Wireless Charging in Consumer Applications

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Applications Engineering Manager

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ST Developers Conference

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Santa Clara Convention Center - Mission City Ballroom
Santa Clara, CA

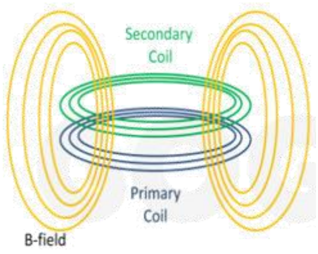
Agenda

- 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

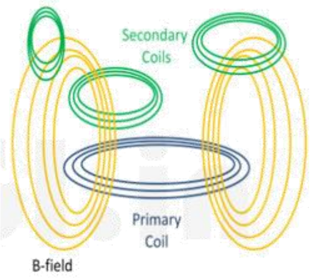
Magnetic induction



Inductive Power Transfer
Depends on close proximity and significant portion of the primary coil B fields intersecting the secondary coil

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



Resonant Power Transfer
Depends only on secondary coils intersecting a reasonable amount of primary coil flux lines

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

ST 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

qi

- Baseline Power Profile: 5W (rel 1.2.4)
- Extended Power Profile: 15W (rel 1.2.4)
- Medium Power Working Group up to 200W
- kitchen appliances 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

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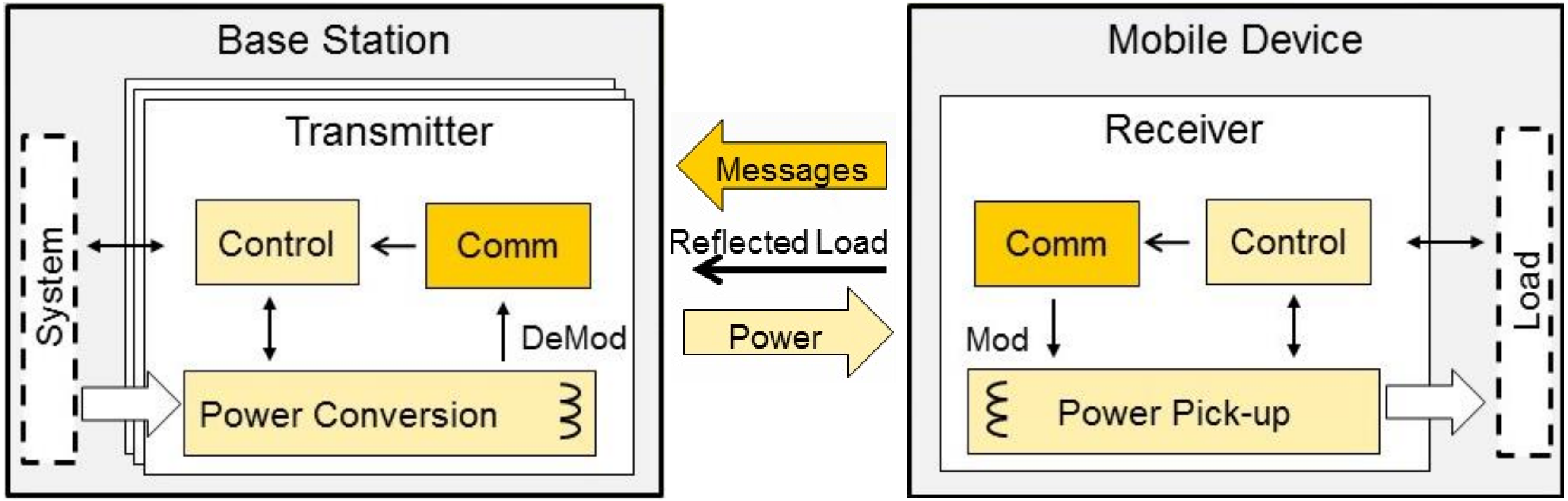
Magnetic Induction Power Transfer

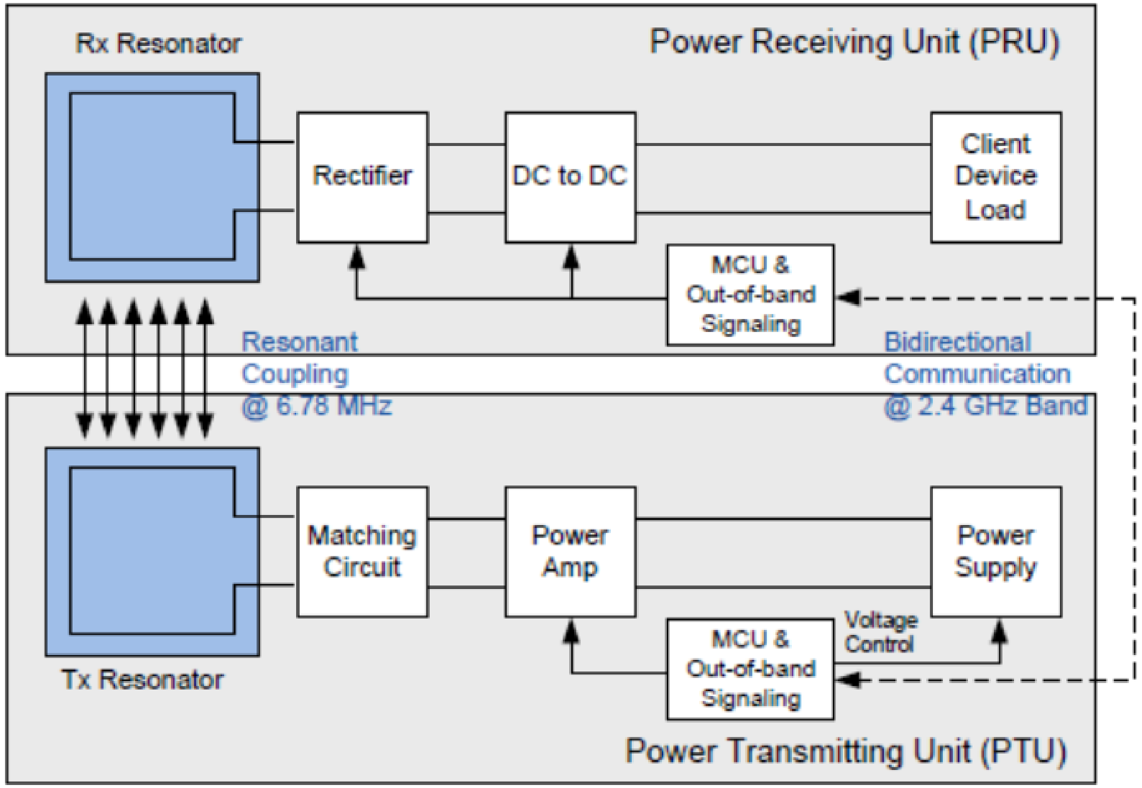
WPC Qi/AirFuel Inductive (Was PMA)



- 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)

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



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Introduction to WPC Qi Battery Charging

(Magnetic Induction)

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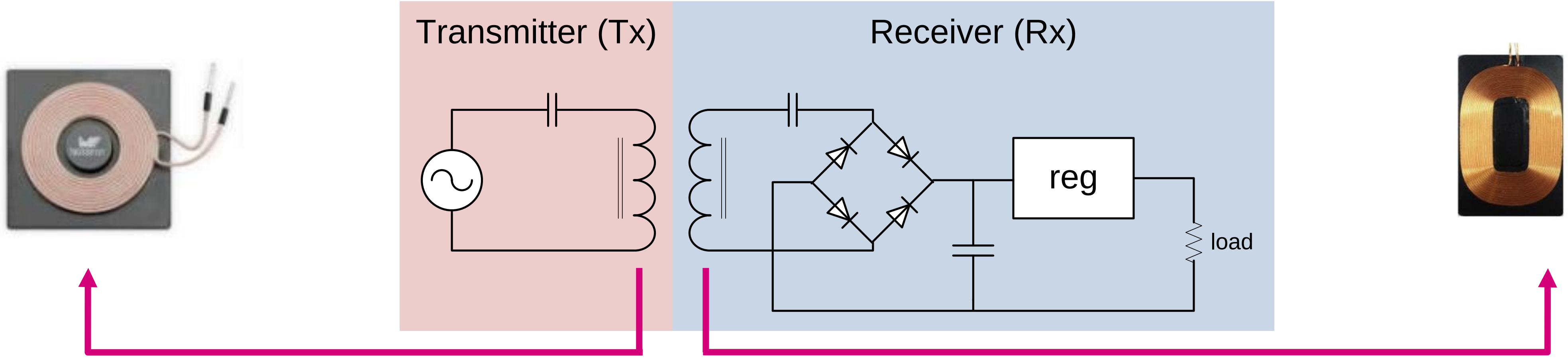
Power Transfer Principles

