15 W 3-coil fixed frequency Qi-certified wireless charger TX evaluation kit based on STWBC-MC

Introduction

The STEVAL-ISB047V1 wireless charger evaluation kit includes the STEVAL-ISB047V1T transmitter reference design board and an STEVAL-WBCDNGV1 USB-to-UART dongle for PC communication.

The transmitter is based on an MP-A15 3-coil topology, with a sepic DC-DC stage supplying a half bridge inverter operating at 127.7 kHz fixed frequency, for compatibility with proprietary fast charge modes of popular smartphones.

The transmitter is designed to accept a 15 W, 5 to 20 V input as per the USB type-C™ power delivery specification, or limit the input to 5 W if supplied by legacy 5 V USB chargers.

The STEVAL-ISB047V1T is certified under WPC 1.2.4 EPP specification, thus interoperable with all Qi-certified receivers, including mobile phones, cases and power banks, and supports resistive and capacitive modulation.

The transmitter is capable of 15 W potential power Qi EPP bi-directional communication and is backward compatible with 5 W BPP receivers.

The STWBC-MC controller monitors and drives the STEVAL-ISB047V1T transmitter, including the digital DC/DC controller that regulates the transmitted power. The controller supports automatic coil selection based on the best coupling with the receiver, as well as a patented Q-factor measurement for accurate foreign object detection (FOD).

You can communicate with the controller via UART, and monitor the behavior of the transmitter on your PC using the STSW-STWBCGUI graphical interface.

Figure 1. Wireless charger kit top side with coils

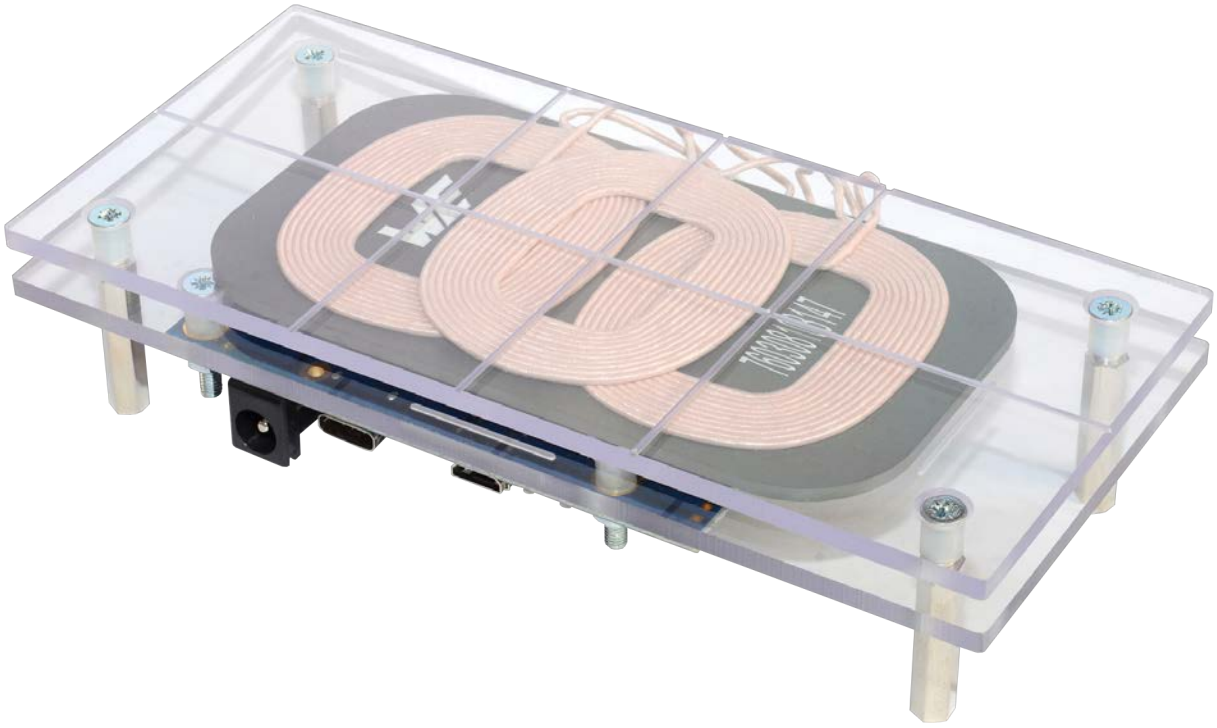
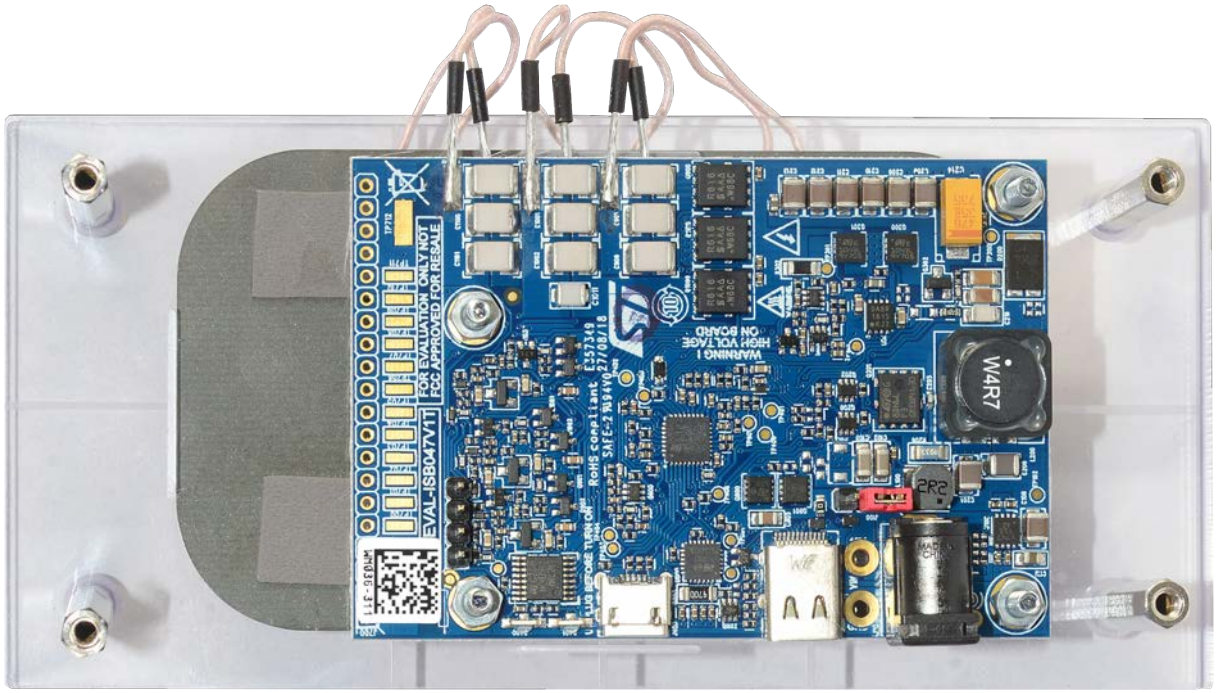


Figure 2. **Wireless charger kit bottom side with transmitter board**



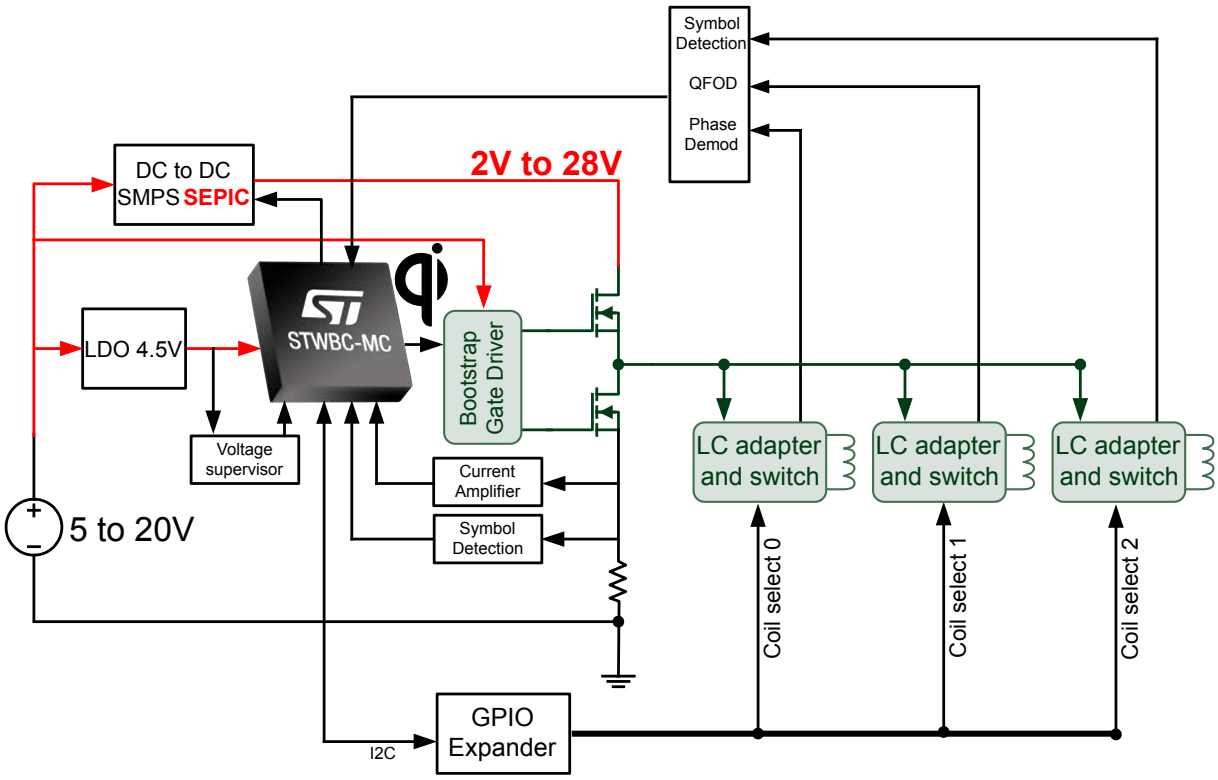
1 Getting started

You need the following items to use the evaluation kit:

- Evaluation kit components:
  - Wireless charger system with STEVAL-ISB047V1T transmitter board and 3 coils
  - STEVAL-WBCDNGV1 USB to UART interface dongle with micro USB cable for debugging and GUI interaction
  - 12 V, 24 W AC/DC adapter
  - USB Type A to Micro USB Type B cable
- Additional hardware:
  - PC running Windows XP or higher and the .NET framework 4.0
  - ST-LINK/V2 in-circuit debugger/programmer with single wire interface module (SWIM)
  - 30 W USB-C PD wall charger
- Software:
  - ST-LINK USB driver
  - STVP programming tool from STMicroelectronics (integrated in the sttoolset available on st.com)
  - FTDI VCP driver http://www.ftdichip.com/Drivers/VCP.htm
  - STSW-STWBCGUI PC GUI installation package

2 STEVAL-ISB047V1 wireless charger kit overview

Figure 3. **STEVAL-ISB047V1 block diagram**



2.1 STEVAL-ISB047V1T wireless transmitter board

The STEVAL-ISB047V1T transmitter board features:

- WPC Qi 1.2.4 certification
- Standard Qi MP-A15 3-coil transmitter
- Qi EPP bi-directional communication
- Triple path signal demodulation
- Best coupling-based coil selection and presence detection
- Coil current and temperature monitoring
- Input voltage monitoring
- Foreign object detection (FOD)
- Quality factor measurement
- LEDs for charge status indication
- UART connection for user interface and firmware download
- SWIM connection for firmware download
- 5-20 V power supply
- STUSB4500 Auto-run Type-C™ and USB PD sink controller
- USB quick charge

Table 1. Electrical characteristics

Parameter	Description	Notes and Conditions	Min	Typ	Max	Unit
Vin	Input Voltage		5	12	20	V
Iin	Input current	Vin 15V, load 15W on MP1B Rx		1.27	2	A
	Input No-load current			-		mA
	Input Standby current	At typical voltage		1.4		mA
Fs	Fixing frequency		120	128	136	kHz
Duty cycle	Duty cycle modulation	duty cycle	5		50	%
η	Full load efficiency	Vin= 15V, P Out Rx = 13 W		75		%

Figure 4. STEVAL-ISB047V1T transmitter board interfaces

1. J101 Power supply jack connector
2. J800 Power supply USB connector
3. J400 UART connector
4. Green LED and Red LED
5. J401 SWIM connector
6. Power Coil connections
7. Test points
8. Jumper for supply selection:

- DC jack supply: jumper on left position
- USB PD supply: jumper on right position

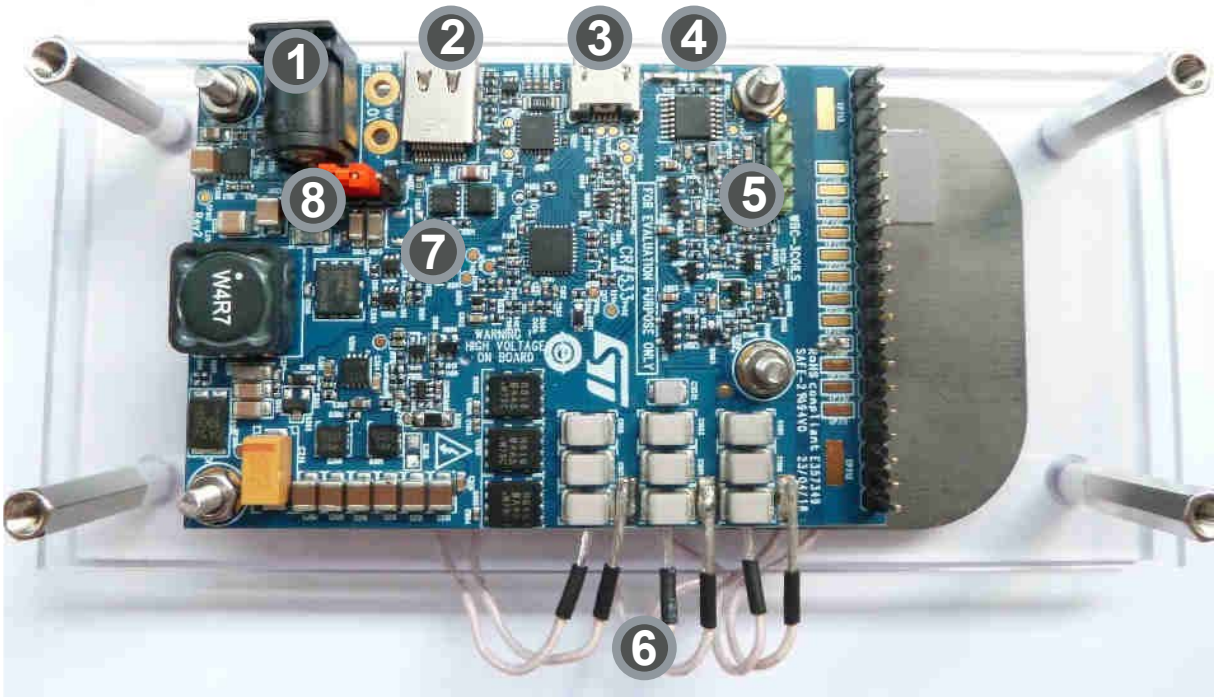


Table 2. Test points

Test point reference	Signal	Description
TP100	VINPUT	power supply input connection
TP101	GND	GND power connection

Test point reference	Signal	Description
TP102	VIN	Input voltage
TP103	VDD_STWBC	4.5V LDO output voltage
TP200	VDCDC	SEPIC output voltage
TP300	GND	Power GND connection (Rsense)
TP301	VRSENSE	Rsense resistor voltage
TP400	GND	GND connection
TP401	GND	GND connection
TP402	GND	GND connection
TP403	I2C_SDA	STWBC I2C signal
TP404	I2C_SCL	STWBC I2C signal
TP405	I2C_Q0	I2C first pulse
TP406	GPIO 1	GPIO 1
TP600	SYMBOL_DETECT	Symbol detector
TP601	CURRENT_DEMOD	Symbol detector
TP800	CC1	USB-C configuration Channel 1
TP801	CC2	USB-C configuration Channel 2
TP900	Coil 1	Coil 1 connection
TP901	Coil 1 bridge	Coil 1 connection
TP1000	Coil 2	Coil 2 connection
TP1001	Coil 2 bridge	Coil 2 connection
TP1100	Coil 3	Coil 3 connection
TP1101	Coil 3 bridge	Coil 3 connection

2.2 STWBC-MC pinout and pin description for 3-coil MP-A15 configuration

The STWBC-MC is a multifunction device that can support several wireless charging architectures. This section shows the pinout used by the digital controller when the 3-coil MP-A15 configuration is used.

Figure 5. **STWBC-MC in 3-coil MP-A15 configuration**

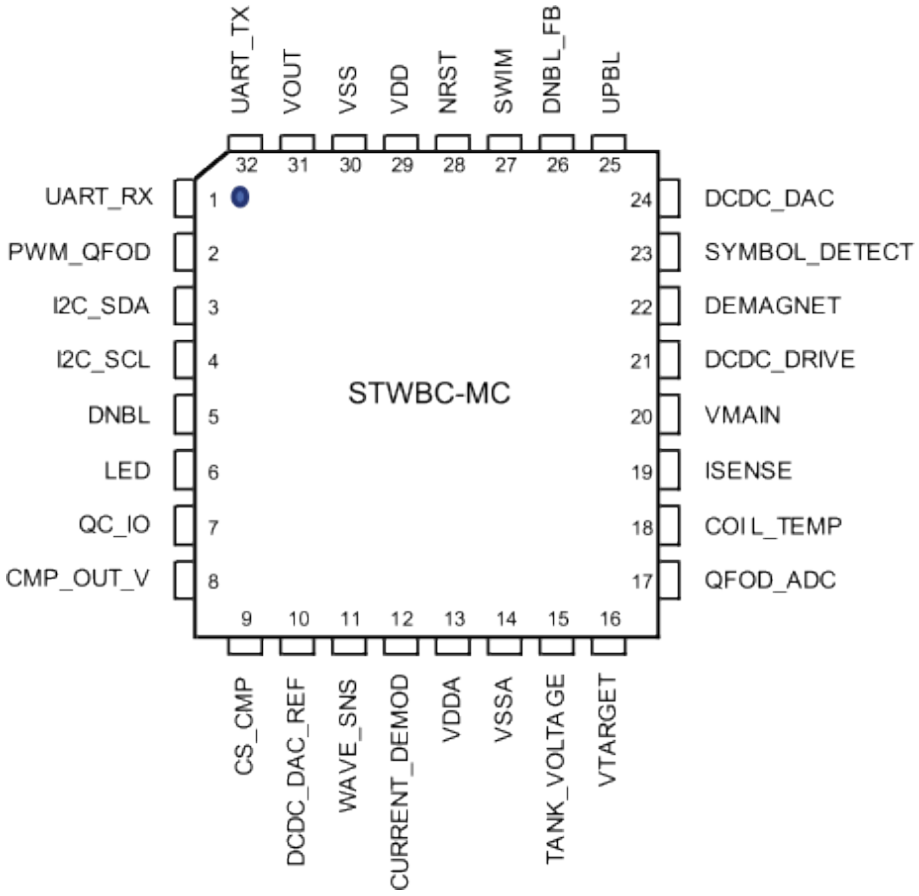


Table 3. **Pinout description**

Pin Number	Pin Name	Pin Type	Firmware description
1	UART_RX	DI	UART RX link on USB debug connector
2	PWM_QFOD	DO	PWM dedicated to QFOD circuit
3	I2C_SDA	DO	I2C_SDA
4	I2C_SCL	DO	I2C_SCL
5	DNBL	DO	Output signal for HB low side driver
6	LED	DO	Digital output for green and red LEDs indicators
7	QC_IO	DO	Quick Charge circuit signal
8	CMP_OUT_V	AI	SEPIC output voltage sensing
9	CS_CMP	AI	SEPIC current sensing
10	DCDC_DAC_REF	AI	DAC reference value for SEPIC output voltage
11	WAVE_SNS	AI	Symbol detector based on delta frequency
12	CURRENT_DEMOD	AI	Current demodulation
13	VDDA	PS	Analog power supply
14	VSSA	PS	Analog ground
15	TANK_VOLTAGE	AI	Analog input to measure the LC voltage (power calculation)
16	VTARGET	AI	SEPIC voltage measurement

Pin Number	Pin Name	Pin Type	Firmware description
17	QFOD_ADC	AI	High sensitivity peak voltage detector used for Quality Factor measurement
18	COIL_TEMP	AI	Analog input for temperature measurement. The input is connected to external NTC biased to VDD_STWBC
19	ISENSE	AI	Analog input to measure the current flowing into the power bridge
20	VMAIN	AI	Analog input to measure the main power supply
21	DCDC_DRV	DO	DCDC SEPIC PWM drive
22	DEMAGNET	DI	Transformer demagnetization sensing
23	SYMBOL_DETECT	DI	Voltage demodulation
24	DCDC_DAC	DO	SEPIC PWM output DAC (setting the CPP3 comparator voltage reference)
25	UPBL	DO	Output signal for HB high side driver
26	DNBL_FB	DI	Hardware PWM feedback
27	SWIM	DIO	Digital IO for debug interface
28	NRST	DI	Reset input monitoring
29	VDD	PS	Digital and I/O Power supply
30	VSS	PS	Digital and I/O Ground
31	VOUT	Supply	Internal LDO output
32	UART_TX	DO	UART TX link on USB debug connector

Note: The operative voltage of analog inputs (AI) ranges from 0 V to 1.2 V.

3 Firmware download and update procedure

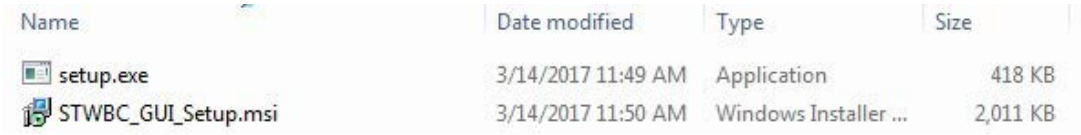
To download the firmware to the board, install the GUI software which allows complete board monitoring via UART signals. To use the STSW-STWBCGUI, UART signals must therefore be accessible.

If you experience problems, you can use ST-LINK and STVP software to erase the STWBC-MC Flash memory.

3.1 STSW-STWBCGUI software installation

Step 1. Install the GUI by launching the STWBC_GUI_Setup.msi installation file.

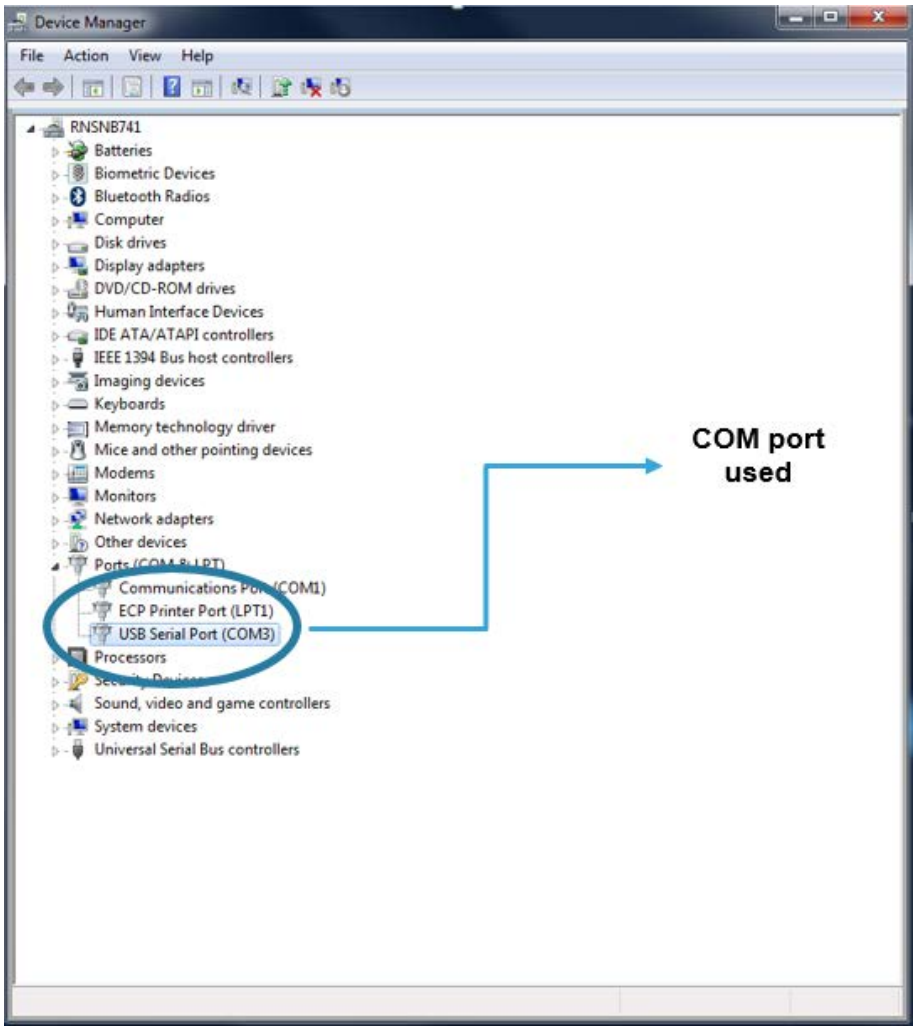
Figure 6. STSW-STWBCGUI installation file



Step 2. Connect the UART cable from the transmitter board to the USB-to-UART dongle on your PC or laptop.

Step 3. Check Windows Device Manager to identify the correct port number and select the appropriate USB serial COM port.

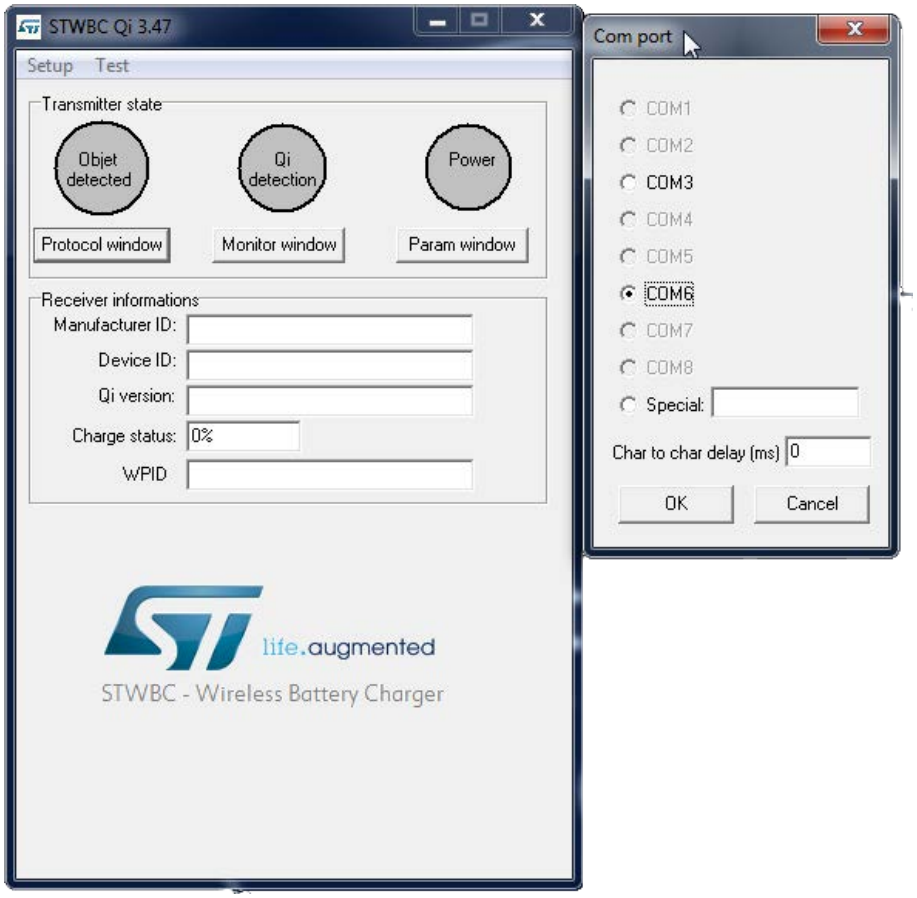
Figure 7. **Windows Device Manager: COM port selection**



Step 4. Enter a specific COM port number (if not listed in the selection window) in the [**Special**] text box (e.g., “COM12” or the specific syntax \\.*COM12*).

