UM2742
User manual

High-power RFID reader system based on ST25RU3993

Introduction

The ST25RU3993-HPEV is a high-power RAIN® (UHF) RFID reader system based on the integrated reader IC ST25RU3993.

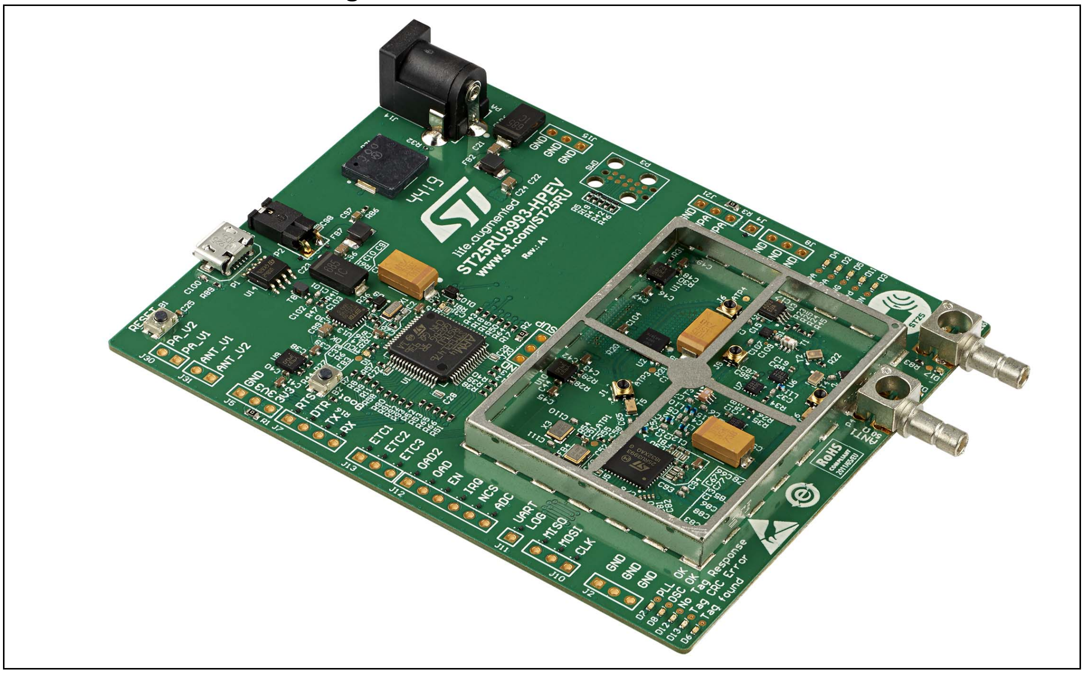
The purpose of ST25RU3993-HPEV is to provide a comprehensive RAIN RFID reader system that allows the user to evaluate the properties and the features of ST25RU3993. To achieve this goal the ST25RU3993-HPEV board, differently from a typical reference design approach, combines a high RF power and a low RF power RFID reader on a single PCB.

Additionally, the ST25RU3993-HPEV board has been outfitted with numerous easy to access test points and measurement possibilities. With minor modification effort it is possible to change the architecture of the reader. For example, it is possible to control the RF circuitry with external MCU or vice versa. Bypassing the external on-board power amplifier or alternate antenna configurations are additional possibilities.

The ST25RU3993-HPEV is controlled by a graphical user interface (GUI) running on a host PC. The corresponding interface is a USB/UART bridge (requires driver installation). The GUI can be found on dedicated pages on www.st.com.

The board supports tuning the radio frequency from 840 to 960 MHz. and provides two SMB (male) antenna connectors that can be controlled via the GUI. To enable scanning for RAIN RFID transponders connect a suitable 50 Ω UHF antenna for the targeted frequency range.

Figure 1. ST25RU3993-HPEV board



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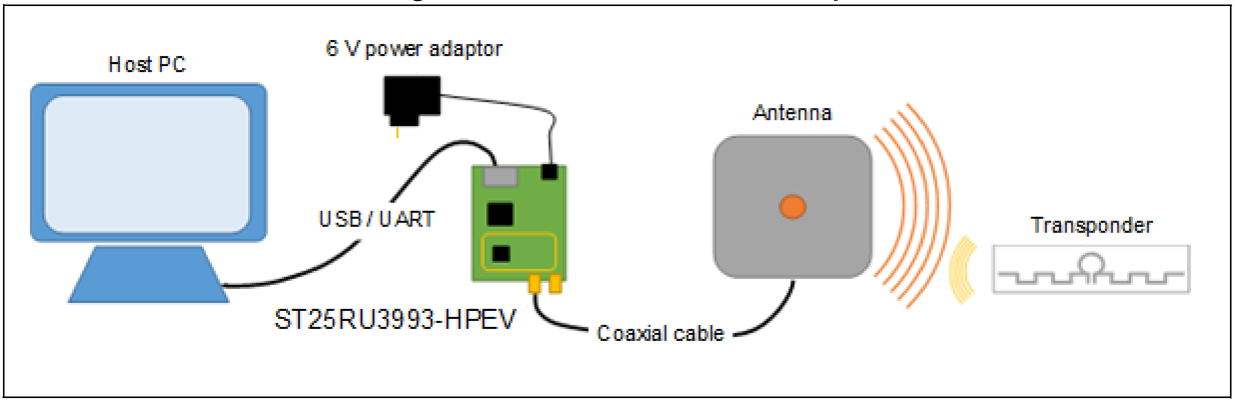
The typical reader setup is shown in *Figure 2*.

Figure 2. Standard connection setup



The host PC running the GUI is connected via a Micro-USB cable. The external power amplifier on the ST25RU3993-HPEV board is powered through the 6 V power adapter and must be connected when the external PA TX option is used. The antenna is connected to the active antenna port through a coaxial cable. A transponder is within the antenna range.

1.1 Board features

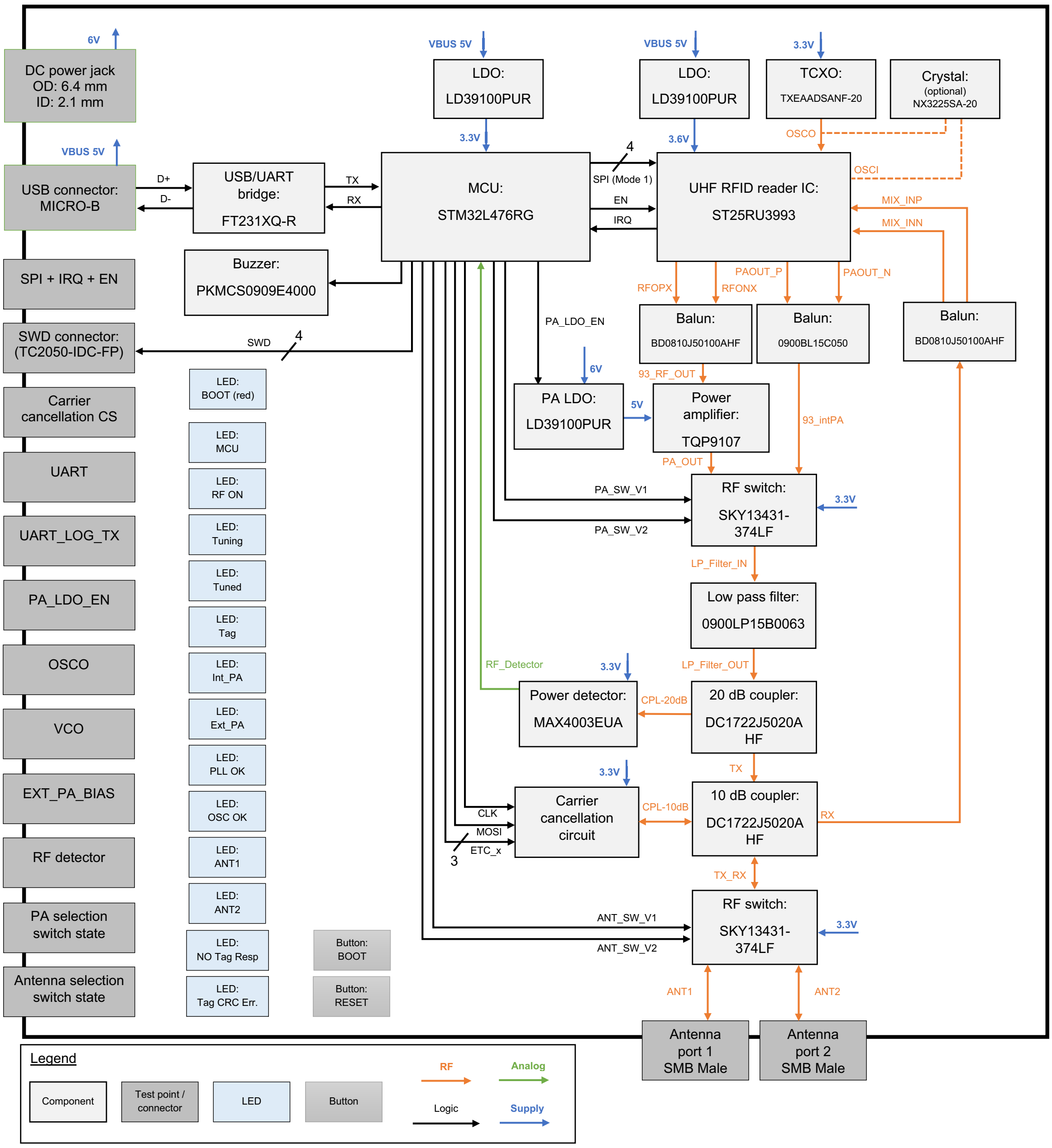
- ST25RU3993 RAIN (UHF) RFID reader IC
- ISO/IEC 18000-63:2015 / Gen2V2
- GB/T 29768-2013
- Two SW-controlled power amplifier (PA) options:
  - External PA: 30 dBm max. TX power
  - Internal PA: 17.5 dBm max. TX power
- Configurable TX power level
- Power detector to monitor TX power
- Automatic carrier cancellation for improved RX sensitivity
- Differential RX input
- RX sensitivity:
  - -80 dBm at 90% read success, one sideband of tag response (ISO18046-3: 2012)
  - -77 dBm at 90% read success, both sidebands of tag response (ISO18046-3: 2020)
- Adaptive / manual RX gain adjustment
- Tunable radio frequency: 840 to 960 MHz
- Minimum frequency step: 25 kHz
- External frequency reference (20 MHz) assembly option
- Adaptive / manual anti-collision slot options
- Continuous wave or Modulated RF output test modes

- Two antenna ports: SMB (M)
- Automatic / Manual antenna port switching
- Carrier sense TX option (LBT)
- UHF tag RSSI measurement
- Configurable SELECT command mask
- UHF transponder EPC Read / Write
- Transponder read based applications trigger
- Custom reader TX command editor tool
- Customizable Gen2 TX commands
- Direct TX modulation through MCU for proprietary protocol support
- Store / Recall reader configuration
- Register map
- Buzzer
- Host interface and supply
  – USB/UART bridge
  – USB receptacle: Micro, B-Type
  – Main supply: 6 V DC jack
- MCU:
  – STM32L476RGT6 (Arm®[a] 32-bit Cortex®-M4)
  – 64 MHz
  – 128-Kbyte RAM
  – 1-Mbyte Flash memory
  – SPI Mode 1 (5 MHz)
  – Firmware programmable through USB/UART
  – SWD debug interface
  – LED indicators
  – Power amplifier selection
  – 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
- Test points:
  – In-circuit RF power levels and signals

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

  - RFID communication TX and RX
  - UART and 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
  - LDO outputs: jumpers for current consumption measurement
  - Main supply: jumper for current consumption measurement
  - Antenna switch state
  - Power amplifier selection switch state
- Buttons:
  - MCU reset
  - MCU boot mode

Figure 3. ST25RU3993-HPEV functional diagram



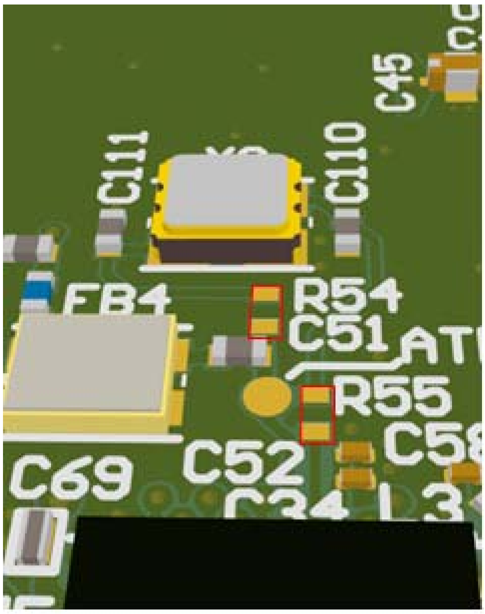
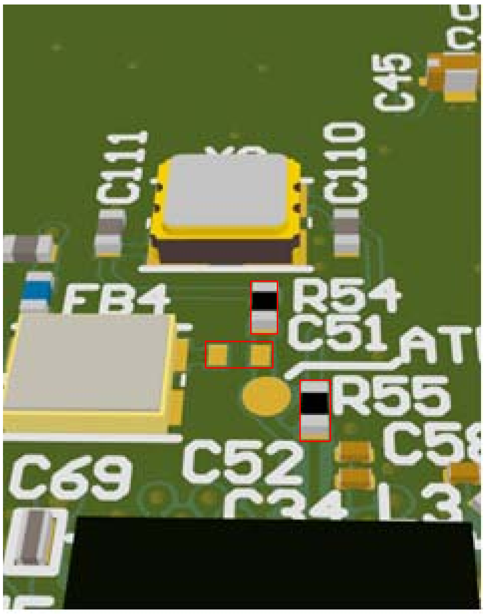
2 Hardware description

2.1 RF circuit

The main component of the RF circuit is the ST25RU3993 device, which receives digital baseband transmit data and commands from the MCU via the SPI interface. It then frames these data and automatically encodes them into PIE symbols. Based on the PIE encoded symbols ST25RU3993 creates a sinusoidal shaped modulation signal (either ASK or PR-ASK), which modulates the RF carrier. ST25RU3993 synthesizes its RF carrier frequency with a VCO / integer-n phase locked loop (PLL). The frequency reference for the PLL can be either a 20 MHz crystal oscillator or a temperature compensated crystal oscillator (TCXO).

