WIRELESS POWER
CONSORTIUM

# Qi Specification

## *Introduction*

**Version 1.3**

**January 2021**

## COPYRIGHT



## DISCLAIMER



## RELEASE HISTORY

| Specification Version | Release Date | Description |
|---|---|---|
| 1.3 | January 2021 | Initial release of this document. |

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# 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 600 companies and with thousands of certified products, Qi has become the international wireless-charging standard for hand-held consumer electronics.

This document introduces the *Qi Specification*, which applies to 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 test and certification procedure outlined in Chapter 6, Product certification and registration. A database of certified 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 other Qi wireless products.

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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 about 30 W, which will accommodate a growing family of Qi product designs.

# 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[3] smartphones (since 2012)**

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 wanted wireless charging, and over 80 phone models around the world were Qi-enabled. From 2016 to 2018, the number of consumers who use wireless charging has grown from 10% to 40%, and awareness of the wireless power technology has increased to 89%.

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, autos, and offices, 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). 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.

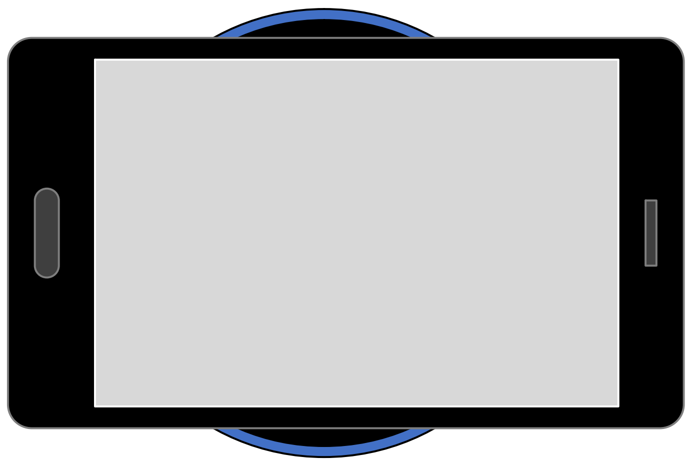
**Figure 3. Cable clutter can be replaced with Qi wireless charging**

# 3 How Qi wireless power transfer works

## 3.1 Basic concepts

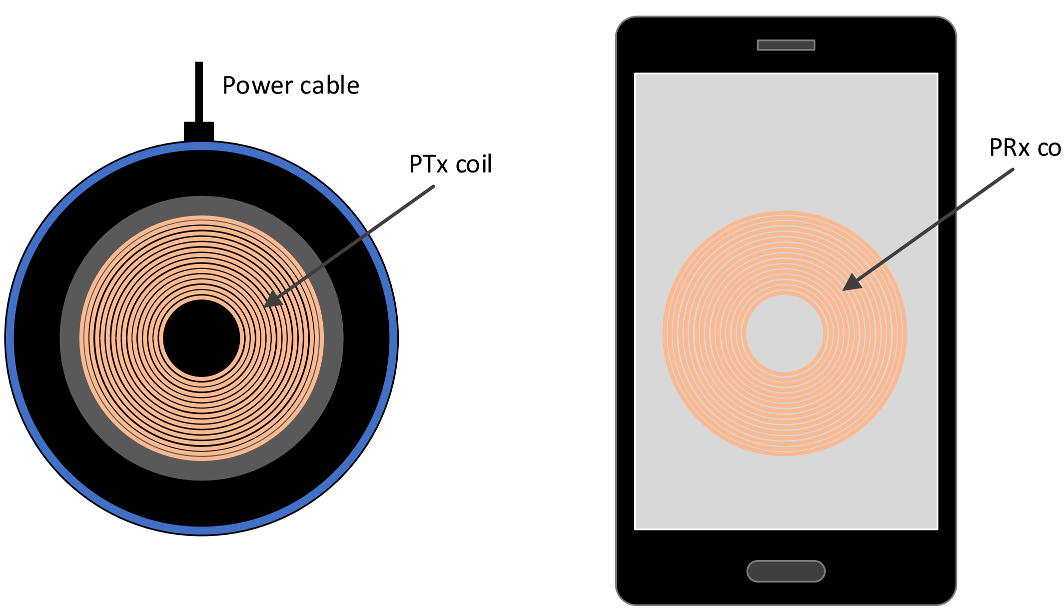
The Qi wireless power transfer system uses magnetic induction to transfer power from a Power Transmitter Product (charger) to a Power Receiver Product (smartphone).

