ST Wireless Charging Solutions

Youth Tan

STMicroelectronics
Inductive wireless charging concept

Qi and other standards

STWBC & STWLC products

Focus on 15W platform

Customer support
Agenda

1. Inductive wireless charging concept
2. Qi and other standards
3. STWBC & STWLC products
4. Focus on 15W platform
5. Customer support
Power Transmission Principle

- Based on **magnetic induction** between Tx and Rx
- Tx generates a magnetic field through a coil, integrated in a **resonant LC** circuit (=TANK)
- Rx coil picks-up this magnetic field, then the received electrical signal is **rectified, filtered and regulated**
The Need of Regulation

- **Some parameters are variable:**
  - The coupling between the coils
  - The load
- So, the system needs **to regulate the magnetic field to:**
  - Sustain the Rx load, in case of weak coupling for instance
  - Improve efficiency when low power is required by Rx
Regulation Principle

- Regulation = adapt Tx Power to real load needs
- Rx produces a digital feedback to TX = closed-loop regulation
To modulate the field, generated from an AC signal, various solutions are used simultaneously:

- Change the oscillator **frequency**
- Change the oscillator **voltage**
- Change the oscillator **duty cycle**

Diagram:
- Transmitter (Tx)
  - DC voltage
  - Drivers
  - Rectification
  - Voltage regulation
  - Load
  - Voltage
  - Duty cycle
  - Frequency

Graph:
- Power operating point decrease/increase vs. Frequency
1. STWBC regularly generates a short magnetic field ("analog ping") and checks if a load consumes it.

2. After Rx is detected, the "real" magnetic field is generated.

3. Tx waits for the digital feedback:
   • If a feedback is received, Tx will adapt the transmitted Power
   • If not, Tx will stop the magnetic field.
Foreign Object Detection (FOD)

- An object can be inserted between Tx and Rx. If it can absorb a part of the magnetic field, it is called “Foreign Object (FO)”. 

- Metallic foreign object (coins, paper clip, …) is critical:
  - The magnetic field absorbed is converted into current
  - The temperature of the FO can be very high.

- To avoid system damage and human injury, FOD is mandatory to stop the power transmission.
• STWBC FOD is based on power balance estimation:
  • Tx estimates the real transmitted Power (including losses)
  • Rx estimates and transmit the real received Power
  • High difference $\rightarrow$ a Foreign Object is probably present
• STWBC FOD is also based on quality factor measurement:
  • Rx transmits its own Q factor (stored in NVM)
  • Tx compares this value with the measured Q factor
  • High difference ? → a Foreign Object is probably present
Power Transfer Waveforms

Startup example in Qi – BPP 5W. Measurements presented from RX Vrect (yellow) and Vout (blue).
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There are essentially 2 standards:

- **Qi (WPC alliance)**
  - Inductive power transfer (100-205kHz)
  - Highly adopted in mobile devices

- **PMA / Rezence (AirFuel alliance)**
  - PMA is also inductive (277-357kHz), main difference = communication protocol. It can be found in some mobile phones.
  - Rezence (from A4WP) is based on resonant power transfer (6.78MHz).
    Allow larger distance but lower efficiency.

⇒ **ST has chosen Qi**
Qi Standard and Tx Profiles (1/3)

- To ensure interoperability, the **magnetic field** created and the **regulation** behavior are normalized.
- Qi defines **Tx architecture**, sorted in 2 main families:
  - **Axx**: Only 1 coil activated at a time (it can be multi-coil).
    → MPAx for 15W
  - **Bxx**: 1 or more coils can be activated **simultaneously**
    → MPBx for 15W
- A **Tx design must comply** with the selected architecture, which defines:
  - Supply voltage of the transmitter
  - Power driver structure (half or full bridge)
  - The way to modulate the power (frequency, voltage, duty, phase)
  - Coil assembly and the tank (capacitor in particular)
  - Mechanical constraints around the coil
  - Number of coils and their activation rules
  - PID parameters for the regulation loop
### Qi Standard and Tx Profiles (2/3)

