Wireless Charging in Consumer Applications

Paolo Battezzato

life.augmented

Technology Tour 2019

Schaumburg, IL | April 25

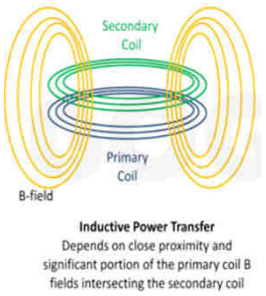
Agenda

- Wireless power-transfer principles
- Main existing standards and key differences
- Introduction to Magnetic Induction power transfer
- ST solutions for Wireless Power - Transmitters
- ST solutions for Wireless Power – Receivers
- Upcoming solutions preview

Wireless Power at a Glance

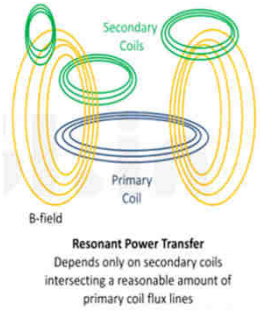
Similar technology
Different Implementation

Magnetic induction



Advantages
simple, efficient, safe, power scalable, mature
Key technology challenges
shield, coil alignment, good coupling
Disadvantages
limited x/y/z space, difficult for multiple device operation simultaneously

Magnetic resonance



Advantages
spatial freedom, multiple devices support, larger charging area
Key technology challenges
power scalable, environment safety, TX and RX design
Disadvantages
increased EMI, efficiency

is a member of Qi and AirFuel (former A4WP + PMA)

Different Standards

*Qi – by Wireless Power Consortium
* PMA – by Power Matter Alliance
A4WP – by Alliance for Wireless Power
Note: A4WP and PMA merged in June 2015

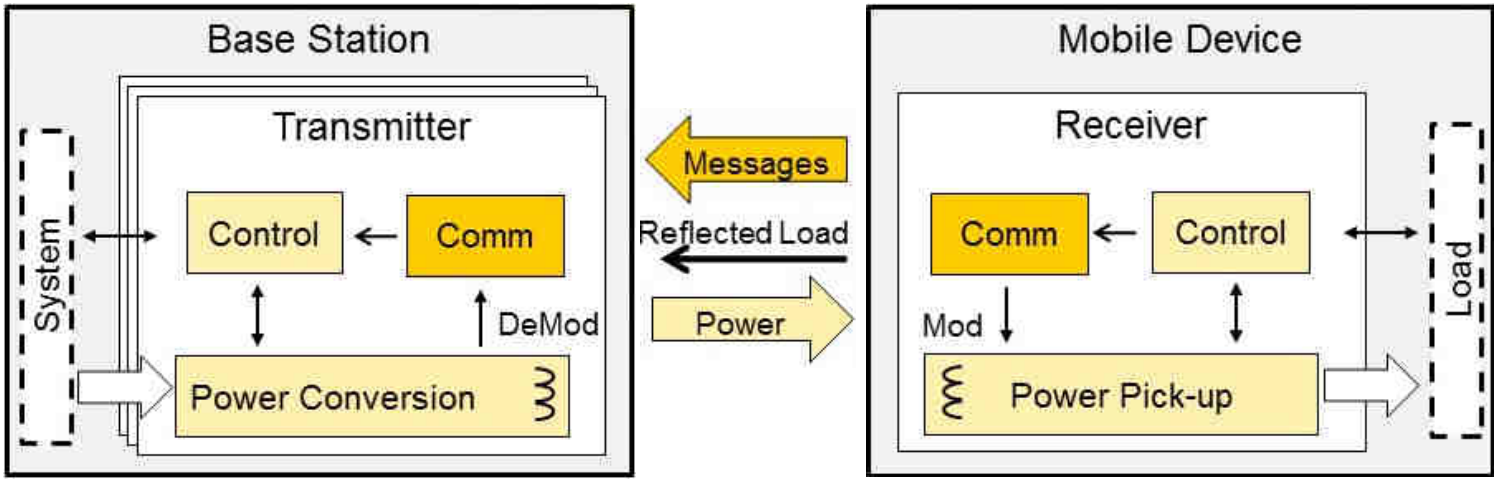
- Baseline Power Profile: 5W (rel 1.2.3)
- Extended Power Profile: 15W (rel 1.2.3)
- Medium Power Working Group up to 200W
- kitchen appliances Working Group up 2.4kW
- Resonant (Under Definition)

- PRU Category 1-7. PTU Class 1-6
- P_{RX} Out Max from 3.5W to 50W (Cat. 1 TBD)
- P_{TX} Input Max from 2W to 70W

life.augmented

Magnetic Induction Power Transfer

WPC Qi/AirFuel Inductive (Was PMA)



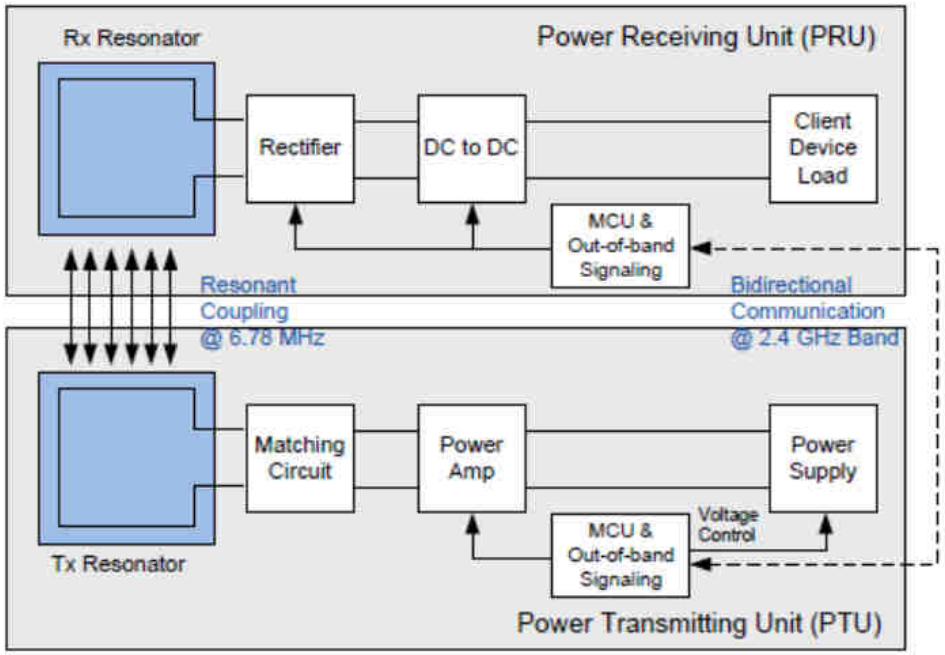
- Operating Frequency is 110-205kHz
- One Base Station typically powers one Mobile Device
- In-band digital link is used for identification of compatible devices and control of power levels (operates through the same coils used for power transfer)

life.augmented

Magnetic Resonance Power Transfer

AirFuel Resonant

- Operating Frequency is 6.78MHz
- Multiple PRUs can be can be powered from a single PTU
- A Bluetooth Low Energy (BLE) link is used for identification of compatible devices and control of power levels



life.augmented

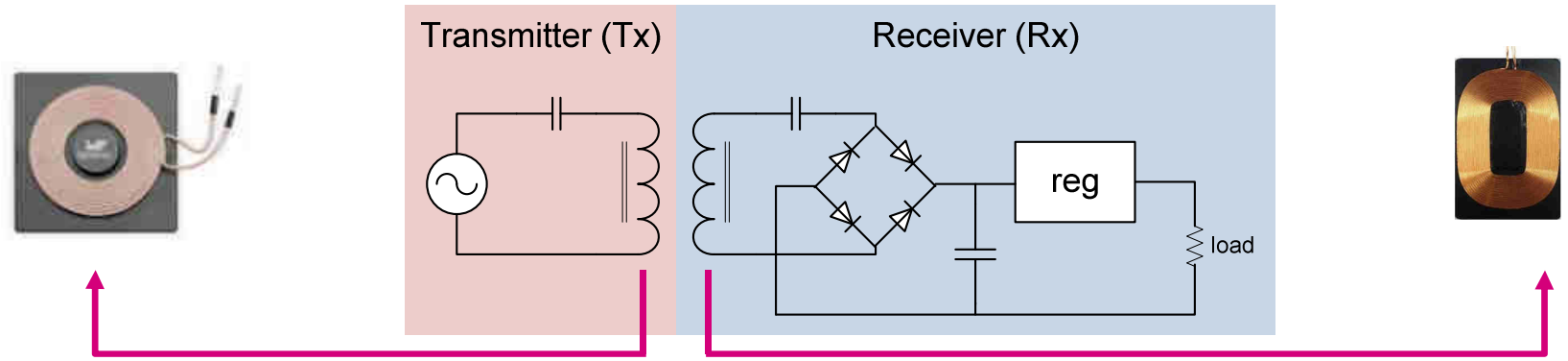
Introduction to WPC Qi Battery Charging

(Magnetic Induction)

