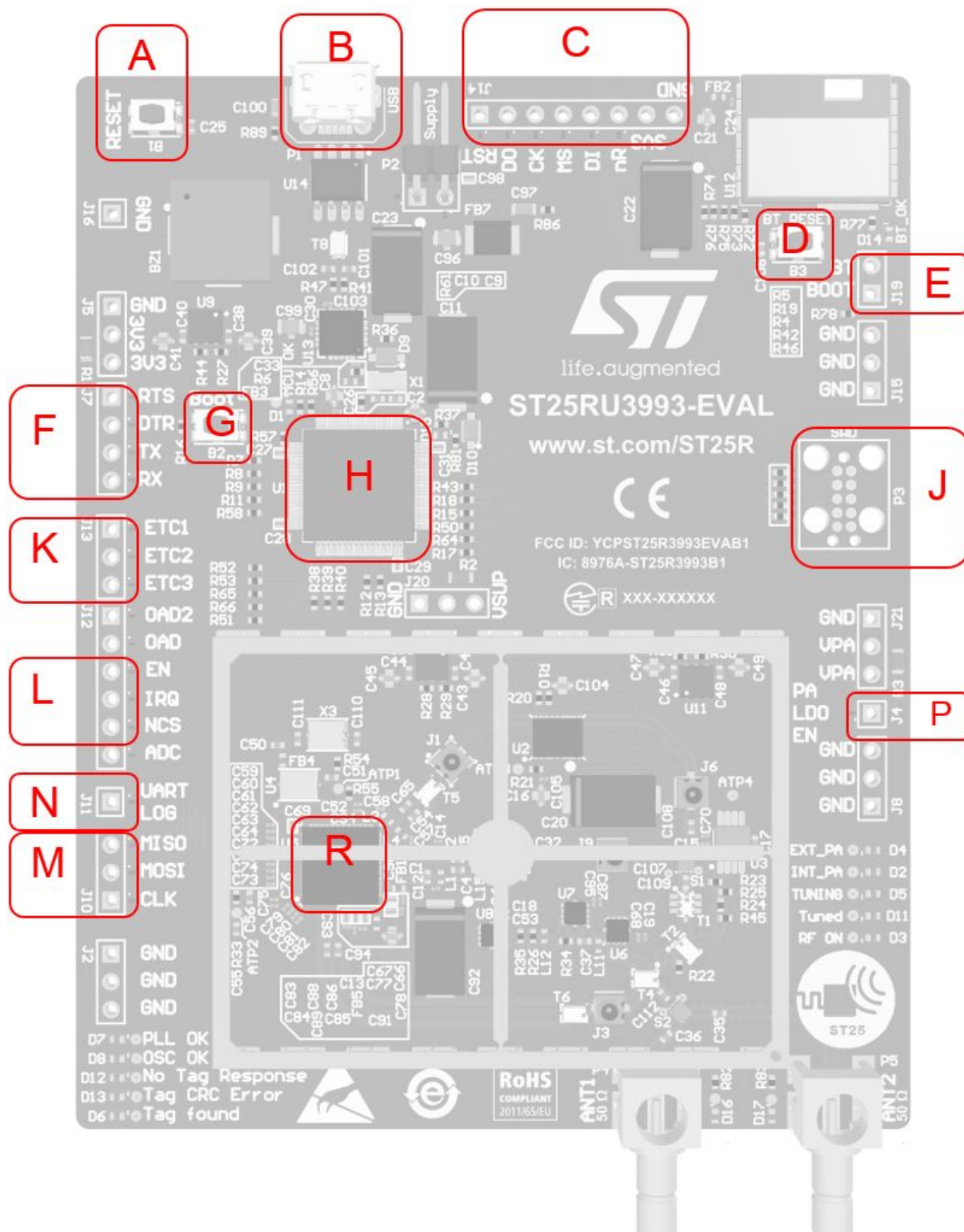
To find the impedance setting of the carrier cancellation circuit that would result to a self-jamming signal cancellation the power of the self-jamming signal needs to be measured. Such a measurement capability is provided by ST25RU3993 and is referred to as reflected power measurement. An optimal impedance setting of the carrier cancellation circuit would result to low reflected power measurement result. The main components of the carrier cancellation circuit are three digital tunable capacitors, which are controlled by the STM32L476RG microcontroller via the SPI interface. The fixed lumped components of the carrier cancellation circuit help to center its impedance to 50 Ω and define the impedance step created by one LSB change of a digital tunable capacitor.

The isolated port of the main directional coupler is connected to a 2:1 Balun to transform the incoming tag response signal to a 100 Ω differential signal that is fed into ST25RU3993 at the pins MIX_INP (4) and MIX_INN (6).

5.2 Microcontroller and connections

Table 2. MCU interfaces and buttons

Button	Description
A	MCU reset button
B	USB receptacle: micro, B-type
C	JTAG interface: for BT module programming
D	BT module reset button (not installed)
E	BT module boot mode jumper (not installed)
F	UART interface connections
G	MCU Boot mode button
H	STM32L476RGT6 (Arm® 32-bit Cortex®-M4)
J	SWD debug interface connections
K, L and M	SPI debug interface connections
N	UART_LOG connection for debugging purposes
P	Enable power amplifier LDO
R	ST25RU3993 RAIN® (UHF) RFID reader device

Figure 7. Main digital interfaces


The ST25RU3993-EVAL is controlled by STM32L476RGTH (U1), which is an ultra-low-power microcontroller with FPU Arm® 32-bit Cortex®-M4 MCU 80 MHz with 1 Mbyte Flash, LCD, USB OTG, DFSDM.

STM32L476RGT6 is supplied by 3.3 volts, which is regulated by an LDO (U9). The clock source for STM32L476RGT6 is an external crystal (X1) generating 32.768 kHz and is connected to OSC32_in (3) and OSC32_out (4).

The STM32L476RGT6 microcontroller communicates with the host PC via UART for which an USB/UART bridge is used.

The STM32L476RGT6 communicates with ST25RU3993 (U5) by the SPI interface, the ENABLE and IRQ line. The SPI interface operates in mode 1 with a 4 MHz serial clock. The SPI interface is also used to control the digital tunable capacitors for the carrier cancellation circuit.

The STM32L476RGT6 also controls the RF switches for changing the power amplifier and changing the active antenna port. The analog output of the RF power detector is connected to one of the ADC inputs (PA1) of STM32L476RGT6 to convert the RF power into a digital format. The LDO (U11) for the external power amplifier is controlled by the STM32L476RGT6, which completely shuts down the external power amplifier when RF power needs to be OFF. E.g. Carrier Sense (LBT).

One pin (UART LOG) is reserved to act as a generic debug pin that can be programmed as a trigger pin for an external measurement equipment. The optional (not installed) BT module connects with the STM32L476RG with its second UART interface.

Table 3. MCU - SPI interface and ST25RU3993 connections

Component: U1		Component: U5		Component: U6		Component: U7		Component: U8	
MCU pin name	MCU pin number	ST25RU3993 pin name	ST25RU3993 pin number	DTC1 pin name	DTC1 pin number	DTC2 pin name	DTC2 pin number	DTC3 pin name	DTC3 pin number
PA4	20	NCS	33	-	-	-	-	-	-
PA5	21	CLK	37	CLK	5	CLK	5	CLK	5
PA6	22	MISO	34	-	-	-	-	-	-
PA7	23	MOSI	35	SDAT	7	SDAT	7	SDAT	7
PC7	38	-	-	-	-	-	-	SEN	6
PC8	39	-	-	-	-	SEN	6	-	-
PC9	40	-	-	SEN	6	-	-	-	-
PA9	42	IRQ	32	-	-	-	-	-	-
PA10	43	EN	31	-	-	-	-	-	-

Table 4. SPI interface pinout at J10, J12 and J13

Component: U5		Component: U6		Component: U7		Component: U8		J10	J12	J13
ST25RU3993 pin name	ST25RU3993 pin number	DTC1 pin name	DTC1 pin number	DTC2 pin name	DTC2 pin number	DTC3 pin name	DTC3 pin number			
SCLK	37	CLK	5	CLK	5	CLK	5	1	-	-
MISO	34	-	-	-	-	-	-	3	-	-
MOSI	35	SDAT	7	SDAT	7	SDAT	7	2	-	-
-	-	-	-	-	-	ETC3 SEN	6	-	-	3
-	-	-	-	ETC2 SEN	6	-	-	-	-	2
-	-	ETC2 SEN	6	-	-	-	-	-	-	1
OAD2	-	-	-	-	-	-	-	-	1	-
OAD	-	-	-	-	-	-	-	-	2	-
EN	31	-	-	-	-	-	-	-	3	-
IRQ	32	-	-	-	-	-	-	-	4	-
NCS	33	-	-	-	-	-	-	-	5	-
ADC	-	-	-	-	-	-	-	-	6	-

Table 5. UART connections and pinout

Component: U1		Component: U13		J7
MCU pin name	MCU pin number	FTDI pin name	FTDI pin number	Connector pin number
NRST	7	RTS	19	1
BOOT0	60	DTR	18	2
PA3	17	TXD	17	3
PA2	16	RXD	1	4

Table 6. MCU - connections to buttons

Component: U1		Component: B1		Component: B2	
MCU pin name	MCU pin number	Reset button pin name	Reset button pin number	Boot button pin name	Boot button pin number
NRST	7	1	1	-	-
NRST	7	4	4	-	-
BOOT0	60	-	-	2	2
BOOT0	60	-	-	5	5

Table 7. MCU - Connections to LEDs

Component: U1		D1	D2	D3	D4	D5	D6	D7	D8	D11	D12	D13	D16	D17
MCU pin name	MCU pin number	MCU_LED	intPA_LED	RF_LED	extPA_LED	TUNING_LED	TAG_LED	PLL_LED	OSC_LED	TUNED_LED	NO_RESP_LED	CRC_ERR_LED	ANT1_LED	ANT2_LED
PA0	14	1 (C)	-	-	-	-	-	-	-	-	-	-	-	-
PD2	54	-	1(C)	-	-	-	-	-	-	-	-	-	-	-
PC10	51	-	-	1(C)	-	-	-	-	-	-	-	-	-	-
PB4	56	-	-	-	1(C)	-	-	-	-	-	-	-	-	-
PC12	53	-	-	-	-	1(C)	-	-	-	-	-	-	-	-
PC6	37	-	-	-	-	-	1(C)	-	-	-	-	-	-	-
PB12	33	-	-	-	-	-	-	1(C)	-	-	-	-	-	-
PB13	34	-	-	-	-	-	-	-	1(C)	-	-	-	-	-
PC11	52	-	-	-	-	-	-	-	-	1(C)	-	-	-	-
PB14	35	-	-	-	-	-	-	-	-	-	1(C)	-	-	-
PB15	36	-	-	-	-	-	-	-	-	-	-	1(C)	-	-
PB2	28	-	-	-	-	-	-	-	-	-	-	-	1(C)	-
PB1	27	-	-	-	-	-	-	-	-	-	-	-	-	1(C)

Table 8. MCU - connections to RF switches

Component: U1		Component: S1		Component: S2	
MCU pin name	MCU pin number	PA switch pin name	PA switch pin number	Antenna switch pin name	Antenna switch pin number
PB0	26	V1	1	-	-
PC5	25	V2	3	-	-
PB10	29	-	-	V1	1
PB11	30	-	-	V2	3

Table 9. MCU - connections to BT module

Component: U1		Component: S1	
MCU pin name	MCU pin number	BT module pin name	BT module pin number
PA11	44	RTS	12
PA12	45	CTS	11
PB6	58	RXD	13
PB7	59	TXD	14
PC13	2	RESETn	10
PB9	62	BOOT0	9

Table 10. MCU - connections to JTAG interface and pinout

Component: U12		Component: J14	
MCU pin name	MCU pin number	JTAG pin name	JTAG pin number
JNTRST	20	RST	1
JTDO	22	DO	2
JTCK	24	CK	3
JTMS	21	MS	4
JTDI	23	DI	5
NRST	19	nR	6
-	-	3V3	7
-	-	GND	8