- Extract of MP architecture table:

<table>
<thead>
<tr>
<th>ARCH</th>
<th>VBridge</th>
<th>Coil</th>
<th>Bridge</th>
<th>F duty</th>
<th>Digital ping</th>
</tr>
</thead>
<tbody>
<tr>
<td>MP-A8</td>
<td>12±1 V</td>
<td>$L_p = 7.5 \mu H \pm 10%$</td>
<td>Half Bridge / Full bridge $f_{op} = 110$ kHz to $205$ kHz</td>
<td>$t_{on}/t_{period} = 10%$ to $50%$.</td>
<td>12±1 V 175 to 180 kHz and a duty cycle of 50%.</td>
</tr>
<tr>
<td>(3 coils)</td>
<td></td>
<td>$L_p = 8.5 \mu H \pm 10%$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$C_p = 320 \pm 5%$ nF</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$C_p = 300 \pm 5%$ nF</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MP-A9</td>
<td>1 to 25V</td>
<td>$L_p = 9.8\pm 10% \mu H$</td>
<td>Full bridge $f_{op} = 120$ kHz to $130$ kHz</td>
<td>$t_{on}/t_{period} 50%$.</td>
<td>7 V 125 kHz and a duty cycle of 50%.</td>
</tr>
<tr>
<td>(1 or 3 coils)</td>
<td></td>
<td>or $L_p = 10.2\pm 10% \mu H$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$C_p = 400\pm 5%$ nF</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MP-A10</td>
<td>15V to 24V</td>
<td>$L_p = 11.3 \pm 0.7 \mu H$</td>
<td>Half Bridge $f_{op} = 110$ kHz to $180$ kHz</td>
<td>$t_{on}/t_{period} = 10%$ to $50%$.</td>
<td>14V 140 to 170 kHz and a duty cycle of 50%.</td>
</tr>
<tr>
<td>(1 coil)</td>
<td></td>
<td>$C_p = 188\pm 10%$ nF</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MP-A11</td>
<td>1 ±5% V to 19 ±5% V</td>
<td>$L_p = 6.3\pm 10% \mu H$</td>
<td>Full bridge $f_{op} = 120$ to $130$ kHz</td>
<td>$t_{on}/t_{period} = 50%$.</td>
<td>4V 125 KHz and a duty cycle of 50%.</td>
</tr>
<tr>
<td>(1 coil)</td>
<td></td>
<td>$C_p = 500\pm 5%$ nF</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MP-A12</td>
<td>1 to 20V</td>
<td>$L_p = 11.3\pm 0.7 \mu H$</td>
<td>Full bridge $f_{op} = 108$ kHz to $114$ kHz</td>
<td>$t_{on}/t_{period} = 50%$.</td>
<td>7±0.5 V 111 kHz and a duty cycle of 50%.</td>
</tr>
<tr>
<td>(3 coils)</td>
<td></td>
<td>$C_p = 300\pm 5%$ nF</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **ST design**
  - Large coil
  - Low cost topology
Qi Standard and Tx Profiles (3/3)

- Qi has defined different **profiles** for Tx
  - Qi BPP (**Baseline** Power Profile): **up to 5W**
  - Qi EPP (**Extended** Power Profile): **up to 15W**

- Qi BPP main revisions:
  - **Rev1.0**: No FOD recognition (no data for power balance estimation)
  - **Rev1.1**: All Tx must be compliant with FOD recognition
  - **Rev1.2**: latest revision, **it includes EPP** (so up to 15W)

- Qi EPP (including BPP as well):
  - **Rev1.2** = Unification of BPP and EPP profiles (prev. called Medium Power) .
    New: **bidirectional Rx / Tx** communication link and enhanced FOD (Q factor)
Qi Compliancy

• Qi certification = Qi conformance + Qi IOP
  
  • Conformance tests: in Qi certified labs
    Pre-testing in-house with testers
  
  • Inter-OPerability tests: Only 2 certified labs (Eurofins in Belgium, TTA in Korea)
    
    **ALL Rx** (~140 units) must work with our **Tx**, no failure accepted!
    
    Same for Rx: must be compatible with all Tx

• No certification required → schedule / costs hugely reduced:
  
  • Development based on reference design, taking into account specific customer constraints (coil choice, “z” distance, etc.).
  
