Wireless Charging in Consumer Applications

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Applications Engineering Manager
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

### 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

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### Similar technology

Different Implementation

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### 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

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### 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 to 2.4kW
- Resonant (Under Consideration)

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

![Diagram of RX Presence Detection and FOD](image)
# Qi Power-Transmitter Design 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 Coil with magnet alignment</td>
<td>#1</td>
<td>12 V</td>
<td>Frequency &amp; Duty cycle</td>
</tr>
<tr>
<td>A2</td>
<td>Single movable Primary Coil</td>
<td>#1</td>
<td>12 V</td>
<td>Voltage</td>
</tr>
<tr>
<td>A3</td>
<td>Single movable Primary Coil</td>
<td>#1</td>
<td>12 V</td>
<td>Voltage &amp; Frequency</td>
</tr>
<tr>
<td>A4</td>
<td>Two oblong Primary Coils</td>
<td>#1</td>
<td>12 V</td>
<td>Voltage &amp; Frequency</td>
</tr>
<tr>
<td>A5</td>
<td>Single Primary Coil with magnet 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 Coil</td>
<td>#2</td>
<td>12 V</td>
<td>Voltage &amp; Frequency</td>
</tr>
<tr>
<td>A8</td>
<td>Single oblong Primary Coil</td>
<td>#4</td>
<td>12 V</td>
<td>Voltage &amp; Frequency</td>
</tr>
<tr>
<td>A9</td>
<td>Single Primary Coil with magnet alignment</td>
<td>#1</td>
<td>15 V</td>
<td>Frequency &amp; Duty cycle</td>
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<tr>
<td>A10</td>
<td>Single Primary Coil without magnet</td>
<td>#1</td>
<td>14 V</td>
<td>Frequency &amp; Duty cycle</td>
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<tr>
<td>A11</td>
<td>Single Primary Coil without magnet</td>
<td>#1</td>
<td>5 V</td>
<td>Frequency &amp; Duty cycle</td>
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<tr>
<td>A12</td>
<td>Single oblong Primary Coil</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>22 V</td>
<td>Frequency &amp; Duty cycle</td>
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<tr>
<td>A15</td>
<td>Single Primary Coil, user assisted alignment</td>
<td>#2</td>
<td>12 V</td>
<td>Voltage &amp; Frequency</td>
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<tr>
<td>A16</td>
<td>Single triangular Primary Coil</td>
<td>#6</td>
<td>5 V</td>
<td>Frequency &amp; Duty cycle</td>
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<tr>
<td>A17</td>
<td>Single Primary Coil</td>
<td>#1</td>
<td>15 V</td>
<td>Voltage &amp; Frequency</td>
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<tr>
<td>A18</td>
<td>Single Primary Coil, 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>
</tr>
<tr>
<td>A20</td>
<td>Single oblong Primary Coil</td>
<td>#4</td>
<td>12 V</td>
<td>Voltage &amp; Frequency</td>
</tr>
<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 Coil</td>
<td>#4</td>
<td>12 V</td>
<td>Voltage &amp; Frequency</td>
</tr>
<tr>
<td>A23</td>
<td>Single oblong Primary Coil</td>
<td>#4</td>
<td>12 V</td>
<td>Voltage, Frequency &amp; Duty cycle</td>
</tr>
<tr>
<td>A24</td>
<td>Single Primary Coil</td>
<td>#1</td>
<td>5 V</td>
<td>Frequency &amp; Duty cycle</td>
</tr>
<tr>
<td>A25</td>
<td>Single oblong Primary Coil</td>
<td>#4</td>
<td>5 V</td>
<td>Frequency &amp; Duty cycle</td>
</tr>
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<td>A26</td>
<td>Single triangular Primary Coil</td>
<td>#0</td>
<td>5 V</td>
<td>Frequency &amp; Duty cycle</td>
</tr>
<tr>
<td>A27</td>
<td>Single Primary Coil</td>
<td>#0</td>
<td>12 V</td>
<td>Voltage</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 Coil</td>
<td>#1</td>
<td>12 V</td>
<td>Voltage control</td>
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<tr>
<td>A30</td>
<td>Single oblong Primary Coil</td>
<td>#4</td>
<td>12 V</td>
<td>Frequency &amp; Duty cycle</td>
</tr>
<tr>
<td>A31</td>
<td>Single oblong Primary Coil</td>
<td>#4</td>
<td>12 V</td>
<td>Frequency &amp; Duty cycle</td>
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<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>
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<td>Linear array of Primary Coils</td>
<td>#9</td>
<td>5 V</td>
<td>Phase</td>
</tr>
</tbody>
</table>

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**Family | Primary Coil Size**
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#1 | Circular: Ø40...43 mm
#2 | Circular: Ø33...39 mm
#3 | Circular/hexagonal: Ø29...32 mm
#4 | Oblong: 65x57...70x60 mm²
#5 | Rectangular: 46.5x37.5...53x45 mm²
#6 | Triangular: 52x46...59x52 mm²
#7 | Square: 45x45 mm²
#8 | Circular: Ø60 mm
#9 | Oblong: 45x34 mm²

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

Flexible, efficient, compliant with leading standards

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
I²C

Customizable

Push buttons
LED
Buzzers
Communication interfaces

STWBC
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
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
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
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

2-Layer PCB and single-side placement

- 17mW consumption
- Ping active
- FOD active
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
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

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

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
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

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
STWLC
Qi/AirFuel Inductive Wireless Battery Charger Receiver IC
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

**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

STEVAl-ISB045V1

STEVAl-ISB043V1

Available Now

Available Q1 ’20
Qi-based Wearable RX Reference Board

STWLC30 – 2.5W STEVAL-ISB043V1

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

26mm Coil
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

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

2.5-15W Wireless Battery Charger RX

STWLC30 – STEVAL-ISB043V1

2.5 Watts

Available Q1 ’20

STWLC68

Qi Certified Wireless Receiver with Transmit capability

5/15/20 Watts

Available Q1 ’20

STWLCxx

2.5 Watts

Available Q1 ’20

2.5-15 Watts Wireless Battery Charger RX

STWLCxx

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Available Q1 ’20

2.5-15 Watts Wireless Battery Charger RX

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Available Q1 ’20
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
Thank You!