If the GUI is turned off, ensure that the COM port is not being used on your computer. Otherwise, try another USB port.

Figure 8. **STSW-STWBCGUI start screen**



Step 5. Press OK.

The GUI is ready to run.

3.2 Firmware download with the STSW-STWBCGUI software

3.2.1 Firmware update procedure (chip already programmed)

The STEVAL-ISB047V1 is delivered with pre-installed firmware. Follow the steps below to update it:

Step 1. Click on the following link and download the FW binary CAB file onto your PC: STSW-ISB047FW

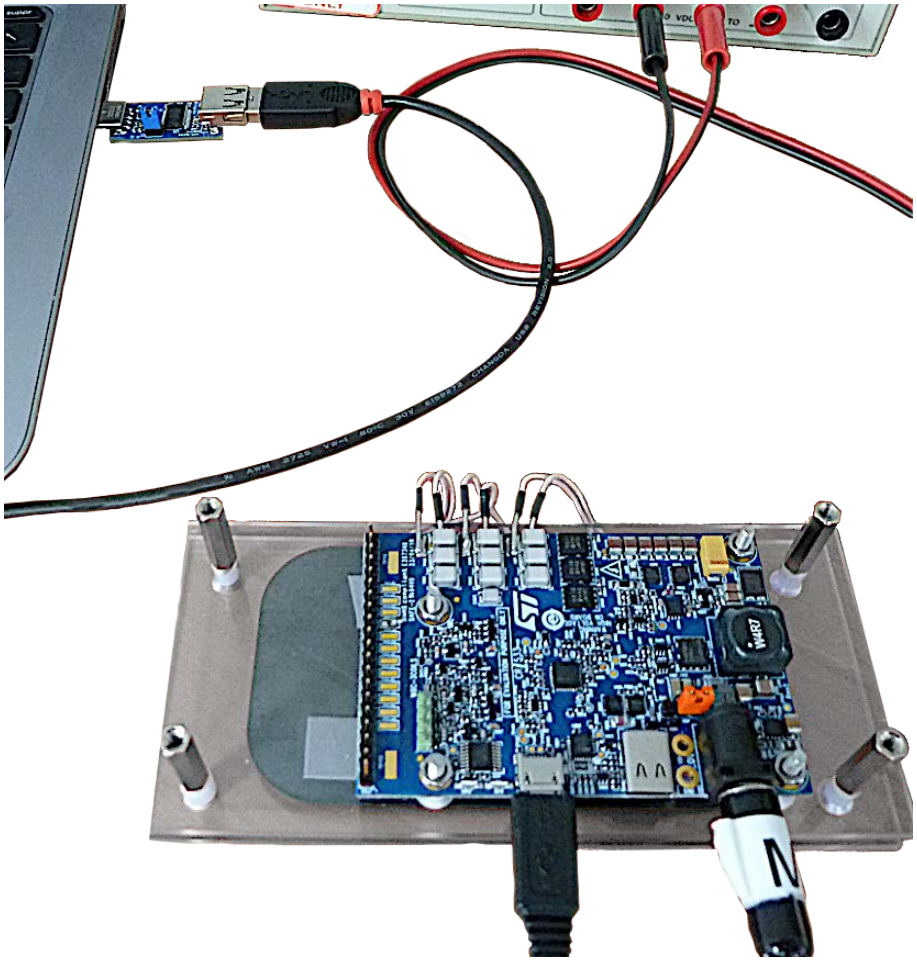
Step 2. Save the file as WBC_FW_ST_MP2_V*.**.cab

Step 3. Supply the transmitter board with the 12V power supply contained in the kit.

Step 4. Connect the USB-to-UART dongle to the transmitter board.

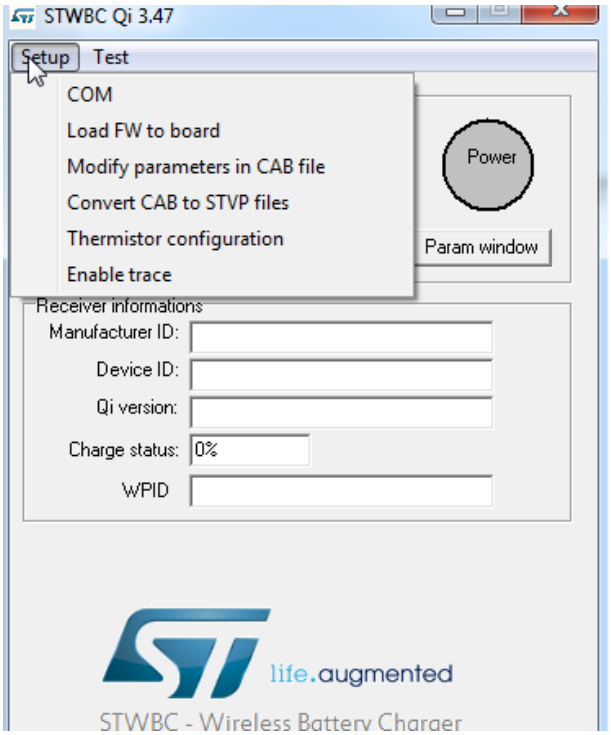
Step 5. The UART RX/TX signals of the STWBC-MC are accessible on the J400 connector of the transmitter board.

Figure 9. STEVAL-ISB047V1 evaluation kit connection



Step 6. From the STWBC GUI user interface, select [**Setup**]>[**Load FW to board**].

Figure 10. Firmware download with STSW-STWBCGUI

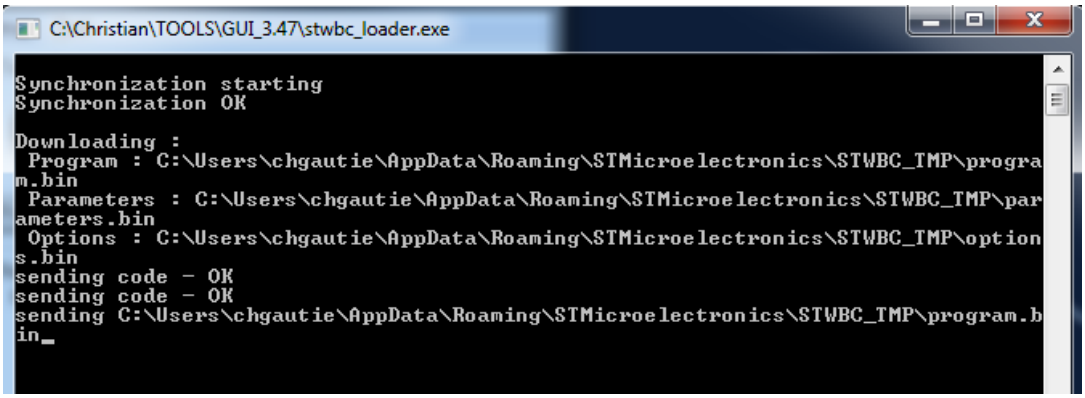


Step 7. Select the CAB file containing the Firmware to download.
file: WBC_FW_ST_MP2_V*.**.cab

Step 8. Power ON the board and keep it powered.

Step 9. Follow the download progress in the DOS window and power off the board when prompted.

Figure 11. DOS window: download in progress



Step 10. Run the calibration procedure.
The board is not usable until it is calibrated.

RELATED LINKS

5.2 Test procedure for board calibration on page 34

3.2.2 Download procedure with a new chip (never programmed)

If for some reason the STWBC-MC is replaced, it will not have been programmed previously, so Download Mode is enabled by default.

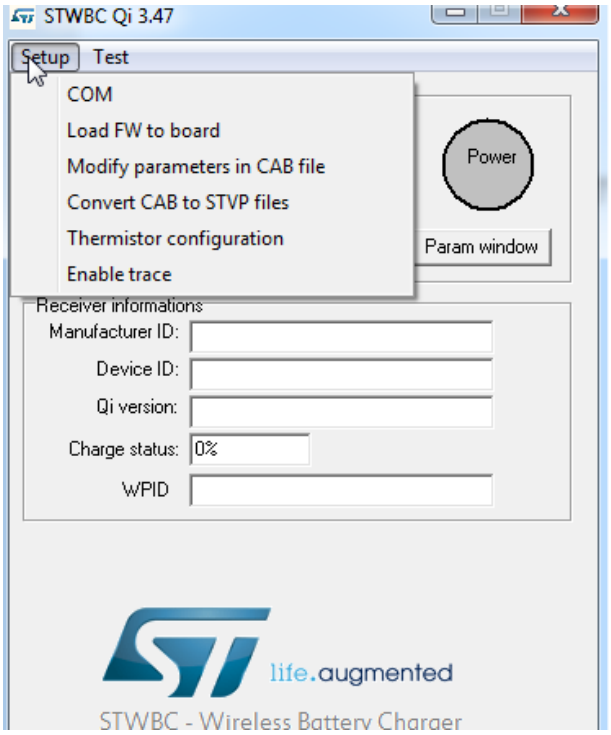
Step 1. Connect the USB-to-UART dongle to the computer.

Do not connect the transmitter board for the moment.
Ensure a jumper is placed on the dongle J3 connector to supply the transmitter board via the PC.

Figure 12. Dongle connection

Step 2. From the GUI, select [**Setup**]>[**Load FW to board**].

Figure 13. Firmware download with STSW-STWBCGUI



Step 3. Select the CAB file containing the firmware to download.
file: WBC_FW_ST_MP"_V*.*.cab

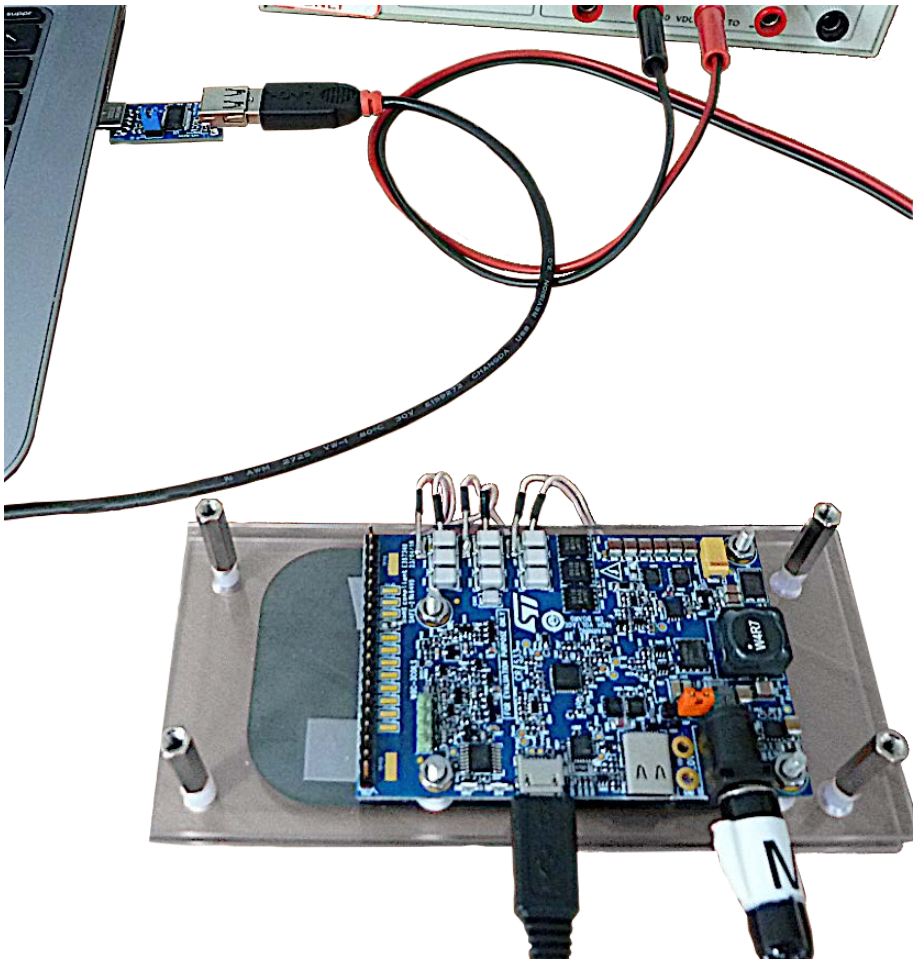
Step 4. Supply the board with 12 V and keep it powered.

Figure 14. **Power on message**

Step 5. When the DOS window appears, power the transmitter board on by connecting it to the dongle using a micro-USB cable.

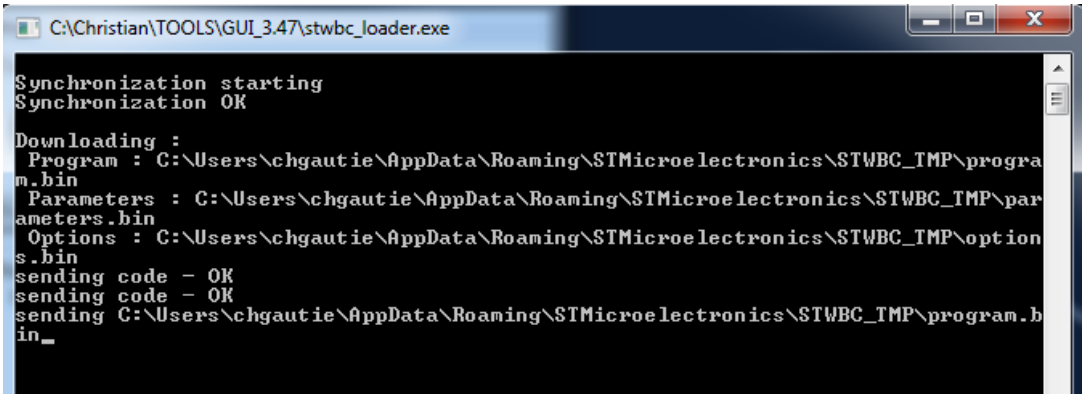
Ensure it is connected through USB debug connector J400 (near the power supply connections).

Figure 15. **STEVAL-ISB047V1 evaluation kit connection**



Step 6. Follow the download progress in the DOS window and power off the board when prompted.

Figure 16. **DOS window: download in progress**



Step 7. Run the calibration procedure.

The board is not usable until it is calibrated.

RELATED LINKS

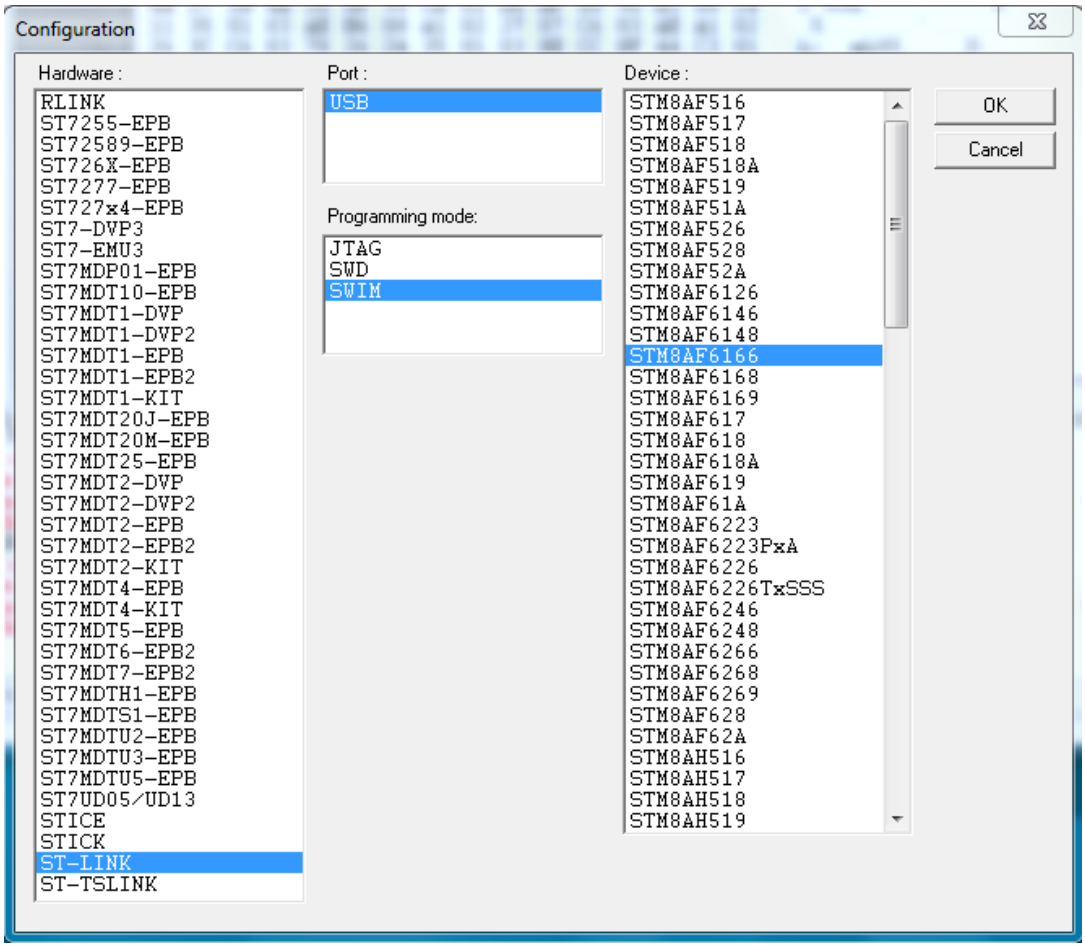
5.2 Test procedure for board calibration on page 34

3.3 Erasing firmware procedure using STVP

Requirements:

- ST-LINK USB driver installed
- ST STVP programming tool installed
- ST-LINK hardware tools connected to the transmitter board SWIM signals
- STVP configured as shown below

Figure 17. **STVP configuration**



Follow this procedure if you encounter problems during a firmware update, such as corrupted firmware code.

Step 1. Power OFF the target.

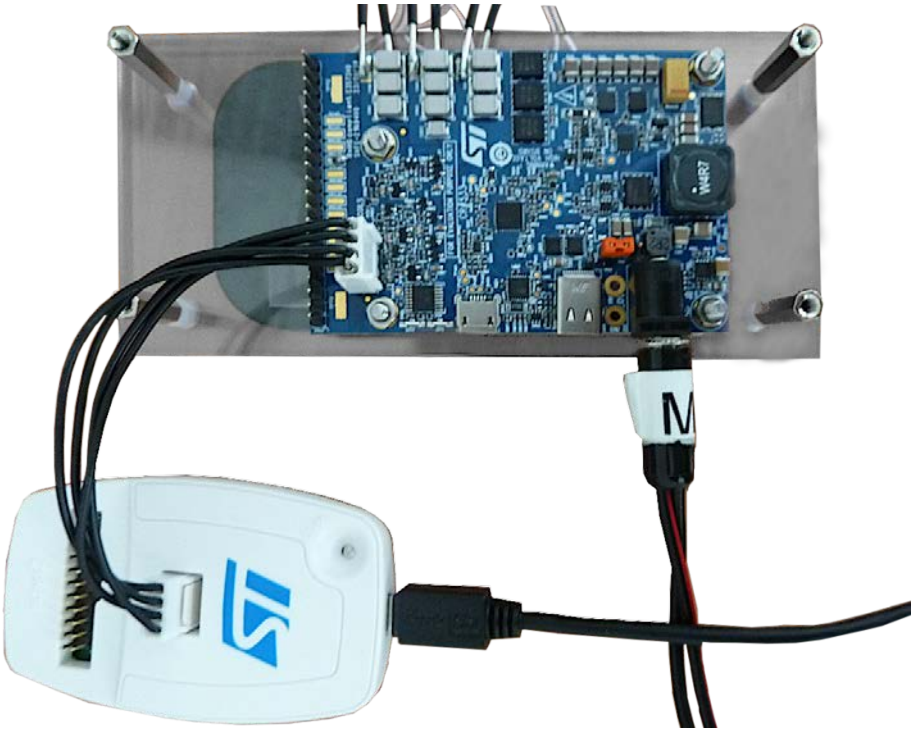
Step 2. Power ON the target.

Step 3. Connect ST-LINK circuit to the PC via USB.

Step 4. Connect the ST-LINK–SWIM cable to the target.

Pay special attention to ensure that the SWIM cable is correctly connected to the transmitter board. Refer to the figure below.

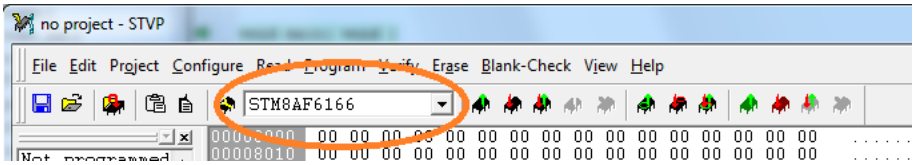
Figure 18. **ST-LINK connection on the board**



Step 5. Launch STVP software program.

Step 6. Select the STM8AF6166 core from the drop-down list at the top.

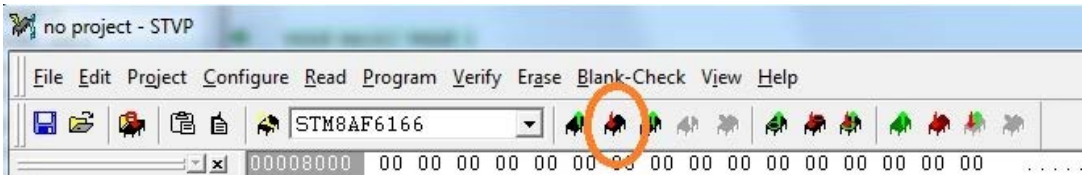
Figure 19. **STVP core selection**



Step 7. Do not load any programs into the STVP RAM area as all bits are erased (load 00 00 00 …)

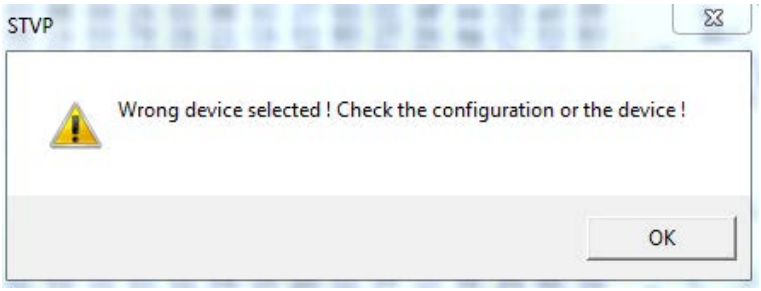
Step 8. Transfer the "00 00" to the STWBC-MC through the SWIM interface using the download button.

Figure 20. **STVP download**



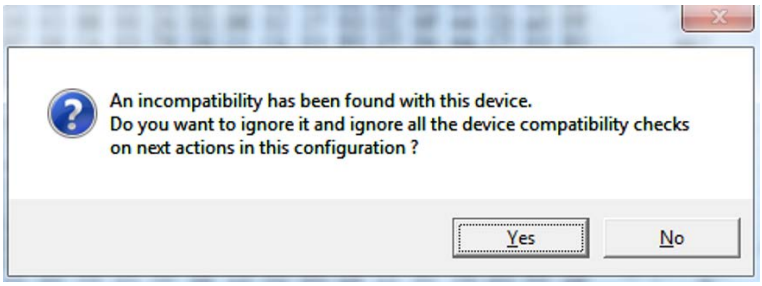
Step 9. Click [**OK**] if the following message appears.

Figure 21. **STVP wrong device selected alert**



Step 10. Click [**Yes**] if the following message appears.

Figure 22. **STVP incompatibility device action query**



Step 11. After this operation, the programming procedure starts.
On completion, the following STVP message appears.

```
< PROGRAM MEMORY programming completed.
> Verifying PROGRAM MEMORY area...
< PROGRAM MEMORY successfully verified.
```

Step 12. Exit the STVP program.

Step 13. Disconnect the SWIM cable.

Step 14. Power OFF the transmitter board.

Once the procedure is complete, you can proceed to retry the UART download procedure if necessary.

3.4 Firmware download with command line

3.4.1 Firmware download with written chip

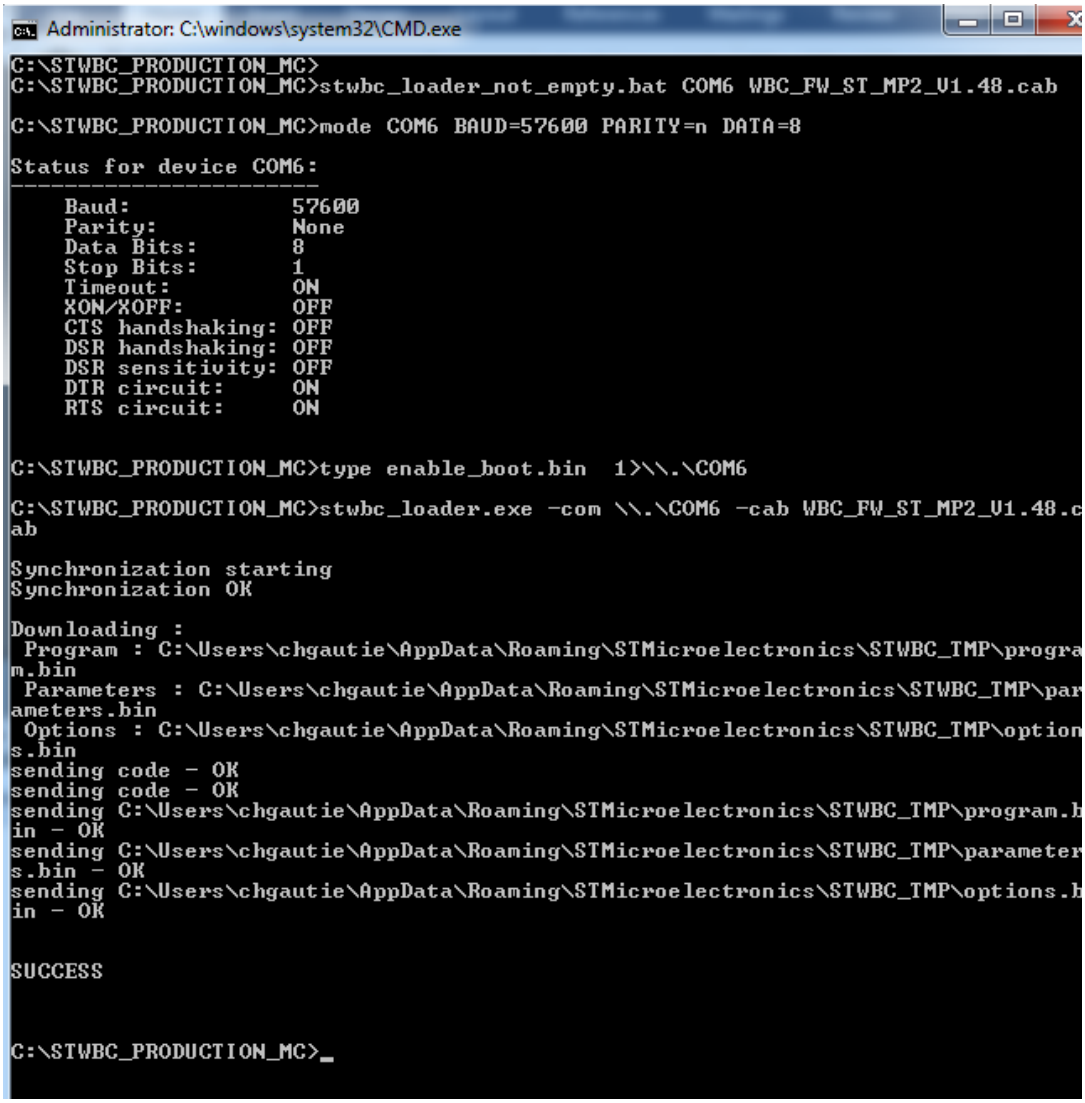
Step 1. Create a dedicated directory with the following files:

- STWBC_Loader.exe
- stwbc_loader_not_empty.bat
- enable_boot.bin
- “firmware version“.cab

Step 2. From the STSW-STWBCGUI folder, call the "stwbc_loader_not_empty.bat" file from the command line. When you call the batch file, you must also specify:

- COM number (e.g. COM2)
- File name ("*firmware name*.cab")

Figure 23. STSW-STWBCGUI command line



3.4.2 Firmware download with blank chip

If the STWBC-MC memory is erased, use the procedure below.

Step 1. Connect the UART cable to the board.

