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.

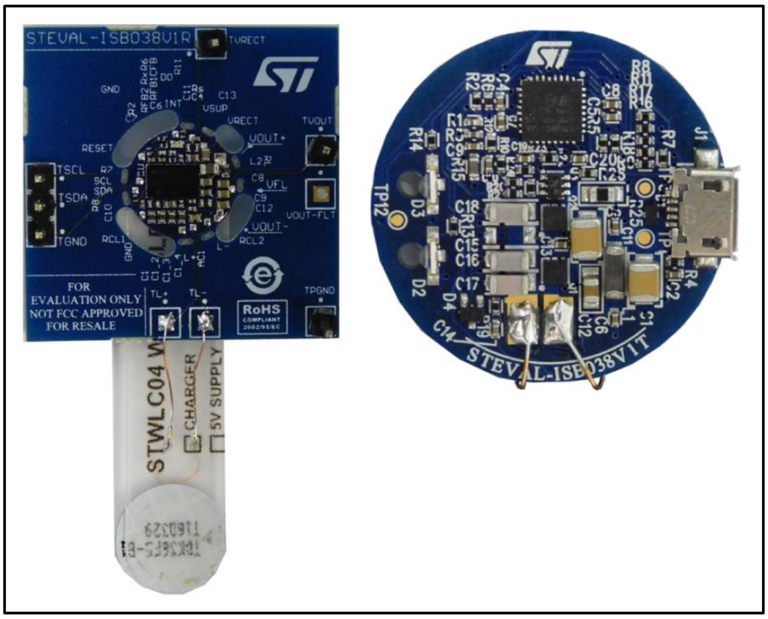
The design is optimized for 1-watt wireless power transfer with a half-bridge topology on the transmitter side and with tiny 11 mm and 20 mm coils on the receiver and transmitter sides, respectively. For power transfers up to 3 watts, the design can be easily modified by using larger coils and a full-bridge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

This application note describes the 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



Contents

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 4.2: "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

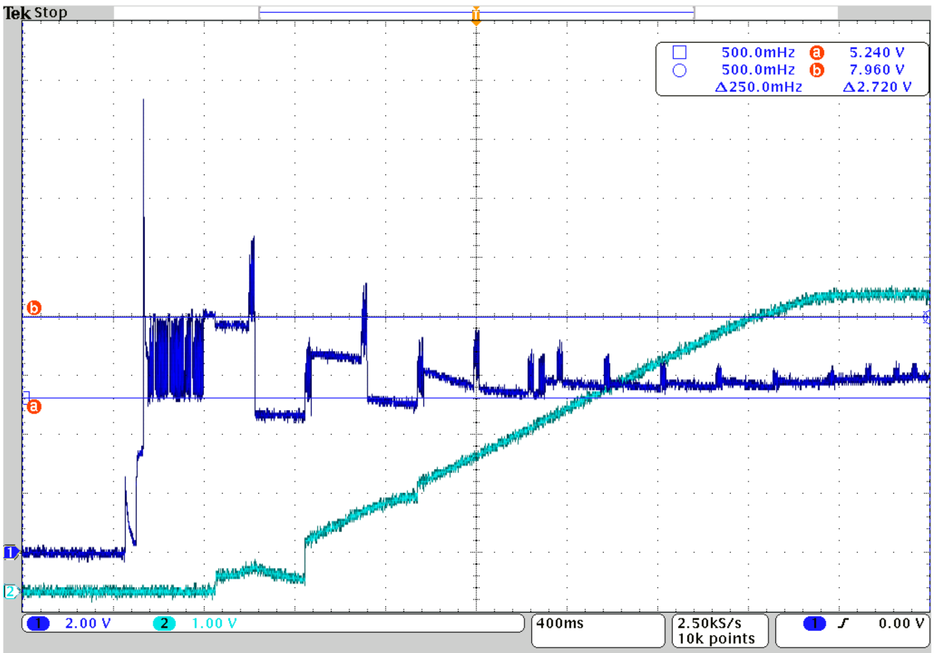
With properly tuned resonant circuits on the Tx and Rx sides, the Rx rectified voltage (VRECT) achieved during the start up with centered attachment should reach about 7 to 8 V.

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 4.1: "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