Table 11. MCU - connections to JLINK (SWD) interface and Pinout of connector

Component: U1		Component: P3	
MCU pin name	MCU pin number	JLINK pin name	JLINK pin number
-	-	3V3	1
PA13	46	SWDIO	2
-	-	GND	3
PA14	49	SWCLK	4
-	-	GND	5
PB3	55	SWO	6
-	-	NC	7
PA15	50	TDI	8
-	-	NC	9
NRST	7	MCU_RESET_N	10

5.3 Firmware programming

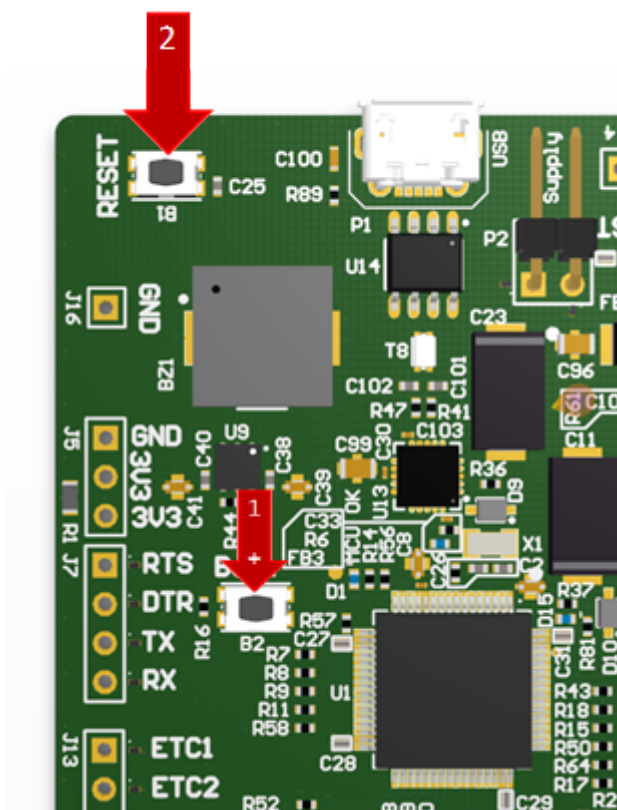
There are two options how to program the firmware of the STM32L476RG microcontroller:

1. The simplest way to program a new firmware version to the MCU is by connecting the ST25RU3993-EVAL board to the host PC with the micro USB cable and use the "Firmware Update" function of the GUI. For more information about this option refer to the user manual of the GUI.
2. Alternatively the firmware can be programmed to the MCU using the ST-LINK connecting to the JLINK (SWD) interface with an J-Link Needle Adapter (e.g.: Digkey: 899-1047-ND). For more information about this option refer to the user manual of the ST-LINK/V2.

5.4 Boot mode

To enter the boot mode of the STM32L476RG microcontroller press and hold the Boot button(1) then press the RESET button(2). At this point the boot mode is active and both buttons can be released.

Figure 8. Entering the boot mode



5.5 Power supply

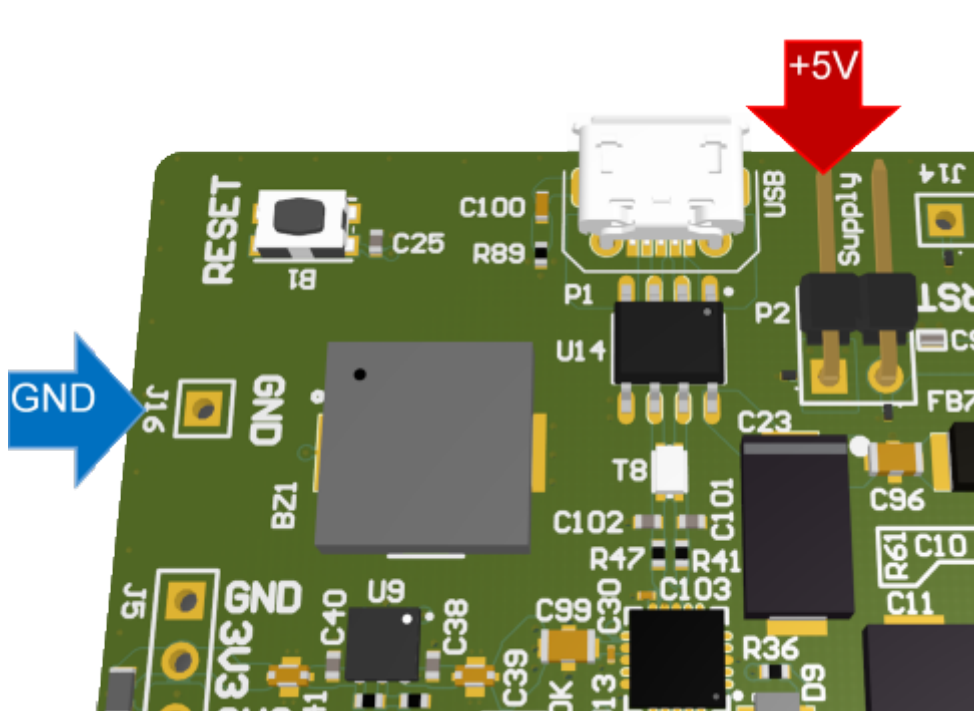
The ST25RU3993-EVAL is supplied by the USB 3.0 port of the host PC. An USB 3.0 port is required if the long range configuration using the external PA is set.

If an USB 3.0 port is not available an USB 2.0 Y-cable or an external power supply can be used to enable the long range capabilities of reader.

If neither is available only the short range reader configuration with lower RF power is available. If the ST25RU3993-EVAL board is configured as short range reader using the internal PA an USB 2.0 port would suffice.

In order to observe and measure the current consumption of the entire reader a 2-pin header is available. In normal operation this 2-pin header is shorted by a jumper. To measure the current consumption remove the jumper and connect an ampere meter in series instead.

To connect an external 5 V supply see [Figure 9](#).

Figure 9. Connecting an external supply voltage


The 5 V (VBUS) of the USB port is connected to three low-dropout regulators, which supply:

- Digital components
- RF components
- External power amplifier

For the digital components a 3.3 V supply is provided. RF components are supplied by 3.6 V and the external power amplifier is supplied by 4.1 V.

Table 12. Typical voltage levels

Voltage domain	Typical voltage level
3V3	3.33
VSUP	3.67
VPA	4.1

Table 13. Components connected to 5 V

5 V			
Schematic page	Component	Pin name	Pin number
Supply	U9, U10, U11	VI	6
Supply	U9, U10	EN	1
USB_Interface	U13	VCC	12

Table 14. Digital components connected to 3V3 (3.3 V)

3V3 (3.3 V)			
Schematic page	Component	Pin name	Pin number
External_Interfaces	P3	1	1
External_Interfaces	J14	7	7
External_Interfaces	U1	VBAT	1
Controller	U1	VDD	19, 32, 48, 64
Controller	U1	VDDA/VREF+ ⁽¹⁾	13
Controller	U1	NRST ⁽²⁾	7
Controller	U1	BOOT0 ⁽³⁾	60
Controller	D1-D8, D11-D13, D16, D17	-	1
Power_Amplifier	U3	VCC	8
UHF_RFID	U4	VCC ⁽⁴⁾	4
UHF_RFID	U5	VDD_IO	38
Carrier_Cancellation	U6, U7, U8	VDD	4
Bluetooth	U12	VIN ⁽⁵⁾	8
Bluetooth	U12	BOOT0 ⁽⁶⁾	9
Bluetooth	B14	-	1
USB_Interface	U12	VCCIO	20

1. Via ferrite bead FB3.
2. Via pull up resistor R61.
3. Via push button B2.
4. Via ferrite bead FB4.
5. Via ferrite bead FB2.
6. Via J19.

Table 15. Components connected to VSUP (3.6 V)

VSUP (3.6 V)			
Schematic page	Component	Pin name	Pin number
UHF_RFID	U5	VEXT ⁽¹⁾	11
UHF_RFID	U5	VEXT_PA ⁽²⁾	14

1. Via ferrite bead FB5.
2. Via ferrite bead FB1.

Table 16. Components connected to VPA (4.1 V)

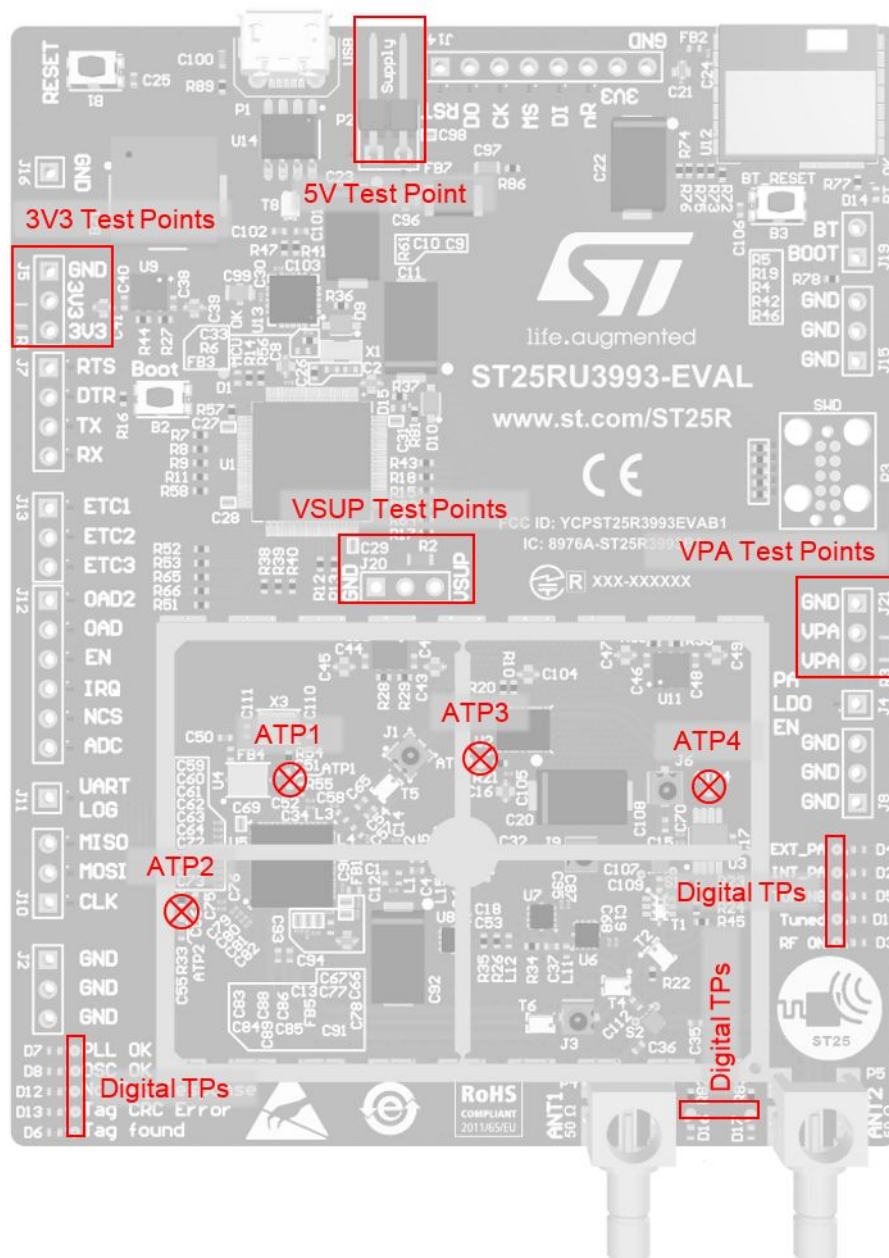
VPA (4.1 V)			
Schematic page	Component	Pin name	Pin number
Power_Amplifier	U2	VPD1	12
Power_Amplifier	U2	VPD2	11
Power_Amplifier	U2	VCC	2
Power_Amplifier	U2	VBIAS ⁽¹⁾	1

1. Via R21.

5.6 Test Points

The ST25RU3993-EVAL board provides numerous test points to test and to evaluate the ST25RU3993 reader device, and important circuit nodes in the reader design.