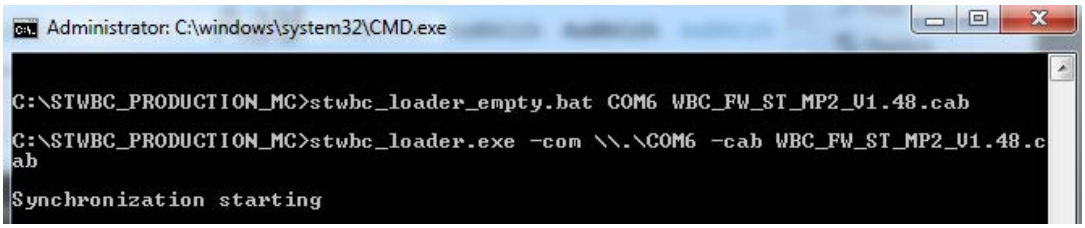
Step 2. From the STSW-STWBCGUI folder, call the "stwbc_loader_empty.bat" file from the command line. When you call the batch file, you must also specify:

– the COM number (e.g., COM6)

– the file name (firmware name.cab)

Step 3. Execute the command line as shown in the example below, with the appropriate firmware file name.

Figure 24. STSW-STWBCGUI command line with blank chip



Note: If the COM port is > COM8, use the syntax \\.\COMx, where COMx is the COM port number.

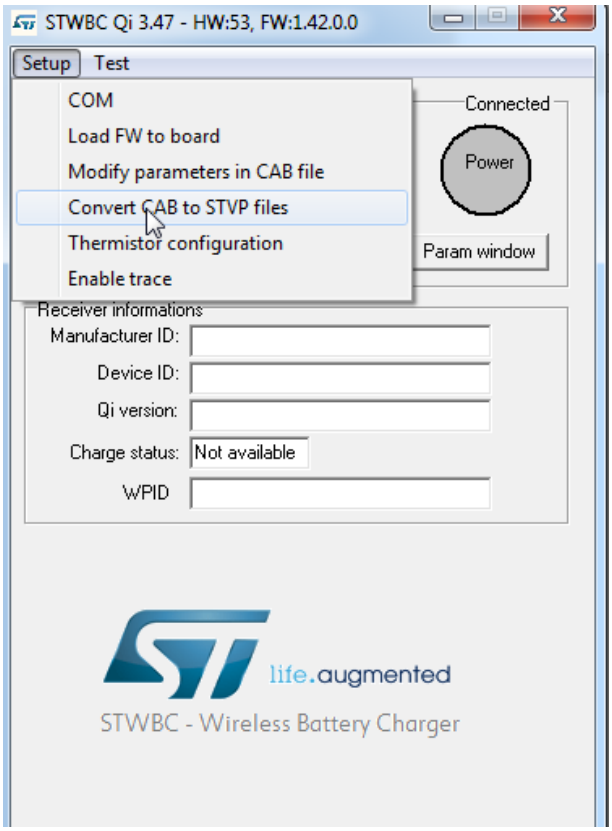
Note: A dedicated tool is available for simultaneous downloads (refer to the STSW-STWBCFWDT firmware downloader tool).

3.5 STVP file creation

To use the STVP to download, you must generate new files from the *.cab via the STSW-STWBCGUI.

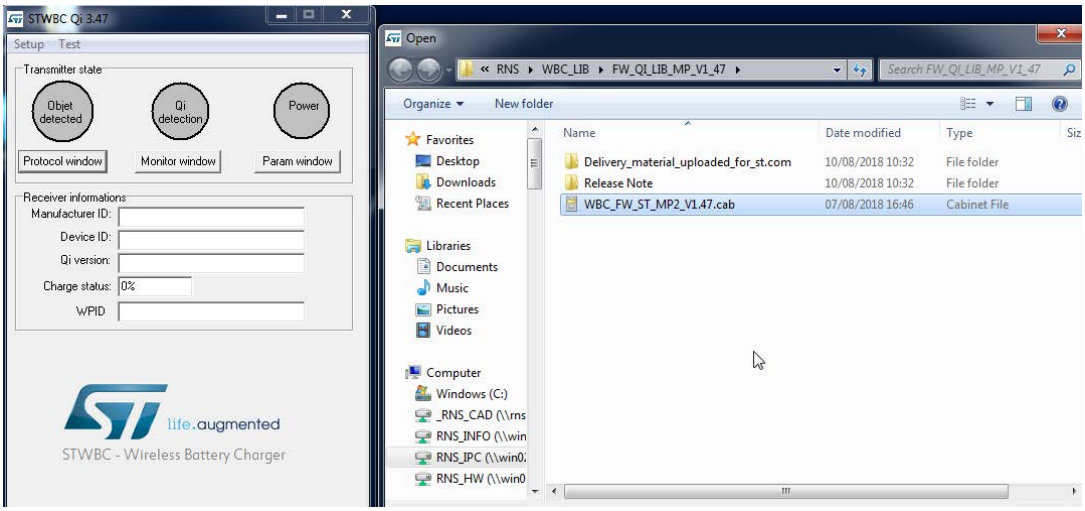
Step 1. Select the convert **CAB to STVP files** command from the STSW-STWBCGUI setup menu.

Figure 25. STSW-STWBCGUI: convert CAB to STVP files



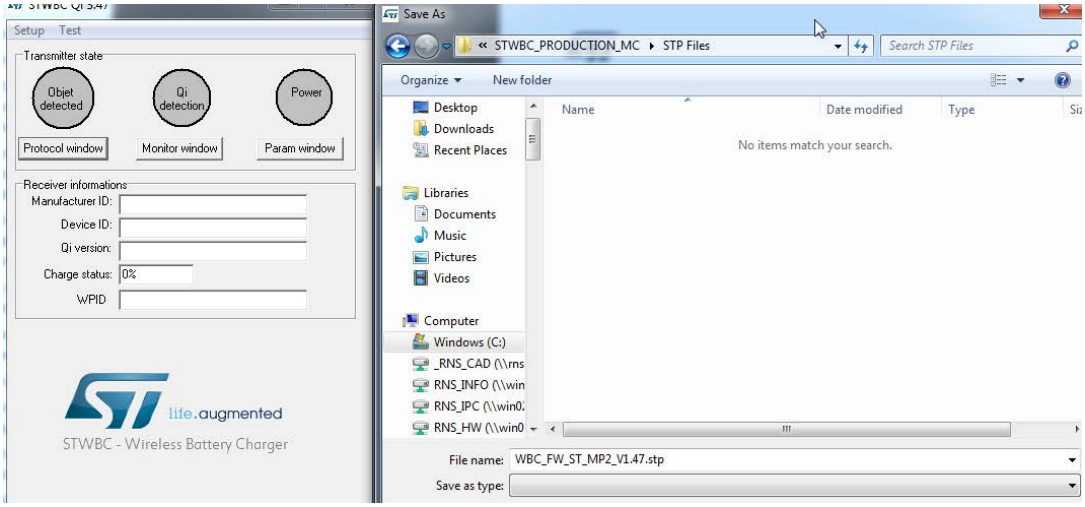
Step 2. Follow the prompt to select the appropriate cab file.

Figure 26. **Selecting the CAB file to be converted**



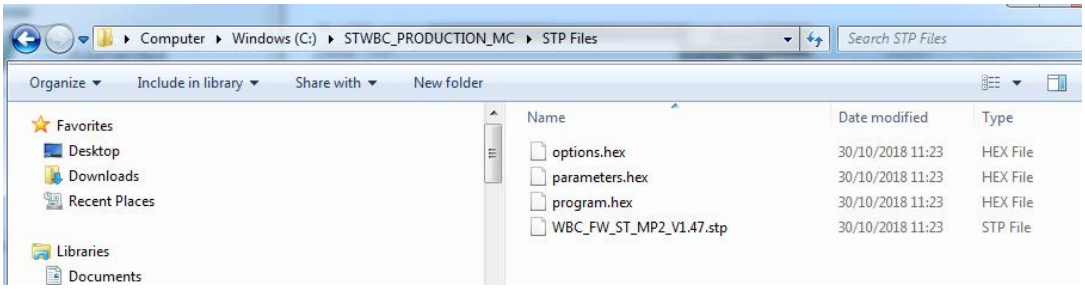
Step 3. Follow the prompt to provide the project file name.

Figure 27. **Selecting the STVP project file name**



Four files are generated as shown below.

Figure 28. **STVP project files**



Note: Refer to STSW-STWBCFWDT STWBC firmware downloader tool for further details.

3.6 Firmware download with STVP

Follow the procedure below to download firmware using the STVP software program.

Note: You can also install and use the IAR toolchain to compile and download firmware.

Step 1. Target power OFF.

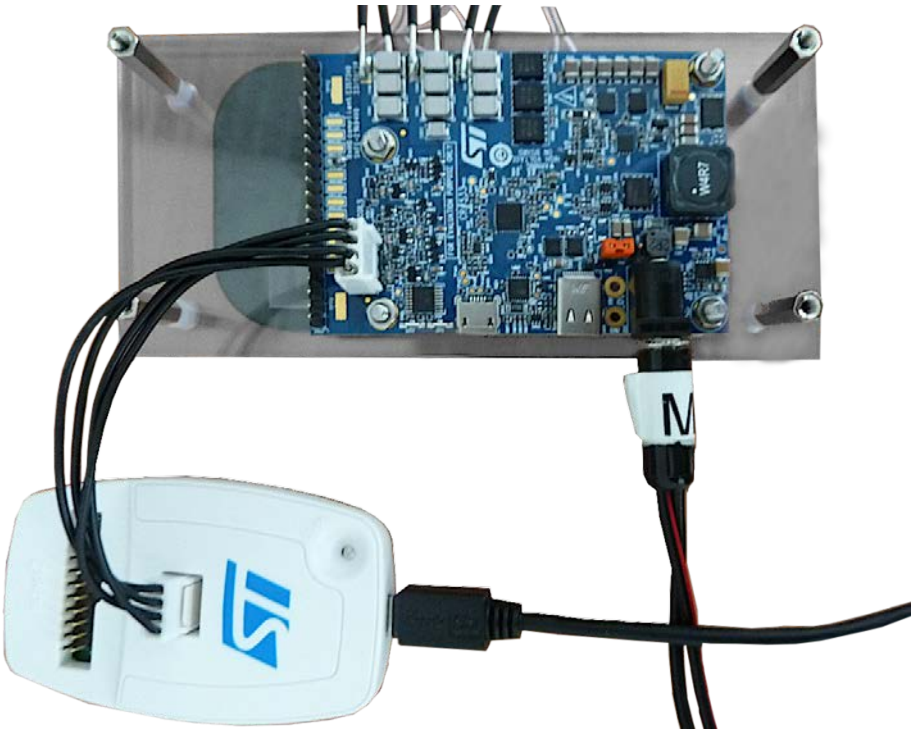
Step 2. Target power ON.

Step 3. Connect ST-LINK circuit to the PC via USB.

Step 4. Connect the ST-LINK–SWIM cable to the target.

Pay special attention to ensure that the SWIM cable is correctly connected to the transmitter board. Refer to the figure below.

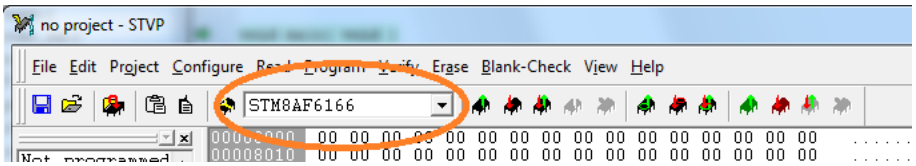
Figure 29. ST-LINK connection on the board



Step 5. Launch STVP software program.

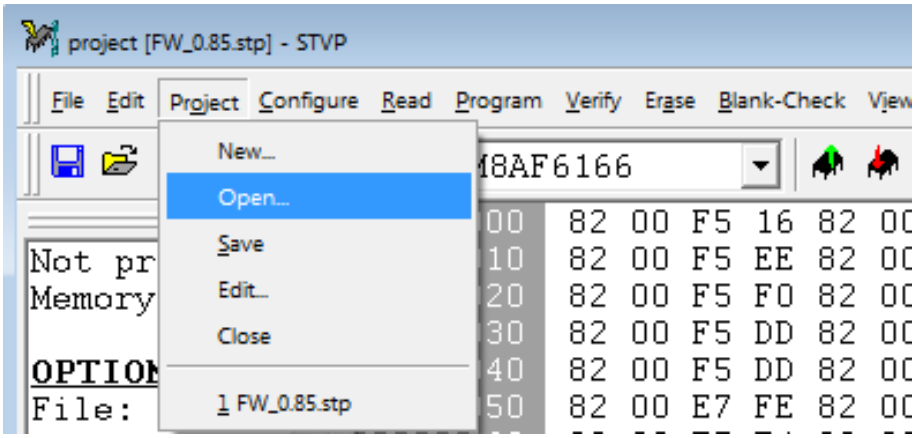
Step 6. Select the STM8AF6166 core from the drop-down list at the top.

Figure 30. STVP core selection



Step 7. Go to [**Project**]>[**Open**] and select the .stp file provided in the zip file.

Figure 31. **STVP open project**



Step 8. After a few seconds, the following message should appear.

```
Loading file program.hex in PROGRAM MEMORY area ...
< File successfully loaded. File Checksum 0x1D1205
```

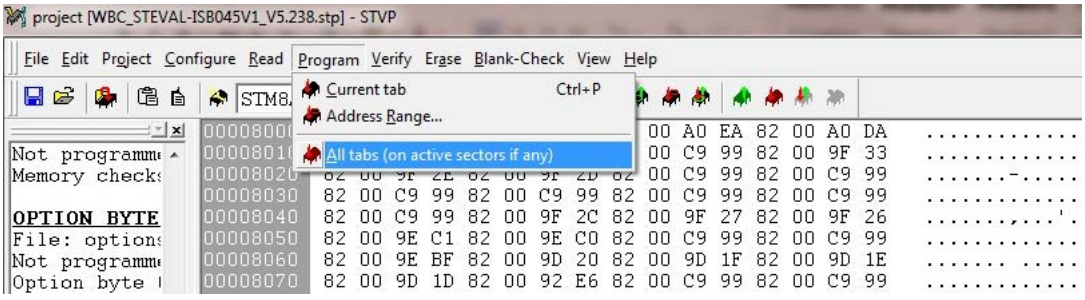
Note: It is normal for warnings like the ones below to appear:

```
> Loading file options.hex in OPTION BYTE area ...
FILE : line 2: Address 0x4802 is out of range and is ignored!
FILE : line 2: Address 0x4804 is out of range and is ignored!
```

Step 9.

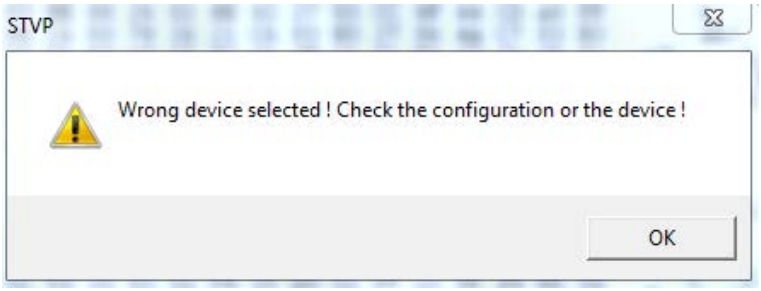
Step 10. Select [**Program**]>[**All tabs (on active sectors, if any)**]

Figure 32. **STVP download**



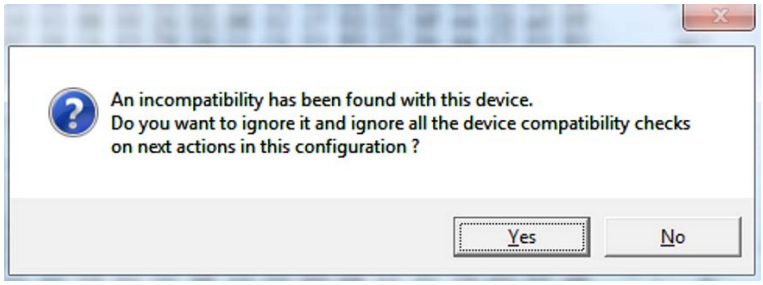
Step 11. Click [**OK**] if the following message appears

Figure 33. **STVP wrong device selected alert**



Step 12. Click [**Yes**] if the following message appears

Figure 34. **STVP incompatibility device action query**



Step 13. After this operation, the programming procedure starts.

Step 14. On completion, the following message appears

```
< PROGRAM MEMORY programming completed.
> Verifying PROGRAM MEMORY area...
< PROGRAM MEMORY successfully verified.
```

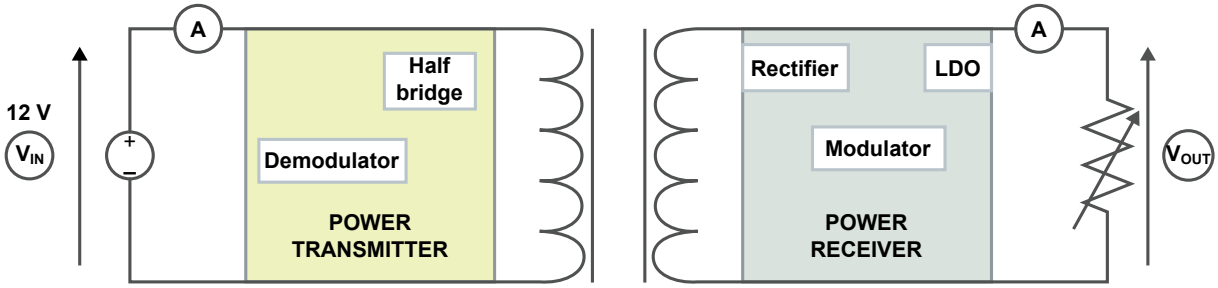
Step 15. Exit the STVP software program.

Step 16. Disconnect the SWIM cable.

Step 17. Power OFF the trnasmitter board.

4 Setting up the evaluation equipment

Figure 35. **Test setup configuration**



The board is powered with an external power supply or with a USB charger. An electronic load is connected on the receiver output to provide a load up to 15 W. Voltmeters and ammeters measure input and output voltage and current.

4.1 How to supply power from an external source

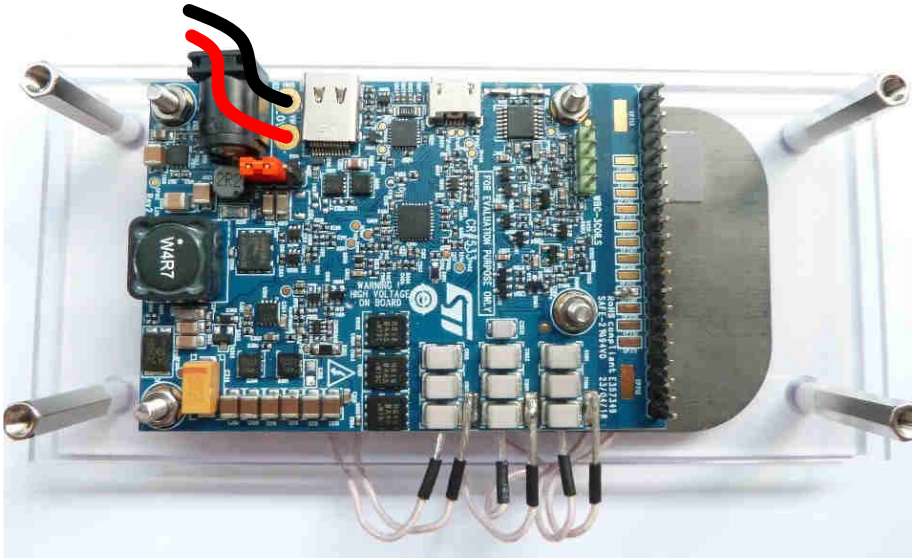
Follow this procedure to supply power from an external power source.

Step 1. Set your power supply:
- 12V/2A for EPP Mode
- 5V/2A for BPP Mode

Step 2. Set jumper J100 for jack/external power supply input.

Step 3. Connect the external power to the board with wires.

Figure 36. **Power supply connection**



4.2 How to supply power via USB

Follow this task to supply power through the USB charger.

Warning: *Disconnect the PC micro-USB cable before connecting USB-C cable.*

Step 1. Set jumper J100 for USB power supply input.

Step 2. Select the type of USB charger you are going to use:

– a simple 5V/2A USB charger (BPP mode only)

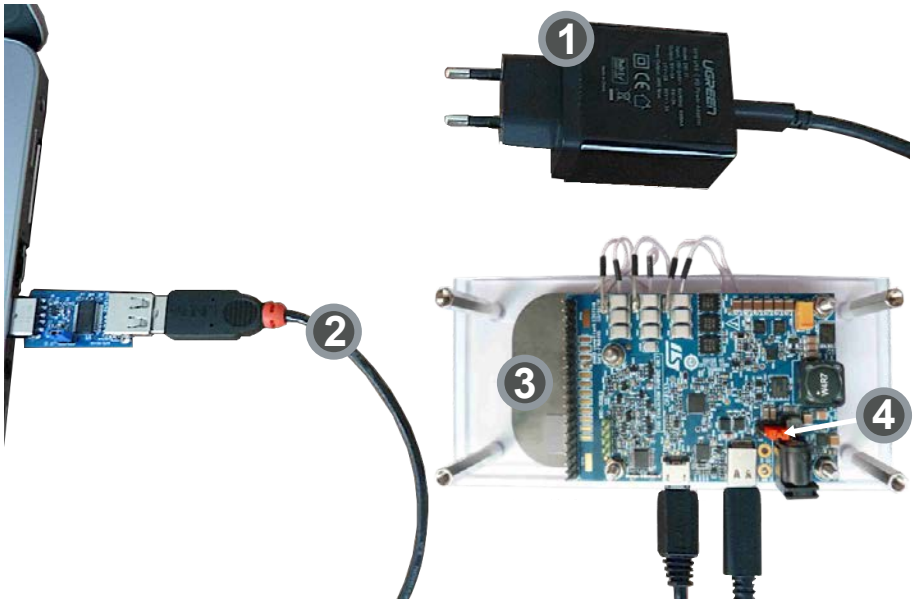
– a 30 W USB-PD wall charger (supports EPP Mode) to provide 15 W on the receiver side. By default, communication on CC lines selects 20 V on Vbus

Testing by ST was performed using the UGREEN 30W USB-C PD power adapter: Model 127.

Note: It is important to use a good quality USB-C cable between the charger and the board.

Figure 37. Power supply connection

1. QC charger
2. USB-C cable
3. Transmitter
4. J100 jumper to select input supply type



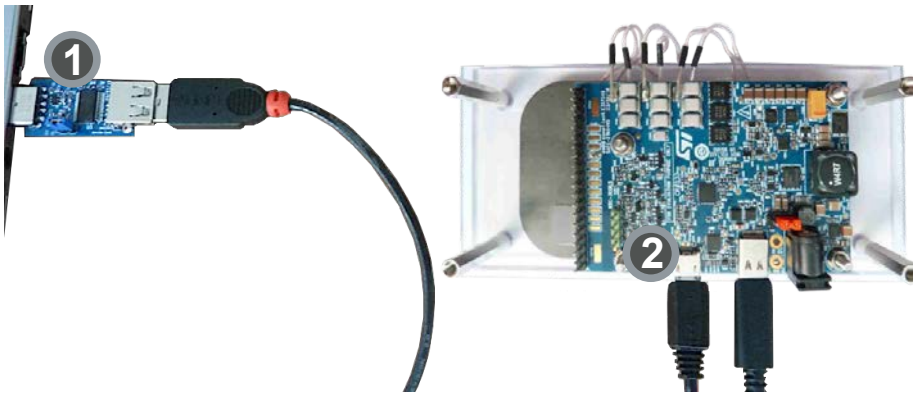
4.3 How to set up a UART connection

A UART connection between the board and your PC is necessary to be able to set parameters and monitor the transmitter board through the STSW-STWBCGUI software.

Step 1. connect the USB connector on the USB to UART cable from the USB to UART dongle on your PC to connector J400 on the board.

Figure 38. **UART connection**

1. USB to UART dongle
2. J400 connector



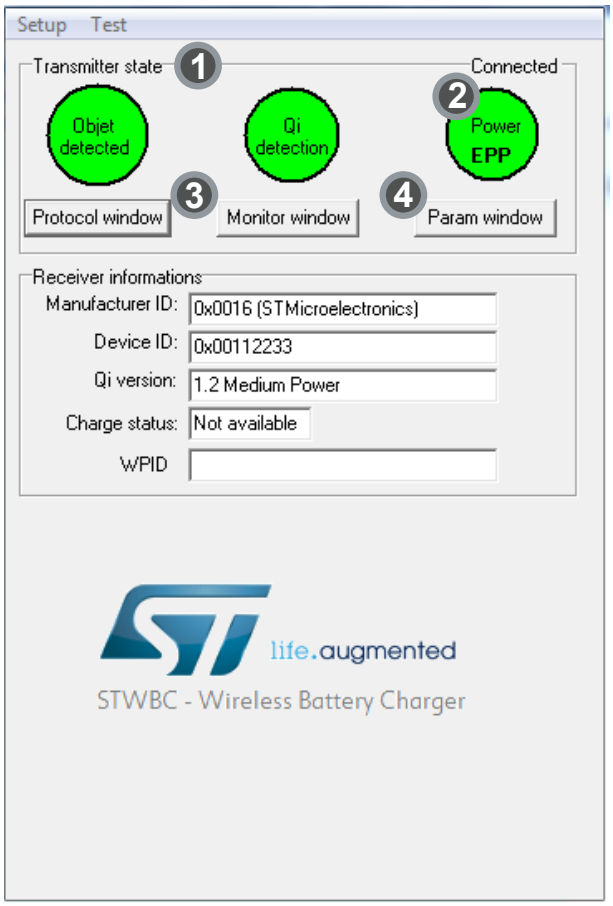
5 GUI and evaluation procedure

The STSW-STWBCGUI lets you monitor STWBC-MC operation. The main screen provides transmitter and Qi receiver status information.

Step 1. Launch the STSW-STWBCGUI user interface software.

Figure 39. STSW-STWBCGUI main window

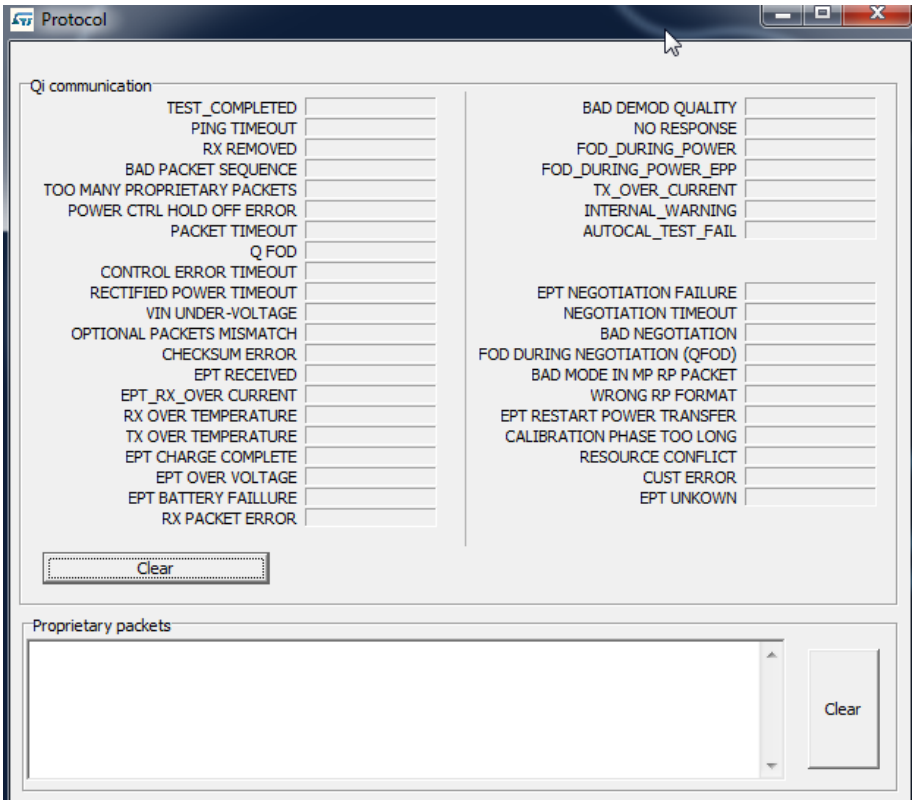
1. Transmitter state section
2. Power mode indicator
3. Protocol and Monitor debug window buttons
4. Parameter window button



Step 2. From the launch screen, select the [**Protocol window**] button.