As shown in *Table 1* the ST25RU3993-HPEV board accommodates both options, the default configuration is the TCXO with a clipped sine wave output wave having 0.8 V_{pp} amplitude. With a small modification it is possible to connect the existing crystal.

Table 1. TXCO / Crystal configuration

Default	Alternate (modified by user)
TCXO connected to ST25RU3993	Crystal connected to ST25RU3993
R54 and R55 not populated	C51 removed, R54 and R55 populated
	

The output of the internal PLL- charge pump is connected to LF_CEXT (pin 45), and the external part of the loop filter is placed in close proximity to it. 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.

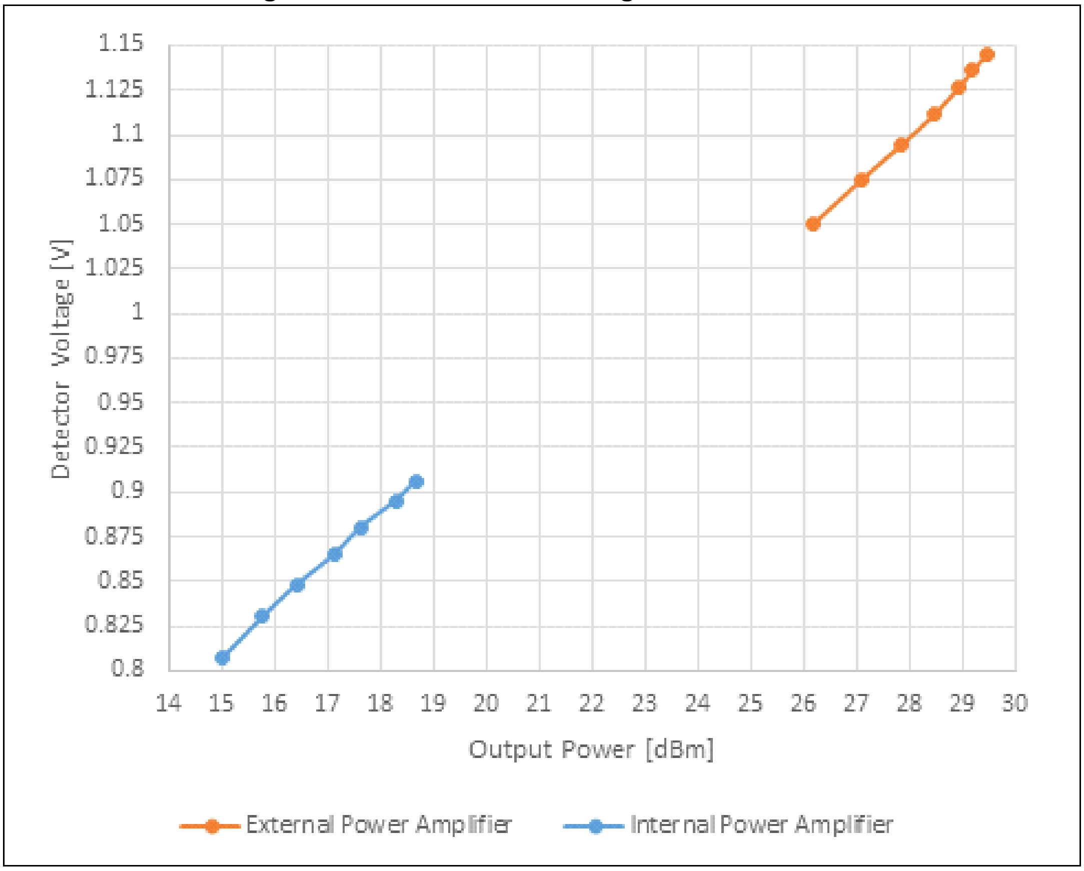
The ST25RU3993 has two differential output port pairs. The low power output and the internal power amplifier output. Depending on which differential output port pair is activated the modulated carrier frequency will be amplified and output accordingly.

The low power output is intended for external signal amplification for a long read range configuration of the ST25RU3993-HPEV reader. The low power output with its differential output pin pairs RFONX (23) and RFOPX (24) is connected to a 2:1 balun, where the transmit signal is transformed from a 100 differential to 50 Ω single-ended signal. The output stage of the low power output is supplied by the V_{DD_B} voltage generated and regulated by ST25RU3993 itself. 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 ST25RU3993-HPEV default transmit power configuration.

The internal power amplifier is used for the short read range configuration of the reader. The output pins of the internal power amplifier are PAOUT_N (16, 17) and PAOUT_P (20, 21). A matching network and a 1:1 balun transforms 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 V_{DD_PA}. L1, L2 are acting as RF chokes, C12 and C14 are bypass capacitors. After the balun the output power of the internal power amplifier is tipically 20 dBm.

Both RF output options the external power amplifier and the output of the internal power amplifier are connected to an RF-switch which is controlled by the PC software (GUI) of the ST25RU3993-HPEV reader. Only one RF output option can be active at a time. Note a UHF RFID reader reference would typically offer only one RF output and hence the PA RF-switch would be stripped from the design avoiding it’s introduced insertion loss of ~0.5 dB. So would be the DC blocking capacitors which this RF-switch requires on all its RF terminals. The output of the RF-switch is connected to a low-pass filter which attenuates 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 negligible small portion of the transmit power, which is further attenuated by a pi-pad attenuator. The limited TX power sample is then fed to the input a logarithmic power detector that converts the RF power to a corresponding DC voltage. The output DC voltage of the power detector versus the generated RF power is shown in *Figure 4*.

Figure 4. Power detector voltage characteristics



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

The majority of RF transmit power which passes through the 20 dB directional coupler is fed to the main directional coupler. The main directional coupler has a coupling factor of 10 dB and acts as the directional unit which should isolate the transmit from the receive path of ST25RU3993. The main directional coupler plays a very important role in the RFID reader system as its parasitics have a great influence on the sensitivity of the reader. The main directional coupler essentially has four terminals:

1. Input
2. Direct
3. Coupled
4. Isolated

The direct terminal is connected to the second RF switch in the reader system. This switch directs the transmit power to either antenna port 1 or antenna port 2. The antenna switch again requires DC blocking capacitors on all its RF terminals. Both antenna ports are SMB (male) type.

To avoid reducing the sensitivity of the reader the self-jamming signal reaching the receiving inputs of ST25RU3993 must be minimized. The self-jamming signal comprises reflections from the antenna (S11) and the leakage across the main directional coupler. To minimize it 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 hence to reflect a certain amount of the coupled power back into the directional coupler. This reflected signal is combined with the self-jamming signal at the isolated port of the main directional coupler. The isolated port of the main directional coupler is connected to the receiving pins of ST25RU3993. If the signal reflected by the carrier cancellation circuit has the same amplitude and opposite phase of the self-jammer the signals cancel them out and vanish.

The main components of the CCC are three digital tunable capacitors controlled by the STM32L476RG microcontroller via SPI. The lumped components of the carrier cancellation circuit help to define its tuning range around 50 Ω and define the impedance step created by one LSB change of a digital tunable capacitor.

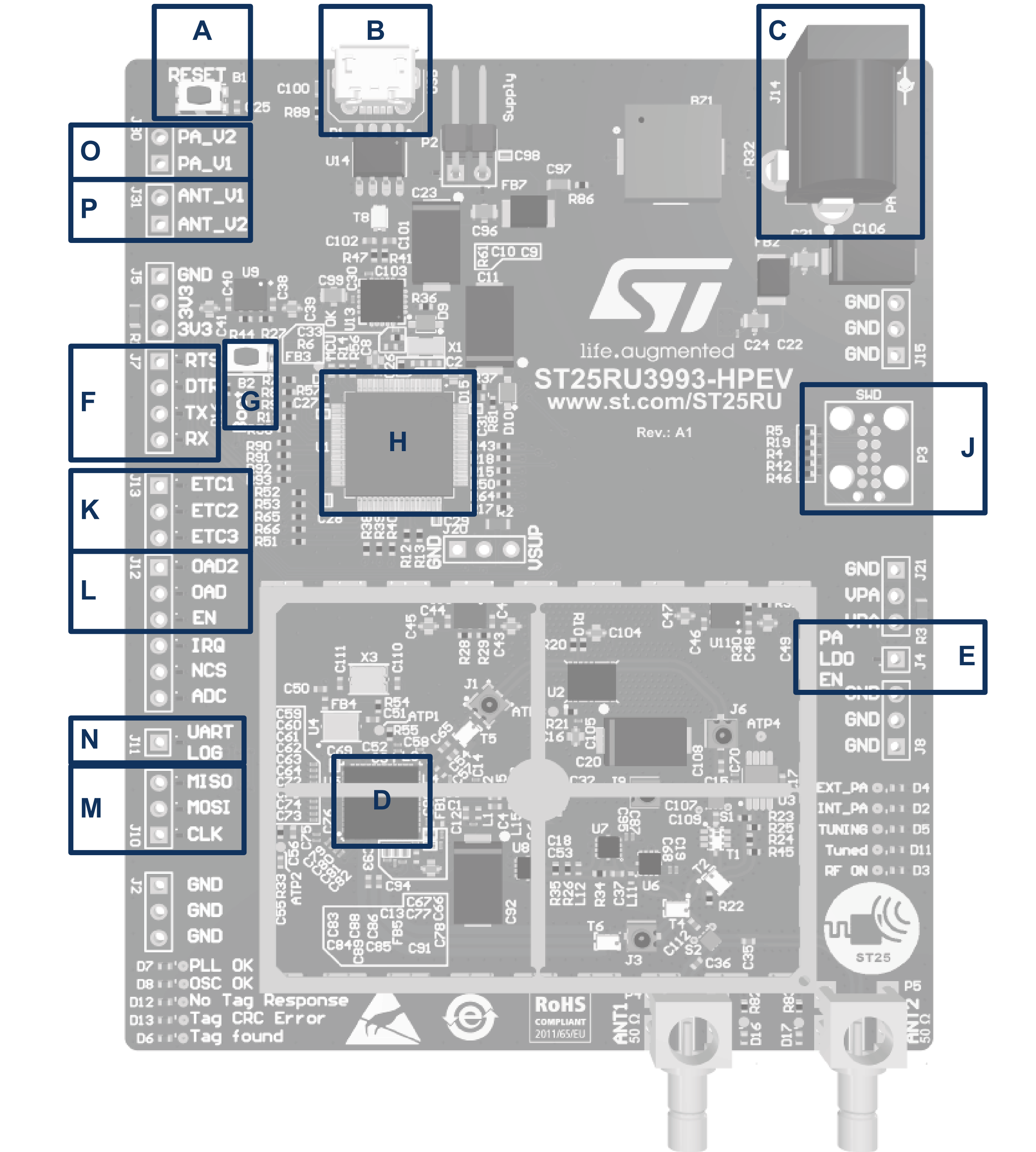
The isolated port of the main directional coupler is connected to a 2:1 balun to transform the incoming tag response signal to a 100 Ω differential signal that is fed into ST25RU3993 receiver section at pins MIX_INP (4) and MIX_INN (6).

2.2 Microcontroller and connections

Table 2. MCU interfaces and buttons (see *Figure 5*)

A	MCU reset button
B	USB receptacle: Micro, B-Type
C	6 V DC power connector: 5 mm barrel connector
D	ST25RU3993 Rain (UHF) RFID reader IC
E	Enable line connection of power amplifier LDO
F	UART interface connections
G	MCU boot mode button
H	STM32L476RGT6 (Arm® 32-bit Cortex®-M4)
J	SWD debug interface connections
L, M	SPI bus interface connections
N	UART_LOG connection for debugging purposes
K	Carrier cancellation circuit (CCC) SPI chip select lines
O	PA output selection switch state
P	Antenna port selection switch state

Figure 5. Main digital interfaces



The ST25RU3993-HPEV is controlled by STM32L476RG, a ultra-low-power MCU with FPU Arm Cortex-M4 core, 80 MHz, 1 Mbyte Flash memory, LCD, USB OTG, DFSDM.

The MCU is supplied by 3.3 Volts, regulated by an adjustable LDO. The clock source is an external crystal generating 32.768 kHz, connected to OSC32_in (3) and OSC32_out (4). It interfaces the host PC via UART for which a USB/UART bridge is used.

The MCU communicates with the ST25RU3993 via an SPI interface controlling the ST25RU3993 lines ENABLE and IRQ. The SPI interface operates in mode 1 with a 6 MHz serial clock. The SPI interface is also used to control the digital tunable capacitors for the carrier cancellation circuit.

