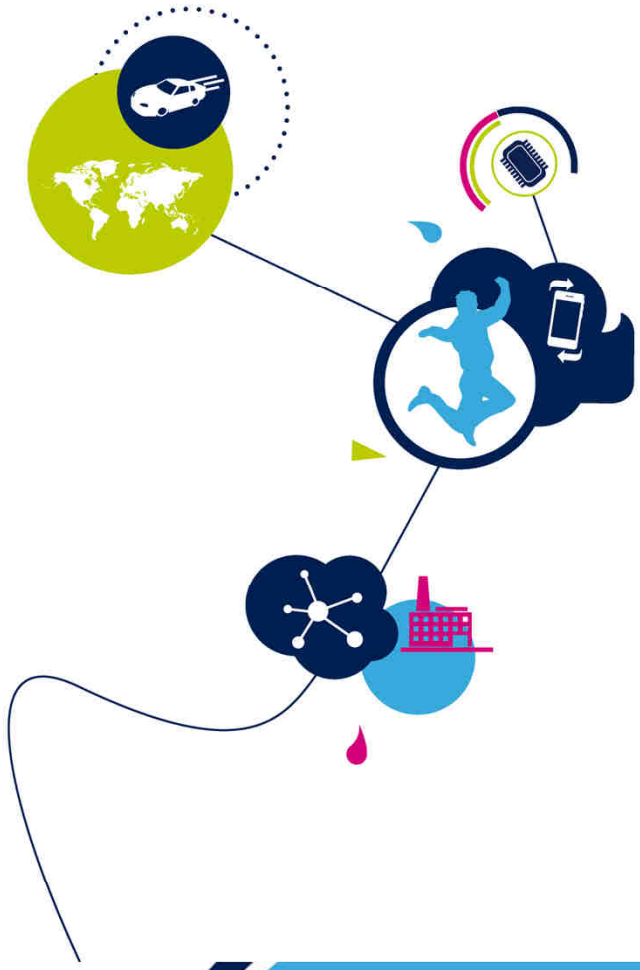
Wireless Charging in Consumer Applications

Paolo Battezzato
Applications Engineering Manager



life.augmented

Technology Tour 2019
Vancouver, BC | September 24

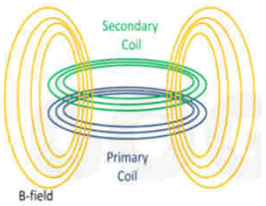
Agenda

- 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

Wireless Power at a Glance

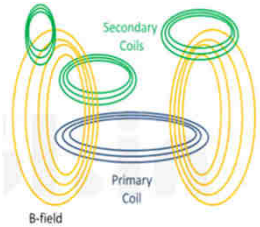
Similar technology
Different Implementation

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 (BPP): 5W (rel 1.2.4)
- Extended Power Profile (EPP): 15W (rel 1.2.4)
- Medium Power Working Group up to 200W
- Kitchen Working Group up 2.4kW
- Resonant (Under Consideration)

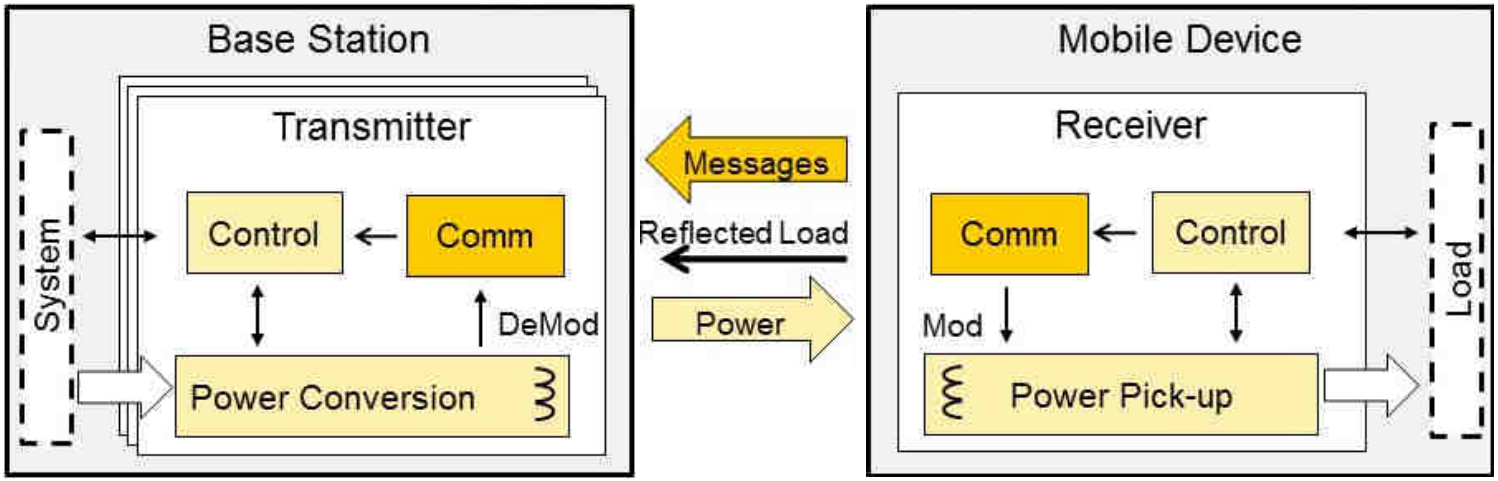
AirFuel™ Alliance
PMA Power Matters Alliance

- 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)



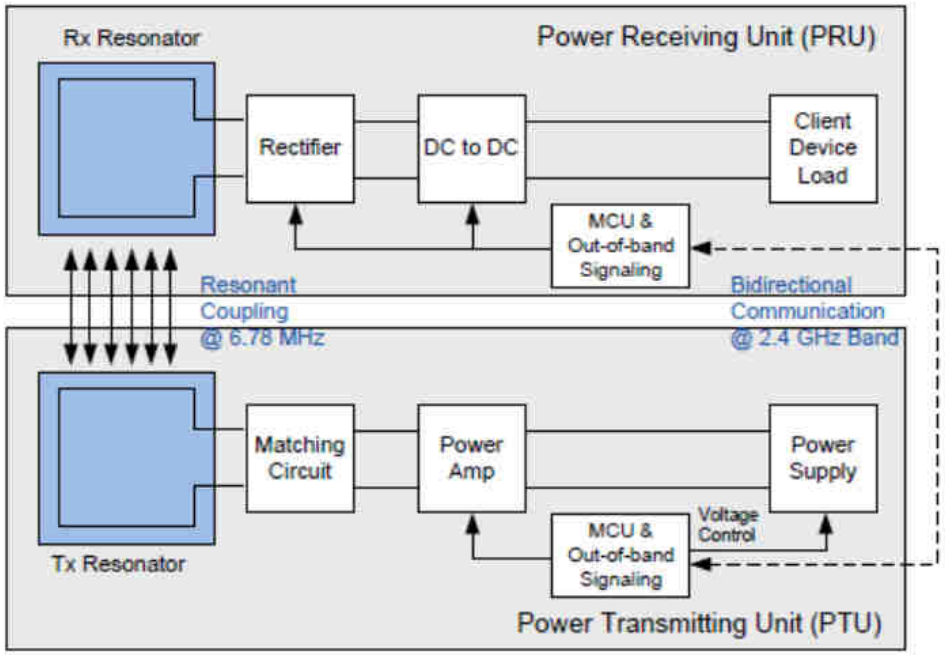
- Operating Frequency is 110-205kHz
- One Base Station typically powers one Mobile Device
- In-band digital link is used for identification of compatible devices and control of power levels (operates through the same coils used for power transfer)

life.augmented

Magnetic Resonance Power Transfer

AirFuel Resonant

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



life.augmented

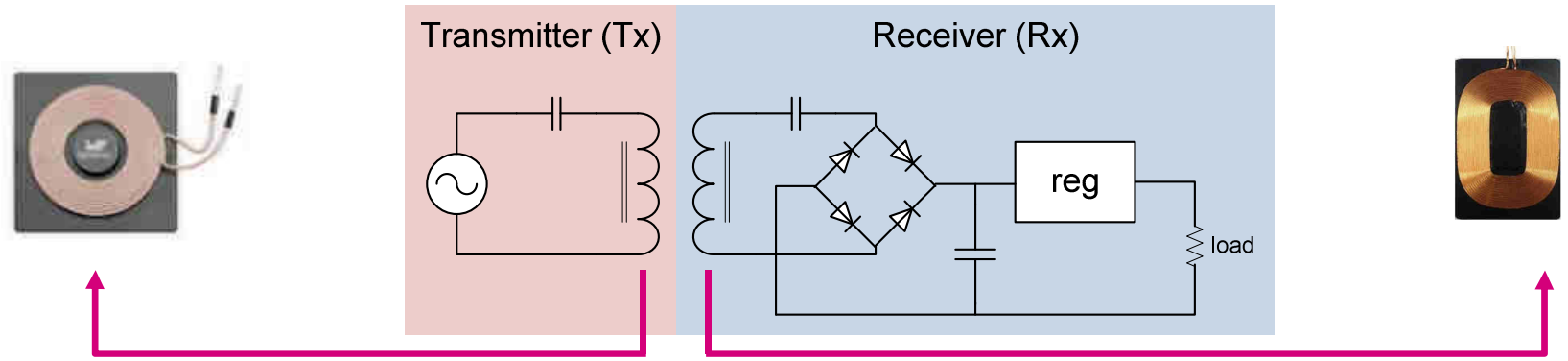
Introduction to WPC Qi Battery Charging

(Magnetic Induction)

