# UM2289

User manual

# Getting started with the dual mode wireless power evaluation board for Qi and Air-fuel inductive receiver and Qi-based transmitter with STWLC33

## Introduction

The STEVAL-ISB042V1 is a 15-watt Qi and 5-watt Airfuel inductive (former PMA) wireless power receiver evaluation board based on the STWLC33 wireless power receiver solution for the WPC/Airfuel mobile device with dual mode coil.

The board lets you evaluate the STWLC33 capabilities as a Qi/Airfuel inductive receiver as well as its ability to power another Qi receiver.

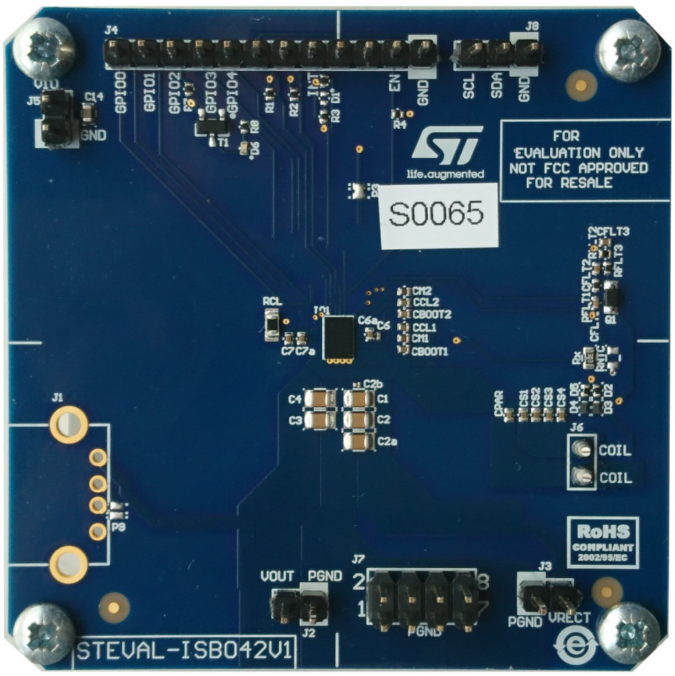
The solution is certified in accordance with the extended power profile Qi v1.2 and Airfuel SR1 standard.

The STWLC33 IC is powered by a dual mode Rx coil attached to a 1.5 mm thick plastic fixture.

The STWLC firmware offers users the flexibility to modify parameters and settings to ensure proper integration of the STWLC33 device with the final application.

The layout is based on a cost-effective 4-layer PCB.

**Figure 1. STEVAL-ISB042V1 evaluation board**



# 1 Getting started

## 1.1 Board configuration and test points

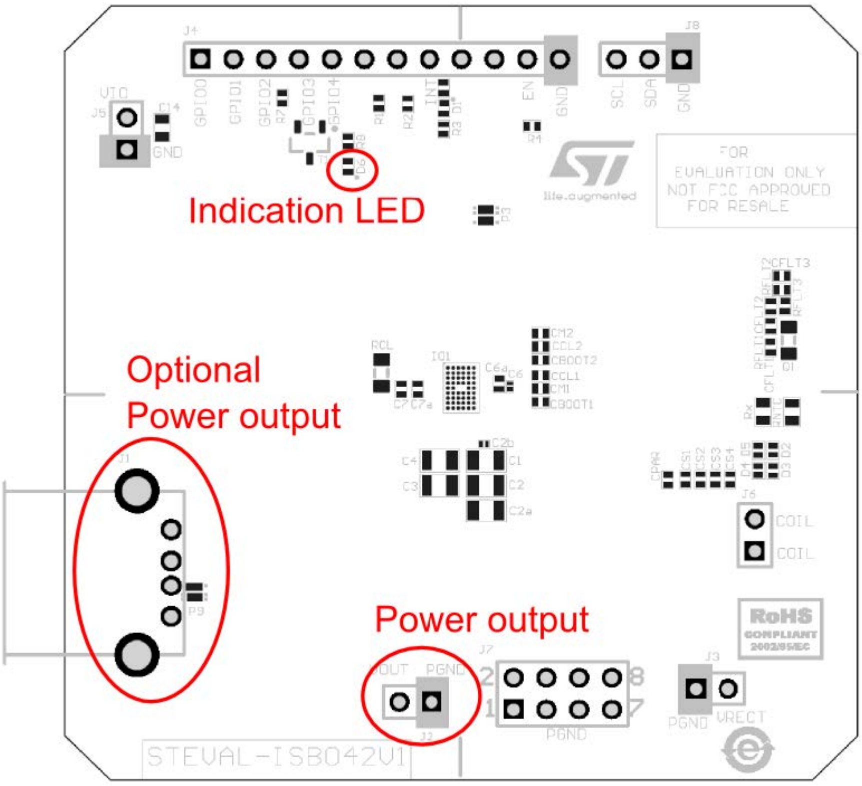
- P3 solder bridge:
  – open = I²C bus and INT pin pull-up voltage provided externally via J5 header
  – shorted = I²C bus and INT pin pull-up voltage provided by STWLC33 (do not connect any load/source to J5 header)
- P9 solder bridge:
  – open = USB port acts as unknown (D+/D- floating)
  – shorted = USB port acts as a dedicated charging port (shorted D+/D-)
- J3 testpoint header:
  – VRECT rectified voltage
- J4 testpoint header:
  – selectable user functions (GPIO0, GPIO1, GPIO2, GPIO4)
  – GPIO3 – do not connect any load during startup
  – INT – open drain interrupt output (active low)
  – EN – enable input (active low), pull on-board R4 down

## 1.2 Receiver mode

The easiest way to test the STEVAL-ISB042V1 evaluation board in receiver mode is to connect the load to J2 header or, optionally, to J1 USB connector and place it on the transmitter surface.

J1 and J2 connectors are essentially different connectors for the same output node.

Figure 2. **STEVAL-ISB042V1 evaluation board: receiver mode**



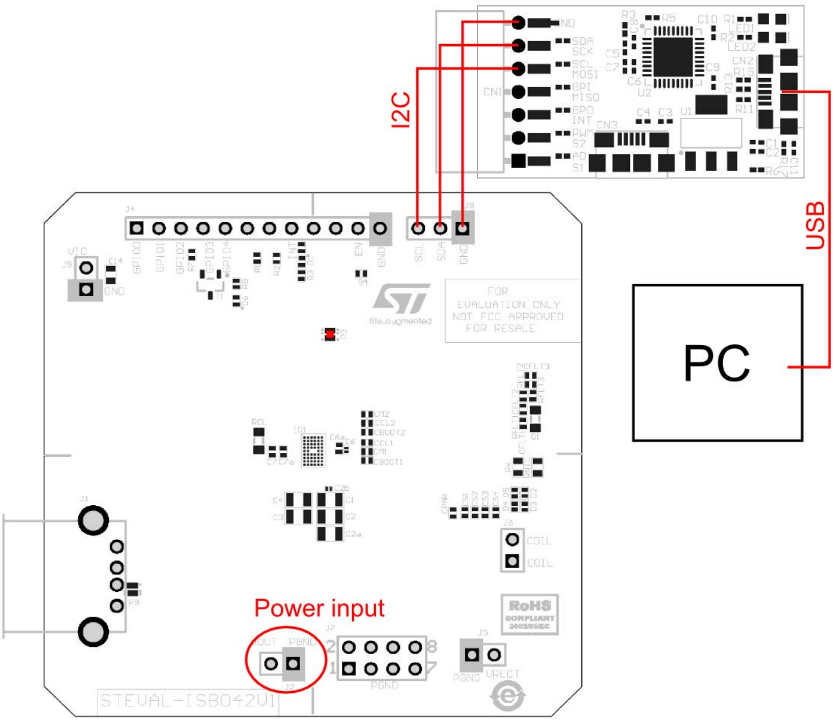

D6 indication LED lights up when the receiver enters the **Power Transfer** phase.

## 1.3 Transmitter mode

To test the board in Tx mode, you must provide a 5 V power supply to the J2 header (ensure STWLC33 is not operating in Rx mode power transfer) and switch STWLC33 to Tx mode over I²C interface (J8 header).