The MCU controls the RF switches for changing the power amplifier and the active antenna port. The analog output of the RF power detector is connected to one of its ADC inputs (PA1) to convert the DC voltage corresponding to the transmit RF power into a digital representation. The LDO for the external power amplifier is enabled by the MCU, making it possible to completely shut down the external power amplifier when RF power needs to be OFF, e.g. as required for carrier sense (LBT). One pin (UART LOG) is reserved to act as a generic debug pin or to be programmed as a trigger output for an external measurement equipment.

Table 3. MCU - SPI interface and ST25RU3993 connections

Component U1		Component U5		Component U6		Component U7		Component U8	
MCU pin		ST25RU3993 pin		DTC1 pin		DTC2 pin		DTC3 pin	
Name	Number	Name	Number	Name	Number	Name	Number	Name	Number
PA4	20	NCS	33	-	-	-	-	-	-
PA5	21	SCLK	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		DTC1 pin		DTC2 pin		DTC3 pin		Connector pin number		
Name	Number	Name	Number	Name	Number	Name	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	-

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

Component U5		Component U6		Component U7		Component U8		J10	J12	J13
ST25RU3993 pin		DTC1 pin		DTC2 pin		DTC3 pin		Connector pin number		
Name	Number	Name	Number	Name	Number	Name	Number			
-	-	-	-	ETC2 SEN	6	-	-	-	2	-
-	-	ETC1 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		FTDI pin		Connector pin number
Name	Number	Name	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		Reset button		Boot button	
Name	Number	Name	Number	Name	Number
NRST	7	1	1	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	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)	-	-	-	-	-	-	-	-
PC8	37	-	-	-	-	-	1 (C)	-	-	-	-	-	-	-
PB12	33	-	-	-	-	-	-	1 (C)	-	-	-	-	-	-
PB13	34	-	-	-	-	-	-	-	1 (C)	-	-	-	-	-
PC11	52	-	-	-	-	-	-	-	-	1 (C)	-	-	-	-
PB14	35	-	-	-	-	-	-	-	-	-	1 (C)	-	-	-
PB15	38	-	-	-	-	-	-	-	-	-	-	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		PA switch pin		Antenna switch pin	
Name	Number	Name	Number	Name	Number
PB0	26	V1	1	-	-
PC5	25	V2	3	-	-
PB10	29	-	-	V1	1
PB11	30	-	-	V2	3

Table 9. Connections to JLINK (SWD) interface and pinout of connector

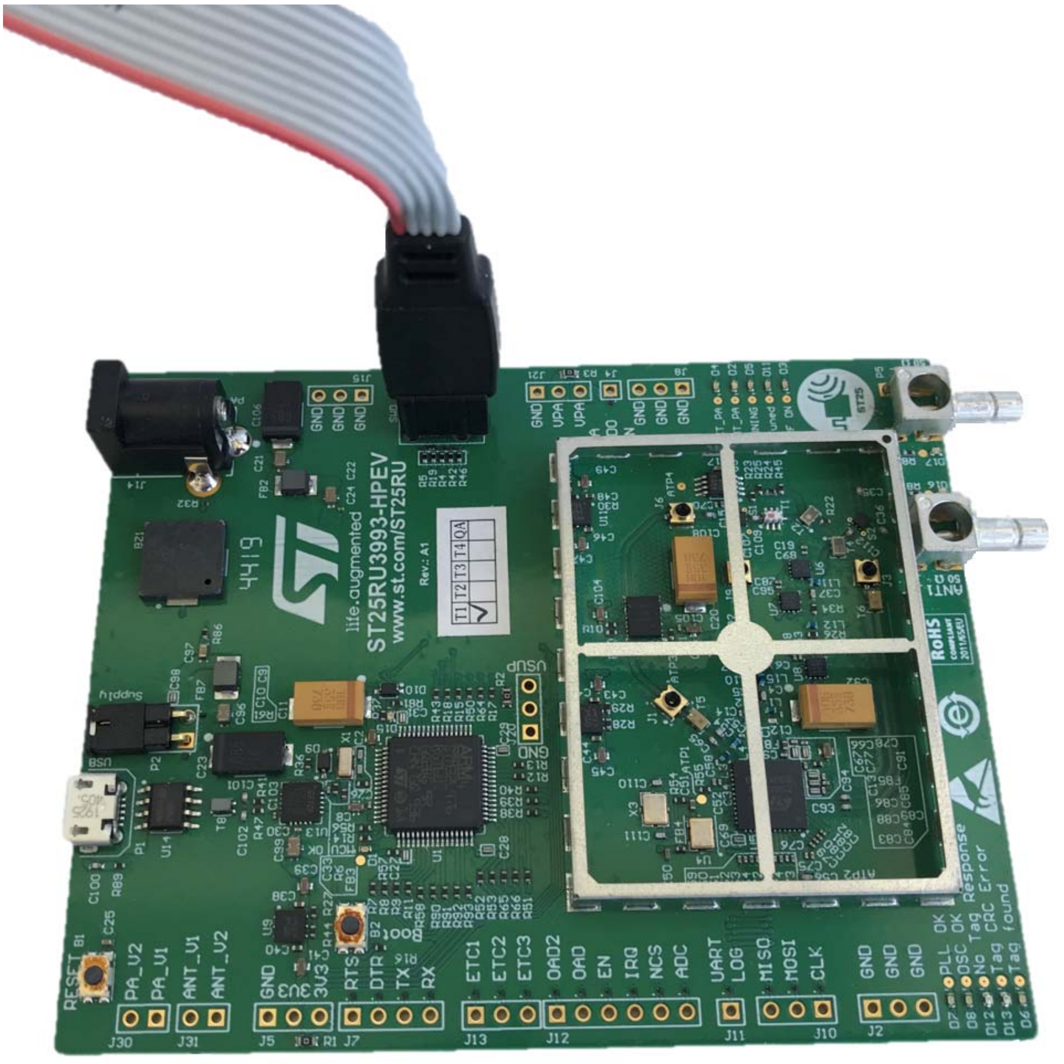
Component U1		Component P3	
MCU pin		JLINK pin	
Name	Number	Name	Number
-	-	VDD	1
PA13	46	SWDIO	2
-	-	GND	3
PA14	49	SWCLK	4
-	-	GND	5
PB3	55	SWO	6
-	-	NC	7
PA15	50	TDI	8
-	-	NC	9
NRST	7	MCU RESET N	10

2.3 Firmware programming

There are two options 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-HPEV 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 connected to the JLINK (SWD) interface (see *Figure 6*) with a J-Link needle adapter (e.g. 8.06.04 J-LINK 10-PIN NEEDLE ADAPTER). For more information about this option refer to the user manual of the ST-LINK/V2.

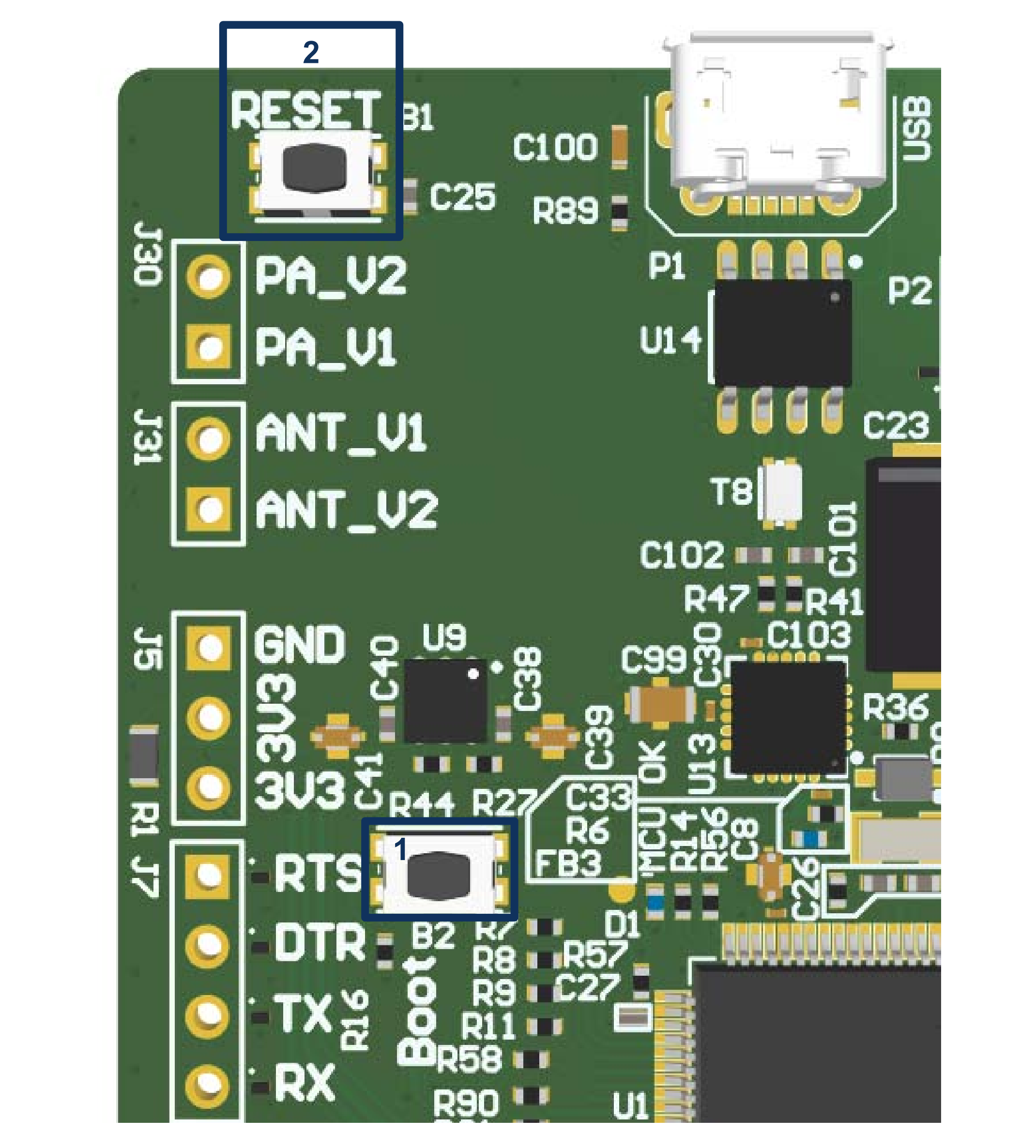
Figure 6. JLink connection using the needle adapter



2.4 Boot mode

To enter the STM32L476RG boot mode press and hold the BOOT button (1) while the RESET button (2) is pressed (see *Figure 7*). At this point the boot mode is active and both buttons can be released.

Figure 7. Entering the Boot mode



2.5 Power supply

The ST25RU3993-HPEV is supplied through the USB Interface (VBAT) and an external 6 V supply connected to J14 a DC power jack. J14 has a hot inner contact with 2.1 mm diameter suitable for a 5.5 mm barrel plug.

The 5V (VBAT) supply rail is distributed to two low-dropout regulators which supply:

- LDO U9 – for powering digital components (3V3),
- LDO U10 - for powering RF components (VSUP)

The 6 V DC input is dedicated to supply the power amplifier supply via an LDO U11 regulating the supply rail VPA.

Table 10. Typical voltage levels

Voltage domain	Voltage (V)
3V3	3.3
VSUP	3.6
VPA	5.0

Table 11. Connection of components

Voltage domain	Schematic	Component(s)	Pin name(s)	Pin number(s)
5 V (VBUS)	Supply (*Figure 20*)	U9, U10	VI	6
			EN	1
	USB interface (*Figure 18*)	U13	VCC	12
6 V	Supply (*Figure 20*)	U11	VI	6
			EN	5
3V3	External interfaces (*Figure 21*)	P3	1	1
	Controller (*Figure 19*)	U1	VBAT	1
			VDD	19, 32, 48, 64
			VDD / VREF+(1)	13
			NRST(2)	7
			BOOT0(3)	60
	Power amplifier (*Figure 14*)	U3	VCC	8
			/SHDN	2
	UHF_RFID (*Figure 13*)	U4	VCC(4)	4
		U5	VDD_IO	38
	Carrier cancellation (*Figure 15*)	U6, U7, U10	VDD	4
	USB interface (*Figure 20*)	U13	VCCIO	20
VSUP (3.6 V)	UHF_RFID (*Figure 13*)	U5	VEXT(5)	11
		U5	VEXT_PA(6)	14

Table 11. Connection of components (continued)