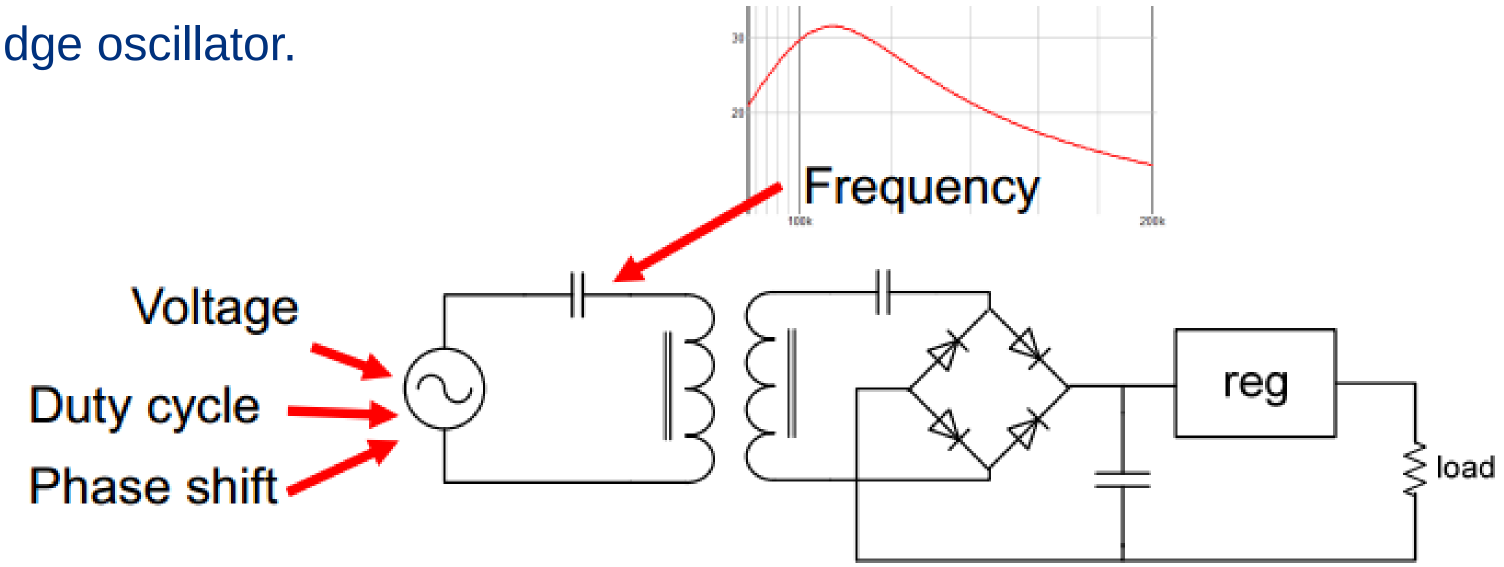
- Tightly coupled wireless charging technology uses magnetic induction to transfer power from a transmitter (TX) to a receiver (RX)
- The magnetic field is generated by a **coil on the TX side**. The field is captured by a **coil on the RX side**. The field works through air, no magnetic circuit links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



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.



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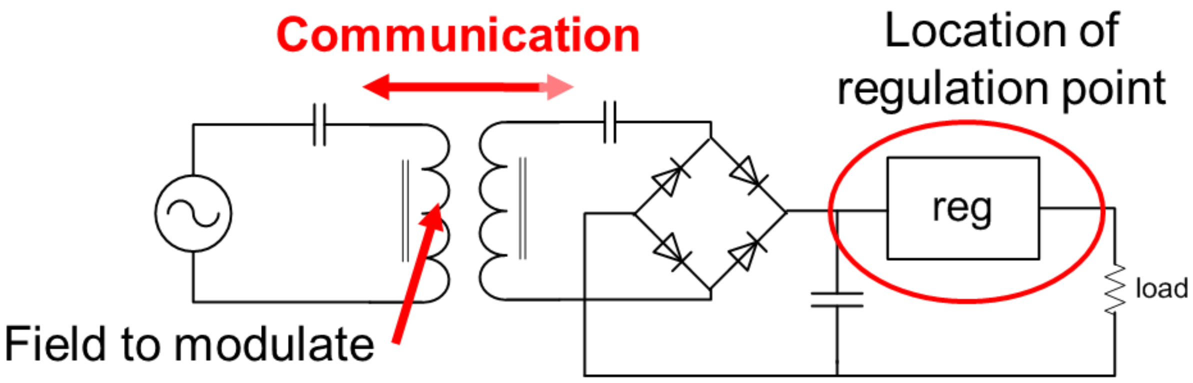
Communication

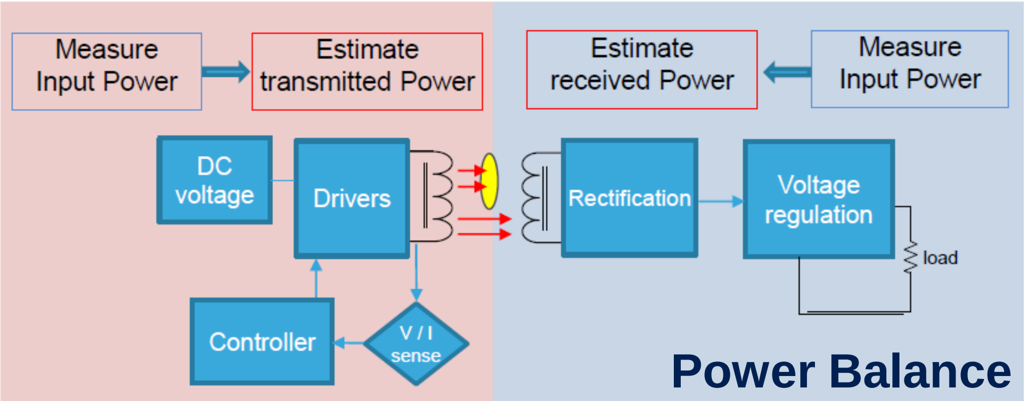
- Because there are too many variables (RX/TX coupling, RX & TX coils, load, …), the TX cannot set the regulation point by itself. The RX will have to pass data to the TX about the regulation set point.
- This communication channel can also be used for auxiliary purposes and extended to bi-directional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

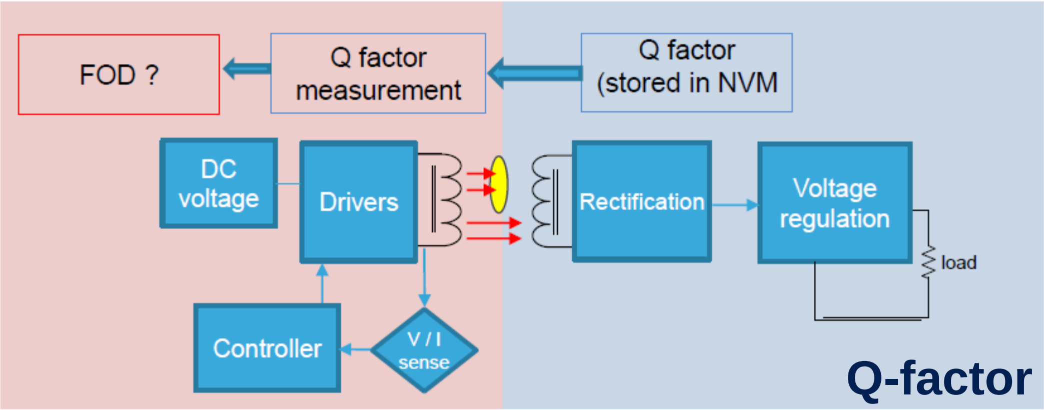


RX Presence Detection and FOD

- 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





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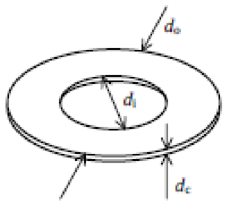
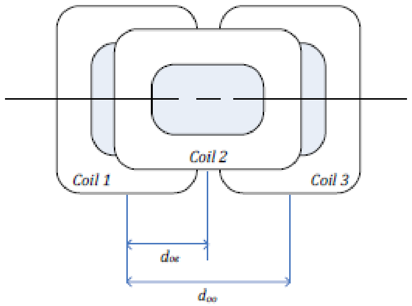
Qi Power-Transmitter Design Overview

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	∅40...43 mm
#2	Circular	∅33...39 mm
#2	Circular/hexagonal	∅28...32 mm
#4	Oblong	65×57...70×60 mm^2
#5	Rectangular	46.5×37.5...53×45 mm^2
#6	Triangular	52×46...59×52 mm^2
#7	Square	45×45 mm^2
#8	Circular	∅60 mm
#9	Oblong	45×34 mm^2

Source: WPC Qi specifications, Version 1.2

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STWBC

Qi Wireless Battery Charging Transmitter IC

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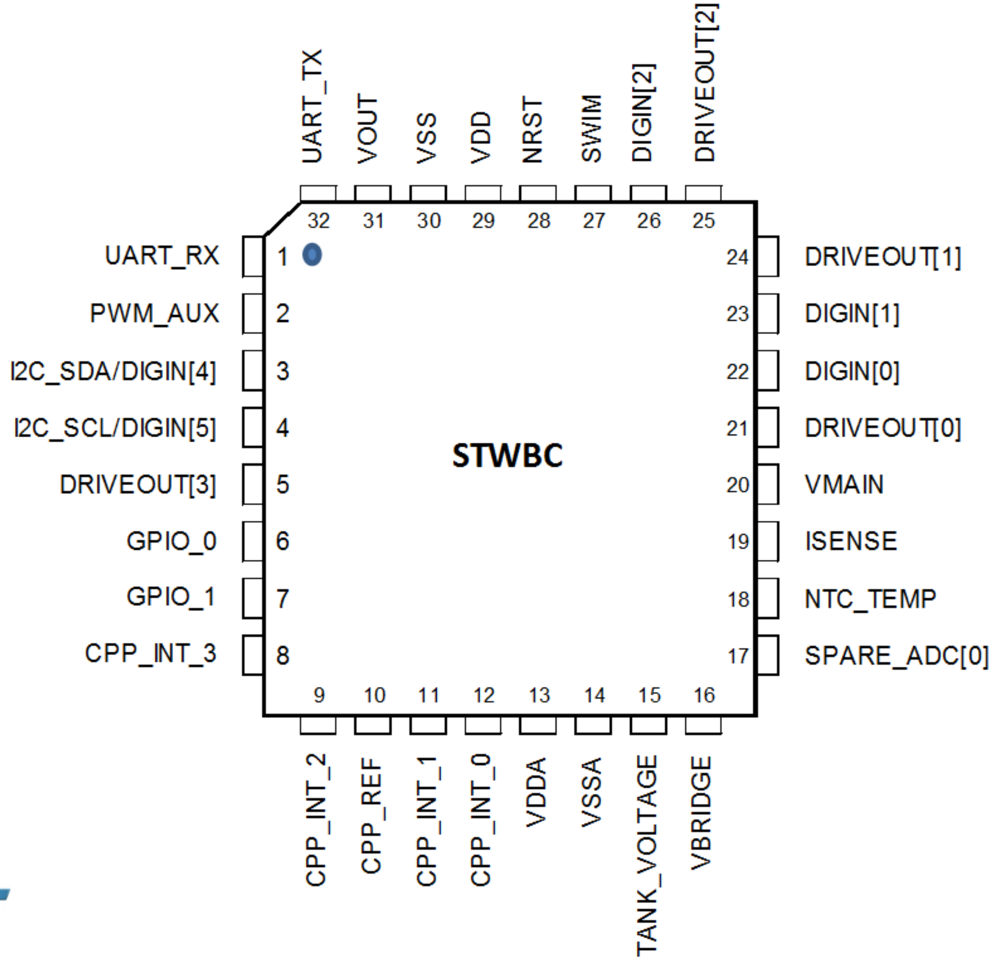
STWBC - Transmitter