**Procedure** **Step 1.** Connect the bundled USB to the I²C bridge.

**Figure 3. STEVAL-ISB042V1 evaluation board: transmitter mode**




**Step 2.** Use the PC GUI application.

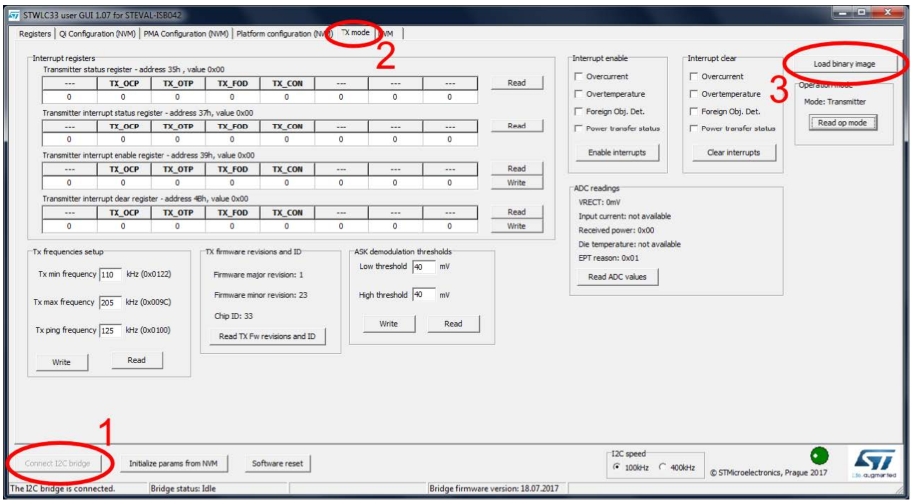
**Step 3.** Connect the I²C bridge.

**Step 4.** Switch to **TX mode** tab.

**Step 5.** Click **Load binary image** button.

**Step 6.** Select the GUI **STWLC33_TxMode_RAM_binary.bin** file.

**Figure 4. STEVAL-ISB042V1 GUI Tx mode tab**

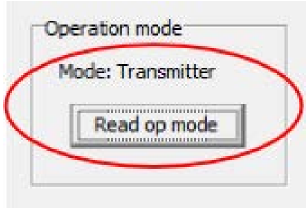



**Step 7.** Verify the result by checking the operation mode.

If the label indicates **Transmitter mode**, the kit is ready and a receiver can be placed on the coil surface.

*Note: The coil used in the kit is a Qi/PMA receiver coil. Using this coil for transmitter mode leads to many compromises and not all Qi certified receivers will work with this kit. For the Tx mode evaluation we recommend to use the STEVAL-ISB043V1 wearable receiver kit as a receiver.*

Figure 5. **STEVAL-ISB042V1 GUI operation mode**




## 1.4 STWLC33 NVM configuration

The STWLC33 NVM configuration is the same default configuration as in STWLC33 samples (see STWLC33 datasheet).

### 1.4.1 Board overview

The STEVAL-ISB042V1 evaluation board default configuration has good performance.

The board features:
- STWLC33 evaluation board with Würth Elektronik dual mode coil (760308102207)
- Qi 1.2 compliant, supporting extended power profile: up to 15 W/10 V maximum output power
- Backward compatible with Qi baseline power profile: up to 5 W/5 V maximum output power
- PMA-SR1 (AirFuel inductive) compliant: 5 W/5.6 V maximum output power
- Transmitter function based on Qi protocol to charge wearable devices using the same Rx coil (up to 3 W power)
- Total system efficiency up to 80%
- Configurable GPIOs for status indication
- I²C interface for communication with the host system
- Foreign object detection (FOD)
- Complete kit (IC, firmware)
- RoHS compliant

## 1.5 GUI: I²C register access

Most fields in the GUI application correspond to a single I²C register.(For further details, see STWLC33 datasheet on www.st.com.)

Many registers are accessible in receiver or transmitter mode only.

Before accessing the registers, you must check the actual operation mode in the **Sys_Op_Mode** register.

### 1.5.1 Rx mode registers

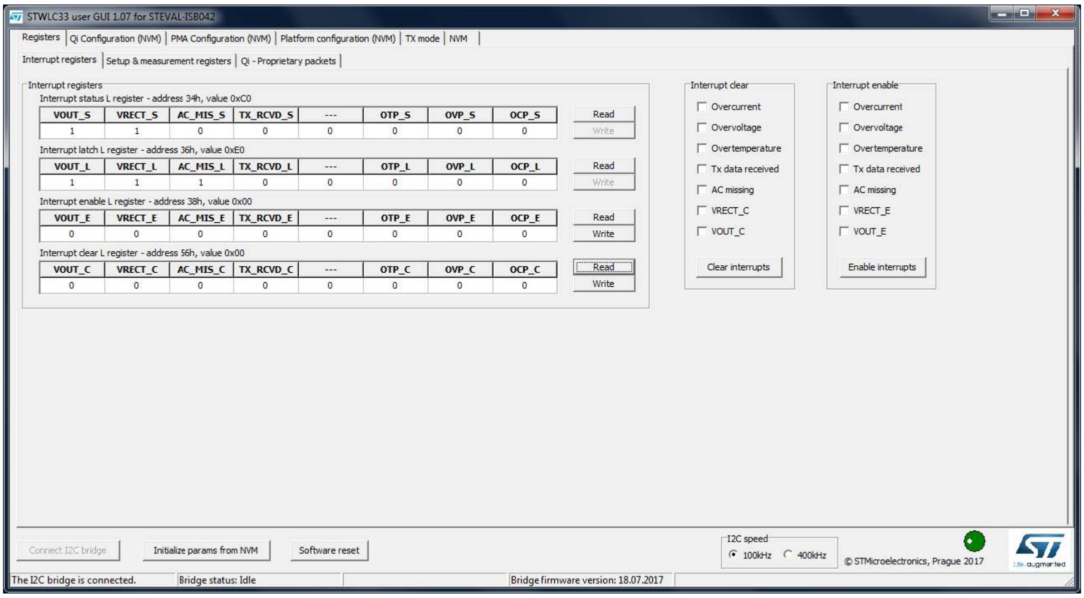
The **Registers** tab contains three sub-tabs related to Rx mode I²C register controls.

Through the **Interrupt registers** sub-tab, you can monitor the following registers:
- Status_Rx
- INT_Rx
- INT_Enable_Rx
- INT_Clear_Rx

The GUI directly reads or writes the target register.

The **Interrupt clear** button first writes the **INT_Clear_Rx** register and then writes 1 in the **Clr_Int bit in Com** register.

Figure 6. **GUI Rx mode: Interrupt registers sub-tab**




The **Setup and measurement registers** sub-tab controls registers and measurement values.

**VOUT_set** or **ILIM_set** modifications are immediate.

The default values are loaded automatically from NVM after wireless operating standard detection.

*Important:* *Refer to 2 Configuration guidelines before changing the values.*

The **Power transfer** termination consists of two steps:

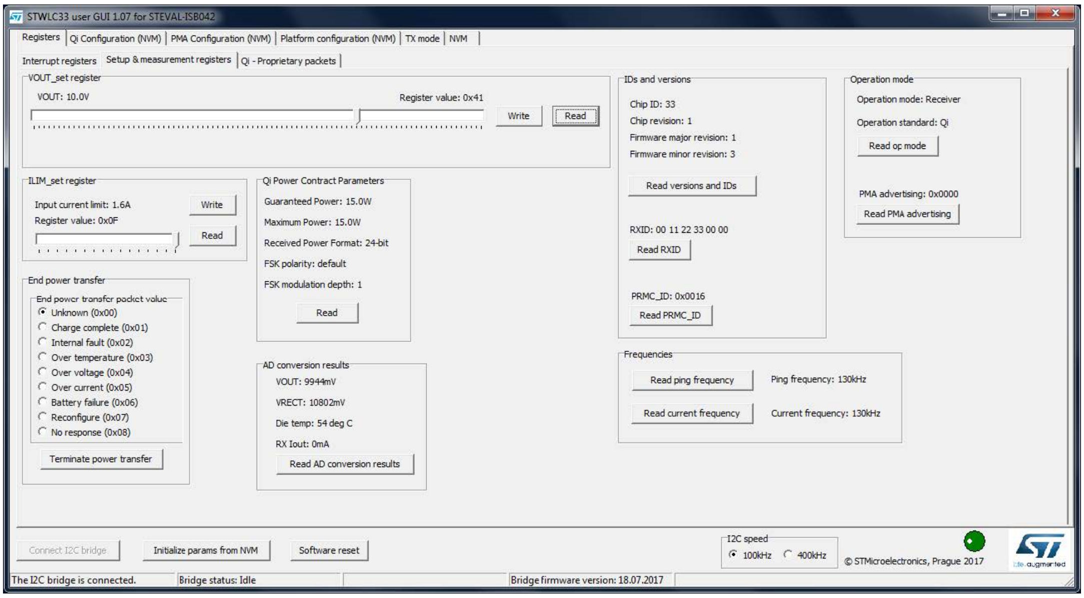
- writing the **EPT** register;
- writing 1 in the **S_EPT bit in Com** register.