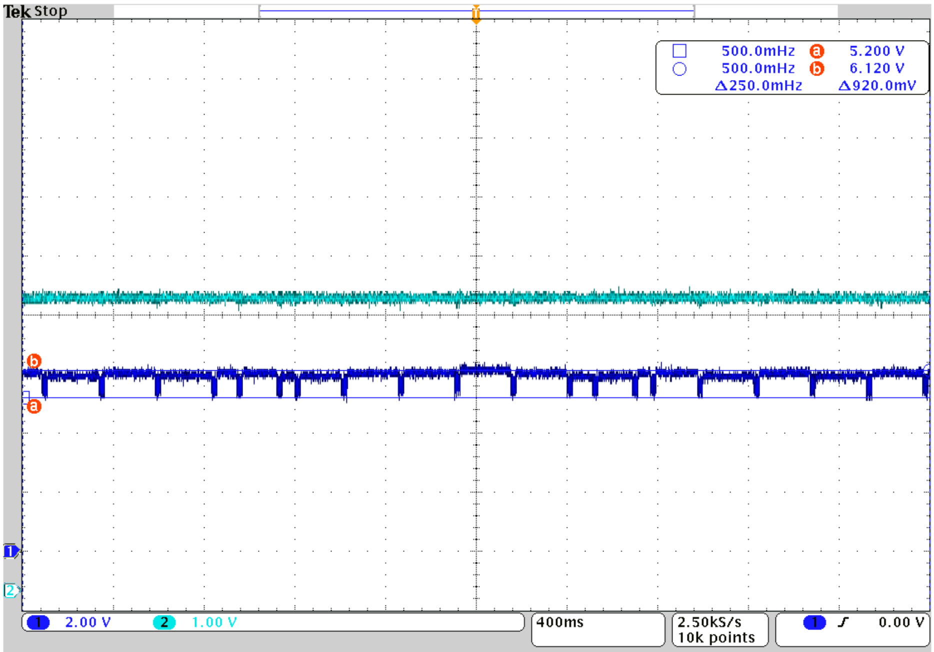


2.5 Power transfer test

If the coupling or ping test in *Section 4.4: "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.

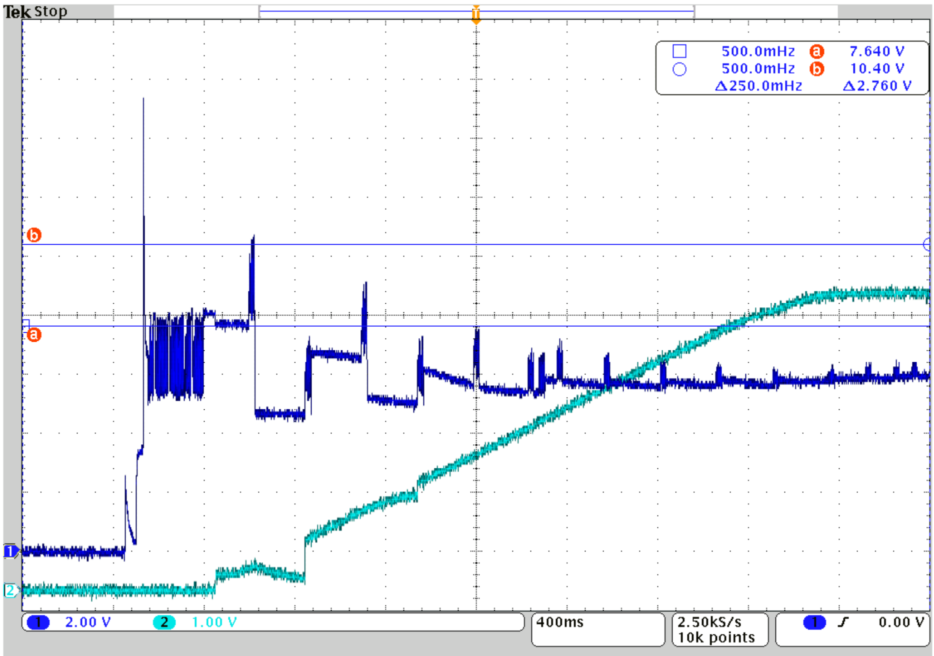
An important parameter to check is the polarity of the ripple coming from the modulation. This ripple must always be positive under almost all load conditions; it may go negative at higher loads, but should never fall below 5.2 V, as shown below.

