Wireless Battery Charging

Paolo Battezzato – Applications Engineer
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*

* Source: IHS October 2016
Wireless Power at a Glance

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

Similar technology
Different Implementation

Different Standards
- Qi – by Wireless Power Consortium
- PMA – by Power Matter Alliance
- A4WP – by Alliance for Wireless Power

*Qi and AirFuel (A4WP + PMA) are a member of Qi and AirFuel (A4WP + PMA)

- Low Power: 5W (rel 1.2)
- Medium Power: 15W (rel 1.2)
- Qi Cordless kitchen appliances from 100W to 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

Note: A4WP and PMA merged in June 2015
## Organizations Defining Standards

<table>
<thead>
<tr>
<th></th>
<th>WPC</th>
<th>Qi</th>
<th>PMA</th>
<th>A4WP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Members</strong></td>
<td>~240</td>
<td></td>
<td>~200 under AirFuel Alliance name</td>
<td></td>
</tr>
<tr>
<td><strong>Available products</strong></td>
<td>&gt;950</td>
<td></td>
<td>~30</td>
<td>2</td>
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<tr>
<td><strong>Technology</strong></td>
<td>Inductive and Resonant-LF</td>
<td>Inductive</td>
<td>Resonant-HF</td>
<td></td>
</tr>
<tr>
<td><strong>Investment areas</strong></td>
<td>Infrastructure Automotive Power increase Larger Z Shared Mode, Resonant Extension</td>
<td>Consumer awareness Infrastructure Medium Power Merge with A4WP (June’15)</td>
<td>Specification Technology Industrialization Marketing Certification program &amp; Test houses Merge with PMA (June’15)</td>
<td></td>
</tr>
</tbody>
</table>

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

(*) also member of the Steering Group
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 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)
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

<table>
<thead>
<tr>
<th>Design</th>
<th>Description</th>
<th>Family</th>
<th>Voltage</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Single Primary Coils with magnetic alignment</td>
<td>#1</td>
<td>19 V</td>
<td>Frequency &amp; Duty cycle</td>
</tr>
<tr>
<td>A2</td>
<td>Single movable Primary Coils</td>
<td>#1</td>
<td>12 V</td>
<td>Voltage</td>
</tr>
<tr>
<td>A3</td>
<td>Single movable Primary Coils</td>
<td>#2</td>
<td>12 V</td>
<td>Voltage &amp; Frequency</td>
</tr>
<tr>
<td>A4</td>
<td>Two oblong Primary Coils</td>
<td>#4</td>
<td>11 V</td>
<td>Voltage &amp; Frequency</td>
</tr>
<tr>
<td>A5</td>
<td>Single Primary Coils with magnetic alignment</td>
<td>#1</td>
<td>5 V</td>
<td>Frequency &amp; Duty cycle</td>
</tr>
<tr>
<td>A6</td>
<td>Linear array of Primary Coils</td>
<td>#5</td>
<td>12 V</td>
<td>Frequency &amp; Duty cycle</td>
</tr>
<tr>
<td>A7</td>
<td>Single movable Primary Coils</td>
<td>#2</td>
<td>12 V</td>
<td>Voltage &amp; Frequency</td>
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<tr>
<td>A8</td>
<td>Single oblong Primary Coils</td>
<td>#4</td>
<td>11 V</td>
<td>Voltage &amp; Frequency</td>
</tr>
<tr>
<td>A9</td>
<td>Single Primary Coils with magnetic alignment</td>
<td>#1</td>
<td>15 V</td>
<td>Voltage &amp; Frequency</td>
</tr>
<tr>
<td>A10</td>
<td>Single Primary Coils without magnet</td>
<td>#1</td>
<td>19 V</td>
<td>Frequency &amp; Duty cycle</td>
</tr>
<tr>
<td>A11</td>
<td>Single Primary Coils without magnet</td>
<td>#1</td>
<td>5 V</td>
<td>Frequency &amp; Duty cycle</td>
</tr>
<tr>
<td>A12</td>
<td>Single oblong Primary Coils</td>
<td>#4</td>
<td>5 V</td>
<td>Frequency &amp; Duty cycle</td>
</tr>
<tr>
<td>A13</td>
<td>Linear array of Primary Coils</td>
<td>#5</td>
<td>12 V</td>
<td>Voltage &amp; Frequency</td>
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<tr>
<td>A14</td>
<td>Two oblong Primary Coils</td>
<td>#4</td>
<td>12 V</td>
<td>Frequency &amp; Duty cycle</td>
</tr>
<tr>
<td>A15</td>
<td>Single Primary Coils with user assisted alignment</td>
<td>#2</td>
<td>12 V</td>
<td>Voltage &amp; Frequency</td>
</tr>
<tr>
<td>A16</td>
<td>Single triangular Primary Coils</td>
<td>#6</td>
<td>5 V</td>
<td>Frequency &amp; Duty cycle</td>
</tr>
<tr>
<td>A17</td>
<td>Single Primary Coils</td>
<td>#1</td>
<td>15 V</td>
<td>Voltage &amp; Frequency</td>
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<tr>
<td>A18</td>
<td>Single Primary Coils with user assisted alignment</td>
<td>#2</td>
<td>12 V</td>
<td>Voltage &amp; Frequency</td>
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<tr>
<td>A19</td>
<td>Dual Primary Coils</td>
<td>#5</td>
<td>12 V</td>
<td>Frequency &amp; Duty cycle</td>
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<tr>
<td>A20</td>
<td>Single oblong Primary Coils</td>
<td>#4</td>
<td>12 V</td>
<td>Voltage &amp; Frequency</td>
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<tr>
<td>A21</td>
<td>Linear array of Primary Coils</td>
<td>#5</td>
<td>12 V</td>
<td>Frequency &amp; Duty cycle</td>
</tr>
<tr>
<td>A22</td>
<td>Single oblong Primary Coils</td>
<td>#4</td>
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<td>Voltage &amp; Frequency</td>
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<tr>
<td>A23</td>
<td>Single oblong Primary Coils</td>
<td>#4</td>
<td>12 V</td>
<td>Voltage &amp; Frequency &amp; Duty Cycle</td>
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<tr>
<td>A24</td>
<td>Single Primary Coils</td>
<td>#1</td>
<td>5 V</td>
<td>Frequency &amp; Duty cycle</td>
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<tr>
<td>A25</td>
<td>Single oblong Primary Coils</td>
<td>#4</td>
<td>5 V</td>
<td>Frequency &amp; Duty cycle</td>
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<td>A26</td>
<td>Single triangular Primary Coils</td>
<td>#6</td>
<td>5 V</td>
<td>Frequency &amp; Duty cycle</td>
</tr>
<tr>
<td>A27</td>
<td>Single Primary Coils</td>
<td>#3</td>
<td>12 V</td>
<td>Phase</td>
</tr>
<tr>
<td>A28</td>
<td>Linear array of Primary Coils</td>
<td>#5</td>
<td>5 V</td>
<td>Frequency &amp; Duty cycle</td>
</tr>
<tr>
<td>A29</td>
<td>Single Primary Coils</td>
<td>#1</td>
<td>12 V</td>
<td>Voltage control</td>
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<tr>
<td>A30</td>
<td>Single oblong Primary Coils</td>
<td>#4</td>
<td>12 V</td>
<td>Voltage &amp; Duty cycle</td>
</tr>
<tr>
<td>A31</td>
<td>Single oblong Primary Coils</td>
<td>#4</td>
<td>12 V</td>
<td>Voltage &amp; Duty cycle</td>
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</tbody>
</table>

