WIRELESS POWER CONSORTIUM

Introduction to the Power Class 0 Specification

Version 1.2.3

February 2017

COPYRIGHT

DISCLAIMER

RELEASE HISTORY

Specification Version	Release Date	Description
1.2.3	February 2017	Initial release of this document.

Contents

1 About the Wireless Power Consortium

The Wireless Power Consortium (WPC) is a worldwide organization that develops and promotes the global interface standard for wireless power transfer called *Qi*.[1] Interface standards ensure the interoperability of devices that conform to that standard. Supported by more than 200 companies and with over 1000 registered products, Qi has become the international wireless-charging standard for hand-held consumer electronics.

This document introduces the Power Class 0 specification, which includes flat surface devices such as mobile phones and tablets that use up to 15 W of power.[2]

The WPC actively investigates new applications for wireless power transfer, such as a cordless kitchen solution that uses power transmitters installed underneath countertops and tables that enable a variety of kitchen appliances and smart cookware to operate without power cords.

The Qi logo is a registered trademark of the Wireless Power Consortium, and is made available to members of the consortium to display on their products after successfully completing the Power Class 0 test and registration procedure outlined in section 6 of this document. A database of registered Qi products is maintained on the WPC's public Web site where consumers can look up products to see whether they have been tested for compliance with the Qi standard and for interoperability with all other Qi wireless products.

[1] Qi (氣; qì) is pronounced "chee," and is the Chinese word for energy flow or life force.

[2] Version 1.2 of the Qi specification introduced fast charging, which covers transmitter and receiver products that use up to 15 W of power. However, the architectural limit of the extended power profile is 30 W, which will accommodate a growing family of product designs in the Power Class 0 category.

2 What is the Qi wireless power transfer system?

The powering of hand-held devices is continuing to evolve. Originally, electrical devices had to be plugged directly into outlets, and the range of operation was limited by the length of the power cord. Next came disposable batteries that severed the power cord's range restriction.

Figure 1. Corded appliance (c. 1950) to battery-powered consumer electronics (c. 1955)

In recent years, rechargeable batteries have all but replaced disposable batteries, eliminating the need to purchase, store, and throw large quantities of these batteries into landfills. But for frequently-used devices—smartphones in particular—recharging became a daily ritual of plugging and unplugging charging cables.

A new era of convenience emerged in 2011 when the first Qi wireless smartphone case was introduced, followed shortly thereafter by smartphones with built-in Qi wireless support. Qi wireless devices need only to be set down on a Qi wireless charger for recharging to occur. The device remains unplugged and ready to be picked up and used at any moment. With the deployment of Qi chargers in cars, enterprises, and public locations, it becomes possible to no longer worry about running out of charge or carrying charger cables.

Figure 1 and Figure 2 show the evolution of corded power to wirelessly-charged portable devices.

Figure 2. Plug-in rechargeable mobile phones (c. 1999) to wirelessly-charged smartphones (since 2012)[3]

The adoption of the Qi standard has grown significantly since the first products were introduced. In a 2014 consumer survey conducted by IHS Inc., 36% of consumers in China, the UK, and the U.S. said they had heard of wireless charging. One year later that number doubled, reaching 76% consumer awareness. In 2015 more than 150 million Qi systems have been shipped, over 83% of smartphone users want wireless charging, and over 80 phone models around the world are Qi-enabled.

Qi wireless chargers are becoming more prevalent and are appearing in varied forms. There are three basic categories of chargers: desktop chargers, power banks, and embedded chargers. Desktop chargers may be in the form of a charging pad or stand, and power banks similar but are designed for travel and contain batteries to provide power when it cannot be plugged in to an outlet. Embedded chargers may be built into furniture, automobiles, other appliances like clock-radios or computer monitors, or provided in public locations like restaurants and hotel rooms. The largest demand for chargers is for home use, but the deployment of public chargers has contributed significantly to public awareness.

