AN4900
Application note

How to tune STEVAL-ISB038V1 wireless charging evaluation kit for wearable applications

Introduction

The STEVAL-ISB038V1 is a wireless battery charger reference design evaluation kit designed for ultra-compact battery operated devices, such as wearable gear, smartwatches, Internet of Things sensors and healthcare devices.

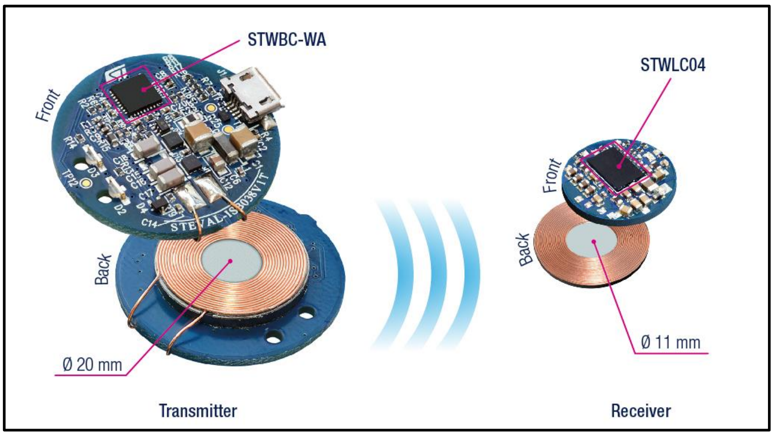
The design is optimized for 1-watt wireless power transfer with a half-bridge topology on the transmitter side and with tiny 11 mm and 20 mm coils on the receiver and transmitter sides, respectively. For power transfers up to 3 watts, the design can be modified by using larger coils and a full-bridge configuration on the transmitter.

The STWBC-WA transmitter can support a cost-effective half-bridge topology (full-bridge optional) and a powerful software API lets you modify the behavior of LED and general purpose IOs as well as connecting external peripherals or devices like sensors to the design via the on-chip I²C and UART ports.

The STWLC04 is designed for 1-watt power transfer based on the Qi protocol, with digital control and precise analog control loops ensuring stable operation. The I²C interface allows a high degree of customization and settings can be stored in the embedded non-volatile memory.

Below you will find information regarding resonance, coupling and communication robustness associated with the STEVAL-ISB038V1R wearable receiver in conjunction with the STEVAL-ISB038V1T transmitter.

Figure 1: STEVAL-ISB038V1R receiver and STEVAL-ISB038V1T transmitter evaluation boards



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1 Overview

1.1 Tuning the STWBC-WA and STWLC04 based wearable system

The main consideration in the wireless charging of wearable and compact applications is the size of the resonant coils or circuits; this is especially true on the receiver side, where there is limited space for an appropriately sized antenna.

The coupling of miniature circuits optimized for wearable applications is far more difficult in terms of proper attachment performance and functionality, than for larger Rx-Tx systems.

1.2 Operating standard

The STWBC-WA- and STWLC04-based wearable kit operation is based on the Qi 1.0 standard with FOD disabled due to low output power and with modified analog/digital ping frequencies. The supported packets comply with the Qi 1.0 specification.

1.3 Maximum transferred power

The power transferred in wearable systems is typically lower than for smartphone charging applications. In this kit, the transferred power is principally limited by the passive components of the receiver, with maximum power in the order of 1 W using certain components; see the STWLC04 datasheet or user manual.

2 Resonant frequency tuning of the wearable kit

2.1 Basic criteria for positioning of the resonant point

The resonant frequencies for the transmitter and receiver are:

Equation 1

$$f_s = \frac{1}{2\pi\sqrt{L_1.C_1}}$$

The second resonance point is not mandatory on the receiver in this wearable kit, but can be set from the parallel capacitor, calculated thus:

Equation 2

$$f_D = \frac{1}{2\pi\sqrt{L_1.\left(\frac{1}{C_1}+\frac{1}{C_2}\right)}}$$

2.2 Transmitter component selection

The LC filter on the transmitter side must allow acceptable coupling with the Rx coil and reasonable freedom regarding its positioning on the wearable kit.

For best results:

- the transmitter coil outer diameter (OD) should be 1.8 to 2.0 times the receiver coil OD
- the receiver coil OD should be about 1.2 to 1.3 times the transmitter coil inner diameter (ID).

For the STWBC-WA supplied by a 5 V DC source, the optimal inductance value is between 6 and 8 µH to contain current ripples in the system and losses in the bridge and Tx coil.

The resonant capacitor is calculated from *Equation 2*, with the DC bias characteristics of the capacitors included.

Because of the weak coupling between very small coils, we often shift the resonant point from the base 100 kHz to the higher 130 kHz empirical value for the 6.3 µH, OD 20 mm Tx coil.

2.3 Receiver component selection

The LC filter selection on the receiver side depends on the components on the Transmitter side. The Rx coil and Tx coil windings must at least overlap partially for reasonable coupling results. The maximum Z distance on which the Rx can be attached is between 10 and 20% of diameter of the receiver coils. At 50%, the coupling is very weak and highly inefficient.

For the Tx coil size suggested in *Section 2.2: "Transmitter component selection"*, a realistic receiver coil diameter would be at least 10 to 11 mm.

The inductance of the coil is selected empirically according the Tx resonant circuit used and the rectified voltage waveform measurement on the receiver. For a 10 to 11 mm coil diameter, good starting values for testing would be around 18 µH and RDC=1 Ω

The resonant capacitor is calculated from *Equation 2*, with the DC bias characteristics of the capacitors included.