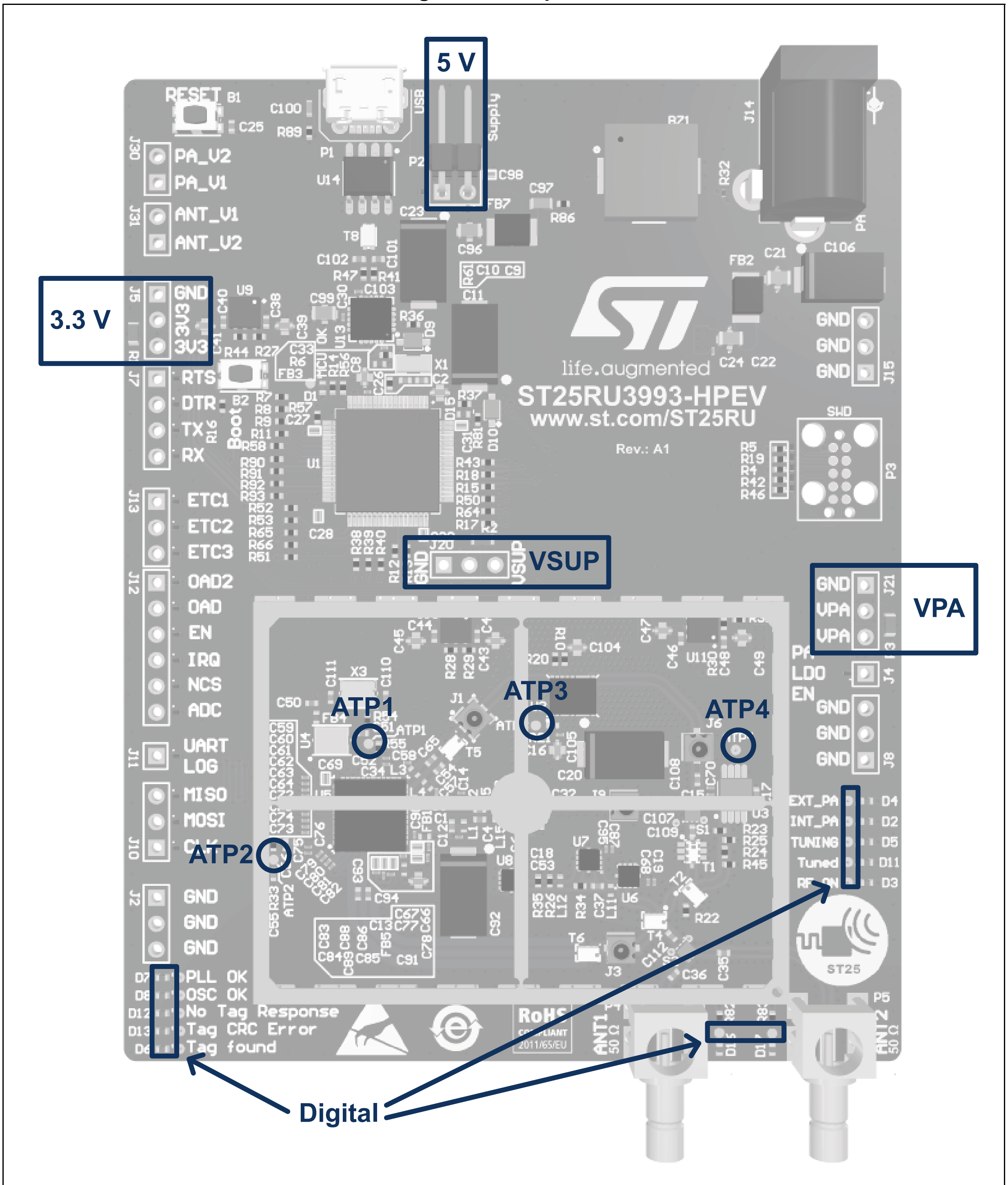
Voltage domain	Schematic	Component(s)	Pin name(s)	Pin number(s)
VPA (5 V)	Power amplifier (*Figure 14*)	U2	VPD1	12
		U2	VPD2	11
		U2	VCC	2
		U2	VBIAS(7)	1

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 FB5.
6. Via ferrite bead FB1.
7. Via R21.

2.6 Test points

The ST25RU3993-HPEV board provides several test points (see *Figure 8*) that allow the user to test and evaluate circuit nodes in the ST25RU3993 reader design.

Figure 8. Test points



2.6.1 Analog test points

Table 12. Connections of analog test points

Component		U5		U2		U3	
Pin		Name	Number	Name	Number	Name	Number
Test point	ATP1	OSCO	30	-	-	-	-
	ATP2	VCO (LF_CEXT)		-	-	-	-
	ATP3	-	-	VBIAS	1	-	-
	ATP4	-	-	-	-	OUT	7

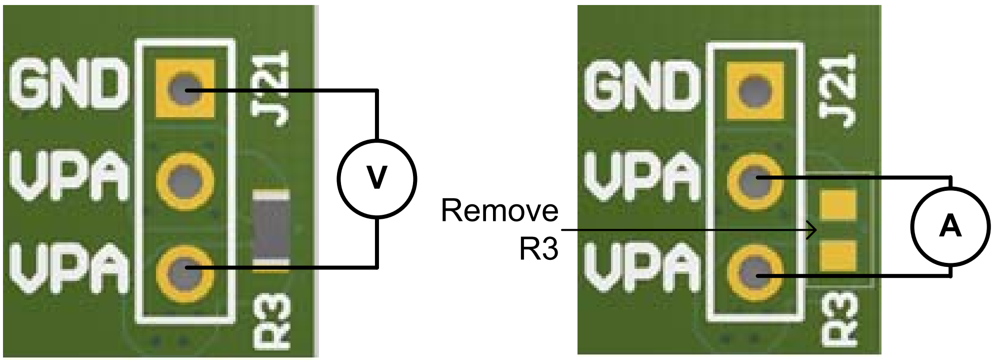
Table 13. Supply voltages of analog test points

5 V (VBUS)		3V3 digital supply		VSUP RF		VPA power amplifier	
P2		J5		J20		J21	
Pin no.	Pin name	Pin no.	Pin name	Pin no.	Pin name	Pin no.	Pin name
1	VBUS	1	GND	1	GND	1	GND
2	VBUS	2, 3	3V3	2, 3	VSUP	2, 3	VPA

Two test points are placed at the output of the three LDOs to easily measure the regulated voltage of each voltage domain. A GND pad is placed close to the voltage test points for accurate voltage measurements (left side of *Figure 9*).

The current consumption of the three regulated voltage domains can be measured separately. To enable this kind of measurement a 0 Ω resistor (R3) must be removed (right side of *Figure 9*). Make sure to restore the connection once the measurement is done, before reverting to normal operation.

Figure 9. Connection of a voltmeter / ammeter to the supply voltage test points



2.6.2 Digital test points

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

PLL OK	Indicates that the PLL of ST25RU3993 is locked and the carrier frequency is stable.
OSC OK	Active low. Indicates that the reference frequency for the PLL is stable.
No tag response	:Pulled low if the sent reader command is not replied by a tag.
Tag CRC error	Pulled low if a CRC error is detected within a tag response.
Tag found	Pulled low every time a tag has been inventoried.
EXT_PA	Pulled low if the reader is in its long read range configuration.
INT+PA	Pulled low if the reader is in its short read range configuration.
TUNING	Pulled low if the reader currently is re-tuning the carrier cancellation circuit.
Tuned	Active low. Indicates that the self-jamming signal is sufficiently suppressed.
RF ON	Active low. Indicates that the RF carrier is ON.
ANT1	Active low. Indicates that antenna port 1 is active.
ANT2	Active low. Indicates that antenna port 2 is active.

2.6.3 Probing RF signals

The ST25RU3993-HPEV board features four RF test points (see *Figure 10*) to measure RF power levels in-circuit. The test point connectors have a switch built-in that disconnects the remainder of the circuit when the test adapter (MS-156-HRMJ-2) is mated. This allows the user to perform measurements with a proper line termination.

Figure 10. RF test points

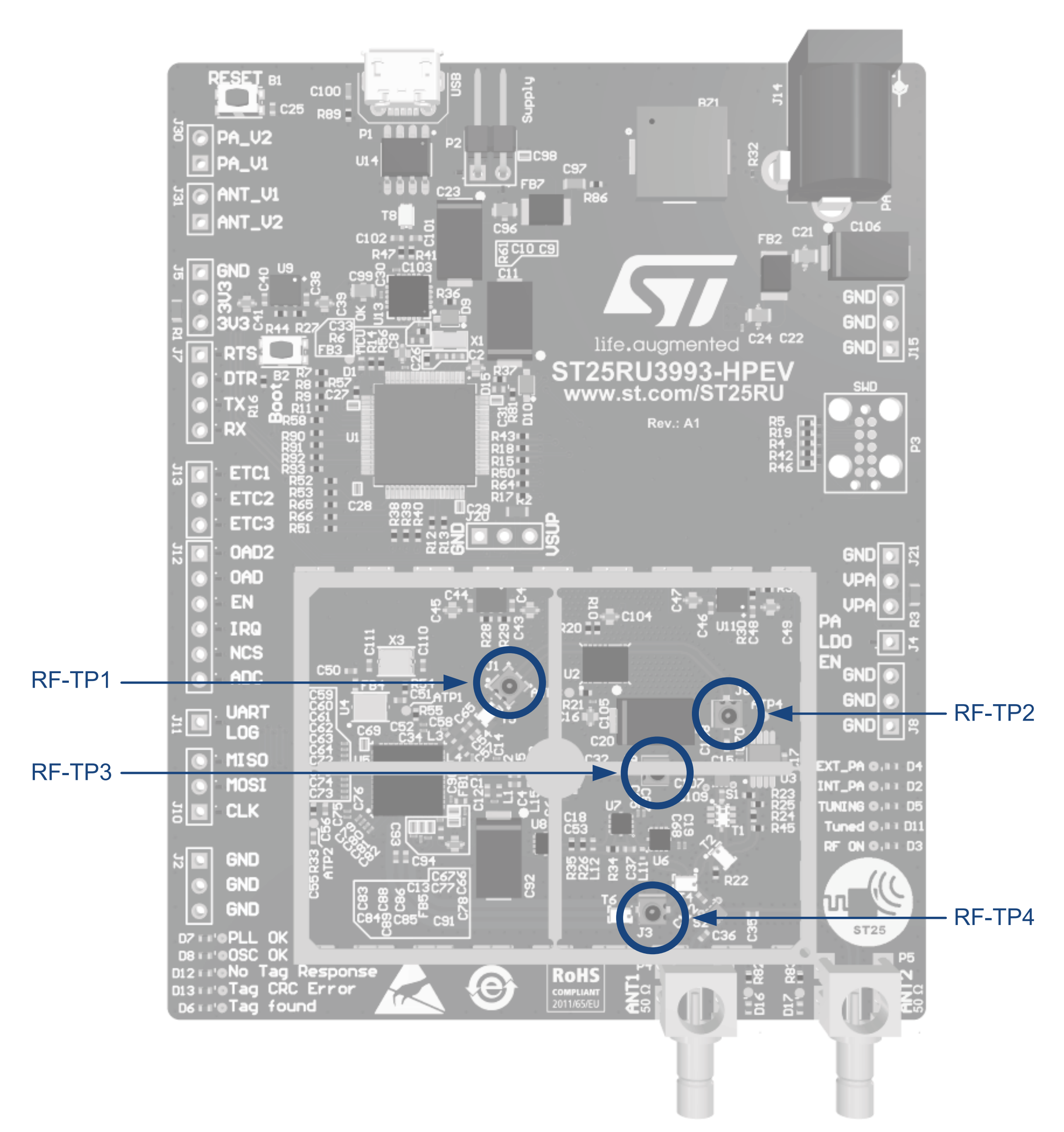


Figure 11. Connecting to the RF test points with the SMA adapter

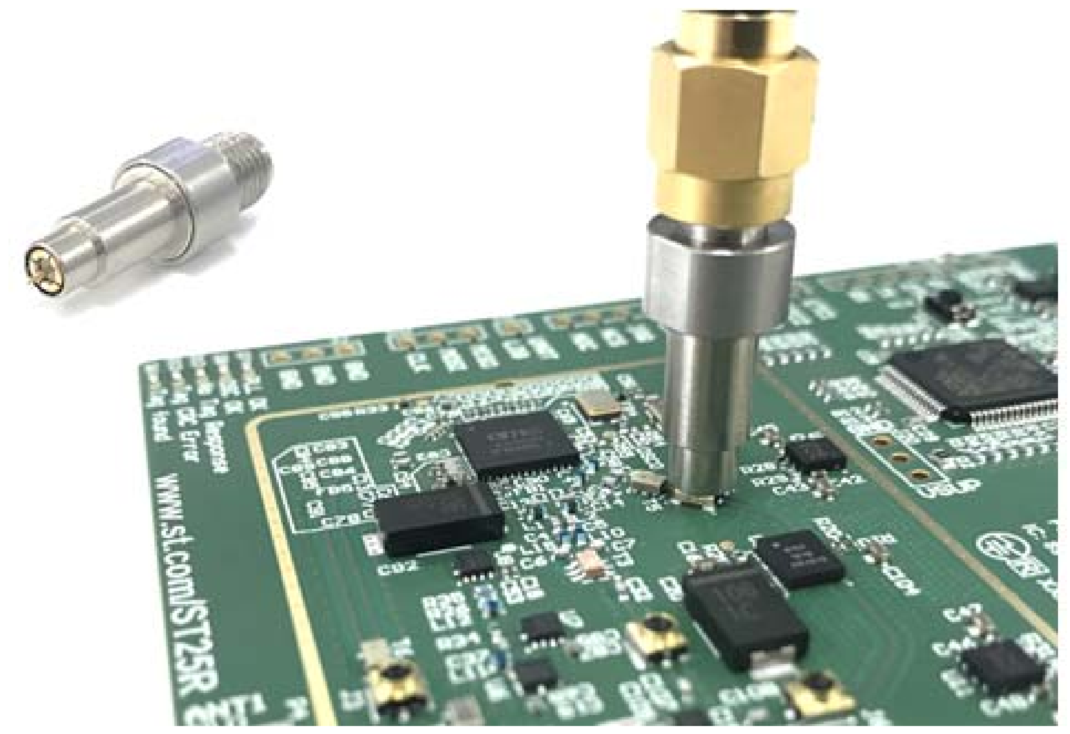


Table 14 lists the typical power levels that can be expected while the ST25RU3993-HPEV board operates in its default configuration.