life.augmented

Power Transfer Principles

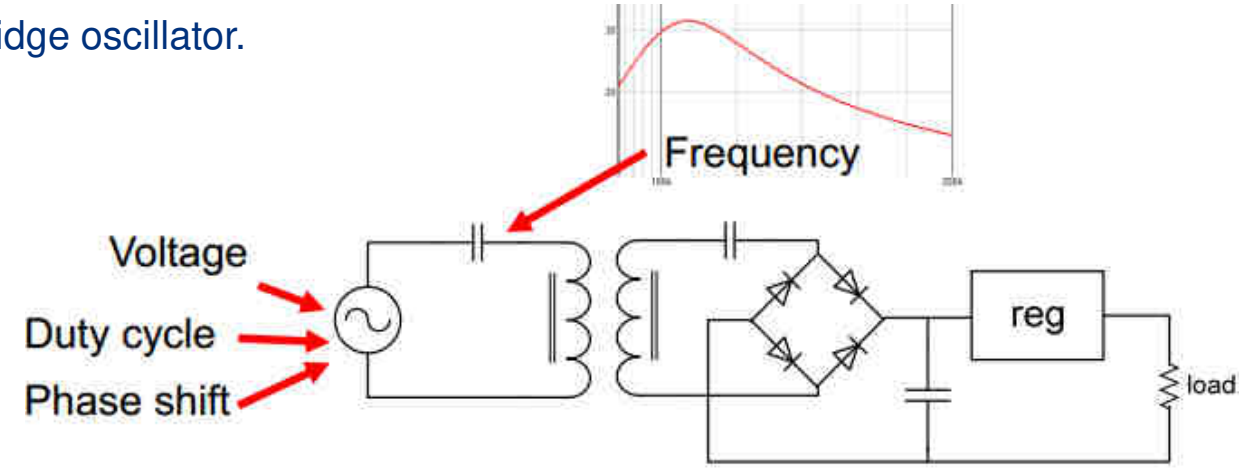
- Tightly coupled wireless charging technology uses magnetic induction to transfer power from a transmitter (TX) to a receiver (RX)
- The magnetic field is generated by a **coil on the TX side**. The field is captured by a **coil on the RX side**. The field works through air, no magnetic circuit links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



life.augmented

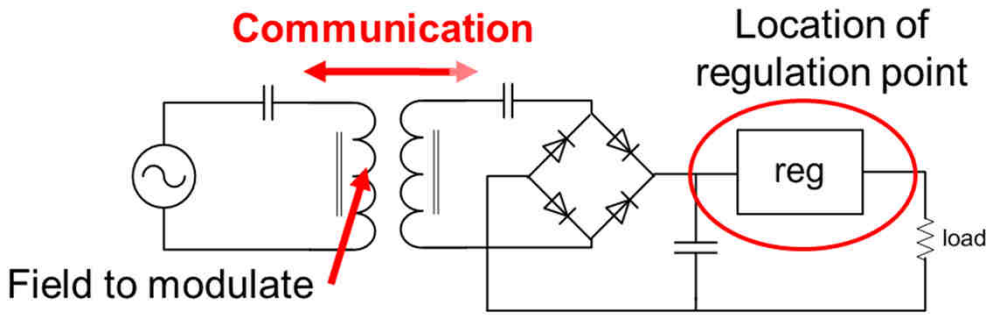
Magnetic Field Control
by Adjusting Power

- 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

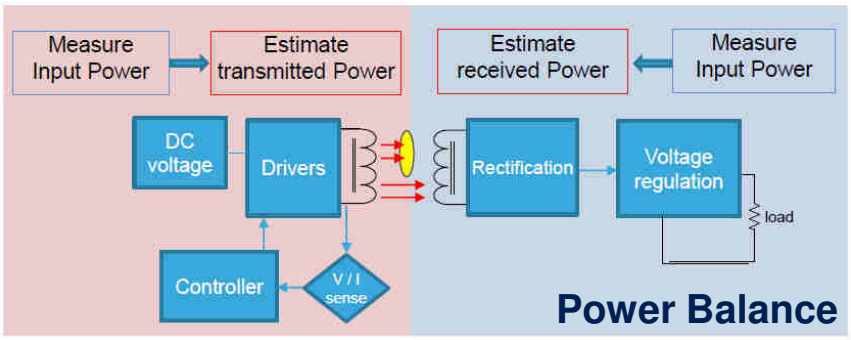
- Because there are too many variables (RX/TX coupling, RX & TX coils, load, …), the TX cannot set the regulation point by itself. The RX will have to pass data to the TX about the regulation set point.
- This communication channel can also be used for auxiliary purposes and extended to bi-directional communication
- Qi 1.2.4 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**

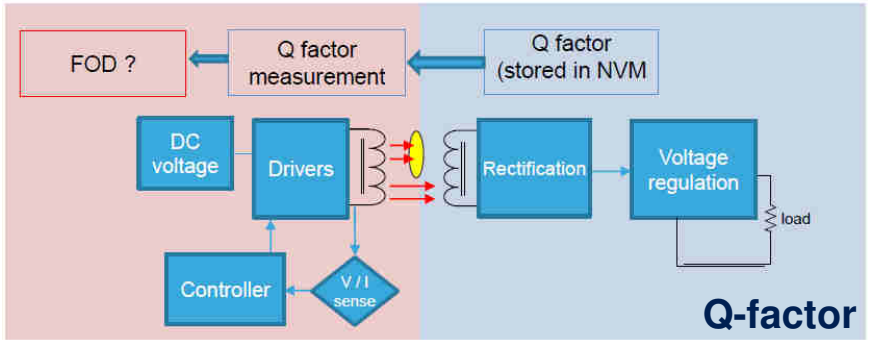


RX Presence Detection and FOD

- 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 1.2.4 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



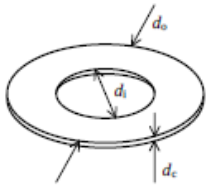


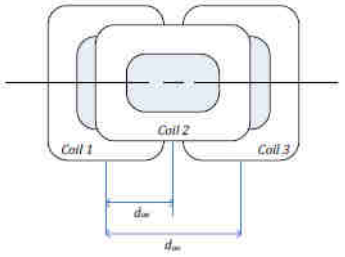
life.augmented

Qi 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

life.augmented

Source: WPC Qi specifications, Version 1.2

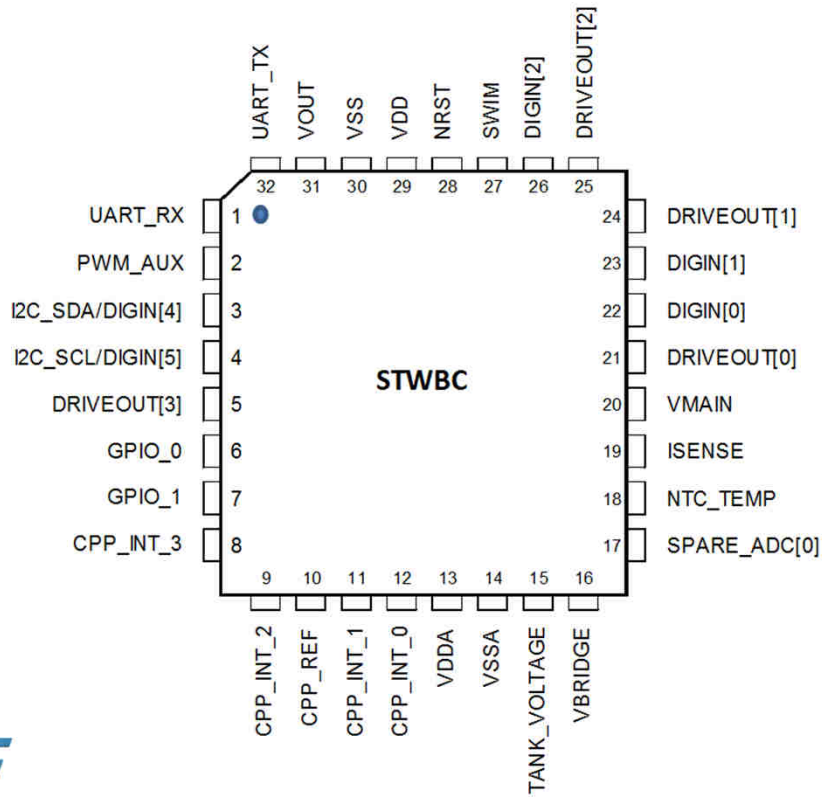
STWBC

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)