Figure 10. Test points



5.6.1 Analog test points

Table 17. Analog test point connections

Component: U5		Component: U2		Component: U3		Analog test point
ST25RU3993 pin name	ST25RU3993 pin number	PA pin name	PA pin number	Power det. pin name	Power det. pin number	
OSCO	30	-	-	-	-	ATP1
VCO (LF_CEXT)	45	-	-	-	-	ATP2
-	-	VBIAS	1	-	-	ATP3
-	-	-	-	OUT	7	ATP4

5.6.2 Supply voltage test points

Table 18. Supply voltage test points

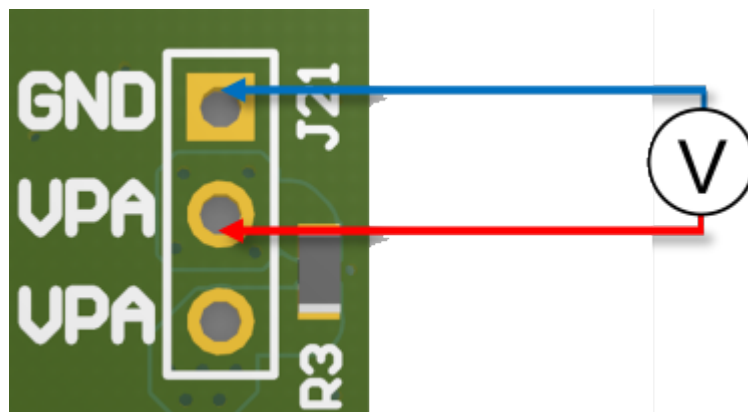
5 V external supply		3V3 digital supply		VSUP RF supply		VPA power amplifier supply	
P2		J5		J20		J21	
Pin number	Pin name	Pin number	Pin name	Pin number	Pin name	Pin number	Pin name
1	VBUS	1	GND	1	GND	1	GND
2	VBUS	2	3V3	2	VSUP	2	VPA
-	-	3	3V3	3	VSUP	3	VPA

Supply voltage measurement

At the output of each of the three LDOs two test points are placed in order to conveniently measure the regulated voltage of each voltage domain. A GND pad is placed directly next to the voltage test point to allow accurate voltage measurements.

Example:

Figure 11. Connection a voltmeter to the supply voltage test points

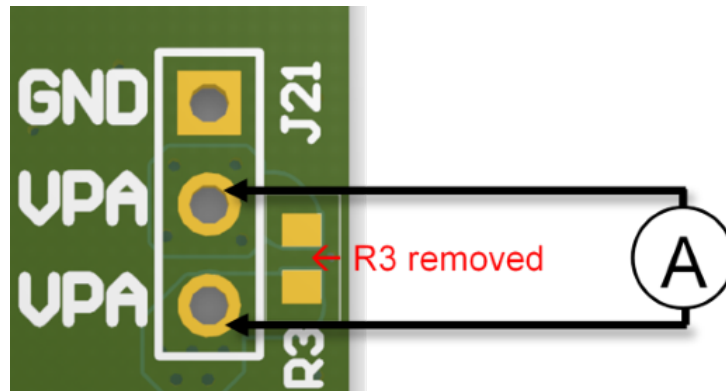


Current Consumption Measurement

The current consumption flowing into each of the three voltage domains can be measured separately. To enable this kind of measurement a 0 Ω resistor needs to be removed. Make sure to establish a connection again once the measurement is done reverting to normal operation.

Example:

Figure 12. Connection an ampere meter to the supply voltage test points



5.6.3 Digital test points

In addition to the four test points shown above a test point for each LED, connected to the STM32L476RG controller is placed.

PLL OK:

Indicates that the PLL of ST25RU3993 is locked and the carrier frequency is stable.

OSC OK:

Low active. Indicates that the reference frequency for the PLL is stable.

No Tag Response:

Is pulled low if the sent reader command is not replied by a tag.

Tag CRC Error:

Is pulled low if a CRC error is detected within a tag response.

Tag found:

Is pulled low every time a tag has been inventoried.

EXT_PA:

Is pulled low if the reader is in its long range configuration.

INT_PA:

Is pulled low if the reader is in its short range configuration.

TUNING:

Is pulled low if the reader currently is re-tuning the carrier cancellation circuit.

Tuned:

Low active. Indicates that the self-jamming signal is sufficiently suppressed.

RF ON:

Low active. Indicates that the RF carrier is ON.

ANT1:

Low active. Indicates that antenna port 1 is active.

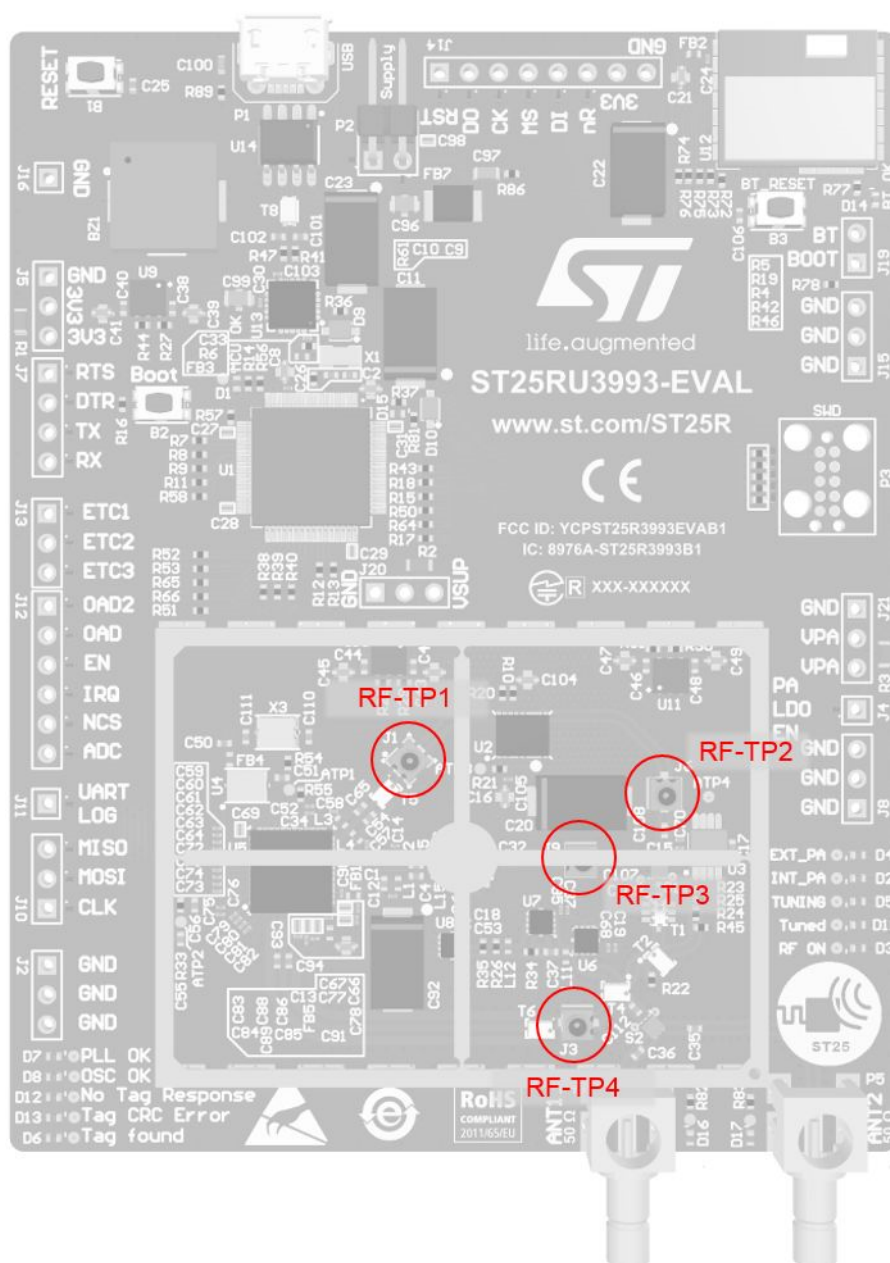
ANT2:

Low active. Indicates that antenna port 2 is active.

5.6.4
Probing RF signals

The ST25RU3993-EVAL board features four RF test points to measure RF power levels in-circuit. The [Figure 13](#) shows available RF test points.

Figure 13. RF test points



In order to make use of these test points a connection adapter is required. (e.g.: Digikey: MS-156-HRMJ-2).

Figure 14. Connecting to the RF test points with the SMB adapter



In the [Table 19](#) it is listed what typical power levels can be expected while the ST25RU3993-EVAL board is operating in its default configuration.

Table 19. RF test points - default power levels

RF test point	Description	Typical RF power level
RF-TP1	ST25RU3993 RF output signal (single-ended). Measure here to evaluate the power and the spectral properties of the RF signal at the 0-dBm output. This RF signal is the input for the external power amplifier.	-1.9 dBm
RF-TP2	External power amplifier RF output signal. Measure here to evaluate the power, Gain and the spectral properties of the RF signal at the output of the external power amplifier.	30.7 dBm
RF-TP3	Internal power amplifier RF output signal (single-ended). Measure here to evaluate the power and the spectral properties of the RF signal at the output of the internal power amplifier.	20.5 dBm
RF-TP4	RX signal. Measure here to evaluate the self-jammer signal or a RN16 tag response.	-14.5 dBm ⁽¹⁾ -25 dBm (with Poynting Patch-25 connected to antenna port 1)

1. Internal power amplifier.

6 Schematics

The following schematics are listed:

- [Figure 15. Schematic diagram of system overview](#)
- [Figure 16. Schematic of UHF RFID reader device](#)
- [Figure 17. Schematic of external power amplifier](#)
- [Figure 18. Schematic of carrier cancellation circuit](#)
- [Figure 19. Schematic of antenna switch](#)
- [Figure 20. Schematic of USB supply / UART bridge](#)
- [Figure 21. Schematic of microcontroller](#)
- [Figure 22. Schematic of supply LDOs](#)
- [Figure 23. Schematic of external interfaces and connections](#)
- [Figure 24. Schematic of BT classic module](#)
- [Figure 25. Schematic of RF shield](#)