Flexible, efficient, compliant with leading standards



5V IC supply voltage

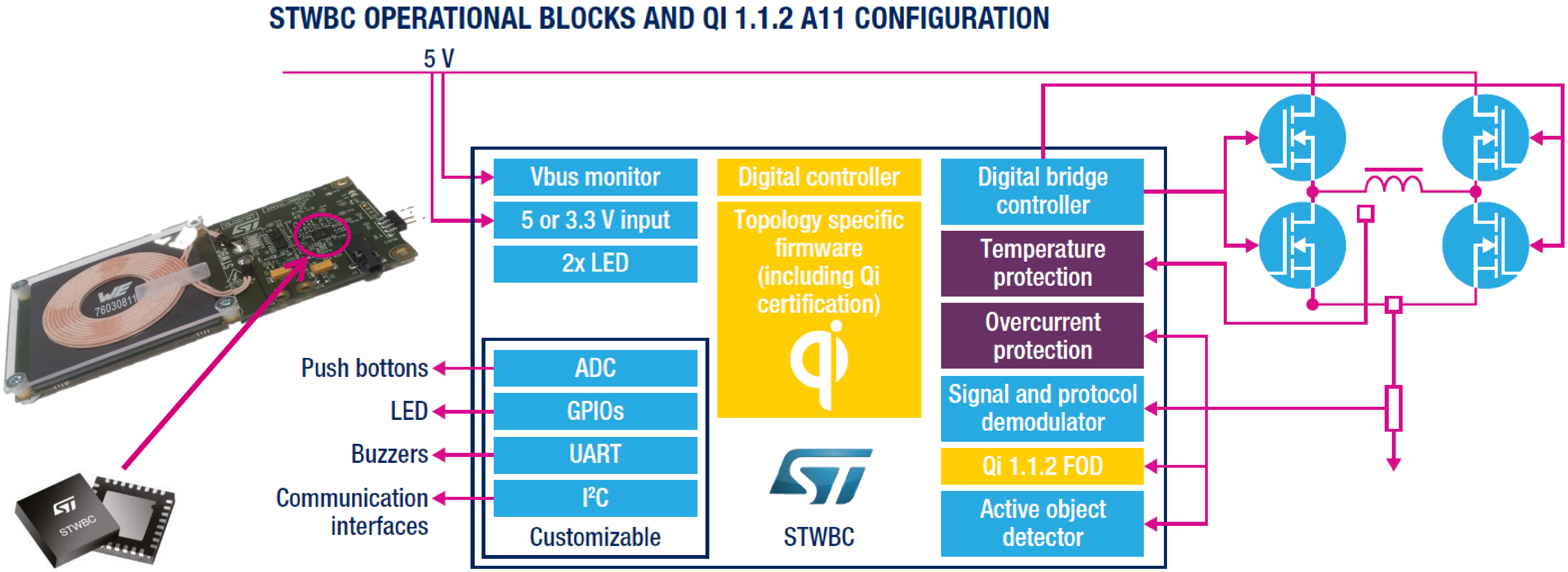
Two Firmware options
- Turn/key solution for quick design
- APIs available for customization

API: Available Peripherals
- ADC with 10 bit precision and 1MΩ input impedance
- UART
- I^2C 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

STWBC - Transmitter

Flexible, efficient, compliant with leading standards

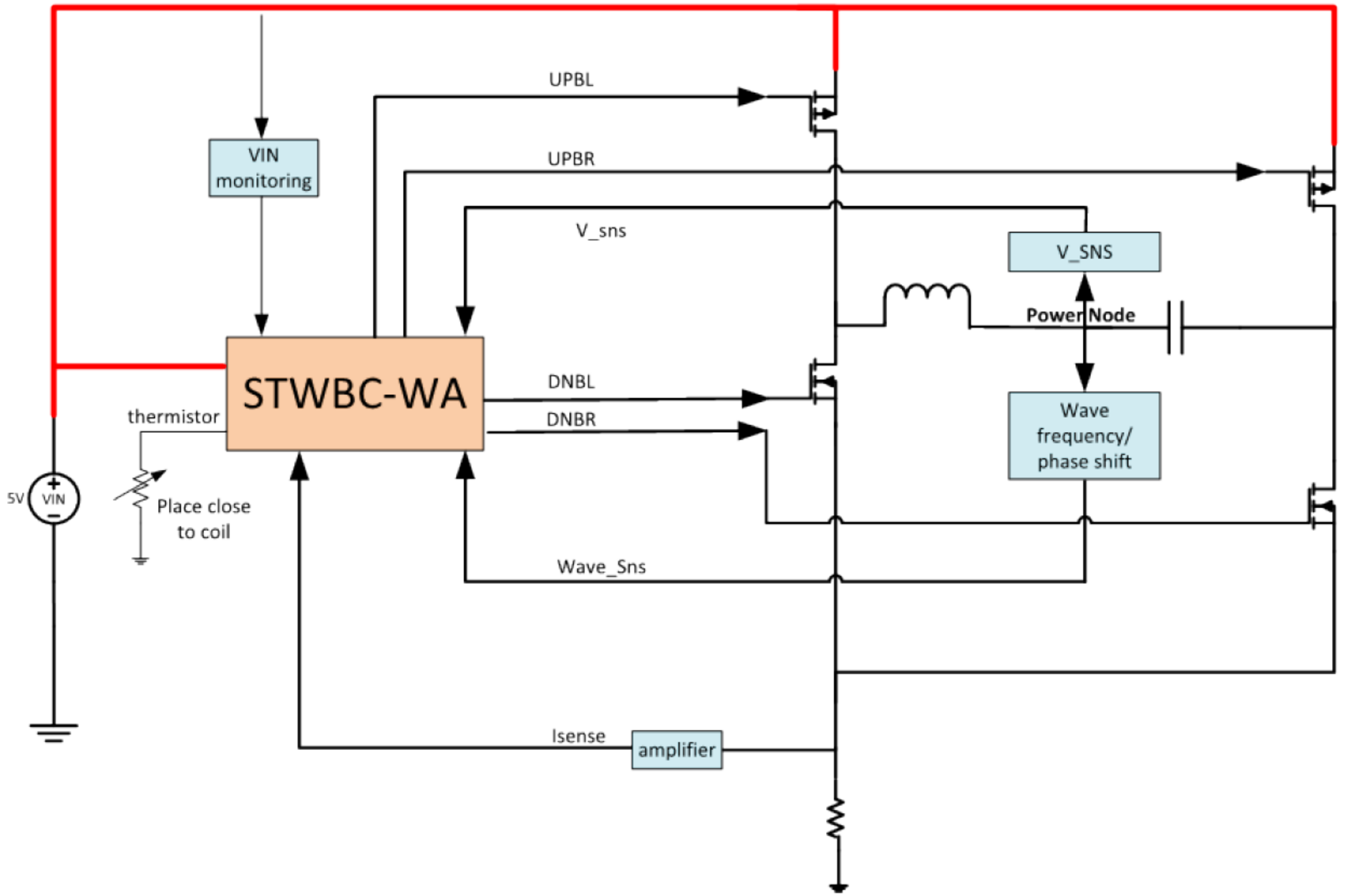


STWBC Transmitter

Qi Reference Designs and Boards

Qi-based 2.5W Wearable TX Configuration

STWBC-WA

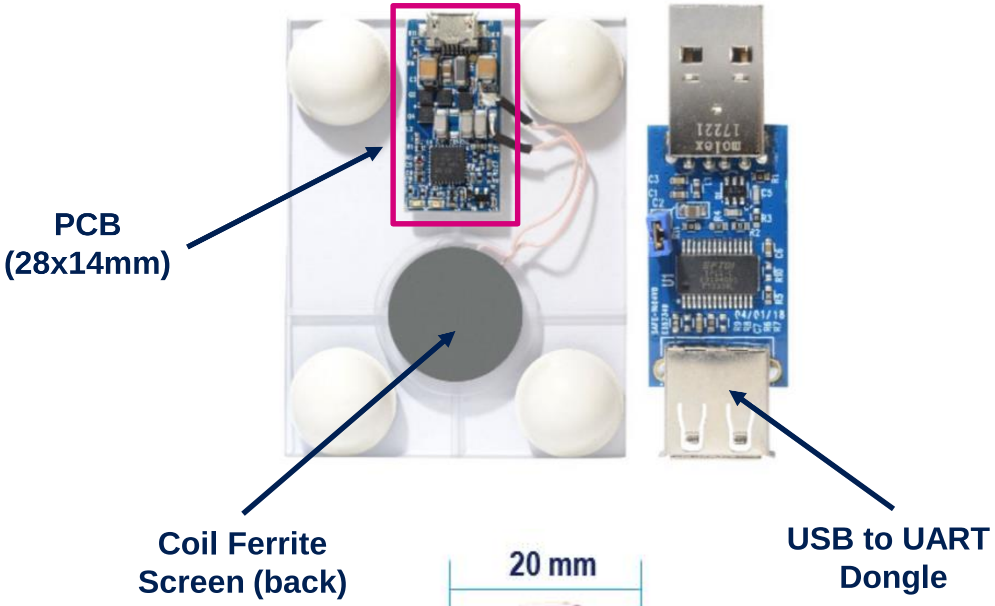


- System, bridge control and Qi protocol are handled by the STWBC-WA
- The transmitter is based on a Full-Bridge topology
- The inverter bridge is supplied by 5V input voltage
- Support up 2.5W with 20mm coil
- Scalable down to 1W with even smaller coil (**15mm**)