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

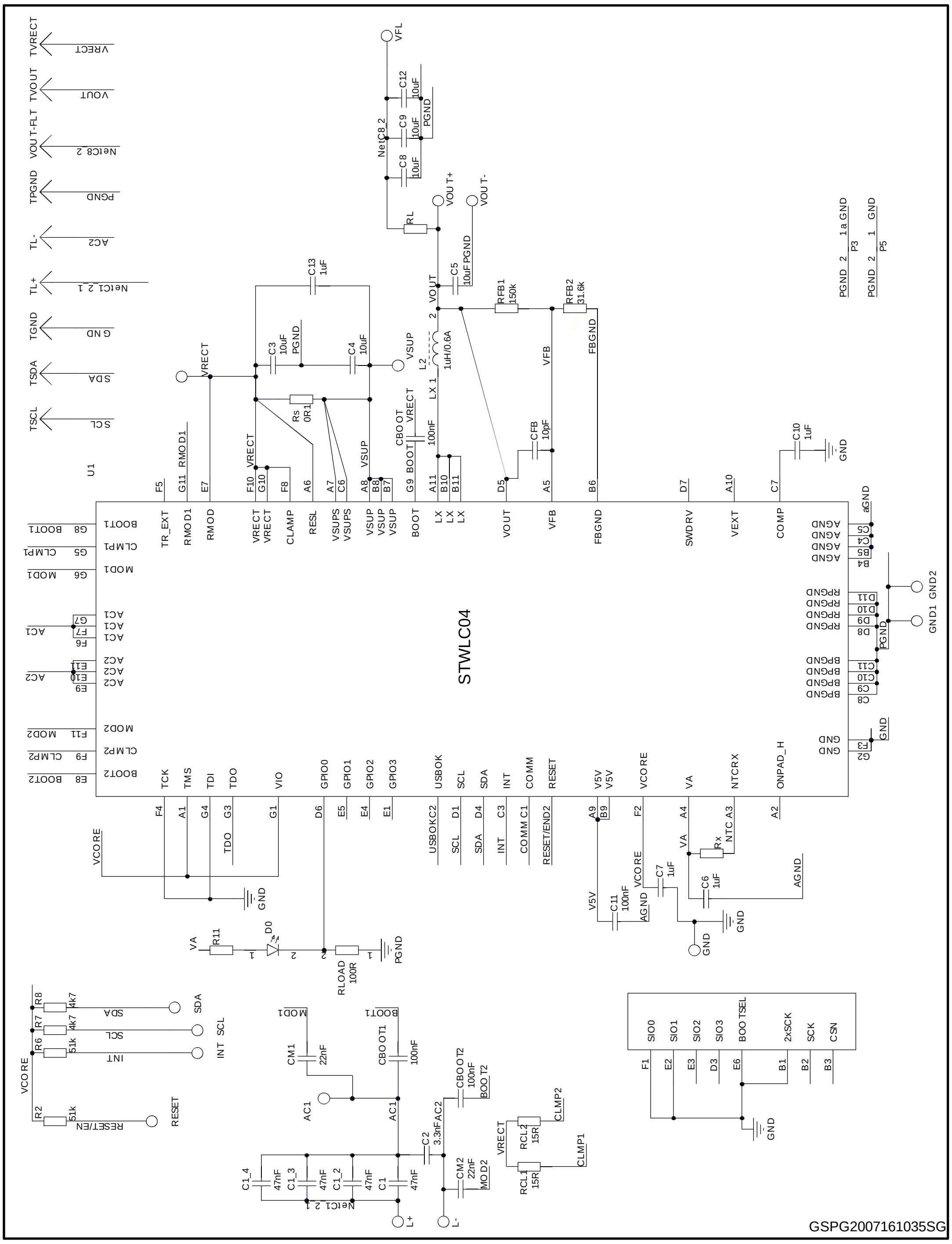
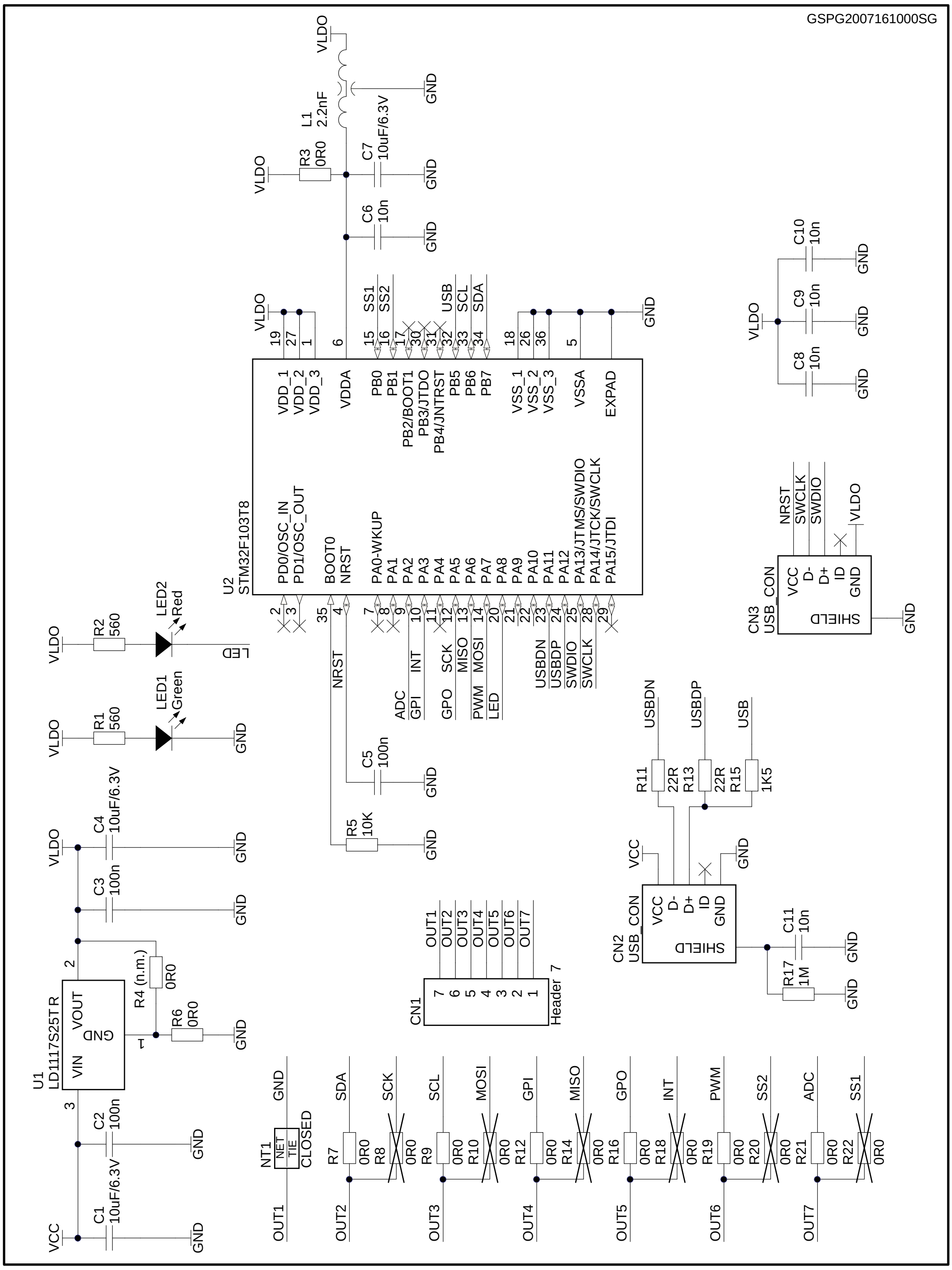