Figure 15. Schematic diagram of system overview

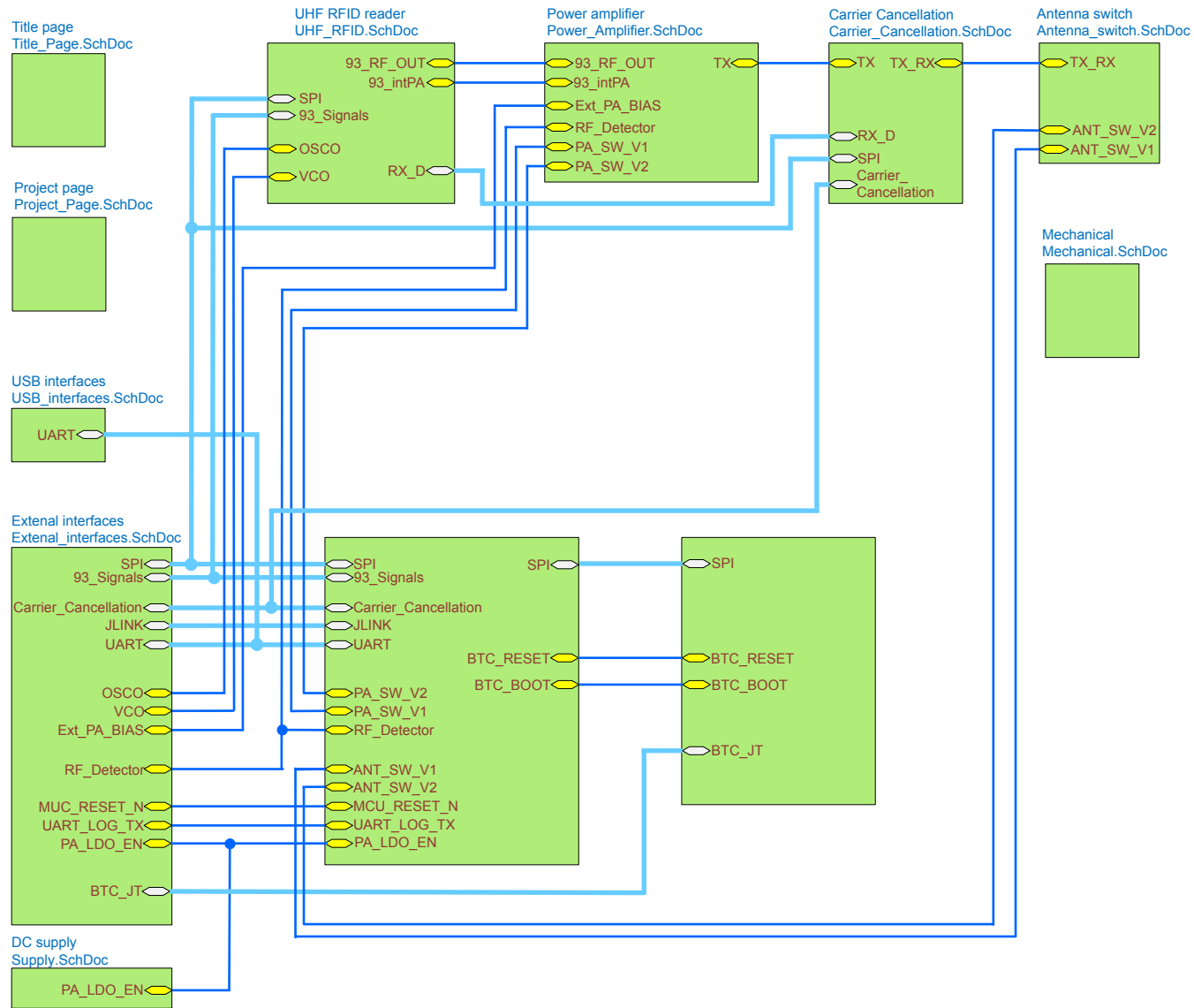


Figure 16. Schematic of UHF RFID reader device

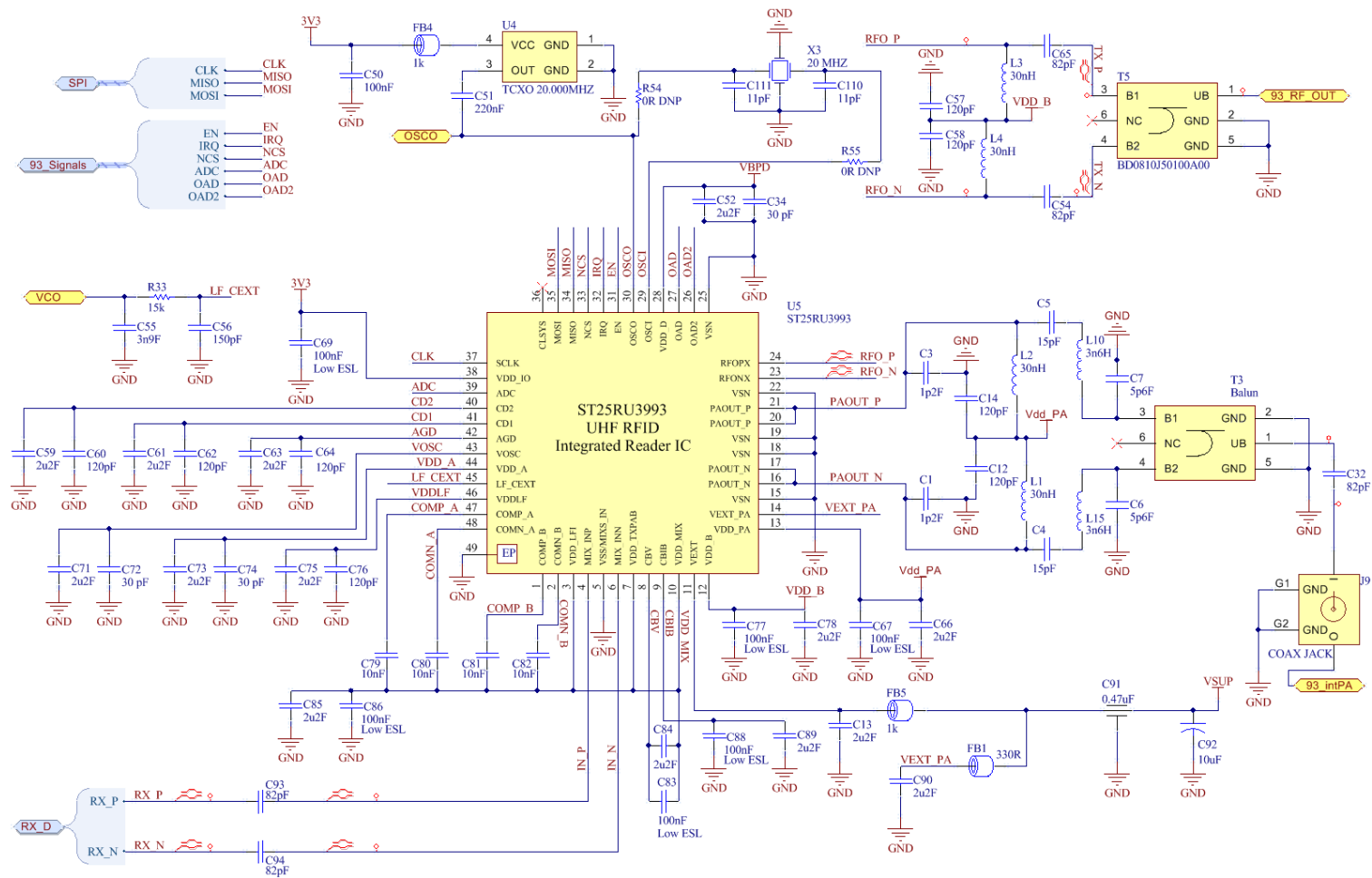
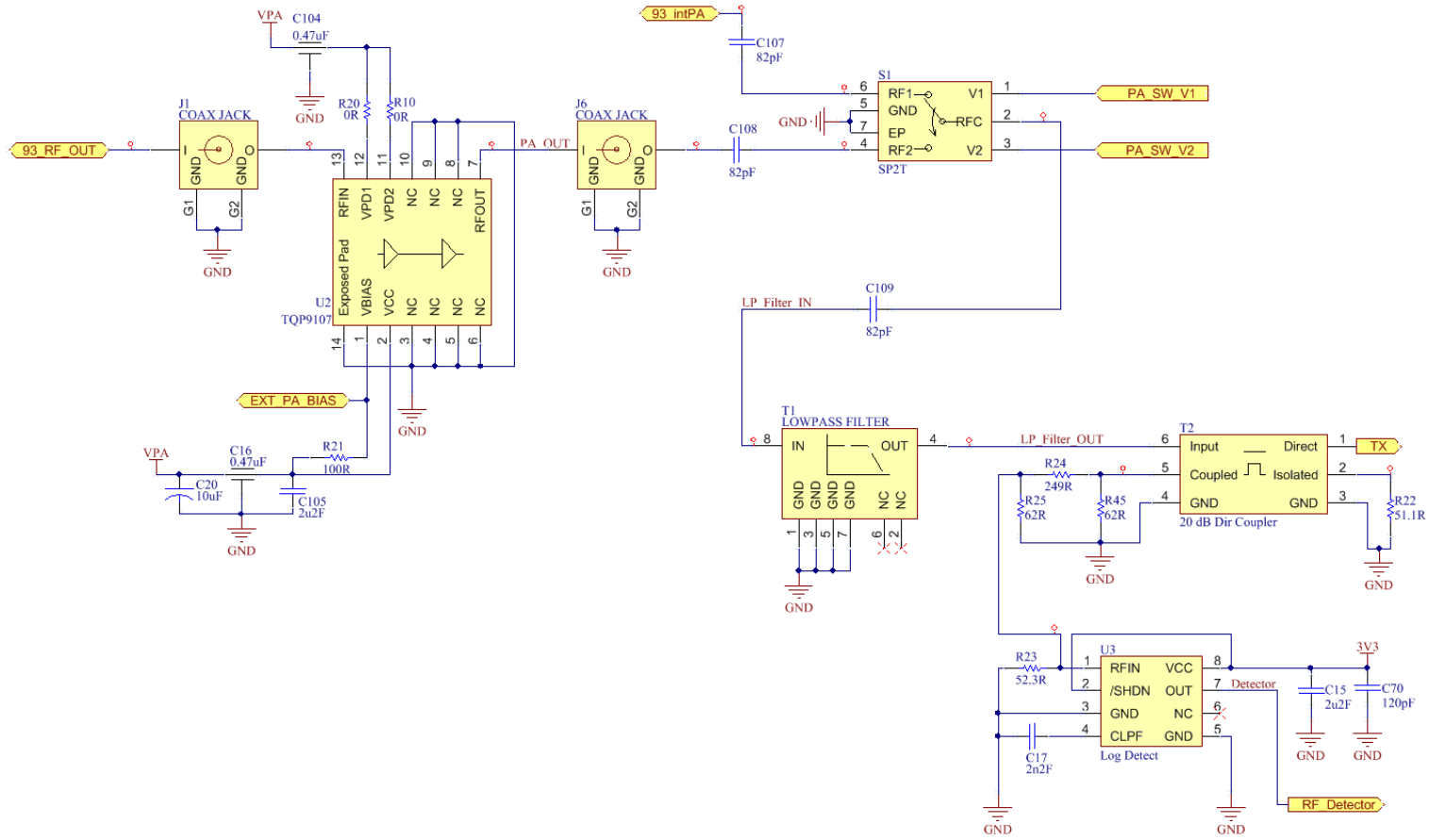