life.augmented

Power Transfer Principles

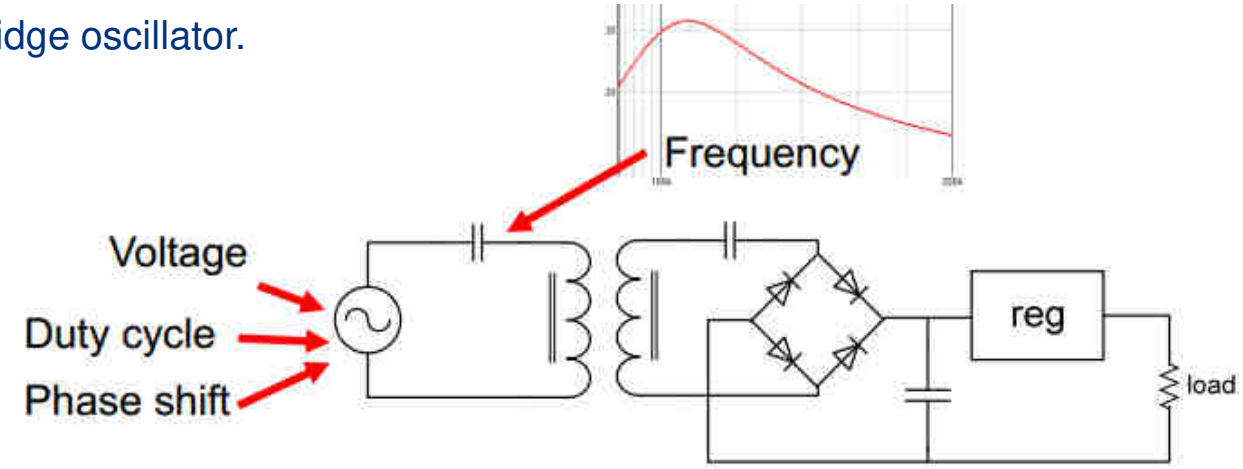
- Tightly coupled wireless charging technology uses magnetic induction to transfer power from a transmitter (TX) to a receiver (RX)
- The magnetic field is generated by a **coil on the TX side**. The field is captured by a **coil on the RX side**. The field works through air, no magnetic circuit links the coils
- The received electrical signal is **rectified, filtered, and regulated** before supplying the load



life.augmented

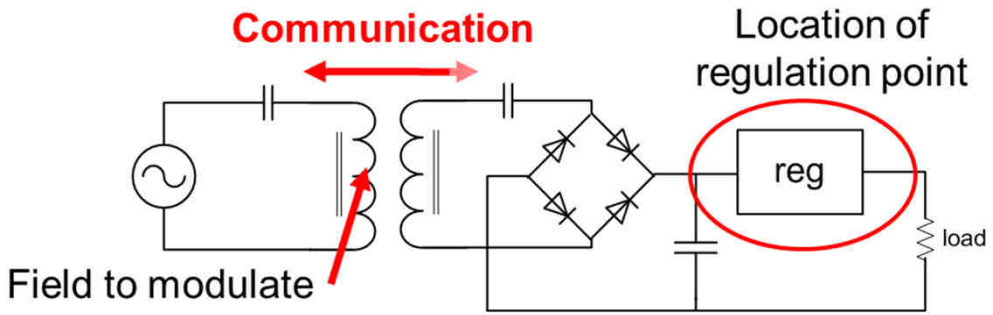
Magnetic Field Control
by Adjusting Power

- To control the field, various solutions can be used (and combined):
  - Use the LC tank properties, changing the oscillator **frequency**.
  - Change the oscillator **duty cycle** (using a square wave oscillator)
  - Change the oscillator **voltage**.
  - Apply **phase** shift to a full bridge oscillator.



Communication

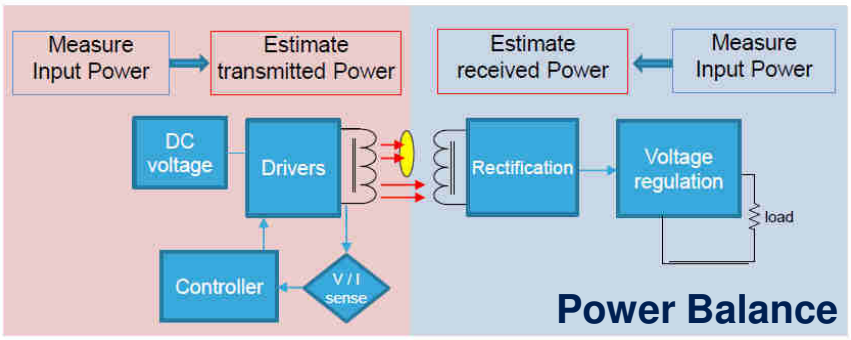
- Because there are too many variables (RX/TX coupling, RX & TX coils, load, …), the TX cannot set the regulation point by itself. The RX will have to pass data to the TX about the regulation set point.
- This communication channel can also be used for auxiliary purposes and extended to bi-directional communication
- Qi 1.2.3 (latest public release) defines two communications methods:
  - **Unidirectional**: RX to TX only, ASK, for BPP (Baseline Power Profile). **Same as in Qi 1.1**
  - **Bidirectional:** RX to TX, ASK and TX to RX, FSK, for EPP (Extended Power Profile). **Did not exist in Qi 1.1**

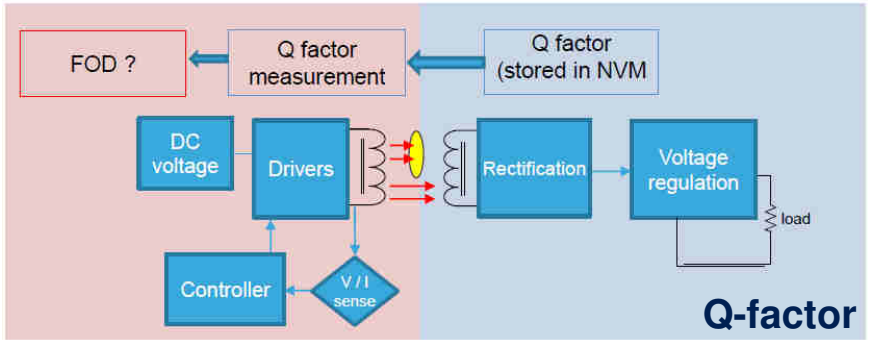


RX Presence Detection and FOD

- Receiver Presence Detection
  - The transmitter generates a magnetic field at regular intervals and check if a load is present and consumes power.

- FOD (Foreign Object Detection)
  - Qi 1.2.3 defines two methods. Qi 1.1 only had one, Power Balance:
    - **Power Balance:** If the TX transmits more power than what the RX reports (including losses), a foreign object is present
    - **Q-factor:** Compares Q measured on TX side with reference value stored in RX NVM



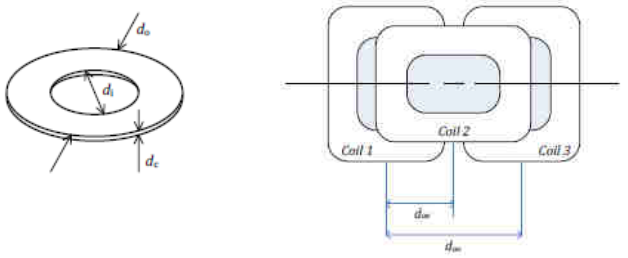


life.augmented

Qi Power-Transmitter Design Overview

Design	Description	Family	Voltage	Control
A1	Single Primary Coil with magnet alignment	#1	19 V	Frequency & Duty cycle
A2	Single movable Primary Coil	#1	12 V	Voltage
A3	Single movable Primary Coil	#2	12 V	Voltage & Frequency
A4	Two oblong Primary Coils	#4	11 V	Voltage & Frequency
A5	Single Primary Coil with magnet alignment	#1	5 V	Frequency & Duty cycle
A6	Linear array of Primary Coils	#5	12 V	Frequency & Duty cycle
A7	Single movable Primary Coil	#2	12 V	Voltage & Frequency
A8	Single oblong Primary Coil	#4	11 V	Voltage & Frequency
A9	Single Primary Coil with magnet alignment	#1	15 V	Voltage & Frequency
A10	Single Primary Coil without magnet	#1	19 V	Frequency & Duty cycle
A11	Single Primary Coil without magnet	#1	5 V	Frequency & Duty cycle
A12	Single oblong Primary Coil	#4	5 V	Frequency & Duty cycle
A13	Linear array of Primary Coils	#5	12 V	Voltage & Frequency
A14	Two oblong Primary Coils	#4	12 V	Frequency & Duty cycle
A15	Single Primary Coil, user assisted alignment	#2	12 V	Voltage & Frequency
A16	Single triangular Primary Coil	#6	5 V	Frequency & Duty cycle
A17	Single Primary Coil	#1	15 V	Voltage & Frequency
A18	Single Primary Coil, user assisted alignment	#2	12 V	Voltage & Frequency
A19	Dual Primary Coils	#5	12 V	Frequency & Duty cycle
A20	Single oblong Primary Coil	#4	12 V	Voltage & Frequency
A21	Linear array of Primary Coils	#5	12 V	Frequency & Duty cycle
A22	Single oblong Primary Coil	#4	12 V	Voltage & Frequency
A23	Single oblong Primary Coil	#4	12 V	Voltage, Frequency & Duty Cycle
A24	Single Primary Coil	#1	5 V	Frequency & Duty cycle
A25	Single oblong Primary Coil	#4	5 V	Frequency & Duty cycle
A26	Single triangular Primary Coil	#6	5 V	Frequency & Duty cycle
A27	Single Primary Coil	#8	12 V	Phase
A28	Linear array of Primary Coils	#5	5 V	Frequency & Duty cycle
A29	Single Primary Coil	#1	12 V	Voltage control
A30	Single oblong Primary Coil	#4	12 V	Frequency & Duty cycle
A31	Single oblong Primary Coil	#4	12 V	Frequency & Duty cycle

Design	Description	Family	Voltage	Control
B1	2D array of Primary Coils (Litz-wire based)	#3	20 V	Voltage
B2	2D array of Primary Coils (PCB based)	#3	20 V	Voltage
B3	2D array of Primary Coils (Litz/PCB hybrid)	#3	12 V	Phase
B4	Linear array of Primary Coils	#7	12 V	Phase
B5	Linear array of Primary Coils	#7	12 V	Phase
B6	Linear array of Primary Coils	#9	5 V	Phase



Family	Primary Coil Shape	Primary Coil Size
#1	Circular	Ø40...43 mm
#2	Circular	Ø33...39 mm
#2	Circular/hexagonal	Ø28...32 mm
#4	Oblong	65×57...70×60 mm²
#5	Rectangular	46.5×37.5...53×45 mm²
#6	Triangular	52×46...59×52 mm²
#7	Square	45×45 mm²
#8	Circular	Ø60 mm
#9	Oblong	45×34 mm²