Figure 6: STEVAL-ISB038V1R USB-I²C dongle



3.2 Transmitter schematic diagrams

Figure 7: STEVAL-ISB038V1T transmitter control stage

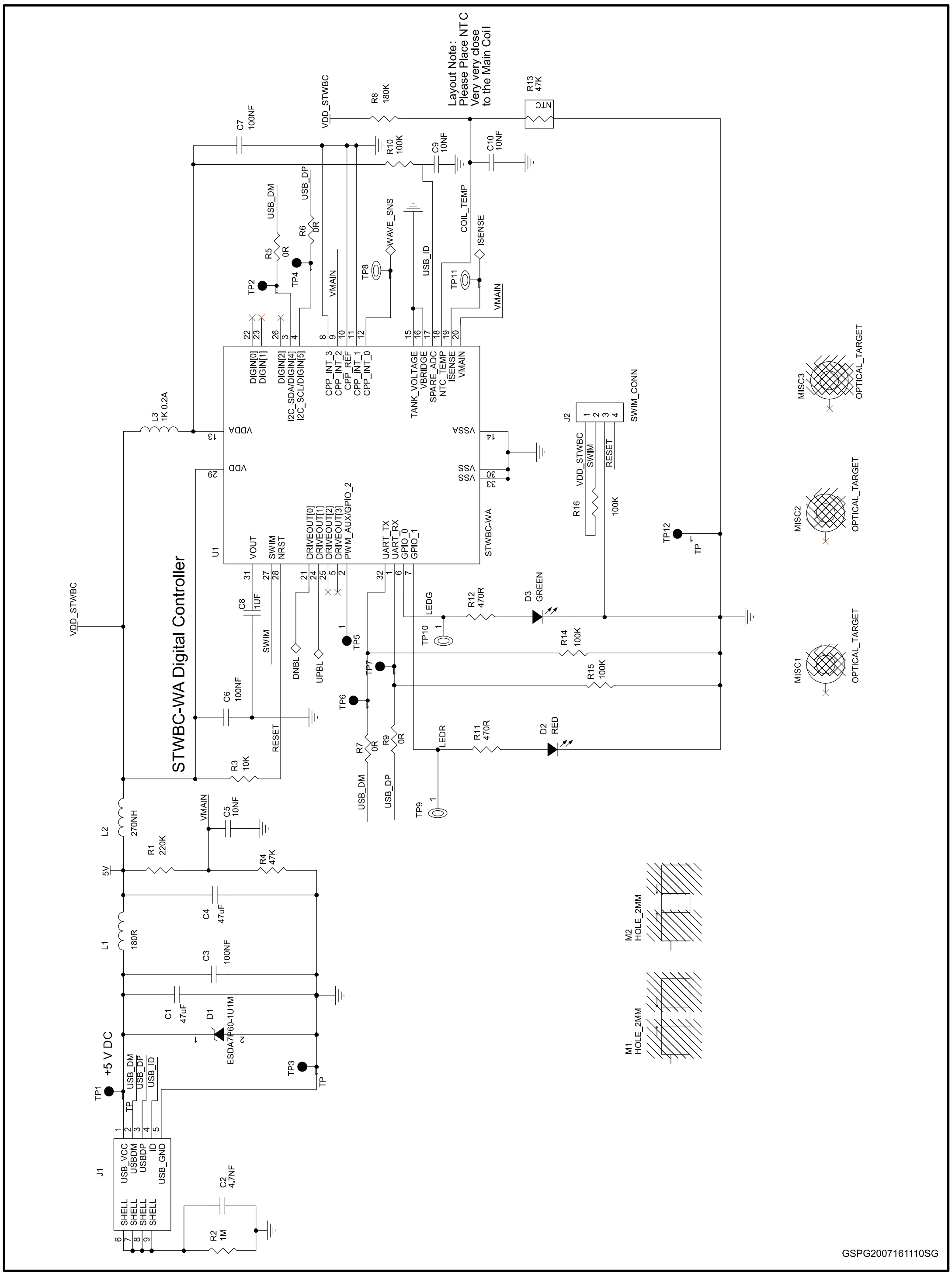