Figure 17. Schematic of external power amplifier



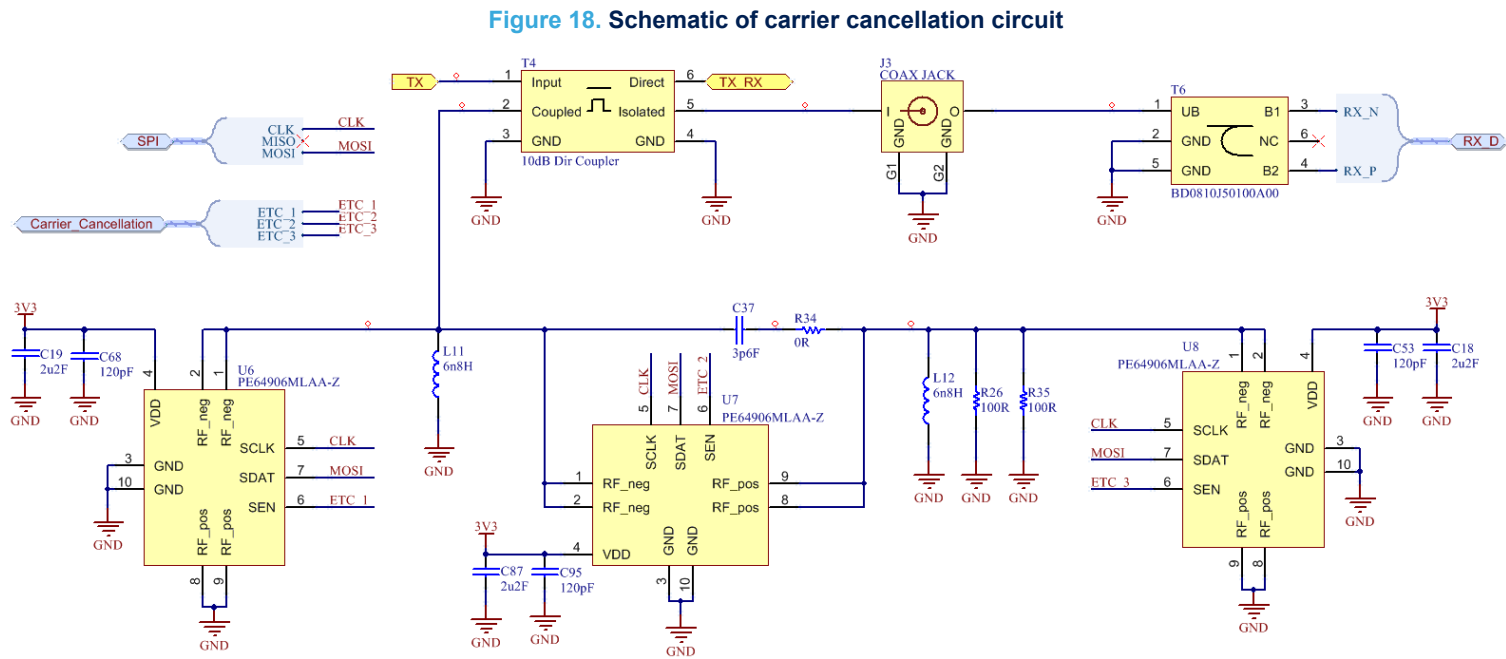


Figure 19. Schematic of antenna switch

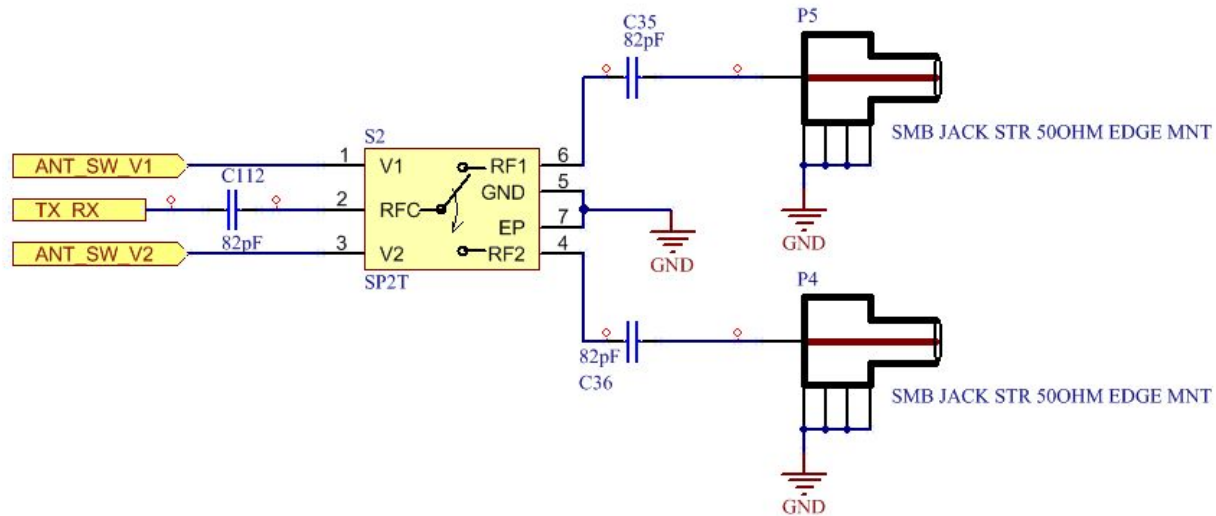


Figure 20. Schematic of USB supply / UART bridge

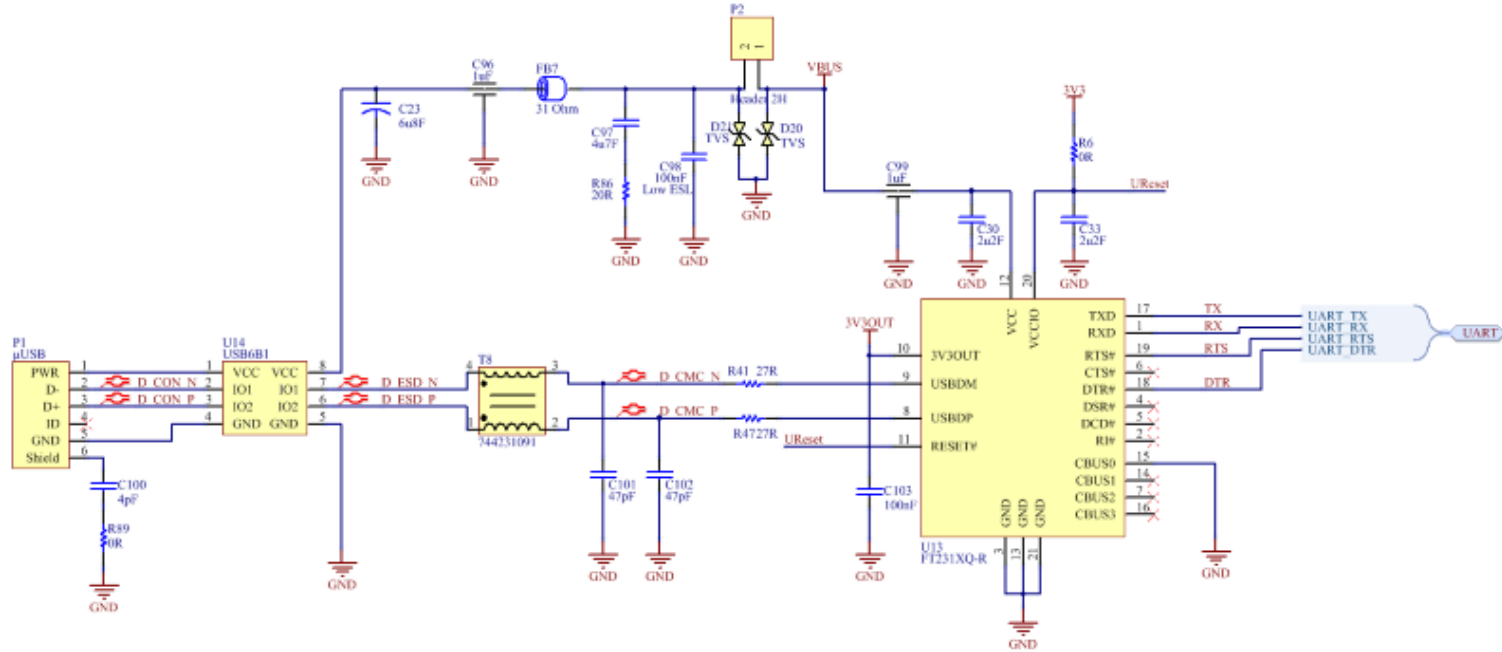
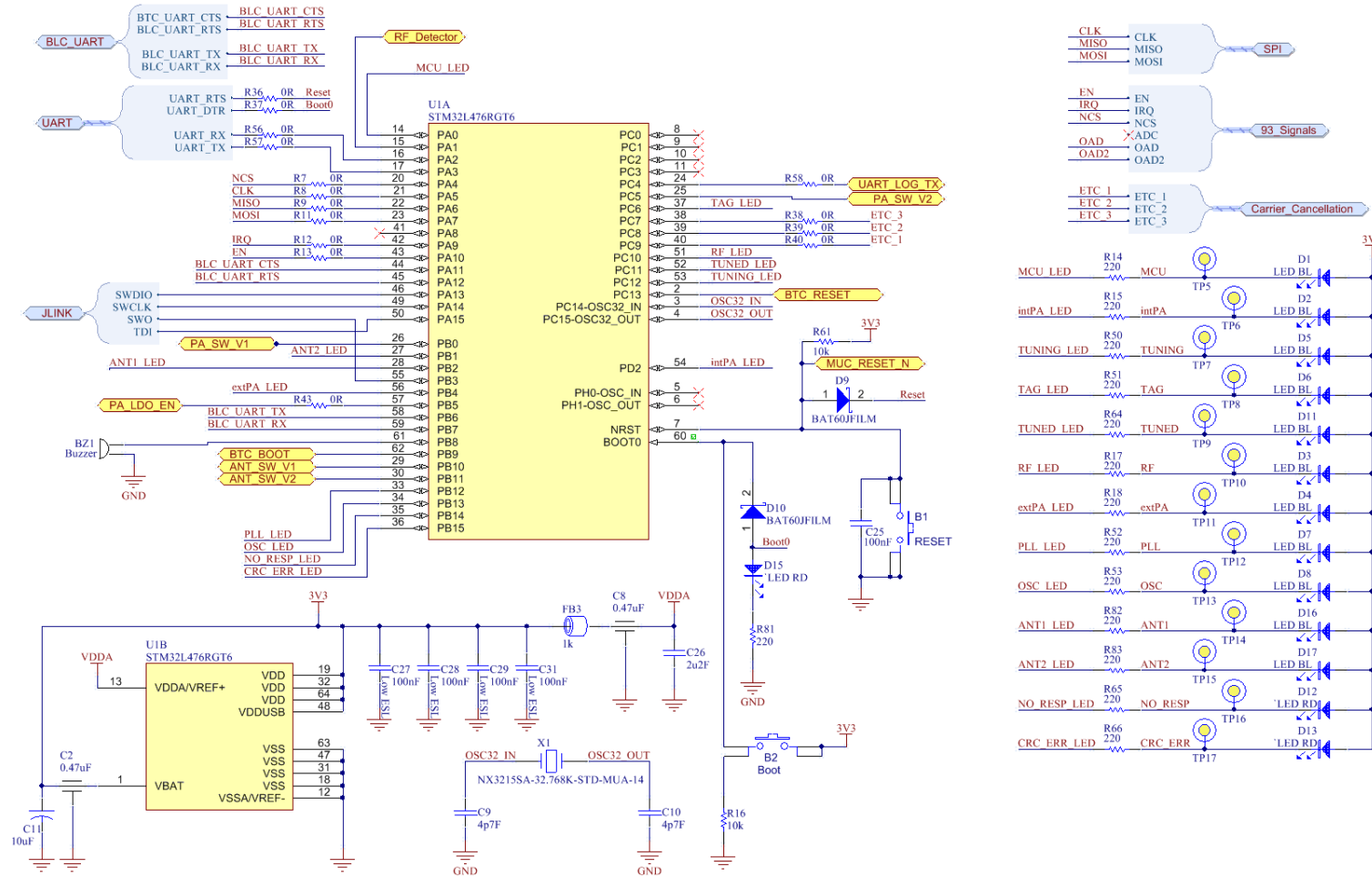