2.4 Coupling (ping) test

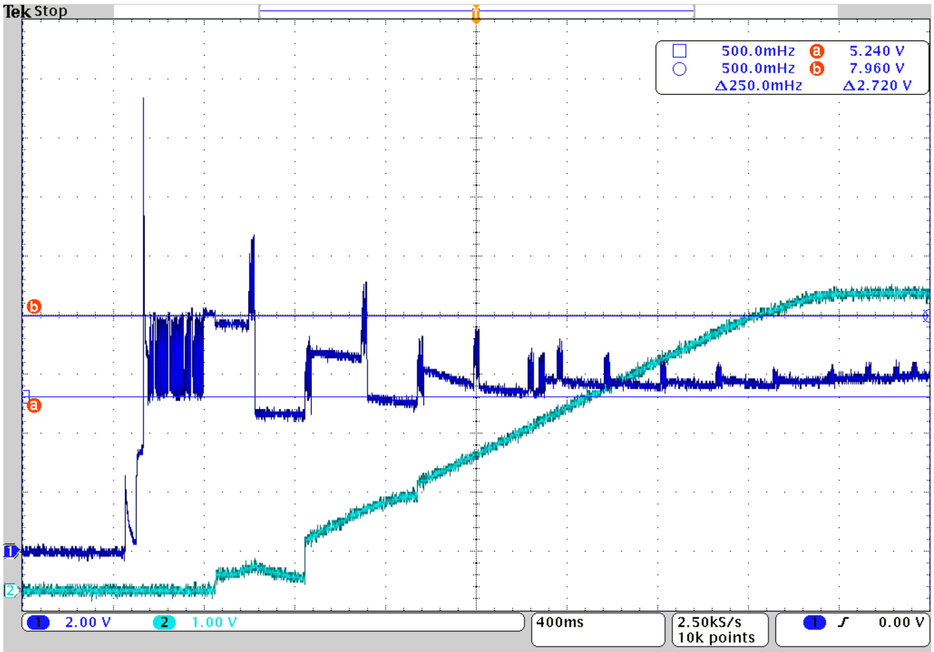
With properly tuned resonant circuits on the Tx and Rx sides, the Rx rectified voltage (VRECT) achieved during the start up with centered attachment should reach about 7 to 8 V.

The voltage reached during this ping phase is under a no load condition as given by the whole Rx resonant circuit. If this voltage is not achieved, the attachment is poor and it may be necessary to increase the overall value of the LC filter with a larger resonant capacitor, for instance.

The increase should not be higher than 20% of the nominal value calculated in *Section 2.1: "Basic criteria for positioning of the resonant point"*.

The modulation in the ping phase is of the resistive type and so has a negative effect on the rectified node. The lowest voltage during modulation in this phase should not fall below 5 V, which often occurs when the Rx coil internal RDC is too high.

Figure 2: Startup of the system CH1 VRECT CH2 VOUT

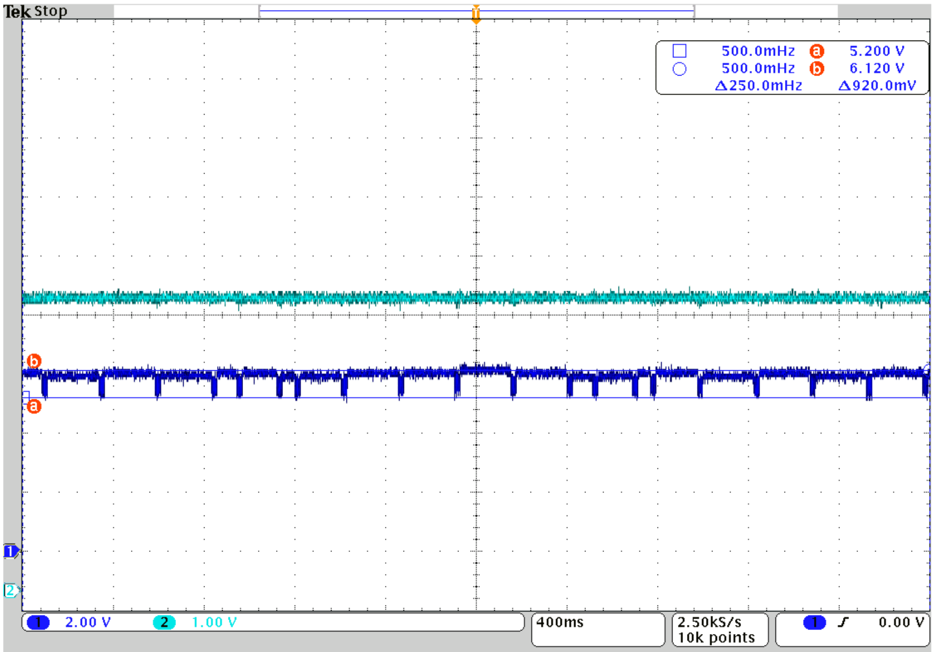


2.5 Power transfer test

If the coupling or ping test in *Section 2.4: "Coupling (ping) test"* is successful, you then need to test the behavior of the system with the power transfer test and modify the value of the Rx coil if needed.

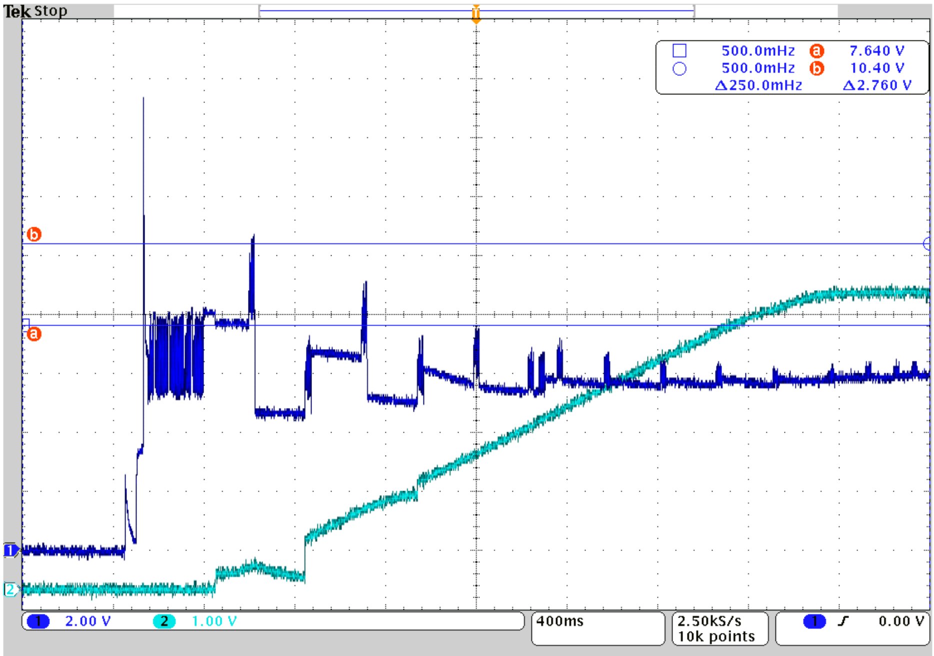
An important parameter to check is the polarity of the ripple coming from the modulation. This ripple must always be positive under almost all load conditions; it may go negative at higher loads, but should never fall below 5.2 V, as shown below.