The continued growth of Qi wireless devices and chargers is also reducing the need for product-specific cables (see Figure 3 on page 7). This simplifies charging for consumers and reduces the frequent failure of the device's charging connector. As wireless charging becomes ubiquitous throughout the consumer's journey, it will be possible to decrease the size of the battery, and with it, the size, weight, and cost of the device itself.

The Qi wireless power transfer system offers both a solution to the daily inconvenience of handling cables and adapters, as well as an opportunity for manufacturers to further distinguish their products in the marketplace.

[3] Photo of the TYLT Vu wireless charger (right) is reprinted by permission from Technocel.

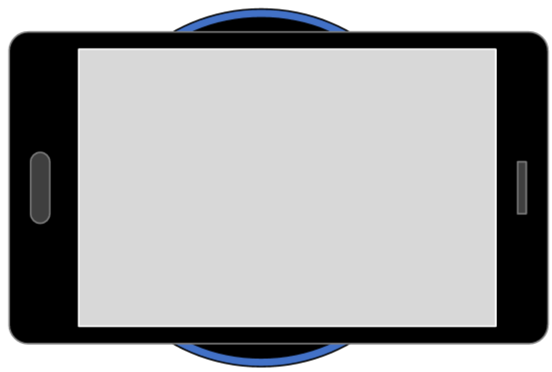
Figure 3. Cable clutter can be replaced with Qi wireless charging [4]

[4] Photo of the TYLT Vu wireless charger is reprinted by permission from Technocel.

3 How Qi wireless power transfer works

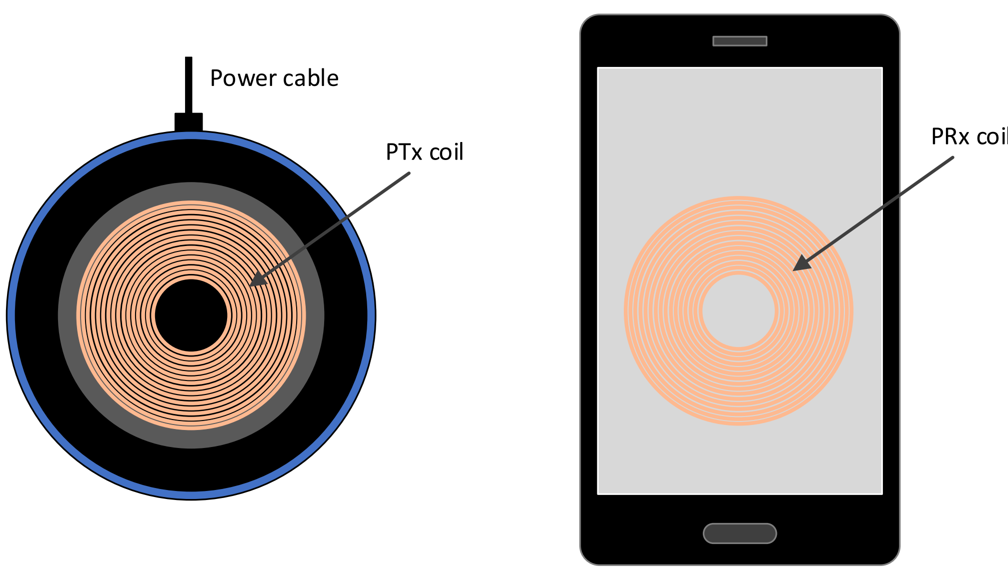
The Qi wireless power transfer system uses magnetic induction to transfer power to a power receiver (PRx) subsystem contained within the mobile device when it is placed on top of a power transmitter (PTx).

Figure 4. A Qi wireless smartphone on a charging pad



Both the PTx and PRx subsystems contain coils, as shown in the conceptual diagram in Figure 5, as well as circuitry that handles the communication and power transfer between them.