This window shows Rx to Tx communication protocol errors, useful for system debugging.

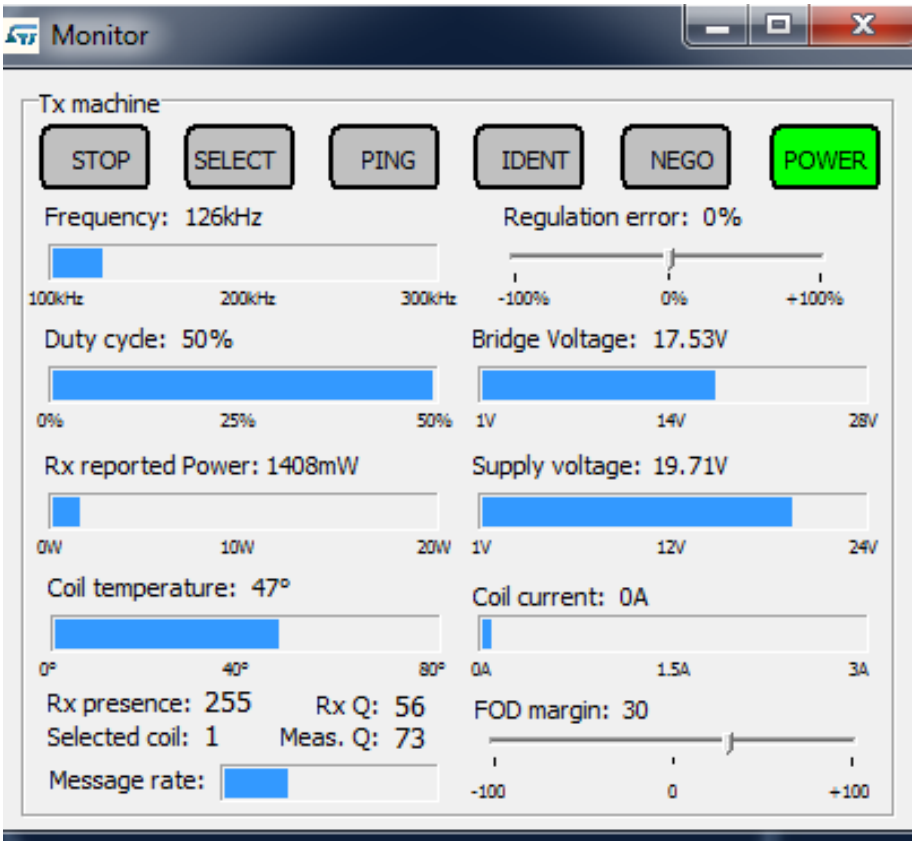
Figure 40. **STSW-STWBCGUI Qi protocol window**



Step 3. From the launch screen, select the [**Monitor window**] button.

This window lets you monitor STWBC-MC internal variables such as bridge voltage and frequency, Rx reported power, coil temperature, etc.

Figure 41. **STSW-STWBCGUI: monitor window**



Step 4. From the launch screen, select the [**Param window**] button.

This window lets you adjust system parameters (thresholds, regulation error) and save the settings.

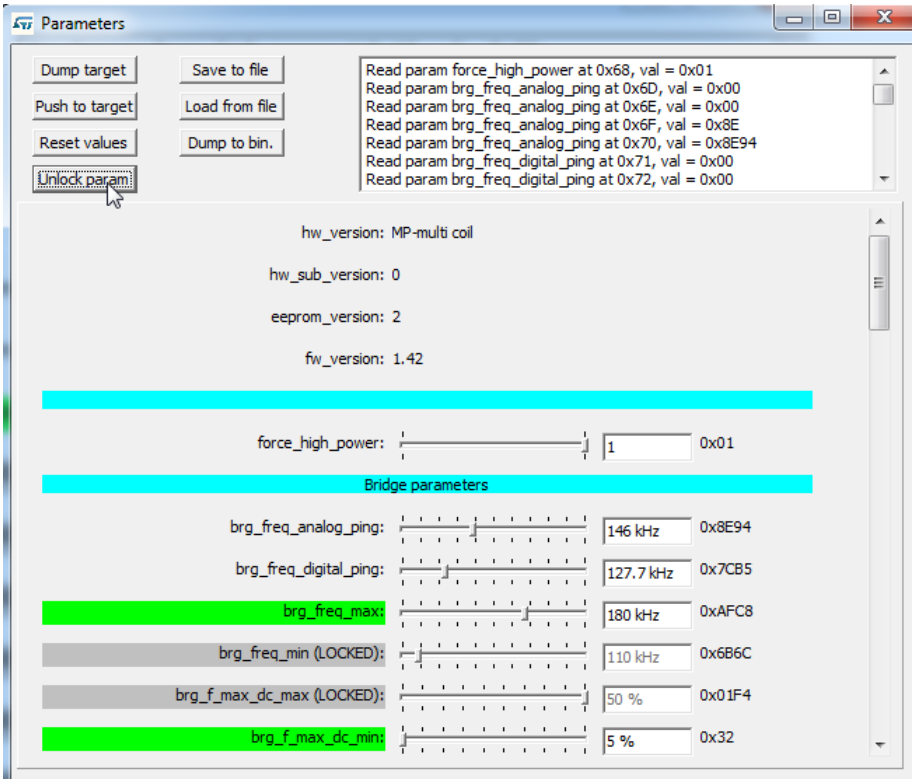
The parameters have the following levels of protection:

– Level 0: parameters can be modified without protection

– Level 1: To modify these parameters, you must first click the [**Unlock param**] button.

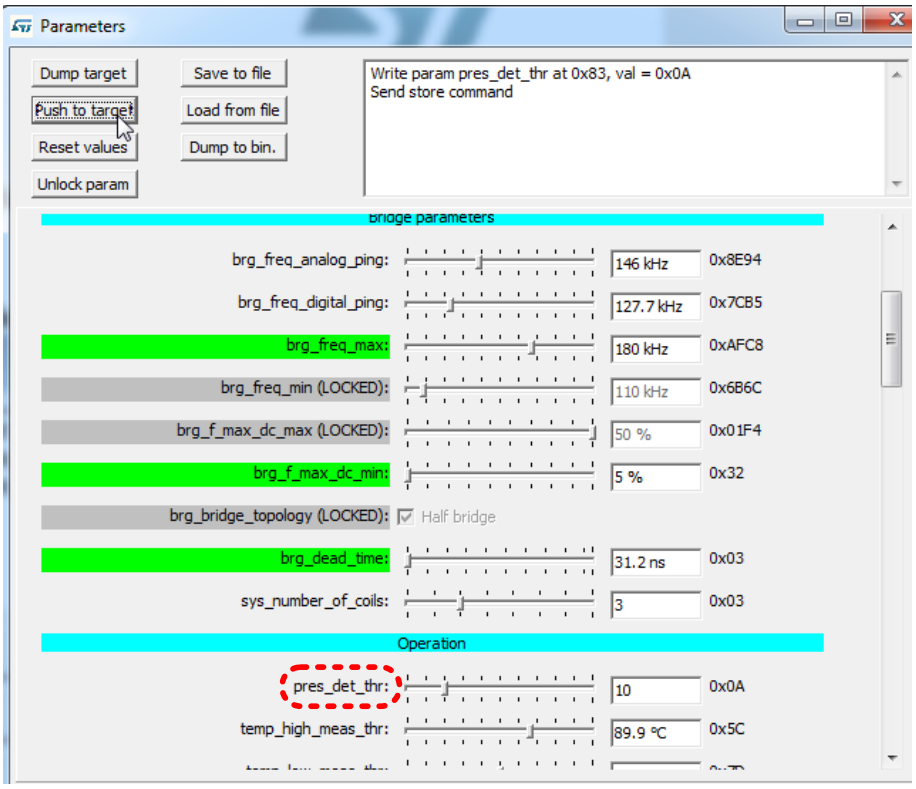
Note: Exercise caution when modifying level 1 parameters, as they can lead to system malfunction and trigger behavior that is not compatible with the Qi standard.

Figure 42. **STSW-STWBCGUI parameter window**



Step 5. Change some parameters and test their impact immediately by clicking [**Push to target**]. Modified parameters lose their highlighted background.

Figure 43. **STSW-STWBCGUI: parameter modification**

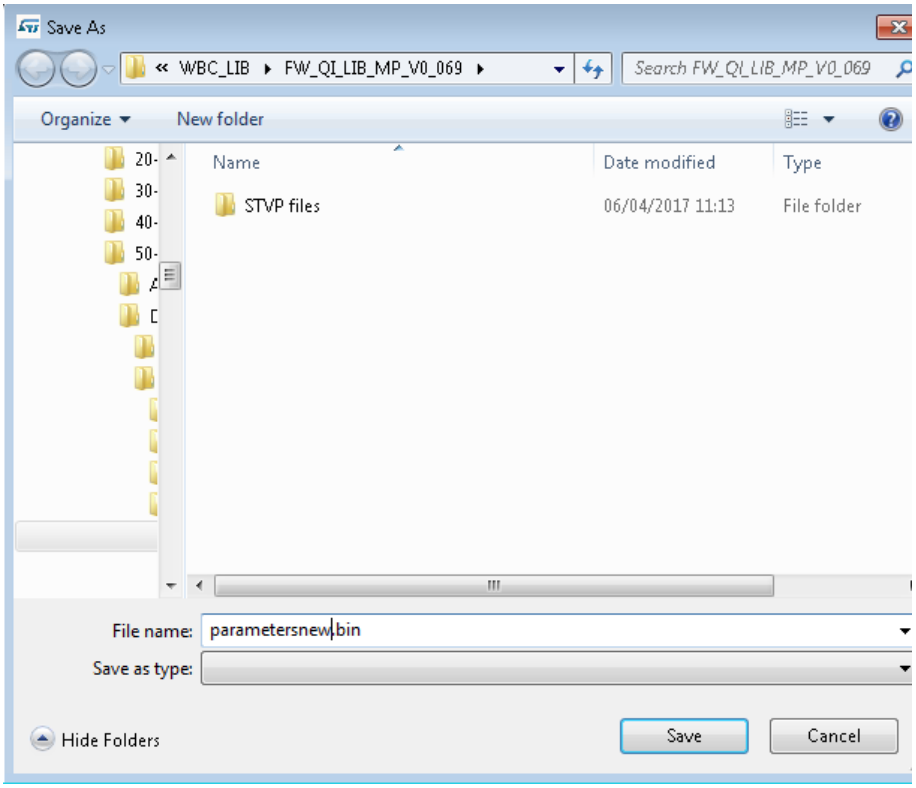


The GUI includes the STSW-STWBCFWDT downloader interface (which uses the UART connection) and includes tools to generate binary files with your changed parameters and to build new firmware packages with these files. Through the GUI, you can change the parameters and produce a new cab to program a batch of new boards.

Step 6. In the Parameters window, select [**Dump to bin.**] to save the changed parameters to a bin file.

You should only do this after you have clicked the [**Push to target**] button.

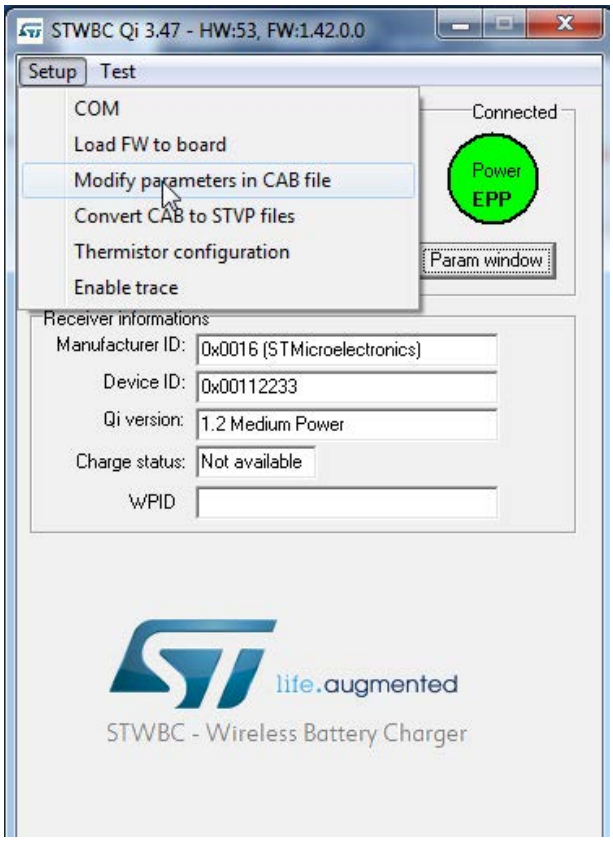
Figure 44. STSW-STWBCGUI dump modified parameters to a bin file



Step 7. From the launch screen, select [**Setup**]>[**Modify parameters in CAB file**] and select the appropriate firmware CAB file to be patched.

This operation will alter the firmware file with new tuning parameters, which can be subsequently loaded using the standard procedure.

Figure 45. **STSW-STWBCGUI: CAB file patch button**



5.1 Status LEDs

The status LEDs give the state of the charge:

At startup

- Red short blinking: when the board auto-calibration is on-going. You have to wait for the LED to be switched off before putting a receiver on the surface.
- Red and green blinking once: an internal reset occurred.
- Red and green steady state: firmware/STWBC chip mismatch
- Red steady and after 2 seconds green steady state: board hardware subversion detected does not match the firmware

In steady state

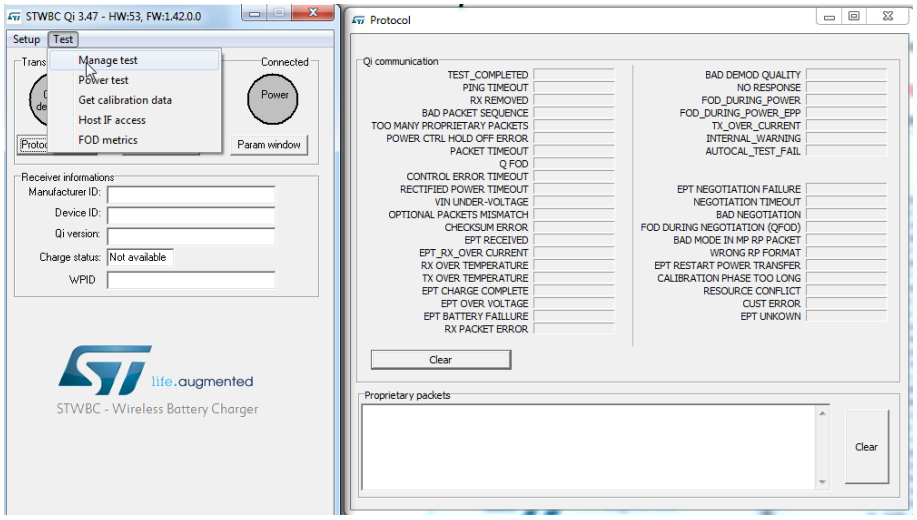
- Green blinking: power transfer in progress
- Green steady state: the charge is complete
- Red blinking: an error has been detected, as incomplete charge due to battery fault, overvoltage, overcurrent, etc.
- Red steady state: the transmitter is stuck until the receiver is removed, as mentioned in the Qi standard (power transfer stopped three times in a row due to the amount of power not provided to the receiver, some types of end power transfer or no response error code)

5.2 Test procedure for board calibration

Important:
Board calibration is mandatory to ensure that the transmitter board functions properly. You must perform the necessary calibration routines only once after each new firmware download.

Step 1. In the STWBC GUI launch screen, select [**Test**]>[**Manage test**].

Figure 46. Start auto calibration



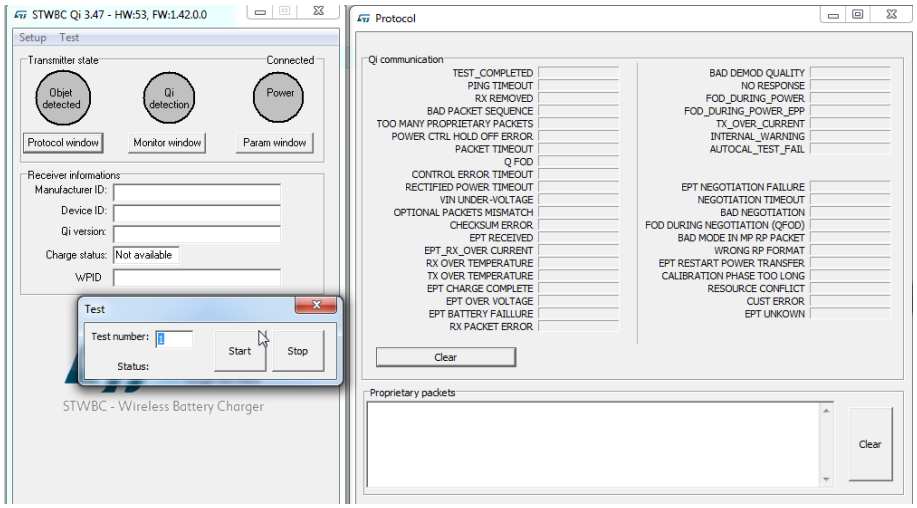
Proceed with the following test routine:

1. Presence detection calibration

5.2.1 Presence detection calibration procedure

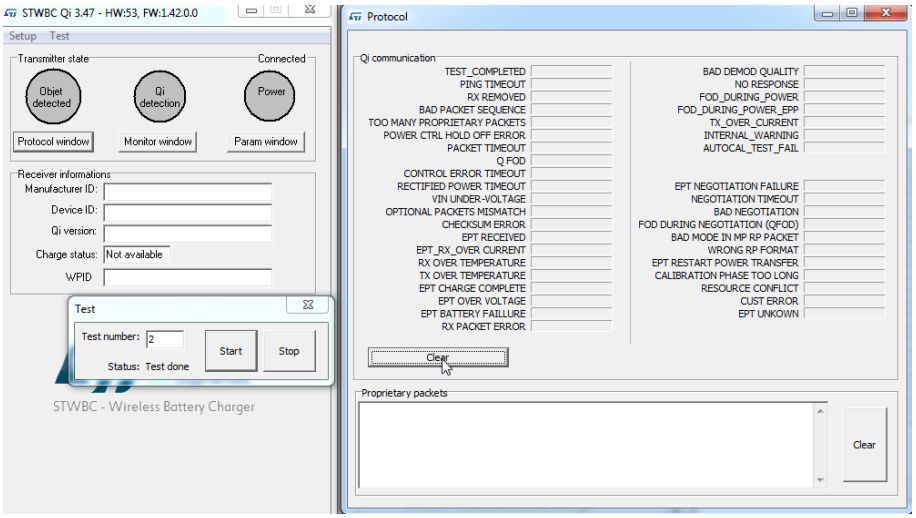
Step 1. In the Test popup window, insert "1" in the [**Test number:**] field and click the [**Start**] button.

Figure 47. Presence detection test



At the end of the test, the [**TEST_COMPLETED**] field is set in the Protocol window and [**Test done**] appears in the [**Status:**] field of the Test window.

Figure 48. **Test result**



If the test completion confirmations do not appear, please start the test again.

Proceed with the following test routine:

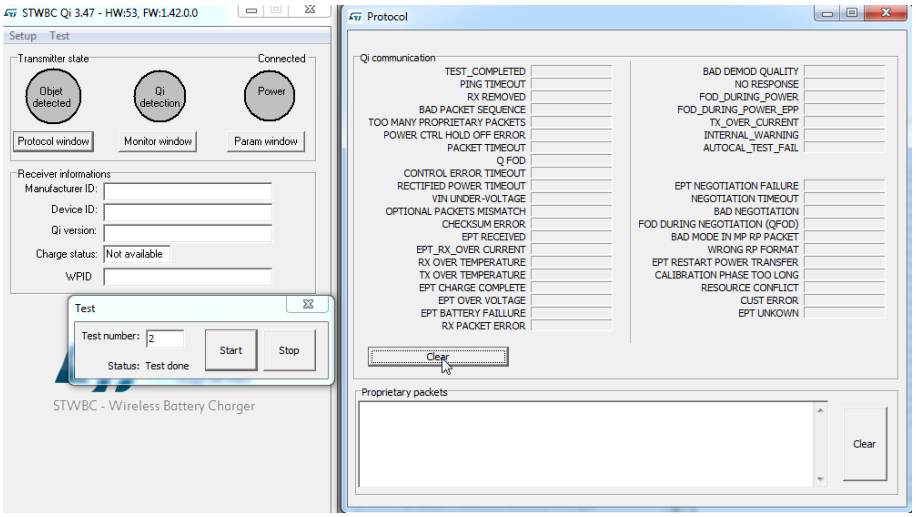
1. QFOD calibration

5.2.2 QFOD calibration procedure

Step 1. In the Protocol window, click the [**Clear**] button.

This clears the [**TEST_COMPLETED**] field.

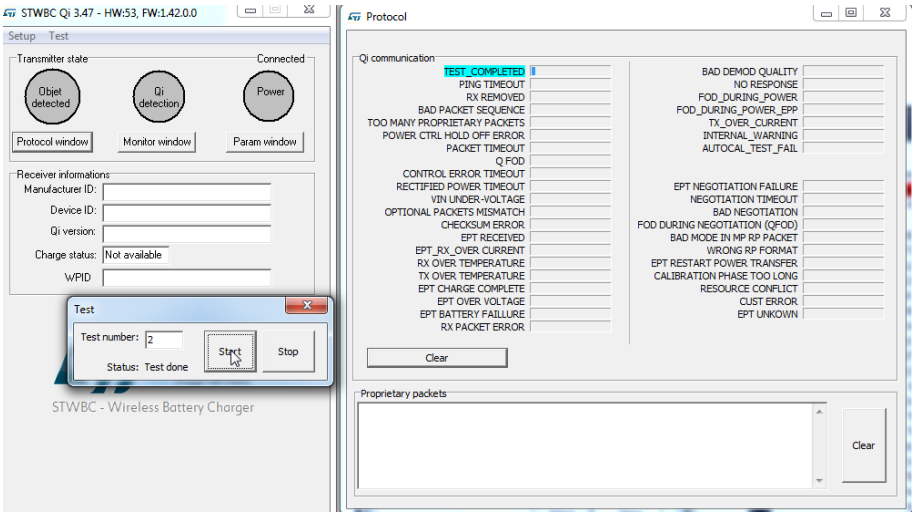
Figure 49. **QFOD test**



Step 2. In the Test popup window, insert "2" in the [**Test number:**] field and click the [**Start**] button.

At the end of the test, the [**TEST_COMPLETED**] field is set in the Protocol window and [**Test done**] appears in the [**Status:**] field of the Test window.

Figure 50. **Test result**



If the test completion confirmations do not appear, please start the test again.

5.3 Efficiency

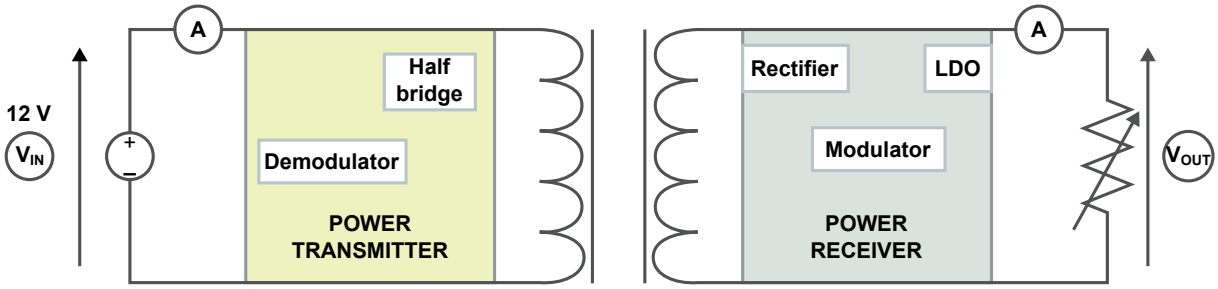
Efficiency measurements are performed on a Qi certification tester.

The STEVAL-ISB047V1T transmitter board is supplied with 12 V/2 A, and the receiver voltage level is 12 V (MP1B).

Pout is the actual output power measured at the output of the receiver and Pin is the input power.

Efficiency is measured using the configuration setup below:

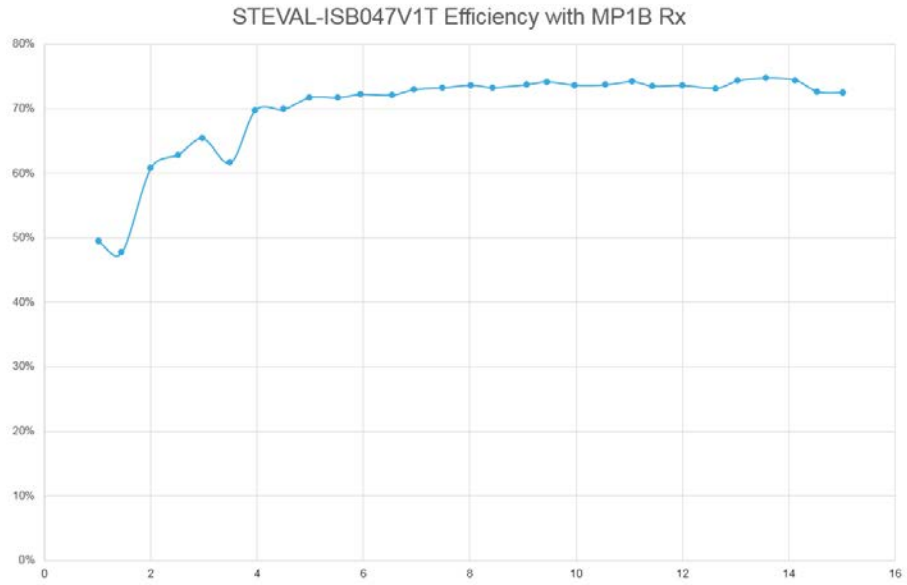
Figure 51. **Efficiency set up**



The following figure shows the typical efficiency performance on the different coils.

Figure 52. Efficiency performance

Efficiency=Pout/Pin.
Max efficiency is 75% at 9 W



5.4 Standby consumption

Very low power consumption is achieved in Standby Mode, with the transmitter board supplied 12 V.

Device detection is still enabled in this mode, but power consumption is reduced down to 1.4 mA on average. The STEVAL-ISB047V1T reference board can operate on a low standby power consumption of only 17 mW.

Note: To measure such low power consumption, the UART cable must be unplugged.

