Wireless Battery Charging

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Technology Tour 2017

Wireless Power Keeps Growing

Leave cables at home and top up batteries

By 2018 over a billion receiver units are expected

to be shipped worldwide*

Wearable

Medical

Mobile phones and tablets

Smart home

Auto

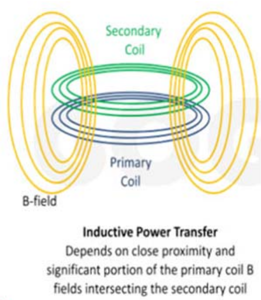
Power tools

* Source: IHS October 2016

Wireless Power at a Glance

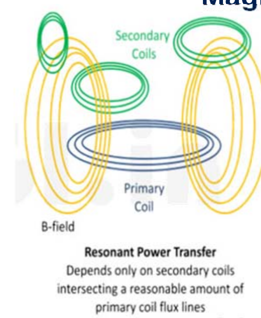
Similar technology
Different Implementation

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 (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

- Low Power: 5W (rel 1.2)
- Medium Power: 15W (rel 1.2)
- Qi Cordless kitchen appliances from 100W to 2.4kW
- Resonant (Under Definition)

AirFuel Alliance
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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Organizations Defining Standards

AirFuel Alliance

	WPC	PMA	A4WP
Members	~240	~200 under AirFuel Alliance name	
Available products	>950	~30	2
Technology	Inductive and Resonant-LF	Inductive	Resonant-HF
Investment areas	Infrastructure Automotive Power increase Larger Z Shared Mode, Resonant Extension	Consumer awareness Infrastructure Medium Power **Merge with A4WP (June'15)**	Specification Technology Industrialization Marketing Certification program & Test houses **Merge with PMA (June'15)**

ST is Regular Member (*) of WPC and Full Member of AirFuel Alliance

(*) also member of the Steering Group

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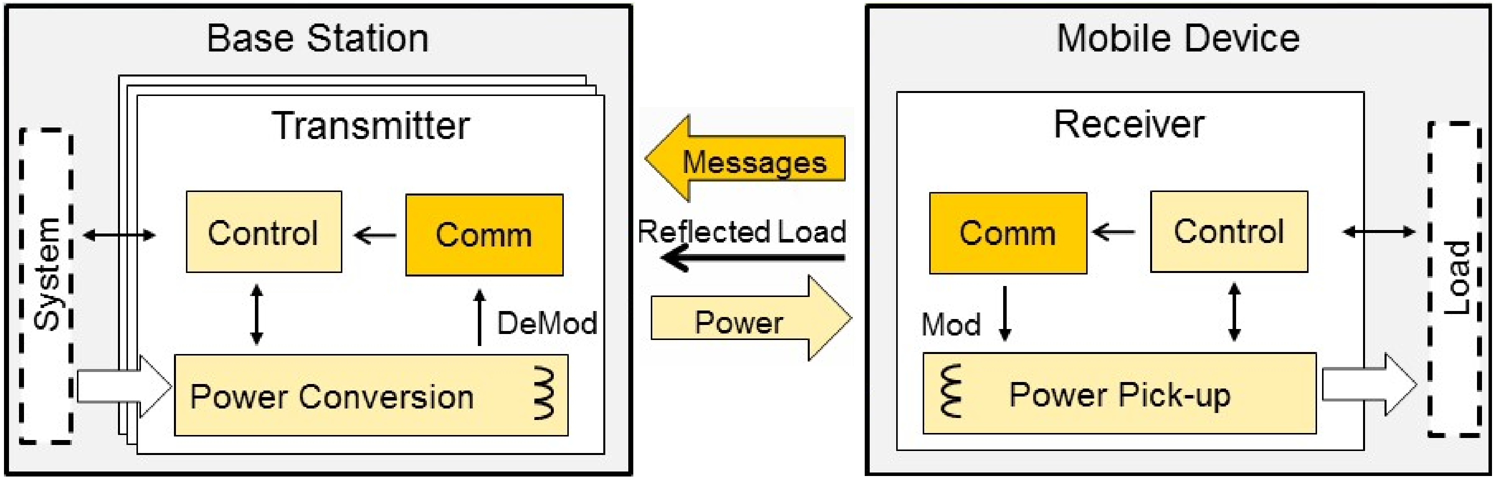
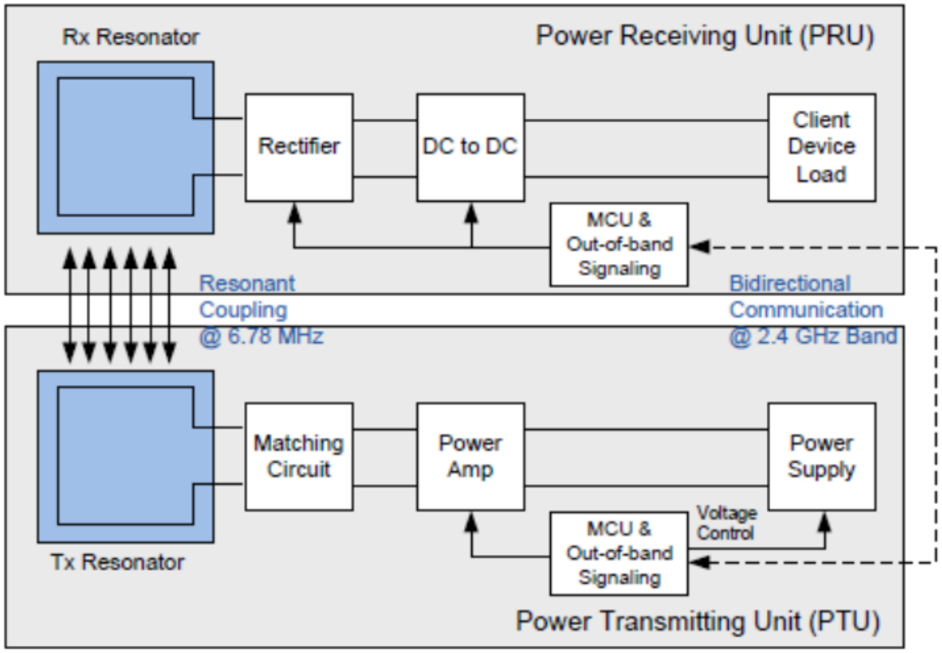
Magnetic Induction Power Transfer WPC Qi



- 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

- 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



Introduction to WPC Qi Battery Charging (Magnetic Induction)

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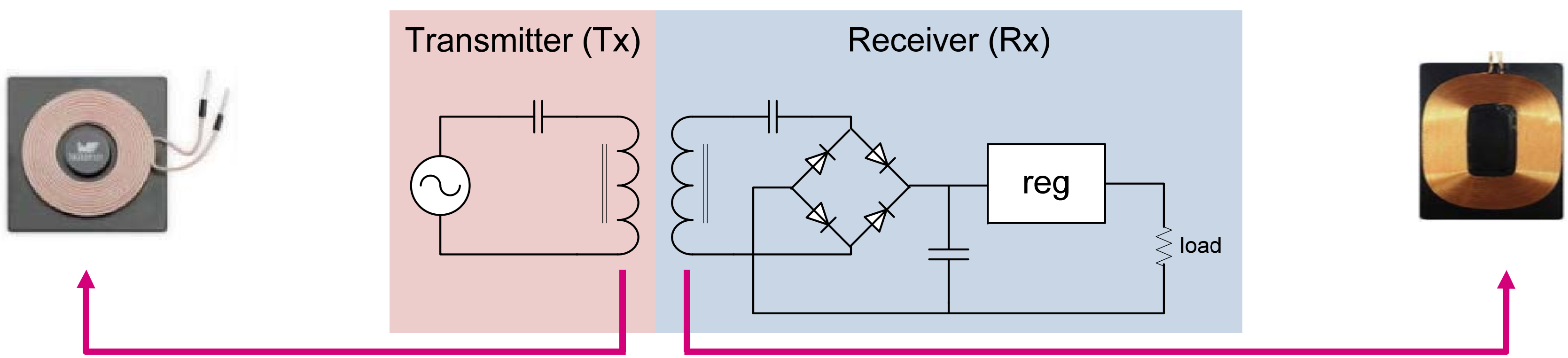
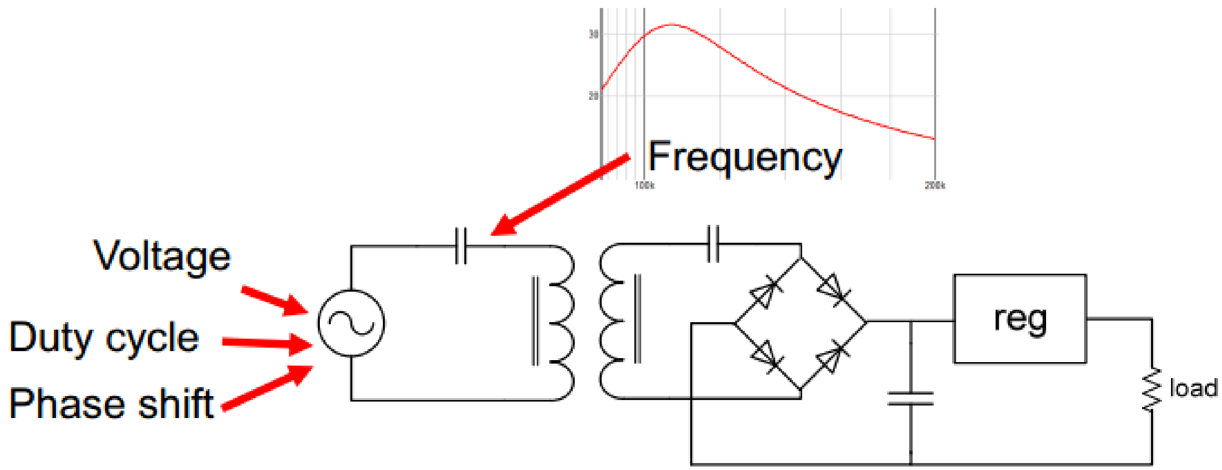
Power Transfer Principle

- 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.