Figure 3: System running at full load CH1 VRECT CH2 VOUT



If the rectified voltage at highest load is falling below this value, it is good to increase the receiver coil value to result back into the positive effect of the modulation. Increasing of the receiver coil value is affecting the ripple value on the rectified node during no load conditions see the picture below.

Figure 4: System start up, ramping VOUT CH1 VRECT CH2 VOUT



An excessive Rx coil value may result in high ripple and acoustic noise on the system.

2.6 Communication robustness test

The communication test monitors the system with the Tx diagnostic system via UART and related transmitter GUI.

System communication drops are usually signaled via Control Error Timeout. System functionality should therefore be checked across the entire range of loads and conditions. If problems occur, you can resize the value of the CM1 and CM2 capacitors on the receiver side (modulation capacitors).

With the STWBC-WA transmitter, these capacitors are asymmetrical 4.7 and 47 nF. The larger capacitor is usually recommended to be 3 to 5 times smaller than the resonant capacitor on the receiver, while the smaller capacitor should be 10 times smaller than the larger capacitor on the same transmitter.

3 Schematic diagrams

3.1 Receiver schematic diagrams

Figure 5: STEVAL-ISB038V1R receiver board

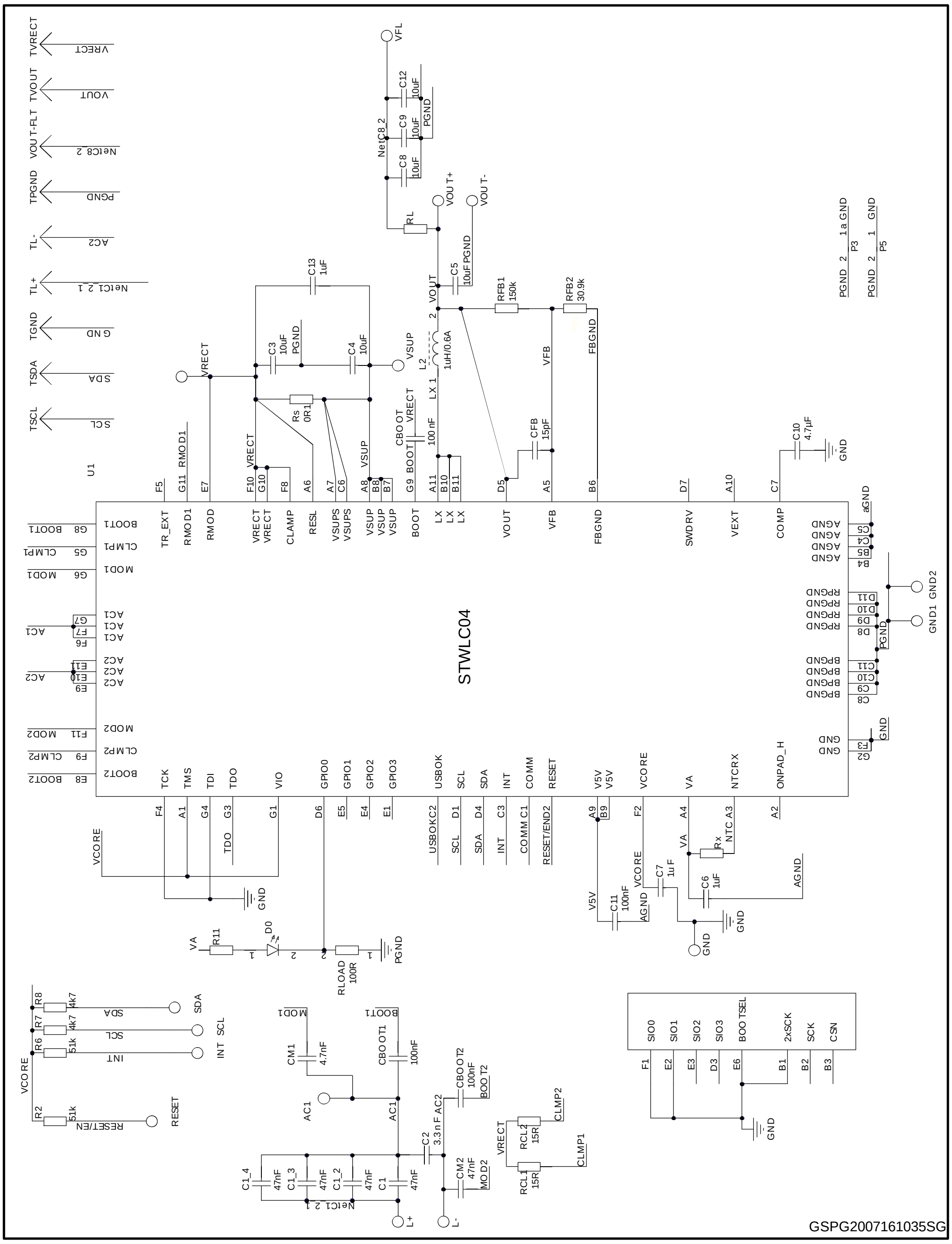
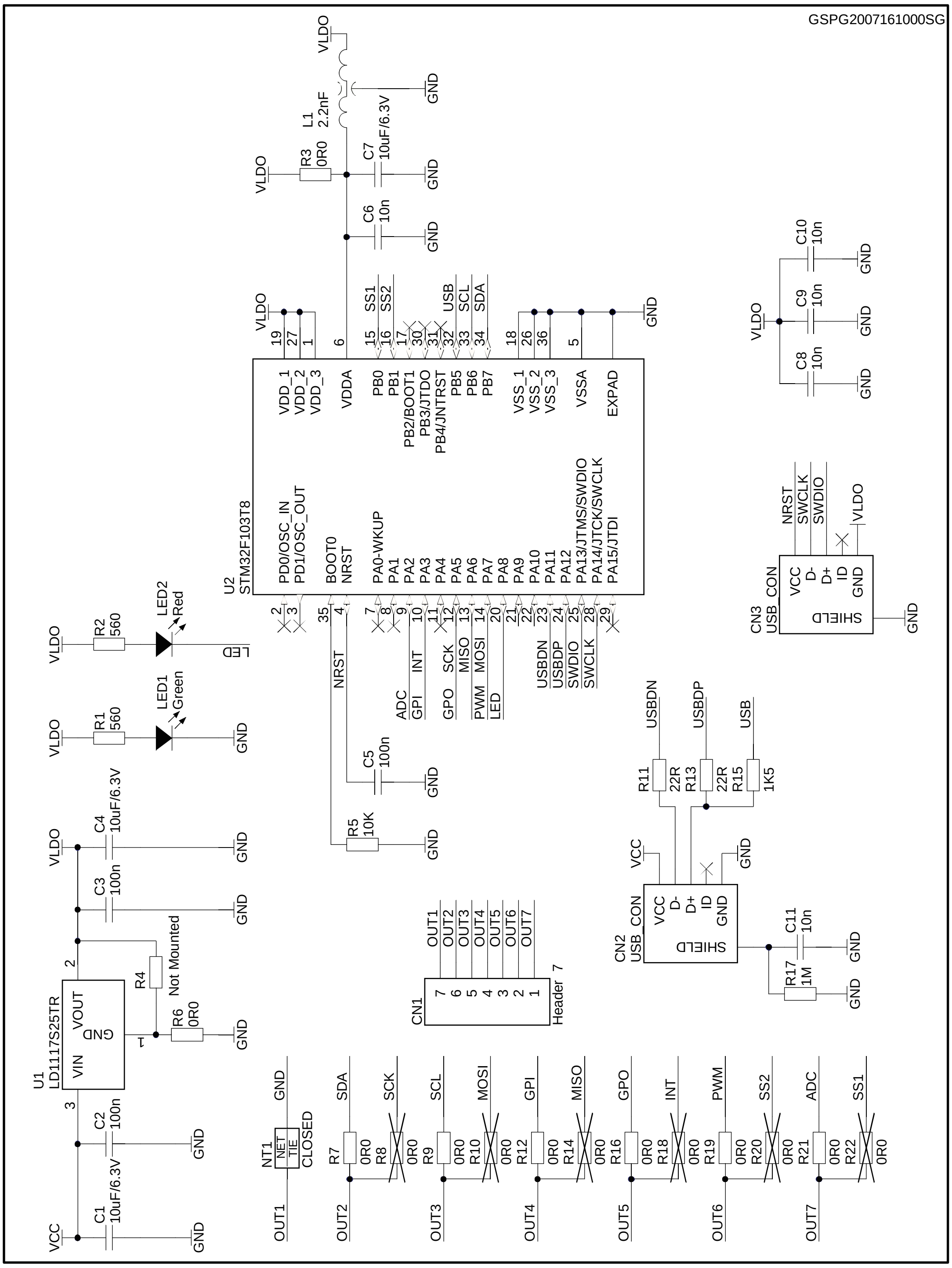