**AD conversion** results provide immediate VRECT and VOUT voltages as well as die temperature and output current during power transfer.

**RXID** and **PRMC_ID** registers become active after wireless standard detection and provide an easy-to-read self-ID (either Qi ID or PMA ID).

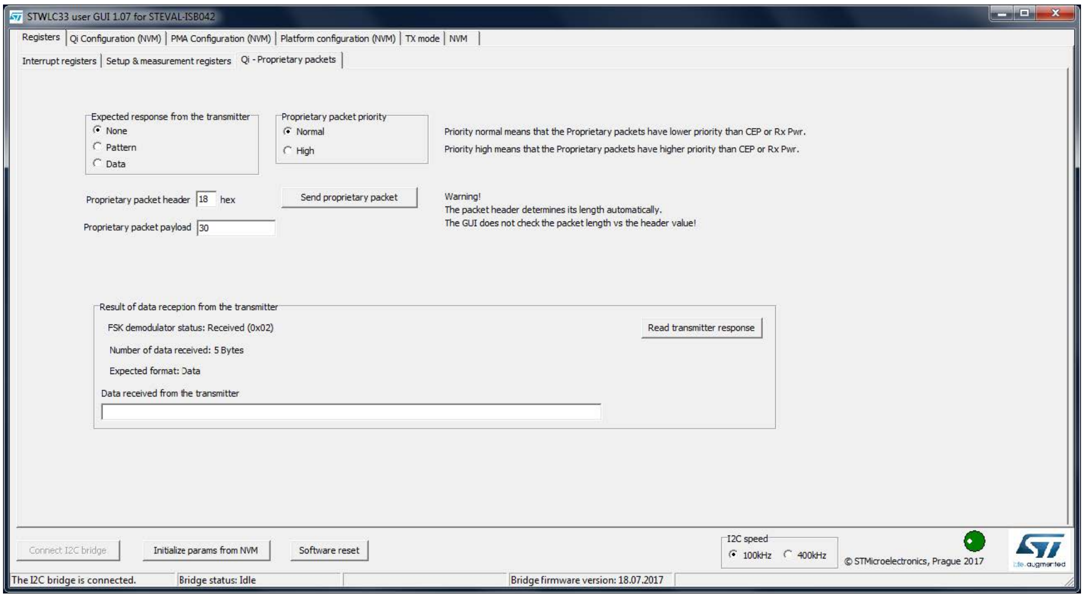
If the STWLC33 receiver is placed on a PMA pad that supports advertising, the advertising ID is captured and can be read through PMA ADV registers.

**Figure 7. GUI Rx mode: Setup and measurement registers sub-tab**




The **Qi – Proprietary packets** sub-tab allows sending any Qi packet and (in Qi 1.2 only) receive the response from the transmitter (both pattern type or data type responses are supported).

**Figure 8. GUI Rx mode: Qi – Proprietary packets sub-tab**




### 1.5.2 Tx mode registers

After entering the mode as described in 1.3 Transmitter mode, the **TX mode** tab lets you monitor the following registers:

- Status_Tx
- INT_Tx
- INT_Enable_Tx
- INT_Clear_Tx

The GUI directly reads or writes the target register.

The **Interrupt clear** button first writes the **INT_Clear_Tx** register and then writes 1 in the **Clr_Int bit in Com** register.

Tx frequency setup allows modifying the regulation control algorithm minimum and maximum frequency and the starting ping frequency.

*Note: The optimal ping frequency for the STEVAL-ISB042V1 evaluation board is approximately 130 kHz.*

**ASK demodulation thresholds** parameter defines the ASK receiver sensitivity.

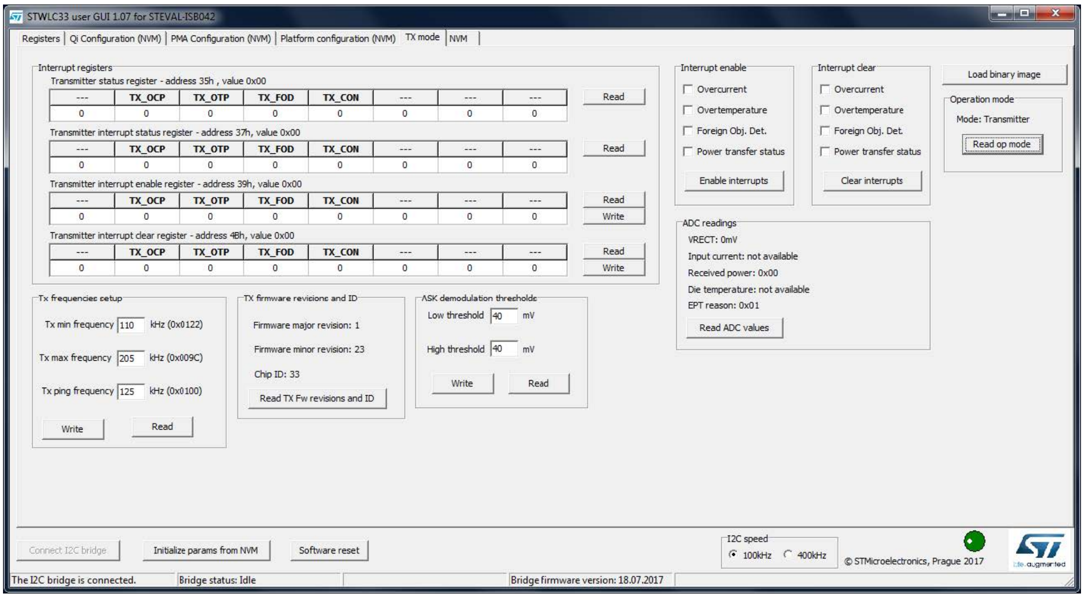



**Figure 9. GUI Rx mode: TX mode tab**

## 1.6 GUI: NVM configuration access

### 1.6.1 Qi NVM configuration

The **Qi configuration** tab contains manufacturer and device identifiers sent over the Qi protocol.

The tab contains also default values for the **VOUT voltage**, **Input current limit** and **Interrupt enable** registers which can be configured separately for baseline power profile (BPP) operation and for extended power profile (EPP). BPP values are loaded in the registers and subsequently updated if EPP is negotiated.

STWLC33 automatically terminates the power transfer if the load is below a certain threshold for a certain period of time. By default, this feature is eliminated by setting the lowest possible current and the longest possible time.