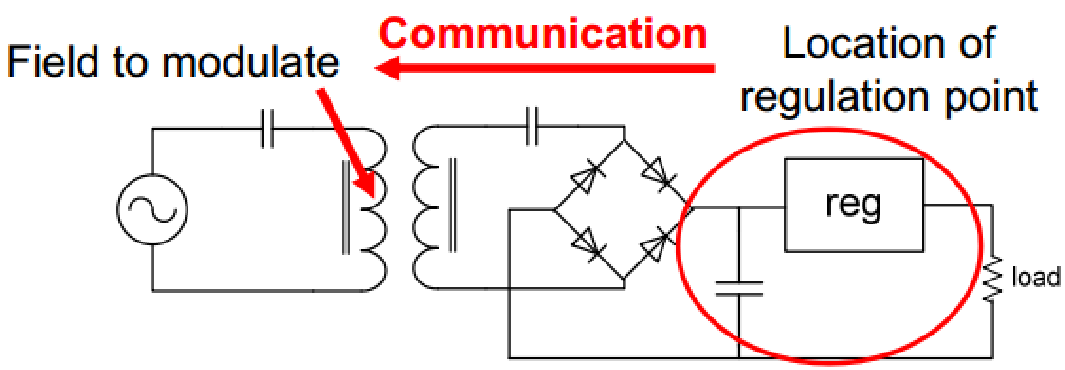
Adjust Power to Control Magnetic Field

- 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.



RX to TX Communication

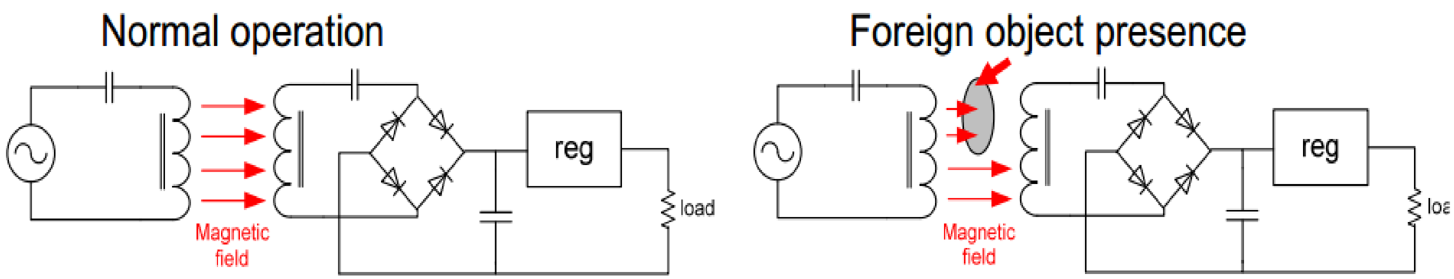
- Because there are too many variables (RX/TX coupling, RX & TX coils, load, …), the TX cannot set the regulation point by itself.
- There is then an absolute need of communication from RX to TX: the RX will have to pass data to the TX about the regulation set point.
- This communication channel can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



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.

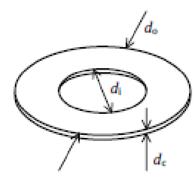
- FOD (Foreign Object Detection)
  - Qi uses the method of power balance to estimate the presence of foreign object.
  - If the TX transmits more power than what the RX reports, a foreign object is present

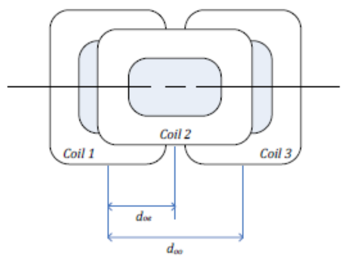


Qi Power Transmitter Designs Overview

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 mm²
#5	Rectangular	46.5×37.5...53×45 mm²
#6	Triangular	52×46...59×52 mm²
#7	Square	45×45 mm²
#8	Circular	∅60 mm
#9	Oblong	45×34 mm²

Source: WPC Qi specifications, Version 1..2

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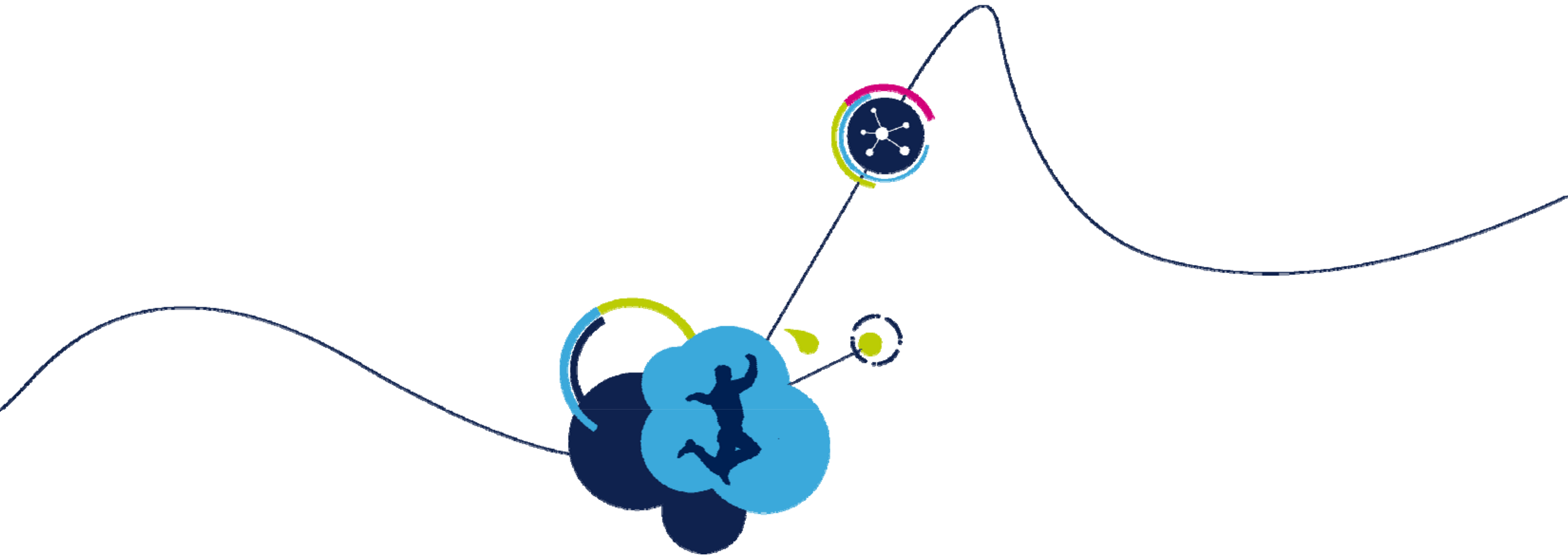

STWBC

Qi Wireless Battery Charging Transmitter IC

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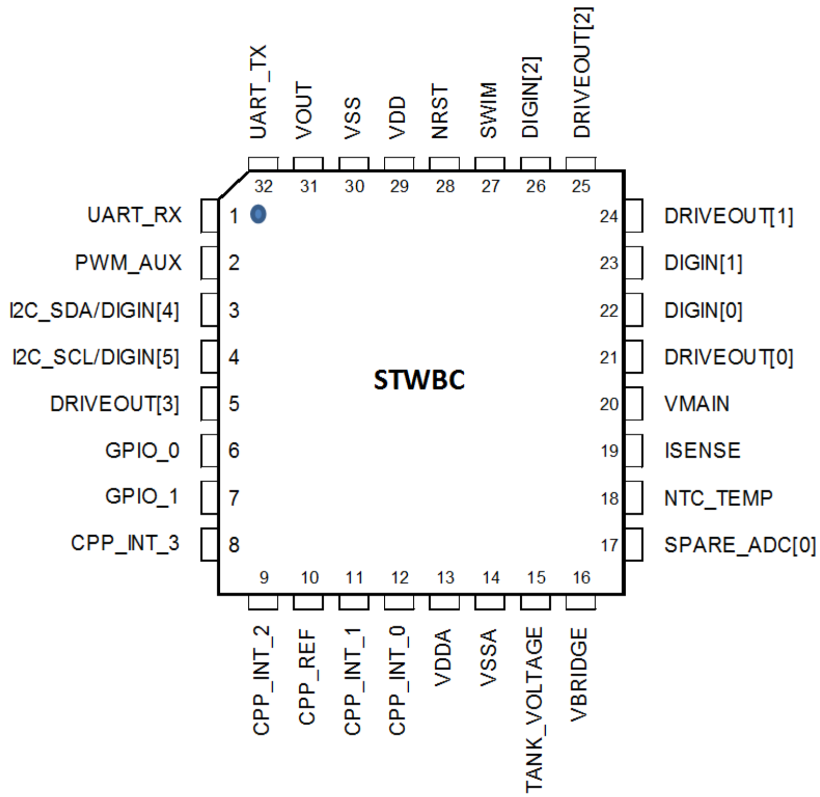
STWBC - Transmitter