Figure 5. Coils in charger and smartphone



The basic physical principle that governs the functionality defined in the Qi wireless power transfer specification is magnetic induction: the phenomenon that a time-varying magnetic field generates an electromotive force in a suitably positioned inductor. In a Qi wireless power transfer system, this electromotive force produces a voltage across the terminals of a coil-shaped inductor, and is used to drive the electronics of an appropriate load to which it is connected. Conventional transformers use the same effect to achieve inductive power transfer between a primary and a secondary coil that are strongly coupled by means of a magnetic core.

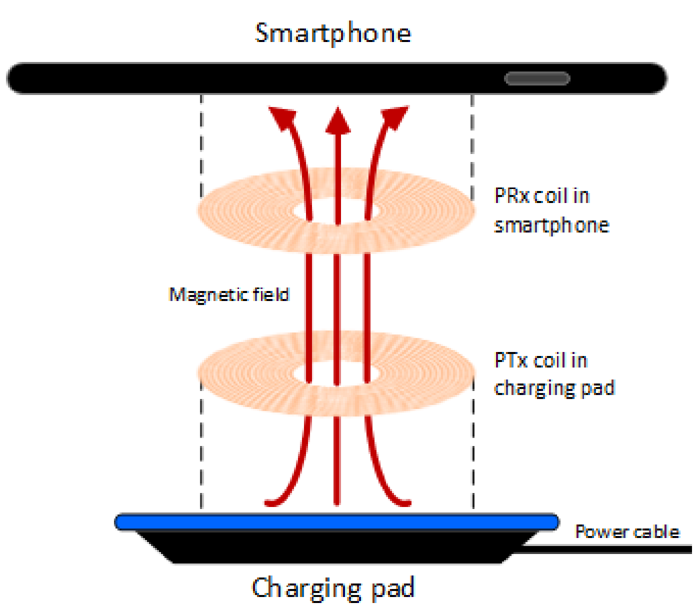
Although a Qi-based system is similar to a conventional transformer in the sense that power is transferred from a first coil to a second coil, it is also very different because of the much lower magnetic coupling between those coils. A conventional transformer has a magnetic coupling coefficient close to one, whereas a Qi-based system typically has a magnetic coupling coefficient in the range of 0.5 or below.

In the Qi-based system illustrated in Figure 4, power is transferred from the PTx contained in the Qi charging pad to a PRx contained in the Qi smartphone. Before charging begins, the PRx and PTx communicate with each other to establish that the mobile device is indeed capable of being charged, whether it needs to be charged, how much power is required, etc. In short, the communication ensures an appropriate power transfer from the power transmitter to the power receiver. The communication channel can also be used to trigger location based services by providing an SSID, a Bluetooth link, or a unique ID.

When charging begins, the power transmitter runs an alternating electrical current through its coil(s), which generates an alternating magnetic field in accordance with Faraday's law. This magnetic field is in turn picked up by the coil inside the power receiver and transformed by a power converter back into an alternating electrical current that can be used to charge the battery.

A critical feature of the magnetic field is that it can transfer through any non-metallic, non-ferrous materials, such as plastics, glass, water, wood, and air. In other words, wires and connectors are not needed between the power transmitter and power receiver.

Figure 6. Qi wireless power transfer using magnetic induction



3.1 Examples of Qi wireless products

3.1.1 Mobile devices

Qi wireless charging is a feature available in dozens of smartphones, and many of the major smartphone makers are participating members of the WPC. For smartphones that do not yet offer wireless charging, third-party manufacturers are integrating power receiver subsystems into smartphone cases or selling charging coils that consumers can insert between the back of their smartphone and the case.

Wireless charging is also appearing in a growing number of other consumer product categories—smart watches, power banks, Bluetooth headsets, cameras, electric shavers, etc. Virtually anything that uses a rechargeable battery can be designed to use Qi wireless technology. However, Qi wireless power transfer is not limited to charging batteries: it can also be used to power devices that require electric current and will remain stationary while in use, such as desktop lamps or speakers.

3.1.2 Chargers

Qi wireless chargers for Power Class 0 products are generally either standalone (portable) power transmitters or integrated into other products, such as furniture, lamps, alarm clocks, audio speakers, etc.