Figure 21. Schematic of microcontroller



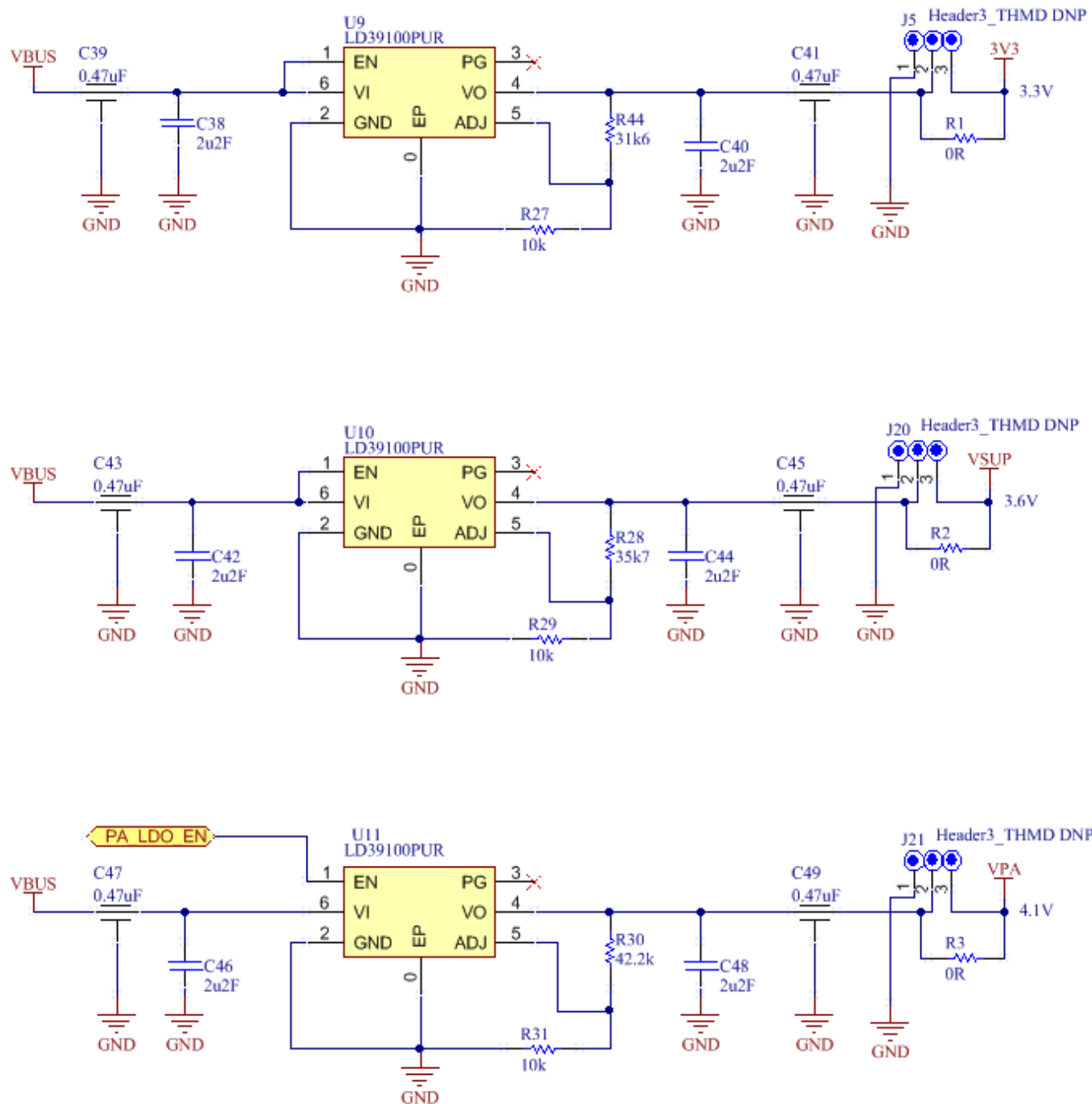


Figure 23. Schematic of external interfaces and connections

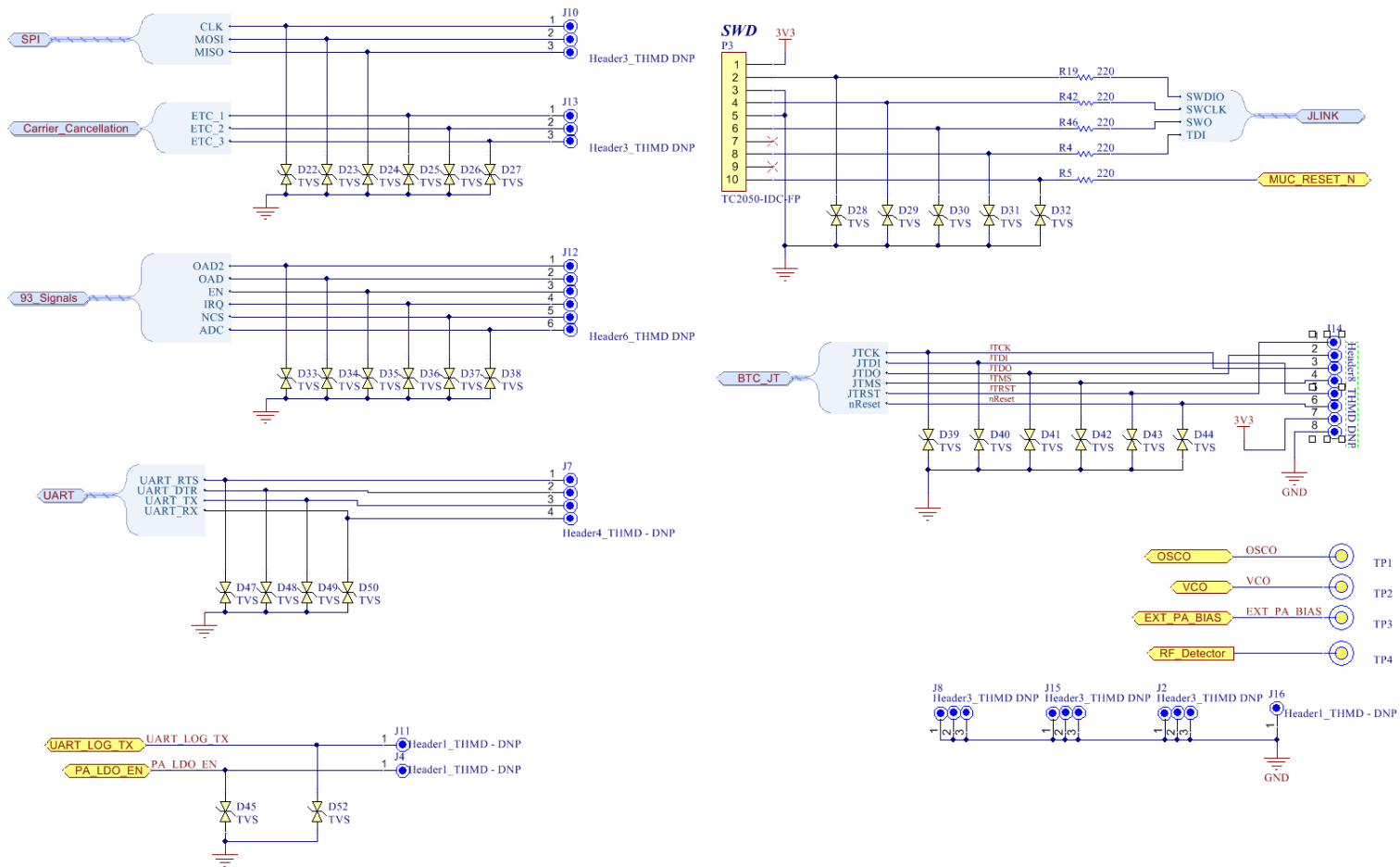


Figure 24. Schematic of BT classic module

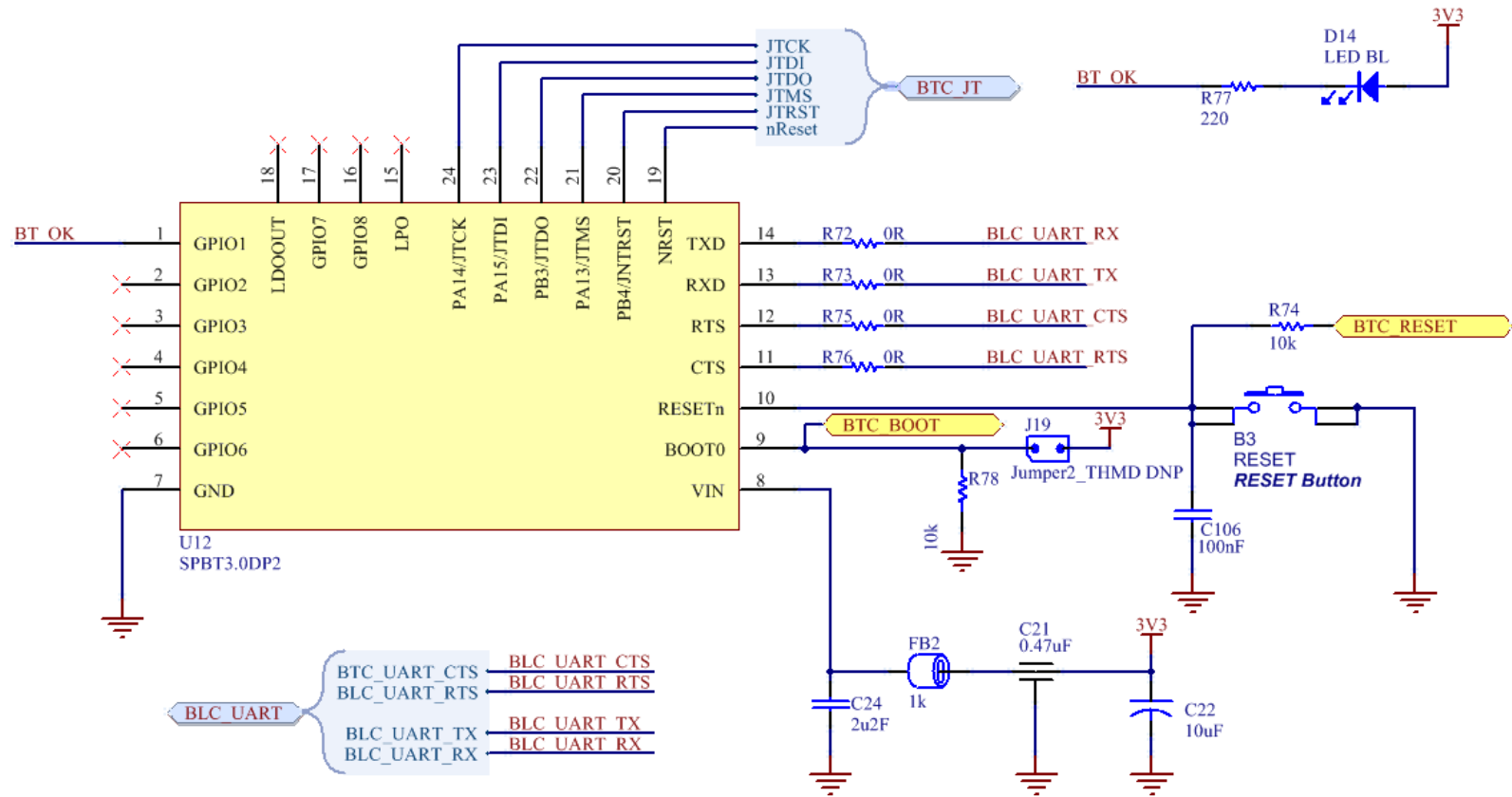
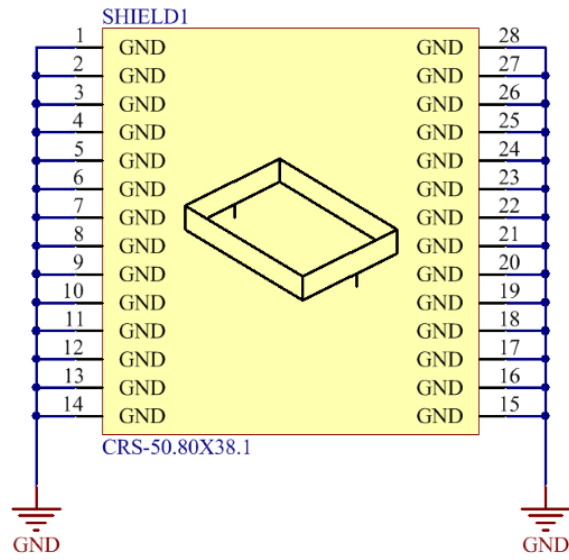


Figure 25. Schematic of RF shield



7 PCB stack up

The ST25RU3993-EVAL board has in total six layers. The dielectric material between all copper layers is FR-4 type. No blind or buried vias are used on the ST25RU3993-EVAL board.

Table 20. PCB layer stack

	Layer number	Layer name	Type	Material	Thickness [mm]	Dielectric material	Dielectric constant
	-	Top overlay	Overlay	-	-	-	-
	-	Top solder	Solder mask/coverlay	Surface material	0.01016	Solder resist	4.5
	1	Top layer	Signal	Copper	0.043	-	-
	-	Dielectric 1	Dielectric	Core	0.25	FR-4 (R-1755M)	4.7
	2	RF GND	Signal	Copper	0.032	-	-
	-	Dielectric 2	Dielectric	CORE	0.1	FR-4 (R-1755M)	4.6
	3	Power	Signal	Copper	0.032	-	-
	-	Dielectric 3	Dielectric	Core	0.1	FR-4 (R-1755M)	4.6
	4	GND	Signal	Copper	0.036	-	-
	-	Dielectric 5	Dielectric	Prepreg	0.1	FR-4 (R-1755M)	4.6
	5	Routing	Signal	Copper	0.036	-	-
	-	Dielectric 4	Dielectric	Core	0.25	FR-4 (R-1755M)	4.6
	6	Bottom GND	Signal	Copper	0.036	-	-
	-	Bottom solder	Solder mask/coverlay	Surface material	0.01016	Solder resist	4.5
	-	Bottom overlay	-	-	-	-	-