6 Schematic diagrams

6.1 STEVAL-ISB047V1T schematic diagrams

Figure 53. **STEVAL-ISB047V1T - circuit schematic (supply)**

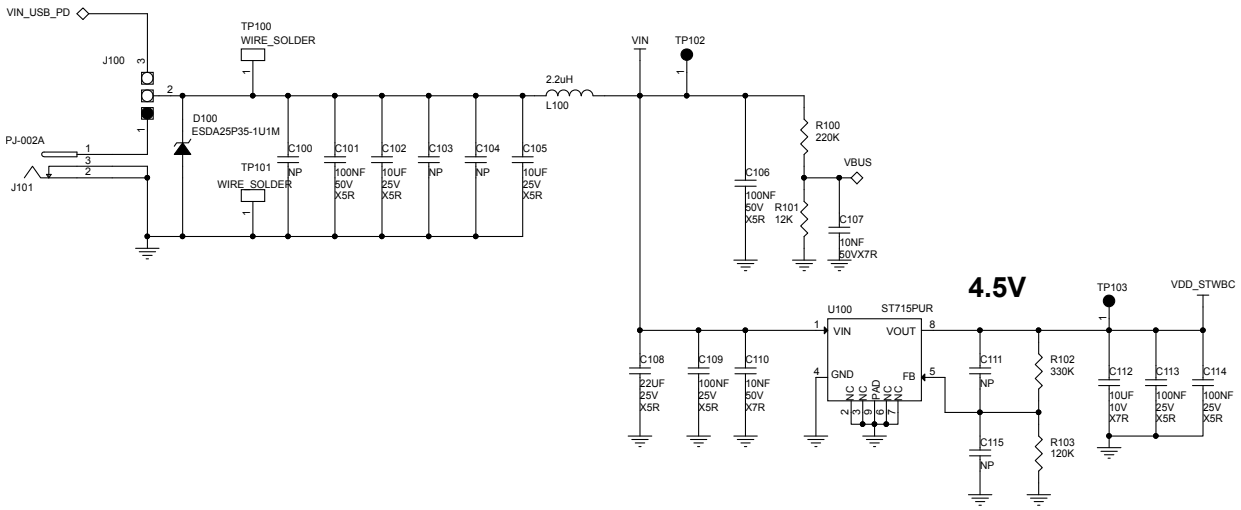


Figure 54. **STEVAL-ISB047V1T - circuit schematic (sepic)**

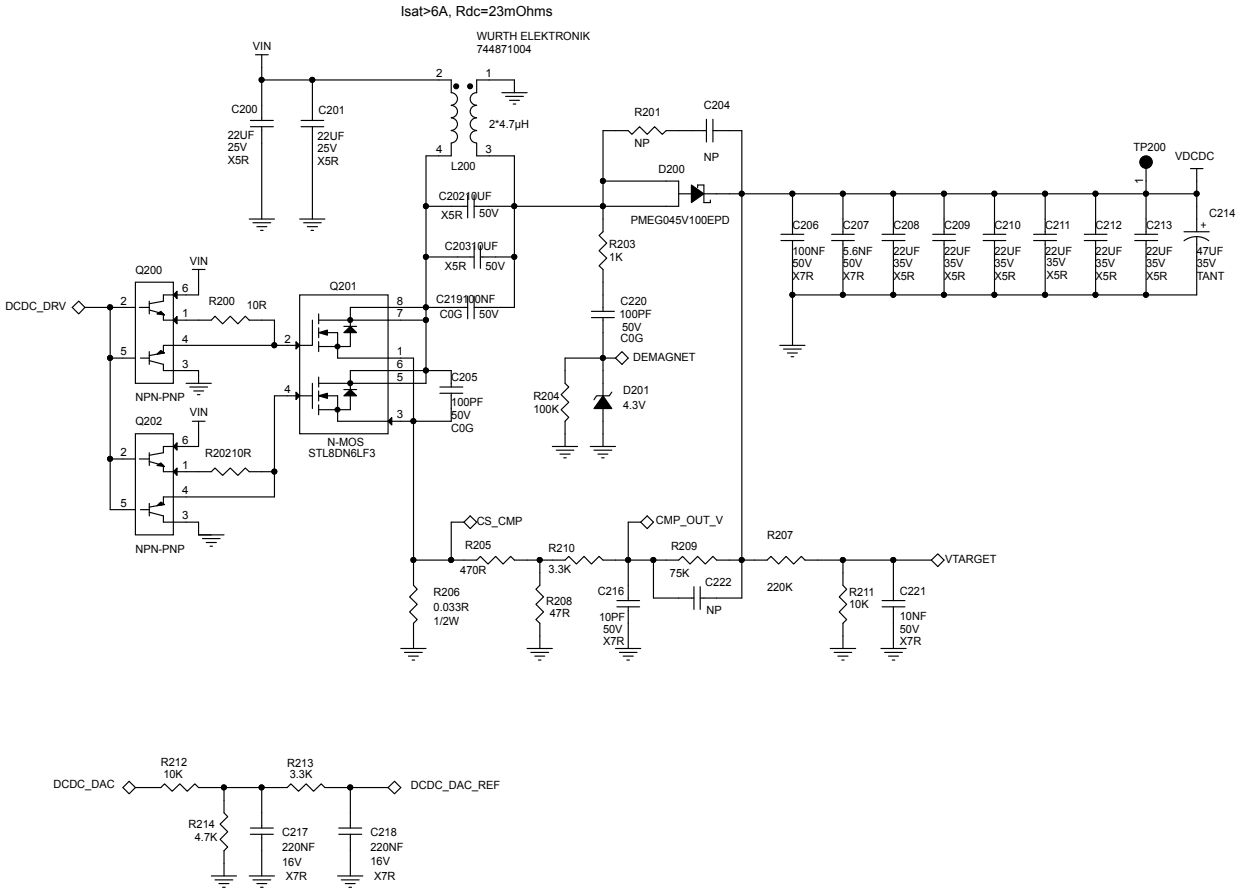


Figure 55. **STEVAL-ISB047V1T - circuit schematic (bridge)**

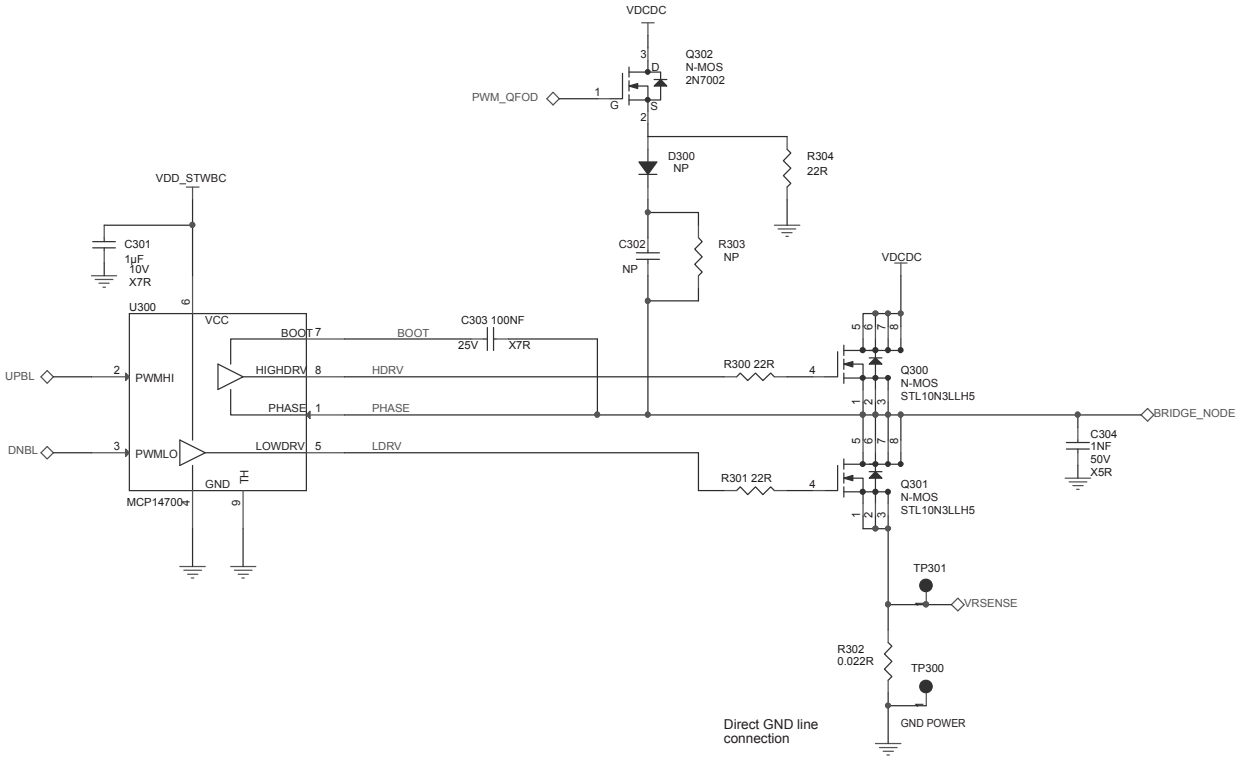


Figure 56. **STEVAL-ISB047V1T - circuit schematic (controller)**

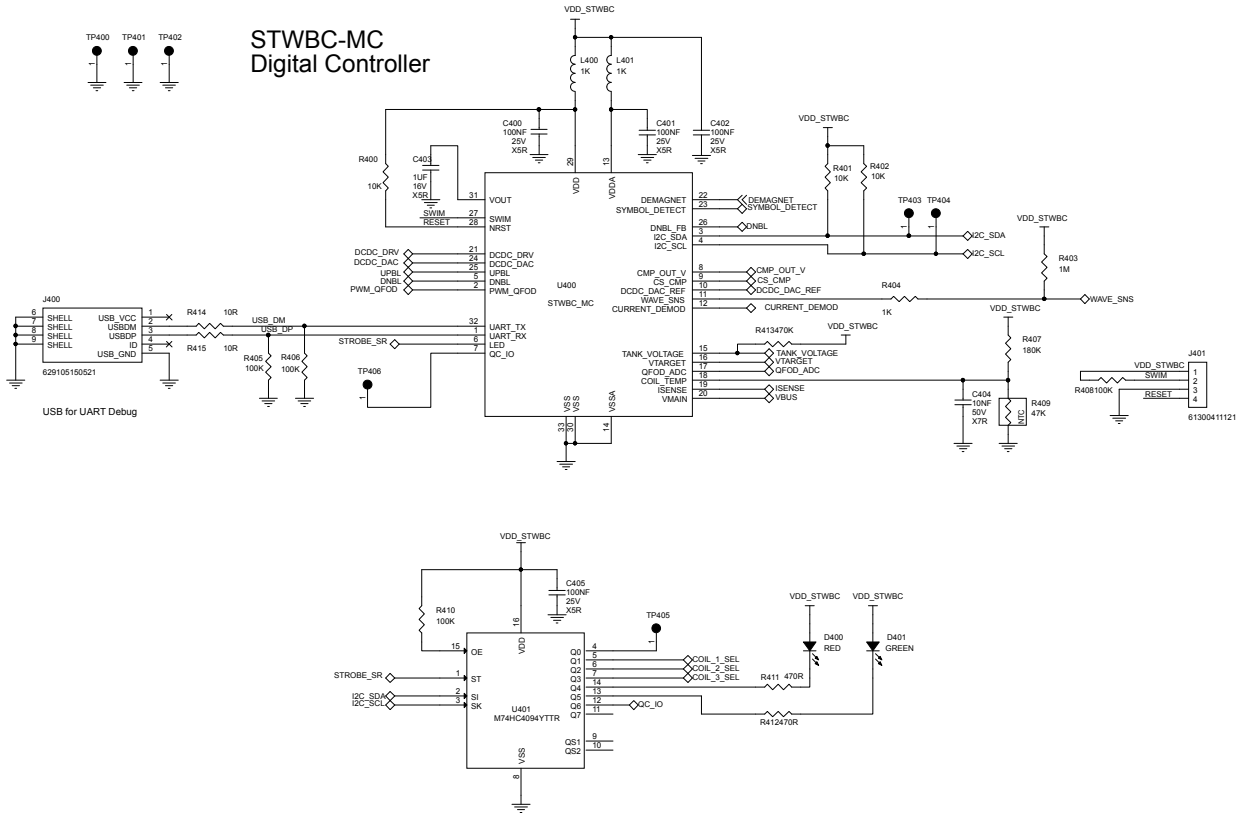


Figure 57. **STEVAL-ISB047V1T - circuit schematic (sensing)**

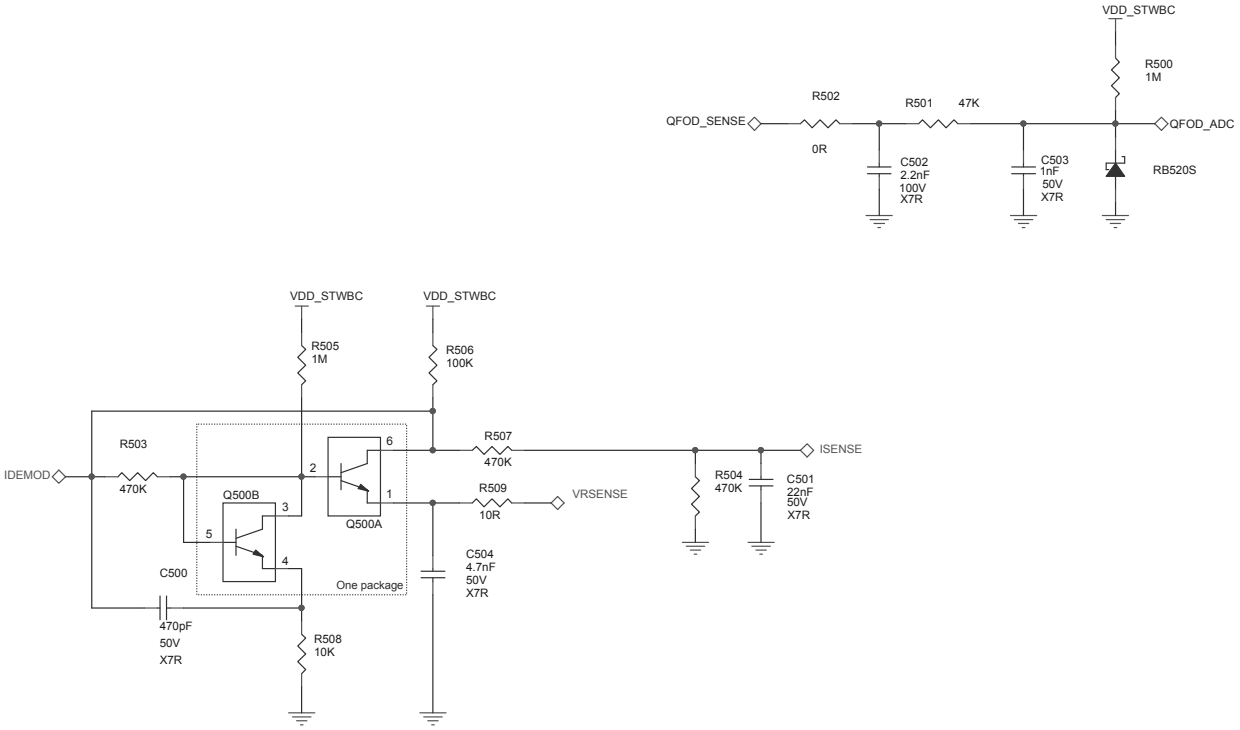


Figure 58. **STEVAL-ISB047V1T - circuit schematic (demod)**

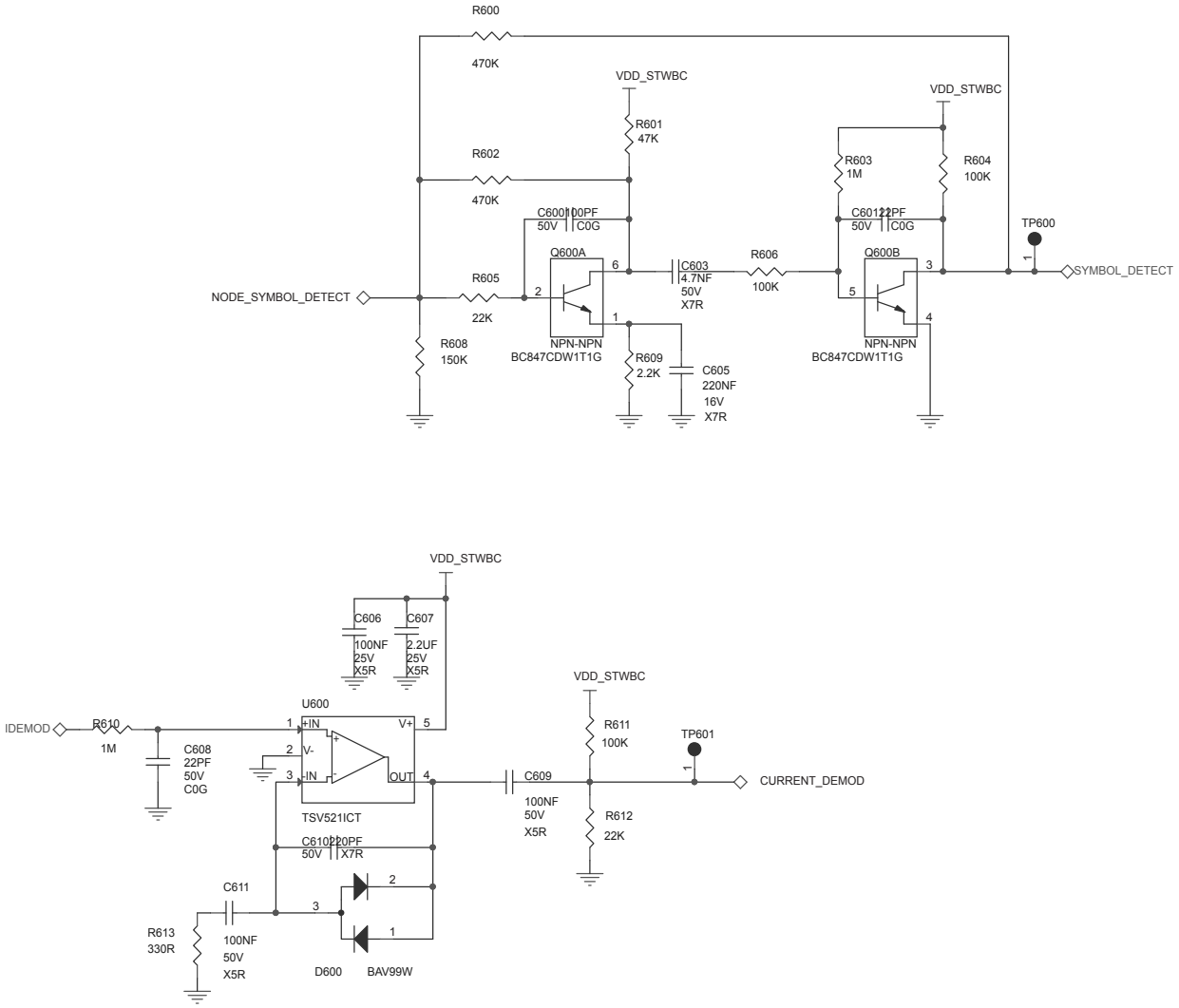


Figure 59. STEVAL-ISB047V1T - circuit schematic (mechanical parts)