Source: WPC Qi specifications, Version 1.2

life.augmented

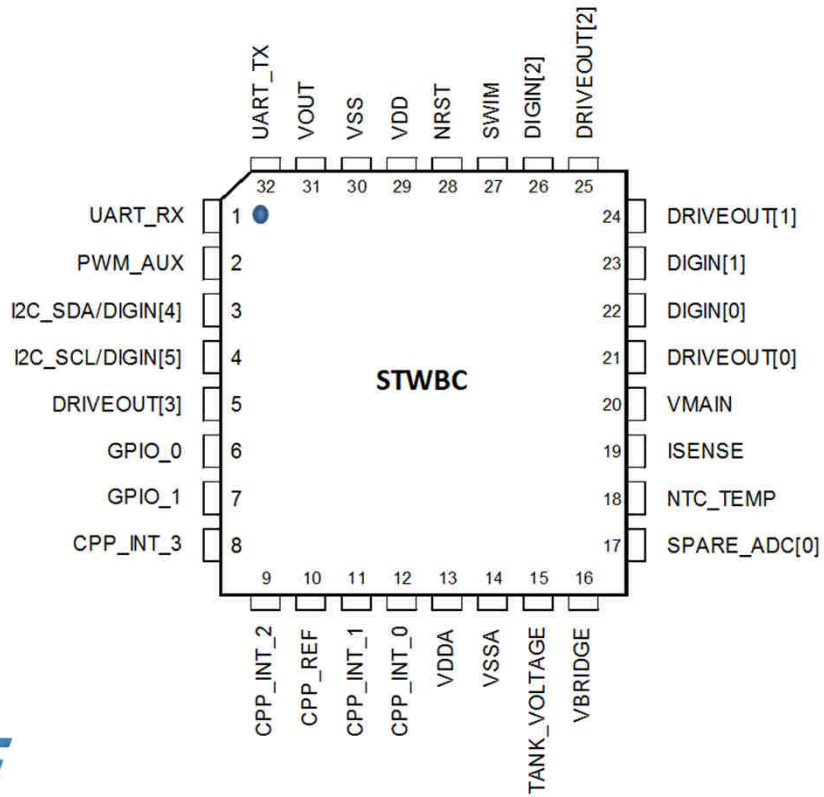
STWBC

Qi Wireless Battery Charging Transmitter IC

life.augmented

STWBC - Transmitter

Flexible, efficient, compliant with leading standards



5V IC supply voltage

Two Firmware options

- Turn/key solution for quick design
- APIs available for customization

API: Available Peripherals

- ADC with 10 bit precision and 1MΩ input impedance
- UART
- I²C master fast-slow speed rate
- GPIOs
- Program memory: 32* kbyte EEPROM
  (*available size for API depends on selected FW)

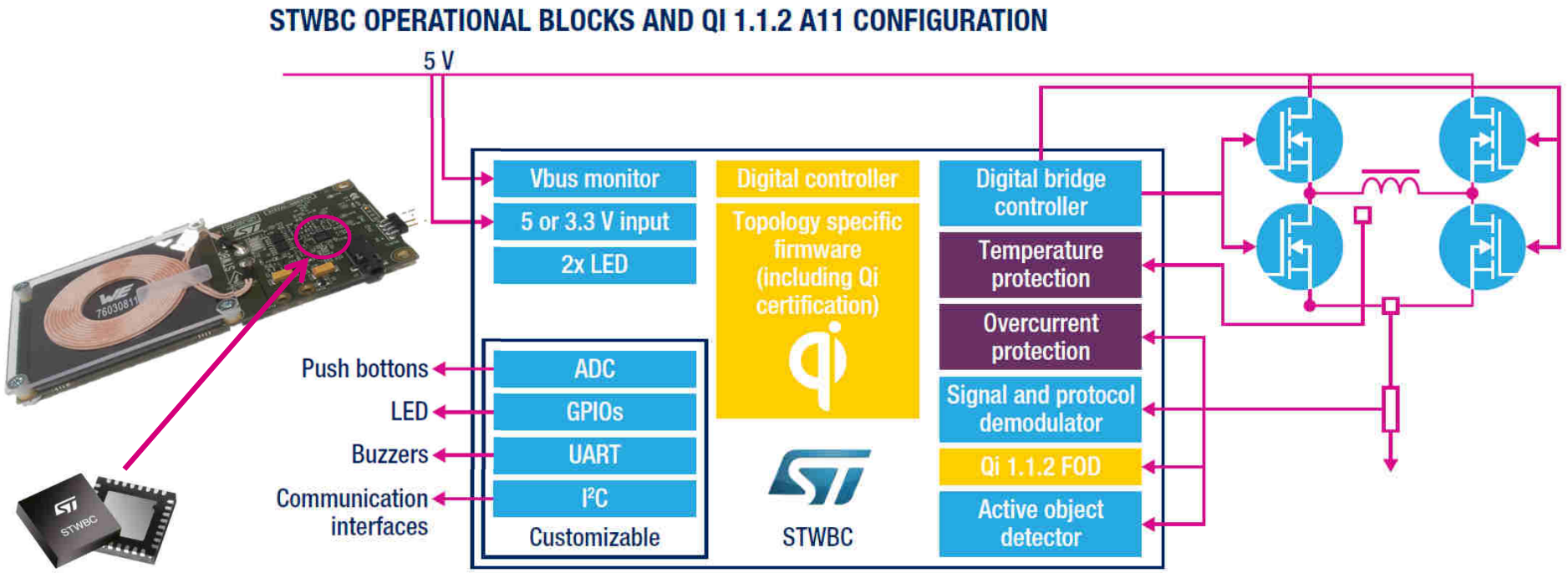
General application features:

- Low cost 2-layer PCBs
- Active object detection
- Graphical user interface for application monitoring
- Evaluation board

life.augmented

STWBC - Transmitter

Flexible, efficient, compliant with leading standards



life.augmented

Two System Approaches

Turn-Key

- Cost down and size reduced solution
- Quickly fit your application with Wireless-Charging technologies
- Firmware ready (No changes required)

Application customization via firmware changes

Customize the application around the Wireless Transmitter. Add:

- LEDs lights
- Sounds
- Connectivity (host controllers, Bluetooth/Wi-Fi modules)

ST takes care of the wireless Power-Transfer algorithms and control loop.

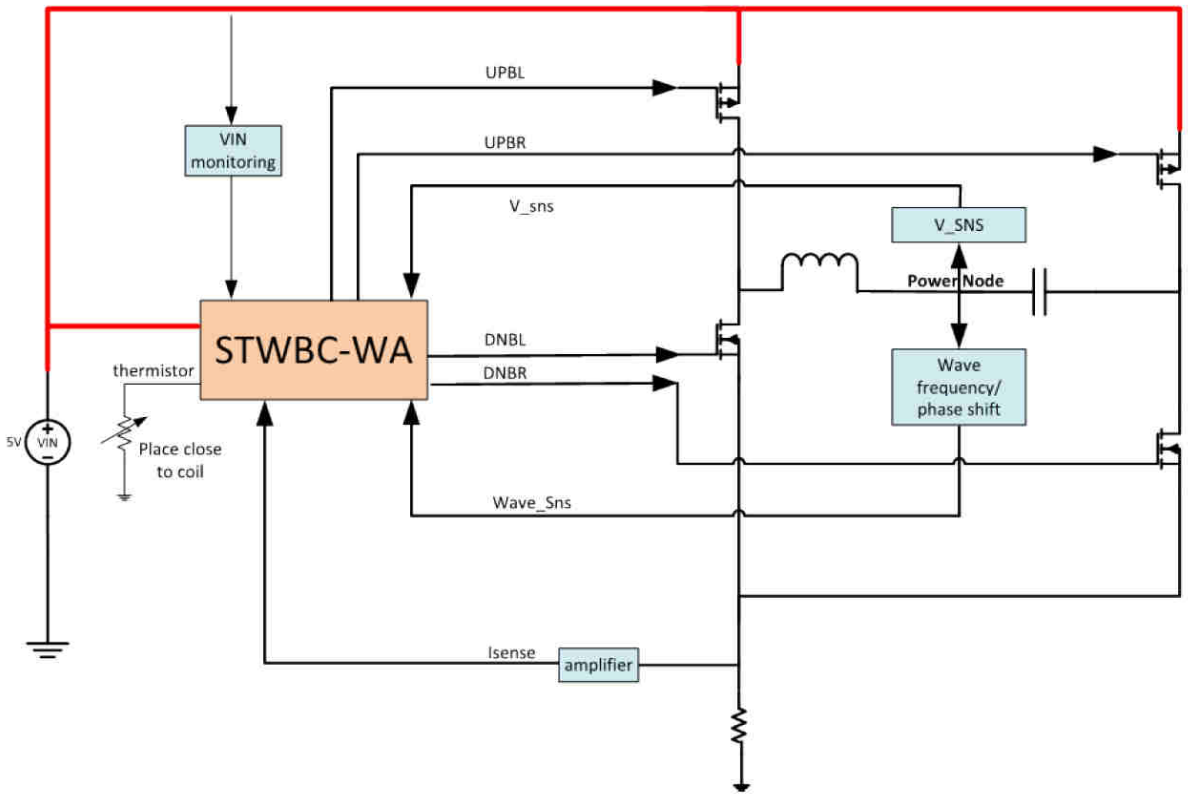
STWBC Transmitter

Qi Evaluation Boards

life.augmented

Qi-based Wearable TX Configuration

STWBC-WA – 2.5W



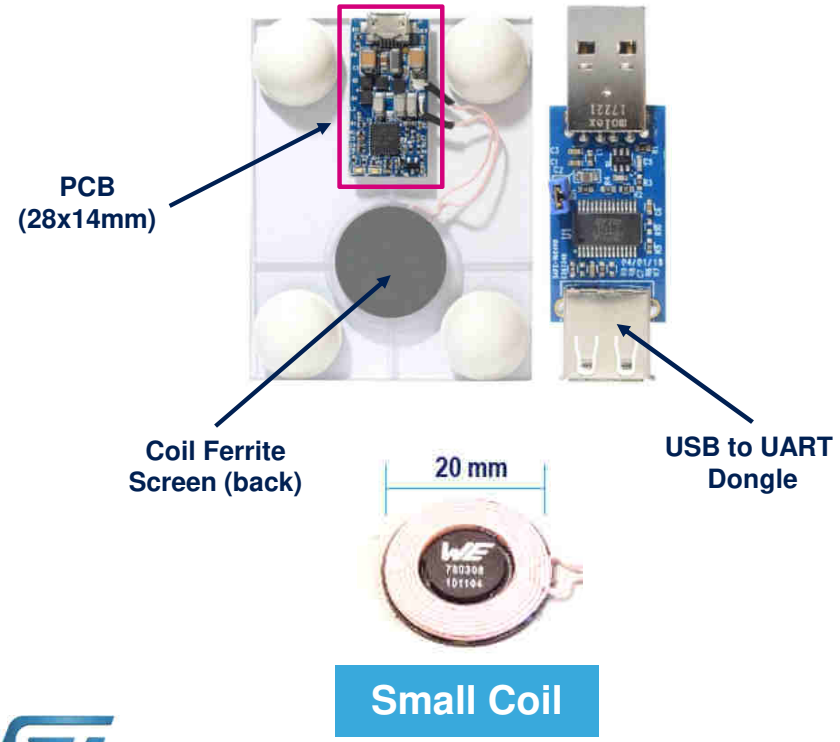
- System, bridge control and Qi protocol are handled by the STWBC-WA
- The transmitter is based on a Full-Bridge topology
- The inverter bridge is supplied by 5V input voltage
- Support up 2.5W with 20mm coil
- Scalable down to 1W with even smaller coil