  • Optimization (mainly coupling) is done directly between Tx and Rx board
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Wearable Solution

1 Watt reference design

Transmitter STWBC-WA

- 5 V USB powered
- Active presence detection
- Optimized eBOM (Half-bridge)
- Stand-by FOD
- Firmware customization with API

Receiver: STWLC04

- Li-Ion direct charging or 5 V output
- Space saving solution with optimized BOM
- Up to 3 mm Z

STEVAL-ISB038V1
2.5 Watt reference design

Transmitter STWBC-WA

- 2.5W full bridge TX
- 5 V USB powered
- Optimized eBOM (ST patent: current sensing circuit removed)
- 13.8mm x 28.1mm 2 layers PCB

Available from Q2/2018-

Receiver: STWLC33

- 5 V regulated voltage
- Output Leakage: <1uA
- Up to 67% efficiency @ 1mm Z
- Up to 4 mm Z

STEVAL-ISB043V1
Consumer Solution

5W reference design: plug and play

- **Transmitter:** STWBC (A11)
- **Receiver:** STWLC03

- Ubiquitous: 5 V USB powered
- Plug & play: **Qi 1.1 LP certified** (5 W)
- Smart Standby: 3mW with FOD
- Flexible: customizable via GUI or software API

- Energy friendly: Integrated high-performance buck converter and synchronous rectifier
- Plug & play: certification Qi (5 W) & PMA (7.5 W)
- Safe: Advanced FOD
- Flexible: **direct battery charging or 5V output**

**STEVAL-ISB027V1**

**STEVAL-ISB036V1**
Extended Power

Up to 15W output

- Up to 15W
- Input Voltage 5V to 13V DC
- Multi-coil option
- Lowest consumption (17mW)
- Qi 1.2.3 certified

Transmitter STWBC-EP

Receiver: STWLC33

- Up to 15W / 10V
- Backward Compatible with 5W / 5V
- System efficiency up to 80%
- Transmitter function up to 3W

STEVAL-ISB044V1

STEVAL-ISB042V1
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**Up to 15W output**

**Transmitter STWBC-EP**

- Up to 15W
- Input Voltage 5V to 13V DC
- Multi-coil option
- Lowest consumption (17mW)
- Qi 1.2.3 certified

Evaluation board can be ordered on st.com (99$): STEVAL-ISB044V1
• 5V < Input voltage < 8V

TX advertizes itself as BPP (5W) to the RX

Both 5W and 15W RXs ask for max 5W

• 8V < Input voltage < 13V

TX advertizes itself as EPP (15W) to the RX

Both 5W and 15W RXs get the requested power
**Tx - Extended Power Consumption**

- Lowest stand-by current consumption (1.39mA) vs competition

- On a typical daily usage STWBC-EP = best overall efficiency *(based on 23h standby + 1h charging)*

<table>
<thead>
<tr>
<th>Tested with 10Wh phone battery</th>
<th>STWBC-EP MP-A10</th>
<th>Competitor 1 MP-A5</th>
<th>Competitor 2 MP-A7</th>
<th>Competitor 3 MP-A2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charge energy (Wh)</td>
<td>12.52</td>
<td>12.17</td>
<td>12.40</td>
<td>12.35</td>
</tr>
<tr>
<td>Idle energy (Wh)</td>
<td>0.38</td>
<td>3.35</td>
<td>9.96</td>
<td>5.22</td>
</tr>
<tr>
<td>Total (Wh)</td>
<td>12.90</td>
<td>15.52</td>
<td>22.36</td>
<td>17.56</td>
</tr>
<tr>
<td>Overall efficiency</td>
<td><strong>77.5%</strong></td>
<td>64.5%</td>
<td>44.7%</td>
<td>56.9%</td>
</tr>
<tr>
<td>Without idle</td>
<td>80%</td>
<td>82.2%</td>
<td>80.6%</td>
<td>81.0%</td>
</tr>
</tbody>
</table>
**Tx - Extended Power Active Charging Area**