Figure 8: STEVAL-ISB038V1T transmitter power stage

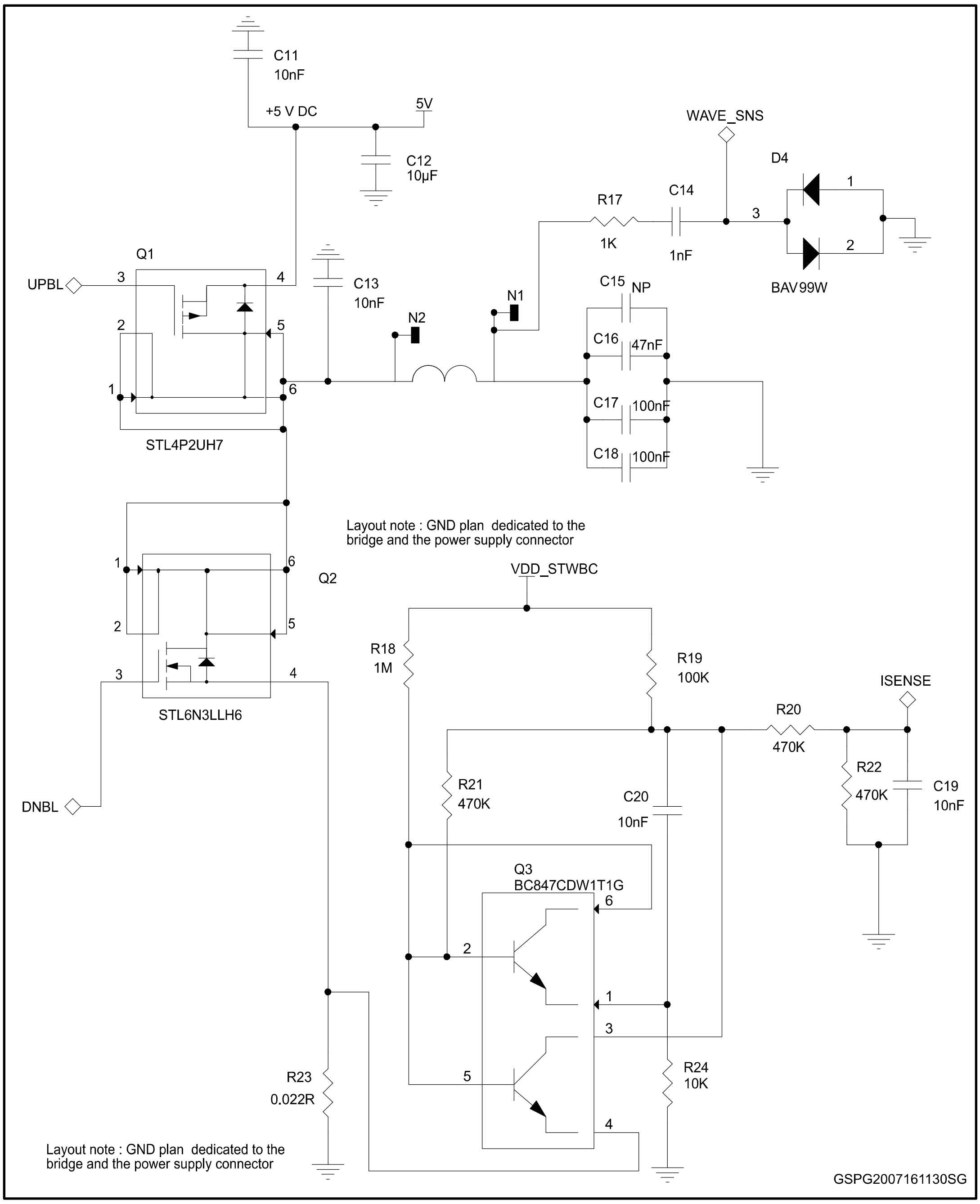
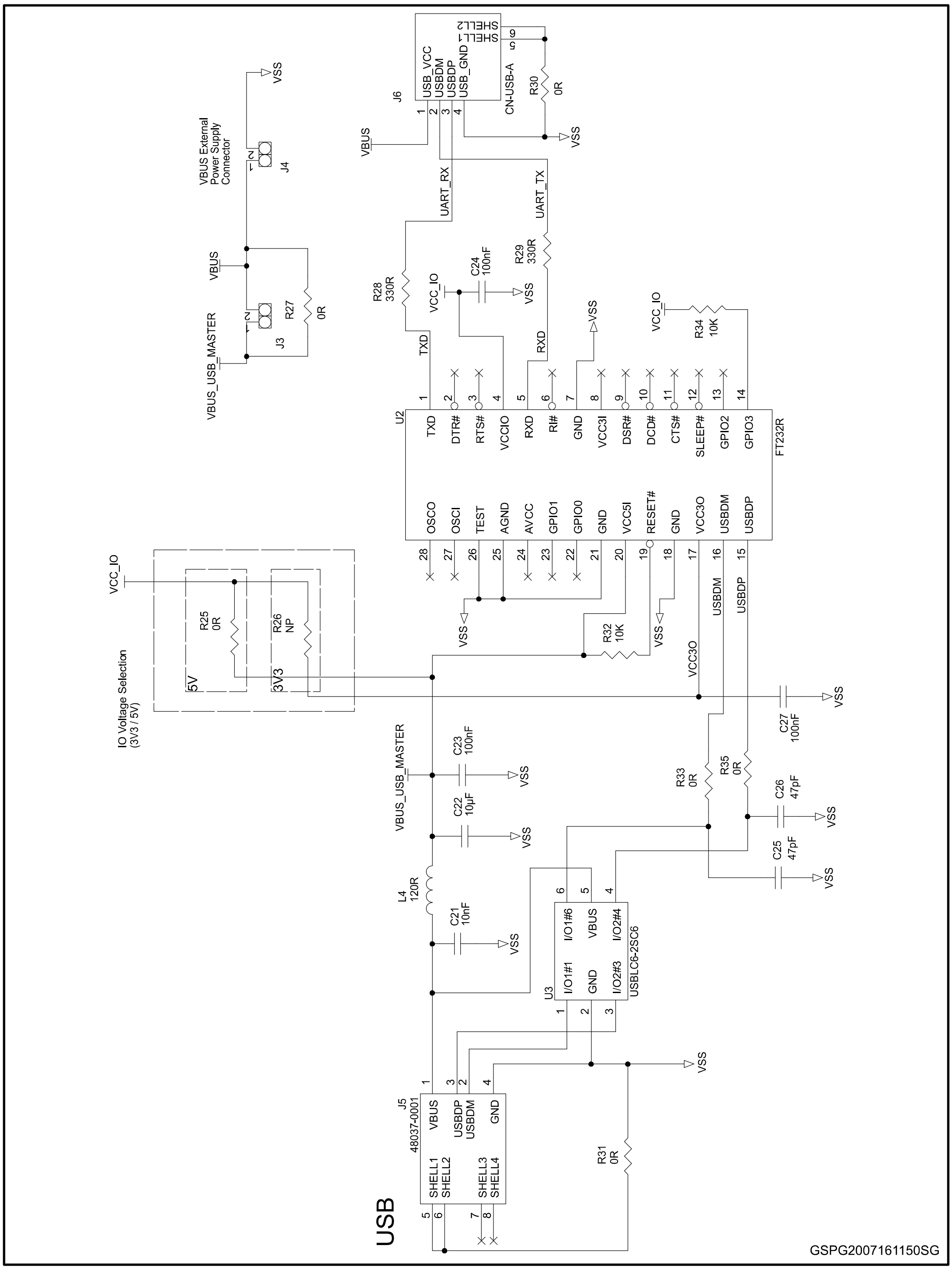