Figure 6: STEVAL-ISB038V1R USB-I²C dongle



3.2 Transmitter schematic diagrams

Figure 7: STEVAL-ISB038V1T transmitter control stage

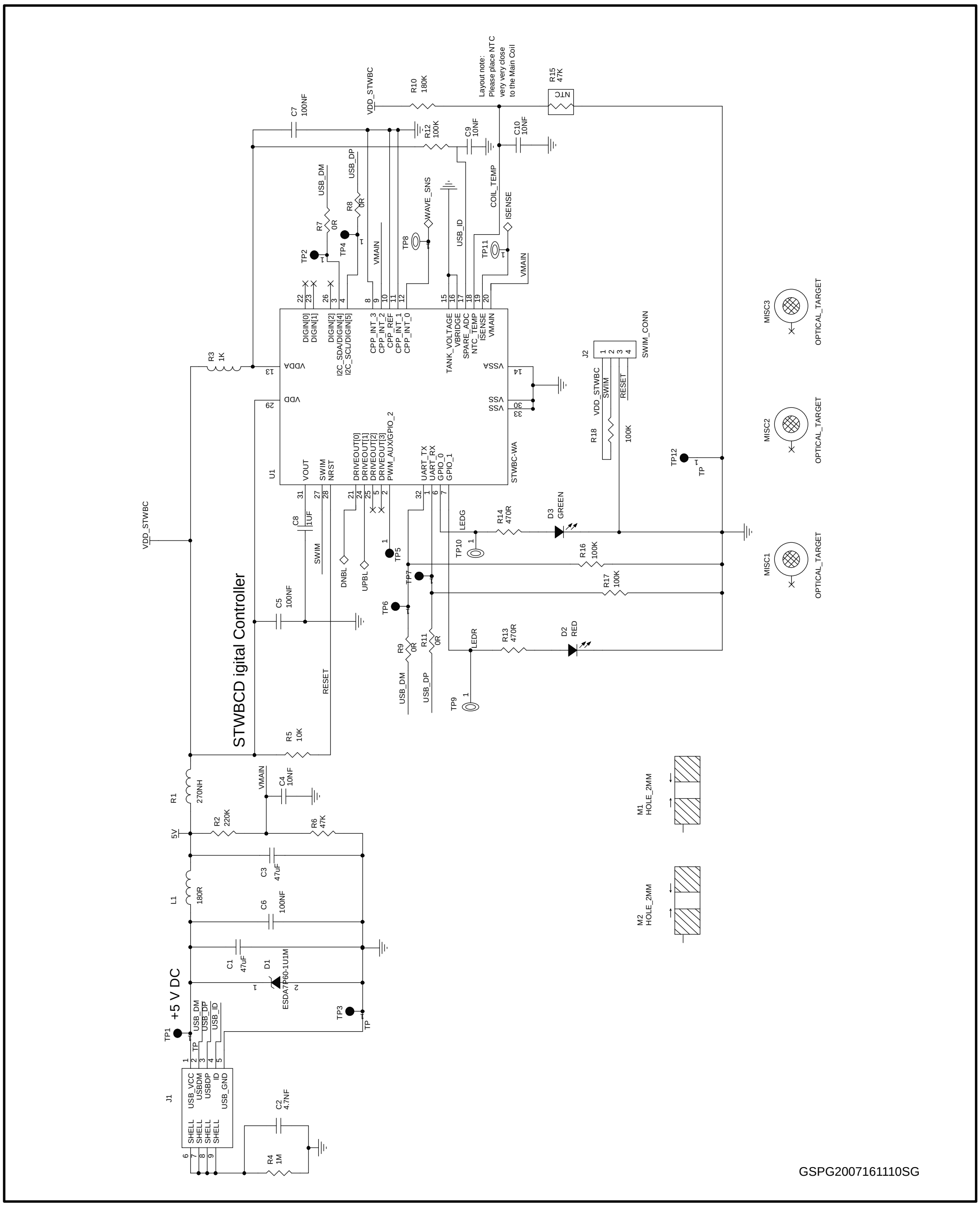