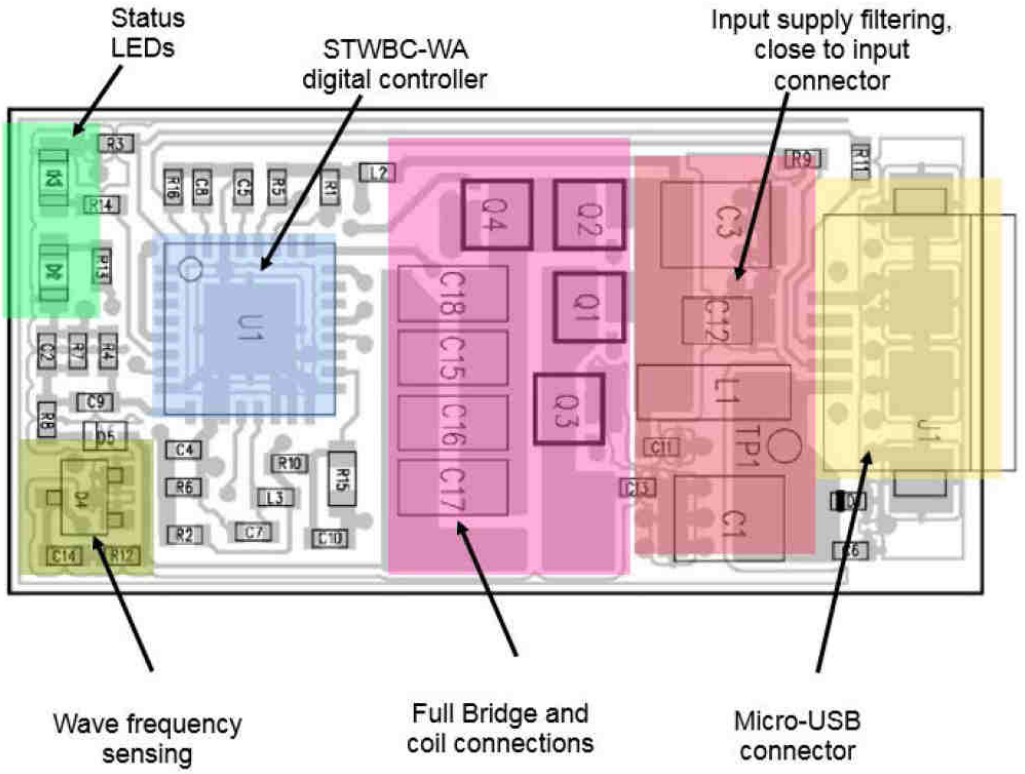
life.augmented

Qi-based Wearable TX Reference Board

STWBC-WA – 2.5W STEVAL-ISB045V1

- 2-Layer PCB and single-side placement

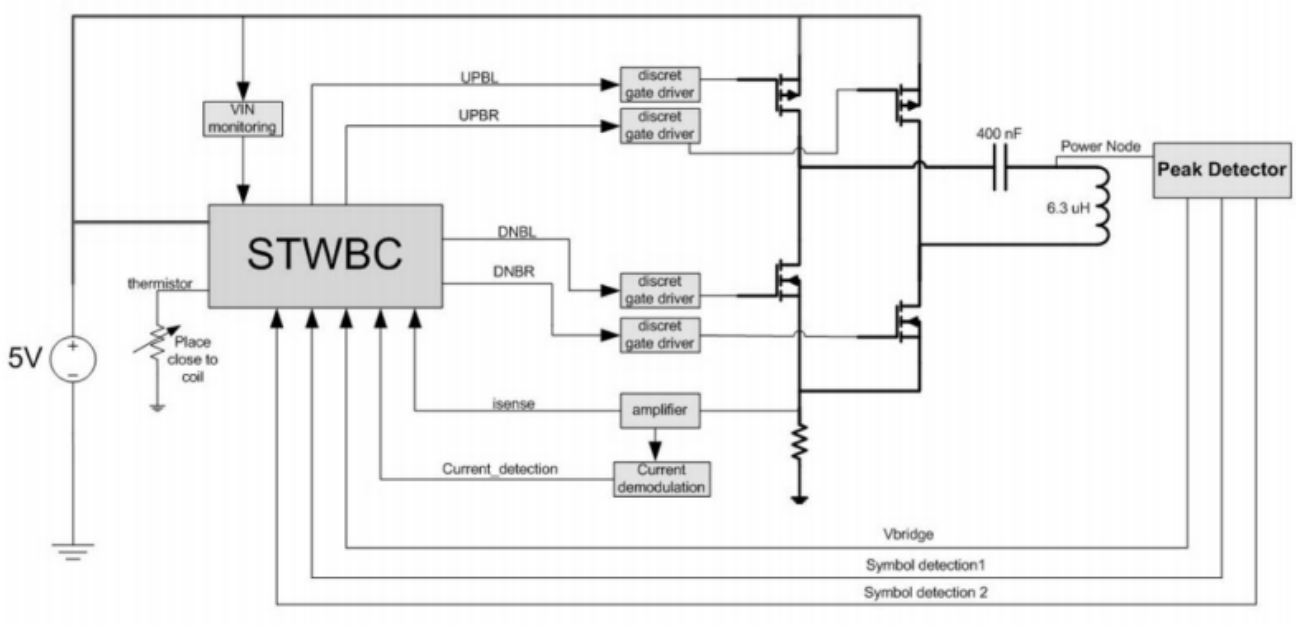




life.augmented

STWBC - A11 Transmitter Configuration

- 5W Qi, 1-Coil, 5V supply
- A11 requires accurate frequency control:
  - Operating frequency range 110kHz – 205kHz
  - Duty cycle 50%-10% @ 205kHz