**ST**
- MP coil (from A6): 52mm x 45mm
- Charging area: 31mm x 24 mm

**Competitor 1**
- MP-A2 coil: 45mm x 45mm
- Charging area: 27mm x 25 mm

**Competitor 2**
- MP-A5 coil: 40mm x 40mm
- Charging area: 20mm x 21mm

*Measurement conditions:* - Using TI Bq51013B Rx evaluation board - Z distance is 0mm from Tx interface surface - Load at 5W - Control error converging to 0
Tx – Extended Power Blocks on Dev Kit
Rx - Extended Power

Up to 15W load

Receiver STWLC33

- Rx up to 15W / 10V
- Backward Compatible with 5W / 5V = best candidate for 5W design
- System efficiency up to 80%
- Transmitter function up to 3W

Evaluation board can be ordered on st.com (215$): STEVAL-ISB042V1
• Default mode= Qi receiver mode 15W or 5W
  • Fully autonomous
  • VOUT (typ. 10V) set in NVM for EPP (typ. 5V for BPP)
  • FW in ROM memory

• PMA receiver mode
  • Fully autonomous (automatic high frequencies during ping sequence)
  • PMA compliant up to 5W

• Transmitter mode
  • A host is mandatory, FW transferred through I2C
  • FW loaded in RAM memory
**Rx - Modulation and Vout Regulation**

- Modulation principles
  - Current sink
  - Modulation capacitors

- Automatic regulation based on load current
  - **Synchronous** rectification On/Off
  - VRECT regulation for better efficiency

- LDO protections
  - Current limitation
  - Protection vs VRECT drop
  - Dissipative clamp (13.5V), thermal protection, ESD
Rx - Extended Power in TX Mode

- **Tx Mode enabling**
  - FW load through I2C
  - IP blocks integrated
  - Power to be provided by host, into Vout pin

- **Demodulation external filter**
  - Signal pre-conditioning
  - Only coil voltage sensing
  - **Tx can not be Qi certified**
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Recommended Solutions for Customer Projects

• **Low power and no compliancy** with standards is requested (typical use case = proprietary TX and RX, no compatibility with others)
  - **Wearable** solutions - up to 2.5W or more
    - **Advantages**: optimized cost, size and TTM (#of tests is reduced)
    - **Notice**: coupling tuning depends on coils/capacitors and z space

• **5W** with/without Qi compliancy is requested:
  - **A11** platform + STWLC33
    - **Advantages**: plug and play HW and SW, easy calibration & customization
    - **Notice**: If requested, customer must pass its own certification

• **15W** power is requested:
  - **MP A10** platform + STWLC33 (5W to 15W)
    - **Advantages for Tx**: Large charging area, consumption, cost
    - **Advantages for Rx**: Simple BOM, low cost
**Customer Support**

- **General recommendations:**
  - If possible, customers should follow the reference schematics & coil used (especially if Qi certification is requested)
  - Support for coil tuning to be evaluated case by case

- **Debug tools and included interface boards in dev kits:**
  - **TX:** STWBC GUI provided to access NVM parameters and to display a dashboard about transmission status. Include UART debug interface in final product.
  - **RX:** STWLC GUI is provided access NVM parameters and to configure GPIOs. Include I2C SCL&SDA + GND in final product*, recommended to have also Vrect & Vout test points for measurements.

*) for Vsupply, provide 5V to RX Vout pin or ensure stable power from Wireless Charging TX
GUI for TX

Protocol messages
Monitoring data
Tuning parameters
The GUI allows to set/read:

- **Vout**
- **Contract parameters**
- **Live AD conversions results**
- **Identification data**
Thank You

ST stands for life.augmented