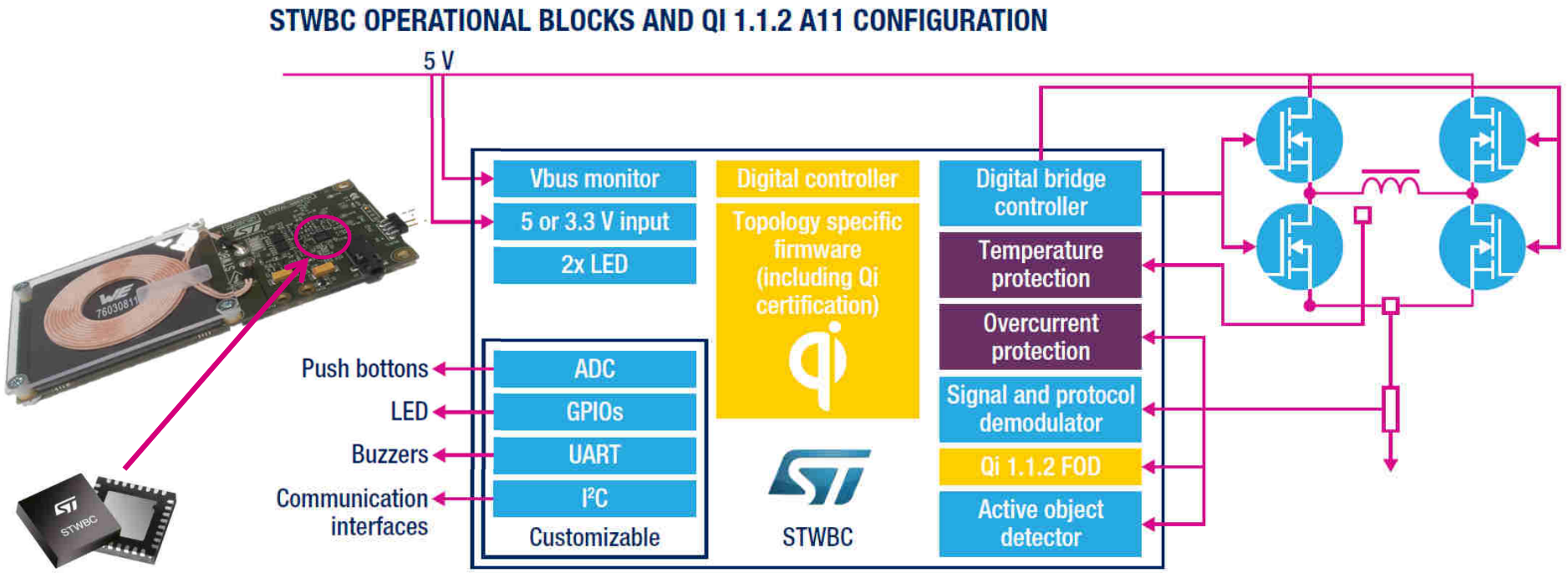
General application features:

- 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

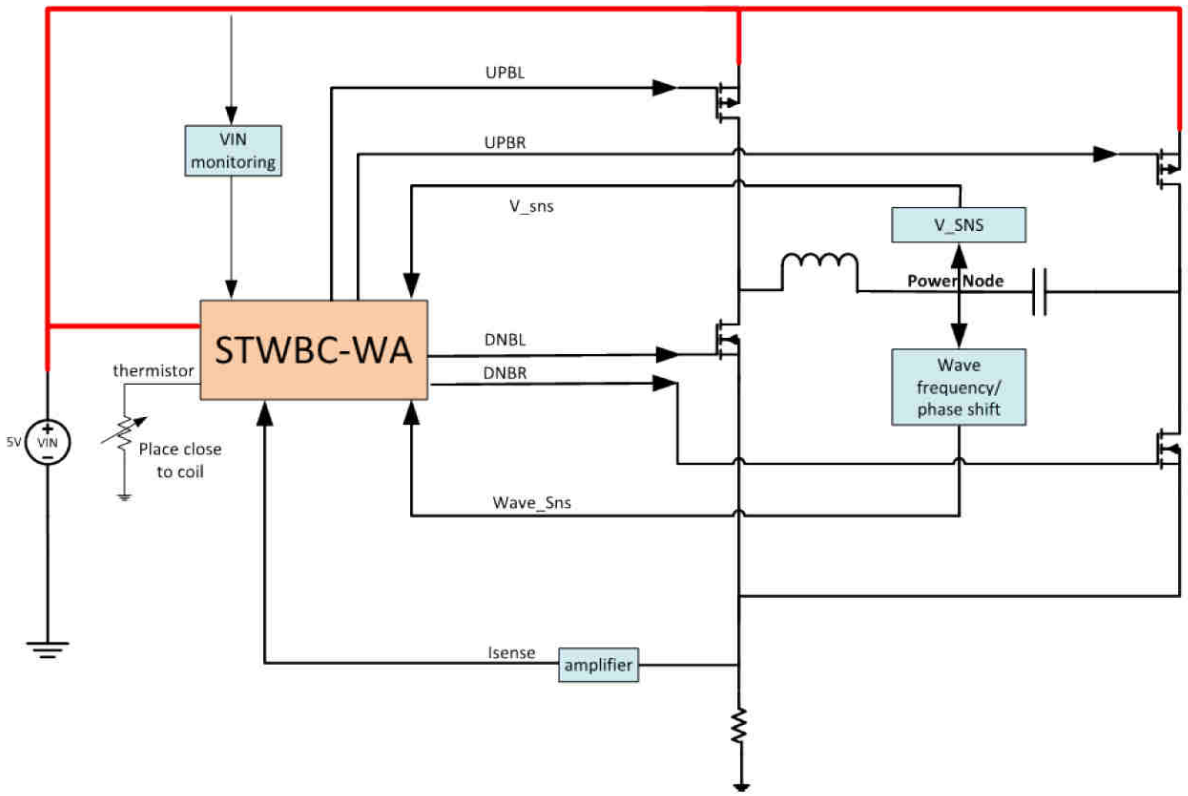
STWBC Transmitter

Qi Reference Designs and Boards

life.augmented

Qi-based 2.5W Wearable TX Configuration

STWBC-WA



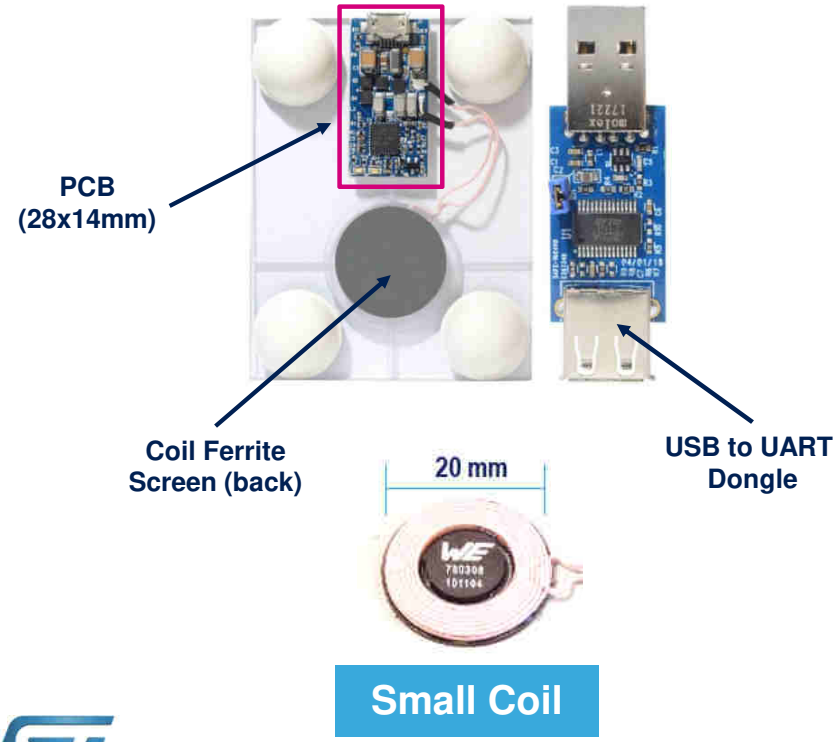
- System, bridge control and Qi protocol are handled by the STWBC-WA
- The transmitter is based on a Full-Bridge topology
- The inverter bridge is supplied by 5V input voltage
- Support up 2.5W with 20mm coil
- Scalable down to 1W with even smaller coil (**15mm**)