Table 14. RF test points – Default power levels

RF test point	Description	Power level
RF-TP1	ST25RU3993 RF output signal (single-ended). To evaluate the power and the spectral properties of the RF signal at the low power output.	-1.9 dBm
RF-TP2	External power amplifier output. To evaluate the power and the spectral properties of the RF signal.	33 dBm
RF-TP3	Internal power amplifier RF output. To evaluate the power and the spectral properties of the RF signal.	20.5 dBm
RF-TP4	RX signal. To evaluate the self-jammer signal level or a RN16 tag response. When connected no tag communication is possible.	-

3 Schematics

Table 15. List of schematics

Module	Reference
System overview	*Figure 12*
UHF RFID reader IC	*Figure 13*
External power amplifier	*Figure 14*
Carrier cancellation circuit	*Figure 15*
Antenna switch	*Figure 16*
RF shield	*Figure 17*
USB supply / UART switch	*Figure 18*
Microcontroller	*Figure 19*
Supply LDOs	*Figure 20*
External interfaces and connectors	*Figure 21*

Figure 12. System overview

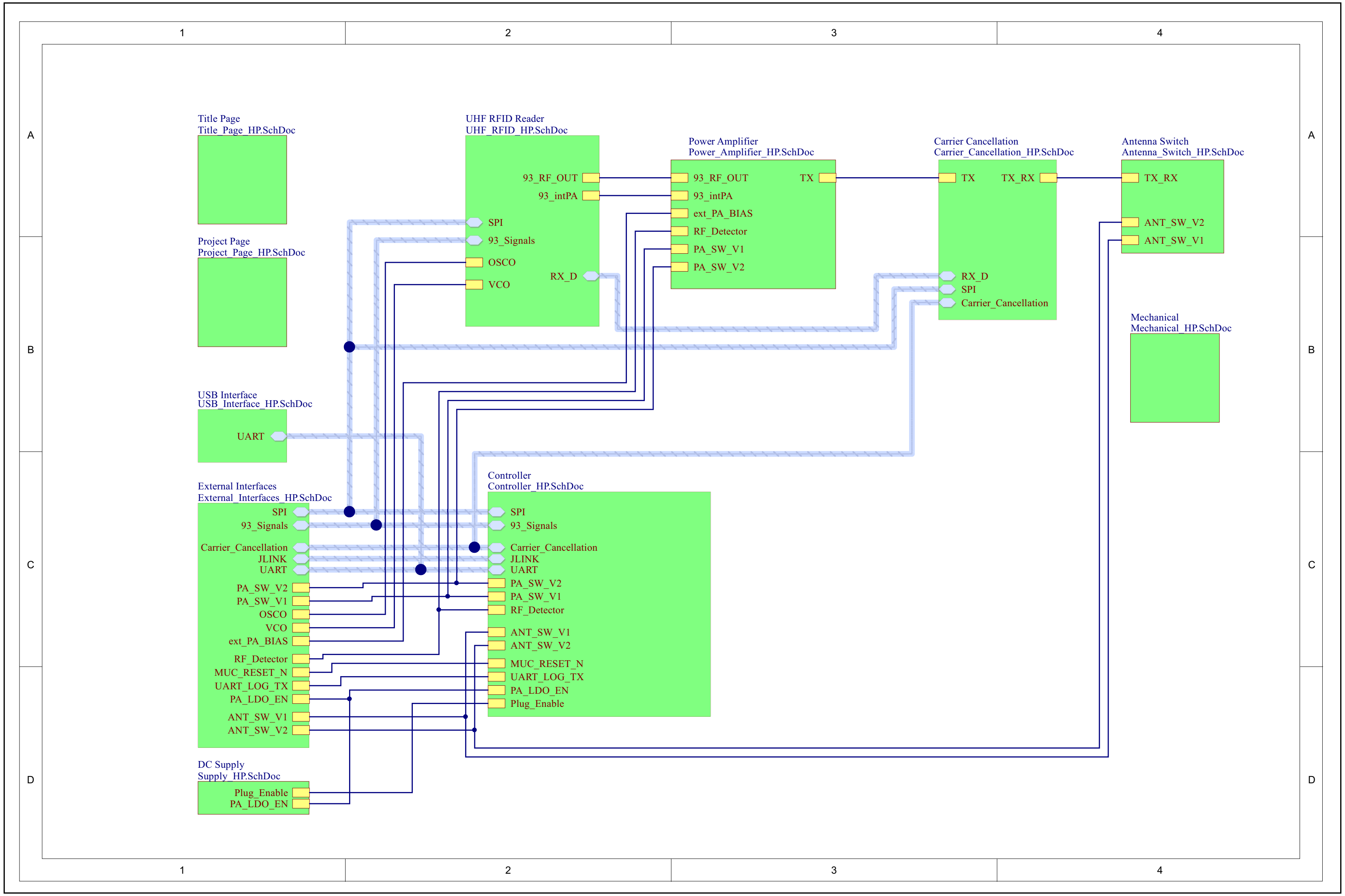


Figure 13. UHF RFID reader IC

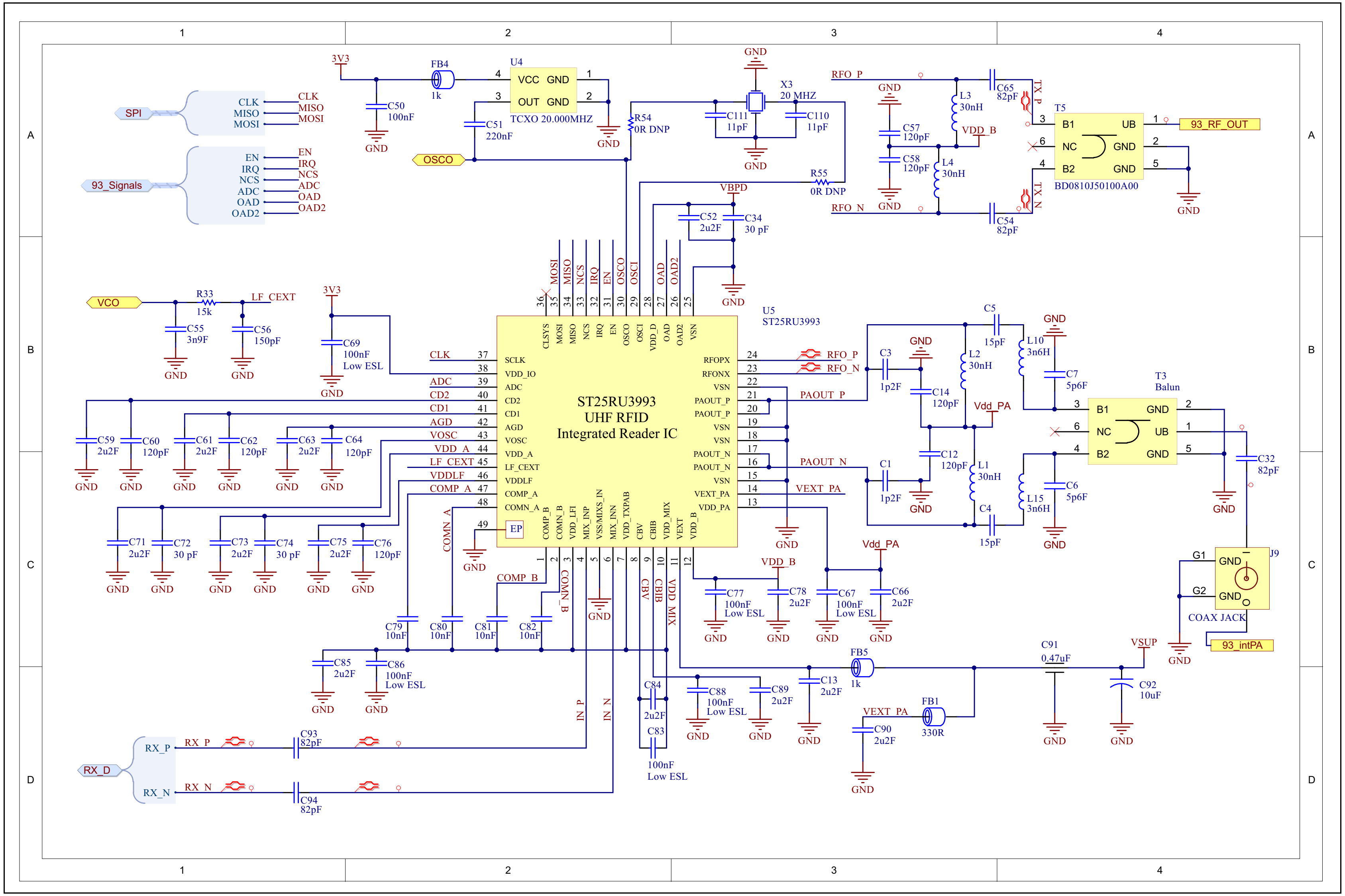


Figure 14. External power amplifier

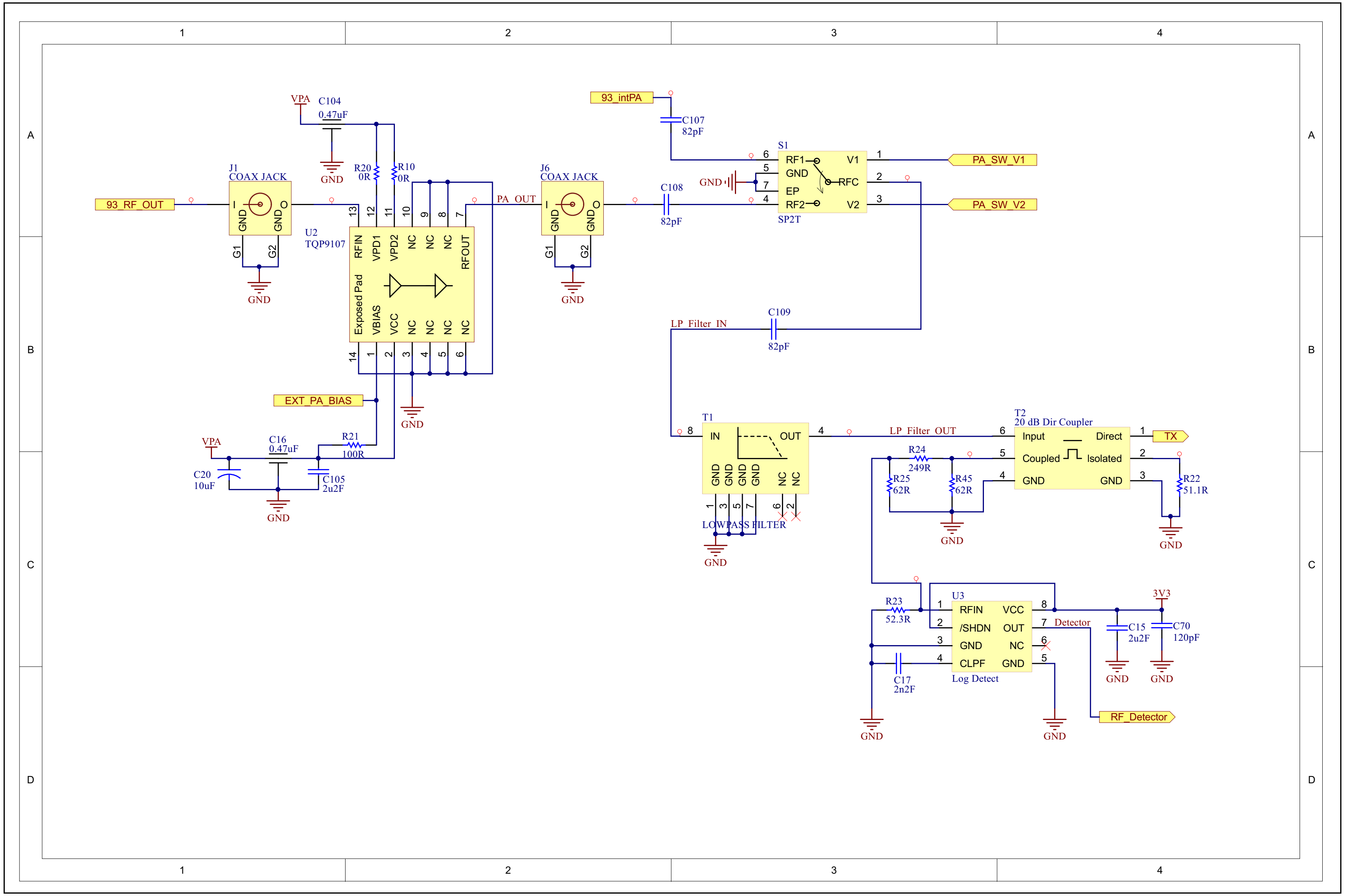