Examples of standalone Qi wireless chargers include:

- charging pads, which lie flat on a table or desktop
- charging stands, which are designed to hold a smartphone upright in a viewing position while charging
- power banks, which are similar to charging pads, but contain internal batteries as a portable power source

Standalone charging pads, charging stands, and power banks typically require a 5 V/2-Amp AC adapter in order to draw sufficient power from an electrical outlet, as well as a USB cable from the adapter to the charger.

Power transmitters that are embedded in lamps, clocks, or other plug-in appliances do not require a separate AC adapter, because the product plugs directly into an electrical outlet and internal circuitry routes the necessary power to the power transmitter component. Similarly, autos that feature an integrated power transmitter in the dash or console use the internal wiring to draw power from the car's electrical system.

4 Qi wireless power transfer features

4.1 Power levels

The Power Class 0 power transfer system enables the transfer of at least 5 W and up to 30 W of load power. The actual amount of power that can be transferred between the power transmitter and power receiver is subject to negotiation between them during the communication phases that occur before power transfer. The power receiver requests a certain amount of power appropriate for the device to be charged, and the power transmitter will deliver the requested amount. This communication assures interoperability between Qi wireless products in the baseline power profile (≤ 5 W) and in the extended power profile (≤ 30 W).

For example, if the power receiver is designed to be charged by a 15 W power transmitter but is placed on a 5 W power transmitter, the power receiver may allow charging at a slower rate. Conversely, if a 5 W power receiver is placed on a 15 W power transmitter, the power receiver will instruct the power transmitter to send no more than 5 W of power.

4.2 Operating frequency

The operating frequency typically is in the range of 87 to 205 kHz. A power transmitter can—but does not have to—use the operating frequency to control the amount of power that is transferred to a power receiver. For this purpose, the frequency response of the power transmitter/power receiver system typically has a resonance near the lower end of the operating frequency range. A lower operating frequency results in a higher amount of power transferred and a higher frequency in a lower amount of power.

4.3 Charging area

The power transfer system in the Power Class 0 specification is based on a single coil in the power transmitter that has an outer diameter of 50 mm (2 in), and a coil in the power receiver that has an outer diameter of 40 mm (1.6 in). Actual power transmitter and power receiver implementations may deviate from these dimensions, as long as they are able to pass all relevant Qi compliance tests.

In a typical use case, a mobile device is positioned on the top surface of a charger with the power transmitter coil and the power receiver coil aligned. Ideally, the coils should be perfectly aligned for maximum power transfer, but misaligning the coils by several millimeters mm (about ¼ inch) should not be a problem.

To accommodate products that require a larger charging area or more tolerance for misalignment, the specification allows for multiple coils in the power transmitter to be connected in an array, as seen in triple-coil charging stands that work with smartphones of different sizes and with different coil locations.

Manufacturers can also submit new coil types to be included in the specification to accommodate their design innovations.

4.4 Coupling requirements

Coupling occurs when current changes in one coil creates a voltage in the other coil via magnetic induction. Coupling is highest—with the most efficient power transfer—when:

- the PTx and PRx use exactly the same coil
- the PTx and PRx are perfectly aligned
- the distance between the coils is small (less than the diameter of the coils)
- the coils are externally shielded by ferrite

Conditions that decrease coupling (and power transfer efficiency) include different power transmitter/power receiver coil sizes and shapes, coil misalignment, excessive distance between coils, and the presence of foreign objects on the power transmitter.

4.5 PTx and PRx communication protocol

To set up power transfer and assist in its control, a power transmitter and power receiver execute a communication protocol with each other. The power receiver uses amplitude shift keying to communicate requests and other information to the power transmitter by modulating its reflected impedance. The power transmitter uses frequency shift keying (FSK) to provide synchronization and other information to the power receiver by modulating its operating frequency.