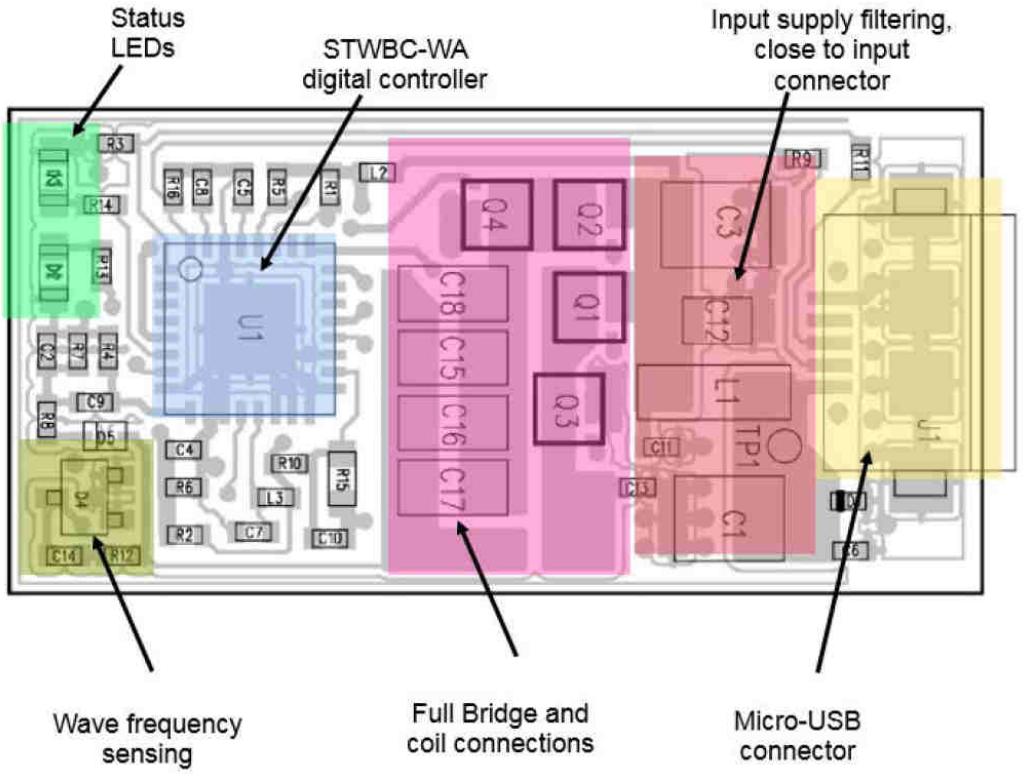
life.augmented

Qi-based Wearable TX Reference Board

STWBC-WA – 2.5W STEVAL-ISB045V1

- 2-Layer PCB and single-side placement



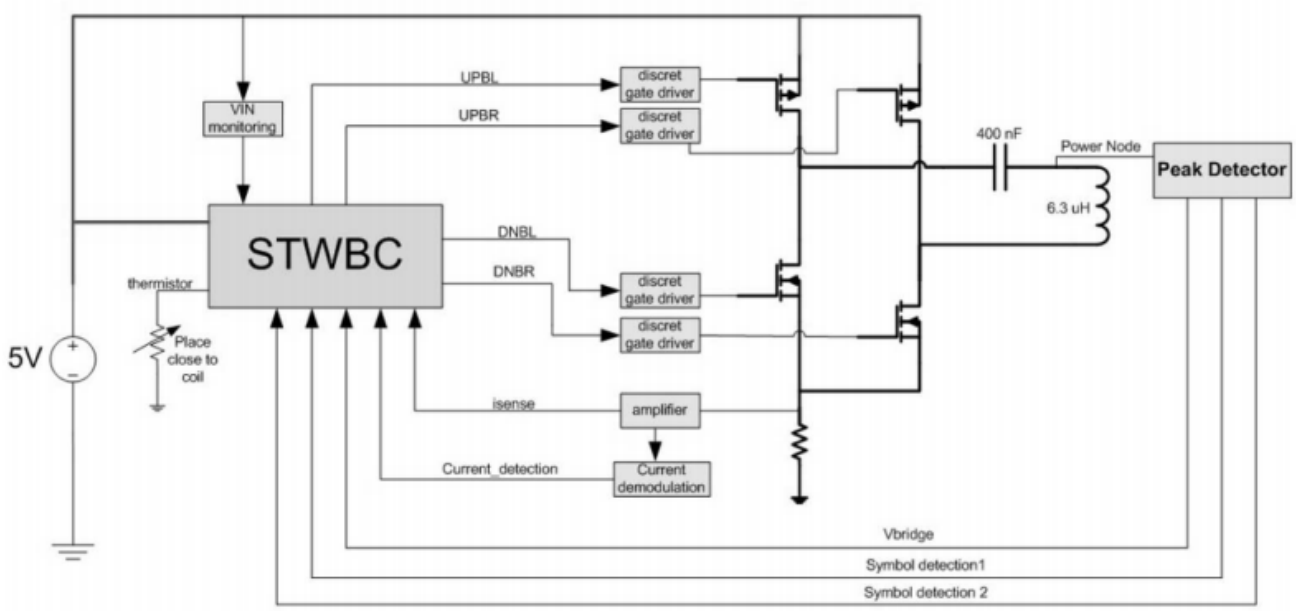


life.augmented

5W BPP Transmitter Configuration

STWBC A-11

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

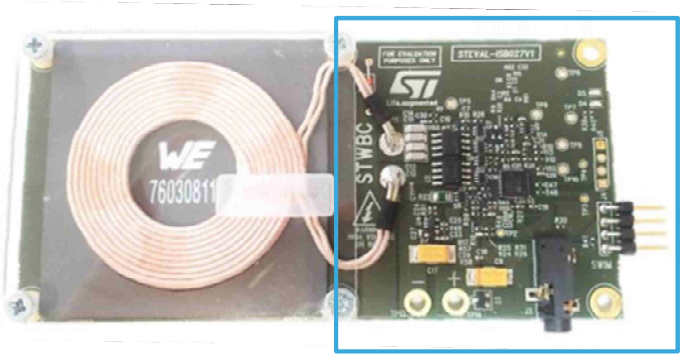


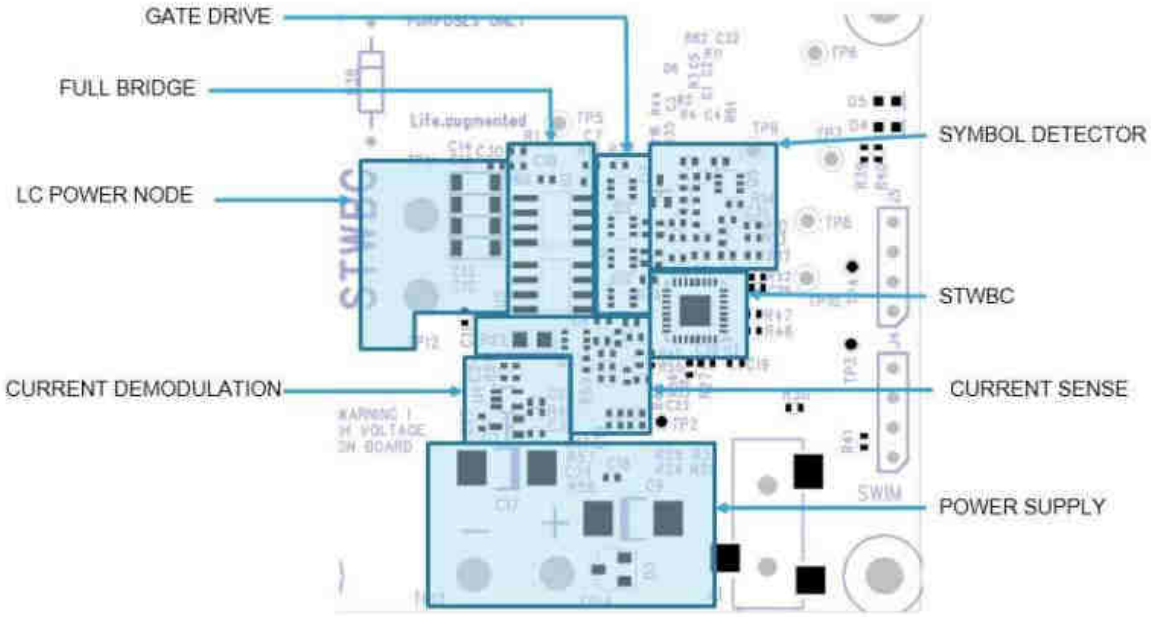
life.augmented

Transmitter Reference Board

STWBC 5W A11 – STEVAL-ISB027V1

2-Layer PCB and single-side placement





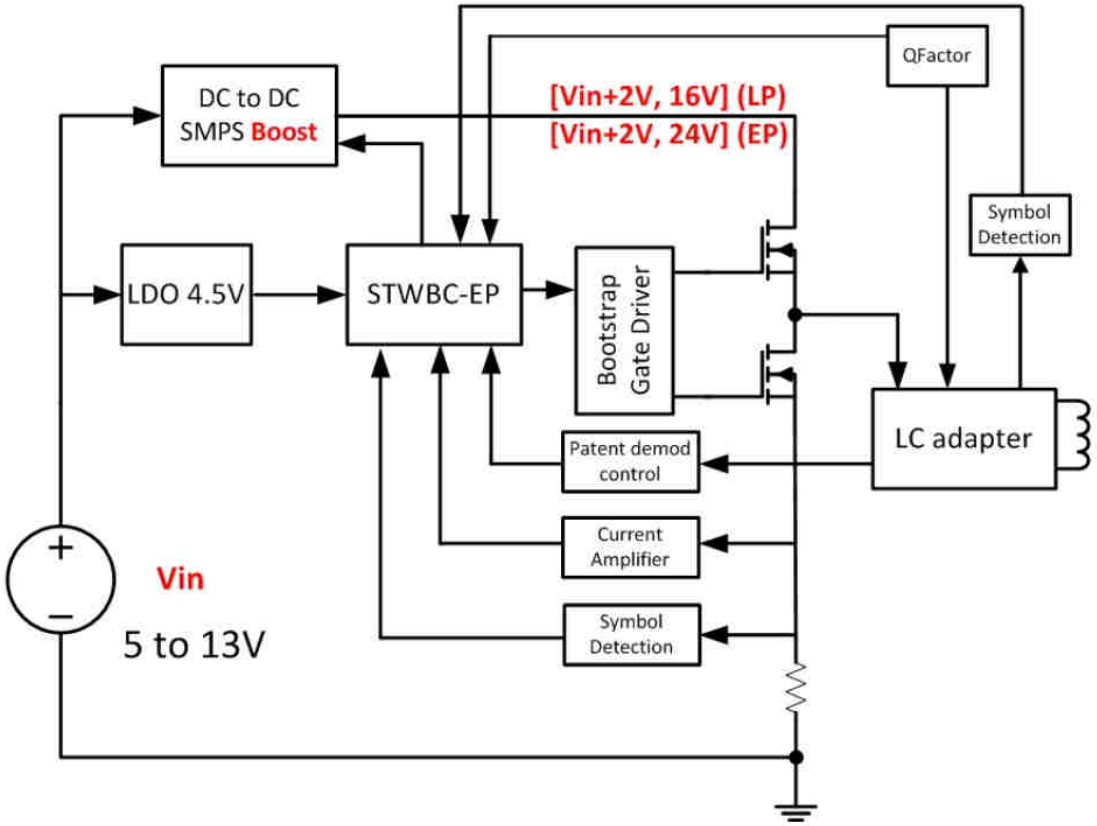
Standby

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

life.augmented

15W EPP Transmitter Configuration

STWBC-EP MP-A10



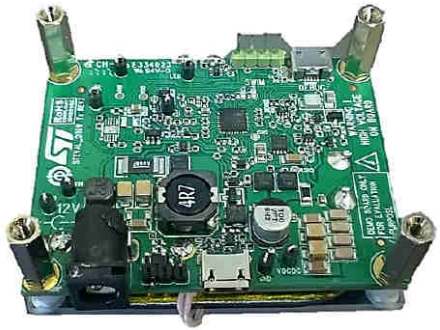
- Qi 1.2.3 EPP (Extended Power Profile) up to 15W
- Half-Bridge topology
- Support Basic Power Profile as well, up to 5W
- Wide supply voltage range, 5 to 13V
- Voltage and Frequency control

life.augmented

Transmitter Reference Board

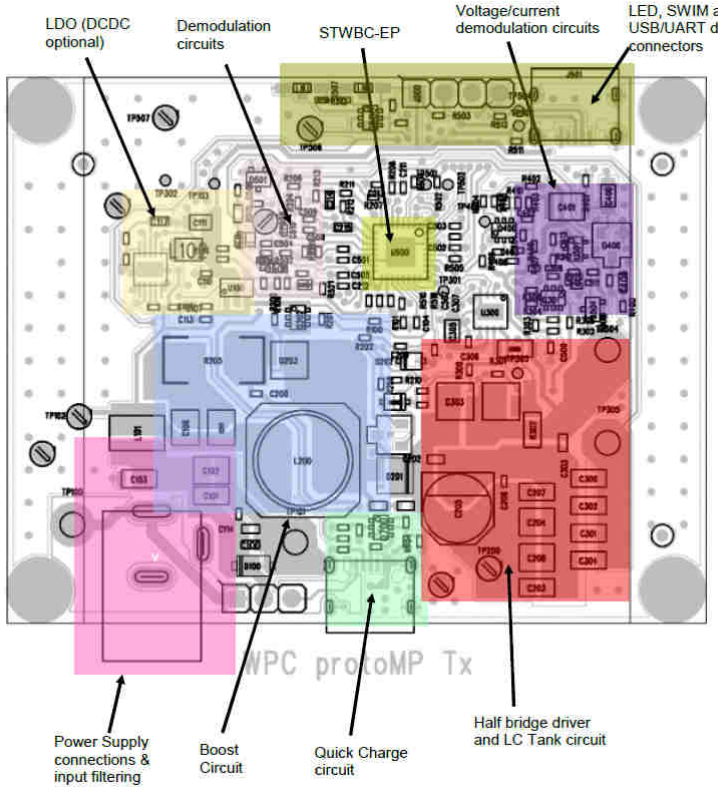