*Note: Qi specification does not require this feature.*

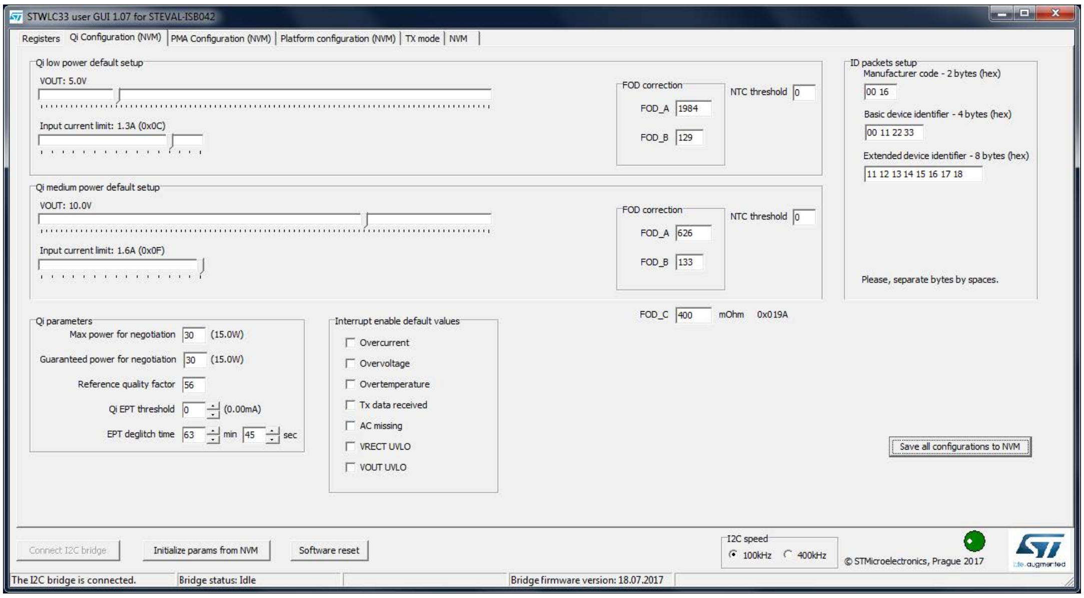
To maintain the Qi foreign object detection feature accurate, you must provide the correct values representing the coil parameters and the mechanical setup.

The evaluation kit contains components with the correct values to be used.

But, if, for example, the coil is replaced by another type of coil, you must update the following parameters:

- **FOD_A**
- **FOD_B** (different values for BPP and EPP)
- **FOD_C** (same value for BPP and EPP)
- **Reference quality factor** (for EPP only)

**Figure 10. GUI: Qi configuration tab**




## 1.6.2 PMA NVM configuration

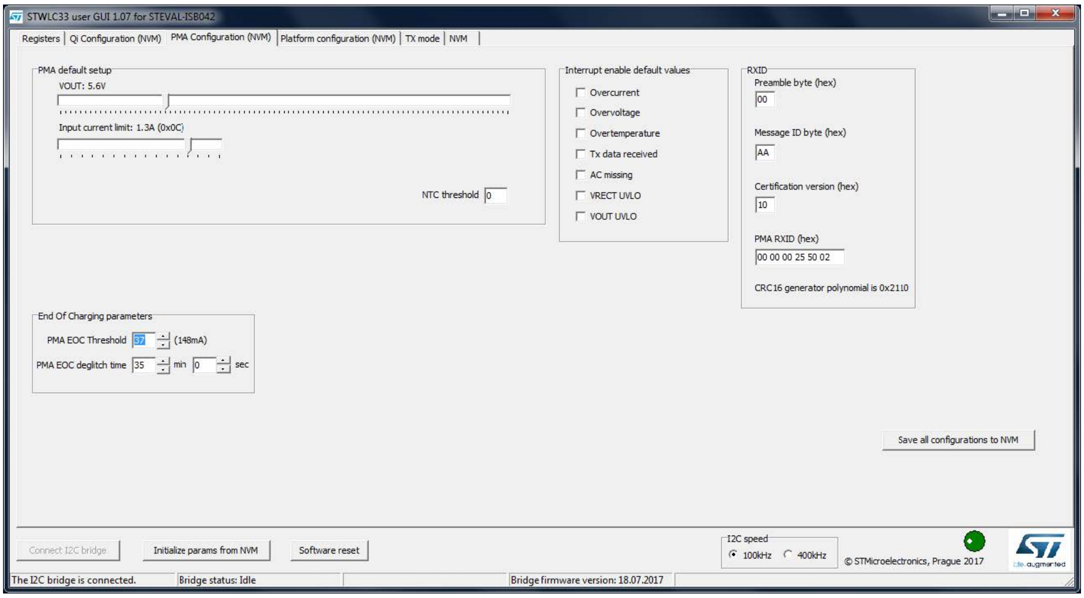
The **PMA configuration** tab contains the RXID identifier sent over the PMA protocol.

The tab contains also default values for the **VOUT voltage**, **Input current limit** and **Interrupt enable** registers.

The PMA specification requires that the receiver automatically terminates the power transfer if the load is below a certain threshold for a certain period of time.

If the power transfer termination is controlled by the host system, the STWLC33 feature can be eliminated (by setting zero current and maximum possible time).

**Figure 11. GUI: PMA configuration tab**



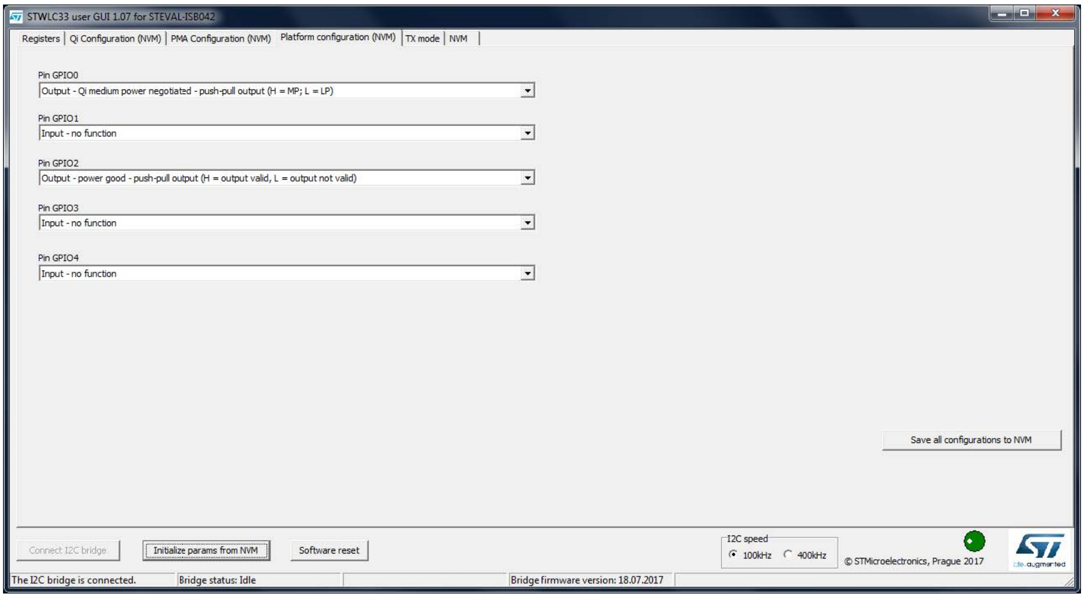

## 1.6.3 Platform NVM configuration

This tab allows assigning GPIO functions related to Rx mode only.

In Tx mode, all the pins are inputs with no function.

In the STEVAL-ISB042V1 evaluation board, the LED diode (D6) is controlled by GPIO2 pin.

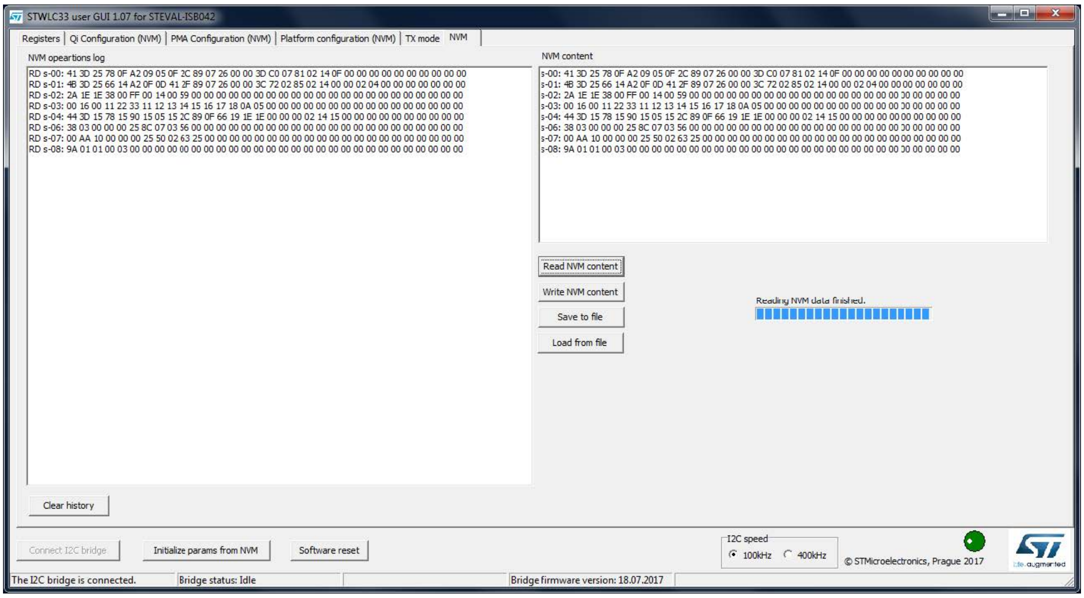
**Figure 12. GUI: platform configuration tab**




## 1.6.4 Generic load/save NVM access

The **NVM** tab allows the backup of the current NVM configuration into a file or loading a new one from a file.