Figure 9: STEVAL-ISB038V1T USB to UART dongle



4 Bill of materials

4.1 Receiver bill of materials

Table 1: STEVAL-ISB038V1R RX board bill of materials

Component	Manufacturer	Order code	Value	Size
L1	TDK	WR111118-36-F5-B1	18 µH	11 x 1.4 mm
L2	TOKO	MFD160806-1R0	1 µH/600 mA	0603
C1	MURATA	4x GRM155R61H473KE19	47 nF/X7R	0402
C2	MURATA	GRM155R71H332KA01	3.2 nF/C0G	0402
C3, C5	MURATA	GRM155R61A106ME11	10 µF/10 V	0402
C4	MURATA	GRM155R61A105KE15D	1 µF/10 V	0402
CBOOT1, CBOOT2, CBOOT, C11	MURATA	GRM033R61A104KE84D	100 nF/10 V	0201
C10	MURATA	GRM035R60J475ME15D	4.7/6.3 V	0201
C6, C7, C13	MURATA	GRM033R60J105MEA2D	1 µF/6.3 V	0201
CM1	MURATA	GRM155R71H473KA12	47 nF/50 V	0402
CM2	MURATA	GRM155R71H472KA12	4.7 nF/50 V	0402
RCL1, RCL2	PANASONIC	ERJ-PA2J150X	15 R	0402
CFB	MURATA	GRM0335C1H150JA01	15 pF	0201
RS	PANASONIC	P.10AKCT	0.1 Ω/1%	0402
R1			51 kΩ	0201
RFB1	STACKPOLE	RGC0201DTD150K-ND	150 kΩ	0201
RFB2	TE-CONNECTIVITY	7-2176074-1	30.9 kΩ	0201
RNTC	MURATA		100 kΩ	0402
CCHG (filter)	MURATA	3x GRM155R61A106ME11	10 µF/10 V	0402
LCHG (filter)	MURATA	LQB15NNR47J10D	470 nH	0402

4.2 Transmitter bill of materials

Table 2: STEVAL-ISB038V1T board bill of materials

Item	Q.ty	Ref	Value	Notes	Part number	Manufacturer
1	2	C1, C4	47µF, 16V ±20%	CAP CER X5R 1210	C1210	MURATA
2	1	C2	4.7nF, 50V ±15%	CAP CER X7R 0402	C0402	
3	3	C3, C6, C7	100nF, 25V ±15%	CAP CER X5R 0402	C0402	
4	7	C5, C9-C11, C13, C19, C20	10nF, 50V ±15%	CAP CER X7R 0402	C0402	
5	1	C8	1µF, 16V ±10%	CAP CER X5R 0402	C0402	
6	2	C12, C22	10µF, 10V ±10%	CAP CER X7R 0805	C0805	MURATA
7	1	C14	1nF, 50V ±15%	CAP CER X5R 0402	C0402	
8	1	C15	NP	CAP NP 1206	C1206	
9	1	C16	47nF, 50V ±5%	CAP CER C0G 1206	C1206	MURATA
10	2	C17, C18	100nF, 50V ±5%	CAP CER C0G 1206	C1206	MURATA
11	1	C21	10nF, 50V ±15%	CAP CER X7R 0603	C0603	
12	3	C23, C24, C27	100nF, 50V ±15%	CAP CER X7R 0603	C0603	
13	2	C25, C26	47pF, 25V ±15%	CAP CER X5R 0603	C0603	
14	1	D1	ESDA7P60-1U1M	HIGH POWER TRANSIENT VOLTAGE SUPPRESSOR	1610-1K-2A	ST
15	1	D2	RED, 2V	LED side view 155124RS73200	LED_155124_RED	WURTH ELEKTRONIK
16	1	D3	GREEN, 2V	LED side view 155124VS73200	LED_155124_GREEN	WURTH ELEKTRONIK
17	1	D4	BAV99W	Double Diode High Speed Switching Diode	BAV99W-SOT323	
18	1	J1	CN-MICRO-USB	USB_B_MICRO_CMS	MICRO_USB_B_136821	WURTH ELECTRONIK
19	1	J2	SWIM_CONN	4 ways single row strip line connector (male connector) 2,54mm pitch	HE14-4	RS
20	2	J3, J4	JUMPER2	STRIP254P-M-2	22-28-4023	MOLEX
21	1	J5	48037-0001	MOLEX 48037-0001 EMBASE USB 2.0 TYPE A TRAVERSANT	CONN_USB_MOLEX_A_480370001	MOLEX
22	1	J6	CN-USB-A	USB_B_TRAV TYPE A - FEMALE	USB-A	WURTH ELECTRONIK
23	1	L1	180R	FERRITE BEAD 0603	L1806	MURATA