Flexible, efficient, compliant with leading standard



5V IC supply voltage

Two Firmware options

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

API: Available Peripherals

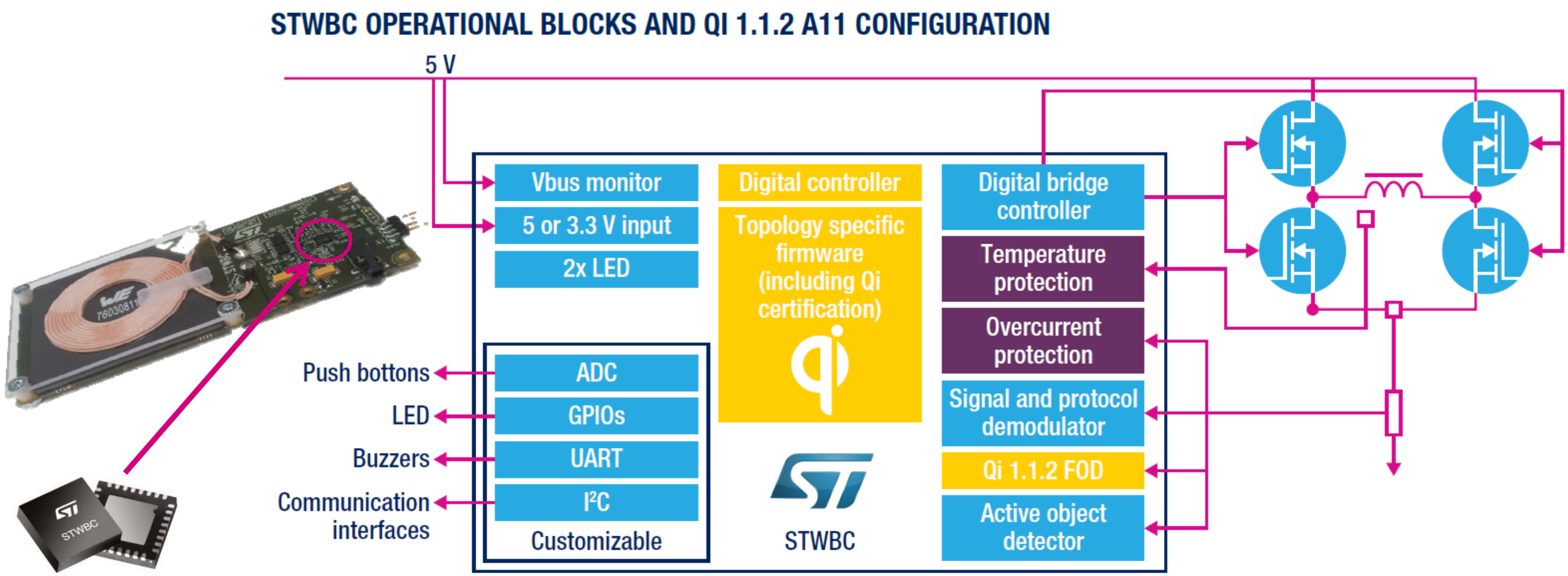
- ADC with 10 bit precision and 1MΩ input impedance
- UART
- I^2C master fast-slow speed rate
- GPIOs
- Program memory: 32* kbyte EEPROM (*available size for API depends on selected FW)

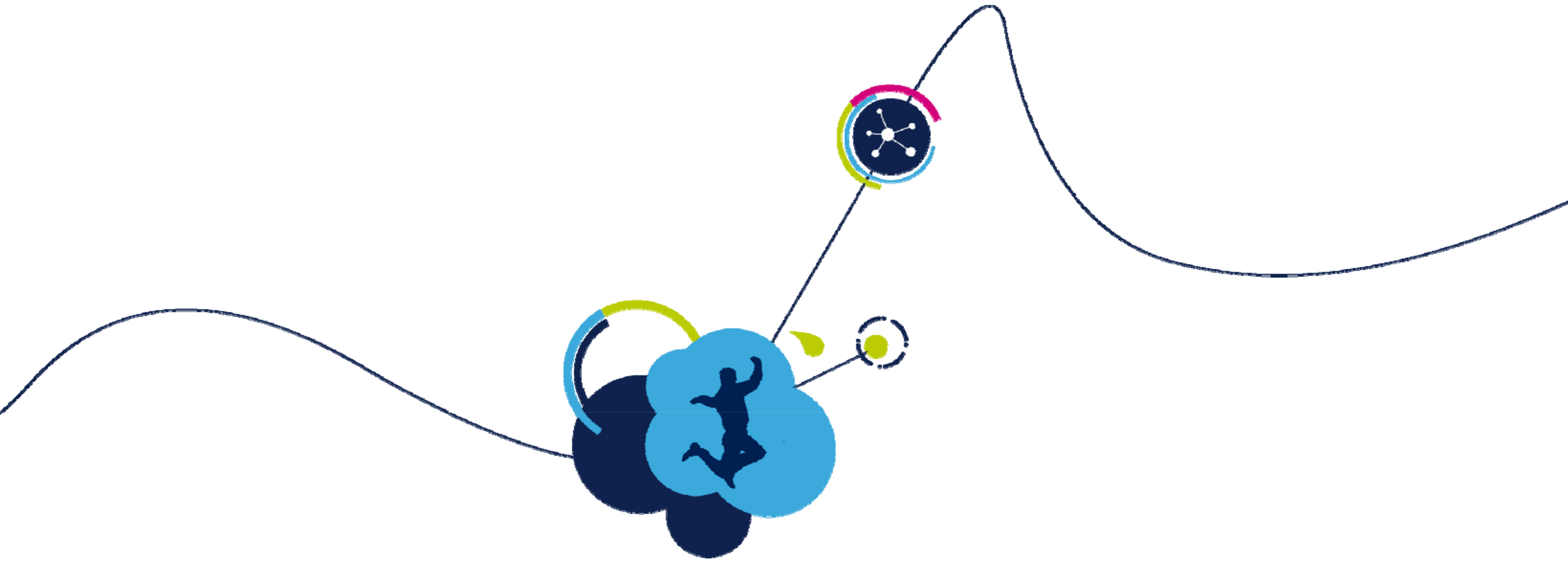
General application features:

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

STWBC - Transmitter

Flexible, efficient, compliant with leading standard

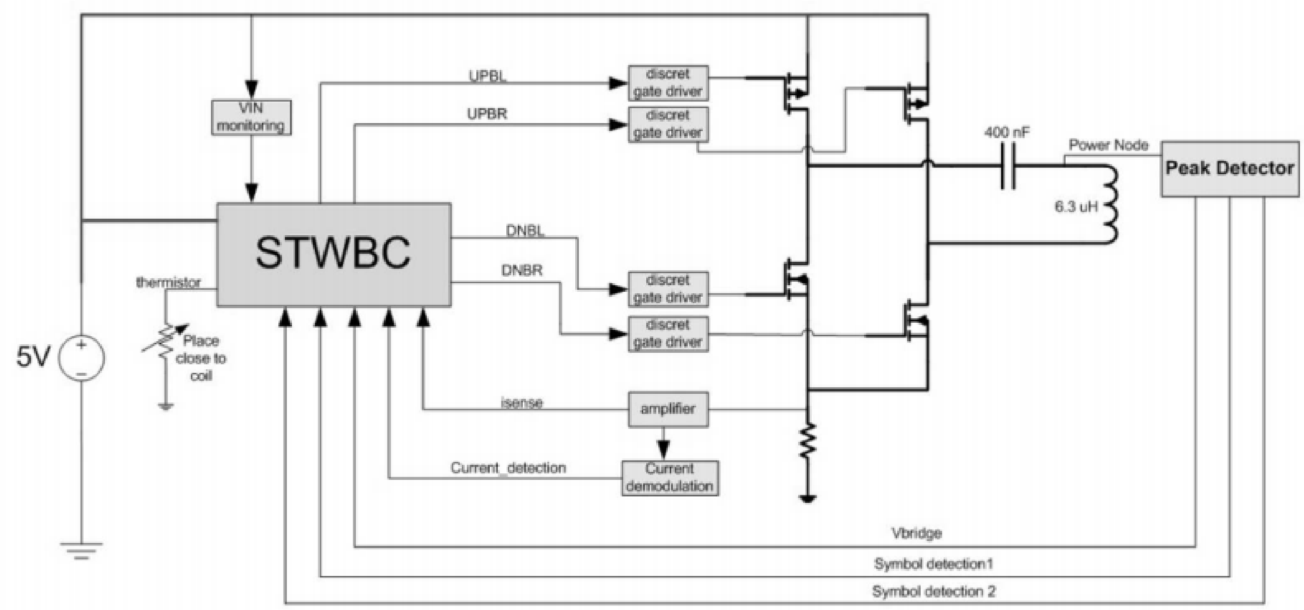




STWBC Transmitter Qi Evaluation Boards

STWBC - A11 Transmitter Configuration

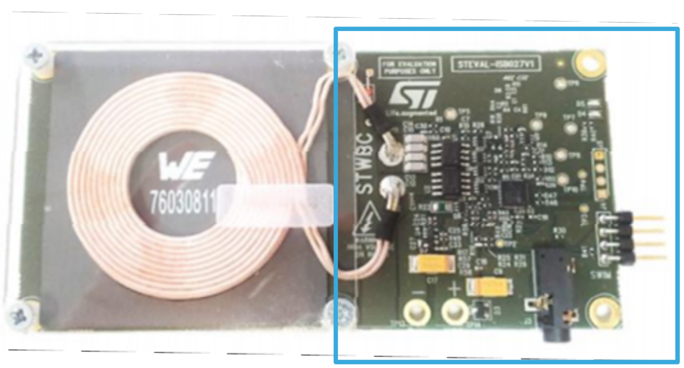
- 5W Qi, 1-Coil, 5V supply

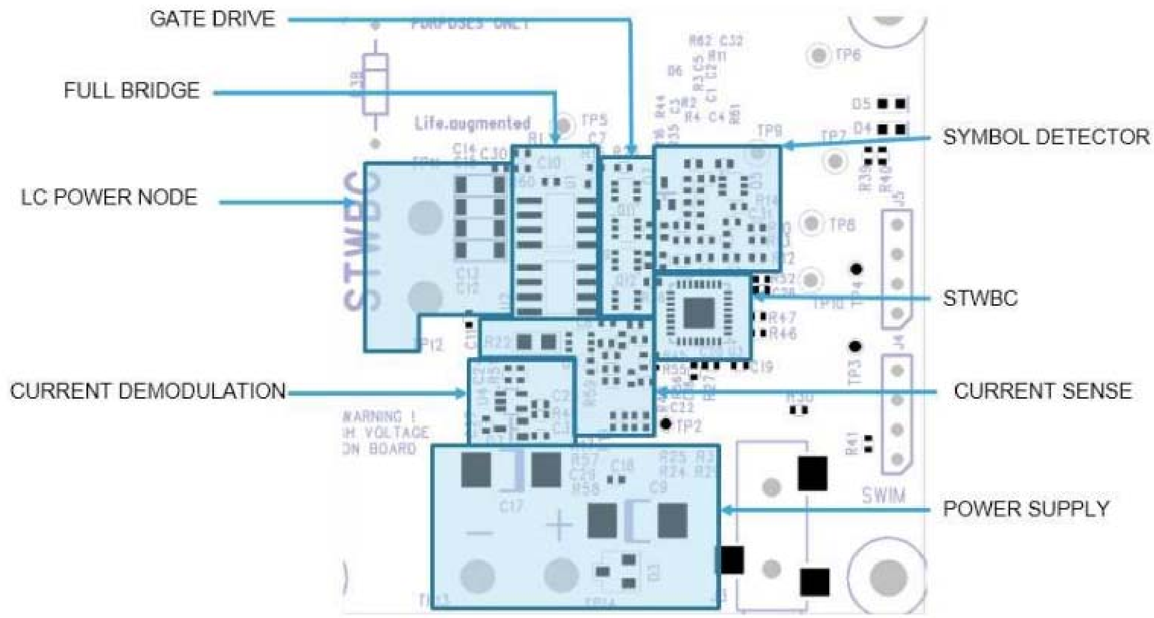


- A11 requires accurate frequency control:
  - Operating frequency range 110kHz – 205kHz
  - Duty cycle 50%-10% @ 205kHz

STWBC 5W A11 Transmitter Reference Board STEVAL-ISB027V1

- 2-Layer PCB and single-side placement



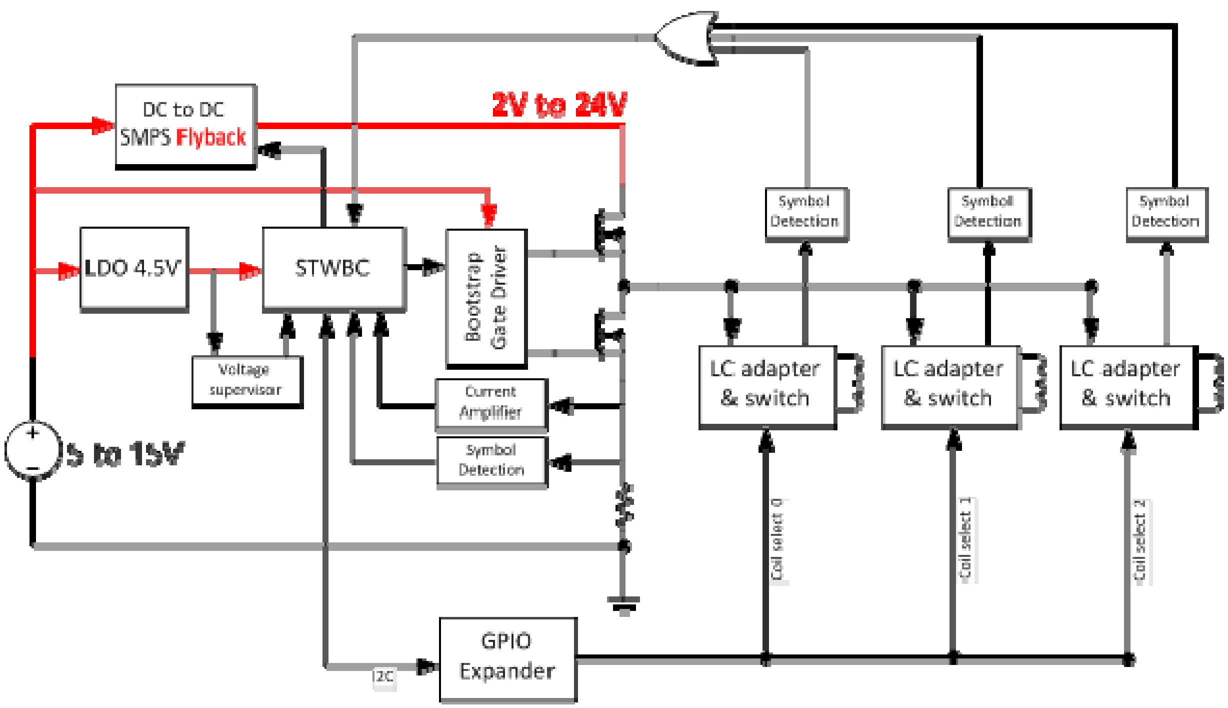


StandBy

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

STWBC – A34 Transmitter Configuration

- Available also as 5W Qi platform for Automotive, 3-Coil system



- Qi protocol, coil choice, bridge and fly back control handled by the STWBC
- The transmitter is based on a half bridge topology
- The inverter bridge is supplied by a Flyback converter

ST A34 Transmitter Special Recipe

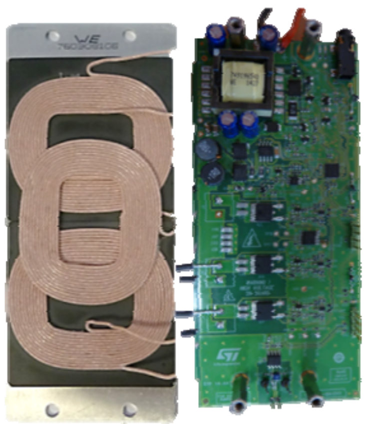
- ST implementation differs from the similar 3-coil A13 design. Here are the differences:
  - Board input voltage: **Exactly same (12V)**
  - Coil: **Exactly same**
  - Resonant tank: **Similar at 110kHz operating frequency**
  - Resonant tank excitation voltage: **Exactly same**
  - Bridge: **Half-bridge instead of full-bridge**
  - Bridge supply average power: **Exactly same**
  - Bridge supply voltage: **2 to 24V instead of 1 to 12V**
  - PID: **Same except that PID output (scaling factor) is doubled**