**Figure 13. GUI: NVM tab**



# 2 Configuration guidelines

## 2.1 Changing VOUT voltage: constraints

The power LDO supports setting VOUT from 3.5 to 12.5 V; but, selecting an appropriate VOUT value is more complex and involves other aspects in the system, like:

1. **OVP and margin for modulation** (especially when using VOUT higher than 9 V): the first line OVP protection is the pre-clamp with fixed trigger at 13.5 V on VRECT node. During modulation (packet data sent from Rx to Tx), the voltage on VRECT rises on the basis of conditions like Tx/Rx coil parameters, loading current, VOUT voltage and so on. The VOUT setting must be always low enough to maintain VRECT during modulation under the pre-clamp level. The safe VOUT voltage for the STEVAL-ISB042V1 evaluation board is 10 V. The user should not set a higher value unless previously verified (via an oscilloscope) that the VRECT modulation has enough margin with respect to the pre-clamp threshold.
2. **Tx coil voltage and Tx/Rx coil ratio**: the whole system can be compared to a transformer where the coil ratio defines the transformation ratio. The transmitter circuits and the Tx coil are designed to operate within the expected optimal range in which the Rx coil and VOUT voltage should fit. If the configured VOUT voltage is too high or too low, it shifts the whole system out of the optimal range. The right VOUT voltage for the STEVAL-ISB042V1 evaluation board is roughly 4 to 5.5 V with 5 W transmitters and 8 to 10 V with 15 W transmitters. Using a different output voltage may require a different Rx coil and input resonant circuit capacitors.

## 2.2 Input current limit

The power LDO is able to limit the output current. This limitation starts softly reducing the VOUT voltage even before reaching the limit.

## 2.3 Minimal load

All wireless systems are designed to transfer power. If power is not being transferred, it becomes hard to maintain Rx-to-Tx communication.

STWLC33 is equipped with a dummyload circuit that increases the load by consuming the power when no output load is present. Due to heat dissipation the dummy consumption is limited to tens of milliamps.

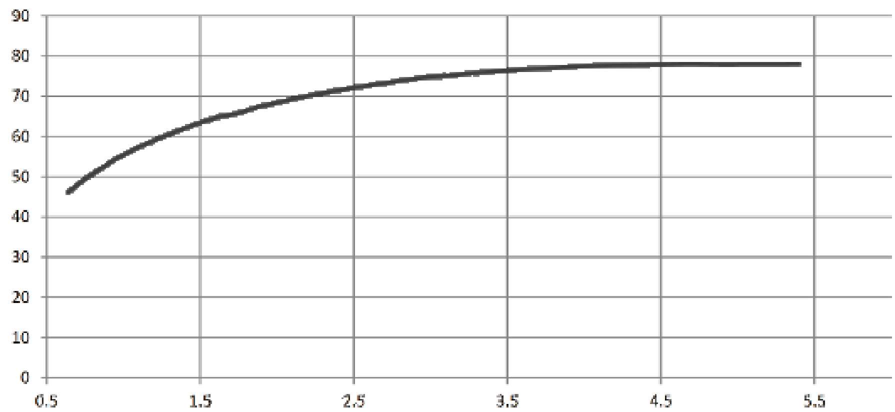
Even if this should be enough to maintain communication with most transmitters, it is recommended to always apply at least 100 mA.

# 3 Performance charts

## 3.1 Baseline power profile (BPP) Rx mode performance

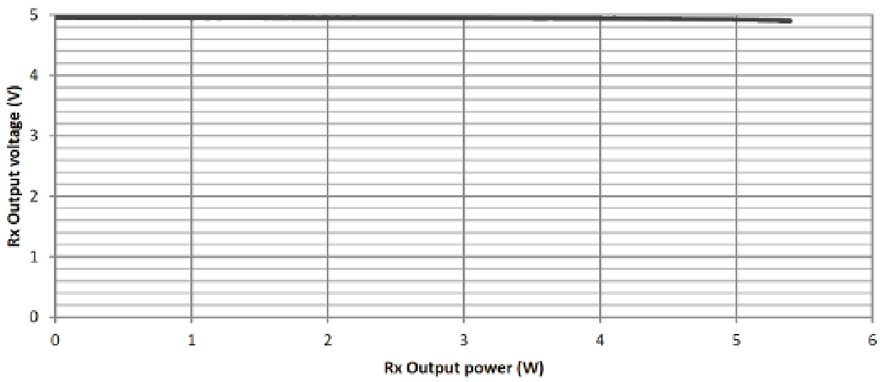
The STEVAL-ISB042V1 evaluation board performance in BPP has been evaluated through a Qi 1.2 BPP certified transmitter. The overall system efficiency is above 78%.

**Figure 14. STEVAL-ISB042V1 evaluation board performance: efficiency vs output power in BPP**




The output voltage regulation is maintained under the threshold of a 1% difference from no load to full load.

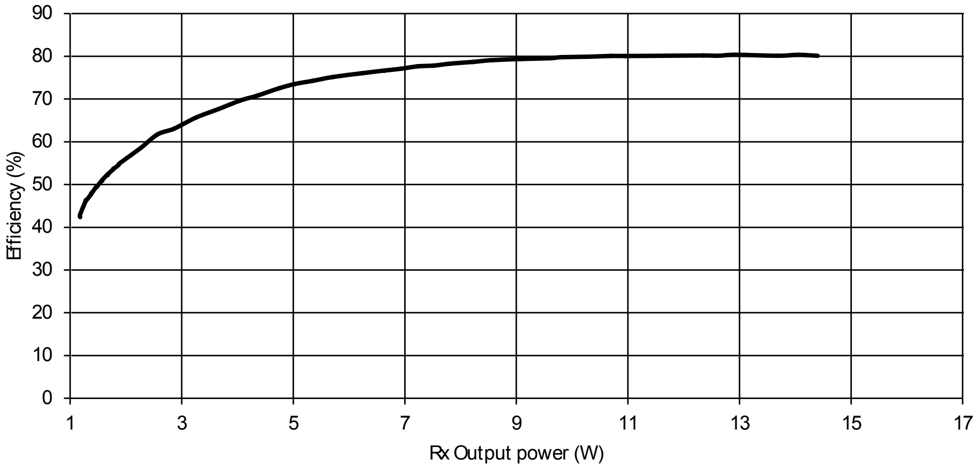
**Figure 15. STEVAL-ISB042V1 evaluation board performance: output voltage vs output power in BPP**




## 3.2 Extended power profile (EPP) Rx mode performance

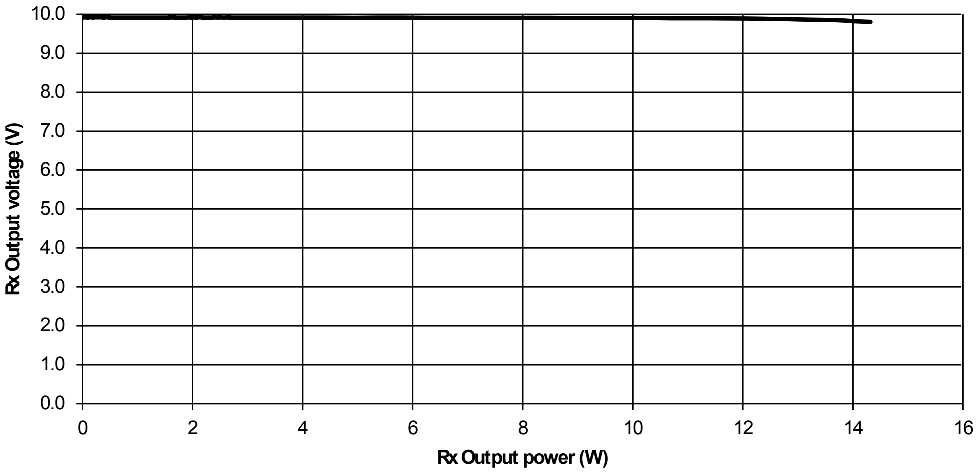
The STEVAL-ISB042V1 evaluation board performance in EPP has been evaluated through a Qi 1.2 EPP certified transmitter capable of delivering up to 15 W at 10 V output voltage. The overall system efficiency is above 80%.