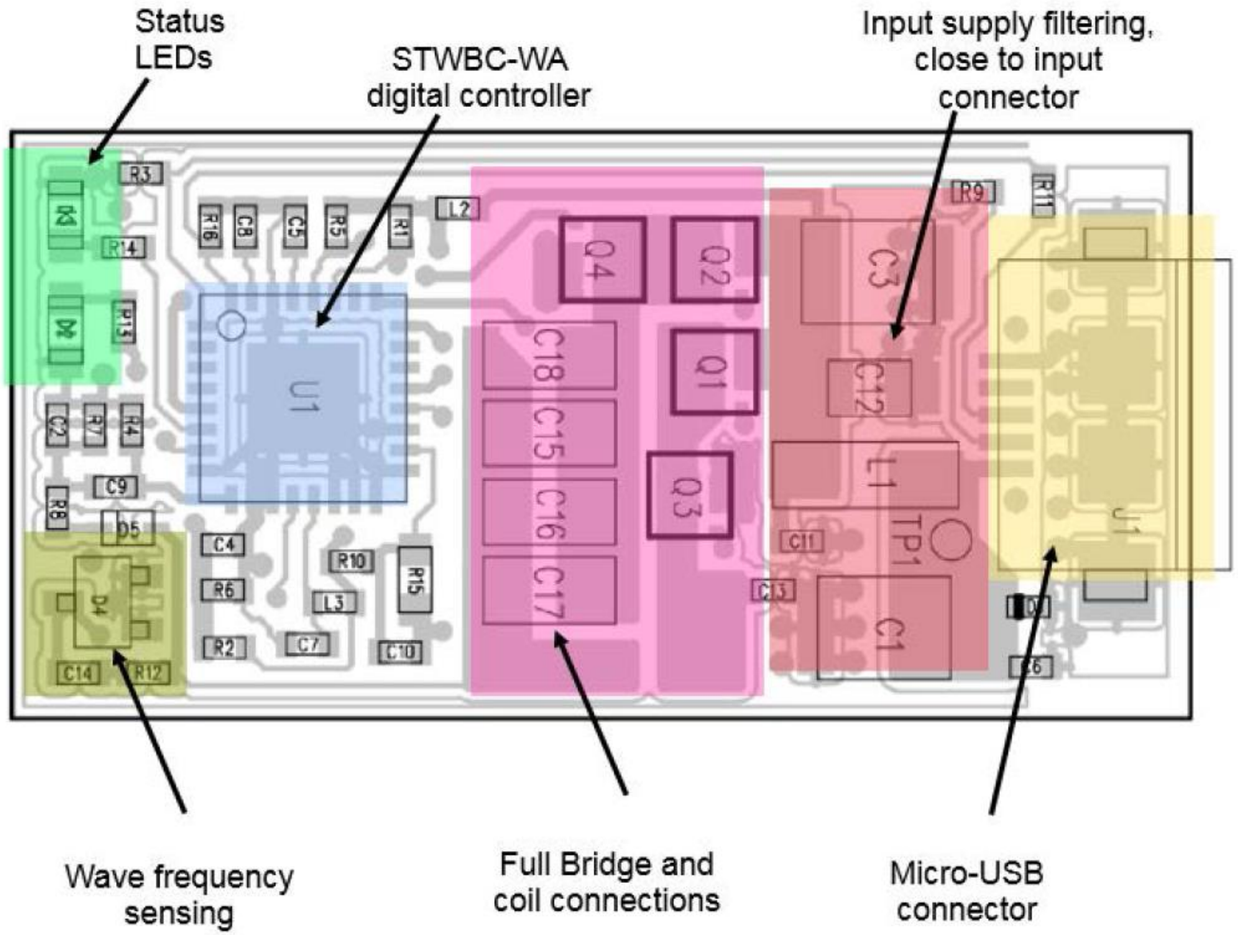
Qi-based Wearable TX Reference Board

STWBC-WA – 2.5W STEVAL-ISB045V1

- 2-Layer PCB and single-side placement



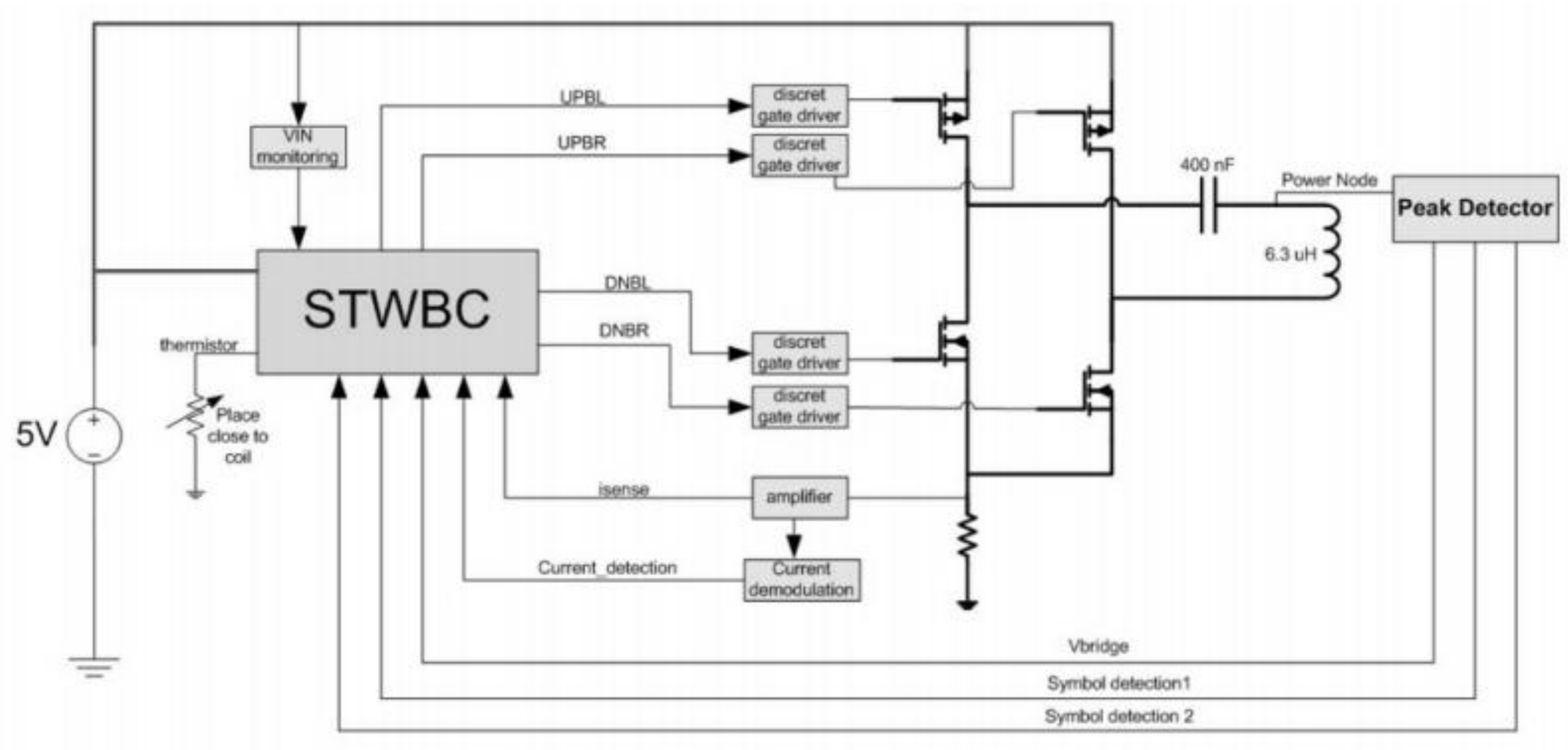
Small Coil



5W BPP Transmitter Configuration

STWBC A-11

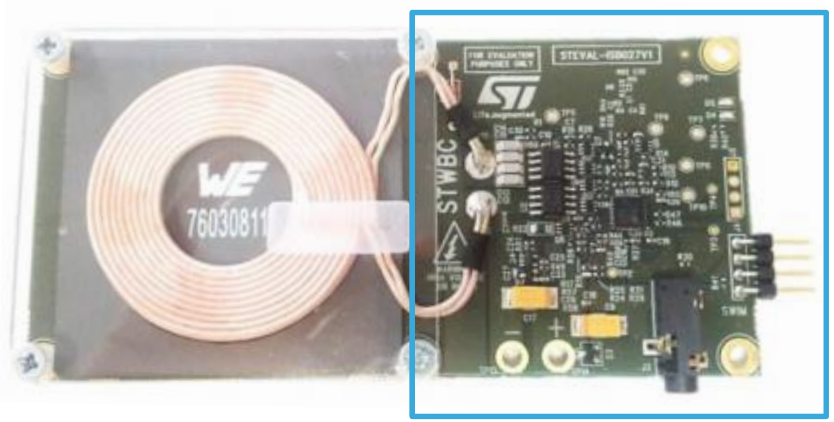
- 5W Qi, 1-Coil, 5V supply
- Frequency and Duty-Cycle control:
  - Operating frequency range 110kHz – 205kHz
  - Duty cycle 50%-10% @ 205kHz