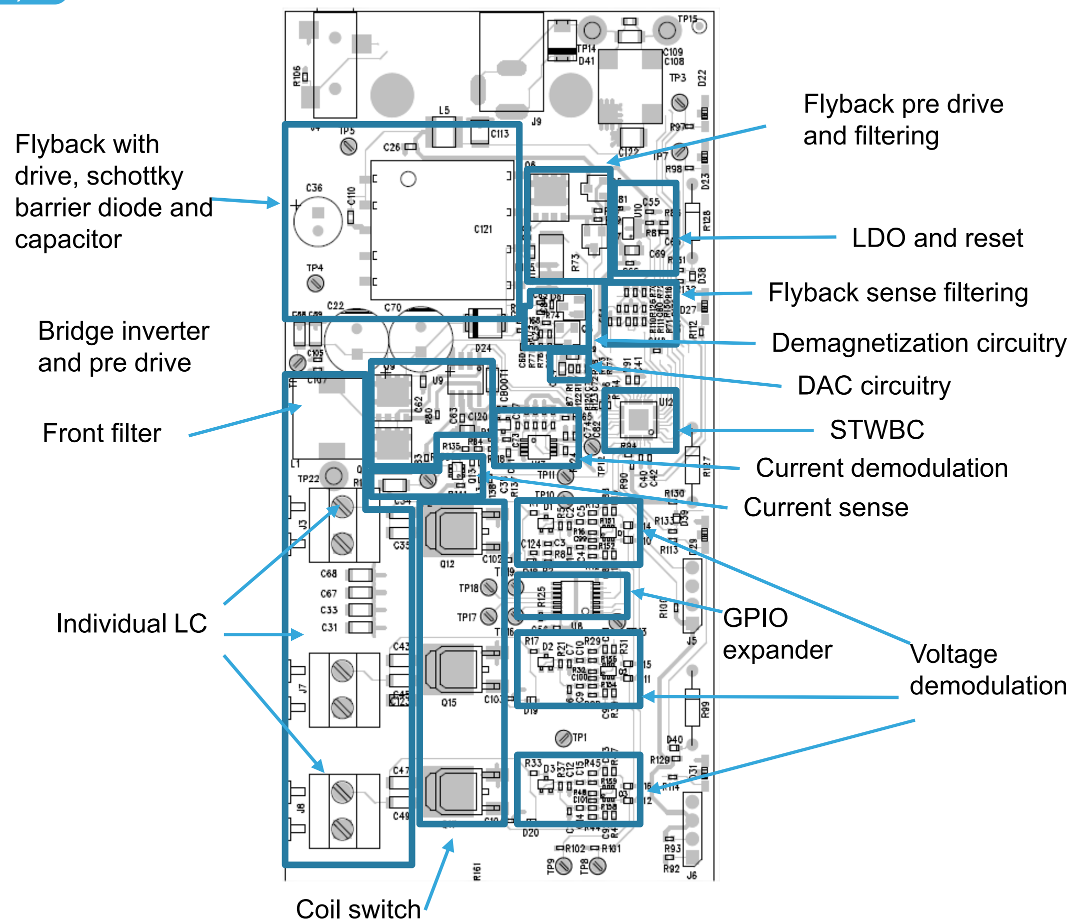
- Those modifications have been submitted to Qi consortium under CR305 ID. It has received the **A34** designation and it is now listed on the Wireless Power Consortium website.

STWBC – 5W A34 Transmitter Reference Board STEVAL-ISB028V1

ASTWBC (H1'17): automotive grade
STWBC-MC: Industrial grade (aftermarket)

- 2-layer PCB and single-side placement (same area as 3-coil assembly)

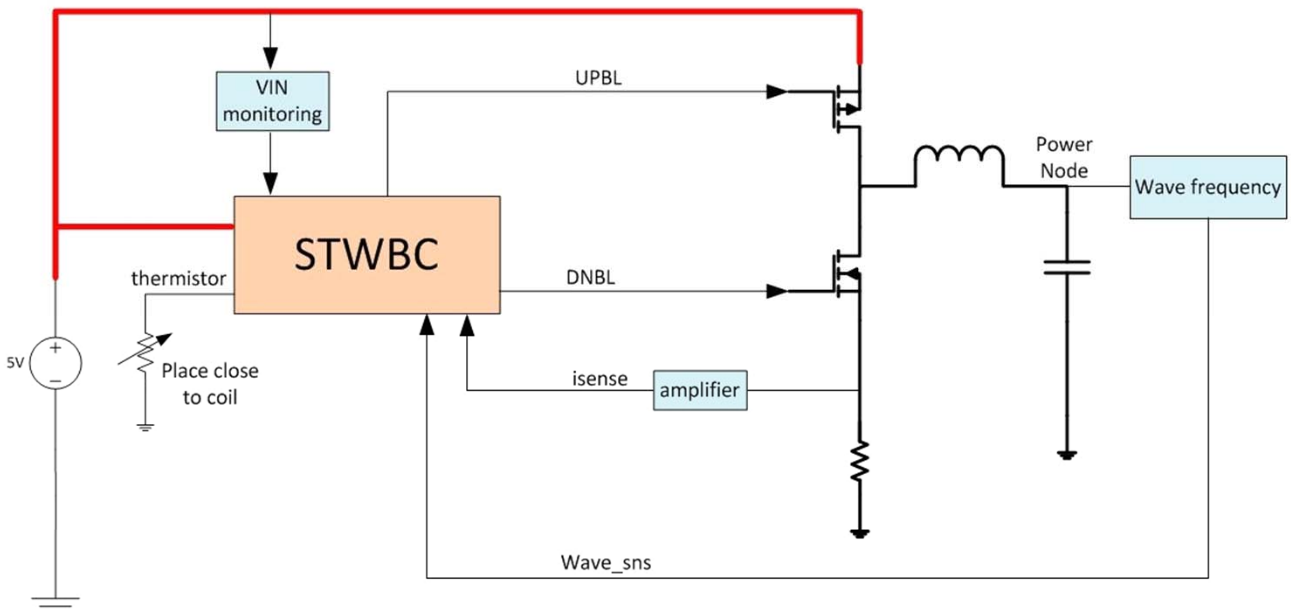




StandBy

- Ping active
- **30mW** consumption
- FOD active

STWBC – Wearable Transmitter Configuration

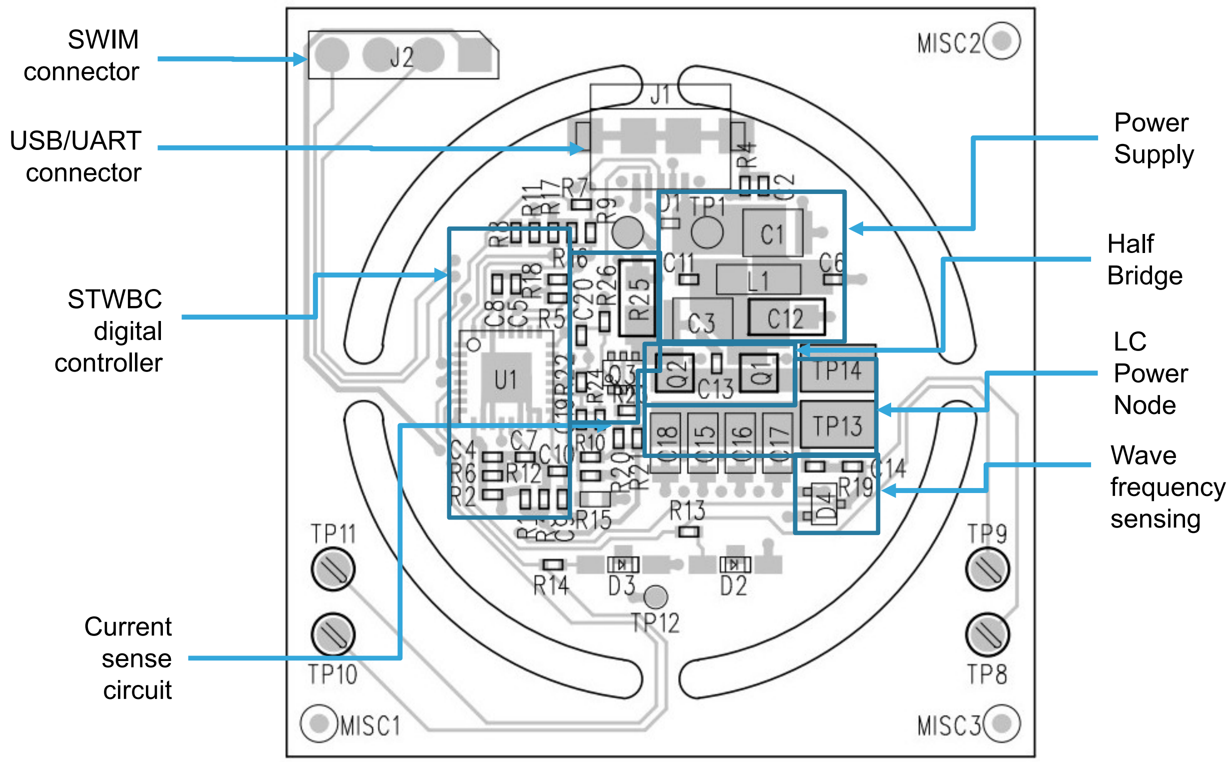


- System, bridge control and Qi protocol are handled by the STWBC
- The transmitter is based on a half bridge topology
- The inverter bridge is supplied by 5V input voltage