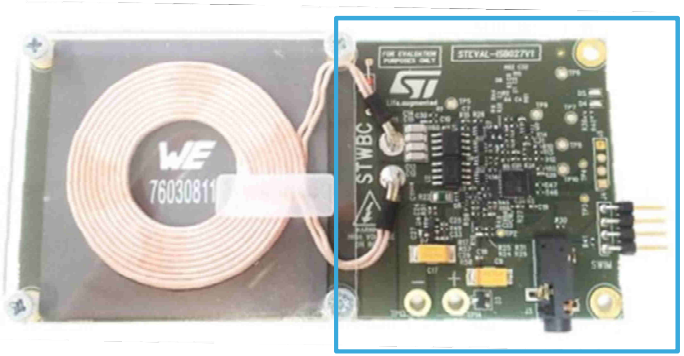


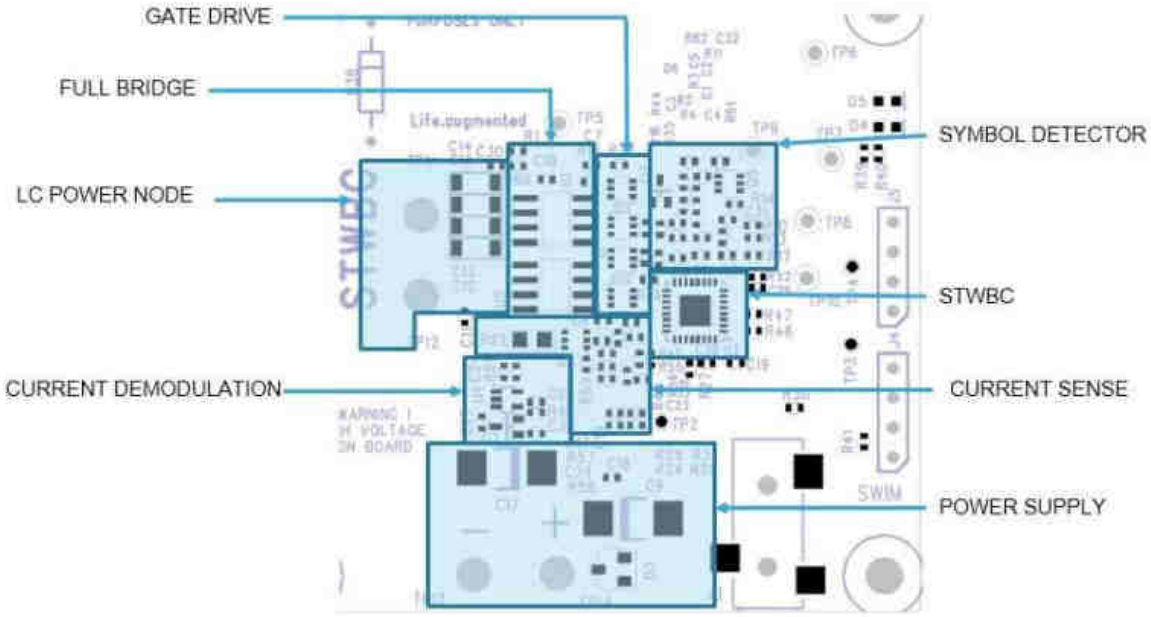
life.augmented

Transmitter Reference Board

STWBC 5W A11 – STEVAL-ISB027V1

2-Layer PCB and single-side placement





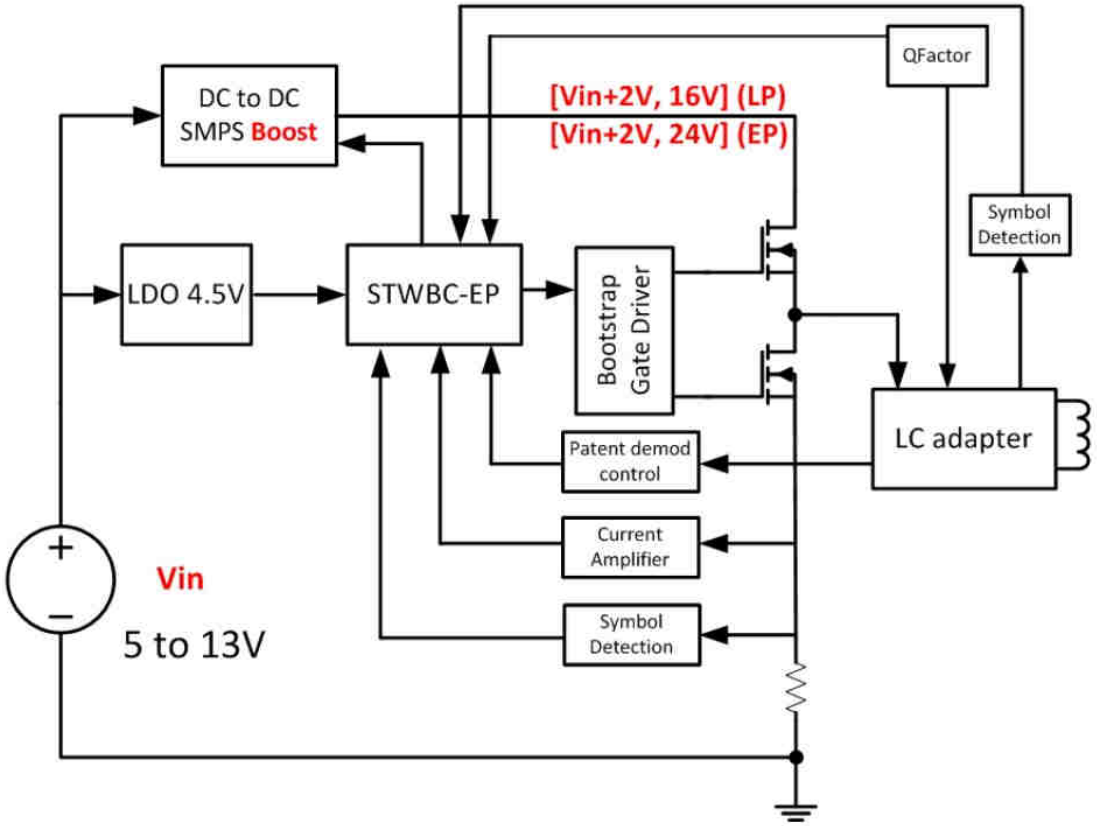
Standby

- **3mW** consumption
- Ping active
- FOD active

life.augmented

15W EPP Transmitter Configuration

STWBC-EP MP-A10



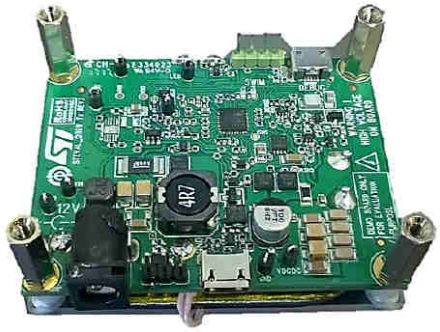
- Qi 1.2.3 EPP (Extended Power Profile) up to 15W
- Based on a half-bridge topology
- Support Basic Power Profile as well, up to 5W
- Wide supply voltage range, 5 to 13V

life.augmented

Transmitter Reference Board

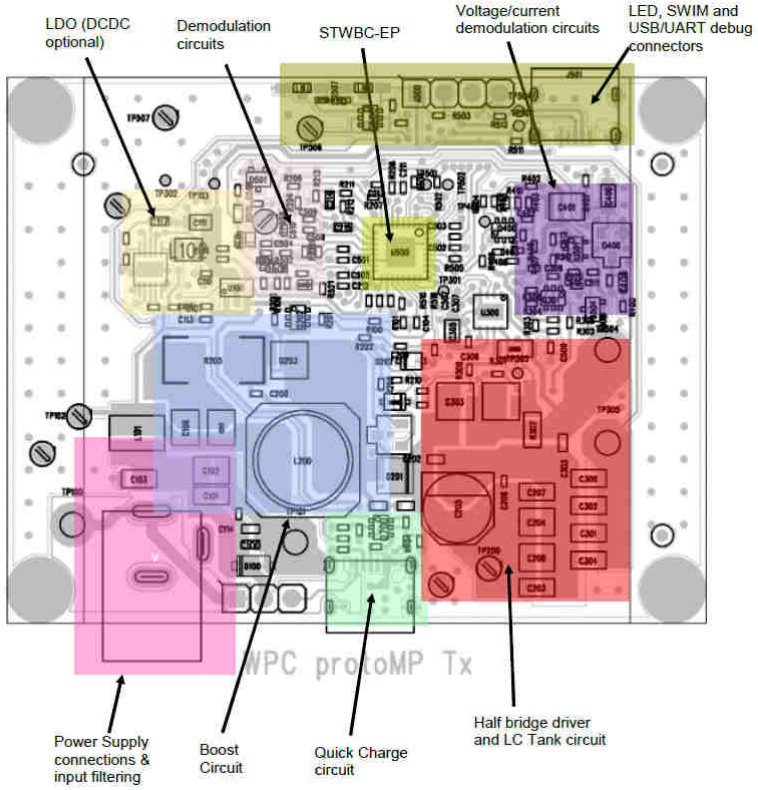
STWBC-EP 15W MP-A10 STEVAL-ISB044V1

2-Layer PCB and single-side placement



StandBy

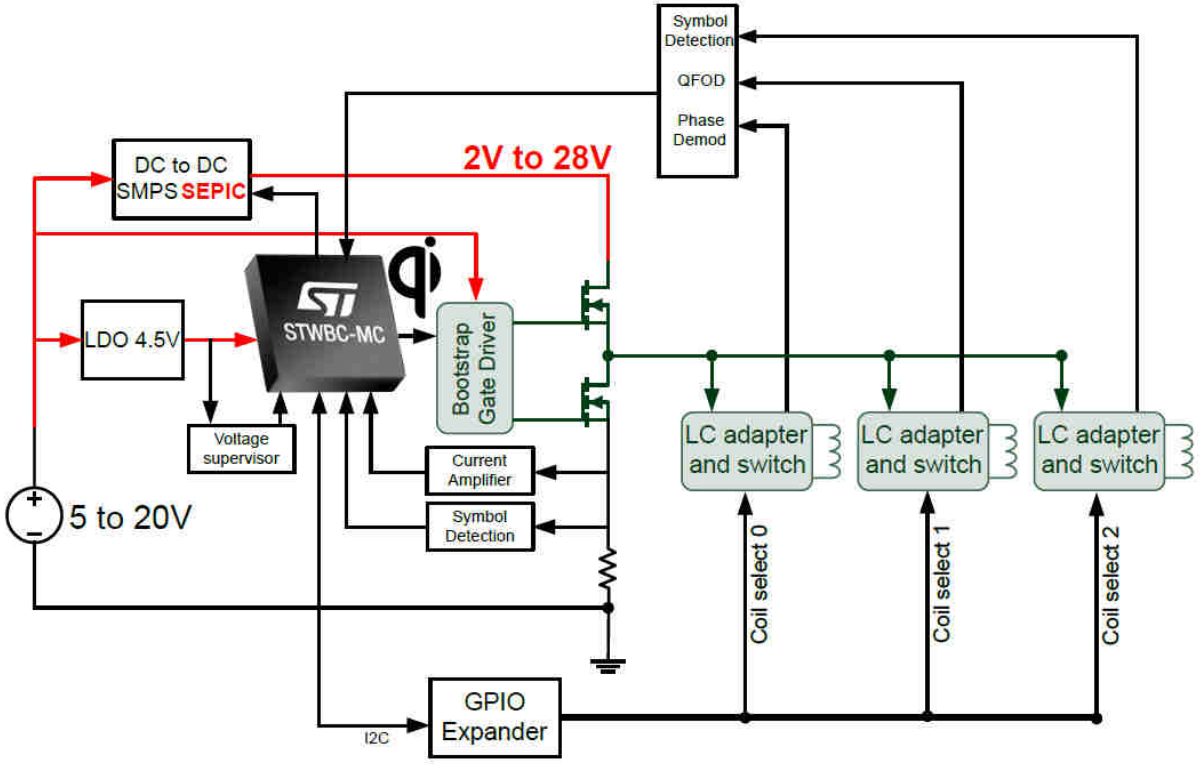
- **16mW** consumption
- Ping active
- FOD active



life.augmented

3-coil 15W EPP Transmitter Configuration

STWBC-MC MP-A15



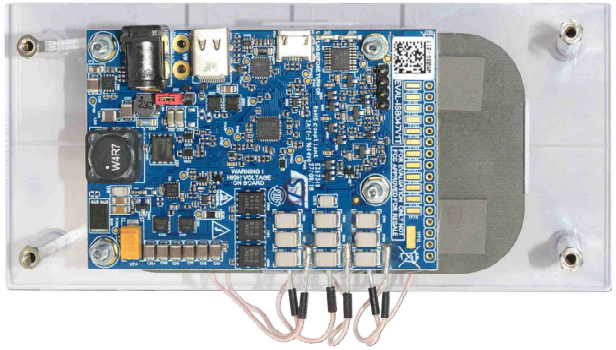
- Qi 1.2.4 EPP (Extended Power Profile) up to 15W and BPP up to 5W
- 127.7 kHz fixed frequency
- **Fast Charge support**
- Wide supply voltage range, 5 to 20V, with USB-C and support for legacy 5V USB