Designs B1 to B6:

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

![Diagram of primary coil designs](image)

Family of Primary Coil Shapes:

<table>
<thead>
<tr>
<th>Family</th>
<th>Primary Coil Shape</th>
<th>Primary Coil Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>Circular</td>
<td>Ø40...43 mm</td>
</tr>
<tr>
<td>#2</td>
<td>Circular</td>
<td>Ø33...39 mm</td>
</tr>
<tr>
<td>#3</td>
<td>Circular/hexagonal</td>
<td>Ø28...32 mm</td>
</tr>
<tr>
<td>#4</td>
<td>Oisolong</td>
<td>65...70×60 mm²</td>
</tr>
<tr>
<td>#5</td>
<td>Rectangular</td>
<td>46.5×37.5...53×45 mm²</td>
</tr>
<tr>
<td>#6</td>
<td>Triangular</td>
<td>52×46...52×52 mm²</td>
</tr>
<tr>
<td>#7</td>
<td>Square</td>
<td>45×45 mm²</td>
</tr>
<tr>
<td>#8</td>
<td>Circular</td>
<td>Ø30 mm</td>
</tr>
<tr>
<td>#9</td>
<td>Oisolong</td>
<td>45×34 mm²</td>
</tr>
</tbody>
</table>

Source: WPC Qi specifications, Version 1.2
STWBC
Qi Wireless Battery Charging Transmitter IC
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
- 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
STWBC - Transmitter

Flexible, efficient, compliant with leading standard

STWBC OPERATIONAL BLOCKS AND QI 1.1.2 A11 CONFIGURATION

5 V

Vbus monitor
5 or 3.3 V input
2x LED

Digital controller
Topology specific firmware (including Qi certification)

Digital bridge controller
Temperature protection
Overcurrent protection
Signal and protocol demodulator
QI 1.1.2 FOD
Active object detector

ADC
GPIOs
UART
PC

Customizable

Push buttons
LED
Buzzer
Communication interfaces

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

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

STWBC – 5W A34 Transmitter Reference Board
STEVAL-ISB028V1

- 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

[Diagram of the board with labeled parts]

- SWIM connector
- USB/UART connector
- STWBC digital controller
- Power Supply
- Half Bridge
- LC Power Node
- Wave frequency sensing
- Current sense circuit
- 20mm Coil
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.

**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.
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

STWBC-MC - STEVAL-ISB028V1
A34 Wireless charger Automotive (5W)
- Multi-coil for expanded positioning area
- Advanced FOD recognition
- 5-16V wide input range

STWBC-WA - STEVAL-ISB038V1T
TX for Wearable
- 20 mm Coil
- 1W delivery at RX side
- Compatible with STWLC04 RX

STWBC-MP joins the STWBC family

STWBC-MP (Q3 -17)
Certified Wireless Charger (15W)
- IC: STWBC-MP
- Reference Design: Qi 1.2 MP Certified
- Graphical Interface for Configuration

15 Watts
STWLC
Qi/AirFuel Inductive Wireless Battery Charger Receiver IC
STWLC0x - Receiver

ST is at the edge of innovation

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

STWLC03

Flip Chip 3.1x4.7mm
STWLC0x Simplified Application Diagram

Buck Regulator

+5V from USB connector

+5V from Wall Adapter (optional)

RX COIL

STWLC0x

Coil NTC

PC + Interrupt

USB IN

PMIC or Battery Charger with Power Path (*)

(*) : with or w/o Fuel Gauge

To Host Processor

(*): with or w/o Fuel Gauge

+5V from USB connector

+5V from Wall Adapter (optional)
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
STWLC03 – 2.5W Small Form Factor Receiver Reference Board
STEVAL-ISB040V1

- 4-layer PCB and single-side placement
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
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

STWLC33 joins the STWLC family

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