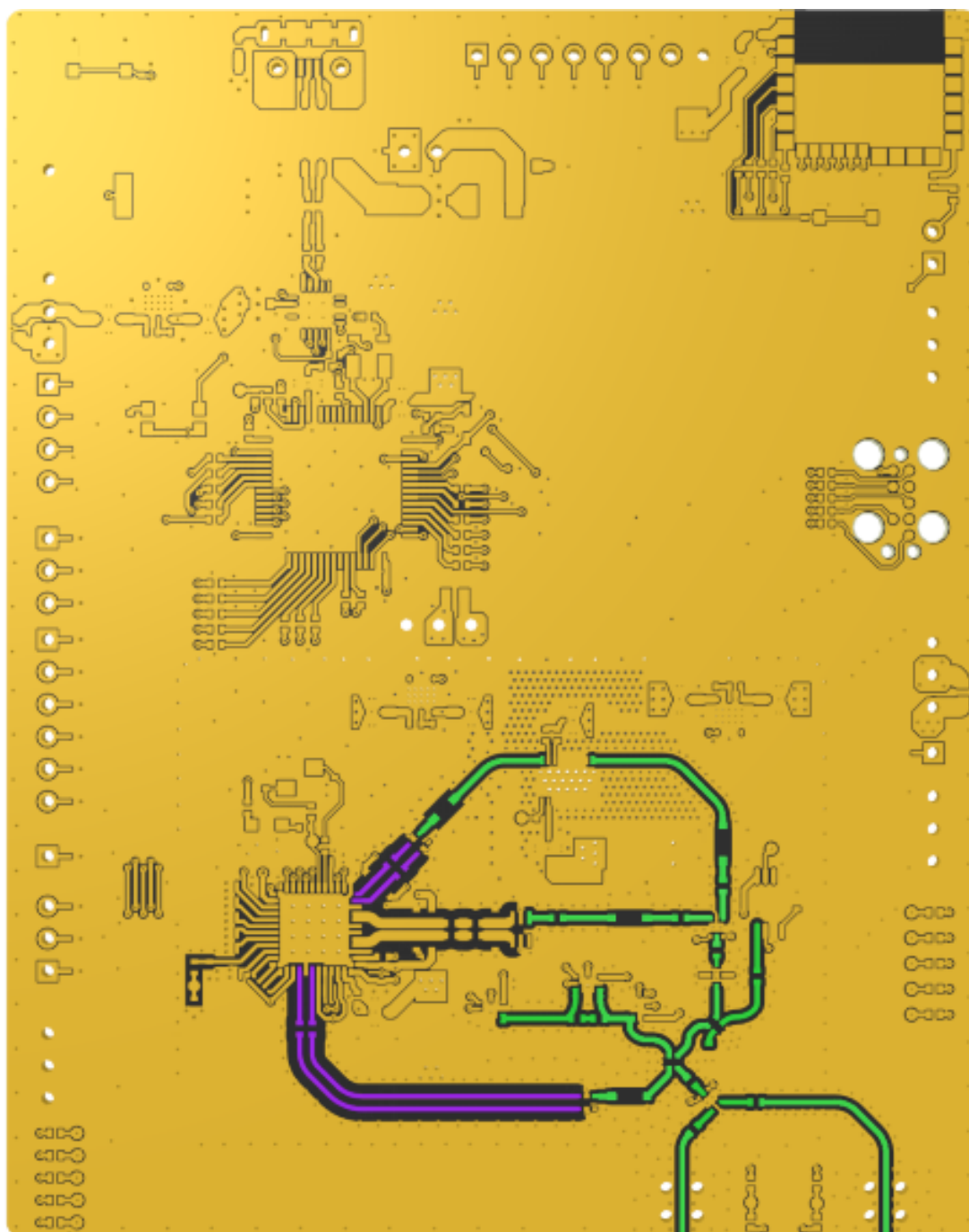
8 **PCB layout**

The ST25RU3993-EVAL board has six layers. The sections below show each layer and provide additional information.

8.1 Top layer

On the Top layer all components are placed. Therefore all component connections are done on this layer. All RF routing including 50 Ω - coplanar wave guide with ground plane, 100 Ω differential traces are done on the top layer. Ground terminals of components have no thermal relief-connect to the ground plane.

Figure 27. Layout - top layer

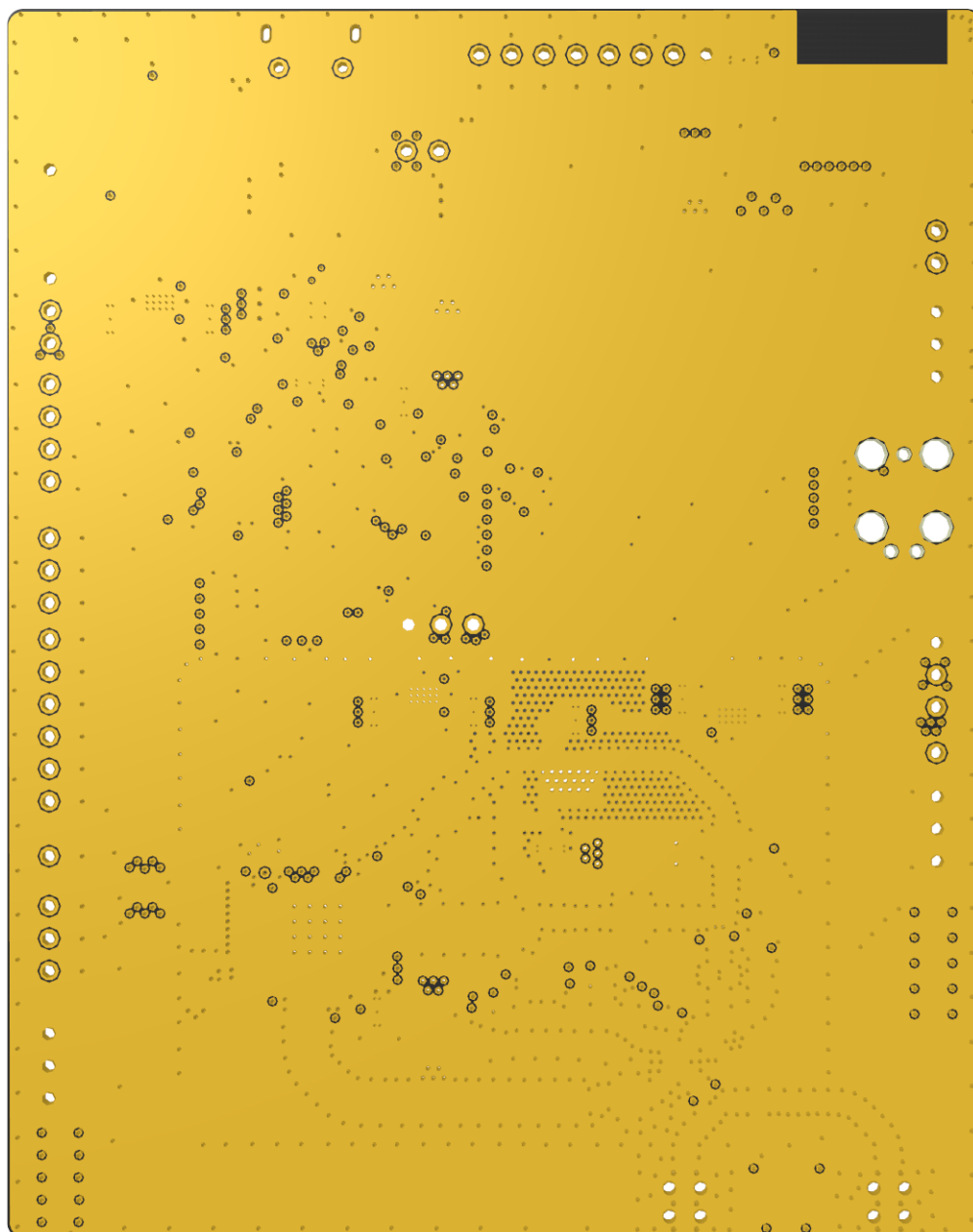


1. Green line = 50 Ω coplanar wave-guides with ground floor.
 Blue line = 100 Ω differential wave-guides

8.2 RF GND layer

The RF GND layer directly below the top layer is needed for the 50 Ω and 100 waveguide traces. The spacing between top layer and RF GND layer is relevant for the impedance of the wave-guides. RF currents tend to run back to its source directly underneath the wave-guides. So it is important that the underlying RF GND layer is solid and uninterrupted providing a direct path for the RF currents. If a trace on this layer would run underneath a waveguide trace slicing the ground plane an unwanted slot antenna may have been created. Therefore it is recommended to avoid routing traces on this layer.