STWBC-EP 15W MP-A10 STEVAL-ISB044V1

2-Layer PCB and single-side placement



StandBy

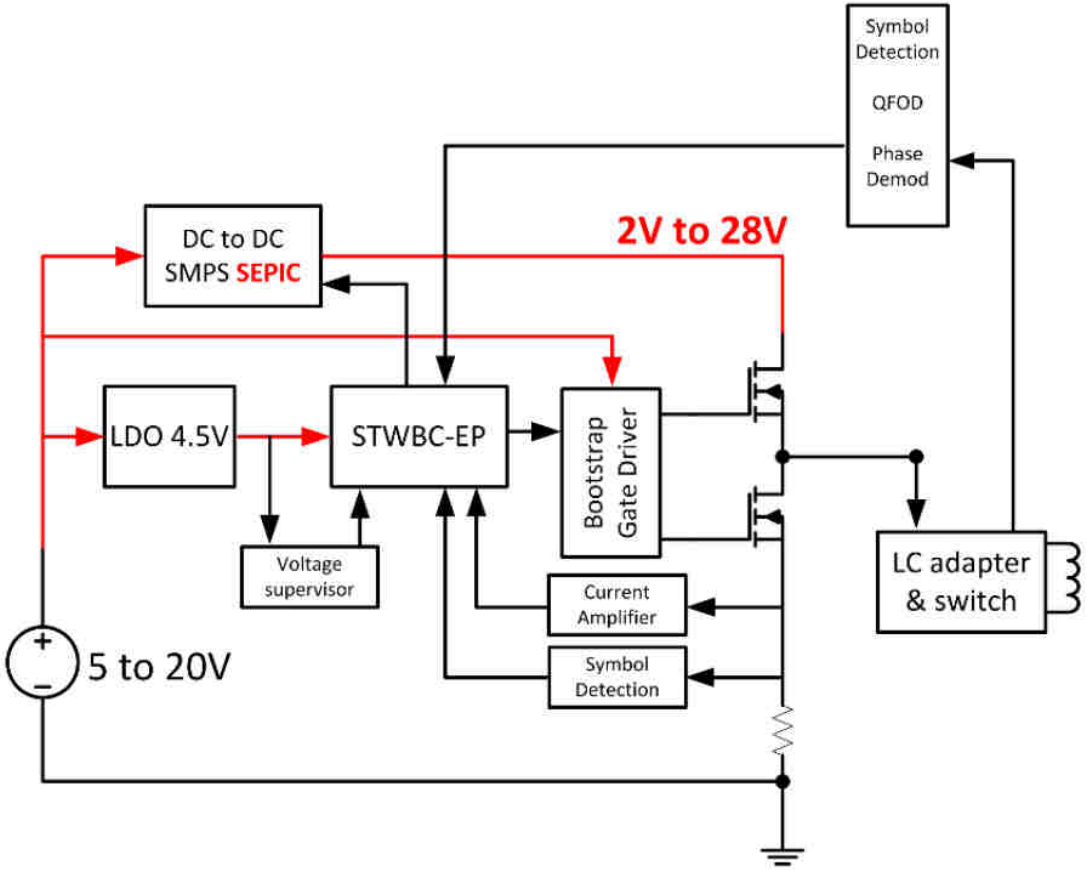
- **16mW** consumption
- Ping active
- FOD active



life.augmented

15W EPP Transmitter Configuration

Fixed Frequency STWBC-EP MP-A15



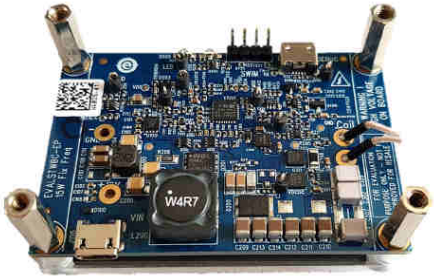
- Qi 1.2.4 EPP (Extended Power Profile) up to 15W
- Half-Bridge topology
- Support Basic Power Profile as well, up to 5W
- 127.7 kHz fixed frequency
- **Fast Charge support**
- Wide supply voltage range, 5 to 20V, with Quick Charge

life.augmented

Transmitter Reference Board

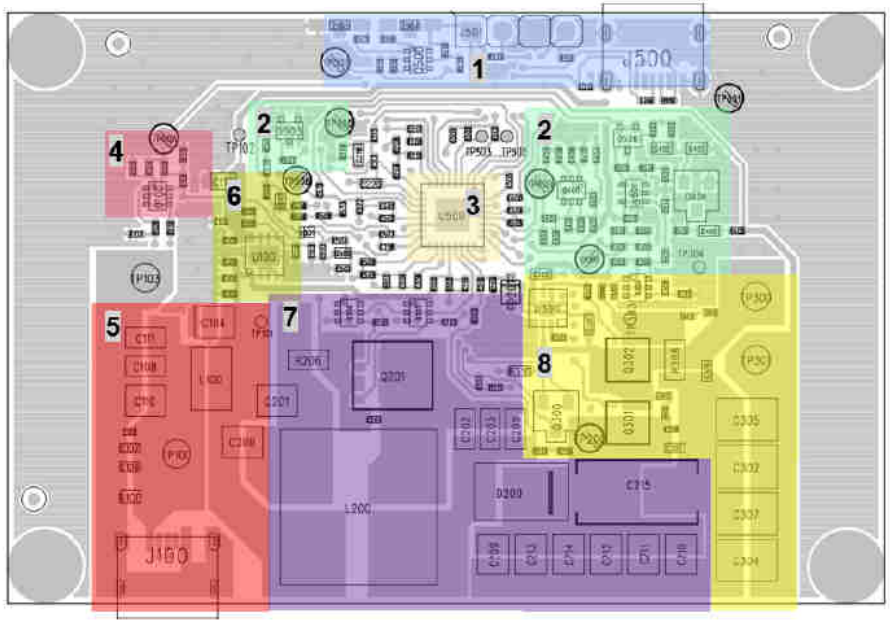
STWBC-EP 15W MP-A15 EVALSTWBC-EP

2-Layer PCB and single-side placement



1. LED, SWIM and USB/UART debug connectors
2. Voltage, current and phase demodulation circuits
3. STWBC-EP
4. Quick charge circuit
5. Power supply connection and input filtering
6. LDO
7. Sepic: coil and power ircuit
8. Half bridge: gate driver, bridge mosfets, tank capacitor and coil