Figure 16. **STEVAL-ISB042V1 evaluation board performance: efficiency vs load in EPP**




The output voltage regulation is maintained under the threshold of a 0.15% difference from no load to 10 W load and 1.5% from no load to full load.

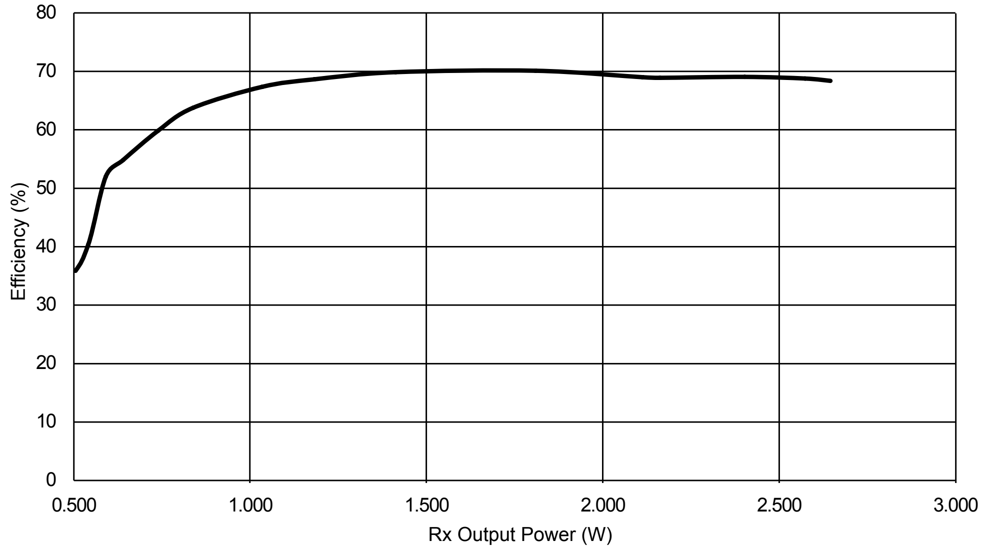
Figure 17. **STEVAL-ISB042V1 evaluation board performance: output voltage vs output power in EPP**




## 3.3 TX mode performance

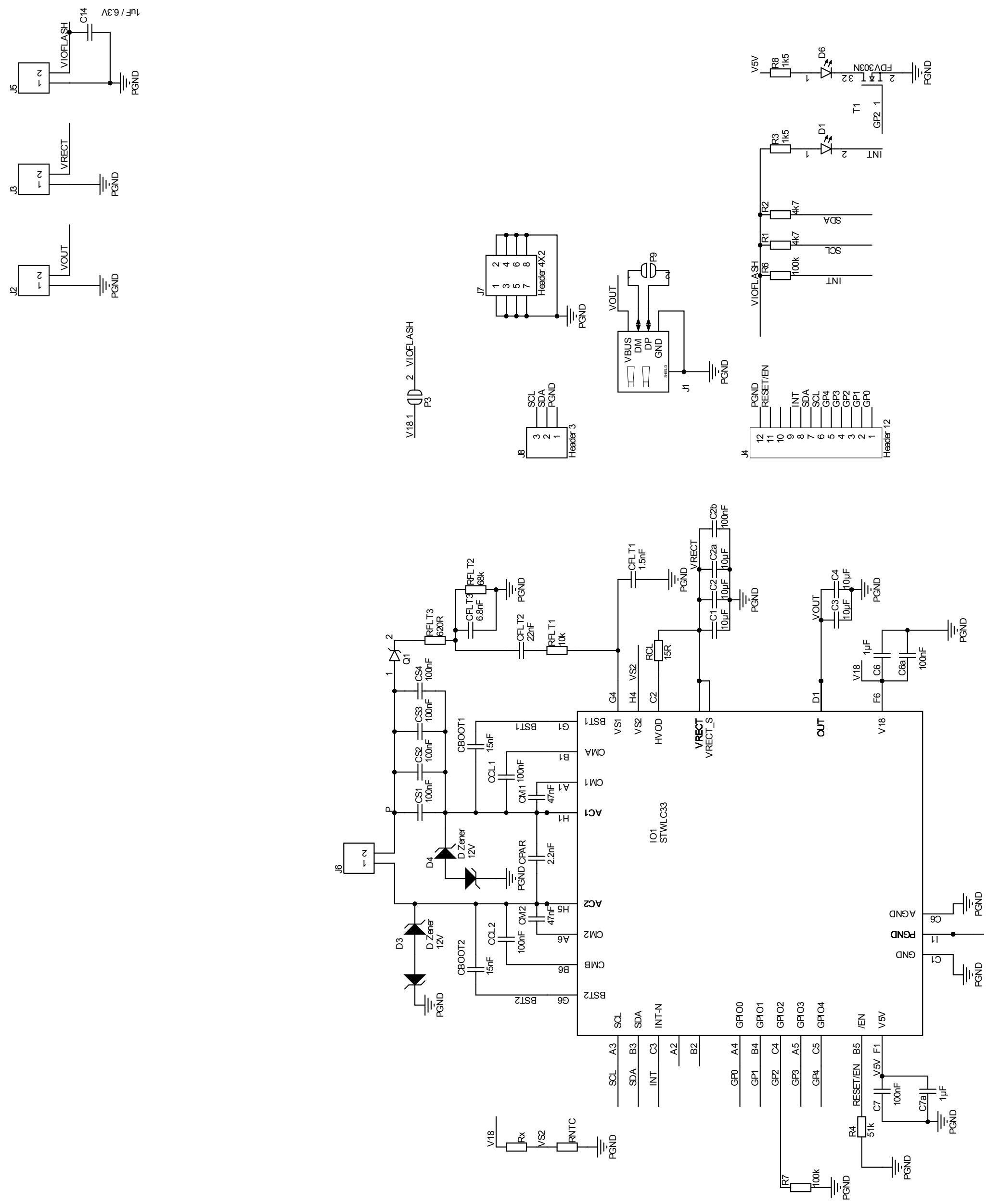
The STEVAL-ISB042V1 evaluation board performance in Tx mode has been evaluated through the STEVAL-ISB043V1 wearable receiver. The overall system efficiency is above 70%.

Figure 18. STEVAL-ISB042V1 evaluation board performance: efficiency vs output power in TX mode