STWBC – 1W Wearable Transmitter Reference Board STEVAL-ISB038V1T

- 2-Layer PCB and single-side placement

20mm Coil



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/Wifi modules)

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

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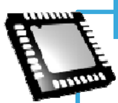
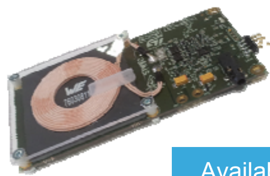
STWBC: Wireless Battery Charger TX



STWBC - STEVAL-ISB027V1

A11 Certified Wireless Charger (5W)

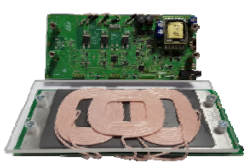
- 5W typical
- Qi A11 1.1.2 Certified (1.2 LP Ready) ref. design
- Foreign Object Detection (FOD)
- Active presence detector
- Turn Key or API customization
- Standby efficiency:
  - 3mW consumption
  - FOD active in standby



Available

STWBC-MC - STEVAL-ISB028V1

A34 Wireless charger Automotive (5W)



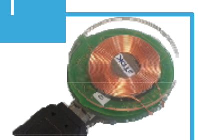
- Multi-coil for expanded positioning area
- Advanced FOD recognition
- 5-16V wide input range

Available on request

STWBC-WA - STEVAL-ISB038V1T

TX for Wearable

- **20 mm Coil**
- 1W delivery at RX side
- Compatible with STWLC04 RX



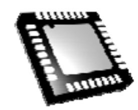
Available

STWBC-MP joins the STWBC family

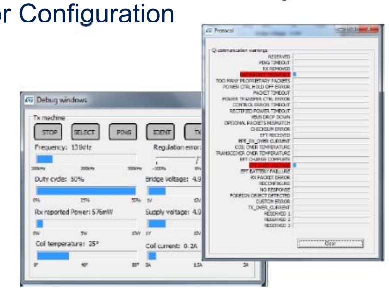
STWBC-MP (Q3 -17)

15 Watts

Certified Wireless Charger (15W)



- IC: STWBC-MP
- Reference Design: Qi 1.2 MP Certified
- Graphical Interface for Configuration



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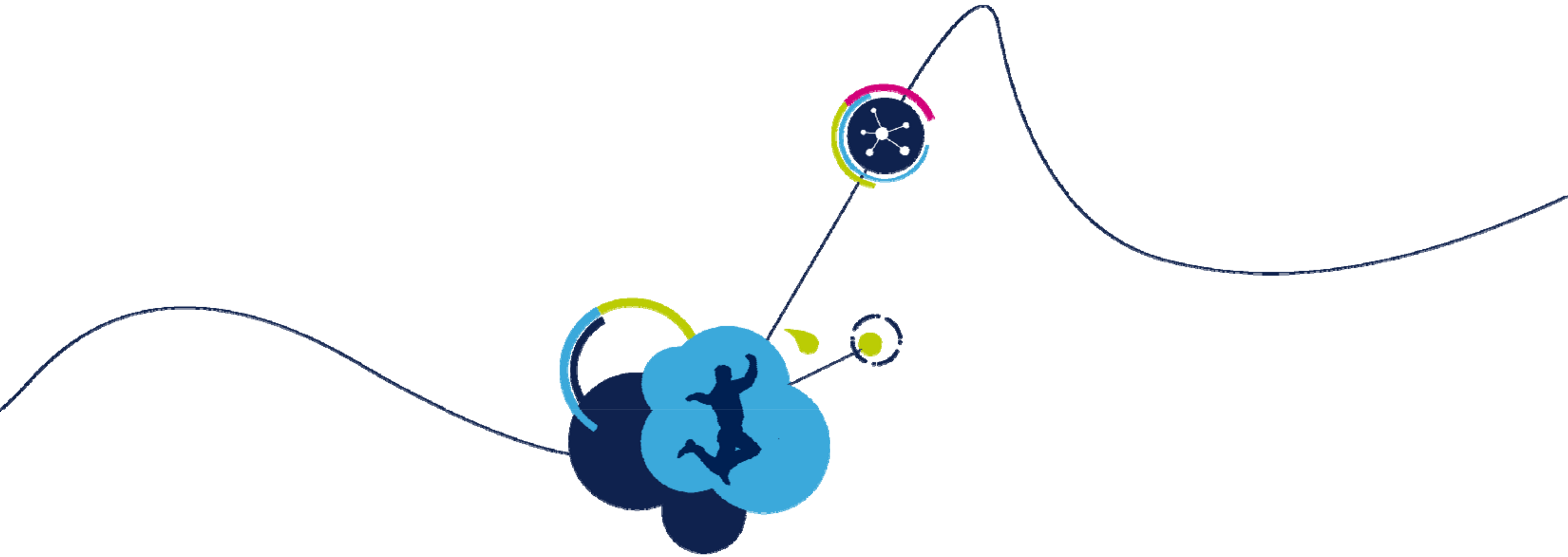
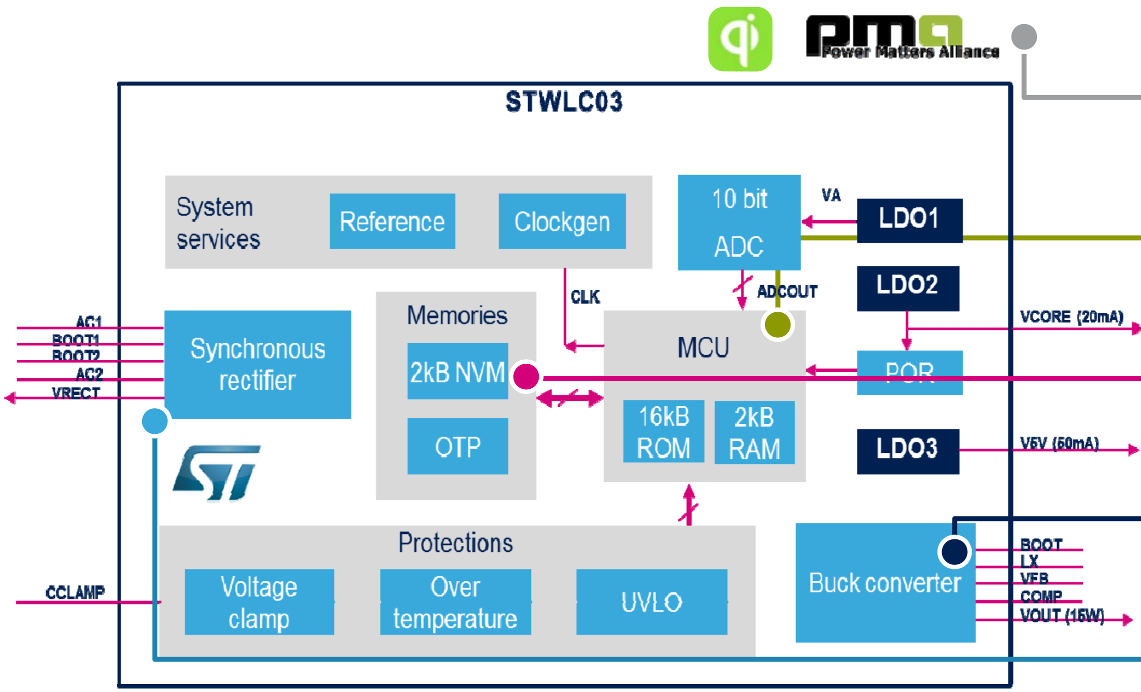