EVALSTWBC-EP evaluation board functional blocks



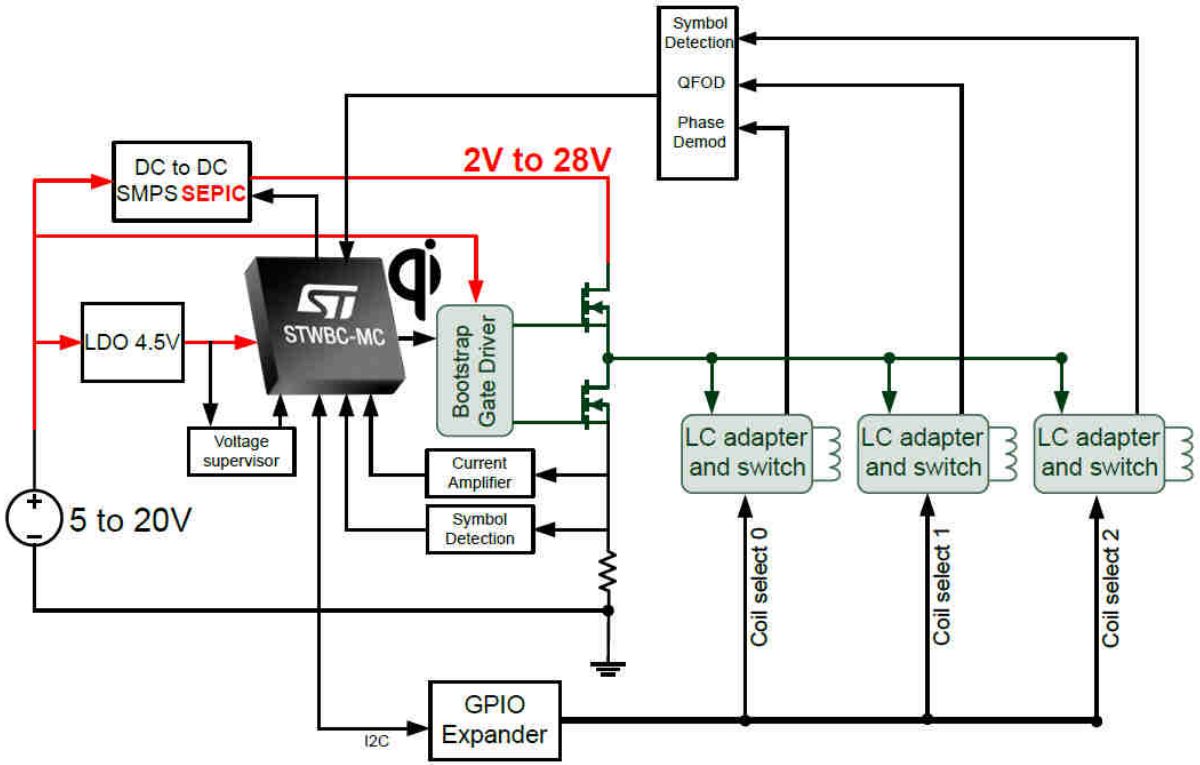
StandBy

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

life.augmented

3-coil 15W EPP Transmitter Configuration

Fixed Frequency STWBC-MC MP-A15



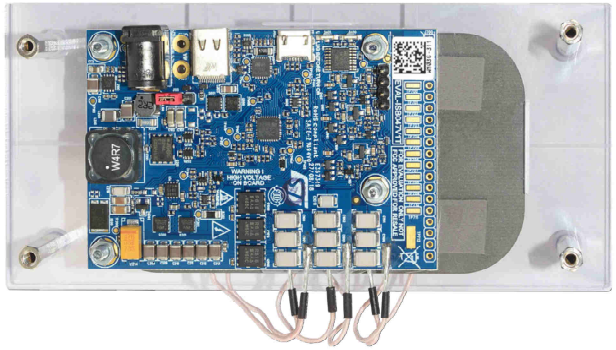
- Qi 1.2.4 EPP (Extended Power Profile) up to 15W and BPP up to 5W
- 127.7 kHz fixed frequency
- **Fast Charge support**
- Wide supply voltage range, 5 to 20V
- USB-C/PD with support for legacy 5V USB