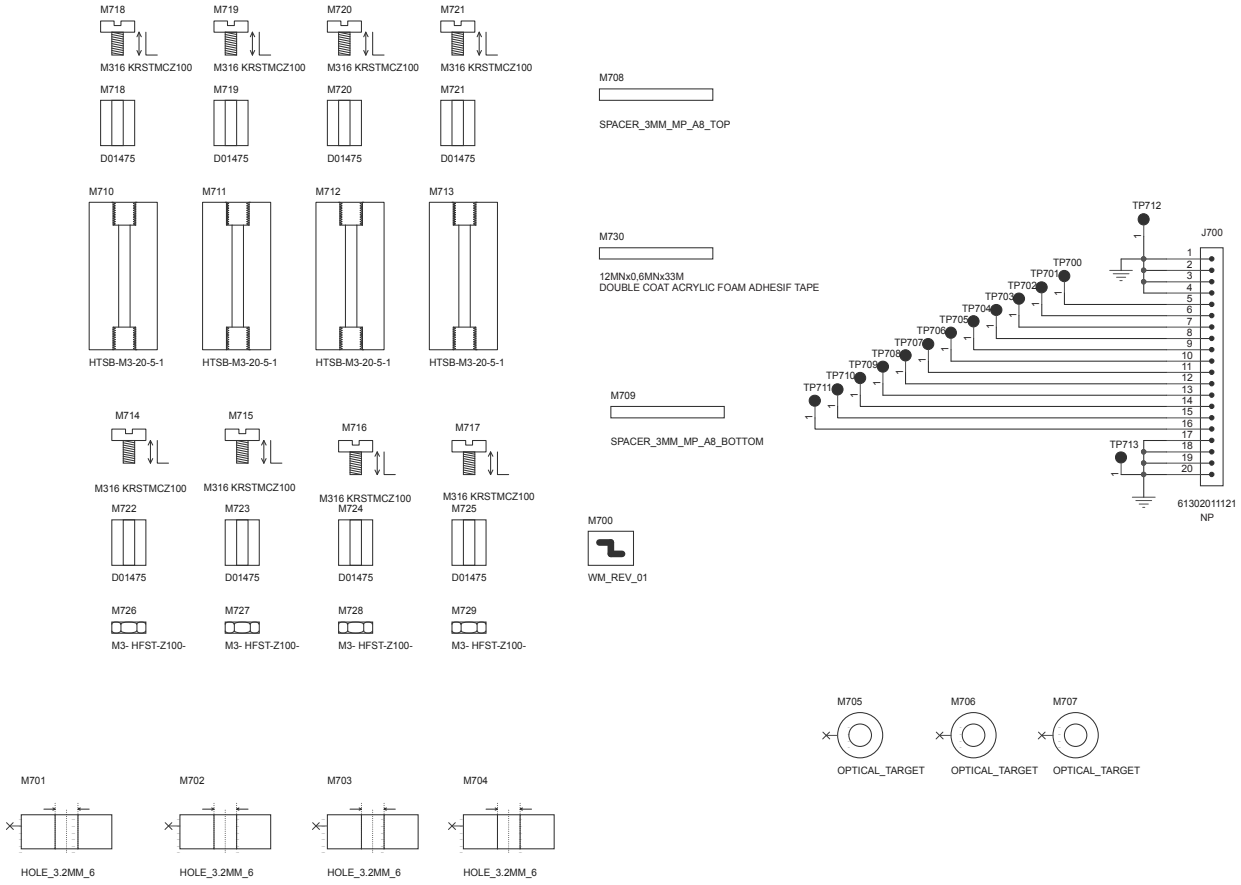


Figure 60. **STEVAL-ISB047V1T - circuit schematic (USB-PD)**

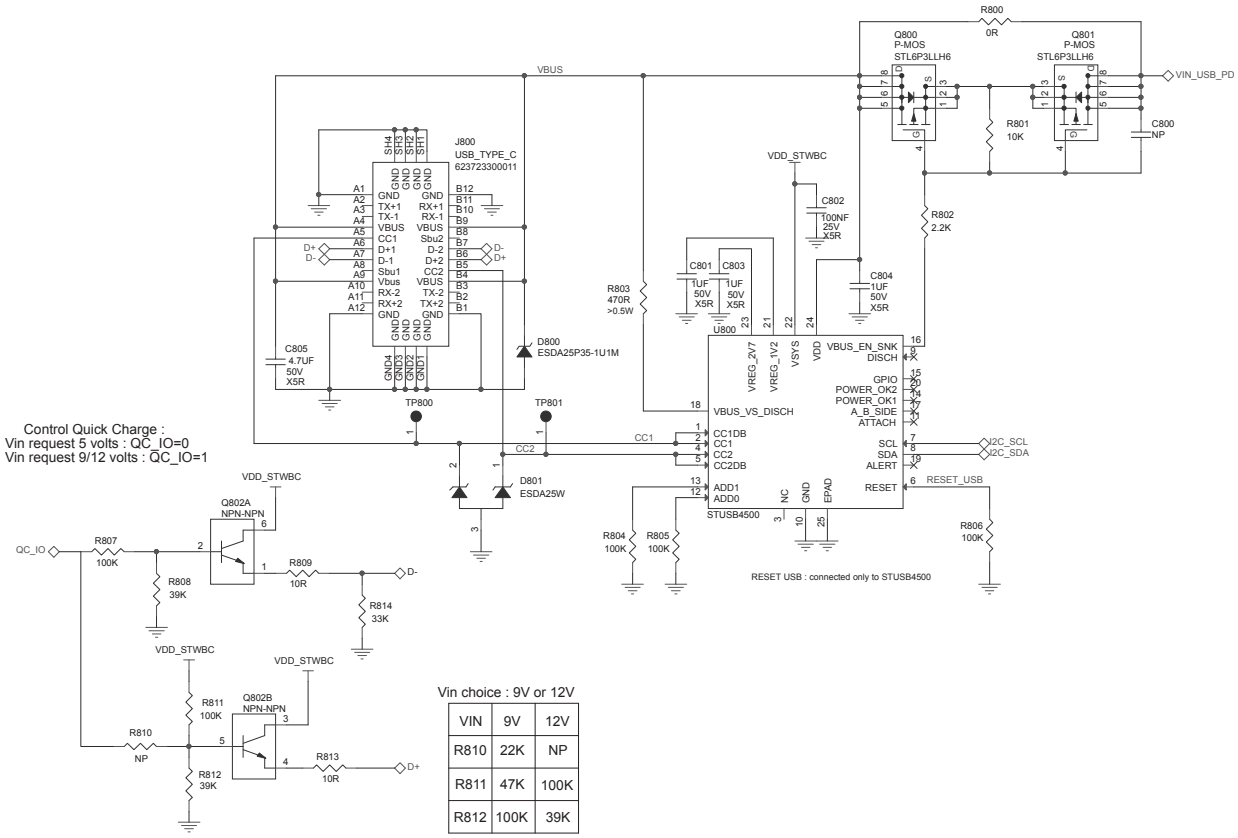


Figure 61. **STEVAL-ISB047V1T - circuit schematic (coil 1)**

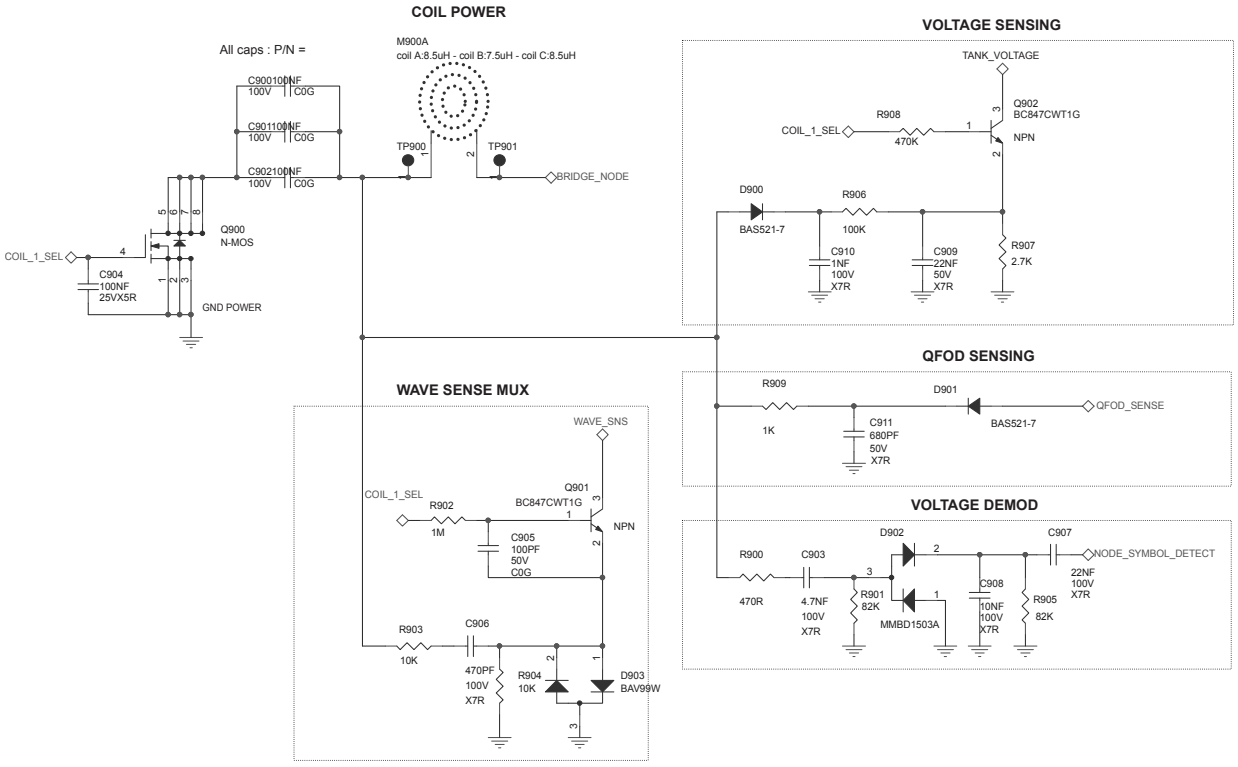


Figure 62. **STEVAL-ISB047V1T - circuit schematic (coil2)**

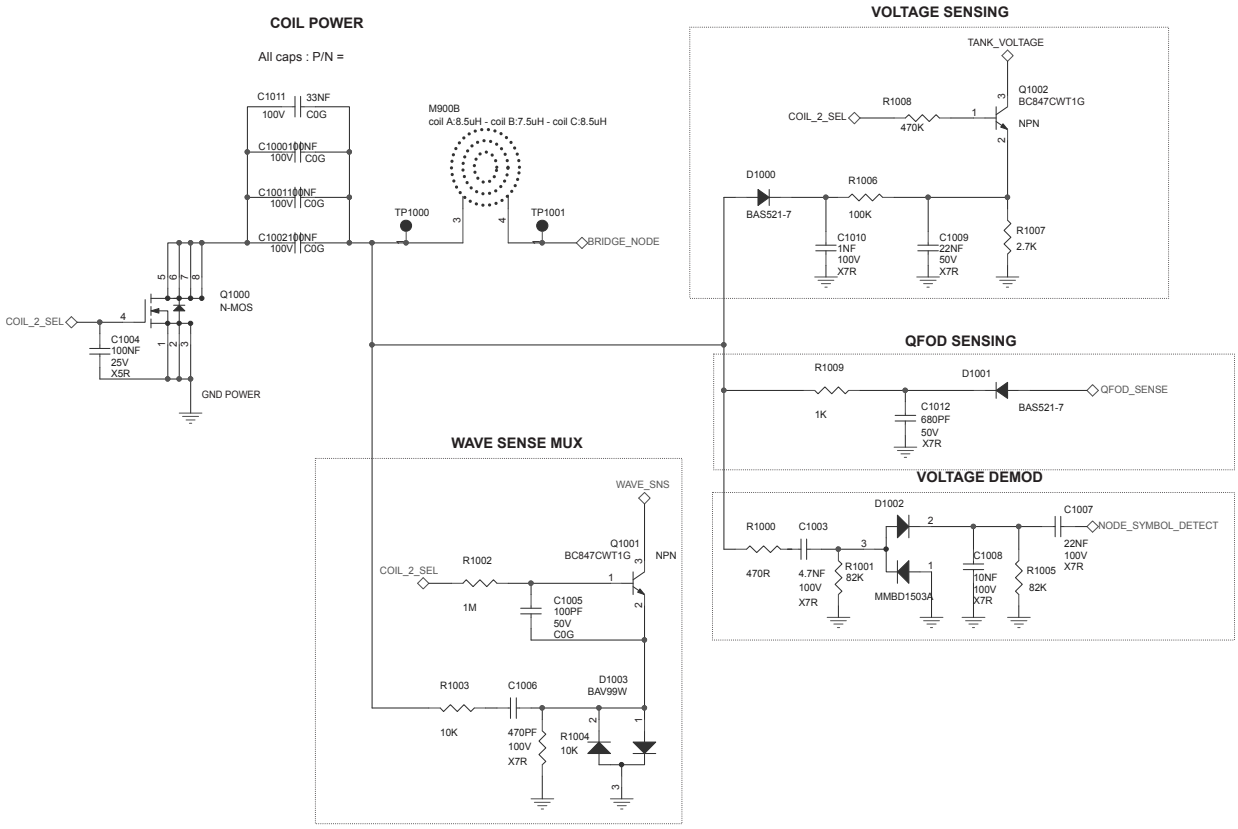
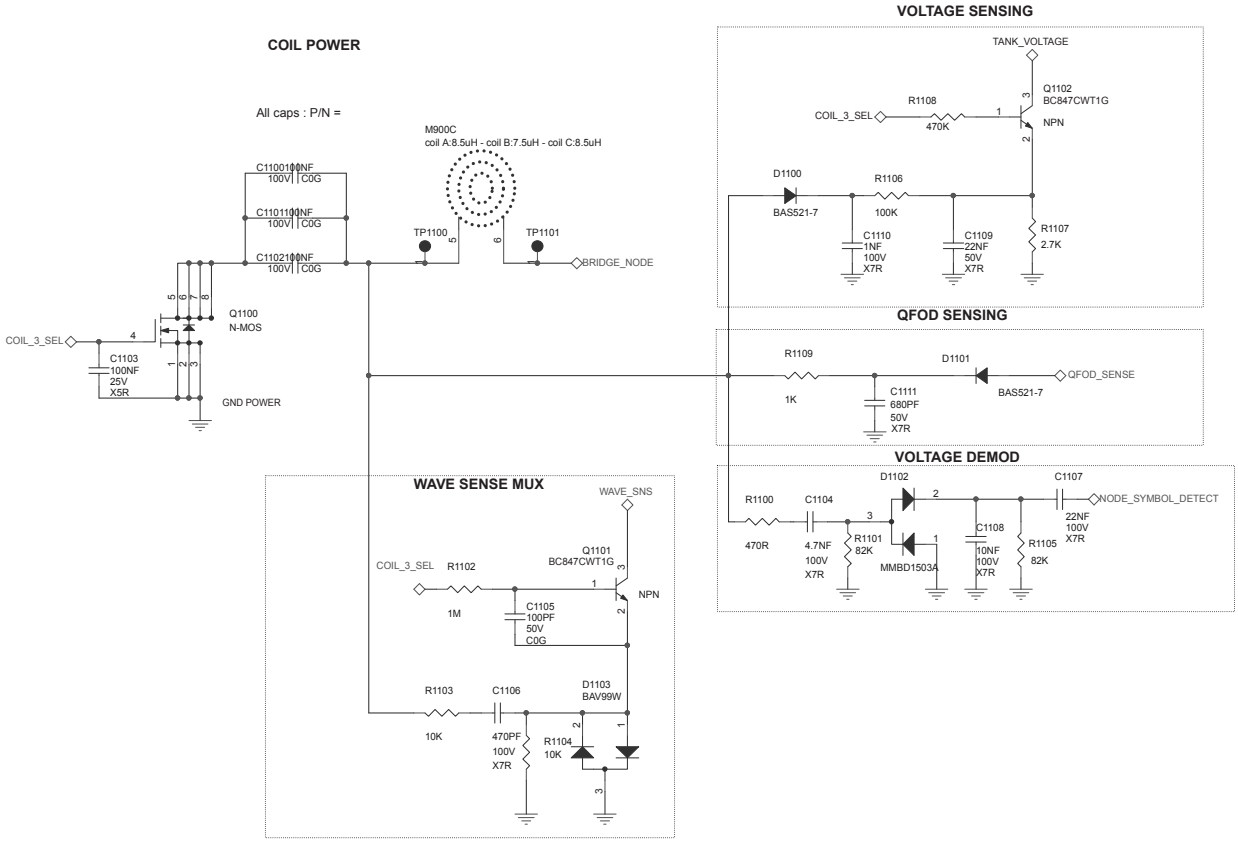
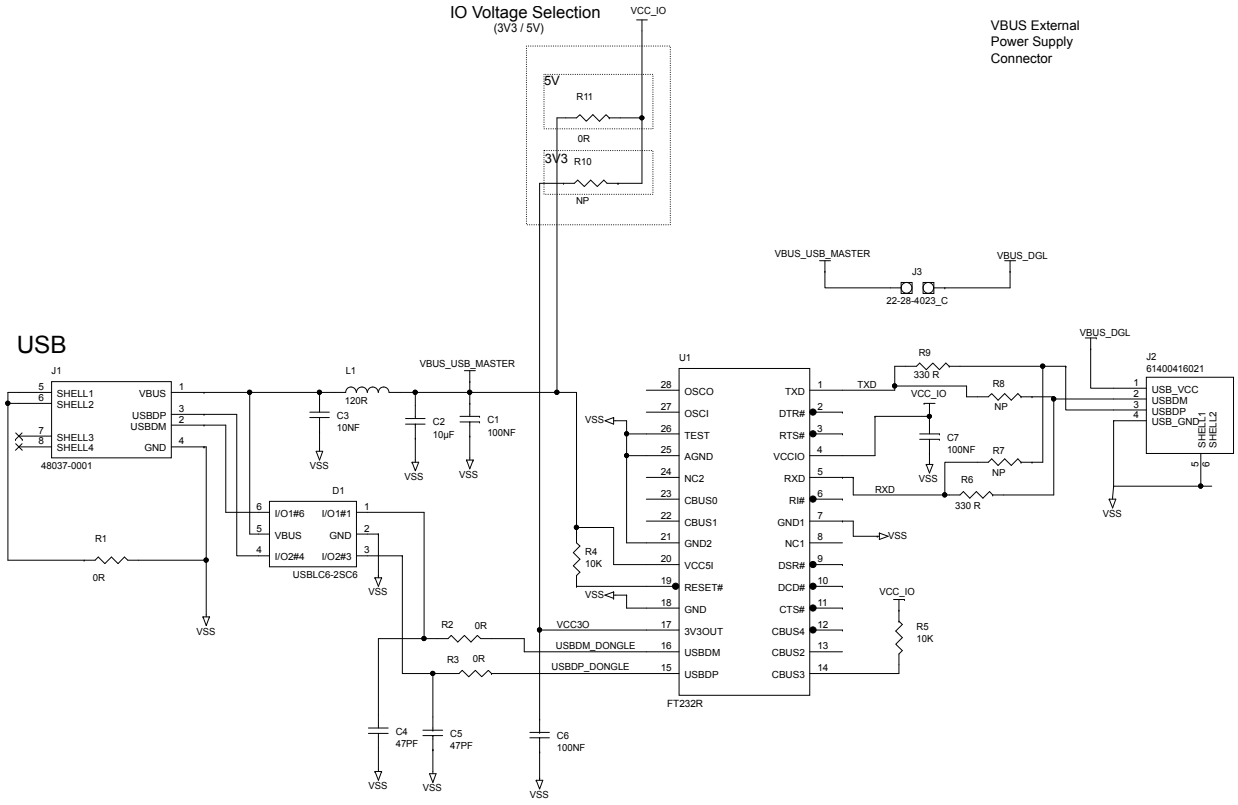


Figure 63. **STEVAL-ISB047V1T - circuit schematic (coil3)**



6.2 STEVAL-WBCDNGV1 schematic diagrams

Figure 64. STEVAL-WBCDNGV1 circuit schematic



7 Bill of materials

7.1 STEVAL-ISB047V1 bill of materials

Table 4. STEVAL-ISB047V1 bill of materials

Item	Q.ty	Ref.	Part / Value	Description	Manufacturer	Order code
1	1	-	STEVAL-ISB047V1T	Qi 3-coil 15W wireless charger TX board	ST	not available separately
2	1	-	STEVAL-WBCDNGV1	Dongle USB To UART	ST	not available separately
3	1	-	12 V, 24 W	AC/DC External Wall Mount Adapter Multi-Blade (Included) Input	XP Power	VER24US120-JA
4	1	-	1 m length, black	USB Type A Plug to Micro USB Type B Plug, USB 2.0	Molex	68784-0001

7.1.1 STEVAL-ISB047V1T bill of materials

Table 5. STEVAL-ISB047V1T bill of materials

Item	Q.ty	Ref.	Part / Value	Description	Manufacturer	Order code
1	2	C100, C103	NP	CER, 603	any	-
2	4	C101, C106, C609, C611	100nF, 50V, 15%	CER, 402	any	-
3	2	C102, C105	10µF, 25V, 20%	CER, 1206	WURTH ELECTRONIK	885012108021
4	1	C104	NP	CER, 1210	any	-
5	4	C107, C110, C221, C404	10nF, 50V, 10%	CER, 402	any	-
6	3	C108, C200, C201	22µF, 25V, 20%	CER, 1210	WURTH ELECTRONIK	885012109014
7	12	C109, C113, C114, C400, C401, C402, C405, C606, C802, C904, C1004, C1103	100nF, 25V, 15%	CER, 402	any	-
8	5	C111, C115, C204, C222, C800	NP	CER, 402	any	-
9	1	C112	10µF, 10V, 10%	CER, 805	MURATA	GRM21BR71A106KE51L
10	2	C202, C203	10µF, 50V, 10%	CER, 1206	any	-
11	6	C205, C220, C600, C905, C1005, C1105	100pF, 50V, 5%	CER, 402	any	-
12	1	C206	100nF, 50V, 5%	CER, 603	MURATA	GRM188R71H104KA93D
13	1	C207	5.6nF, 50V, 15%	CER, 402	any	-

Item	Q.ty	Ref.	Part / Value	Description	Manufacturer	Order code
14	6	C208, C209, C210, C211, C212, C213	22µF, 35V, 20%	CER, 1210	Taiyo Yuden	GMK325BJ226MM-P
15	1	C214	47µF, 35V, 20%	TANT	KEMET	T495X476M035ATE185
16	1	C216	10pF, 50V, 15%	CER, 402	any	-
17	3	C217, C218, C605	220nF, 16V, 10%	CER, 402	any	-
18	1	C219	100nF, 50V, 5%	CER, 1206	TDK	CGA5L2C0G1H104J160AA
19	1	C301	1µF, 10V, 15%	CER, 603	any	-
20	1	C302	NP, 50V, 15%	CER, 402	any	-
21	1	C303	100nF, 25V, 10%	CER, 603	any	-
22	1	C304	1nF, 50V, 15%	CER, 603	any	-
23	1	C403	1µF, 16V, 10%	CER, 402	any	-
24	1	C500	470pF, 50V, 15%	CER, 402	any	-
25	4	C501, C909, C1009, C1109	22nF, 50V, 15%	CER, 402	any	-
26	1	C502	2.2nF, 100V, 10%	CER, 603	AVX	06031C222KAT2A
27	1	C503	1nF, 50V, 10%	CER, 402	any	-
28	2	C504, C603	4.7nF, 50V, 15%	CER, 402	any	-
29	2	C601, C608	22pF, 50V, 5%	CER, 402	any	-
30	1	C607	2.2µF, 25V, 10%	CER, 402	any	-
31	1	C610	220pF, 50V, 15%	CER, 402	any	-
32	3	C801, C803, C804	1µF, 50V, 10%	CER, 402	any	-
33	1	C805	4.7µF, 50V, 15%	CER, 805	any	-
34	9	C900, C901, C902, C1000, C1001, C1002, C1100, C1101, C1102	100nF, 100V, 5%	CER, 1812	TDK	C4532C0G2A104J320KA
35	3	C903, C1003, C1104	4.7nF, 100V, 10%	CER, 603	TDK	CGA3E2X7R2A472K080AA
36	3	C906, C1006, C1106	470pF, 100V, 15%	CER, 402	any	-
37	3	C907, C1007, C1107	22nF, 100V, 15%	CER, 603	any	-
38	3	C908, C1008, C1108	10nF, 100V, 15%	CER, 603	any	-
39	3	C910, C1010, C1110	1nF, 100V, 15%	CER, 402	any	-
40	3	C911, C1012, C1111	680pF, 50V, 15%	CER, 402	any	-
41	1	C1011	33nF, 100V, 5%	CER, 1210	any	-

Item	Q.ty	Ref.	Part / Value	Description	Manufacturer	Order code
42	2	D100, D800	-	TVS/ESD/EMI, QFN1610	ST	ESDA25P35-1U1M
43	1	D200	-	SCHOTTKY, SOT1289	NXP	PMEG045V100EPD
44	1	D201	4.3V	ZENER, SOD323	NXP	BZX384-C4V3-AK
45	1	D300	NP	DIODE, SOD323	any	-
46	1	D400	RED	LED, L3.2_W2.5_H1	WURTH ELEKTRONIK	155124RS73200
47	1	D401	GREEN	LED, L3.2_W2.5_H1	WURTH ELEKTRONIK	155124VS73200
48	1	D500	-	SCHOTTKY, SOD523	ROHM	RB520S
49	4	D600, D903, D1003, D1103	-	DIODE, SOT323	NXP	BAV99W
50	1	D801	-	TVS/ESD/EMI, SOT323	ST	ESDA25W
51	6	D900, D901, D1000, D1001, D1100, D1101	-	DIODE, DIOD_SOD523	any	BAS521-7
52	3	D902, D1002, D1102	-	DIODE, SOT23	FAIRCHILD	MMBD1503A
53	1	J100	-	HEADER, TH_HEADER_1x3_P2 .54	WURTH ELEKTRONIK	61300311121
54	1	J101	-	JACK, POWER JACK DC	CUI	PJ-002A
55	1	J400	-	USB, MICRO USB TYPE B SMD	WURTH ELEKTRONIK	629105150521
56	1	J401	-	HEADER, TH_HEADER_1x4_P2 .54	WURTH ELEKTRONIK	61300411121
57	1	J800	USB_TYPE_C	USB, USB TYPE C	WURTH ELEKTRONIK	623723300011
58	1	L100	2.2µH, 3.8A , 20%	INDUCTOR, L5_W5_H4	WURTH ELEKTRONIK	74404054022
59	1	L200	2*4.7µH, 8A	CM_CHOKE	WURTH ELEKTRONIK	744871004
60	2	L400, L401	1K, 0.2A, 25%	FERRITE, 402	MURATA	BLM15AG102SN1D
61	1	M700	WM_rev3	PCB	any	PCB WM - 2 layers
62	1	M708	-	SPACER	any	-
63	1	M709	-	SPACER	any	-
64	4	M710, M711, M712, M713	-	SPACER	RS	HTSB-M3-20-5-1
65	8	M714, M715, M716, M717, M718, M719, M720, M721	-	SCREW	DURATOOL	M316 KRSTMCZ100
66	8	M718, M719, M720, M721, M722, M723, M724, M725	-	SPACER	DURATOOL	D01475

Item	Q.ty	Ref.	Part / Value	Description	Manufacturer	Order code
67	4	M726, M727, M728, M729	-	SCREW	DURATOOL	M3- HFST-Z100-
68	1	M730	12mm x 33mm	SPACER	3M	GPH-060GF 12MMX33M
69	1	M900	coil A:8.5uH - coil B:7.5uH - coil C:8.5uH, 9A	INDUCTOR	WURTH ELEKTRONIK	760 308 103 147
70	2	Q200, Q202	NPN-PNP	CMS, SOT363	ON SEMICONDUCTOR	MMDT4413
71	1	Q201	N-MOS	CMS, POWERFLAT-5x6	ST	STL8DN6LF3
72	2	Q300, Q301	N-MOS	CMS, POWERFLAT-3x3	ST	STL10N3LLH5
73	1	Q302	N-MOS	CMS, SOT23	ON SEMICONDUCTOR	2N7002
74	3	Q500, Q600, Q802	NPN-NPN	CMS, SOT363	ON SEMICONDUCTOR	BC847CDW1T1G
75	2	Q800, Q801	P-MOS	CMS, L3_W3_H0.75	ST	STL6P3LLH6
76	3	Q900, Q1000, Q1100	N-MOS	CMS, POWERPAK_SO_8	VISHAY	SIR616DP-T1-GE3
77	6	Q901, Q902, Q1001, Q1002, Q1101, Q1102	NPN	CMS, SOT323	ON SEMICONDUCTOR	BC847CWT1G
78	2	R100, R207	220K, 1/16W, 1%	RES, 402	any	-
79	1	R101	12K, 1/16W, 1%	RES, 402	any	-
80	1	R102	330K, 1/16W, 1%	RES, 402	any	-
81	1	R103	120K, 1/16W, 5%	RES, 402	any	-
82	7	R200, R202, R414, R415, R509, R809, R813	10R, 1/16W, 5%	RES, 402	VISHAY	10R_5%_0402
83	2	R201, R810	NP	RES, 402	any	-
84	1	R203	1K, 1/16W, 1%	RES, 402	any	-
85	10	R204, R405, R406, R408, R410, R804, R805, R806, R807, R811	100K, 1/16W, 5%	RES, 402	any	-
86	4	R205, R900, R1000, R1100	470R, 1/16W, 1%	RES, 402	any	-
87	1	R206	0.033R, 1/2W, 1%	RES, 1206	any	-
88	1	R208	47R, 1/16W, 5%	RES, 402	any	-
89	1	R209	75K, 1/16W, 1%	RES, 402	any	-
90	2	R210, R213	3.3K, 1/16W, 1%	RES, 402	any	-

Item	Q.ty	Ref.	Part / Value	Description	Manufacturer	Order code
91	3	R211, R212, R508	10K, 1/16W, 1%	RES, 402	any	-
92	1	R214	4.7K, 1/16W, 1%	RES, 402	any	-
93	2	R300, R301	22R, 1/16W, 1%	RES, 402	any	-
94	1	R302	0.022R, 1W, 1%	RES, 1206	any	-
95	1	R303	NP, 1/16W, 5%	RES, 402	any	-
96	1	R304	22R, 1/10W, 5%	RES, 603	any	-
97	10	R400, R401, R402, R801, R903, R904, R1003, R1004, R1103, R1104	10K, 1/16W, 5%	RES, 402	any	-
98	5	R403, R610, R902, R1002, R1102	1M, 1/16W, 5%	RES, 402	any	-
99	4	R404, R909, R1009, R1109	1K, 1/16W, 5%	RES, 402	any	-
100	1	R407	180K, 1/16W, 1%	RES, 402	any	-
101	1	R409	47K, 1%	THERMISTANCE, 402	MURATA	NCP15WB473F03RC
102	2	R411, R412	470R, 1/16W, 5%	RES, 402	any	-
103	4	R413, R908, R1008, R1108	470K, 1/16W, 5%	RES, 402	any	-
104	3	R500, R505, R603	1M, 1/16W, 1%	RES, 402	any	-
105	2	R501, R601	47K, 1/16W, 1%	RES, 402	any	-
106	1	R502	0R, 1/16W, 5%	RES, 402	any	-
107	5	R503, R504, R507, R600, R602	470K, 1/16W, 1%	RES, 402	any	-
108	7	R506, R604, R606, R611, R906, R1006, R1106	100K, 1/16W, 1%	RES, 402	any	-
109	2	R605, R612	22K, 1/16W, 1%	RES, 402	any	-
110	1	R608	150K, 1/16W, 1%	RES, 402	any	-
111	2	R609, R802	2.2K, 1/16W, 5%	RES, 402	any	-
112	1	R613	330R, 1/16W, 5%	RES, 402	any	-
113	1	R800	0R, 1/10W, 5%	RES, 603	any	-
114	1	R803	470R, 1/2W, 1%	RES, 1206	any	-
115	1	R808	39K, 1/16W, 1%	RES, 402	any	-
116	1	R812	39K, 1/16W, 5%	RES, 402	any	-
117	1	R814	33K, 1/16W, 1%	RES, 402	any	-

Item	Q.ty	Ref.	Part / Value	Description	Manufacturer	Order code
118	6	R901, R905, R1001, R1005, R1101, R1105	82K, 1/16W, 1%	RES, 402	any	-
119	3	R907, R1007, R1107	2.7K, 1/16W, 1%	RES, 402	any	-
120	2	TP100, TP101	WIRE_SOLDER	TEST POINT	any	-
121	16	TP102, TP103, TP200, TP300, TP301, TP400, TP401, TP402, TP403, TP404, TP405, TP406, TP600, TP601, TP800, TP801	-	TEST POINT	any	TPSMD-1MM
122	6	TP900, TP901, TP1000, TP1001, TP1100, TP1101	-	TEST POINT	any	TPSMD-2x5MM
123	1	U100	-	CONVERTER, DFN8_L3_W3	ST	ST715PUR
124	1	U300	-	DRIVER, DFN8_L3_W3	MICROCHIP	MCP14700_DFN8
125	1	U400	-	CONTROLLER, QFN32	ST	STWBC-MC
126	1	U401	-	LOGIC, TSSOP16	ST	M74HC4094YTTR
127	1	U600	-	AMPLIFIER, SOT353	ST	TSV521ICT
128	1	U800	-	CONTROLLER, QFN24	ST	STUSB4500
129	1	J700	NP	HEADER, TH_HEADER_1x20_P 2.54	WURTH ELEKTRONIK	61302011121
130	12	TP700, TP701, TP702, TP703, TP704, TP705, TP706, TP707, TP708, TP709, TP710, TP711	-	TEST POINT,	any	TPSMD-1x3MM

7.1.2 STEVAL-WBCDNGV1 bill of materials

Table 6. STEVAL-WBCDNGV1 bill of materials

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
1	3	C1, C6, C7	100 NF 50 V ±15%	Ceramic capacitors, X7R, 0603	any	-
2	1	C2	10 µF 25 V ±10%	Ceramic capacitor X7R, 0805	any	-
3	1	C3	10 NF 50 V ±15%	Ceramic capacitor, X7R, 0603	any	-
4	2	C4, C5	47 PF 25 V 0.15	Ceramic capacitors, X5R, 0603	any	-

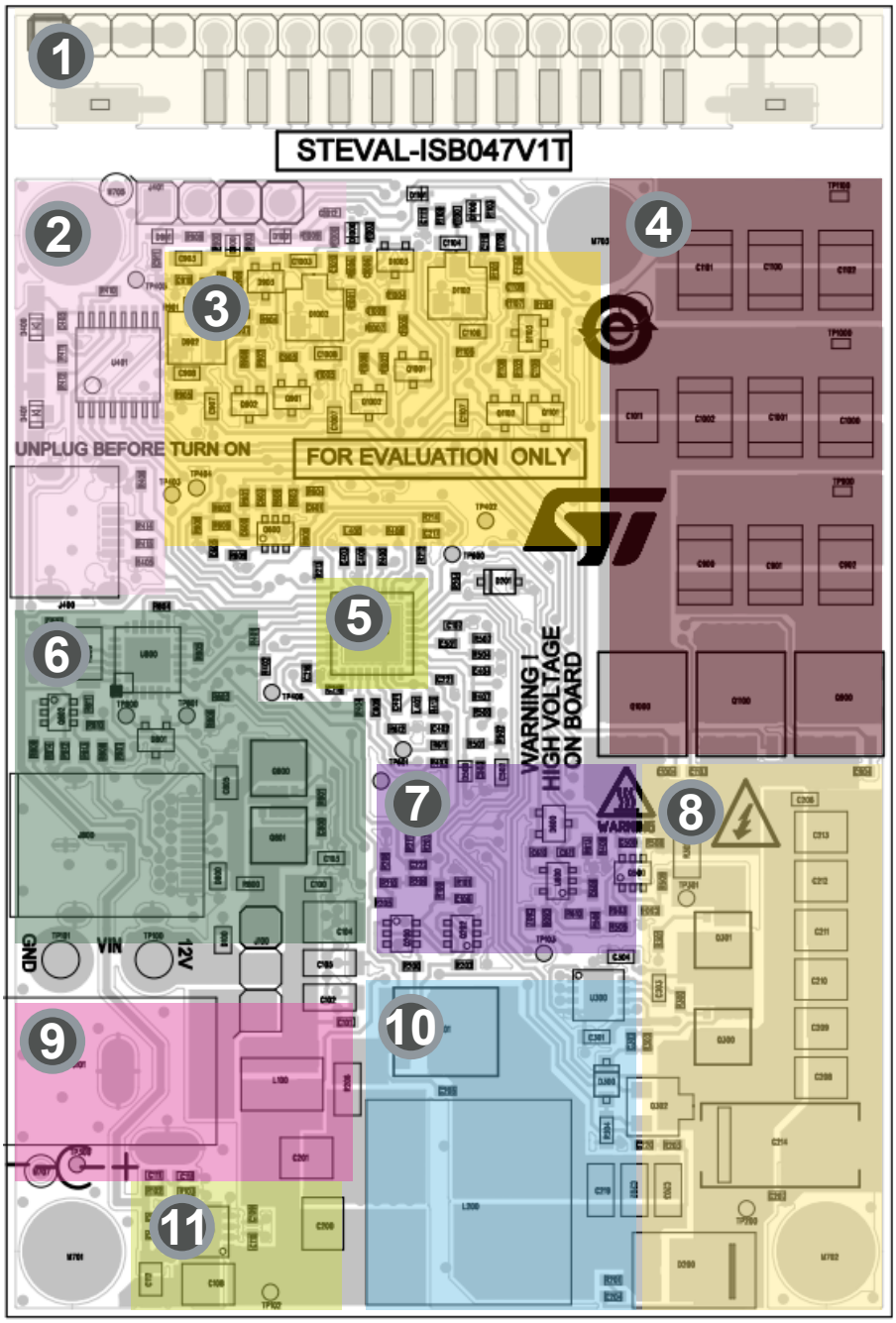
Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
5	1	D1	-	Very low capacitance ESD protection - SOT23-6L	ST	USBLC6-2SC6
6	1	J1	-	USB	Molex	48037-0001
7	1	J2	-	USB	Wurth Elektronik	61400416021
8	1	J3	JUMP254P-M-2	Header	Molex	22-28-4023_C
9	1	L1	120 R 0.5 A ±25%	Ferrite, 0603	Wurth Elektronik	74279262
10	4	R1, R2, R3, R11	0 R 1/10 W ±5%	Resistors, 0603	any	-
11	2	R4, R5	10 K 1/10 W ±5%	Resistors, 0603	any	-
12	2	R6, R9	330 R 1/10 W ±5%	Resistors, 0603	any	-
13	3	R7, R8, R10	NP	Resistors, 0603	any	-
14	1	U1	FT232R SSOP28	Converter	FTDI	FT232R

8 Board assembly and layout

The STEVAL-ISB047V1T evaluation board uses a low cost 2-layer PCB design with all the components on the top side. The test points allow user evaluation of the STWBC-MC solution with probes. In addition, UART is accessible through a micro USB connector and SWIM is routed to a header connector.