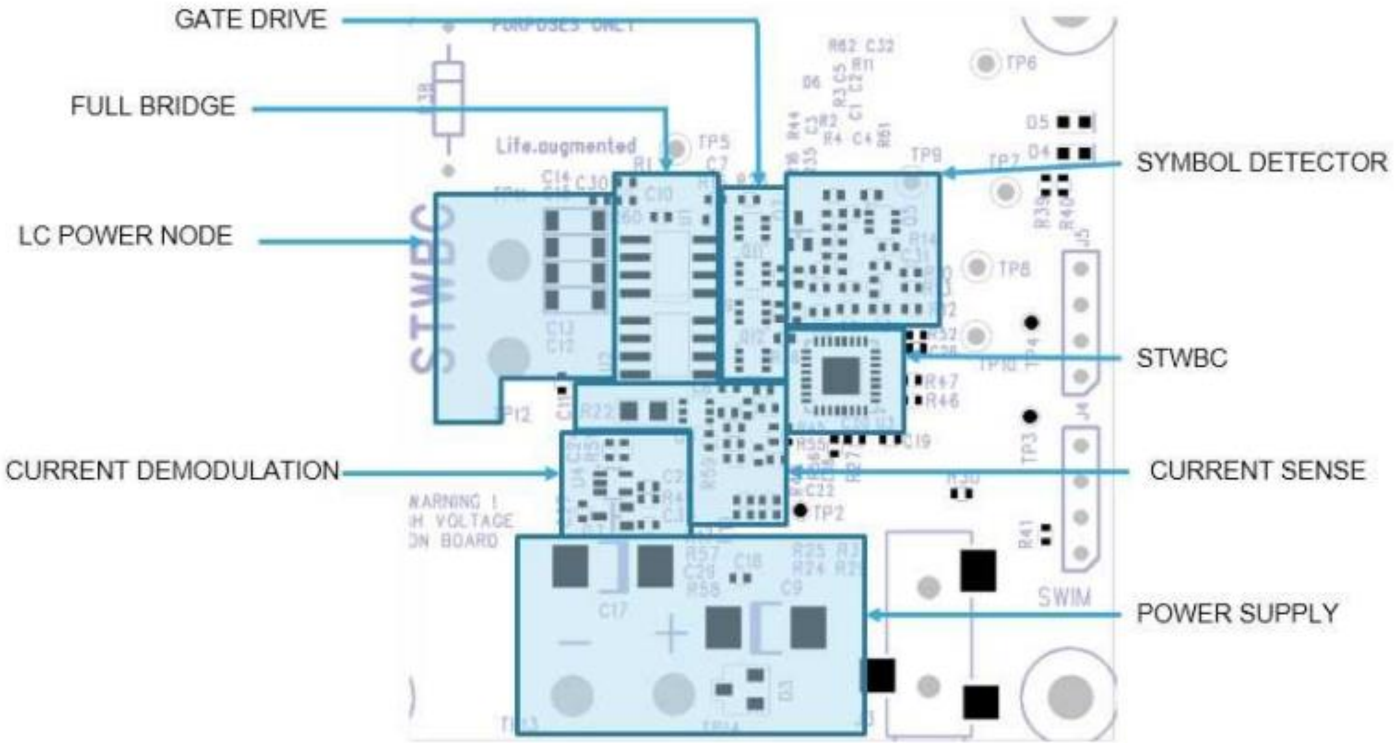


Transmitter Reference Board

STWBC 5W A11 – STEVAL-ISB027V1

2-Layer PCB and single-side placement





Standby

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

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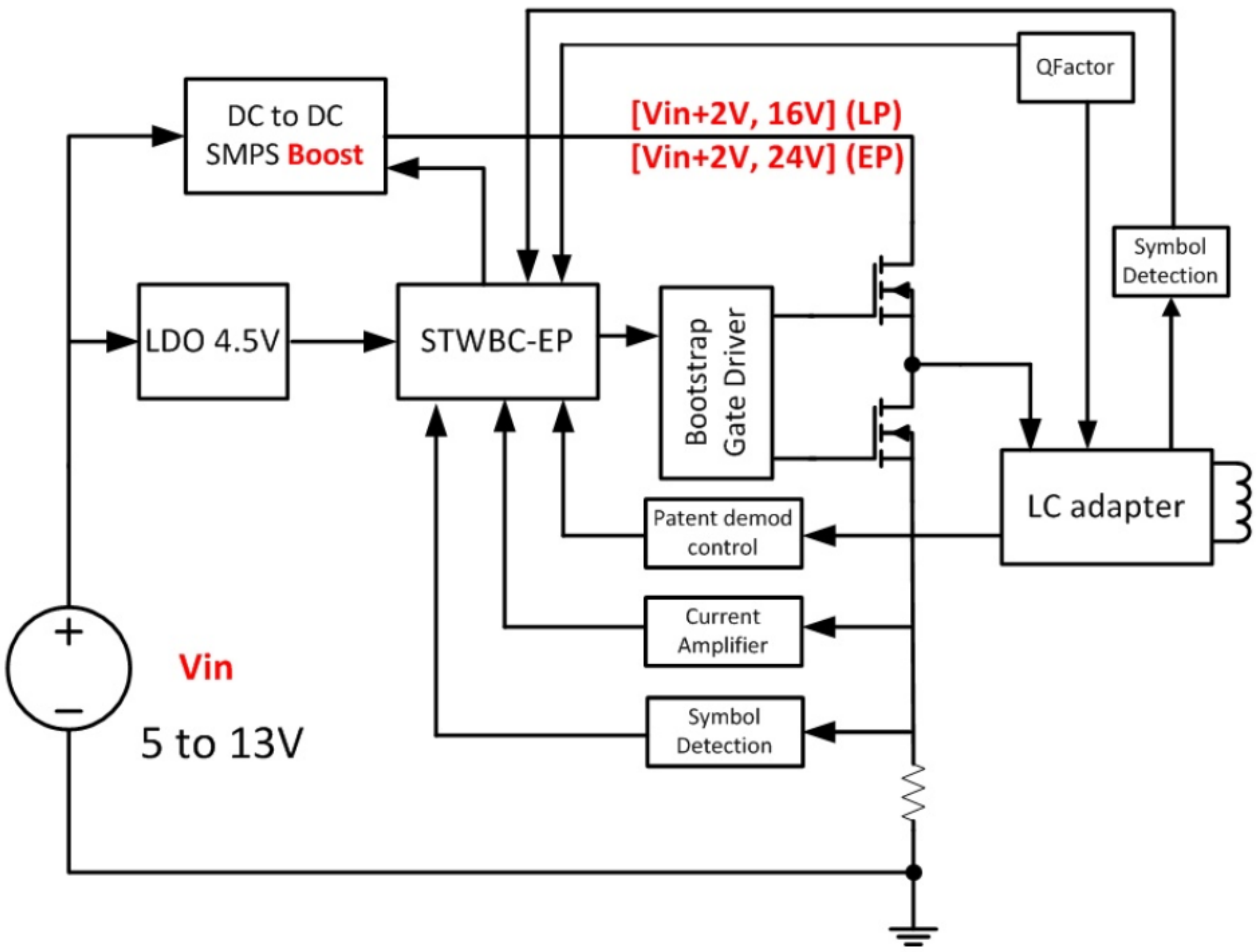
15W EPP Transmitter Configuration

STWBC-EP MP-A10

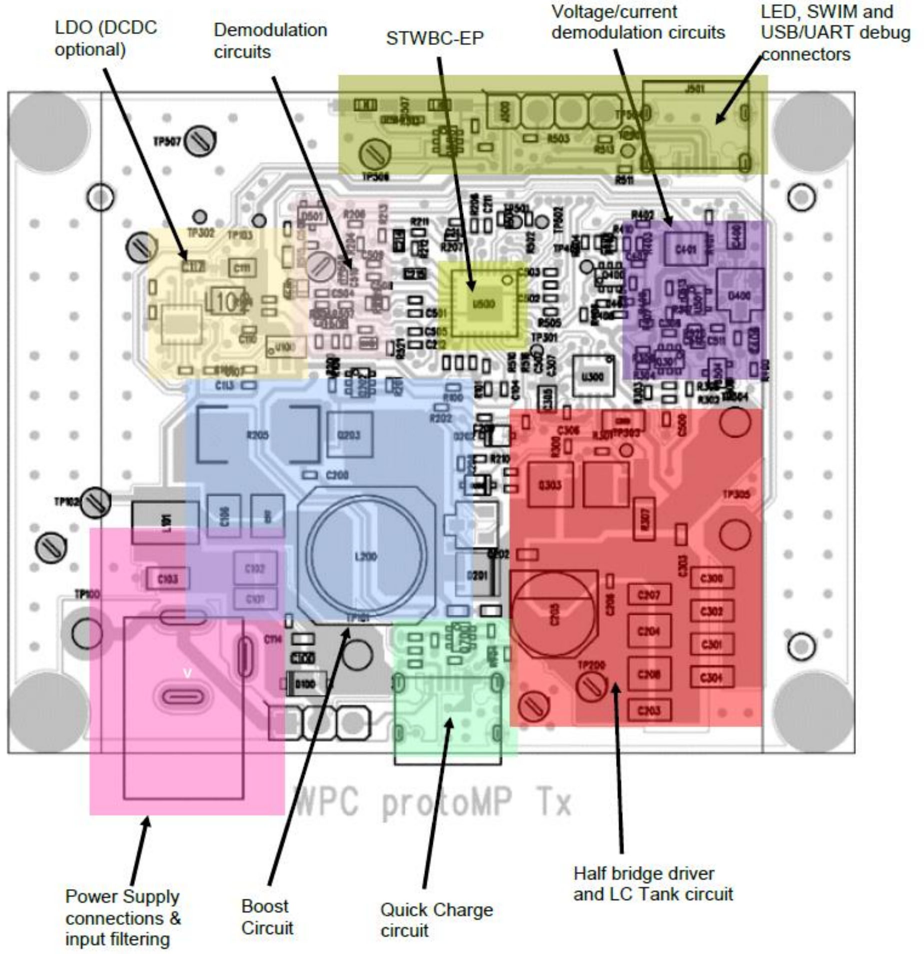


- Qi 1.2.3 EPP (Extended Power Profile) up to 15W
- Half-Bridge topology
- Support Basic Power Profile as well, up to 5W
- Wide supply voltage range, 5 to 13V
- Voltage and Frequency control