**Figure 4. A Qi wireless smartphone on a charging pad**



Within these products are Power Transmitter (PTx) and Power Receiver (PRx) subsystems, which 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.

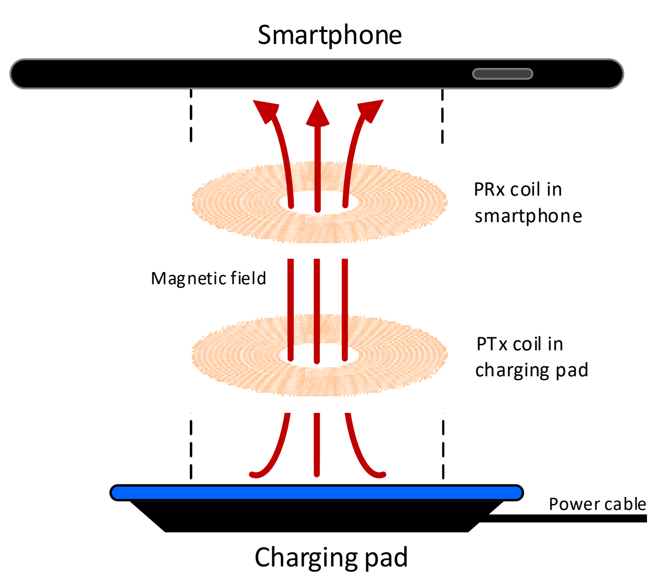
Although a Qi-based system is similar to a conventional transformer in the sense that power is transferred from a first coil to a second coil, it is also very different because of the much lower magnetic coupling between those coils. A conventional transformer has a magnetic coupling coefficient close 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 Power Transmitter contained in the Qi charging pad to a Power Receiver contained in the Qi smartphone. Before charging begins, the Power Receiver and Power Transmitter communicate with each other to establish that the Power Receiver Product 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 Product to the Power Receiver Product. 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 a direct 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 Product and Power Receiver Product.

**Figure 6. Qi wireless power transfer using magnetic induction**



## 3.2 Examples of Qi wireless products

### 3.2.1 Power Receiver Products

Qi wireless charging is a feature available in dozens of smartphones, and many of the major smartphone makers are participating members of the WPC.

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.

### 3.2.2 Chargers

Qi wireless Power Transmitter Products are generally either standalone wireless chargers or they are integrated into other products, such as furniture, lamps, alarm clocks, audio speakers, etc.

Examples of standalone Power Transmitter Products 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 Product 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 *Qi Specification* applies to wireless power transfers of at least 5 W and up to the architectural limit of about 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 (up to 15 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.

Power profiles also describe the communication capabilities between the Power Receiver and Power Transmitter. The earliest versions of *Qi Specification* (versions 1.0 and 1.1) introduced a simple unidirectional communication protocol from the Power Receiver to the Power Transmitter for power transfers ≤ 5 W. This is now known as the *Baseline Protocol*.

Version 1.2 of *Qi Specification* introduced an extended protocol for bidirectional communication between the Power Receiver and the Power Transmitter. This extended communications protocol enables enhanced foreign object detection features (see section 4.6), and applies to power transfers up to 15 W.

## 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 *Qi 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 Power Receiver Product is positioned on the top surface of a Power Transmitter Product 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 Power Receiver Products 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 Power Transmitter and Power Receiver use exactly the same coil
- the Power Transmitter and Power Receiver 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 Product.

## 4.5 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, paper clips, 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 Products.

**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.

# 5 Structure of the *Qi Specification*

The *Qi Specification* is developed and maintained by members of the Wireless Power Consortium. The specification comprises this introduction plus the following documents.