Figure 65. STEVAL-ISB047V1T evaluation board functional blocks

1. Test point for debugging only (may be removed)
2. LED, SWIM and USB/UART debug connectors
3. Sensing detection circuits
4. Coil selection and detection
5. STWBC-MC
6. USB PD/QC IO charger
7. Voltage/current demodulation circuits
8. Half bridge driver and LC Tank circuit
9. Jack power supply connections and input filtering
10. Sepic circuit
11. LDO



8.1 Power signals (SEPIC, GND, LC)

Figure 66. STEVAL-ISB047V1T power signal routing

1. Large tracks for high current circuits from power supply
2. Large GND tracks with many vias for high power circuits
3. Large tracks for high current circuits (booster, half bridge, LC tank, coil connection)

Figure 67. **Ground plan**

1. Full GND plan on Layer 2 (white area)
2. A few noisy signals routed partially on this layer (PWM, etc.)
3. Bridge and coil connection

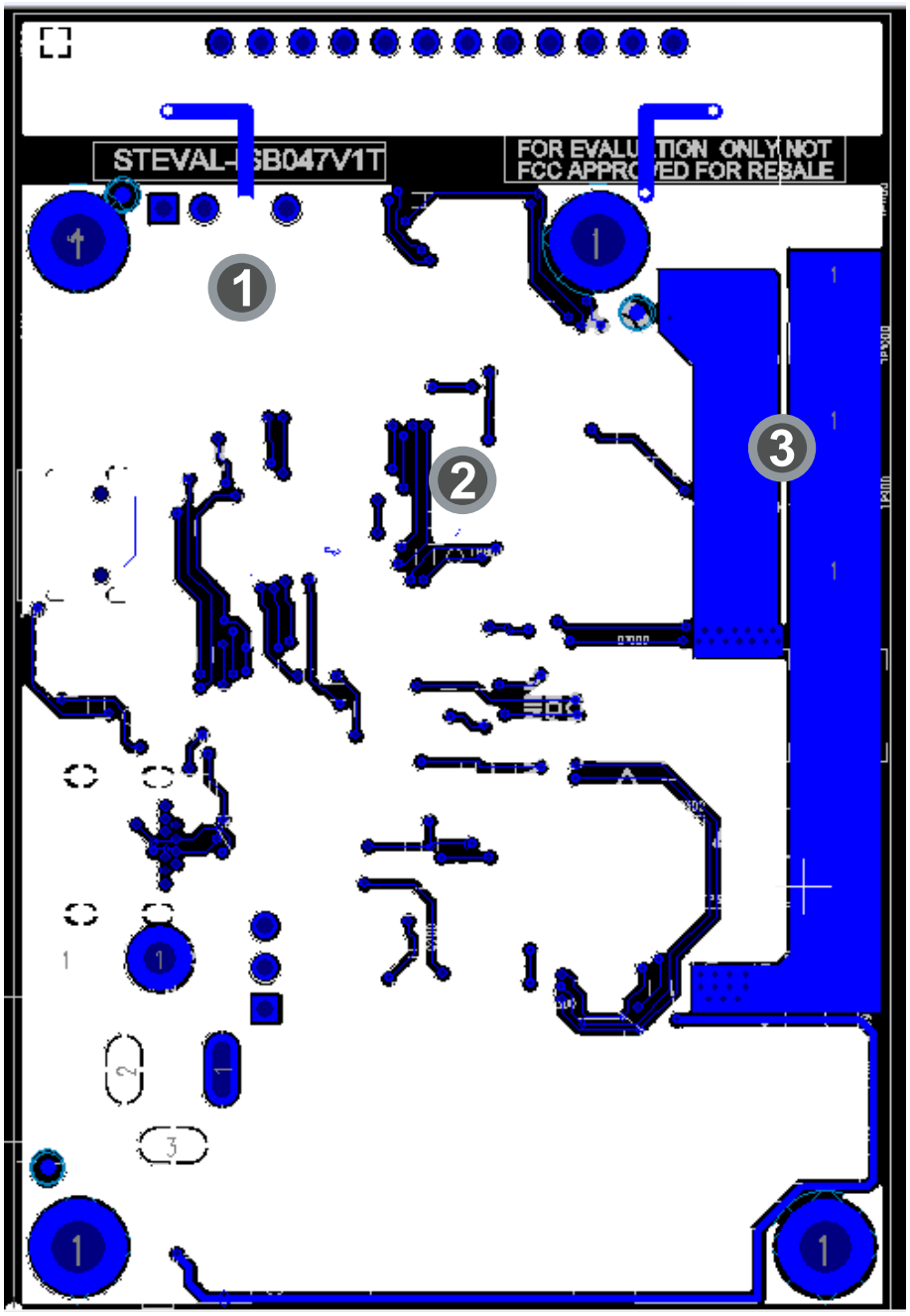


Figure 68. Supply and Vin routing details

1. V Jack
2. VIN: L100 directly to C200 C201 and L200
3. Vin USB PD
4. Supply from J100: connected with capacitors (C100 to C105) and L100
5. Vin connection to LDO input

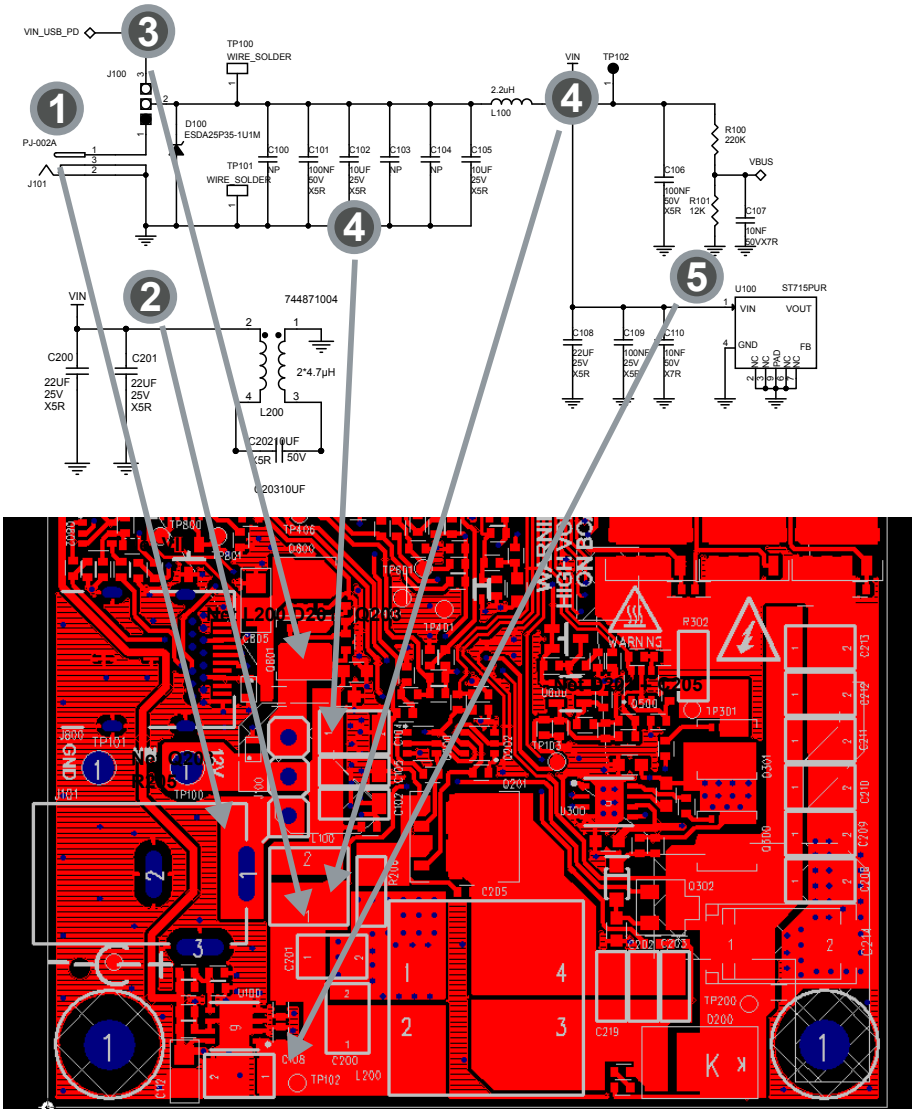


Figure 69. Details on Power GND routing

1. TP101: large GND
2. All caps connected to GND bottom side with many vias
3. GND of LDO with large trace (needed for thermal reasons)

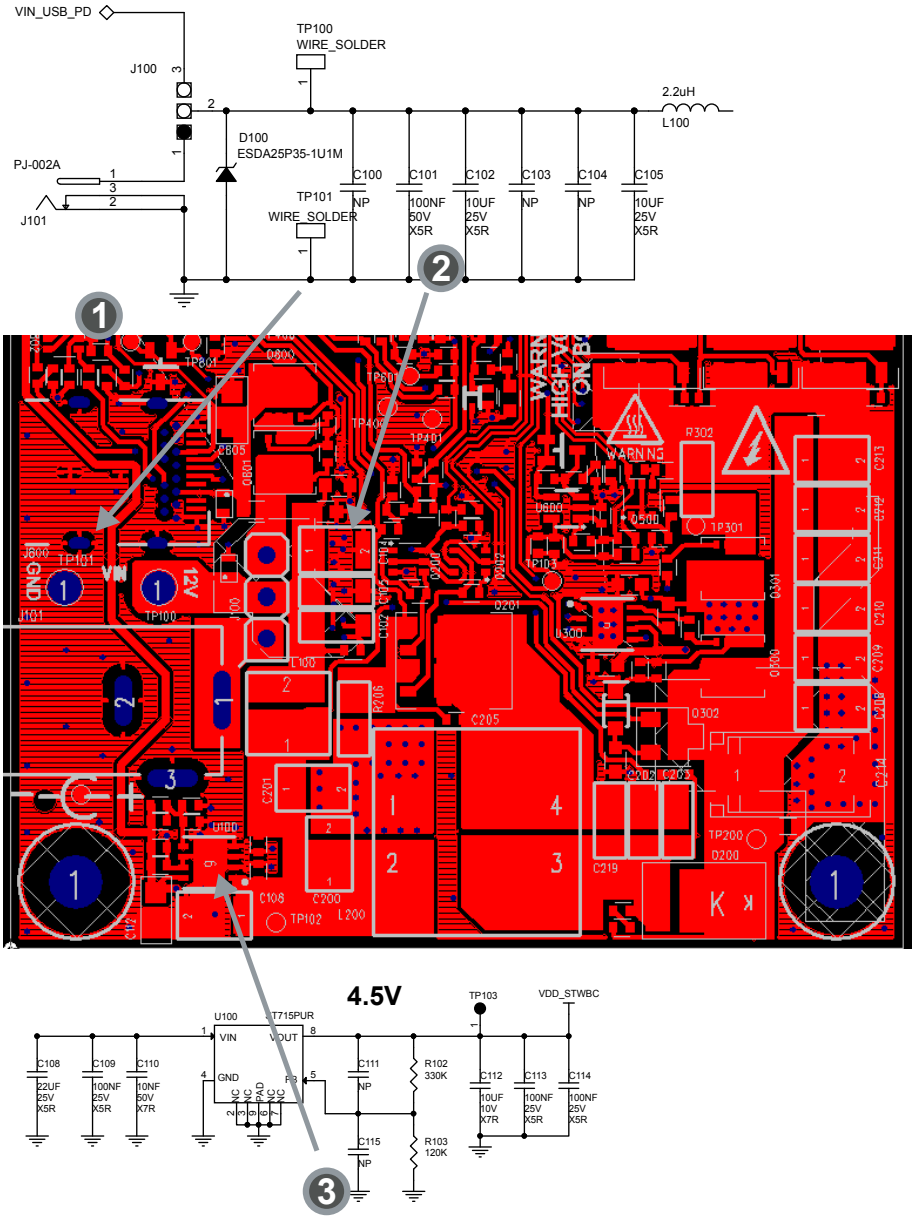


Figure 70. Details DCDC routing

1. Q201 - R206
2. L200 & C202 &C203 &C219 & Q201
3. Connect L200 – C202-C203-C219 & D200
4. DCDC: D200-C206 to C214 and Q300 –Q302

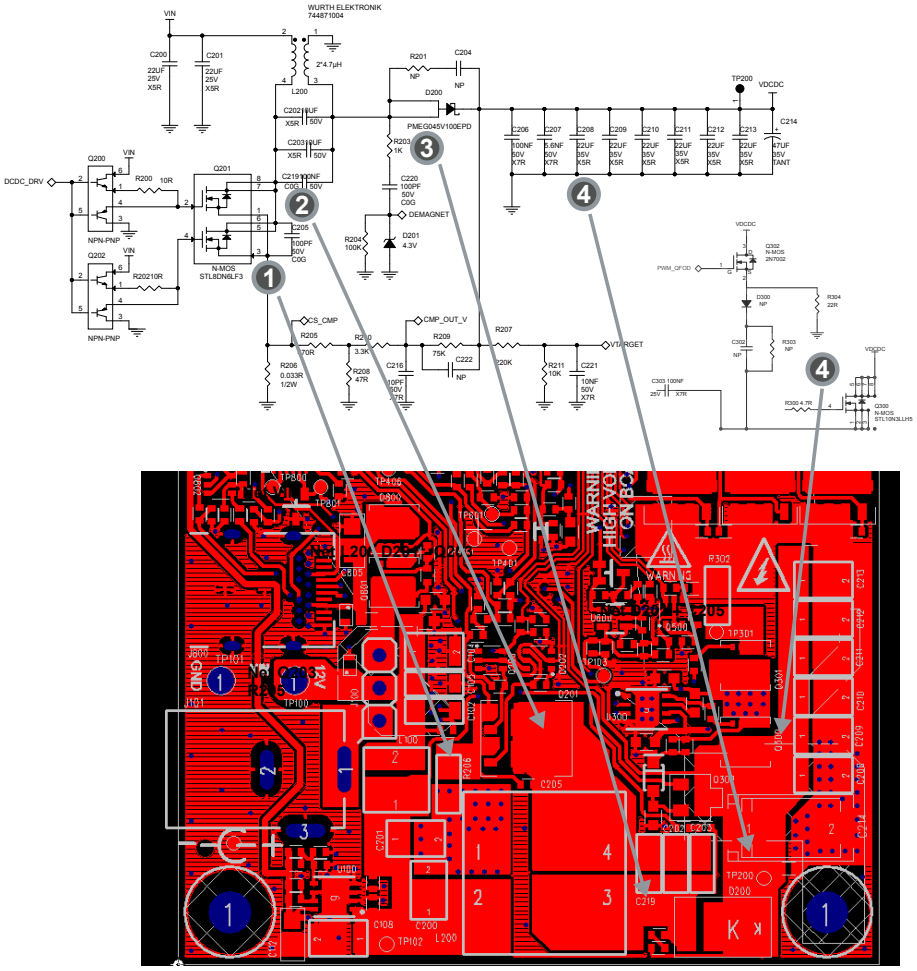


Figure 71. Details on SEPIC GND routing

1. High current of GND of C200-C201-L200 & R206. This area is connected to bottom with a lot of via in the same zone

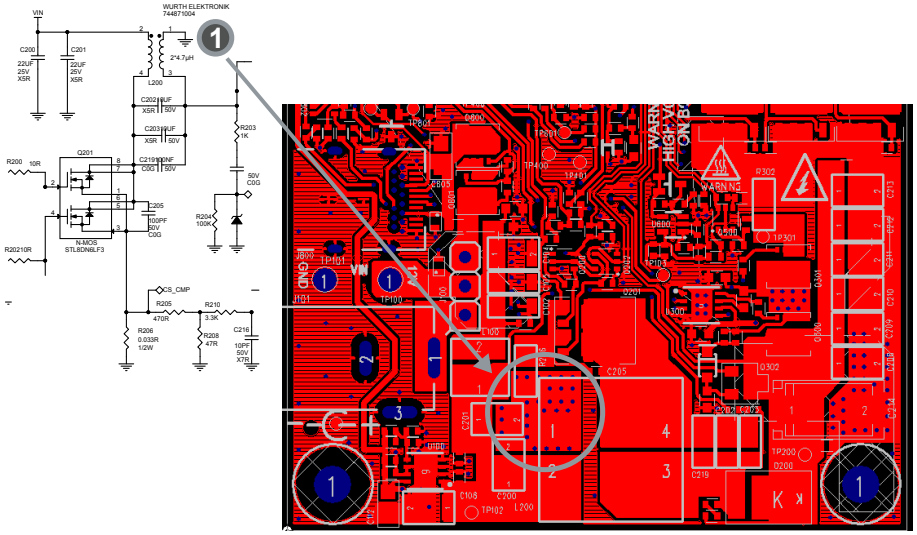


Figure 72. Power GND routing details

1. High current of GND from Coil : this GND Pow er must be connected between DCDC GND (C206 to C214) – R Sense (R303 & R508) and MOS (Q900-Q1000-Q1100)
2. Place many vias near C214 between GND power and GND bottom side

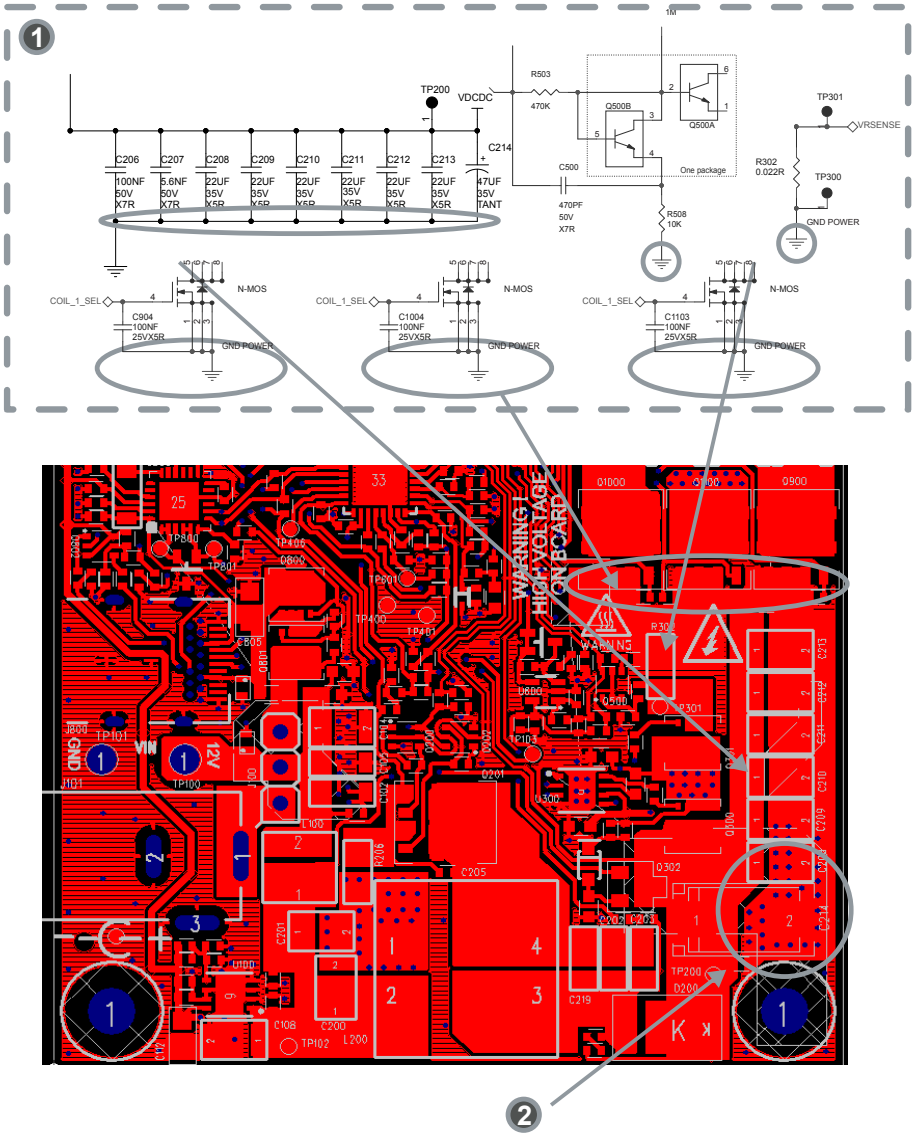
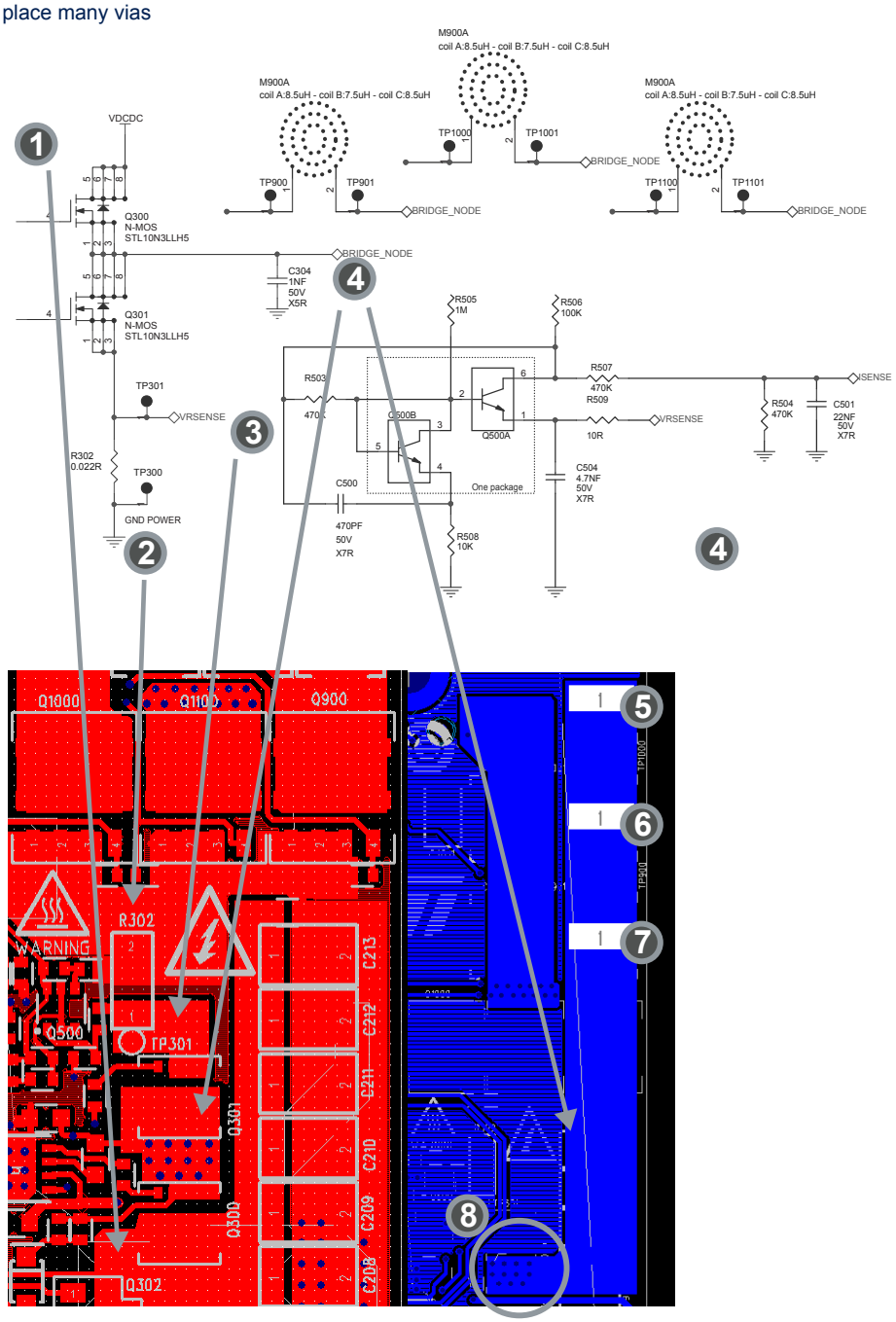


Figure 73. Bridge node routing details

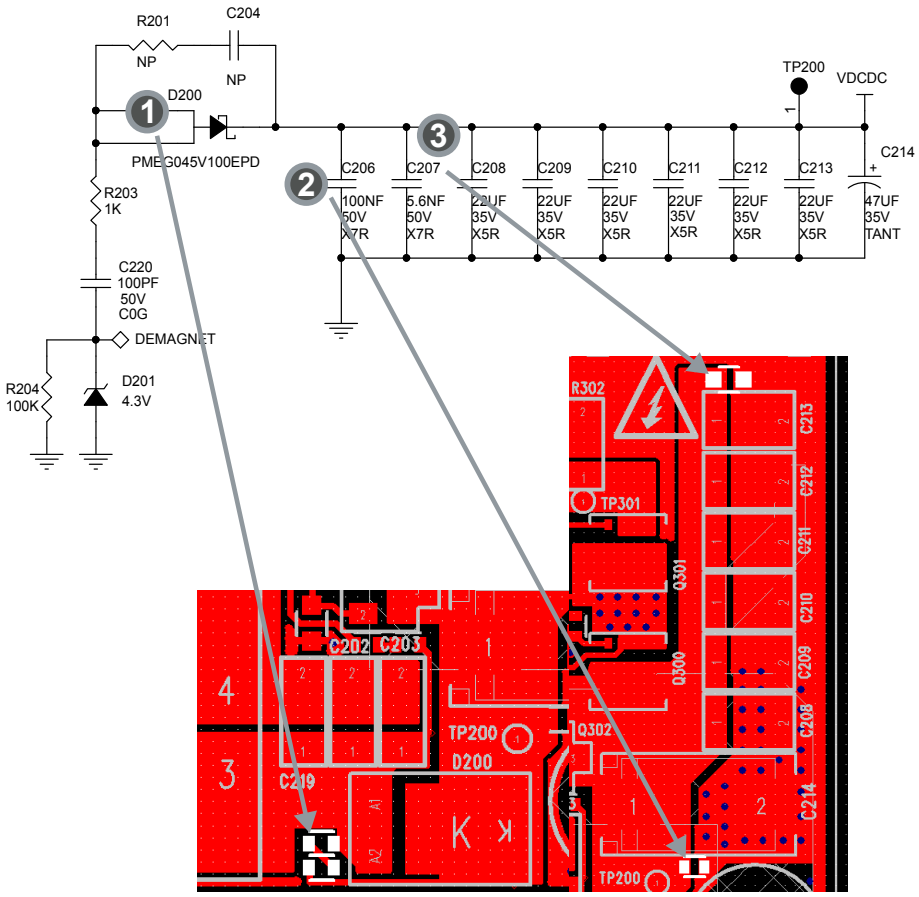
1. VDCDC Sheet 64
2. GND sheet 67
3. VR sense must be very short Q301 R302 & R509
4. Bridge node large nets
5. Connection COIL bridge node TP1100
6. Connection COIL bridge node TP1000
7. Connection COIL bridge node TP900
8. Bridge node place many vias



8.2 EMI Components

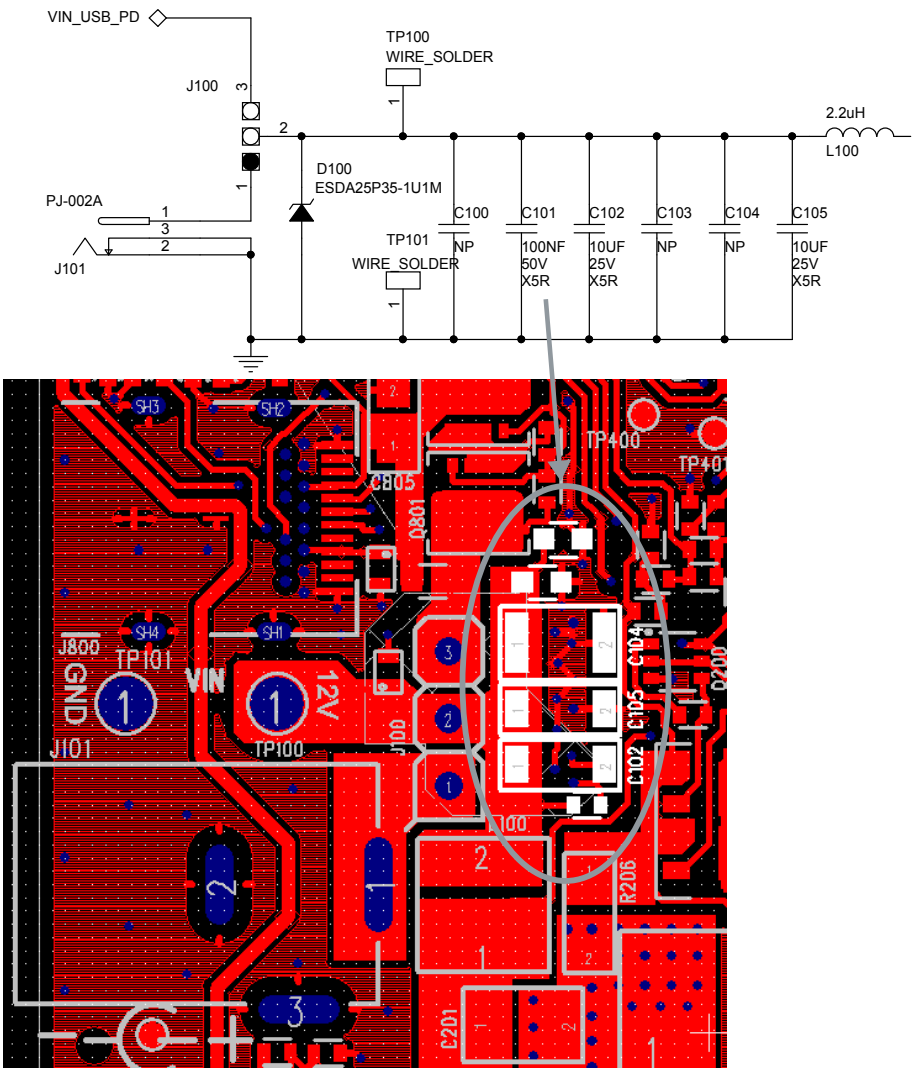
Figure 74. EMI components

1. R201 & C204: very close to D200
2. C206 near top of VDCDC
3. C207 near C214



Ceramic capacitors (C100, C101, C102, C103, C104, C105) for EMI and filters must be placed close to the supply input and L100. The GND of these components must not be connected to a noisy GND.