Item	Q.ty	Ref	Value	Notes	Part number	Manufacturer
24	1	L2	270nH, 100mA ±5%	INDUCTOR 0402	L0402	WURTH ELEKTRONIK
25	1	L3	1K 0.2A, ±25%	FERRITE BEAD 0402	L0402	MURATA
26	1	L4	120R, 500mA ±25%	FERRITE BEAD, 0603, WE-CBF series	L0603	WURTH
27	1	Q1	20 V, 0.087Ω typ., 4 A	P-channel STripFET H7 Power MOSFET in PowerFLAT 2x2 package	STL4P2UH7	ST
28	1	Q2	30 V, 21mΩ typ., 6A	N-channel STripFET H6 Power MOSFET, PowerFLAT 2x2 package	STL6N3LLH 6	ST
29	1	Q3	45V,100mA, 225mW	XSTR,GEN PURP,dual NPN, SOT-363	BC847CDW 1T1G-SOT363	ON SEMICONDU CTOR
30	1	R1	220K ±%	RES 1/16W 0402 SMD	R0402	
31	2	R2, R18	1M ±5%	RES 1/16W 0402 SMD	R0402	
32	2	R3, R24	10K ±5%	RES 1/16W 0402 SMD	R0402	
33	1	R4	47K ±1%	RES 1/16W 0402 SMD	R0402	
34	4	R5-R6[(1)], R7, R9	0R ±5%	RES 1/16W 0402	R0402	
35	1	R8	180K ±5%	RES 1/16W 0402 SMD	R0402	
36	5	R10, R14-R16, R19	100K ±5%	RES 1/16W 0402 SMD	R0402	
37	2	R11, R12	470R ±5%	RES 1/16W 0402	R0402	
38	1	R13	47K ±5%	Thermistance CTN, 0603	R0603	MURATA
39	1	R17	1K ±5%	RES 1/16W 0402 SMD	R0402	
40	3	R20-R22	470K ±5%	RES 0402	R0402	
41	1	R23	0.022R ±2%	RES	R0805	
42	4	R25, R31, R33, R35	0R ±5%	RES 1/10W 0603	R0603	
43	1	R26	NP	RES NP 0603	R0603	
44	2	R27, R30	0R ±5%	RES 1/10W 0603	R0603	YAGEO
45	2	R28, R29	330R ±5%	RES 1/10W 0603	R0603	
46	2	R32, R34	10K ±5%	RES 1/10W 0603 SMD	R0603	
47	4	TP8-TP11		Test Point TPTH-ANELLO-1mm black	TPTH-ANELLO-1MM	KEYSTONE
48	1	U1		Digital controller QFN32-5x5	STWBC-WA	ST

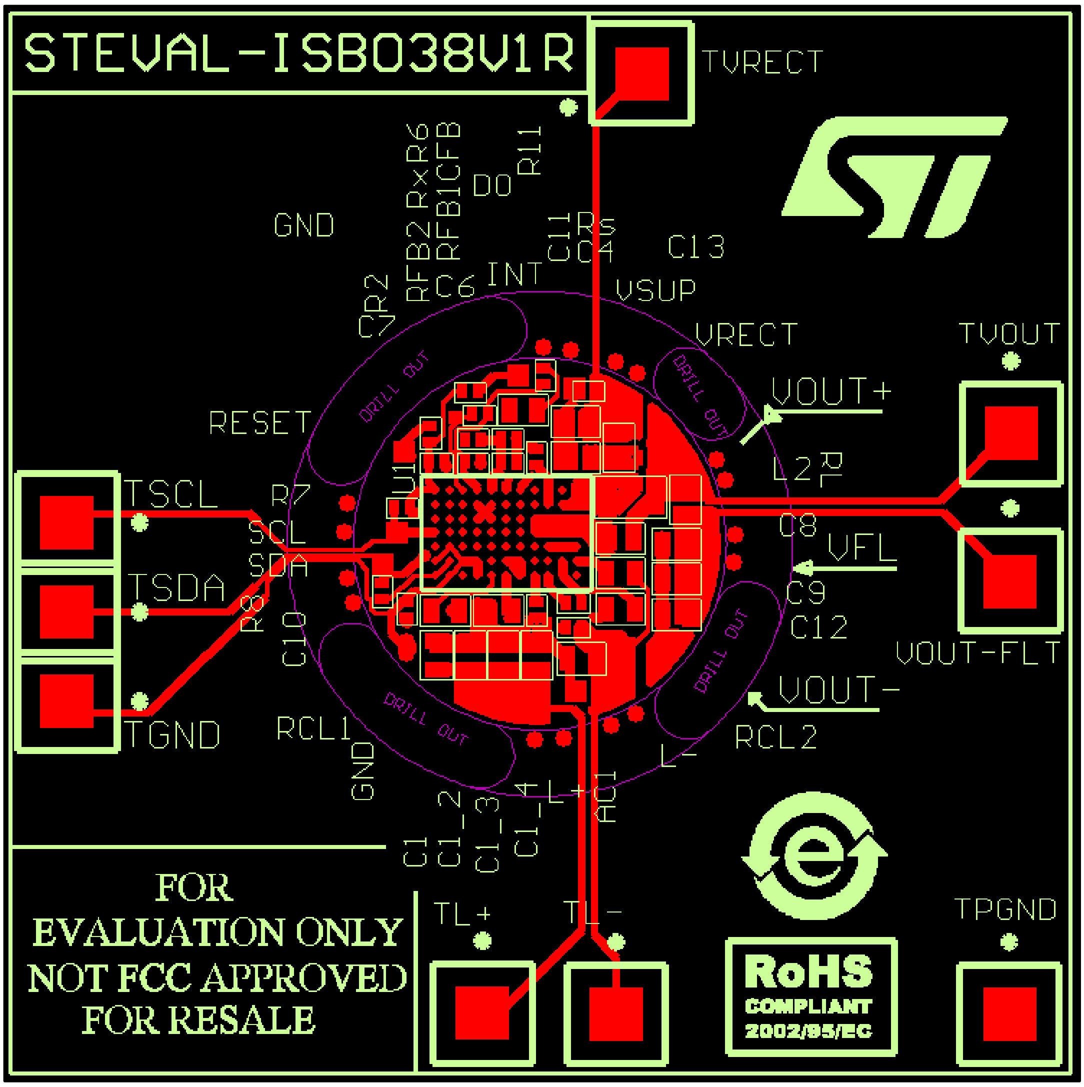
Item	Q.ty	Ref	Value	Notes	Part number	Manufacturer
49	1	U2		UART over USB bridge, SSOP28	FT232R	FTDI
50	1	U3		USBLC6-2SC6 - RESEAU DE DIODE TVS USB2	USBLC6-2SC6	ST
51	1			Wireless power charging transmitter coil (TDK) 6.3µH / 20mm diameter	WT202030-16M8	TDK
52	1			Polycarbonate cover plate 30mm dia 1mm thick to be attached to coil with 0.3mm double faced tape)		