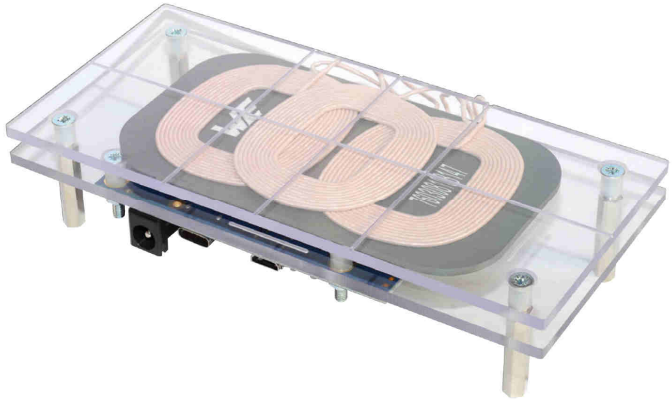
life.augmented

3- coil Transmitter Reference Board

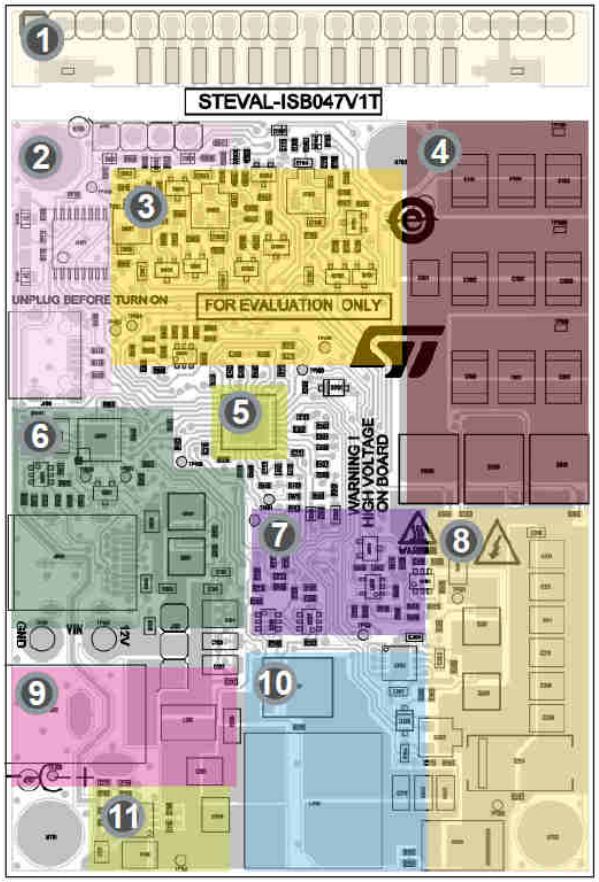
STWBC-MC 15W MP-A15 STEVAL-ISB047V1

2-Layer PCB and single-side placement





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

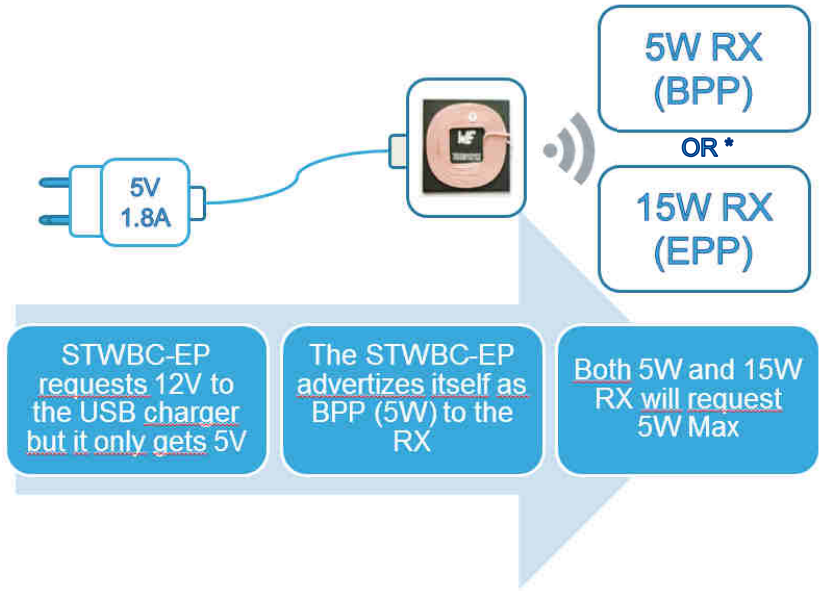


Standby

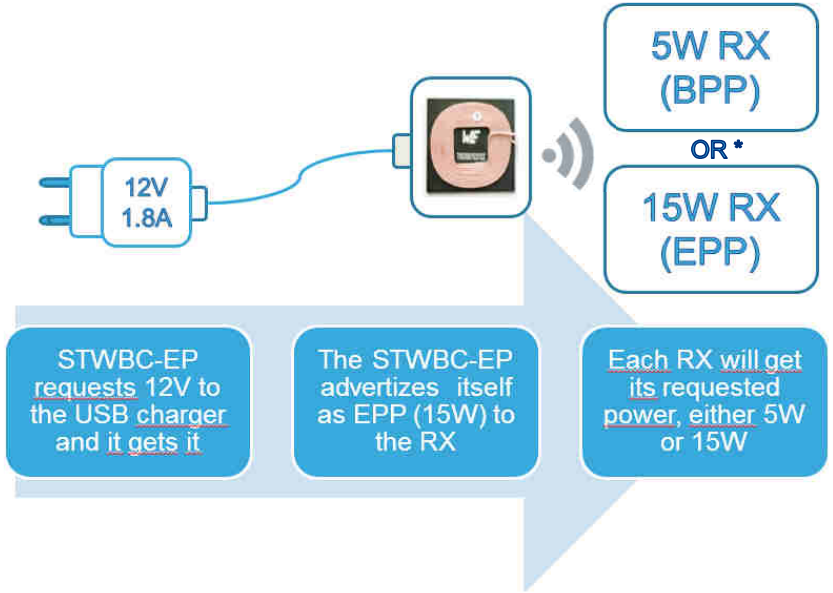
- **17mW** consumption
- Ping active
- FOD active

life.augmented

STWBC-EP 5W or 15W use cases



STWBC-EP supplied at 5V



STWBC-EP supplied at 12V

life.augmented

* Only one RX can be paired to a single TX, as per cuurent Qi spec

Wireless Battery Charger TX

STWBC-WA - STEVAL-ISB045V1

TX for Wearable (2.5W)

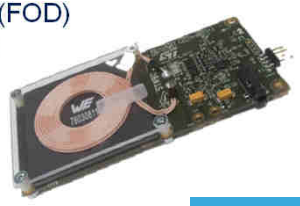
- IC: STWBC-WA
- **20 mm Coil**
- 2.5W delivery at RX side
- 5V Supply
- Compatible with STEVAL-ISB043V1 RX

Available

STWBC - STEVAL-ISB027V1

A11 Certified Wireless Charger (5W)

- IC: STWBC
- Qi A11 1.1.2 Certified (1.2 BPP Ready) ref. design
- Foreign Object Detection (FOD)
- Active presence detection
- Turn Key or API customization
- Standby efficiency:
  - 3mW consumption
  - FOD active in standby



Available

STWBC-EP - STEVAL-ISB044V1

15 Watts

Certified Wireless Charger (15W)

- IC: STWBC-EP
- MP-A10 Design, Qi 1.2.3 Certified
- Support BPP and EPP (5W/15W)
- Foreign Object Detection (FOD)
- 5-13V input voltage range
- Half-Bridge topology
- Voltage/Frequency Control
- Graphical Interface for testing

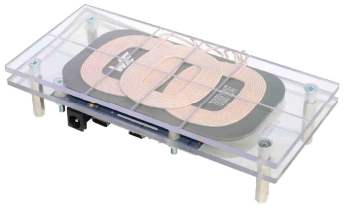
Available

STWBC-MC - STEVAL-ISB047V1

15 Watts

Certified Wireless Charger (15W)

- IC: STWBC-MC
- Qi 1.2.4 Certified
- Support BPP and EPP (5W/15W)
- Foreign Object Detection (FOD)
- 5-20V Vin with USB-C
- Half-Bridge topology
- 127.7kHz Fixed Frequency
- Graphical Interface for testing