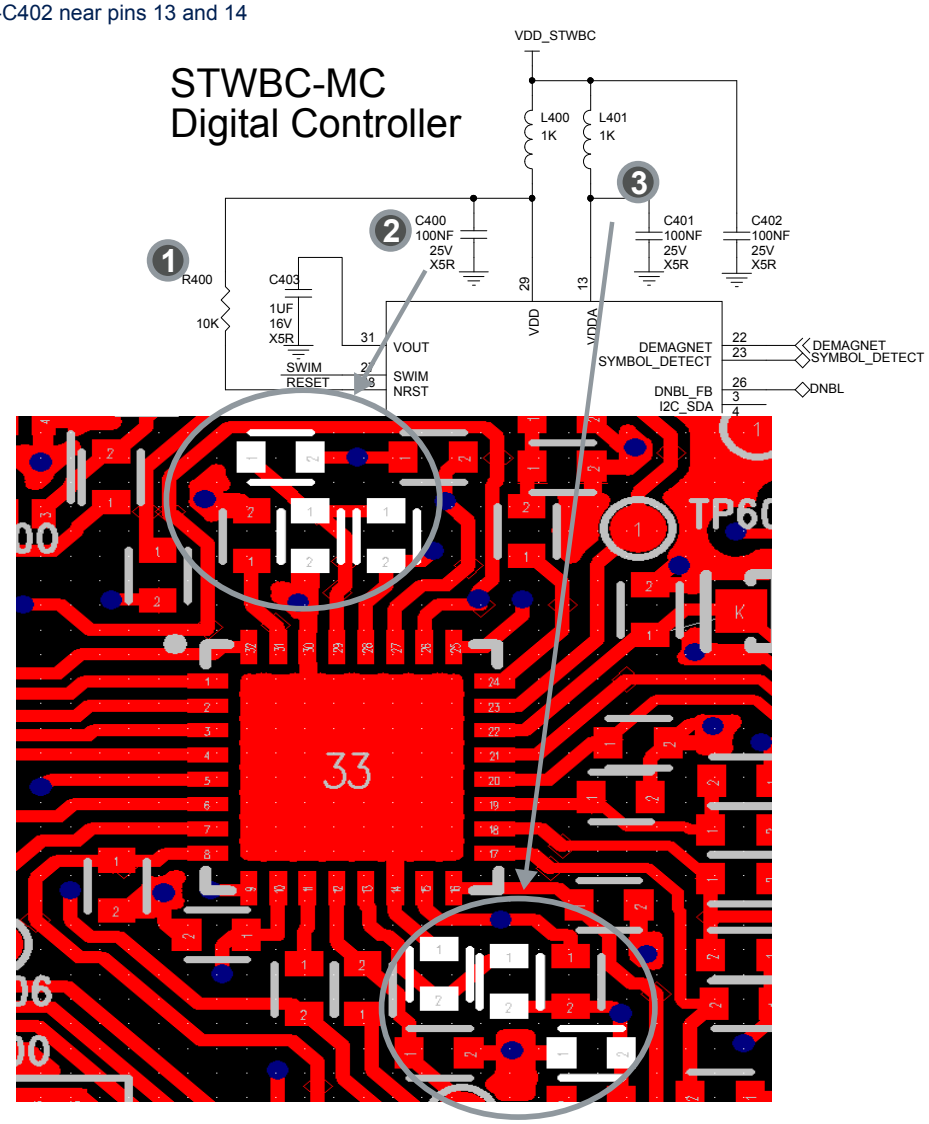
Figure 75. **EMI components – 2**



8.3 STWBC-MC digital controller

Figure 76. STWBC-MC digital controller

1. R400 near pin 28 and 29
2. C400 and L400 near pins 29 and 30
3. C401-L401-C402 near pins 13 and 14



8.4 Current sense and demodulation

Figure 77. Current sensing

1. C501 – R504 close to U400 net isense
2. R507 near U400 net idemod must be protected (no noisy GND or signal)
3. VRSENSE (Q301-R302 and R509) near current amplifier Q500 and R&C
4. Warning: R 508 GND connected to GND on Rsense R302: Do not mix this track with ground plane.
5. R508

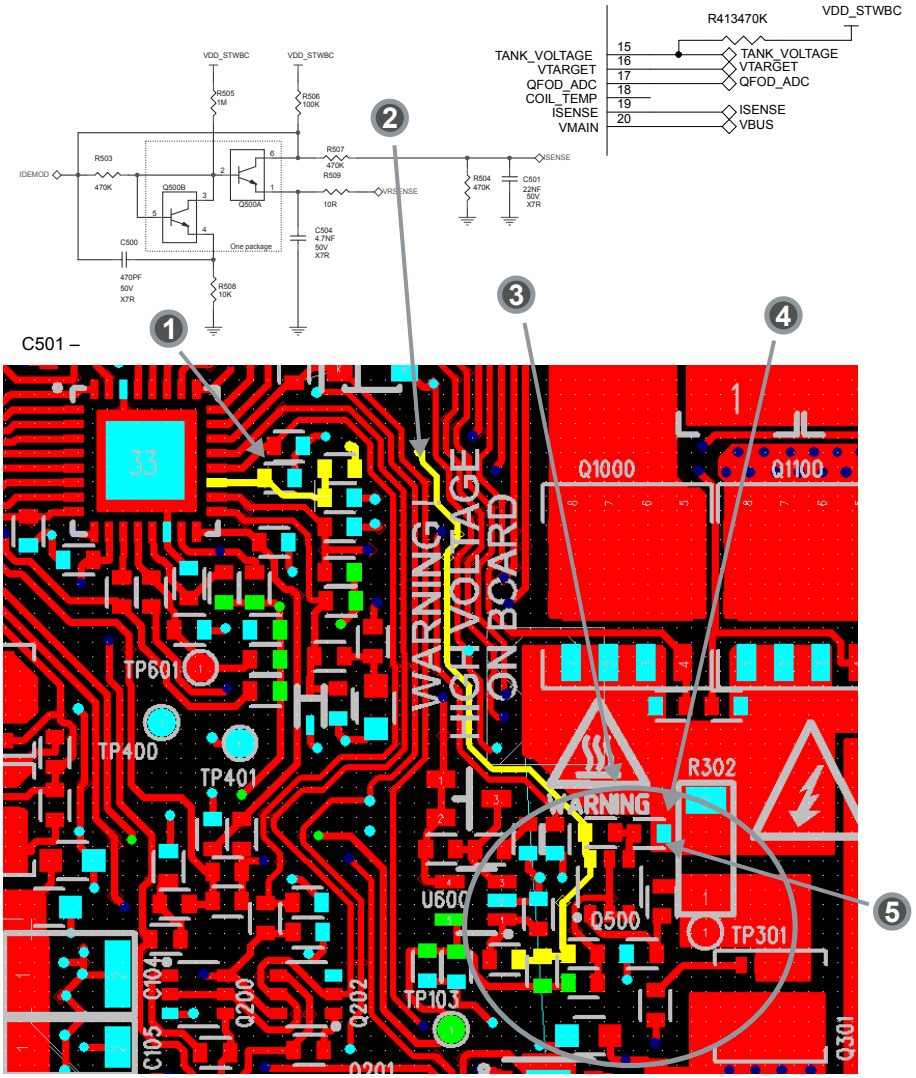


Figure 78. Current demodulation

1. Current demod (C509-R611-R612) closed to U400 pin 12
2. Current amplifier U600 near current sensing (Q500)

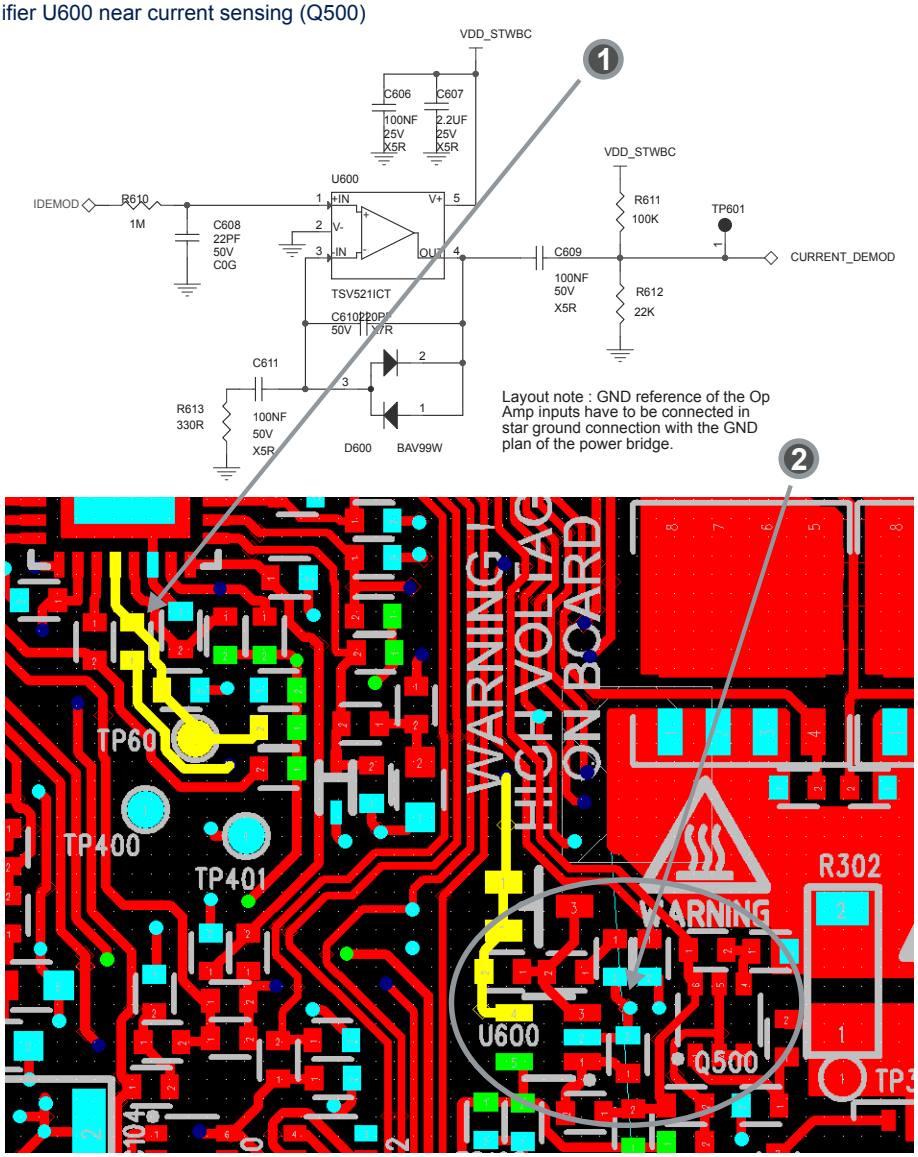
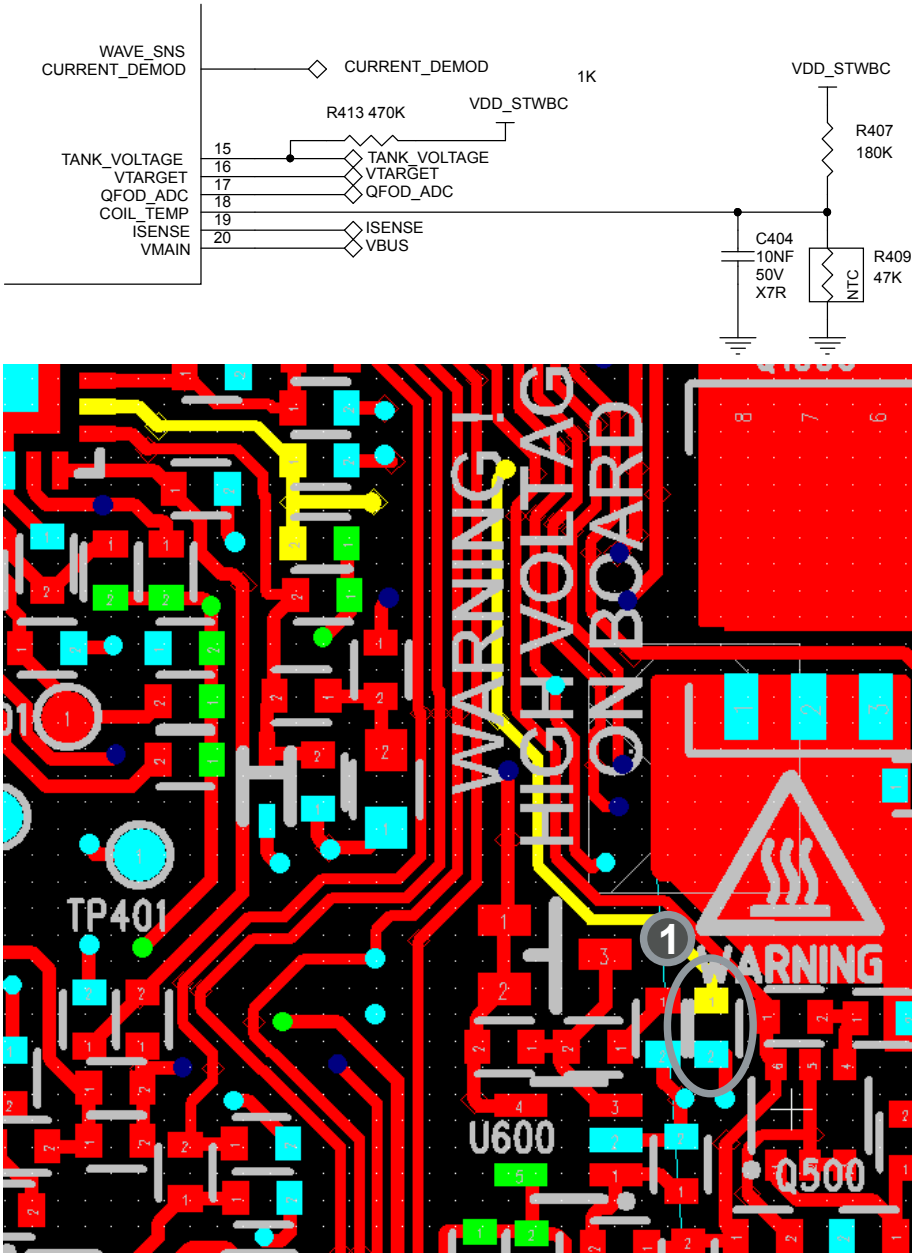


Figure 79. Thermistor

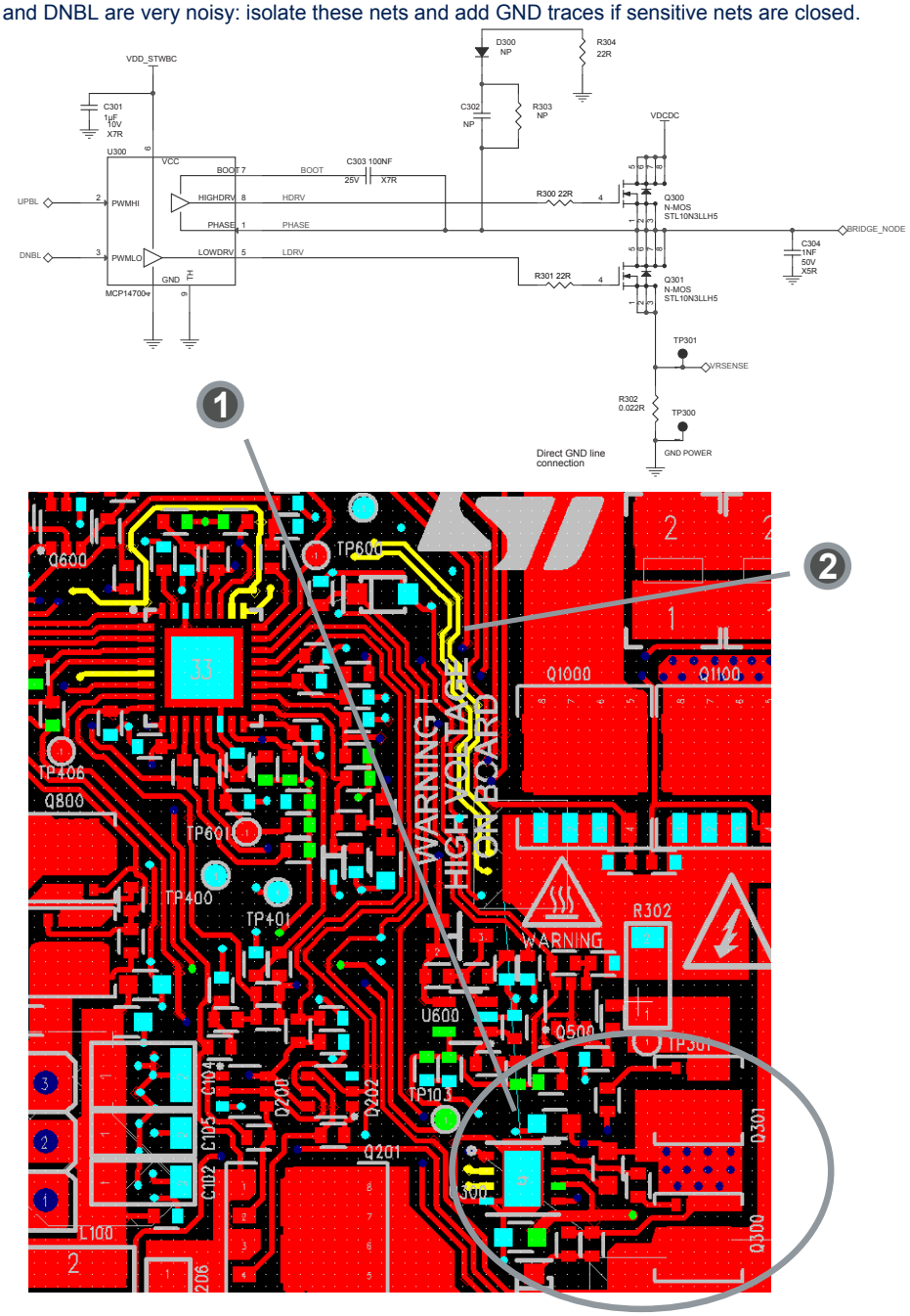
1. NTC R409 must be placed near current sensing (Q500)



8.5 Driver bridge

Figure 80. Bridge driver routing

1. Bridge driver U300 near MOS Q300 and Q301
2. Nets UPBL and DNBL are very noisy: isolate these nets and add GND traces if sensitive nets are closed.



9 Mechanical assembly

9.1 Coil connection

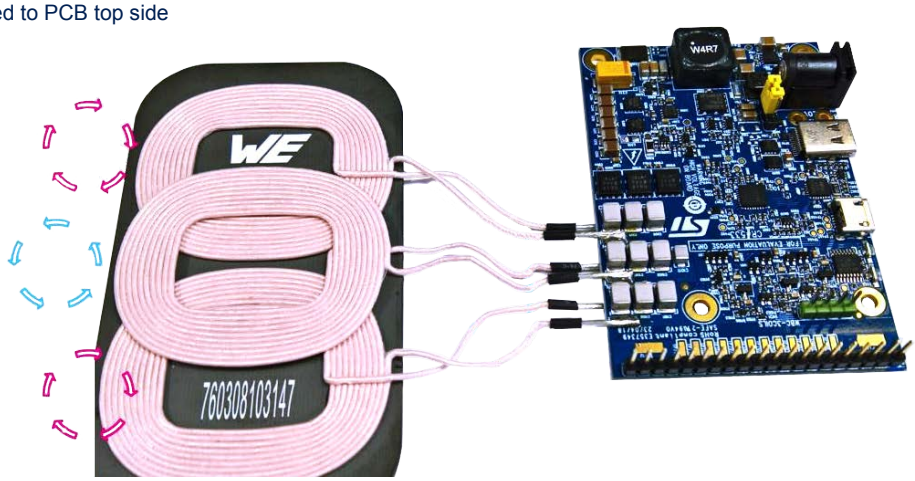
Step 1. Connect each coil according to the following scheme:

– Coil top and bottom: same direction (CW)

– Coil center: opposite direction (CCW)

Figure 81. Coil connection

Wires connected to PCB top side



9.2 PCB mechanical assembly

Use this procedure to insert the plastic pieces between the bottom side nad the PCB.

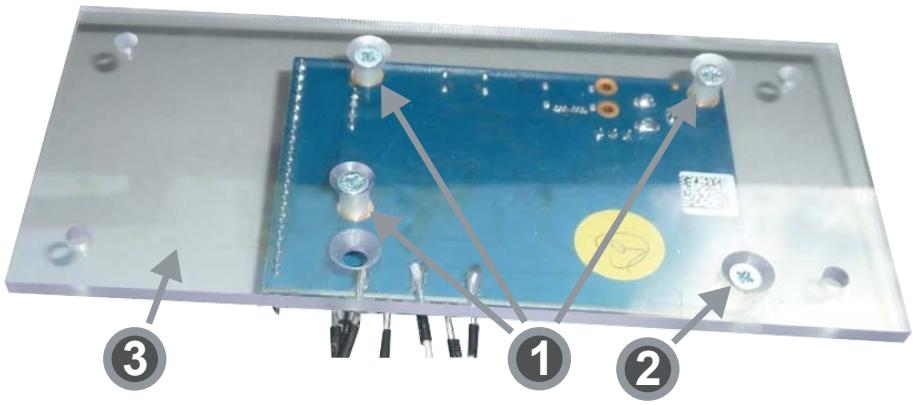
Step 1. Insert x4 plastic 5 mm columns between the PCB and plexiglass.

Step 2. Insert x4 M3x16 screws in the countersunk holes.

Step 3. Insert x4 nut M3 on PCB side (on other side).

Figure 82. PCB assembly

1. Plastic column 5mm
2. Screw M3x16
3. Plexiglass 3mm



9.3 Coil mechanical assembly

Step 1. Place two 8 cm strips of adhesive tape on the bottom side of the coil plate.

Figure 83. **Coil assembly - adhesive tape**

Double coat acrylic foam adhesive tape
12 mm wide x 0.6 mm thickness

Step 2. Center the coil plate on the plexiglass and press to ensure contact with the adhesive tape.

Note: Once the coil is attached, it is difficult to remove.

Figure 84. **Coil assembly - on plexiglass**

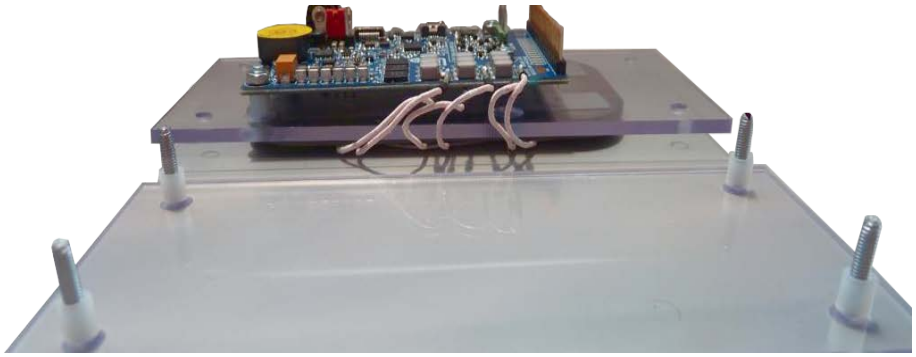
9.4 Top side assembly

Perform the following actions on the top plexiglass plate that covers the coils.

Step 1. Insert 4 M3x16 screws with countersunk head.

Step 2. Insert 5 mm plastic spacers over the screws.

Figure 85. **Top plate assembly**



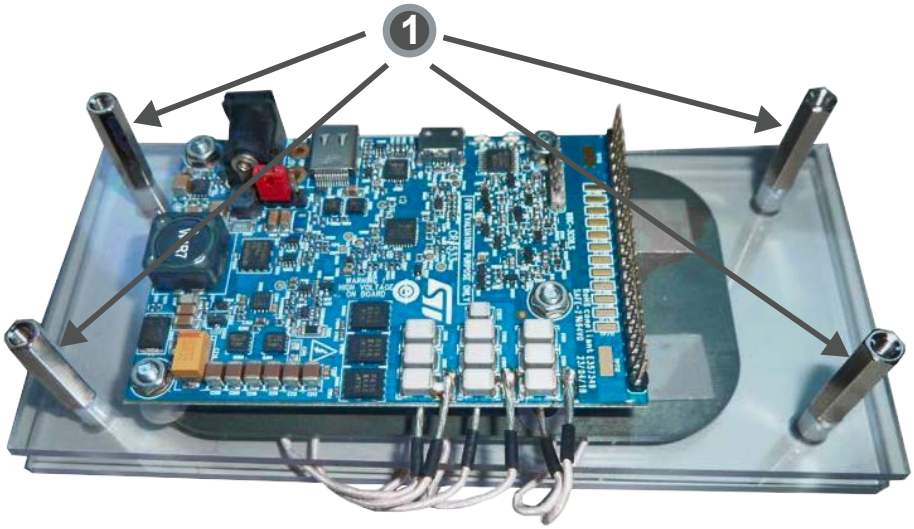
9.5 Final mechanical assembly

Step 1. Fit the plexiglass plate with the transmitter board onto the cover plate with the scews and spacers.

Step 2. fasten the 4x 20 mm standoffs onto the screws.

Figure 86. **Final assembly**

1. 20 mm M3xM3 female/female standoffs



10 References

Datasheet DS12373: Digital controller for wireless battery chargers transmitters for Qi multicoil applications.

Data brief DB3701: Qi 3-coil 15W wireless charger TX evaluation kit based on STWBC-MC.

Data brief DB3702: Firmware for the STEVAL-ISB047V1 Qi 3-coil - FF wireless power transmitter evaluation kit based on STWBC-MC.

Data brief DB3418: Graphical user interface for wireless power transmitter evaluation boards based on the STWBC chip family.

Data brief DB3410: STWBC firmware downloader tool.

Revision history

Table 7. **Document revision history**

Date	Version	Changes
13-Nov-2018	1	Initial release.
02-Jan-2019	2	Updated Section 6.1 Schematic diagrams.
06-Feb-2019	3	Updated Introduction, Section 2.1 STEVAL-ISB047V1T wireless transmitter board, Section 2.2 STWBC-MC pinout and pin description for 3-coil MP-A15 configuration, Section 7.1.1 STEVAL-ISB047V1T bill of materials, Section 6.1 Schematic diagrams and Figure 80. Bridge driver routing. Minor text changes.

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