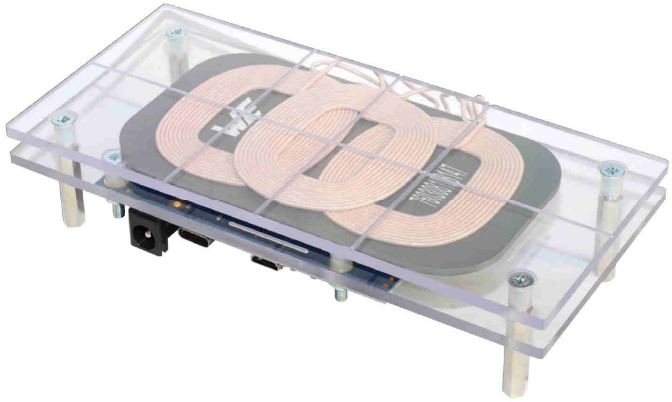
life.augmented

3- coil Transmitter Reference Board

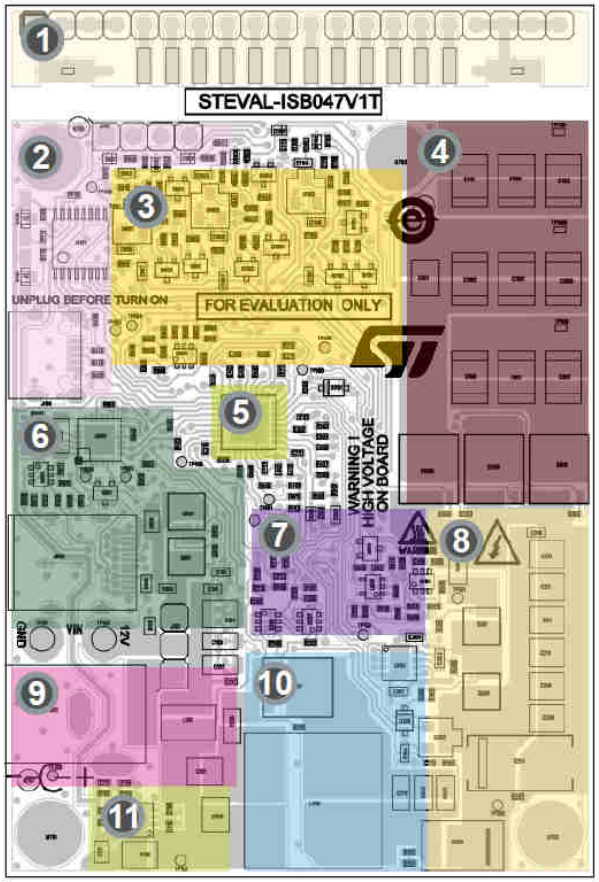
STWBC-MC 15W MP-A15 STEVAL-ISB047V1

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

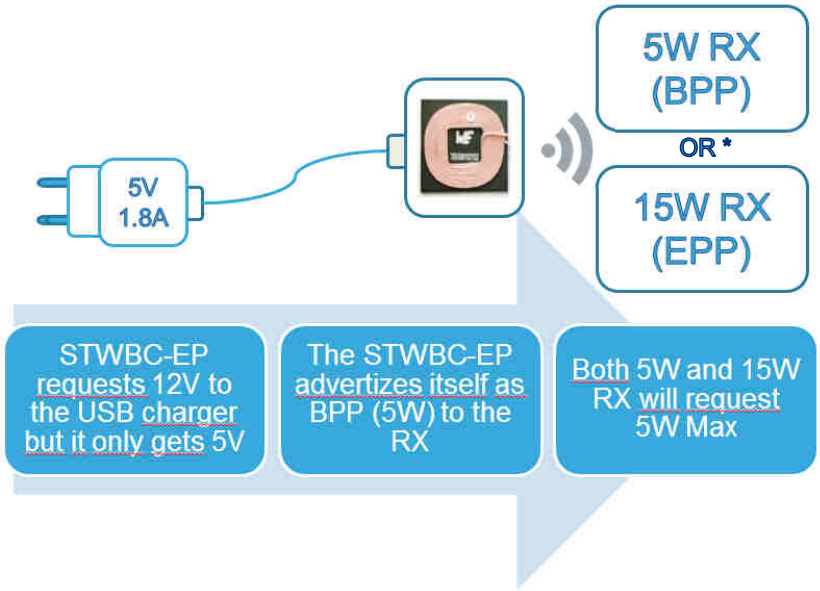


Standby

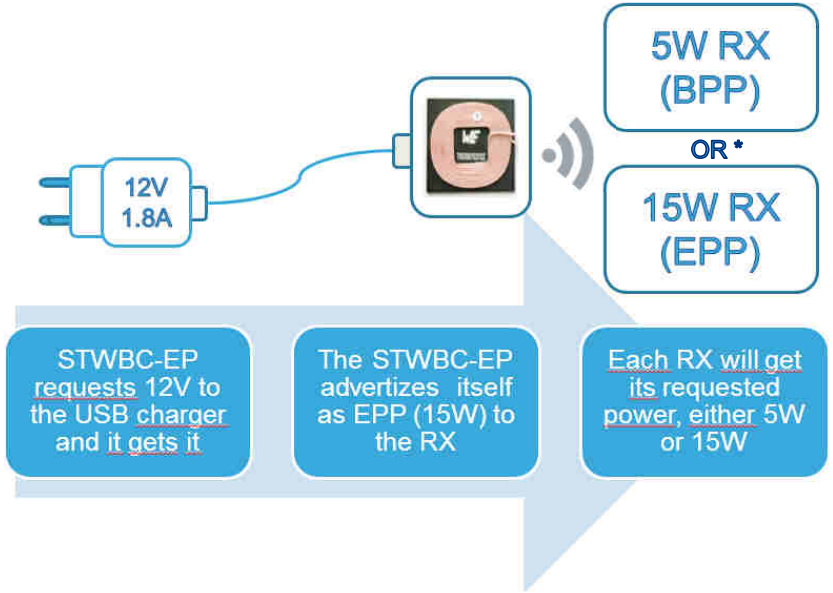
- **17mW** consumption
- Ping active
- FOD active

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 current Qi spec

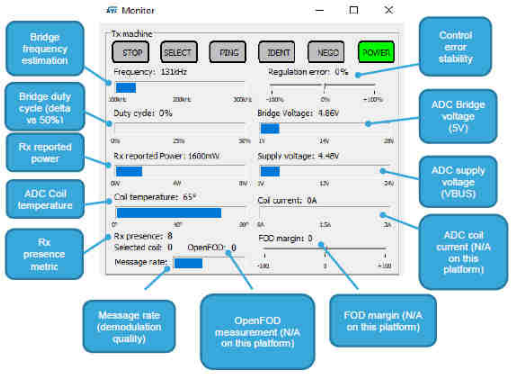
Wireless Battery Charger TX – up to 5W

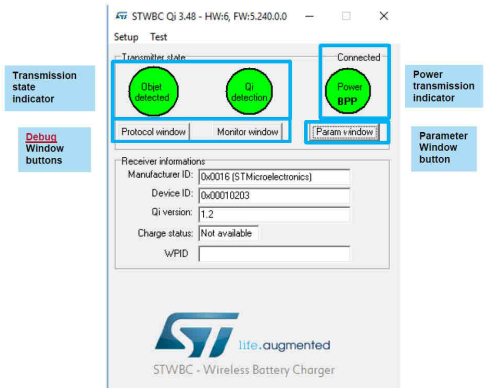
STWBC-WA - STEVAL-ISB045V1

TX for Wearable (2.5W)

- IC: STWBC-WA
- **20 mm Coil**
- 2.5W delivery at RX side
- Scalable to **1W** with **15mm** coil
- 5V Supply
- Only 1.6mW stand-by power
- 70% typical efficiency with 2.5W RX P_{out}
- Compatible with STEVAL-ISB043V1 RX
- GUI for evaluation and testing

Available





STWBC - STEVAL-ISB027V1

Certified Wireless Charger (5W)

- IC: STWBC
- Qi A11 design, 1.1.2 Certified (1.2 BPP Ready)
- Foreign Object Detection (FOD)
- Active presence detection
- 5V supply
- Turn Key or API customization
- Stand-by efficiency:
  - 3mW consumption
  - FOD active in standby
- GUI for evaluation and testing

Available

life.augmented

Wireless Battery Charger TX – up to 15W

STWBC-EP - STEVAL-ISB044V1

Certified Wireless Charger (15W)

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

Available

STWBC-EP – EVALSTWBC-EP

Certified Wireless Charger (15W)

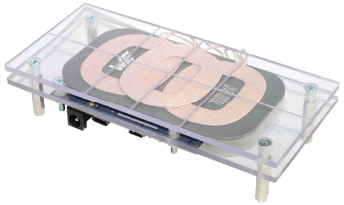
- IC: STWBC-EP
- MP-A15 Design, Qi 1.2.4 Certified
- BPP and EPP (5W/15W)
- Fast Charge Support
- Foreign Object Detection (FOD)
- 5-20V input voltage range with QC
- Half-Bridge topology
- 127.7kHz Fixed Frequency
- GUI for evaluation and testing

Available

STWBC-MC - STEVAL-ISB047V1

Certified Wireless Charger (15W)

- IC: STWBC-MC
- 3-coil for improved positioning freedom
- Automatic selection of best coupling coil
- Qi 1.2.4 Certified
- BPP and EPP (5W/15W)
- Fast Charge Support
- Foreign Object Detection (FOD)
- 5-20V Vin with USB-C/PD
- Half-Bridge topology
- 127.7kHz Fixed Frequency
- GUI for evaluation and testing



Available

life.augmented

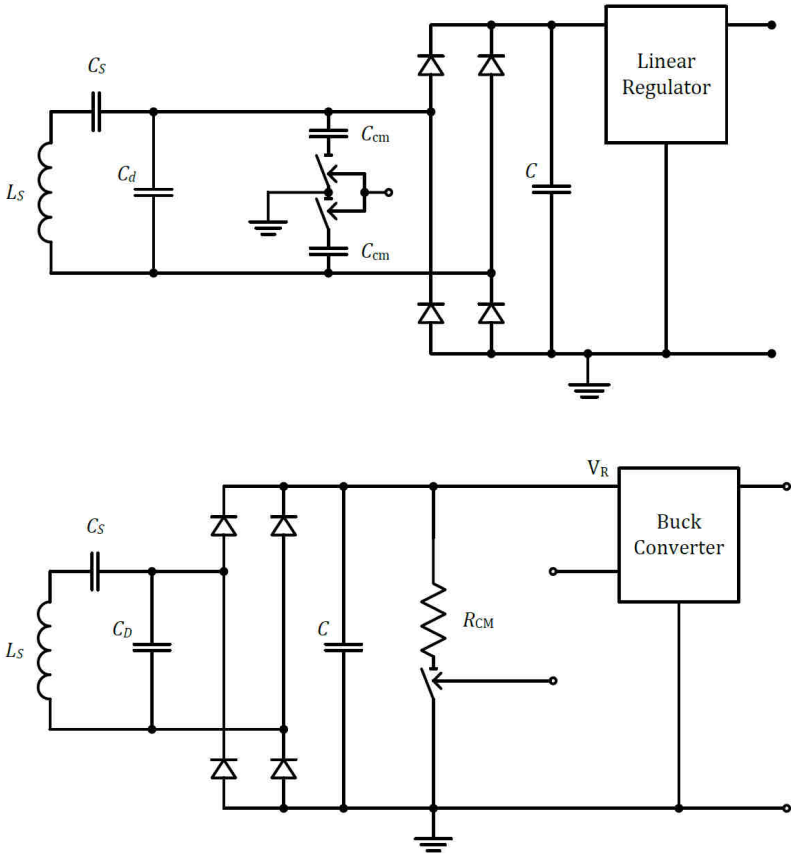
STWLC

Qi Wireless Battery Charger Receiver

life.augmented

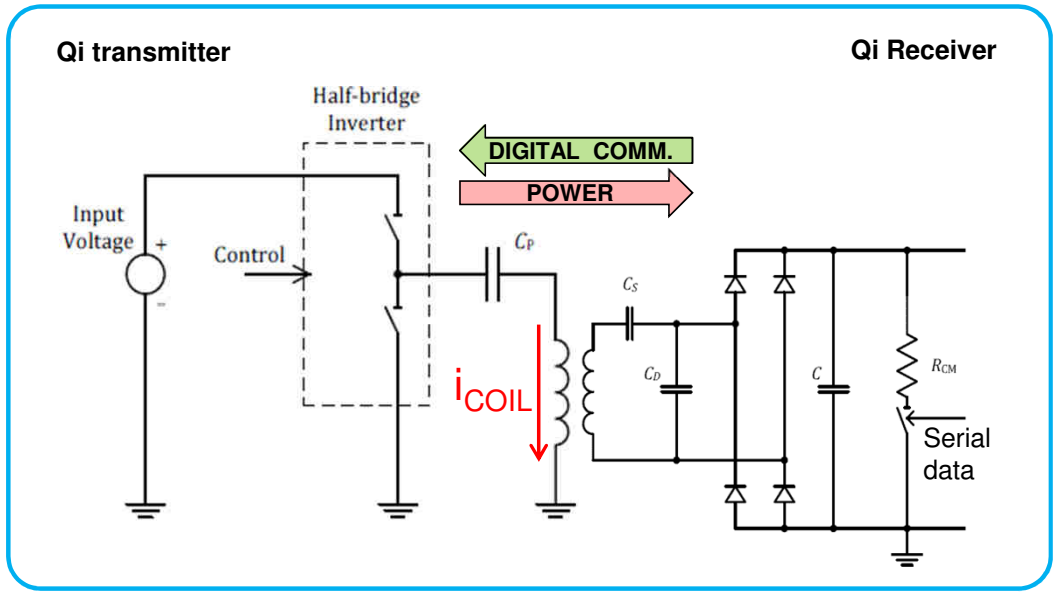
Qi Receiver Typical Configurations

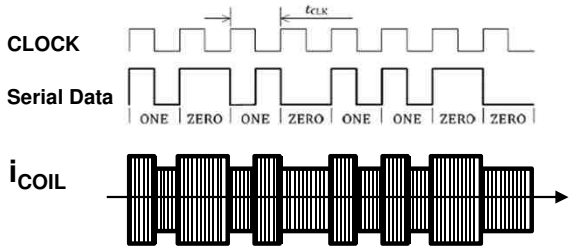
- C_S sets the reference100kHz resonant point
- C_{cm} or R_{cm} is used to modulate the load current to communicate with the Transmitter
- The Full-Bridge rectifier circuit is usually a Synchronous Rectification stage to maximize efficiency
- The Linear Regulator operates at low drop to minimize losses and thus power dissipation