Figure 15. Carrier cancellation circuit

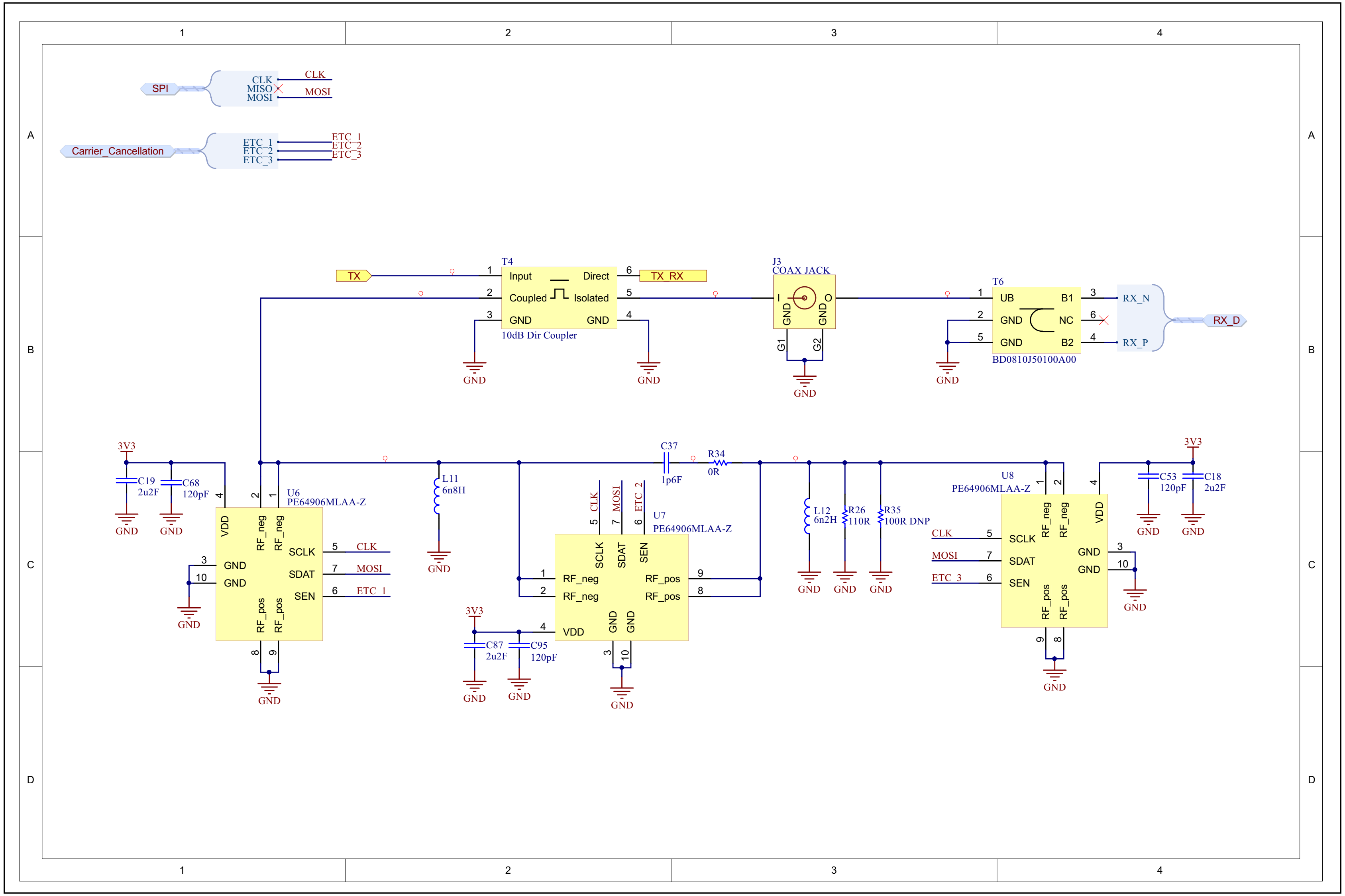


Figure 16. Antenna switch

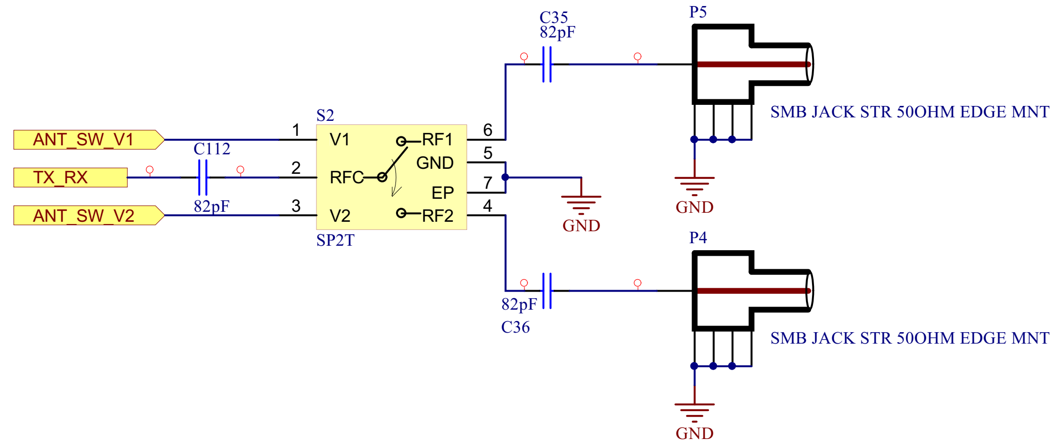


Figure 17. RF shield

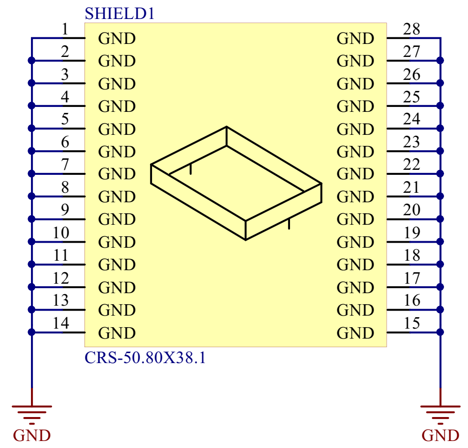


Figure 18. USB supply / UART bridge

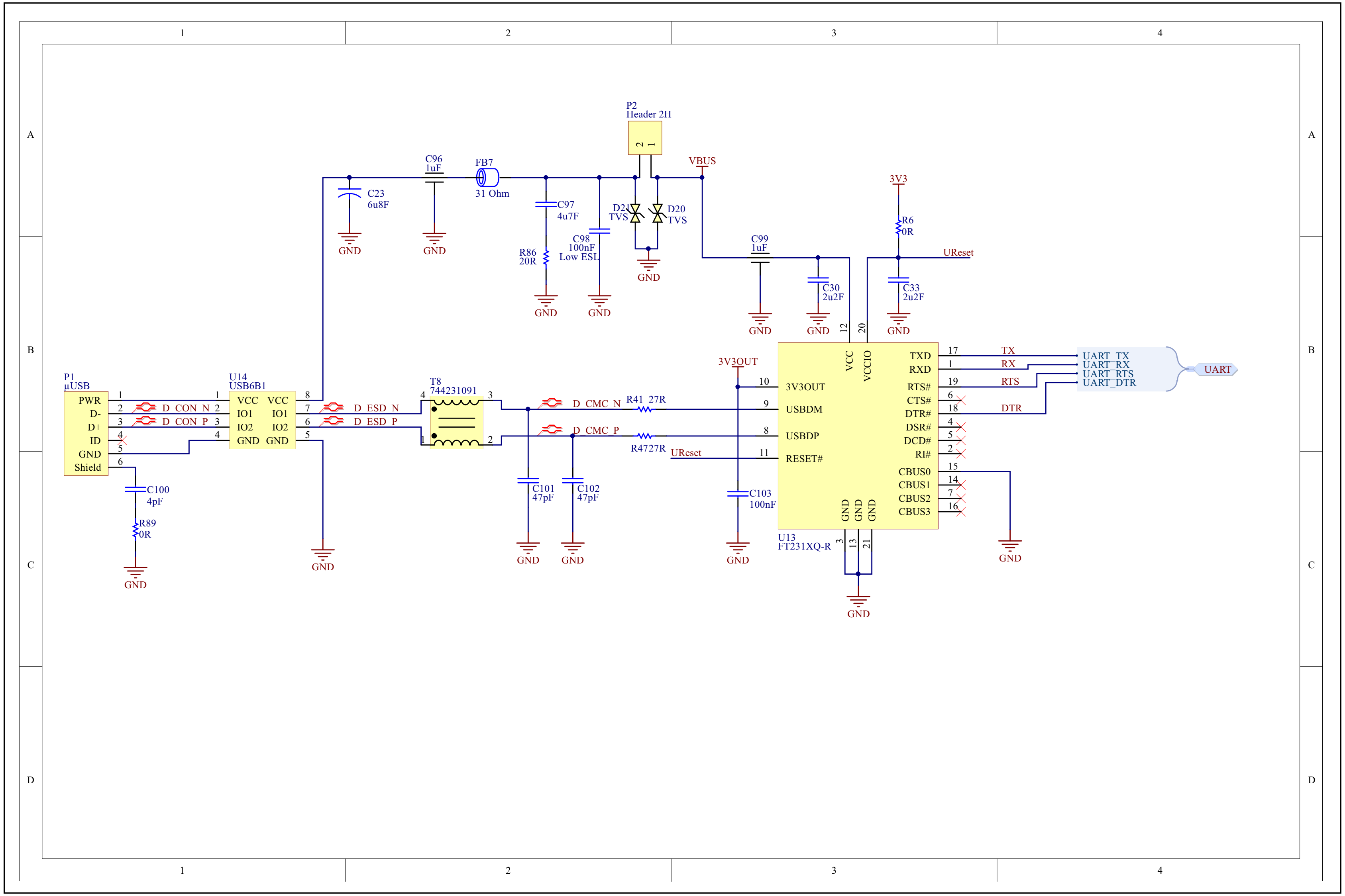


Figure 19. Microcontroller

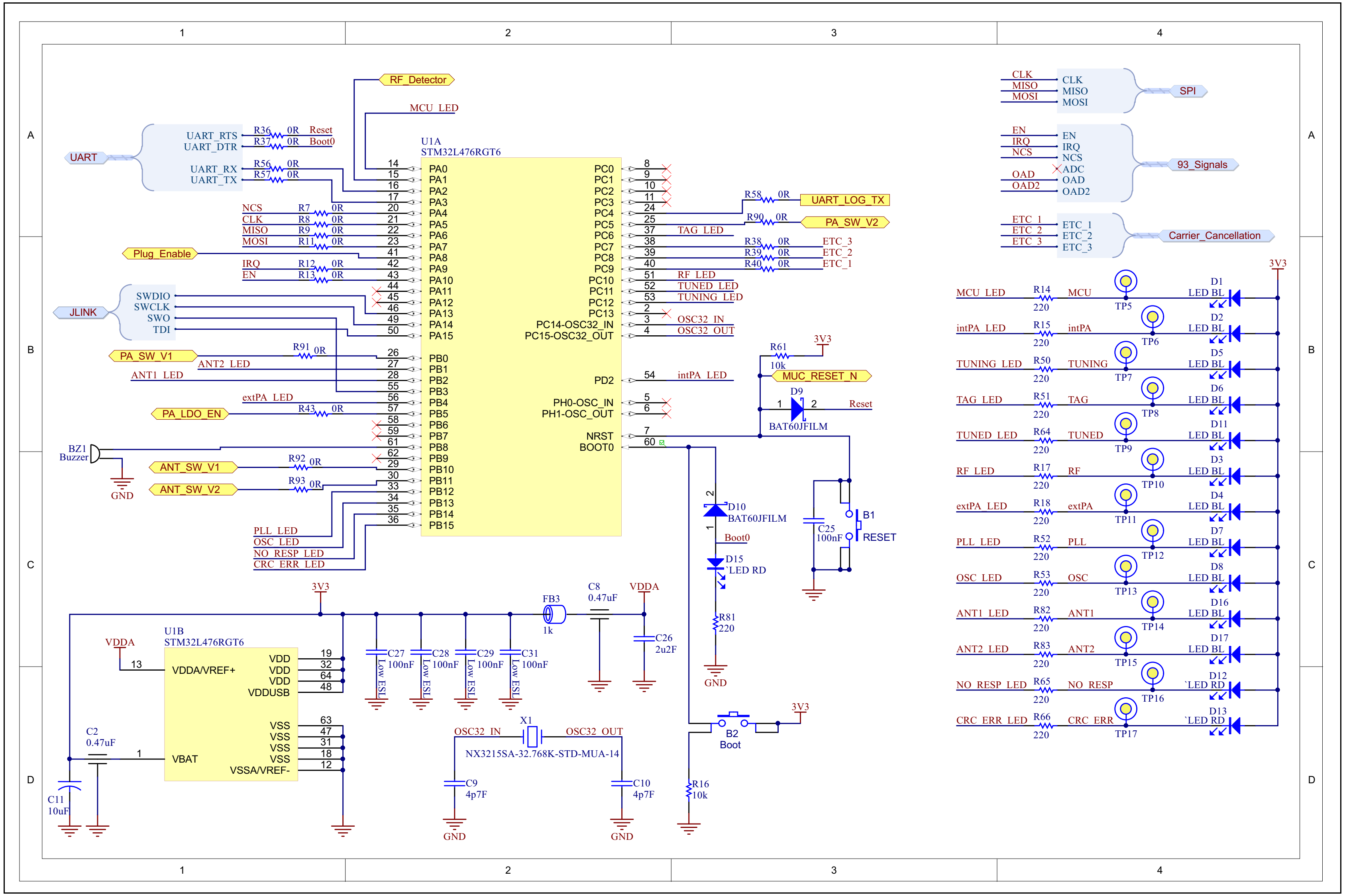


Figure 20. Supply LDOs

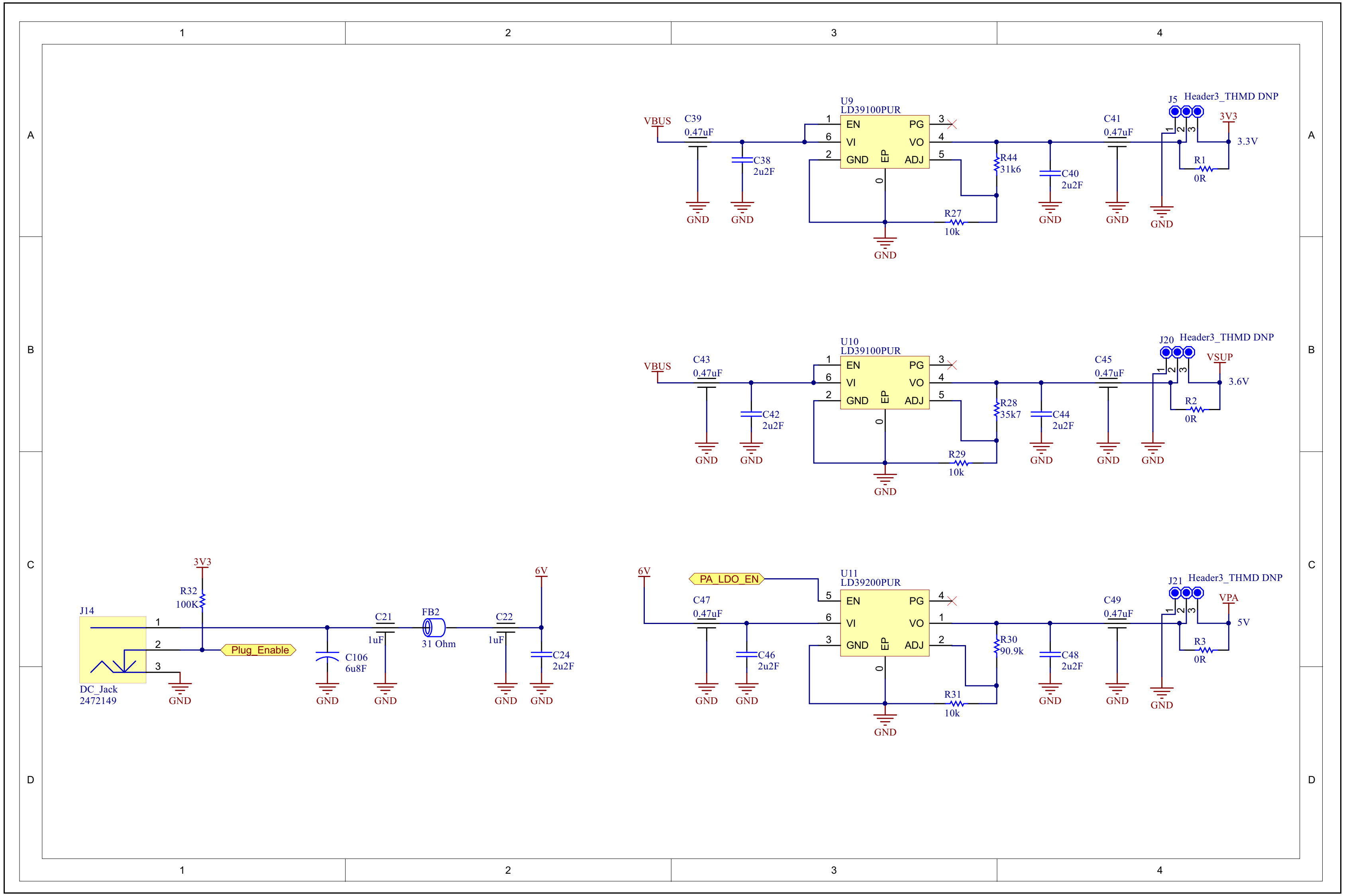
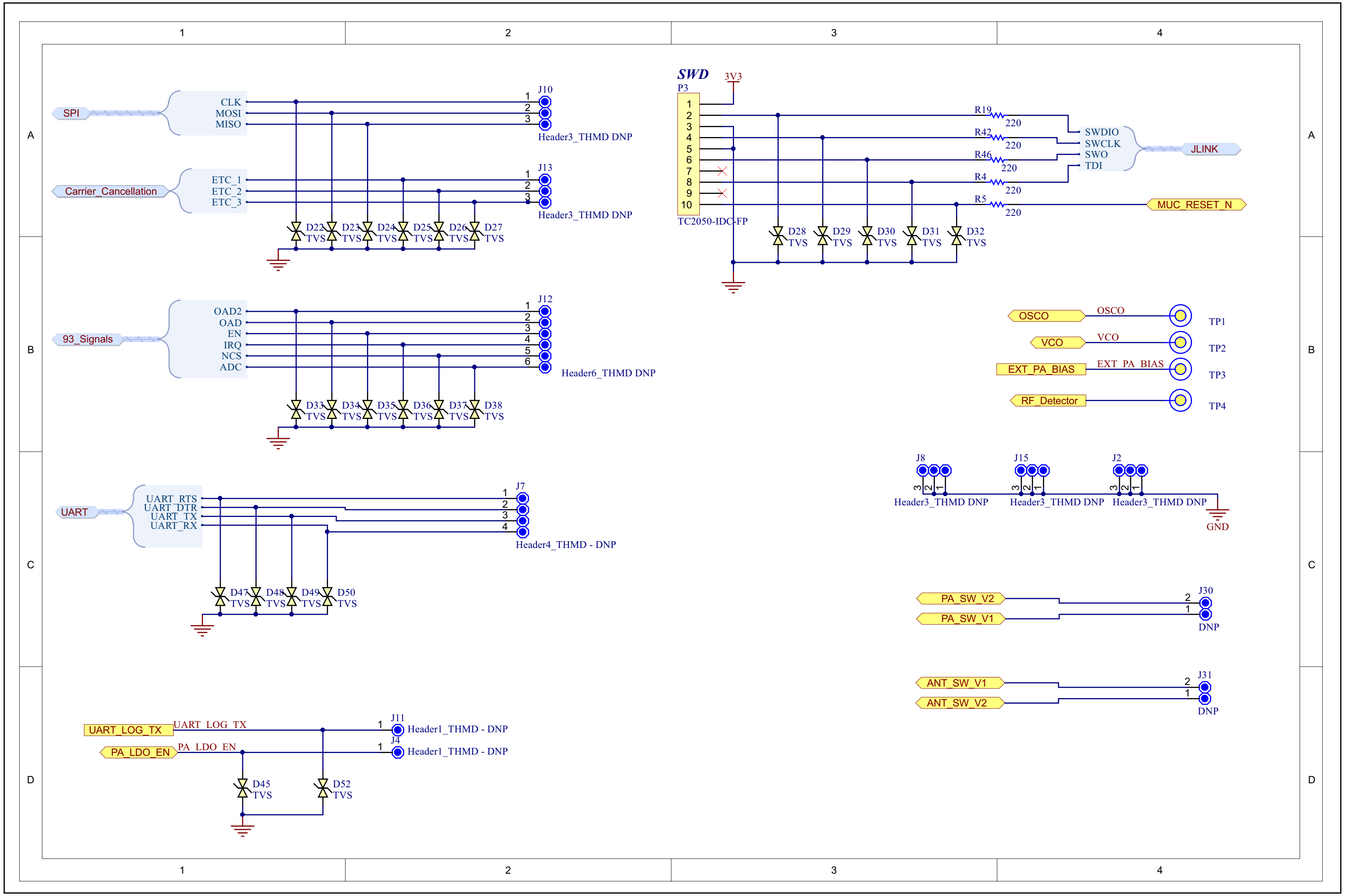


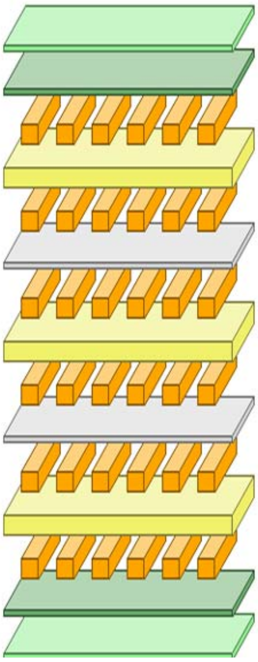
Figure 21. External interfaces and connections



4 PCB

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

Table 16. PCB stack

Scheme	Layer				Dielectric	
	Name	Type	Material	Th (mm)	Material	ε_r
	Top overlay	Overlay				
	Top solder	Solder mask/Coverlay	Surface	0.01016	Solder resist	4.5
	Top layer	Signal	Copper	0.043	-	
	Dielectric 1	Dielectric	Core	0.25	FR-4 (R-1755M)	4.7
	RF GND	Signal	Copper	0.032	-	
	Dielectric 2	Dielectric	Prepreg	0.1	FR-4 (R-1755M)	4.6
	Power	Signal	Copper	0.032	-	
	Dielectric 3	Dielectric	Core	0.1	FR-4 (R-1755M)	4.7
	GND	Signal	Copper	0.036	-	
	Dielectric 4	Dielectric	Prepreg	0.1	FR-4 (R-1755M)	4.6
	Routing	Signal	Copper	0.036	-	
	Dielectric 5	Dielectric	Core	0.25	FR-4 (R-1755M)	4.7
	Bottom GND	Signal	Copper	0.043	-	
	Bottom solder	Solder mask/Coverlay	Surface	0.01016	Solder resist	4.5
	Bottom overlay	Overlay				

All components and almost all interconnections are on the top layer (*Figure 22*).

Impedance-controlled RF traces such as singled-ended 50 Ω (CBCPW) and differential 100 Ω traces are located on the top layer. For best ground connection all component ground terminals have a direct connection to the surrounding GND plane. This means that no thermal relief-connection exist.

The RF GND layer directly below the top layer is needed for the 50 Ω and 100 Ω waveguide traces. The spacing between top layer and RF GND layer is relevant for the impedance of the waveguides. RF currents tend to run back to their source directly underneath the waveguides, so it is important that the RF GND layer is solid and uninterrupted especially underneath the RF traces, to provide a direct path for the RF return currents.

The Power layer (*Figure 24*) is used to distribute the supply voltages through power planes, and only a few traces are on it.

The Routing layer (*Figure 25*) is used to interconnect the components minimizing cross-talk effects on RF traces.