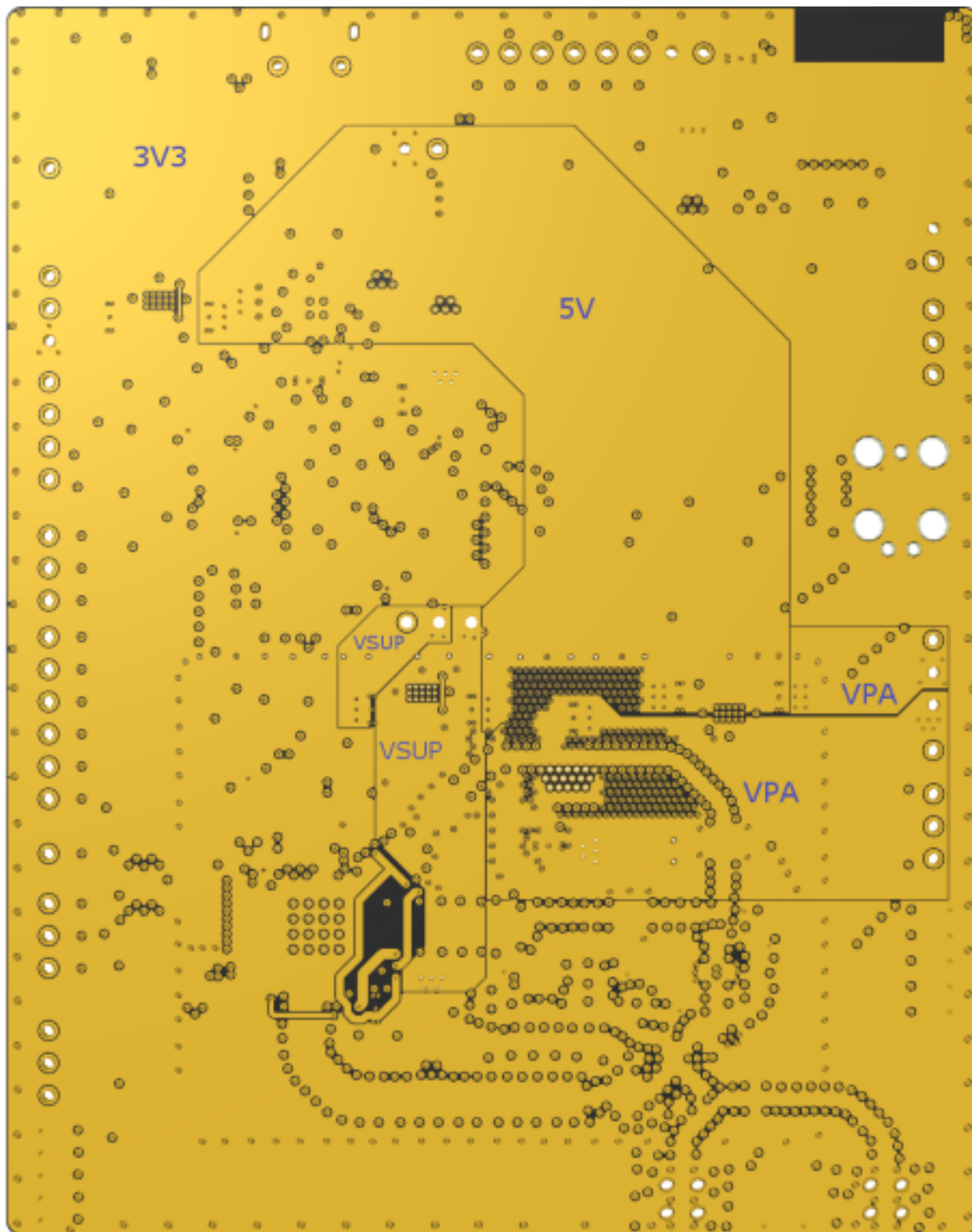
Figure 28. Layout - RF GND layer



8.3 Power layer

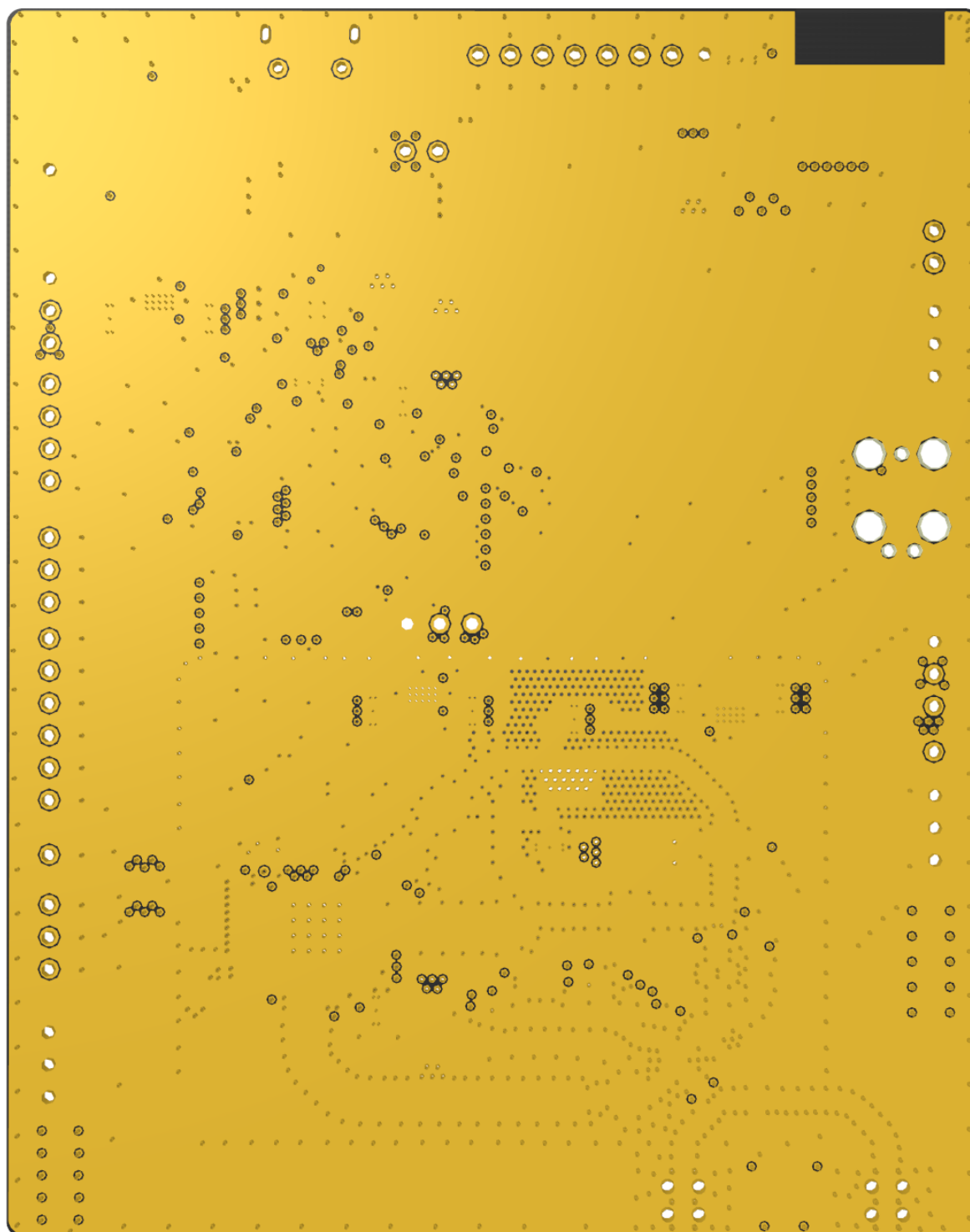
The power layer is used to distribute the supply voltages through power planes as well as with few traces.

Figure 29. Layout - Power layer



8.4 GND layer

Figure 30. Layout - GND layer

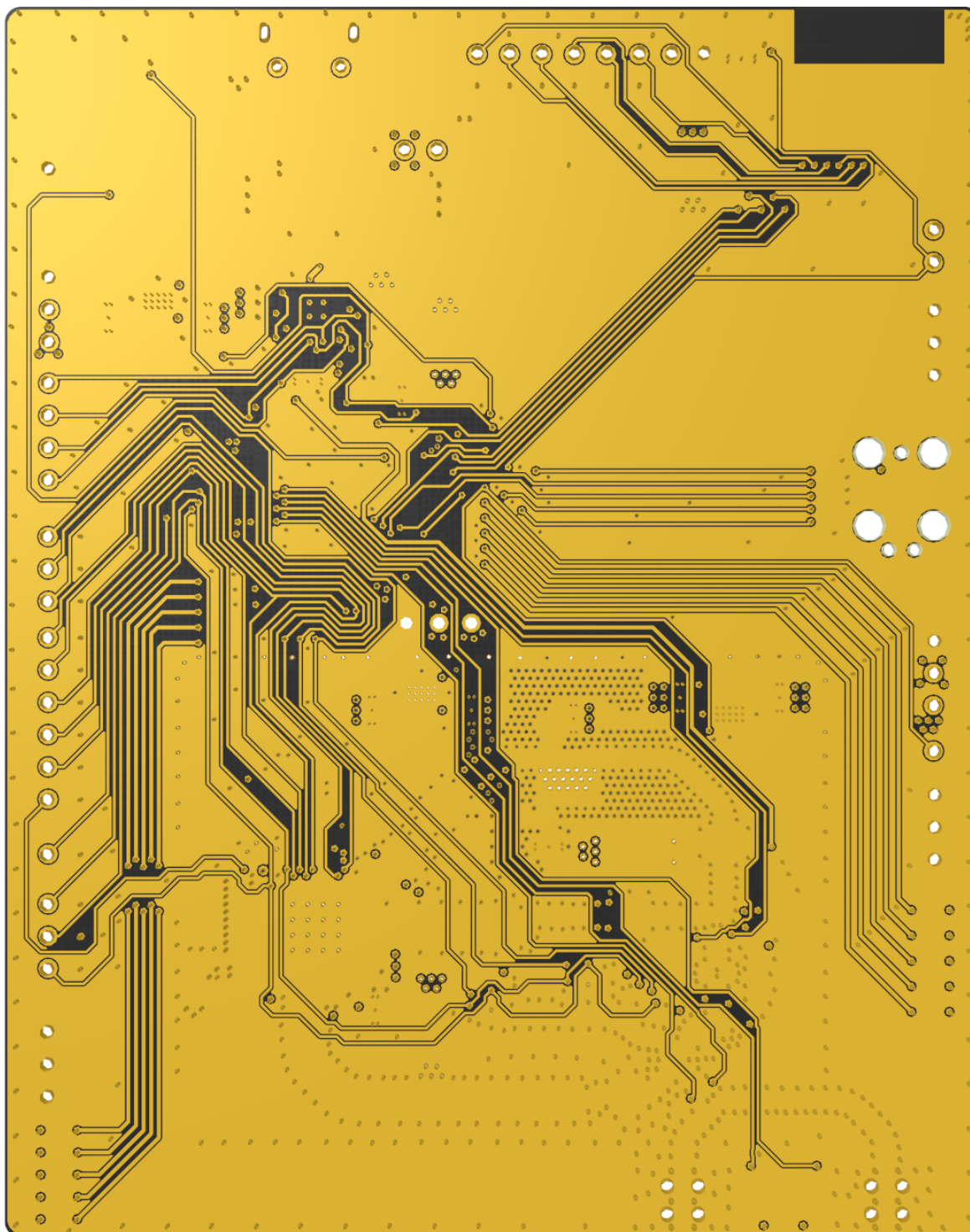


8.5

Routing layer

The Routing layer is used to interconnect the components, which help to minimize cross-talk effects on RF traces.

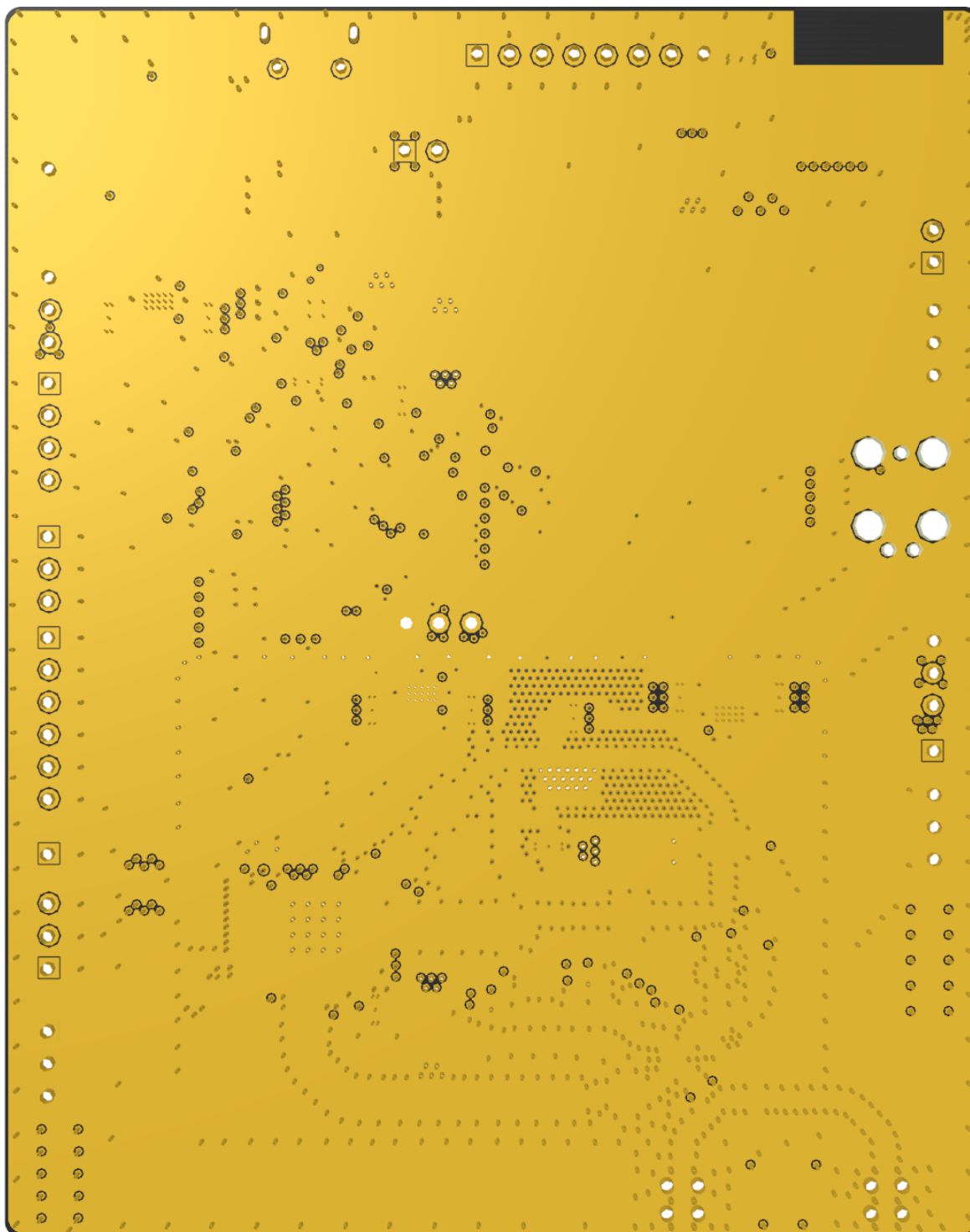
Figure 31. Layout - Routing layer



8.6 Bottom layer

The bottom layer mostly consists of a GND plane, which acts as a shield for the above lying Routing layer.

Figure 32. Layout - Bottom layer



9 Federal Communications Commission (FCC) and Industry Canada (IC) compliance statements

9.1 FCC Compliance Statement

9.1.1 Part 15.19

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.

9.1.2 Part 15.21

Any changes or modifications to this equipment not expressly approved by STMicroelectronics may cause harmful interference and void the user's authority to operate this equipment.

9.2 IC Compliance Statement

9.2.1 Compliance Statement

This device complies with Industry Canada license-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation.

9.2.2 Déclaration de conformité

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Revision history

Table 21. Document revision history

Date	Revision	Changes
04-Apr-2018	1	Initial release.
12-Nov-2018	2	Updated: • Introduction, Section 4 ST25RU3993-EVAL board features, Section 5.1 RF circuit, Section 5.3 Firmware programming • Figure 1. ST25RU3993-EVAL board (top view), Figure 3. Functional block diagram, Figure 7. Main digital interfaces, Figure 10. Test points, Figure 13. RF test points, Figure 14. Connecting to the RF test points with the SMB adapter, Section 6

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