Figure 8: STEVAL-ISB038V1T transmitter power stage

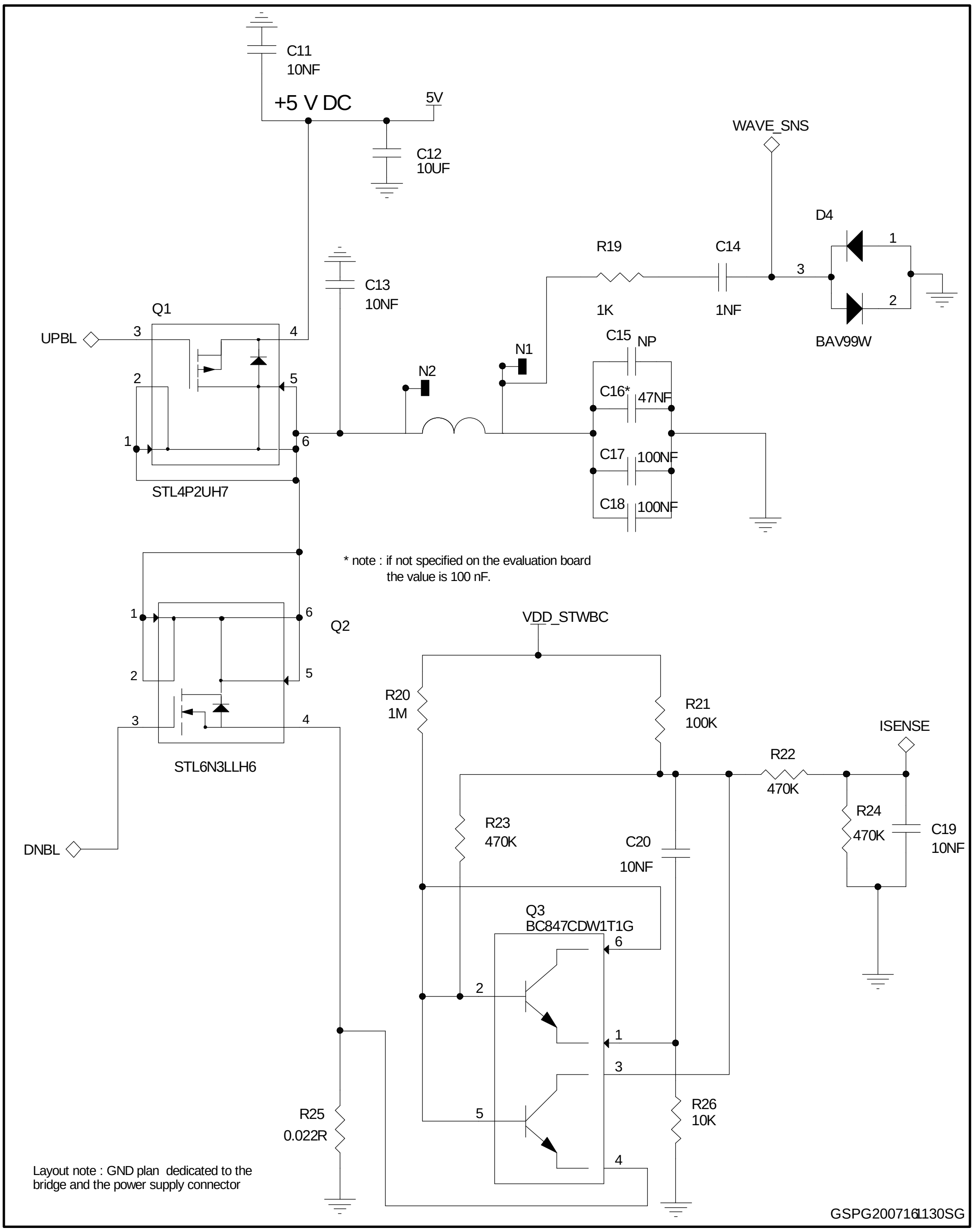
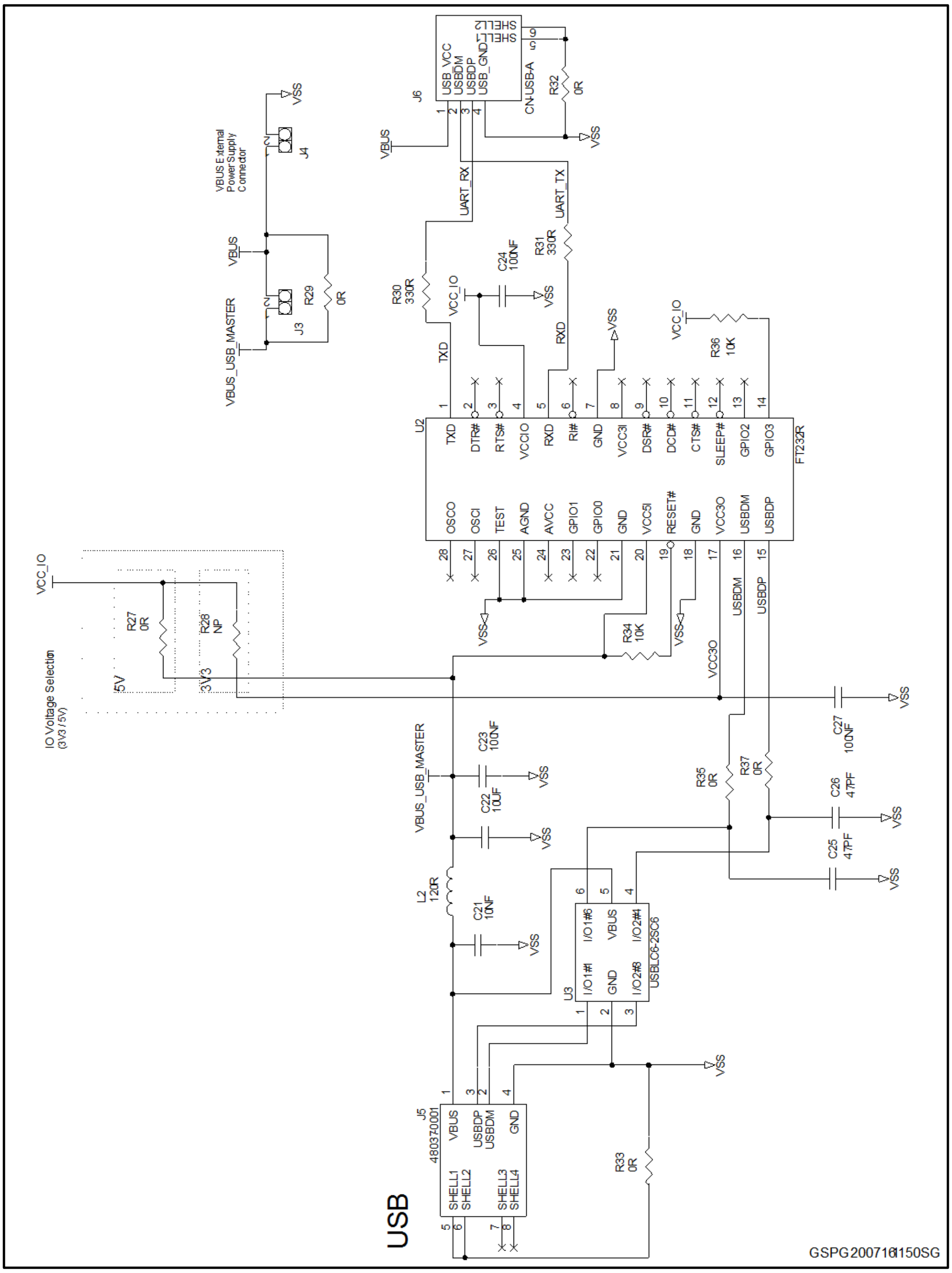