Figure 22. Top layer layout

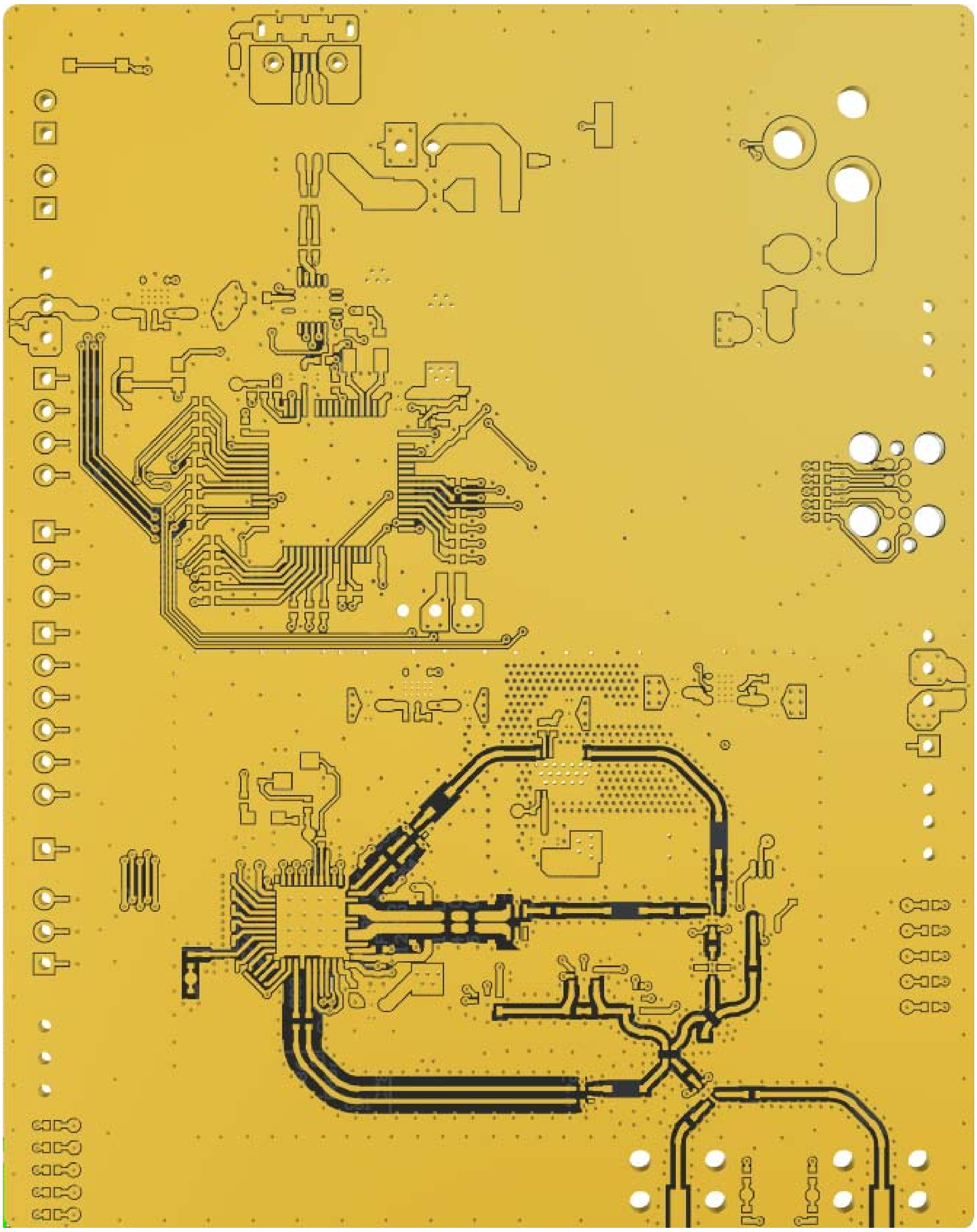


Figure 23. RF GND layer (L2), GND layer (L4) and bottom layer (L6) layout

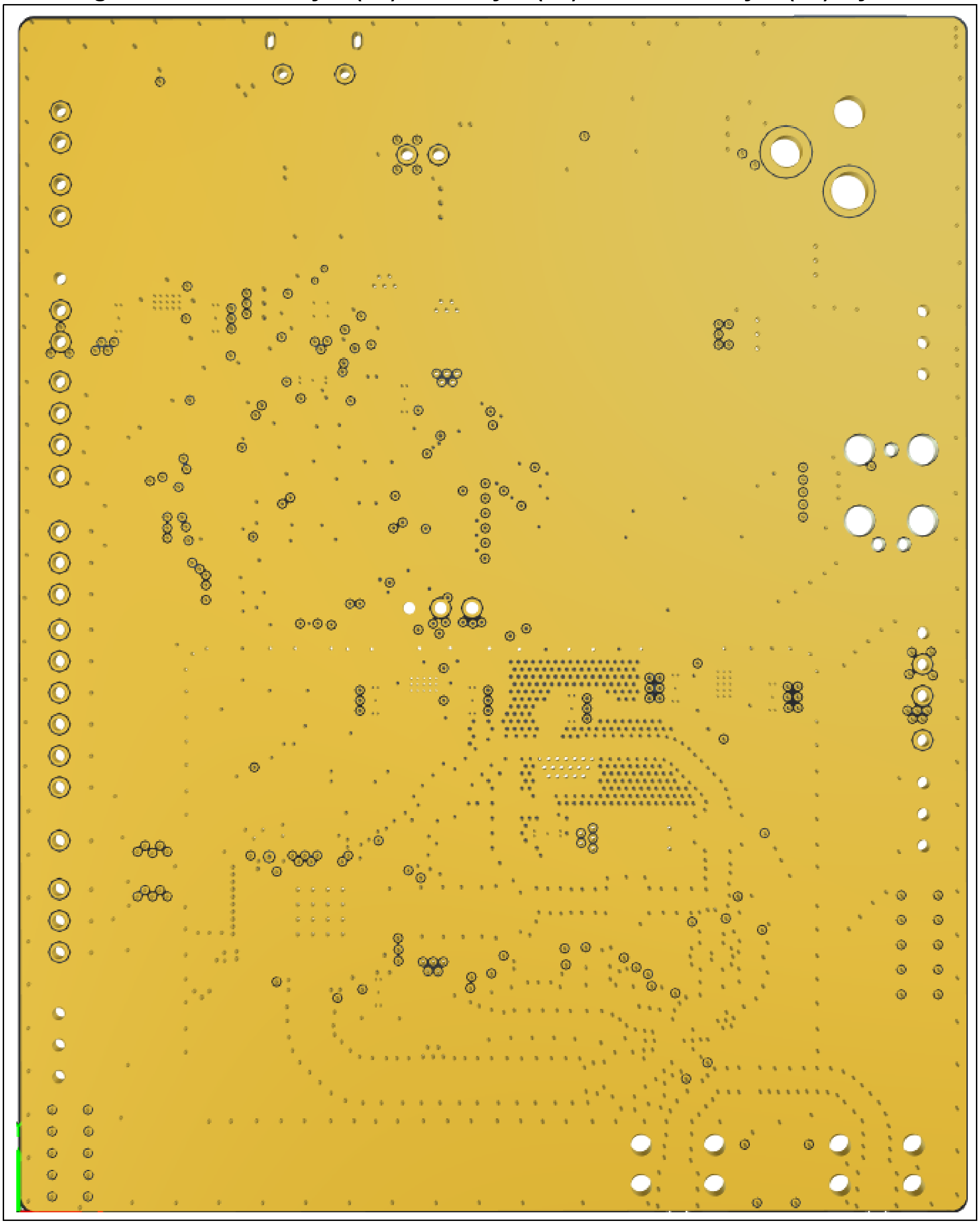


Figure 24. Power layer (L3) layout

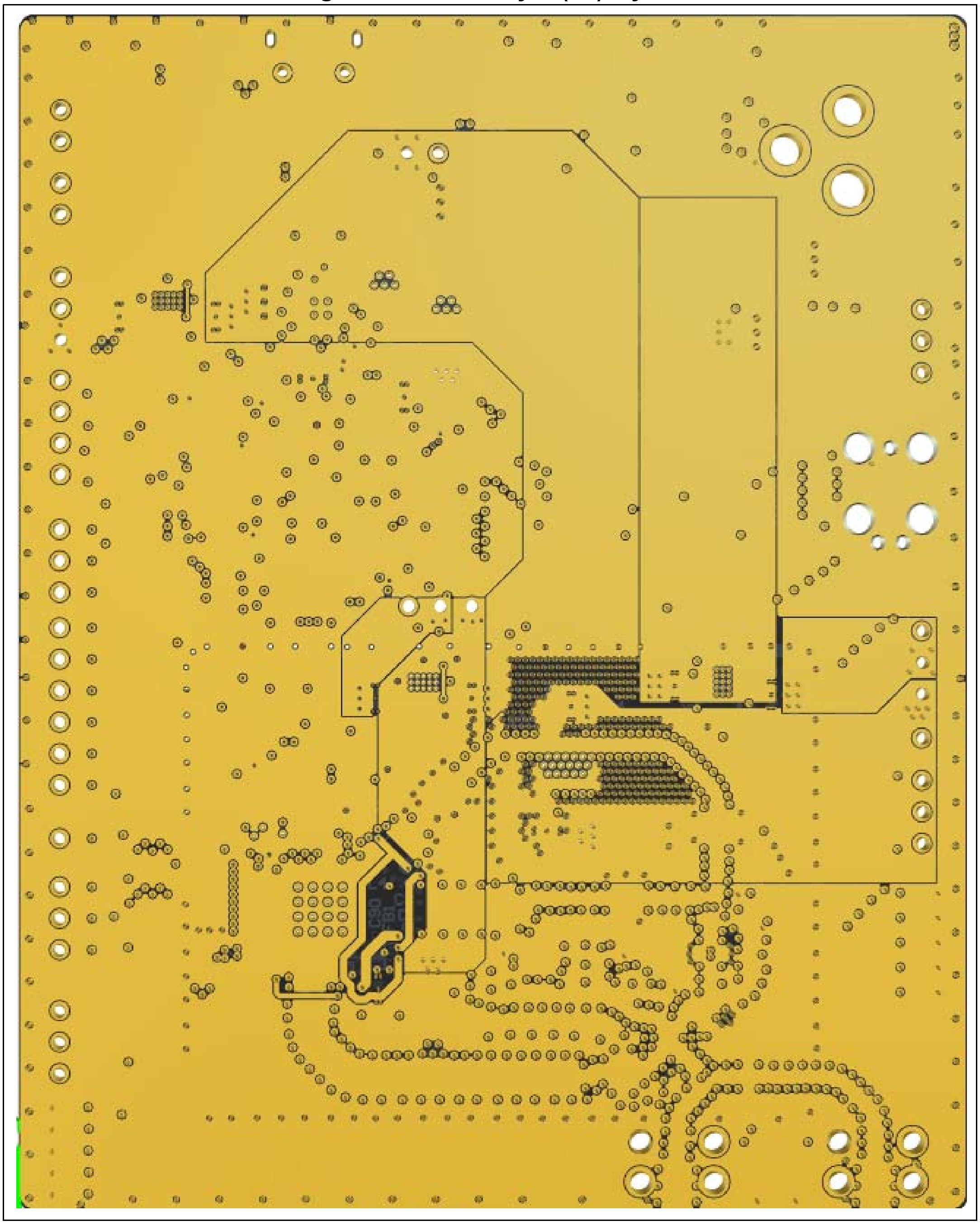
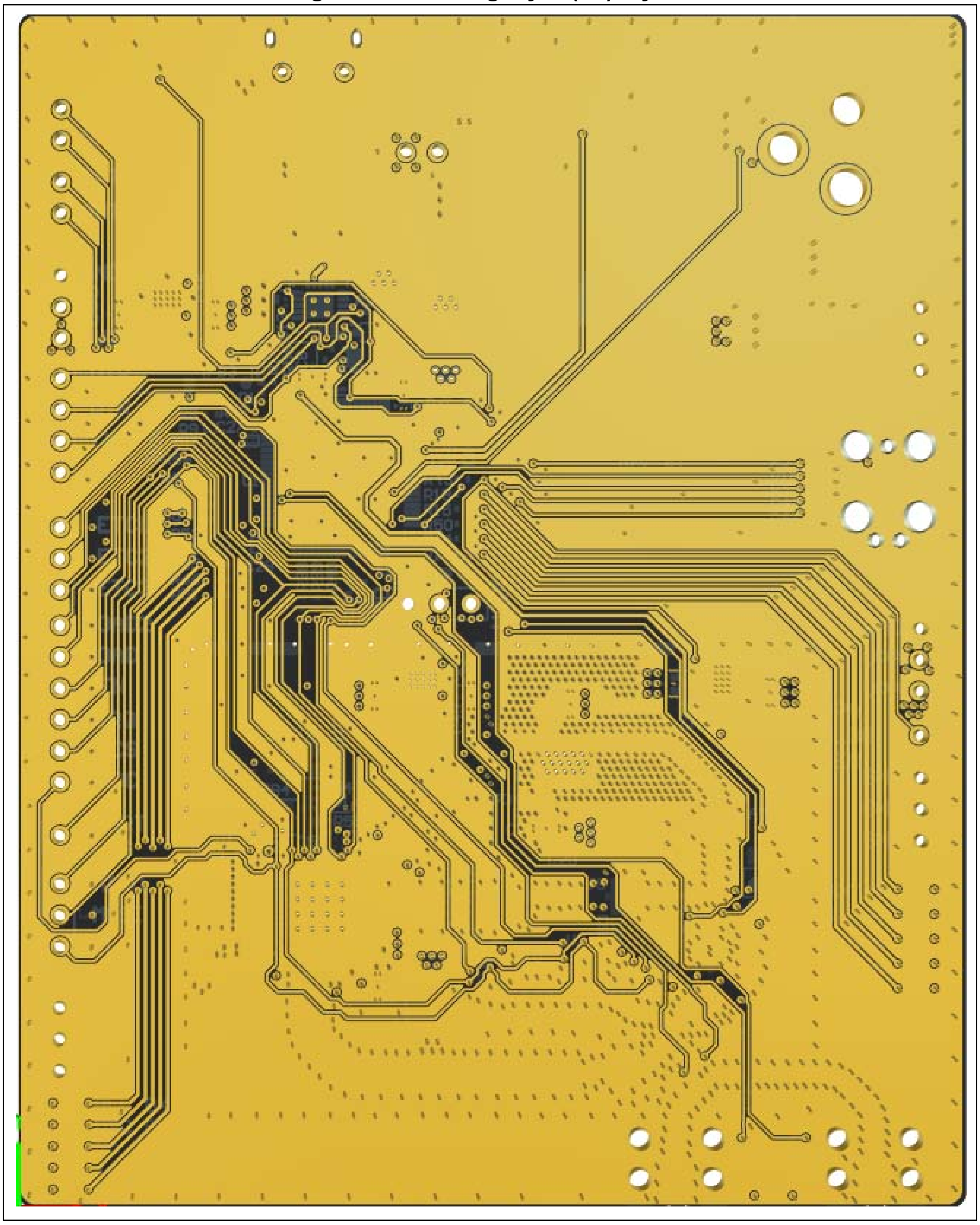


Figure 25. Routing layer (L5) layout



5 Electrical characteristics

Violating the values listed in *Table 17* may damage the reader. Correct operation is not guaranteed when operating outside these specifications.

Table 17. Absolute maximum ratings

Operation temperature	0 °C to +55 °C
Storage temperature	30 °C to +85 °C
DC supply voltage	+6.5 V

Table 18. DC characteristics (V_{BUS} = 5.0 V, 25 °C)

Symbol	Parameter	Min	Typ	Max	Unit
V_{BUS}	Supply voltage	4.5	5.0	5.5	V
I_{BUS}	Supply current	110	119	125	mA
I_{PAext}	External PA current(1)	735	840	945	
I_{PAint}	Internal PA current(1)	325	353	385	

1. Default power setting.

6 Revision history

Table 19. Document revision history

Date	Revision	Changes
10-Aug-2020	1	Initial release.
17-Nov-2020	2	Updated *Section 1.1: Board features* and *Section 2.1: RF circuit*. Updated *Table 11: Connection of components*, *Table 13: Supply voltages of analog test points* and *Table 18: DC characteristics (VBUS = 5.0 V, 25 °C)*.