# 4 Schematic diagrams

**Figure 19.** STEVAL-ISB042V1 circuit schematic



# 5 Bill of materials

**Table 1. STEVAL-ISB042V1 bill of materials**

| Item | Q.ty | Ref. | Part / Value | Description | Manufacturer | Order code |
|---|---|---|---|---|---|---|
| 1 | 1 | $IO_1$ | CSP 6x9, 400 µm pitch | Wireless power receiver | ST | STWLC33 |
| 2 | 4 | $C_{S1}$, $C_{S2}$, $C_{S3}$, $C_{S4}$ | 100 nF/50 V, SMD 0402 | Capacitors | Murata | GRM155R61H104KE19 |
| 3 | 1 | $C_{PAR}$ | 3.9 nF/50 V, SMD 0402 | Capacitors | Murata | GRM155R71H392KA01 |
| 4 | 2 | $C_{BOOT1}$, $C_{BOOT2}$ | 15 nF/10 V, SMD 0402 | Capacitors | Murata | GRM155R71H153KA12 |
| 5 | 2 | $C_{M1}$, $C_{M2}$ | 47 nF/50 V, SMD 0402 | Capacitors | Murata | GRM155R61H473KE19 |
| 6 | 2 | $C_{CL1}$, $C_{CL2}$ | 100 nF/50 V, SMD 0402 | Capacitor | Murata | GRM155R61H104KA |
| 7 | 5 | $C_1$, $C_2$, $C_{2a}$, $C_3$, $C_4$ | 10 µF/25 V, SMD 0805 | Capacitors | Murata | GRM21BR61E106KA73L |
| 8 | 1 | $C_{2b}$ | 100 nF/25 V, SMD 0201 | Capacitor | Samsung | CL03A104KA3NNNC |
| 9 | 1 | $C_6$ | 1 µF/6.3 V, SMD 0201 | Capacitor | Samsung | CL03A105MQ3CSNH |
| 10 | 2 | $C_{6a}$, $C_7$ | 100 nF/25 V, SMD 0402 | Capacitors | Murata | GRM155R61E104KA87D |
| 11 | 1 | $C_{7a}$ | 1 µF/10 V, SMD 0402 | Capacitor | Murata | GRM155R61A105KE15 |
| 12 | 1 | $C_{14}$ | 1 µF/10 V, SMD 0603 | Capacitor | Murata | GRM188R61A105MA |
| 13 | 1 | $R_{CL}$ | 30 Ω, SMD 0805 | Resistor | Panasonic | ERJ-P6WF30R0V |
| 14 | 0 | $D_1$ | SMD 0402 | | Any | Not assembled |
| 15 | 2 | $D_3$, $D_4$ | SOD882 | Protection diode | NXP | PESD12VV1BL |
| 16 | 0 | $D_5$, $D_2$ | SOD882 | | Any | Assembled short |
| 17 | 1 | $D_6$ | 2 mA, SMD 0402 | Red LED | Any | |
| 18 | 1 | $Q_1$ | | Schottky diode | ST | BAT48 |
| 19 | 1 | $R_{FLT1}$ | 10 kΩ±1%, SMD 0402 | Resistor | Any | |
| 20 | 1 | $R_{FLT2}$ | 68 kΩ±1%, SMD 0402 | Resistor | Any | |
| 21 | 1 | $R_{FLT3}$ | 620 Ω±1%, SMD 0402 | Resistor | Any | |
| 22 | 2 | $R_1$, $R_2$ | 4k7 SMD 0402 | Resistors | Any | |
| 23 | 2 | $R_3$, $R_8$ | 1k5, SMD 0402 | Resistors | Any | |
| 24 | 1 | $R_4$ | 51 kΩ, SMD 0402 | Resistor | Any | |
| 25 | 2 | $R_6$, $R_7$ | 100 kΩ, SMD 0402 | Resistors | Any | |

| Item | Q.ty | Ref. | Part / Value | Description | Manufacturer | Order code |
|---|---|---|---|---|---|---|
| 26 | 1 | $C_{FLT1}$ | 1.5 nF/50 V SMD 0402 | Capacitor | Murata | GRM155R71H152KA01 |
| 27 | 1 | $C_{FLT2}$ | 22 nF/50 V SMD 0402 | Capacitor | Murata | GRM155R71H223KA12 |
| 28 | 1 | $C_{FLT3}$ | 6.8 nF/50 V SMD 0402 | Capacitor | Murata | GRM155R71H682KA88 |
| 29 | 1 | $R_X$ | 30 kΩ SMD 0603 | Resistor | Any | |
| 30 | 0 | $R_{NTC}$ | SMD 0603 | Resistor | Any | Not assembled |
| 31 | 1 | $T_1$ | SOT23 | Digital FET | Fairchild | FDV303 |
| 32 | 0 | $J_1$ | | | Any | Not assembled |
| 33 | 3 | $J_2$, $J_3$, $J_5$ | THT 2.54 mm pitch | 2-pin header | Any | |
| 34 | 1 | $J_4$ | THT 2.54 mm pitch | 12-pin header | Any | |
| 35 | 1 | $J_6$ | THT 2.54 mm pitch | Coil wire connection | Any | |
| 36 | 1 | $J_7$ | THT 2.54 mm pitch | 2x4-pin header | Any | |
| 37 | 1 | $J_8$ | THT 2.54 mm pitch | 3-pin header | Any | |
| 38 | 1 | $P_3$ | Soldered | Solder option | Any | |
| 39 | 1 | $P_9$ | Open | | Any | Open |
| 40 | 1 | L | 8 µH | Coil connected to $J_6$ | Wurth | 760308102207 |
| 41 | 1 | | 62x62x21 mm | Plastic frame | Any | |
| 42 | 1 | | 3x10 mm | 2x wood screw | Any | |

# 6 Board layout

Figure 20. **STEVAL-ISB042V1: top silkscreen and pads**

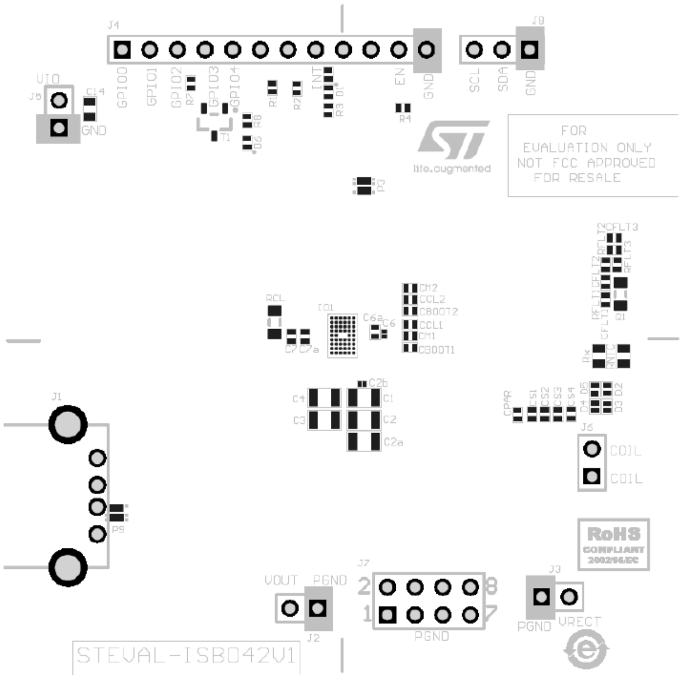
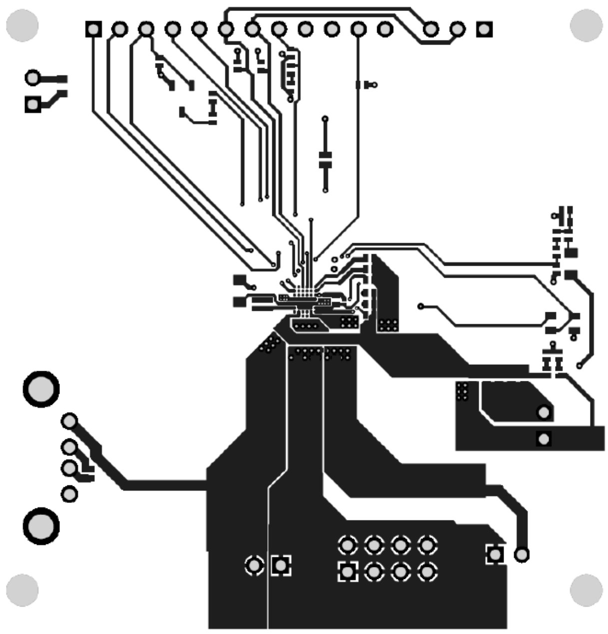