Transmitter Reference Board

STWBC-EP 15W MP-A10 STEVAL-ISB044V1

2-Layer PCB and single-side placement



StandBy

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

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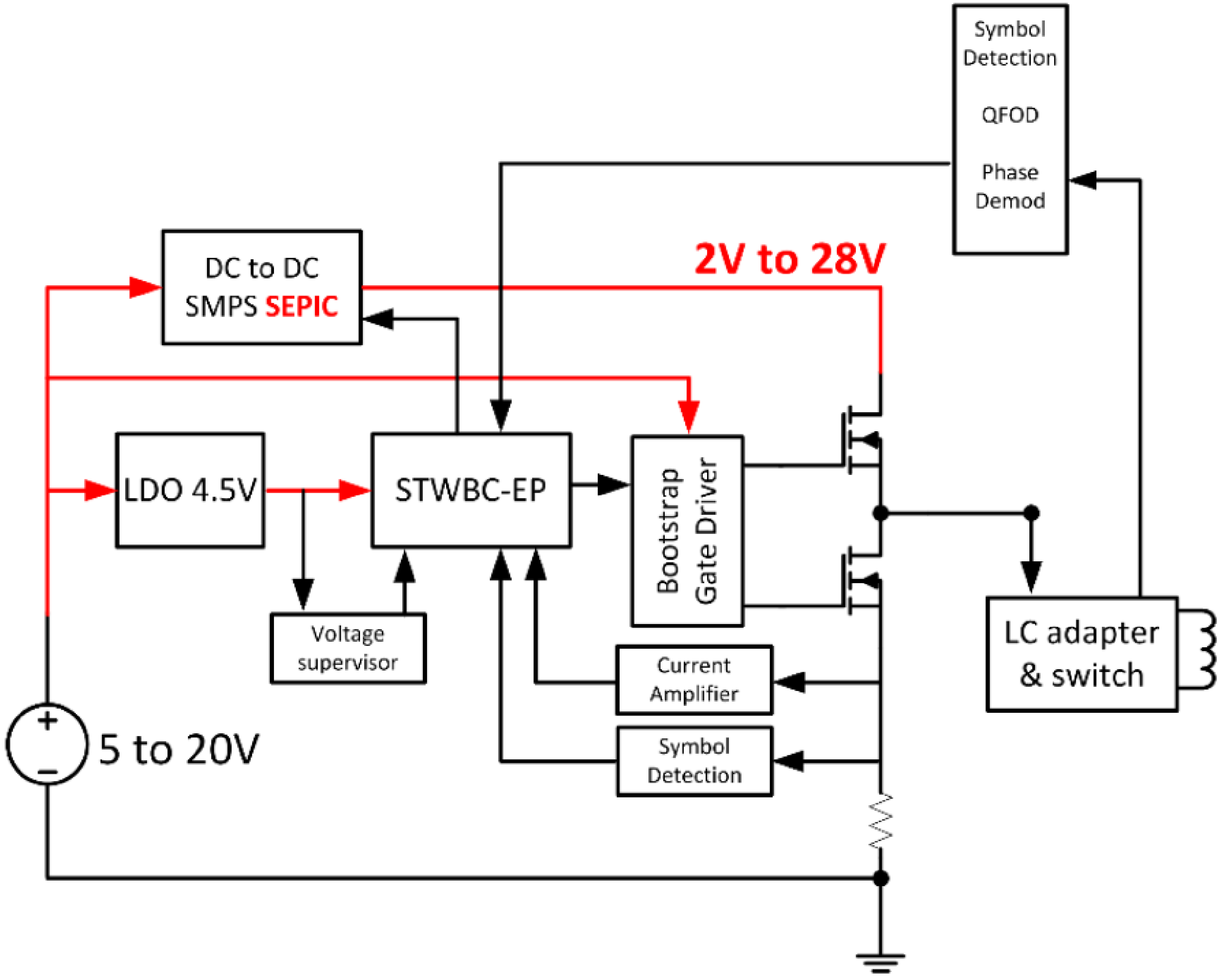
15W EPP Transmitter Configuration

Fixed Frequency STWBC-EP MP-A15

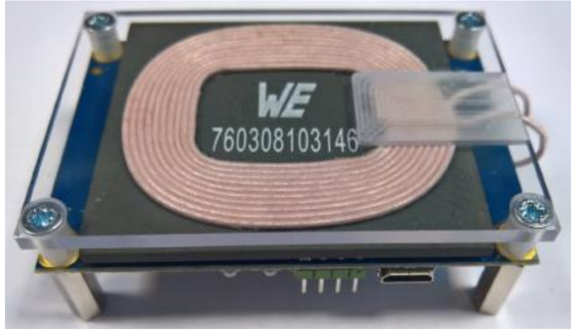


- Qi 1.2.4 EPP (Extended Power Profile) up to 15W
- Half-Bridge topology
- Support Basic Power Profile as well, up to 5W
- 127.7 kHz fixed frequency
- **Fast Charge support**
- Wide supply voltage range, 5 to 20V, with Quick Charge

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

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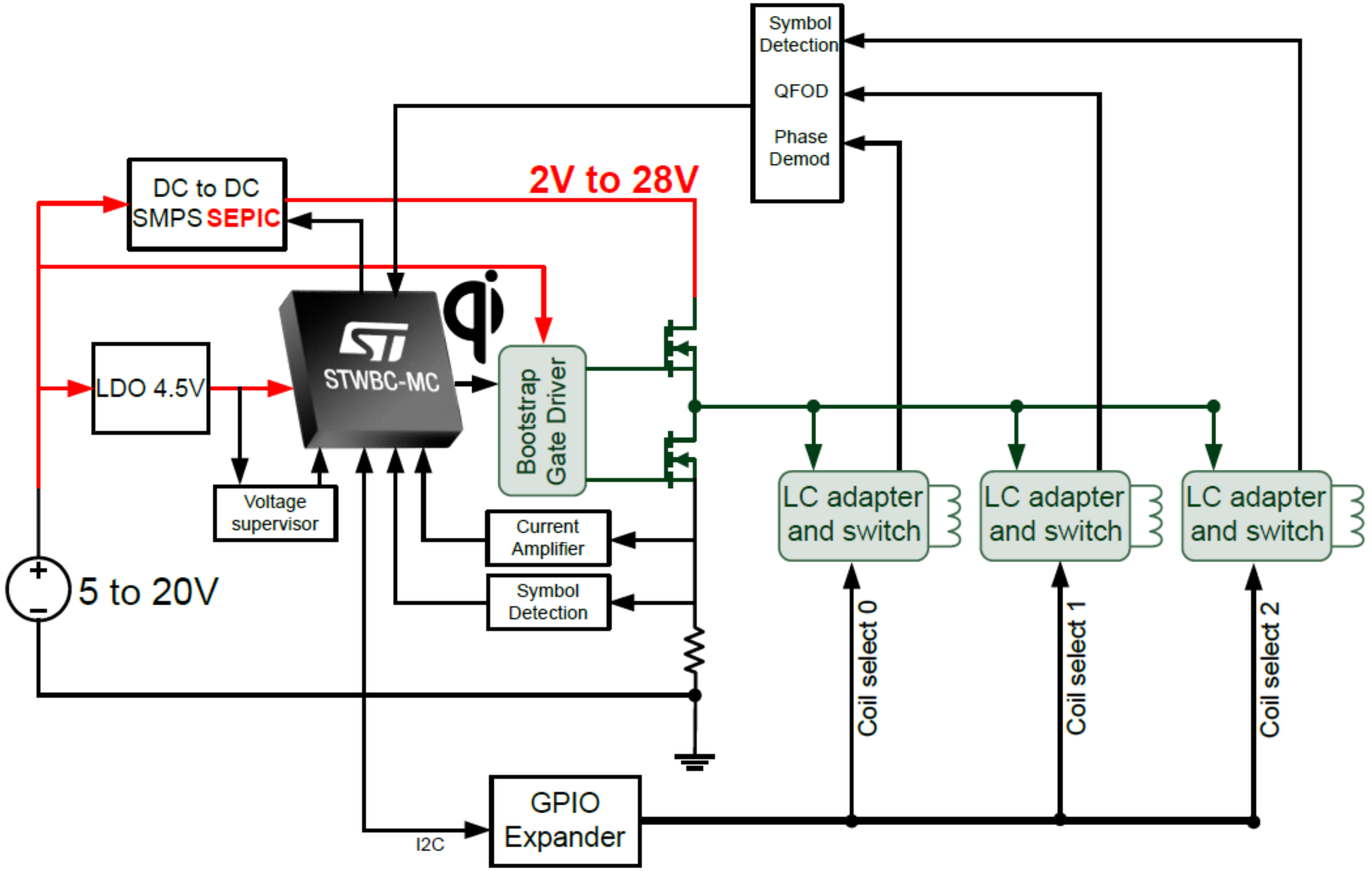
3-coil 15W EPP Transmitter Configuration