**Table 1: *Qi Specification* documents and topics**

| Document name | Topics |
|---|---|
| Glossary | ▪ Definitions<br>▪ Acronyms<br>▪ Symbols |
| *Mechanical, Thermal, and User Interface* | ▪ Power Receiver design requirements<br>▪ Mechanical design guidelines (Informative)<br>▪ Interface Surface temperature rise<br>▪ User interface requirements |
| *Power Delivery* | ▪ Power Receiver construction<br>▪ Power Receiver design guidelines (informative)<br>▪ Power Transmitter construction<br>▪ Power consumption<br>▪ Meaningful functionality<br>▪ Unintentional magnetic field susceptibility (informative)<br>▪ Load steps<br>▪ Over-voltage protection<br>▪ External power input (informative)<br>▪ Power levels (Extended Power Profile only)<br>▪ System efficiency (informative)<br>▪ Stand-by power (informative)<br>▪ Object detection (informative)<br>▪ Power Receiver localization (informative) |
| *Communications Physical Layer* | ▪ Load modulation<br>▪ Frequency-Shift Keying |
| *Communications Protocol* | ▪ Power Receiver and Power Transmitter identification<br>▪ Ping phase<br>▪ Configuration phase<br>▪ Negotiation phase<br>▪ Power transfer phase<br>▪ Power Receiver data packets<br>▪ Power Transmitter data packets |
| *Foreign Object Detection* | ▪ Avoidance of Foreign Object Heating<br>▪ Pre-power transfer FOD methods<br>▪ In-power transfer FOD methods<br>▪ Determining the reference FOD values (informative) |

**Table 1: *Qi Specification* documents and topics (Continued)**

| Document name | Topics |
|---|---|
| *NFC/RFID Card Protection* | ▪ NFC/RFID card detection by a Power Transmitter<br>▪ NFC/RFID card detection by a Power Receiver<br>▪ Object detection using the NFC unit<br>▪ Testing the impact of a Power Transmitter on an NFC/RFID device |
| *Authentication Protocol* | ▪ Certificates and Private Keys<br>▪ Authentication protocol<br>▪ Authentication messages<br>▪ Timing requirements<br>▪ Protocol flow examples<br>▪ Cryptographic examples |
| *Power Transmitter Reference Designs* | ▪ Power Transmitter reference designs A1 to A*x* and B1 to B*x*<br>▪ Power Transmitter reference designs MP-A1 to MP-A*x* and MP-B1 to MP-B*x* |
| *Power Receiver Design Examples* | ▪ Power Receiver design examples 1 - 5 |
| *Power Transmitter Test Tools*<br>(restricted-access document) | ▪ Test Power Receivers<br>▪ Default configurations<br>▪ Representative Foreign Objects (normative) |
| *Power Receiver Test Tools*<br>(restricted-access document) | ▪ Test Power Transmitters<br>▪ Default configurations |
| *Power Transmitter Compliance Tests*<br>(restricted-access document) | ▪ Self-Declaration Form consistency check<br>▪ Conformance to mechanical and thermal requirements<br>▪ Conformance to power delivery requirements<br>▪ Conformance to communications physical layer requirements<br>▪ Conformance to communications protocol requirements<br>▪ Conformance to authentication requirements<br>▪ Conformance to Foreign Object Detection requirements |
| *Power Receiver Compliance Tests*<br>(restricted-access document) | ▪ Self-Declaration Form consistency check<br>▪ Conformance to mechanical and thermal requirements<br>▪ Conformance to power delivery requirements<br>▪ Conformance to communications physical layer requirements<br>▪ Conformance to communications protocol requirements<br>▪ Conformance to authentication requirements<br>▪ Conformance to Foreign Object Detection requirements |

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

- *Power Transmitter Test Tools*
- *Power Receiver Test Tools*
- *Power Transmitter Compliance Tests*
- *Power Receiver Compliance Tests*

# 6 Product certification and registration

In order to carry the Qi logo on a product, the product designer must sign the Logo License Agreement with the WPC and submit product samples for compliance and interoperability testing to demonstrate that the product is both fully compliant with *Qi Specification* and will work with other registered Qi products.

Product certification occurs in two stages:

1. The product must pass all relevant compliance tests in a WPC-authorized test lab (ATL), as defined in the *Qi Specification, Power Transmitter Compliance Tests* or in the *Qi Specification, Power Receiver Compliance Tests*.
2. The product must pass all compatibility tests with currently-registered Qi products in an Inter-Operability Center (IOC).

When all tests are successfully completed, the product will be registered with the WPC, that is, it will be added to the database of certified Qi products on the WPC public Web site and will be granted permission to carry the Qi logo. 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 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 carefully checking that all required conditions are met.

**NOTE:** 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. Certifying these products as substantially similar to the previously-certified original product is a simpler procedure since testing is not required.

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