(1)These components may be removed to decrease the global current consumption.

5 Board assembly and layout

5.1 Receiver board assembly and layout

Figure 10: Board assembly

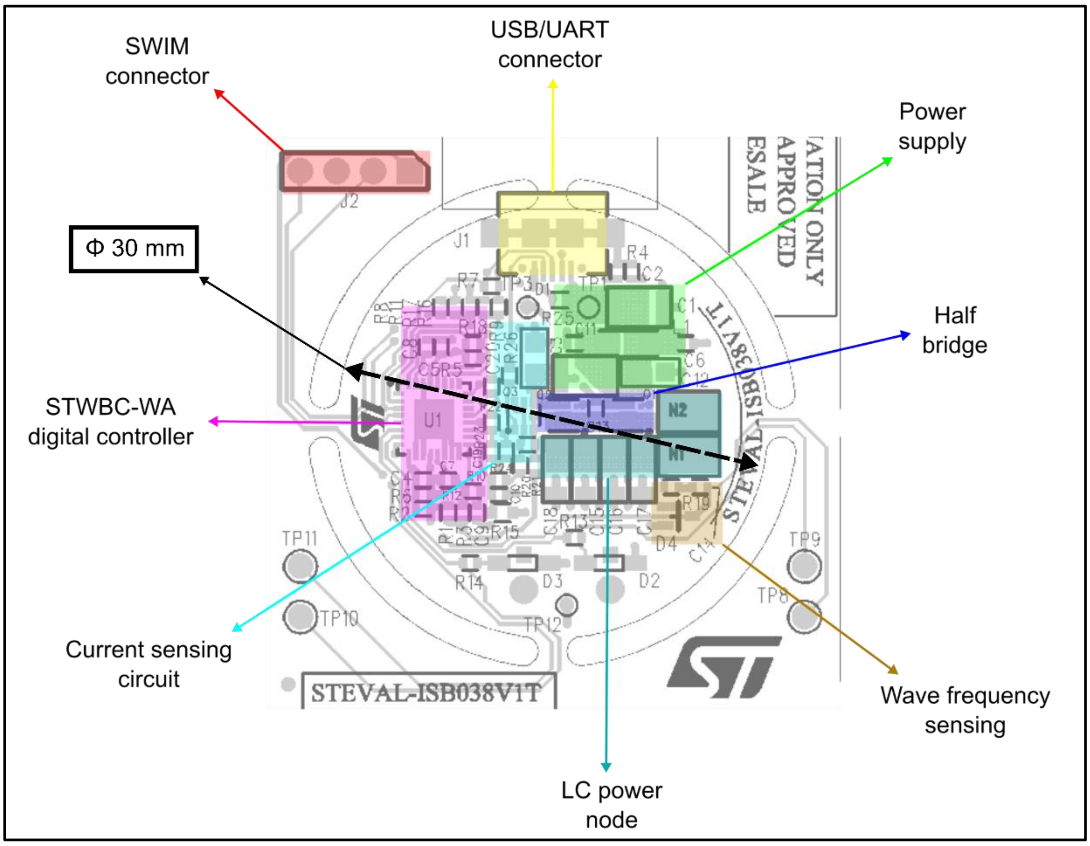


5.2 Transmitter board assembly and layout

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 3: Document revision history

Date	Version	Changes
02-Sep-2016	1	Initial release.