Figure 21. **STEVAL-ISB042V1: copper layer 1**



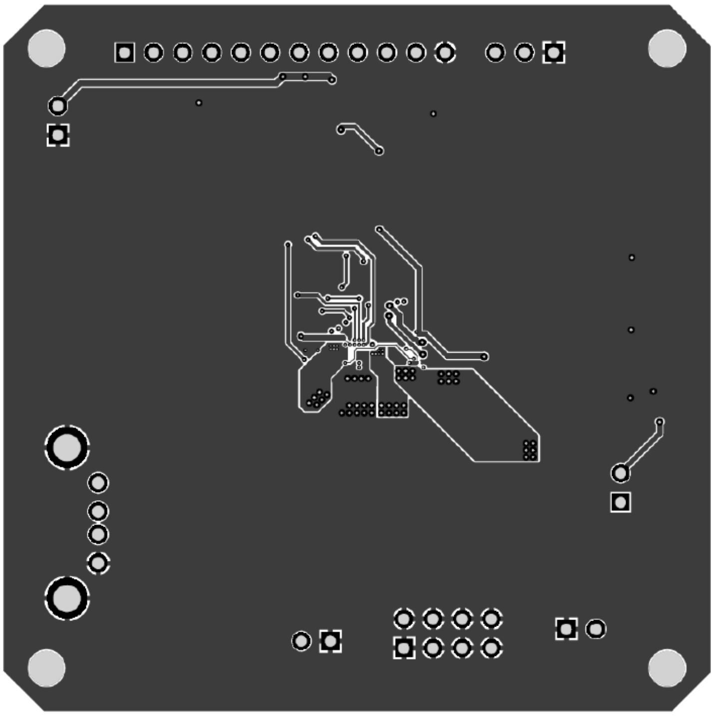


Figure 22. STEVAL-ISB042V1: copper layer 2

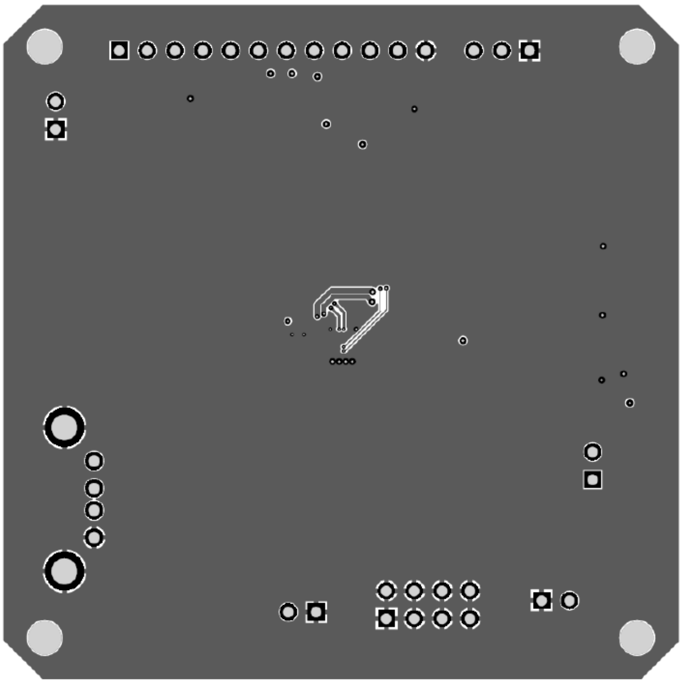


Figure 23. STEVAL-ISB042V1: copper layer 3

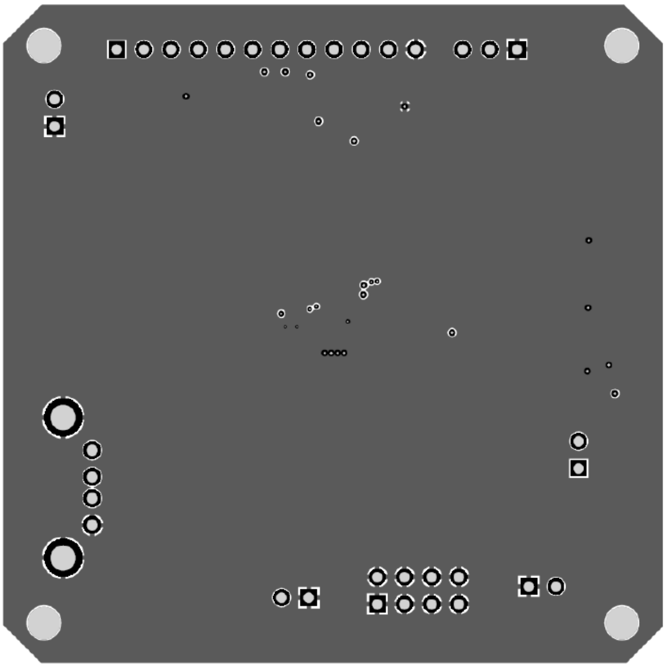


Figure 24. STEVAL-ISB042V1: copper layer 4

# 7 References

Freely available on www.st.com:

1. STWLC33 datasheet.

## Revision history

Table 2. **Document revision history**

| Date | Version | Changes |
| --- | --- | --- |
| 02-Oct-2017 | 1 | Initial release. |
| 22-Dec-2017 | 2 | Updated Table 1. STEVAL-ISB042V1 bill of materials.<br>Added references to the STEVAL-ISB043V1 wearable receiver. |

# Contents

1 **Getting started** . . . . . 2
1.1 Board configuration and test points . . . . . 2
1.2 Receiver mode . . . . . 2
1.3 Transmitter mode . . . . . 3
1.4 STWLC33 NVM configuration . . . . . 5
1.4.1 Board overview . . . . . 5
1.5 GUI: I²C register access . . . . . 5
1.5.1 Rx mode registers . . . . . 5
1.5.2 Tx mode registers . . . . . 7
1.6 GUI: NVM configuration access . . . . . 8
1.6.1 Qi NVM configuration . . . . . 8
1.6.2 PMA NVM configuration . . . . . 9
1.6.3 Platform NVM configuration . . . . . 9
1.6.4 Generic load/save NVM access . . . . . 10
2 **Configuration guidelines** . . . . . 11
2.1 Changing VOUT voltage: constraints . . . . . 11
2.2 Input current limit . . . . . 11
2.3 Minimal load . . . . . 11
3 **Performance charts** . . . . . 12
3.1 Baseline power profile (BPP) Rx mode performance . . . . . 12
3.2 Extended power profile (EPP) Rx mode performance . . . . . 12
3.3 TX mode performance . . . . . 13
4 **Schematic diagrams** . . . . . 15
5 **Bill of materials** . . . . . 16
6 **Board layout** . . . . . 18
7 **References** . . . . . 21
**Revision history** . . . . . 22

# List of tables

Table 1. STEVAL-ISB042V1 bill of materials . . . . . 16
Table 2. Document revision history . . . . . 22

# List of figures

**Figure 1.** STEVAL-ISB042V1 evaluation board . . . 1
**Figure 2.** STEVAL-ISB042V1 evaluation board: receiver mode . . . 3
**Figure 3.** STEVAL-ISB042V1 evaluation board: transmitter mode . . . 4
**Figure 4.** STEVAL-ISB042V1 GUI Tx mode tab . . . 4
**Figure 5.** STEVAL-ISB042V1 GUI operation mode . . . 5
**Figure 6.** GUI Rx mode: Interrupt registers sub-tab . . . 6
**Figure 7.** GUI Rx mode: Setup and measurement registers sub-tab . . . 7
**Figure 8.** GUI Rx mode: Qi – Proprietary packets sub-tab . . . 7
**Figure 9.** GUI Rx mode: TX mode tab . . . 8
**Figure 10.** GUI: Qi configuration tab . . . 9
**Figure 11.** GUI: PMA configuration tab . . . 9
**Figure 12.** GUI: platform configuration tab . . . 10
**Figure 13.** GUI: NVM tab . . . 10
**Figure 14.** STEVAL-ISB042V1 evaluation board performance: efficiency vs output power in BPP . . . 12
**Figure 15.** STEVAL-ISB042V1 evaluation board performance: output voltage vs output power in BPP . . . 12
**Figure 16.** STEVAL-ISB042V1 evaluation board performance: efficiency vs load in EPP . . . 13
**Figure 17.** STEVAL-ISB042V1 evaluation board performance: output voltage vs output power in EPP . . . 13
**Figure 18.** STEVAL-ISB042V1 evaluation board performance: efficiency vs output power in TX mode . . . 14
**Figure 19.** STEVAL-ISB042V1 circuit schematic . . . 15
**Figure 20.** STEVAL-ISB042V1: top silkscreen and pads . . . 18
**Figure 21.** STEVAL-ISB042V1: copper layer 1 . . . 18
**Figure 22.** STEVAL-ISB042V1: copper layer 2 . . . 19
**Figure 23.** STEVAL-ISB042V1: copper layer 3 . . . 19
**Figure 24.** STEVAL-ISB042V1: copper layer 4 . . . 20