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

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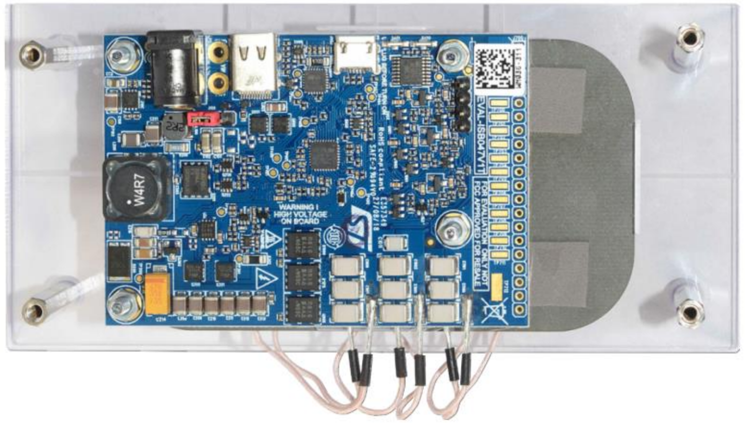
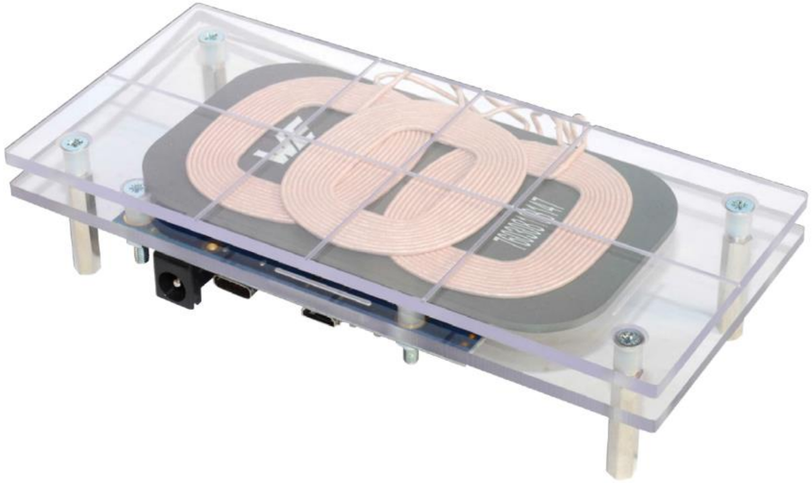
3- coil Transmitter Reference Board

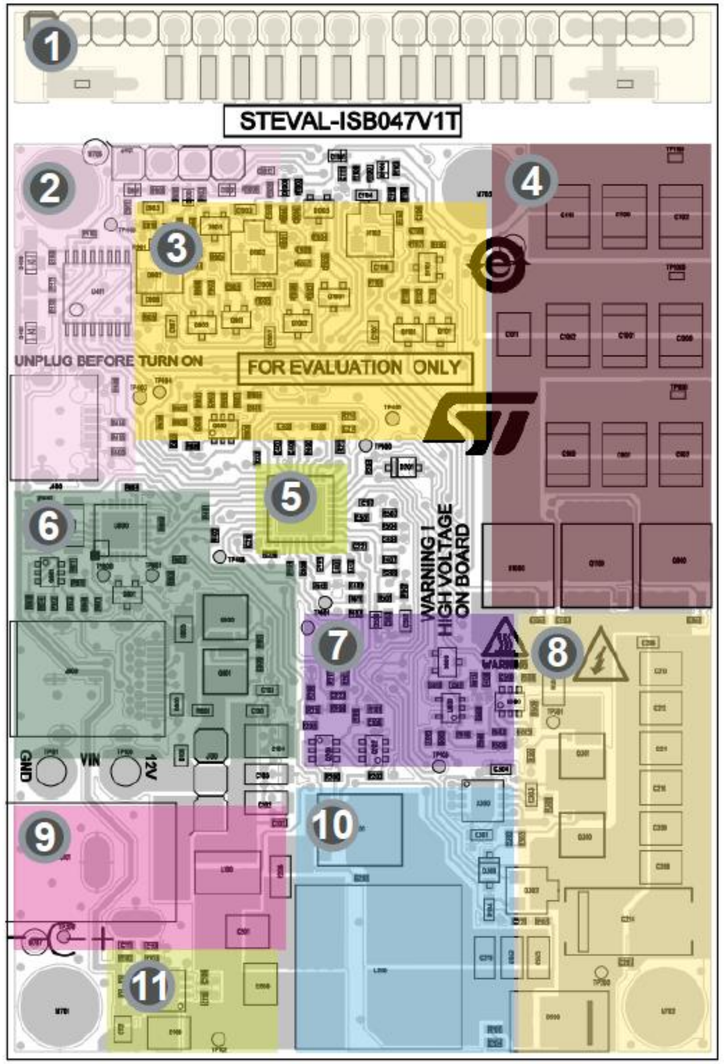
STWBC-MC 15W MP-A15 STEVAL-ISB047V1

2-Layer PCB and single-side placement





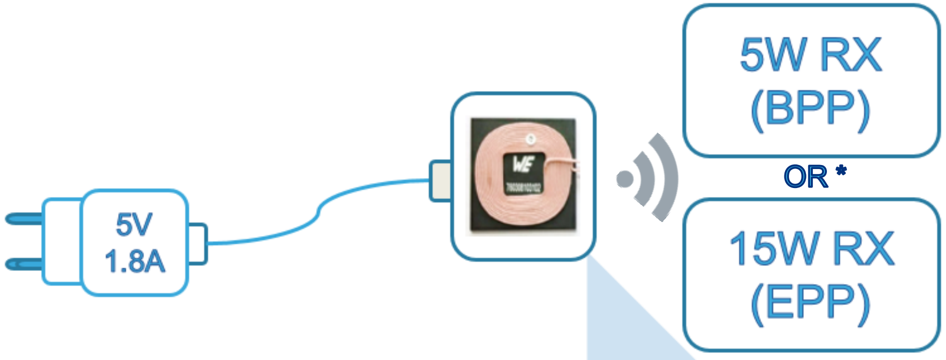
1. Test point for debugging only (may be removed)
2. LED, SWIM and USB/UART debug connectors
3. Sensing detection circuits
4. Coil selection and detection
5. STWBC-MC
6. USB PD/QC IO charger
7. Voltage/current demodulation circuits
8. Half bridge driver and LC Tank circuit
9. Jack power supply connections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



Standby

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

STWBC-EP 5W or 15W Use Cases



STWBC-EP requests 12V to the USB charger but it only gets 5V

The STWBC-EP advertizes itself as BPP (5W) to the RX

Both 5W and 15W RX will request 5W Max

STWBC-EP supplied at 5V

STWBC-EP requests 12V to the USB charger and it gets it

The STWBC-EP advertizes itself as EPP (15W) to the RX

Each RX will get its requested power, either 5W or 15W

STWBC-EP supplied at 12V

* Only <u>one</u> RX can be paired to a single TX, as per current Qi spec

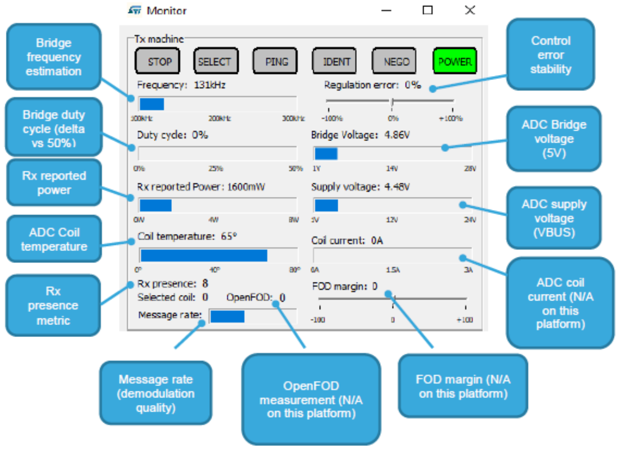
Wireless Battery Charger TX – up to 5W

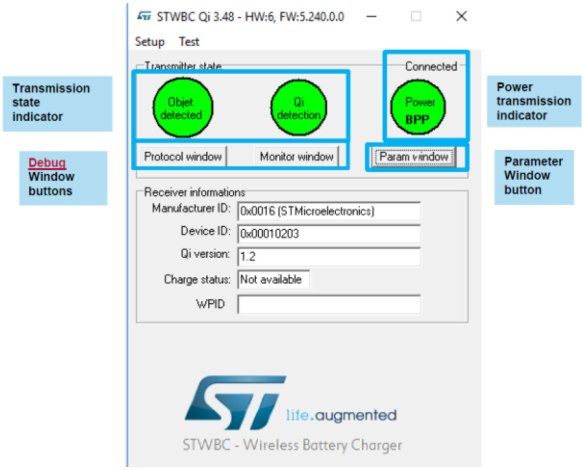
STWBC-WA - STEVAL-ISB045V1

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

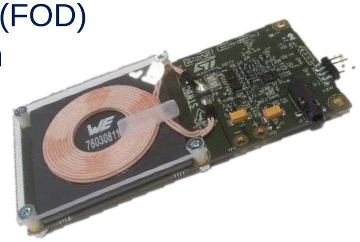




STWBC - STEVAL-ISB027V1

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

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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)

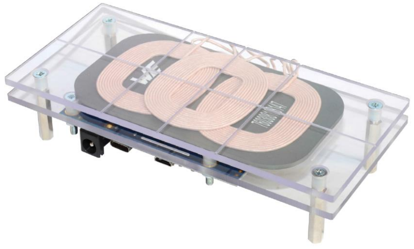
- IC: STWBC-EP
- MP-A15 Design, Qi 1.2.4 Certified
- BPP and EPP (5W/15W)
- Fast Charge Support
- Foreign Object Detection (FOD)
- 5-20V input voltage range with QC
- Half-Bridge topology
- 127.7kHz Fixed Frequency
- GUI for evaluation and testing