Figure 9: STEVAL-ISB038V1T USB to UART dongle



4 Bill of materials

4.1 Receiver bill of materials

Table 1: STEVAL-ISB038V1R (receiver board) bill of materials

Item	Quantity	Reference	Part/Value	Description	Manufacturer	Part number
1	4	C1, C1_2, C1_3, C1_4	47 nF/50 V/X5R		TDK	GRM155R61H473KE19
2	1	C2	3.3 nF/50 V		Murata	GRM155R71H332KA01
3	5	C3, C5, C8, C9, C12	10 µF/10 V/X5R		Murata	GRM155R61A106ME11
4	1	C4	1 µF/10 V		Murata	GRM155R61A105KE15D
5	3	C6, C7, C13	1 µF/6.3 V		Murata	GRM033R60J105MEA2D
6	4	C11, CBOOT, CBOOT1, CBOOT2	100 nF/10 V		Murata	GRM033R61A104KE84D
7	1	CM1	4.7 nF/50 V		Murata	GRM155R71H472KA01D
8	1	CM2	47 nF/50 V		Murata	GRM155R61H473KE19
9	2	RCL1, RCL2	15 R		Panasonic	ERJ-PA2J150X
10	1	CFB	15 pF/25 V		Murata	GRM0335C1H150JA01
11	1	L2	1 R0/600 mA		TOKO	MFD160806-1R0
12	3	R2, R6, Rx	51k			
13	2	R7, R8	4.7 k			
14	1	RFB1	150 k		STACKPOLE	RGC0201DTD150K-ND
15	1	RFB2	30.9 k		TE-CONNECTIVITY	7-2176074-1
16	1	Rs	0R10/1%		Panasonic	P.10AKCT
17	1	U1		Wearable wireless power receiver (STWLC04)	ST	STWLC04JR
18	1	RL	470 nH		Murata	LQB15NNR47J10D
19	1	RLOAD	100 R			
20	1	R11	1 k			
21	1	D0	2-5 mA	Red LED	Panasonic	LNJ247W82RACT
22	1	C10	4.7 µF/6.3 V		Murata	GRM035R60J475ME15D
23	1	Coil				WR111180-36F5-B1