Available

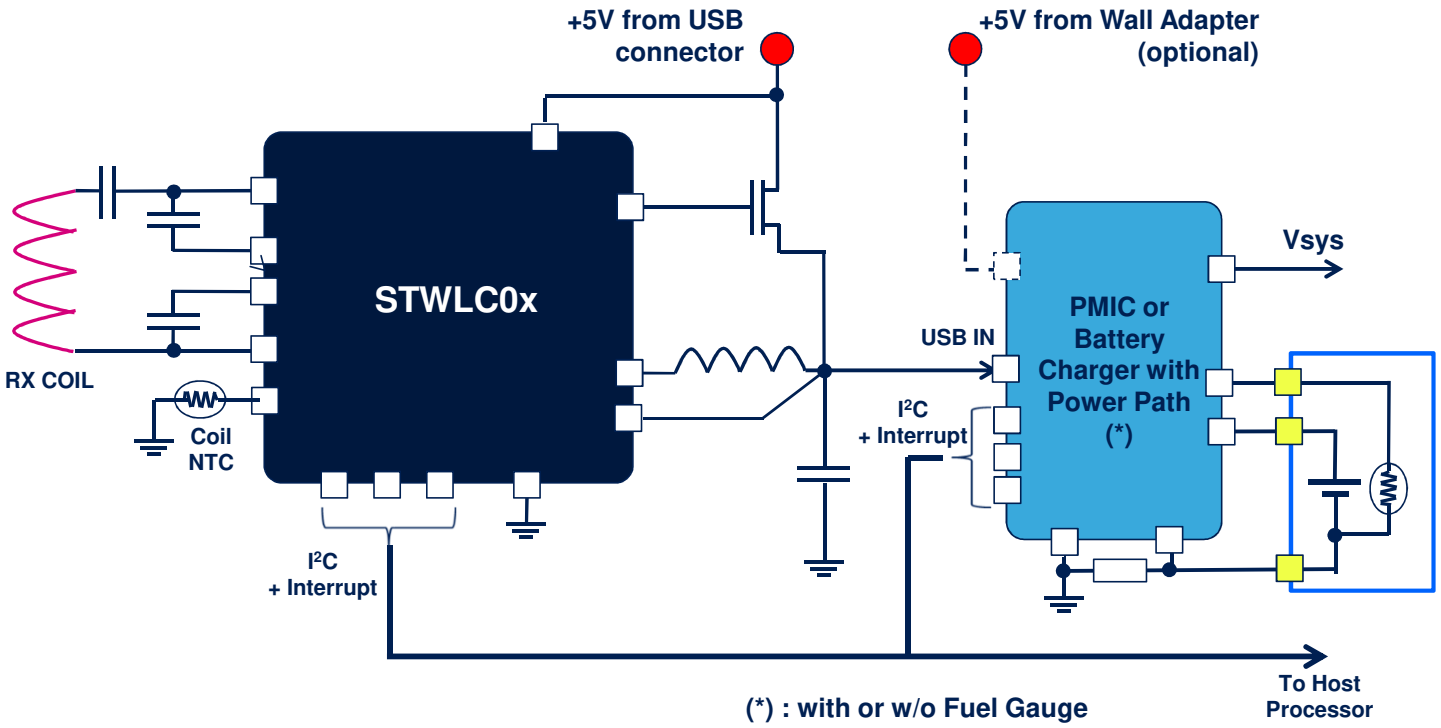
life.augmented

STWLC

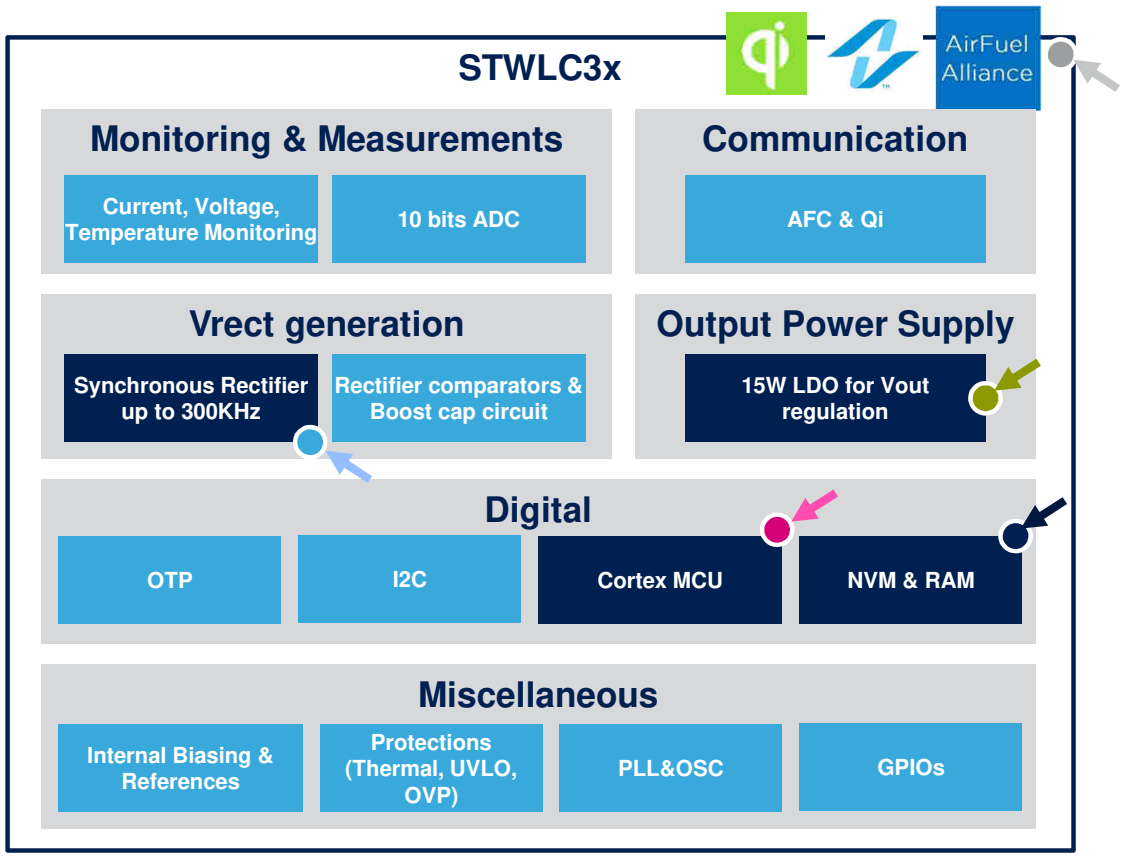
Qi/AirFuel Inductive Wireless Battery Charger Receiver IC

life.augmented

STWLC3x Simplified Application Diagram



STWLC3x – 5/15W Dual Function TX/RX



Up to Qi 1.2 15W output power & AirFuel inductive 5W

LDO for output voltage regulation with input current loop and input/output control

Embedded 32bit 32MHz ARM Cortex M4 MCU with 32kB ROM and 8KB RAM

4Kb NVM memory for customization

Integrated high efficiency synchronous rectifier

Flip Chip 2.68 x 4.026mm

life.augmented

STWLC Receiver

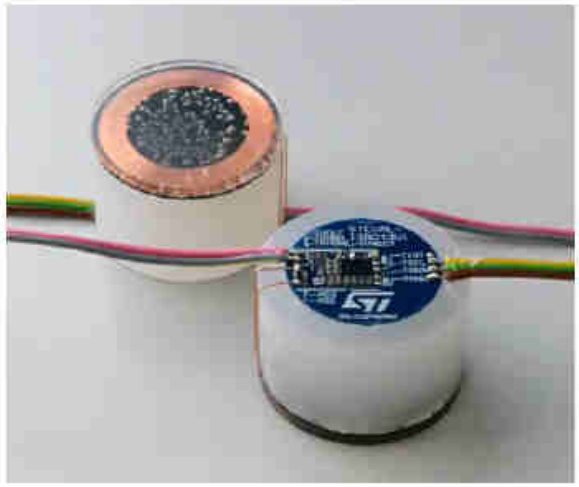
Qi Evaluation Boards

life.augmented

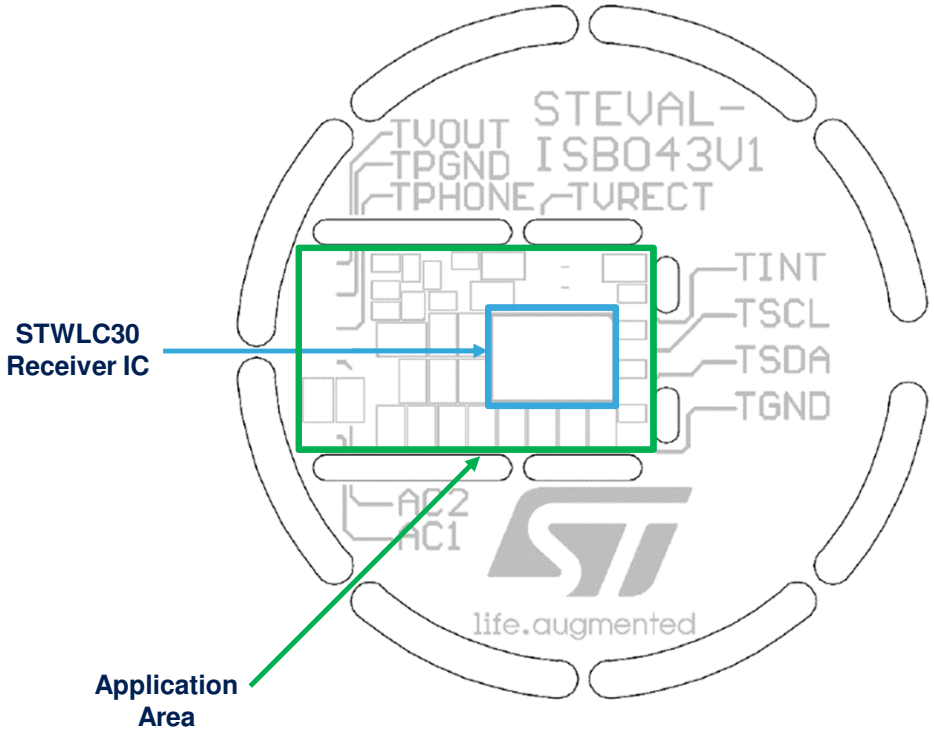
Qi-based Wearable RX Reference Board

STWLC30 – 2.5W STEVAL-ISB043V1

- 3-Layer PCB and single-side placement
- Application area 10x6mm



26mm Coil



life.augmented

New Wearable Solution

Wireless power TX - RX kit – 2.5 Watt wireless delivery

Full Bridge 2.5W Transmitter based on STWBC-WA

5V 1A USB input power

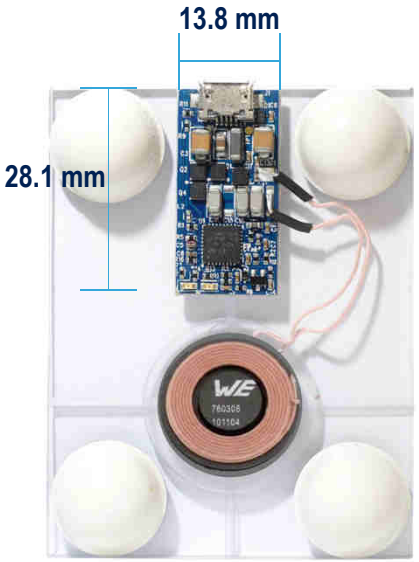
Smart standby
Automatic receiver recognition
Open FOD for increased safety
Patented demodulation