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

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STWLC

Qi/AirFuel Inductive Wireless Battery Charger Receiver IC

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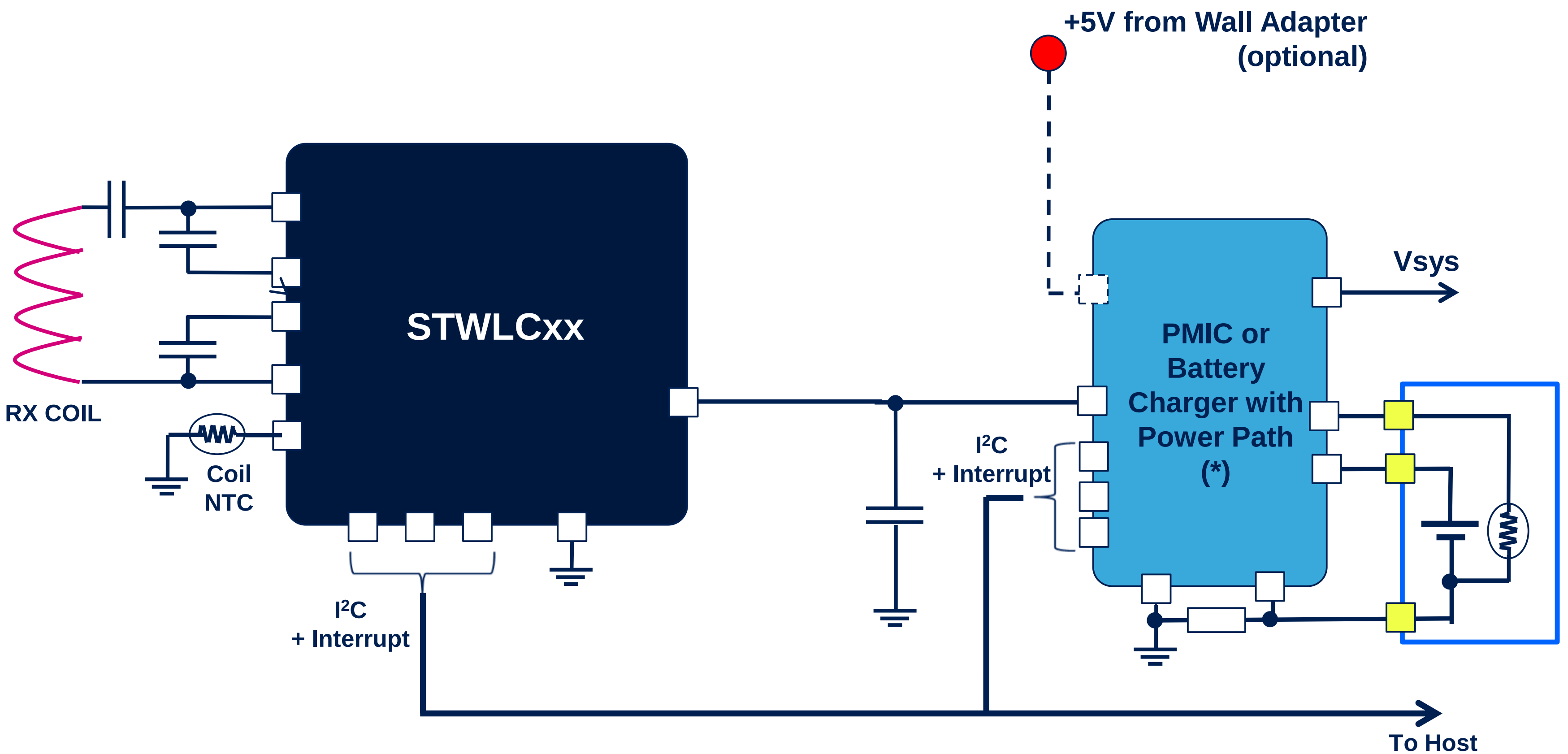
STWLCxx Simplified Application Diagram



(*) : with or w/o Fuel Gauge

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

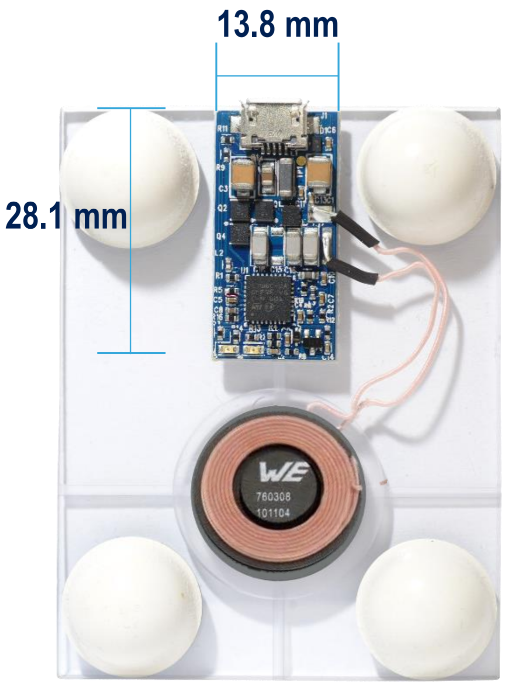
Smart standby
Automatic receiver recognition
Patented demodulation

Wurth 760308101104
20 mm diameter coil

2-layer PCB with optimized BOM
Possible remote coil with 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

~70% total system efficiency with 1mm gap

Flip Chip **2.68mm x 4.026mm**

Available Q1 ‘20

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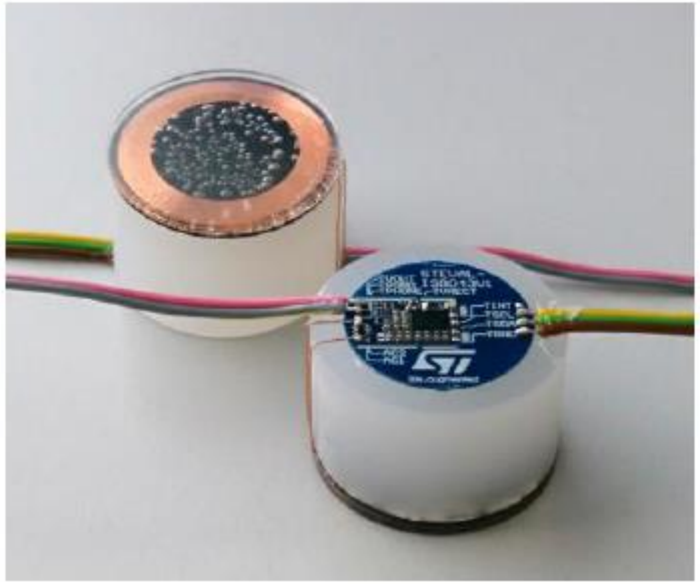
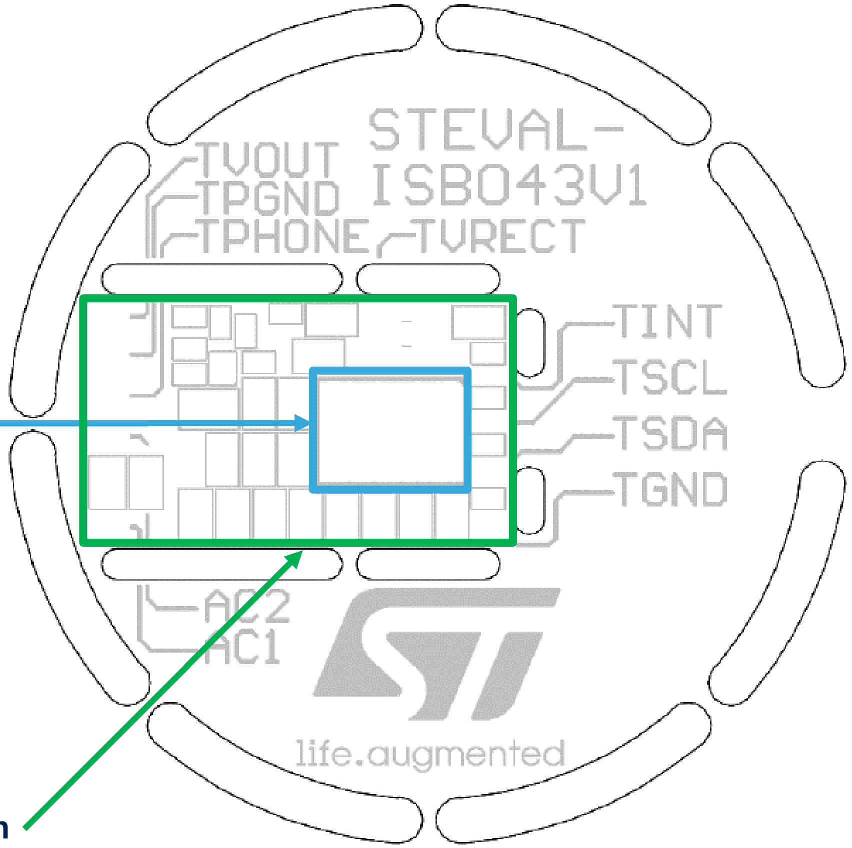
Qi-based Wearable RX Reference Board

STWLC30 – 2.5W STEVAL-ISB043V1

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



26mm Coil



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2.5-15W Wireless Battery Charger RX

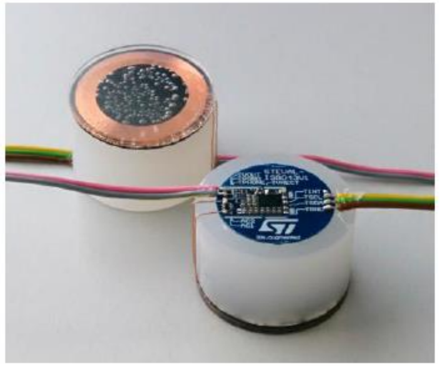
STWLCxx

STWLC30 – STEVAL-ISB043V1

2.5 Watts

Qi-based Wireless Receiver for Wearables

- Up to 2.5W output power
- 26mm Coil
- Scalable to 1W with 11mm coil
- Application area 10x6mm
- Total system efficiency 70% (2.5W)
- Optimized for 5V output operation
- Foreign Object Detection (FOD)
- I²C interface
- CSP 2.68x4.026mm,
  400 µm pitch 52 balls



Available Q1 '20

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

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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

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Thank You!

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