4.6 Foreign object handling

The alternating magnetic field between a power transmitter and a power receiver can induce eddy currents in electrically-conductive materials that are exposed to the field. The eddy currents cause those materials to heat up. Friendly metals—metallic parts that are used in the construction of power transmitter and power receiver products—are usually shielded from the magnetic field, which prevents them from heating up substantially. Foreign objects with electrically-conductive materials that are placed in the field, such as coins, keys, paperclips, etc., are not part of the wireless charging system and are not protected by the shielding in either the power transmitter or the power receiver.

NOTE Some special-purpose smartphone cases may contain metallic objects, such as external decorations or internal metallic layers. These objects may affect the efficiency of the wireless power transfer or prevent it altogether.

Neither the power transmitter nor the power receiver can prevent foreign objects from being placed in the field, because they cannot control a user's actions. However, the power transmitter and/or power receiver have to detect the presence of such foreign objects and take appropriate action to prevent the objects from heating up to unacceptably high temperatures.

Typically, only the power transmitter has sufficient knowledge of the extent and strength of its magnetic field to determine whether foreign objects are present. However, a complication is that the power transmitter cannot by itself distinguish between foreign objects and friendly metals that are insufficiently shielded. In order to reliably detect foreign objects, the power transmitter therefore needs to receive appropriate information from each power receiver it is serving. The Qi specification defines the kind of information that a power receiver has to provide for this purpose. However, the specification does not define a single method for foreign object detection (FOD) that a power transmitter has to apply. Instead, compliance testing verifies that a power transmitter does not heat up a set of reference foreign objects in a set of reference scenarios.

FOD extensions use bidirectional communications and negotiation between the power transmitter and power receiver to enhance the options for foreign object detection. Support for FOD extensions is optional in the baseline power profile (≤ 5 W) but mandatory in the extended power profile (≤ 15 W).

5 The Qi specification

The *Qi wireless power transfer system, Power Class 0 Specification* is developed and maintained by members of the Wireless Power Consortium. The specification comprises four online (PDF) documents:

1. *Introduction to Power Class 0 Specification* (this document).
2. *Parts 1 and 2: Interface Definitions*:
   - *Part 1: Primary Interface Definition*; the interface between the power transmitter and the power receiver, including mechanical, power, thermal, and information interfaces;
   - *Part 2: Secondary Interface Definition*; the interface between the system and its environment, including the external power source, object detection, and the user interface.
3. *Part 3: Compliance Testing*; tests required for Qi registration (restricted-access document);
4. *Part 4: Reference Designs*; power transmitter reference designs and power receiver design examples.

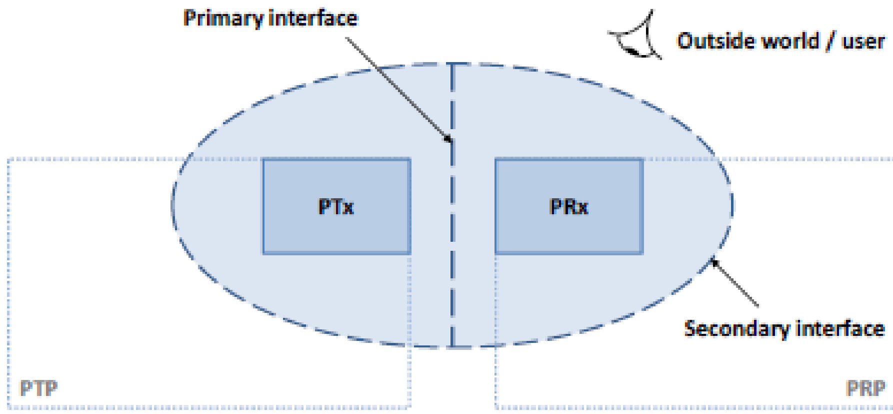
NOTE All of the specification documents are available for public download on the WPC Web site except for *Part 3: Compliance Testing*, which is restricted to members of the WPC.

Parts 1 through 4 of the specification are briefly described in the following subsections.