Wurth 760308101104
20 mm diameter coil

2-layer PCB with optimized eBOM possible remote coil w/ dedicated tuning

Turnkey solution customization via GUI

Available Now



STEVAL-ISB045V1

STEVAL-ISB043V1

2.5W Receiver based on STWLC30

- 5V output voltage

- Space saving solution: 6x10mm
  1mm total thickness (PCB + BOM)
- Coil Rx –Wurth 760308101309

Max. Z @ 2.5 W: 4 mm
Output Leakage: <1uA

67% total system efficiency with 1mm gap

Flip Chip **2.68mm x 4.026mm**

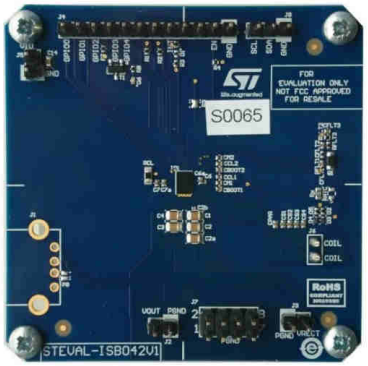
Available now

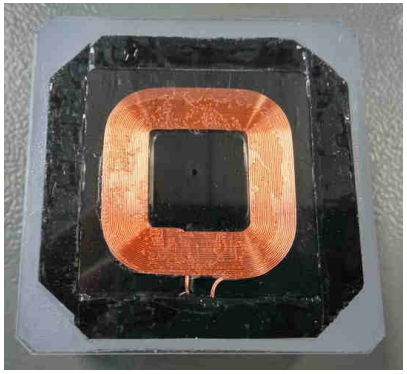
life.augmented

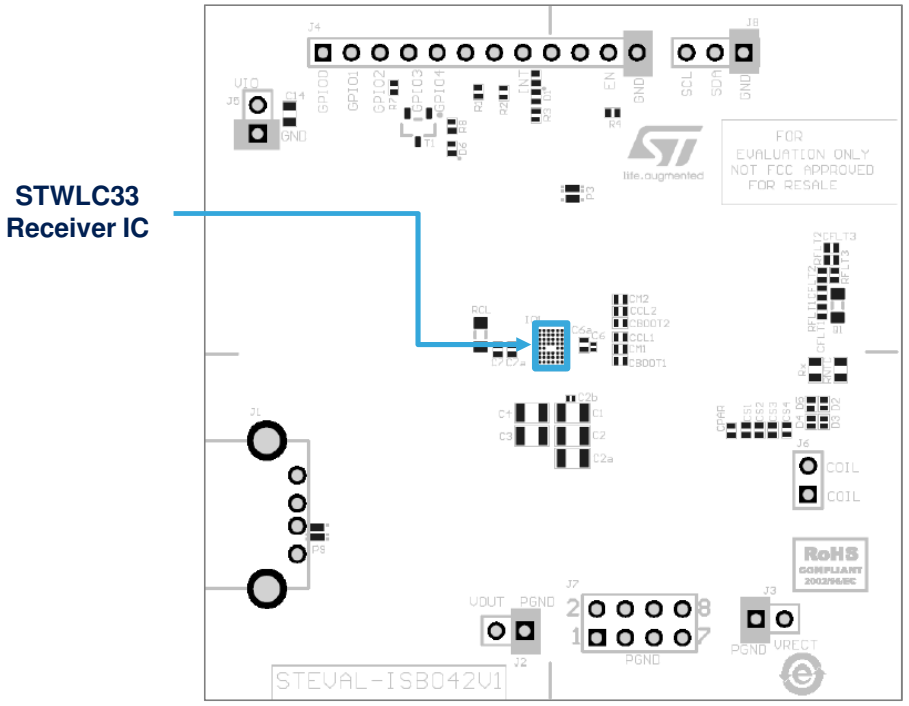
Receiver Reference Board

STWLC33 – 5W/15W Qi/AirFuel STEVAL-ISB042V1

- 4-Layer PCB and single-side placement
- Qi 1.2.3 and AirFuel Inductive certified
- 42x42mm coil
- TX capable up to 3W with same coil
- BPP/EPP RX auto-switch (it senses TX type)

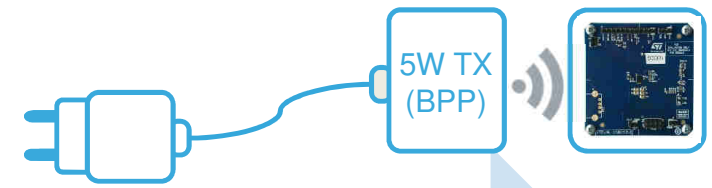






life.augmented

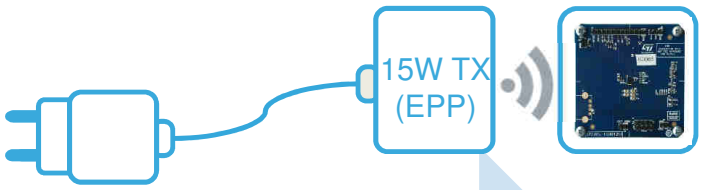
STWLC33 5W & 15W use cases



The TX advertises itself as BPP 5W TX to the STWLC33

STWLC33 will set itself to 5V output as a 5W BPP RX

STWLC33 paired to a 5W TX



The TX advertises itself as EPP 15W TX to the STWLC33

STWLC33 will set itself to 10V output as a 15W EPP RX

STWLC33 paired to a 15W TX

life.augmented

2.5-15W Wireless Battery Charger RX

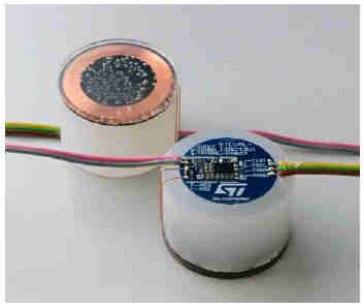
STWLC3x

STWLC30 – STEVAL-ISB043V1

2.5 Watts

Qi-based Wireless Receiver for Wearables

- Up to 2.5W output power
- 26mm Coil
- Application area 10x6mm
- Total system efficiency 70%
- Optimized for 5V output operation
- Foreigh Object Detection (FOD)
- I²C interface
- CSP 2.68x4.026mm, 400 µm pitch 52 balls



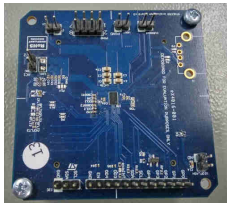
Available

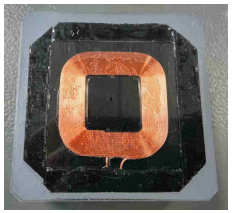
STWLC33 – STEVAL-ISB042V1

5/15 Watts

Qi/AirFuel Inductive Certified Wireless Receiver with <u>Transmit capability</u>

- Up to 15 W output power in RX mode and **3W in TX mode**
- Qi 1.2 and AirFuel inductive standard
- Integrated high efficiency synchronous rectifier
- Low drop regulator
- Total system efficiency up to 80%
- 32-bit, 32 MHz ARM Cortex microcontroller with 32 kB FW memory, 8 kB RAM memory, 4 kB NVM for configuration
- 10-bit 8-channel A/D converter
- Up to 5 configurable GPIOs
- Integrated 5 V LDO for auxiliary features
- Precise voltage and current measurements for FOD function
- Overvoltage clamp protection
- HW FSK and ASK demodulators
- I²C interface
- CSP 3.97x2.67 mm, 400 µm pitch 52 balls





Available

life.augmented

What's Next?

life.augmented

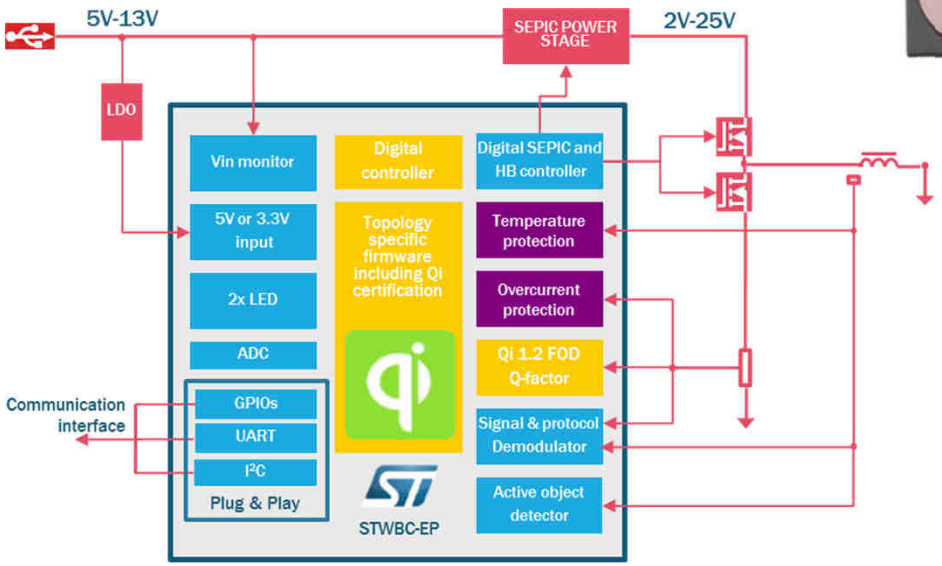
STWBC-EP 15W Fixed Frequency

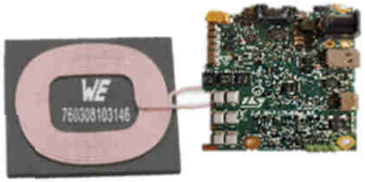
MP-A15 Single Coil

- Qi 1.2.4 EPP compliant
  SEPIC + Half bridge topology
- MP-A8 coil
  with large active area (25x30mm)
- EU RED Compliant
  127.7kHz fixed frequency operation
- USB-QC compatible input
- 2 Layers PCB with coil on top

iPhone® 7.5W fast charge

SAMSUNG 9W fast charge





Available End of Q1 2019

life.augmented

Wireless Charging
ST Strengths

- Member of WPC and AirFuel Alliance
- System knowledge of both TX and RX sides
- BCD Technology well matches voltages present in these architectures
- IPs availability and integration capability
- TX and RX Silicon BOM fully covered by ST

Transmitter

Receiver

Thank You!

life.augmented