Table 2: STEVAL-ISB038V1R (USB-I²C dongle) bill of materials

Item	Quantity	Reference	Part/Value	Description	Manufacturer	Part number
1	3	C1, C4, C7	10 µF/6.3 V	Capacitor	Murata	GRM155R60J106ME44
2	3	C2, C3, C5	100 n	Capacitor	Murata	GRM155R61H104KE14
3	5	C6, C8, C9,C10, C11	10 n	Capacitor	Murata	GRM155R71H103KA88
4	1	CN1	1x07 TH/SMD - 90°	Header		
5	2	CN2, CN3		Connector	FCI	10118192-0001LF
6	1	L1	2.2 nF/25 V/6 A	LC filter	Murata	NFE31PT222Z1E9L
7	1	LED1		Green LED	Rohm Semiconductor	SML-210MTT86
8	1	LED2		Red LED	Rohm Semiconductor	SML-210LTT86
9	2	R1, R2	560	Resistor		
10	9	R3, (R4 not mounted), R5, R6, R7, R9, R12, R16, R19, R21	0R0	Resistor		
11	1	R5	10 k	Resistor		
12	2	R11, R13	22 R	Resistor		
13	1	R15	15 k	Resistor		
14	1	R17	1 M	Resistor		
15	1	U1		LDO	ST	LD1117S25TR
16	1	U2		MCU	ST	STM32F103T8U6

4.2 Transmitter bill of materials

Table 3: STEVAL-ISB038V1T board bill of materials

Item	Q.ty	Ref	Part/Value	Description	Manufacturer	Part number
1	2	C1, C3	47 µF, 16 V	CAP CER X5R 1210	Murata	GRM32ER61C476ME15
2	1	C2	4.7 nF, 50 V	CAP CER X7R 0402		4.7NF_50V_X7R_0402
3	7	C4, C9, C10, C11, C13, C19, C20	10 nF, 25 V ±15%	CAP CER X7R 0402		10NF_50V_X7R_0402
4	3	C5, C6, C7	100 nF, 25 V	CAP CER X5R 0402		100NF_25V_X5R_0402
5	1	C8	1 µF, 16 V	CAP CER X5R 0402		1UF_16V_X5R_0402
6	2	C12, C22	10 µF, 10 V	CAP CER X7R 0805	Murata	GRM21BR71A106KE51L
7	1	C14	1 nF, 50	CAP CER X5R 0402		1NF_50V_X5R_0402
8	1	C15		CAP NP 1206		C_NP_1206
9	1	C16	47 nF, 50 V ±5%	CAP CER C0G 1206	Murata	GRM31M5C1H473JA01L
10	2	C17, C18	100 nF, 50 V ±5%	CAP CER C0G 1206	Murata	GRM31C5C1H104JA01L
11	1	C21	10 nF, 50 V	CAP CER X7R 0603		10NF_50V_X7R_0603
12	3	C23, C24, C27	100 nF, 50 V	CAP CER X7R 0603		100NF_50V_X7R_0603
13	2	C25, C26	47 pF, 25 V	CAP CER X5R 0603		47PF_25V_X5R_0603
14	1	D1		High power transient voltage suppressor	ST	ESDA7P60-1U1M
15	1	D2	RED, 2 V	LED side view 155124RS73200	WURTH ELEKTRONIK	LED_155124_RED
16	1	D3	GREEN, 2 V	LED side view 155124VS73200	WURTH ELEKTRONIK	LED_155124_GREEN
17	1	D4		Double diode high speed switching diode		BAV99W-SOT323
18	1	J1		USB_B_MICRO_ CMS	WURTH ELECTRONIK	629105136821

Item	Q.ty	Ref	Part/Value	Description	Manufacturer	Part number
19	1	J2		4-way single row strip line connector (male connector) 2,54 mm pitch	RS	495-8470
20	2	J3, J4		STRIP254P-M-2	Molex	22-28-4023
21	1	J5		MOLEX 48037-0001 embase USB 2.0 type A traversant	Molex	48037-0001
22	1	J6		USB_B_TRAV type A - female	Wurth Elektronic	61400416021
23	1	L1	180 R	FERRITE BEAD, 180 Ohm, 0603	Murata	BLM41PG181SN1
24	1	L2	120 R, 500 mA, ± 25%	FERRITE BEAD, 120 Ohm, 0603, WE-CBF series	Wurth Elektronic	74279262
25	1	Q1	20 V, 0.087 Ohm typ., 4 A	P-channel STripFET H7 Power MOSFET in PowerFLAT 2x2 package	ST	STL4P2UH7
26	1	Q2	30 V, 21 mΩ typ., 6 A	N-channel STripFET H6 Power MOSFET, PowerFLAT 2x2 package	ST	STL6N3LLH6
27	1	Q3	45 V,100 mA, 225 mW	XSTR,GEN PURP,dual NPN, SOT-363	ONSemiconductors	BC847CDW1T1G
28	1	R1	270 nH, ±5%, 110 mA	Inductor 0402	Wurth Elektronic	744784227A
29	1	R2	220 k Ohm 1% 1/16 W	RES 1/16W 0402 SMD		220K_1%_0402
30	1	R3	1 K/0.2 A ± 25%	FERRITE BEAD 0402	Murata	BLM15AG102SN1D
31	2	R4, R20	1 m Ohm - 1/16 W	RES 1/16W 0402 SMD		1M_5%_0402
32	2	R5, R26	10 k Ohm 5%- 1/16 W	RES 1/16W 0402		10K_5%_0402
33	1	R6	47 k - Ohm 1% - 1/16 W	RES 1/16 W 0402 SMD		47K_1%_0402
34	4	R7, R8, R9, R11	0 Ohm 5% 1/16 W	RES 1/16 W 0402 SMD		0R_5%_0402
35	1	R10	180 k Ohm 5% 1/16 W	RES 1/16 W 0402		180K_5%_0402