STWLC

Qi/AirFuel Inductive Wireless Battery Charger Receiver IC

STWLC0x - Receiver

ST is at the edge of innovation



Flip Chip 3.1x4.7mm

Multi Mode Qi 1.1.2 and AirFuel Inductive SR1 standards

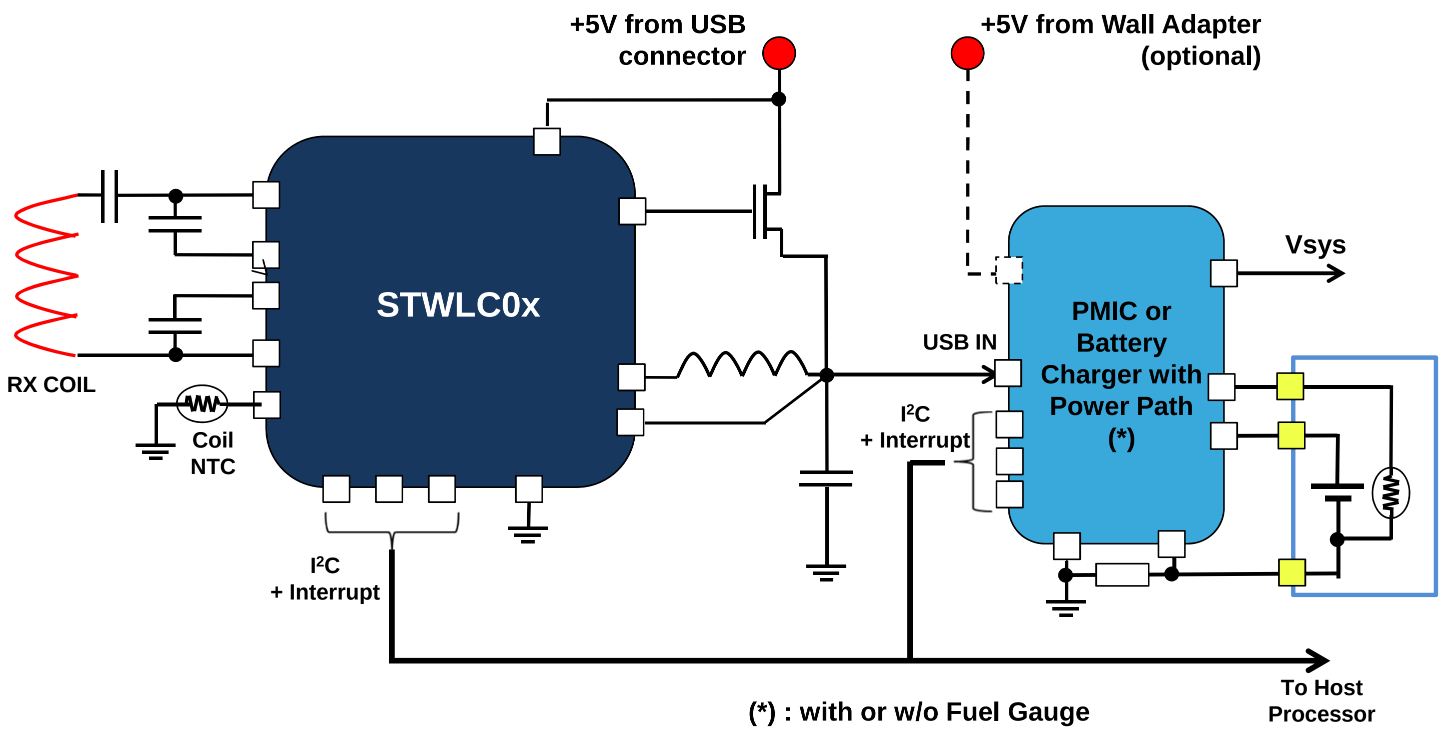
Embedded MCU with 16Kb ROM and 2Kb RAM

2kB NVM memory for customization

Programmable buck converter with current and voltage regulation (fsw=1MHz)

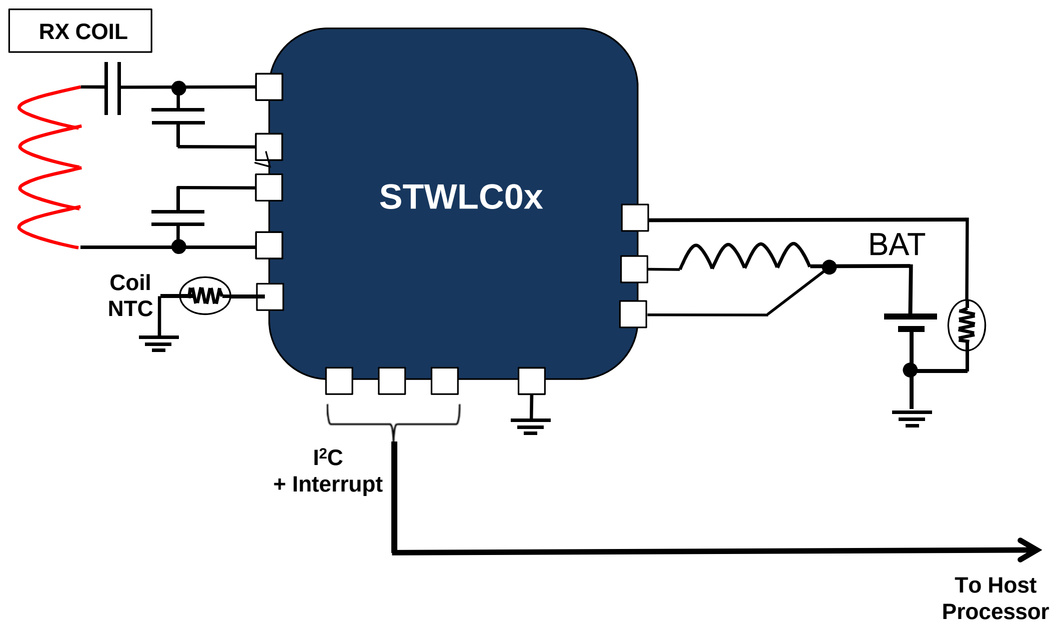
Integrated high efficiency synchronous rectifier

STWLC0x Simplified Application Diagram
Buck Regulator



(*) : with or w/o Fuel Gauge

STWLC0x Simplified Application Diagram Direct Charging



Lowest Output Leakage Current in the market!

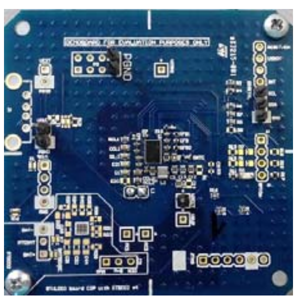
Guaranteed at <1µA

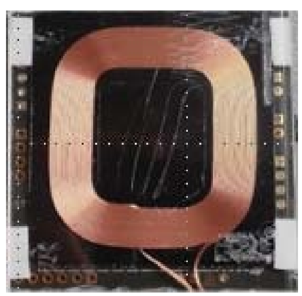
Measured as low as 0.14µA

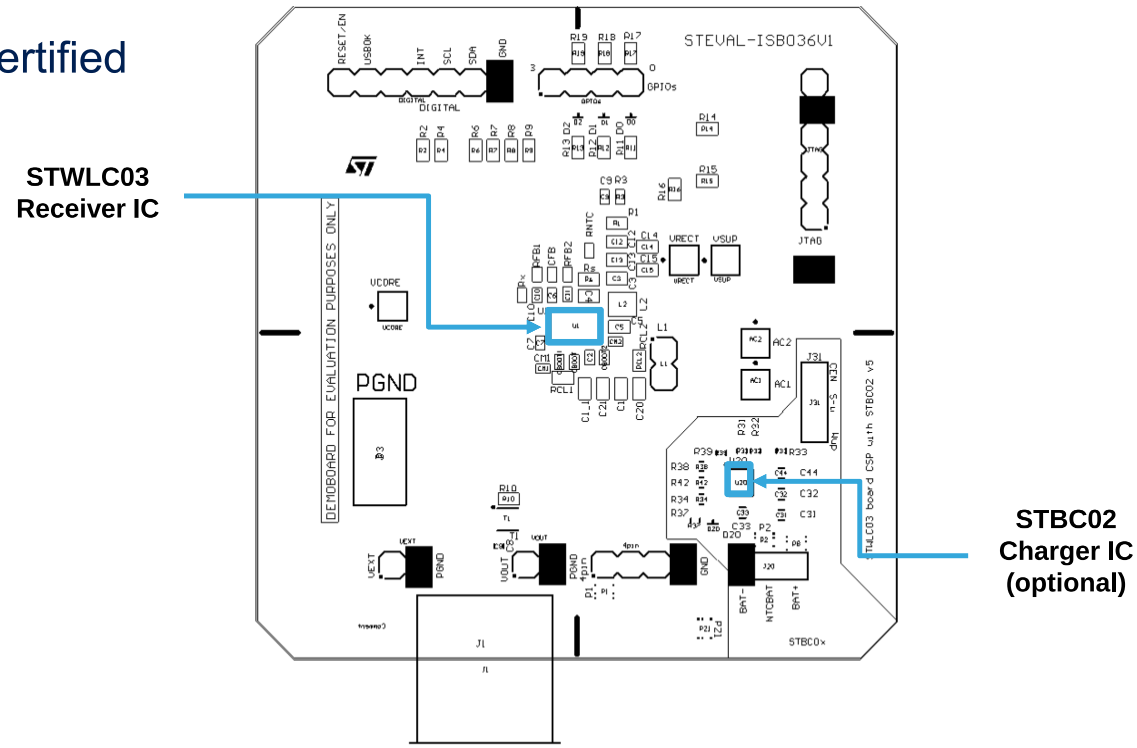
STWLC Receiver
Qi Evaluation Boards

STWLC03 – 5W Qi/AirFuel Inductive Receiver Reference Board STEVAL-ISB036V1

- 4-Layer PCB and single-side placement
- Qi 1.1 and AirFuel Inductive SR1 certified