Source: WPC Qi specifications, Version 1.2.3

Qi RX to TX Communication





Data rate	2kbps
Bit Encoding	Differential bi-phase (*)

(*) 1 transition per clock cycle = Zero
2 transitions per clock cycle = One

Switching on/off a resistor or capacitor (or both) on the secondary side causes a variation in the primary current (i_{COIL}).
The i_{COIL} is **AM modulated (ASK)** by those variations, making possible to extract the serial data coming from the Receiver.

life.augmented

Qi Receiver Coil Examples

Figure 224. Secondary Coil of Power Receiver example 1

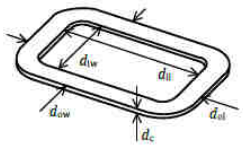


Table 155. Secondary Coil parameters of Power Receiver example 1

Parameter	Symbol	Value
Outer length	d_{ol}	$44.25^{\pm 0.25}$ mm
Inner length	d_{il}	$28.75^{\pm 0.25}$ mm
Outer width	d_{ow}	$30.25^{\pm 0.25}$ mm
Inner width	d_{iw}	$14.75^{\pm 0.25}$ mm
Thickness	d_c	0.6 mm
Number of turns per layer	N	14
Number of layers	–	1

Figure 228. Secondary Coil of Power Receiver example 2

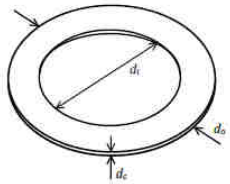


Table 156. Parameters of the Secondary Coil of Power Receiver example 2

Parameter	Symbol	Value
Outer diameter	d_o	$32^{\pm 0.25}$ mm
Inner diameter	d_i	$21.7^{\pm 0.6}$ mm
Thickness	d_c	$0.9^{\pm 0.2}$ mm
Number of turns per layer	N	9
Number of layers	–	2

Figure 231. Secondary Coil of Power Receiver example 3

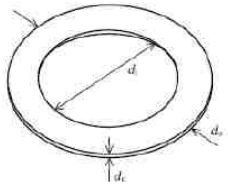


Table 157. Secondary Coil parameters of Power Receiver example 3

Parameter	Symbol	Value
Outer diameter	d_o	$47^{\pm 2}$ mm
Inner diameter	d_i	$24.25^{\pm 0.25}$ mm
Thickness	d_c	$0.9^{\pm 0.1}$ mm
Number of turns per layer	N	12
Number of layers	–	1

Figure 234. Secondary Coil of Power Receiver example 4

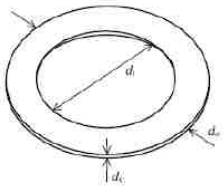


Table 158. Secondary Coil parameters of Power Receiver example 4

Parameter	Symbol	Value
Outer diameter	d_o	$47.0^{\pm 2}$ mm
Inner diameter	d_i	$28.0^{\pm 0.25}$ mm
Thickness	d_c	$1.8^{\pm 0.1}$ mm
Number of turns per layer	N	10
Number of layers	–	2

Figure 237. Secondary Coil of Power Receiver example 5

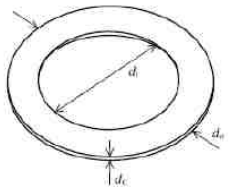


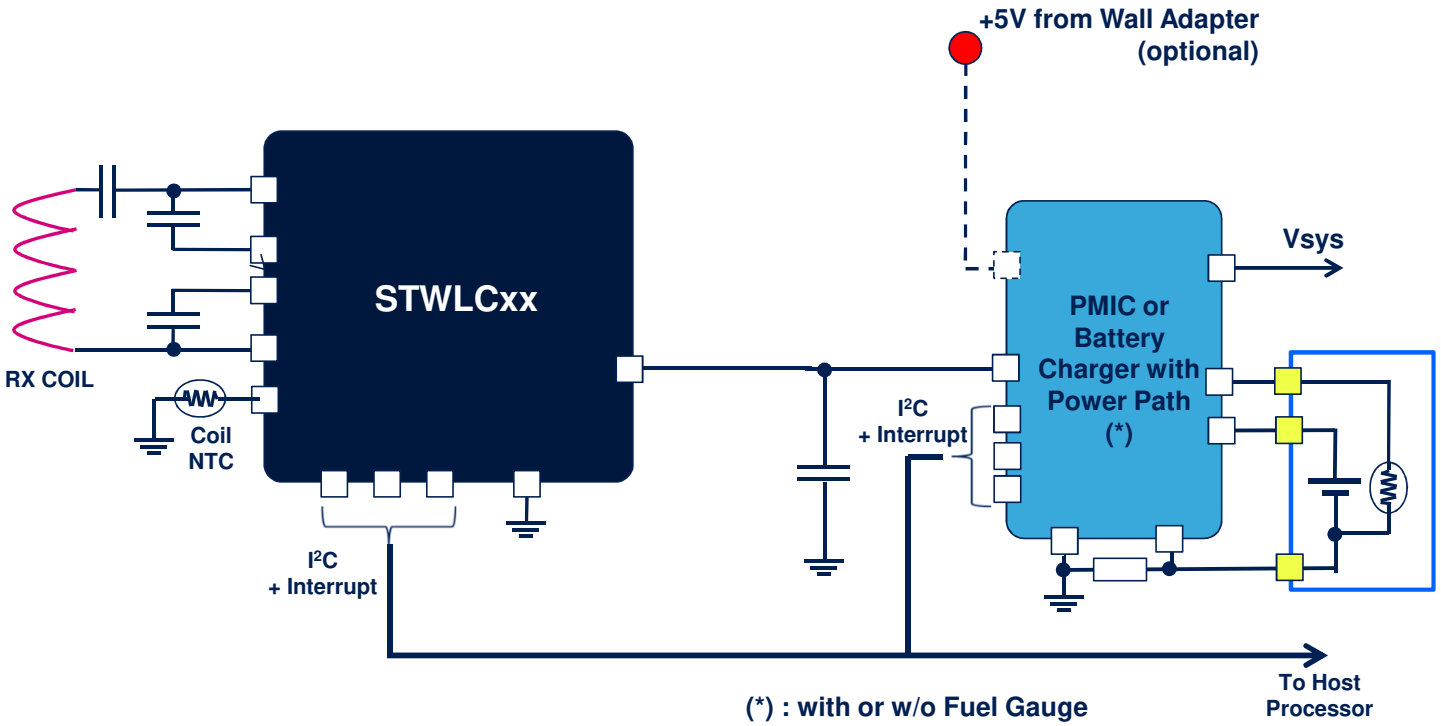
Table 159. Secondary Coil parameters of Power Receiver example 5

Parameter	Symbol	Value
Outer diameter	d_o	$40.0^{\pm 0.25}$ mm
Inner diameter	d_i	$22.0^{\pm 0.25}$ mm
Thickness	d_c	$0.29^{\pm 0.1}$ mm
Number of turns per layer	N	15
Number of layers	–	1

life.augmented

Source: WPC Qi specifications, Version 1.2.3

STWLCxx Simplified Application Diagram



Up to 20W Wireless Battery Charger RX

STWLC68

STWLC68

5/15/20 Watts

Qi Certified Wireless Receiver with Transmit capability

- Up to **20W** RX output power, with support for 5W BPP and 15W EPP modes
- Qi 1.2.4 certified (upgradable by OTP patch if needed)
- Up to 5W output power in Transmit Mode, coil dependent
- LDO output 5V-20V programmable in 25mV steps
- True 10 bit ADC
- I2C 400kbit/s and SPI 8Mbps for NFC
- 7 GPIO
- 40kB ROM, 8kB RAM
- OVP, OTP,OCP Protections
- High efficiency, 50-300kHz built-in Synchronous Rectifier
- Qi In-Band FSK/ASK or Out-Of-Band NFC communication
- 32bit 64Mhz Cortex M0+ embedded MCU

Available Q1 '20

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
- IP availability and integration capability
- TX and RX Silicon BOM fully covered by ST

Transmitter

Receiver

Thank You!

life.augmented