Item	Q.ty	Ref	Part/Value	Description	Manufacturer	Part number
36	5	R12, R16, R17, R18, R21	100 k Ohm 5% 1/16 W	RES 1/16 W 0402		100K_5%_0402
37	2	R13, R14	470 Ohm 5% 1/16 W	RES 1/16 W 0402 SMD		470R_5%_0402
38	1	R15	47 0K ±5%	Thermistance CTN	Murata	NCP18WB473J03RB
39	1	R19	1 k Ohm 5% 1/16 W	RES 1/16 W 0402 SMD		1K_5%_0402
40	3	R22, R23, R24	470 k Ohm 5%	RES		470K_5%_0402
41	1	R25	0.022 Ohm 2%	RES		0.022_ohm_2%_0805
42	4	R27, R33, R35, R37	0 Ohm 5% 1/10 W	RES 1/10 W 0603		0R_5%_0603
43	1	R28		RES NP 0603		R_NP_0603
44	2	R29, R32	0.0 Ohm 5% 1/10 W	RES 0603	Yageo	RC0603JR-070RL
45	2	R30, R31	330 R Ohm 5% 1/10 W	RES		330R_5%_0603
46	2	R34, R36	10 k Ohm 5% 1/10 W	RES		10K_5%_0603
47	1	U1		Digital controller	ST	STWBC-WA
48	1	U2		UART over USB bridge, SSOP28	FTDI	FT232R
49	1	U3		USBLC6-2SC6 - Reseau de diode TVS USB2	ST	USBLC6-2SC6
50	1	WT202030-16M8[(1)]	6.3 µH	Wireless power charging transmitter coil (TDK) 6.3 µH / 20 mm diameter	TDK	WT202030-16M8

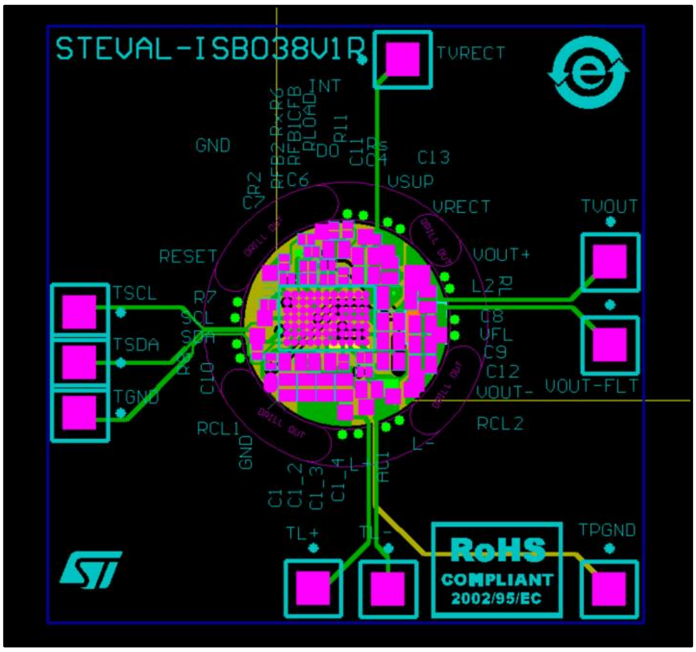
Notes:

[(1)]Wireless power charging transmitter coil WT202030-16M8 can be replaced by the reference WT151512-22F2 by TDK (15mm diameter)

5 Board assembly and layout

5.1 Receiver board assembly and layout

Figure 10: Board assembly

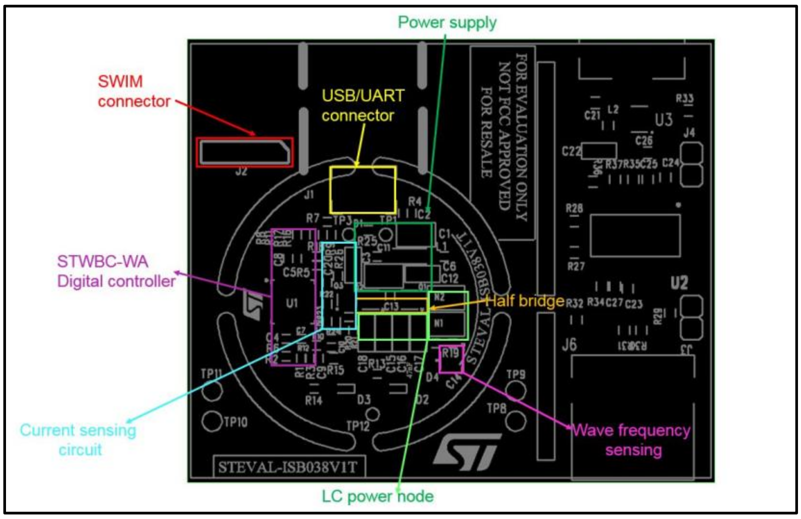


5.2 Transmitter board assembly and layout

The evaluation board is designed using a low cost two-layer PCB, with all the components on the top side. The test points allow the user to evaluate the STWBC-WA solution with probes. The UART is accessible through a micro-USB connector and SWIM connection is routed to a header connector on the cuttable section of the board.

The following figure shows the main functional block divisions on the board.

Figure 11: STEVAL-ISB038V1T evaluation board functional blocks



6 Revision history

Table 4: Document revision history

Date	Version	Changes
02-Sep-2016	1	Initial release.
21-Nov-2016	2	Updated *Figure 1: "STEVAL-ISB038V1R receiver and STEVAL-ISB038V1T transmitter evaluation boards"*, *Figure 7: "STEVAL-ISB038V1T transmitter control stage"*, *Figure 8: "STEVAL-ISB038V1T transmitter power stage"*, *Figure 9: "STEVAL-ISB038V1T USB to UART dongle"*, *Figure 5: "STEVAL-ISB038V1R receiver board"*, *Figure 6: "STEVAL-ISB038V1R USB-I²C dongle"*, *Table 1: "STEVAL-ISB038V1R (receiver board) bill of materials"*, *Table 2: "STEVAL-ISB038V1R (USB-I²C dongle) bill of materials"*, *Table 3: "STEVAL-ISB038V1T board bill of materials"* and *Figure 10: "Board assembly"*
27-Jan-2017	3	Updated *Table 3: "STEVAL-ISB038V1T board bill of materials"*
11-Apr-2017	4	Updated *Table 1: "STEVAL-ISB038V1R (receiver board) bill of materials"*