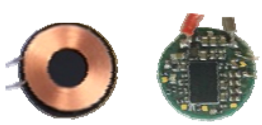






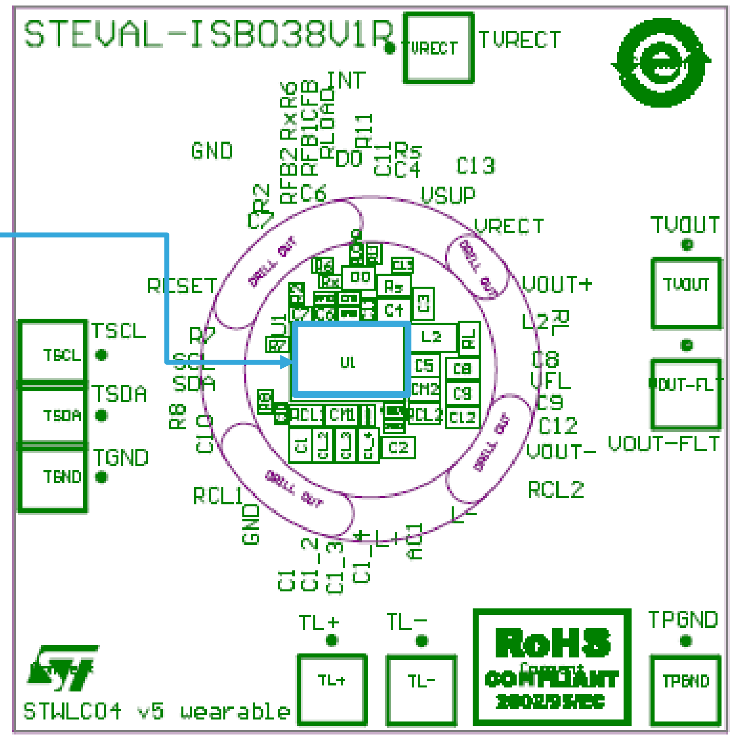
STWLC04 – 1W Wearable Receiver Reference Board STEVAL-ISB038V1R

- 4-layer PCB and single-side placement



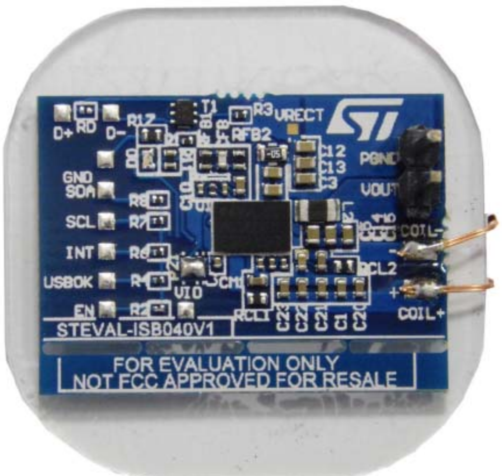
11mm Coil

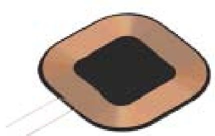
STWLC04
Receiver IC



STWLC03 – 2.5W Small Form Factor Receiver Reference Board STEVAL-ISB040V1

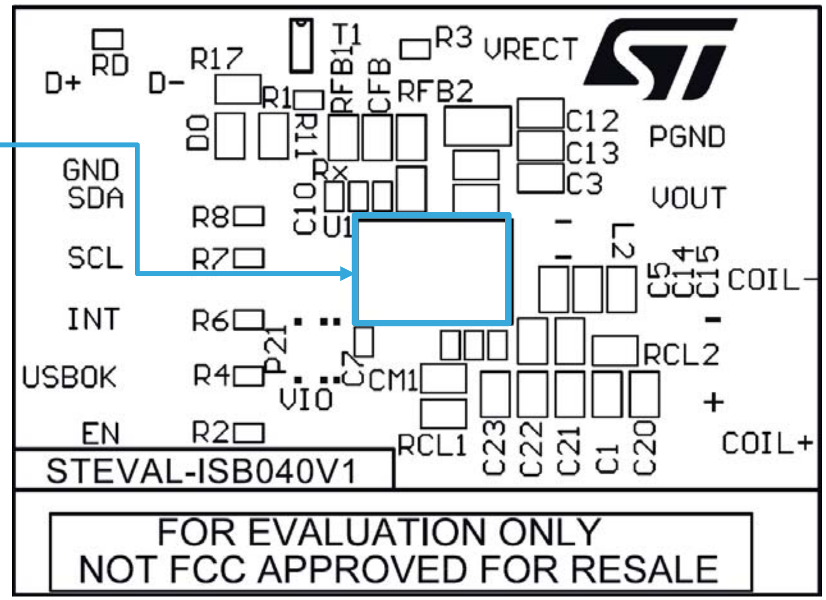
- 4-layer PCB and single-side placement





30x30mm Coil

STWLC03
Receiver IC



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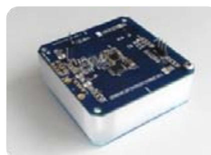
STWLC03/04: Wireless Battery Charger RX

STWLC03 - STEVAL-ISB036V1

Qi/AirFuel Ind. Certified Wireless Charger (5W)

- 5W Certified, 7.5W Max
- Qi 1.1 and AirFuel SR1 Certified Reference Design
- Foreign Object Detection (FOD)
- I²C Interface
- Voltage Source or Direct Charging configurations



Available

STWLC04 - STEVAL-ISB038V1R

Wireless Charger for Wearable (1W)

- **11mm Coil**
- 1W Received Power
- Qi-based Reference Design
- I²C Interface
- Voltage Source or Direct Charging configurations

Available

STWBC-WA + STWLC04 STEVAL-ISB038V1

Wireless Charger Evaluation Kit for Wearable (1W)

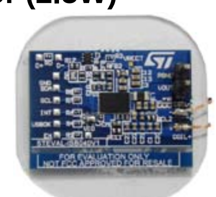
- Coils: **20mm TX, 11mm RX**
- Complete End to End evaluation platform
- GUI-controlled for Monitoring and Parameters Setting
- 5V USB Supply
- Can support up to 3W with larger size coils

Available

STWLC03 - STEVAL-ISB040V1

Wireless Charger Small Form Factor (2.5W)

- **30x30mm Coil**
- 2.5W Received Power
- Qi-based Reference Design
- I²C Interface
- Voltage Source or Direct Charging configurations



Available

life.augmented

STWLC33: 15W Wireless Battery Charger RX

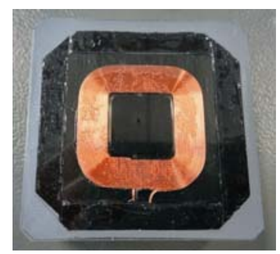
STWLC33 joins the STWLC family

STWLC33 – STEVAL-ISB0xxV1

15 Watts

Qi/AirFuel Inductive Certified Wireless Receiver with Transmit capability

- Up to 15 W output power in RX mode and **5 W in TX mode**
- Qi 1.2 and AirFuel inductive wireless standard communication protocol
- Integrated high efficiency synchronous rectifier
- Low drop regulator with output current and input voltage regulation loop
- Total system efficiency up to 80% at 5V VOUT
- 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

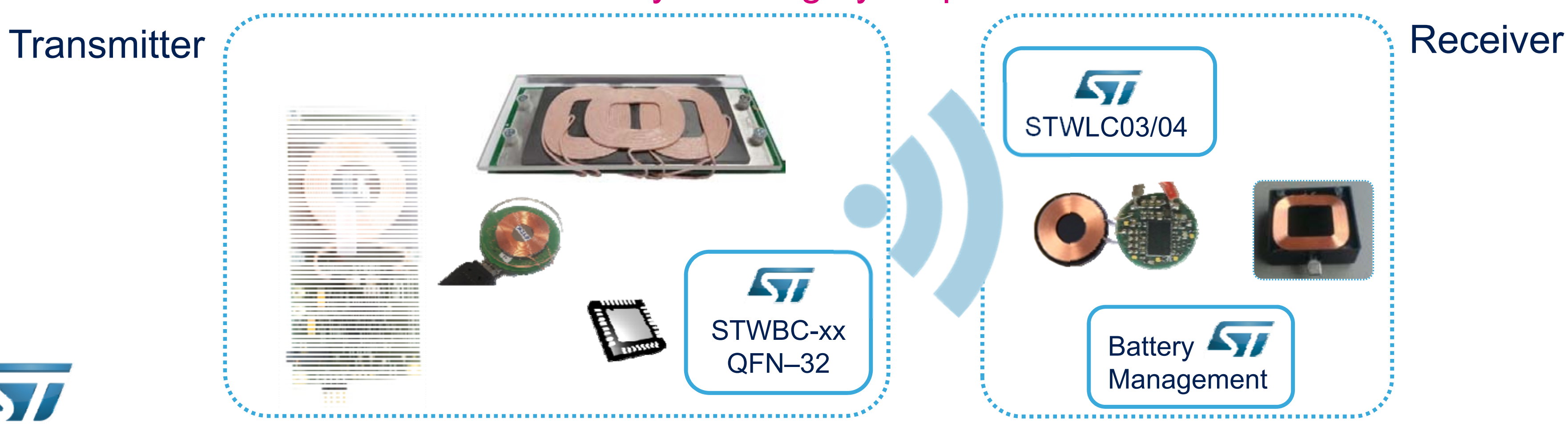


Available Q3 ‘17

ST Strengths in Wireless Charging

- Member of WPC and AirFuel Alliance
- System knowledge in 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
- **Design collaboration with WiTricity to develop solutions for Magnetic Resonant systems**

The easiest way to charge your portable devices



Thank you!

ST stands for life.augmented

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