5.1 Parts 1 and 2: Interface Definitions

Parts 1 and 2 of the Qi specification are covered in one document. Part 1 describes the primary interface, and Part 2 describes the secondary interface. Figure 7 illustrates the role of these two interfaces.

Figure 7. Primary and secondary interfaces in the Qi wireless power transfer system



The primary interface governs the interaction of a power transmitter and a power receiver. In particular, this interface comprises

- the positioning of the PRx relative to the PTx;
- their electrical behavior, in terms of the PTx coil current and power consumption, as well as the voltage and current generated in the PRx coil; and
- the physical layer and protocol for data communications and system control.

The secondary interface deals with the interaction of the system and its environment. This interface comprises

- external power usage;
- user interface features;
- detection of foreign objects that can unintentionally heat up in the magnetic field;
- any heat exchange between the power transmitter product and the power receiver product.

5.2 Part 3: Compliance Testing

Part 3 of the Qi specification defines the tests that are used to qualify products for Qi registration. The tests are used to ensure compliance with the Qi specification and compatibility with other Qi products. The compliance tests are divided into two sections: one for base stations (power transmitters) and another for mobile devices (power receivers). Each test includes information about the required tools, the test configuration, the test procedure, and the test results.

Additional topics include:

- Specialized testing tools for base stations and mobile devices, including schematic diagrams, configurations, and operating ranges
- The mechanical construction of
  - test power transmitters
  - test power receivers
  - representative foreign objects

5.3 Part 4: Reference Designs

Part 4 of the Qi specification provides reference designs for power transmitters and power receiver design examples. Each of the designs include a general description, a functional block diagram, mechanical details, and electrical details.

Over 40 power transmitter reference designs approved by the WPC are provided, and are divided into three basic categories:

- Baseline power profile designs that activate a single primary coil at a time
- Baseline power profile designs that activate multiple primary coils simultaneously
- Extended power profile designs

Several examples of power receiver designs are also provided in Part 4 of the Qi specification. The designs represent power receivers with different purposes or power requirements (5 W, 8 W, 12 W, and 15 W).

6 Product registration

In order to carry the Qi logo on a product, the product designer must sign the Logo License Agreement, apply with the WPC for compliance and interoperability testing, and demonstrate that the product is both fully compliant with the Qi specification and will work with other registered Qi products. Once tested, the product will be registered and added to the database of registered Qi products on the WPC public Web site.

Product testing is in two stages:

1. The product must pass all relevant compliance tests defined in *Part 3: Compliance Testing* in a WPC-authorized test lab (ATL).

2. The product must be tested for compatibility with existing registered Qi products in the Inter-Operability Center (IOC).

Details are found in the publication, *Qi Product Testing Procedure,* which is available for download to WPC members. Here are some of the main points to consider.

- Product development. It is recommended to use the latest version of the Qi wireless power transfer system specification, since earlier versions are eventually phased out. Also, to avoid any unnecessary rejections by an authorized test lab, product manufactures are strongly encouraged to perform self-tests of the new product before arranging for formal compliance testing.

- Compliance testing. Product designers are free to select an ATL for compliance testing of their product. Some ATLs may offer pre-compliance testing & consultancy. Bear in mind that at least four identical product samples must be submitted for test; two for undergoing tests at the ATL and IOC labs, and the other two to serve as backup samples at these test centers.

- Test completion. Upon successful completion of compliance testing, the ATL will send a Declaration of Conformance. Similarly, the IOC will issue a declaration of interoperability. Product registration with the WPC will be done by the Logo License Administrator after careful checking that all required conditions are met. Note that product registration can either be for original products or for substantially-similar products.

- Substantially-similar products are those that are identical to the original product except for properties that do not influence the wireless power functionality, such as color or brand name. Registering these products as substantially similar to the previously-registered original product is a simpler procedure since testing is not required.

For further information about product certification, please visit the Wireless Power Consortium members' Web site at members.wirelesspowerconsortium.com/members/ or send an email with your inquiry to info@wirelesspowerconsortium.com.