# IEC 63563-6

Edition 1.0 2025-02

# INTERNATIONAL STANDARD

# NORME INTERNATIONALE

## Qi Specification version 2.0 –
## Part 6: Communications Protocol

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# QI SPECIFICATION VERSION 2.0 –

## Part 6: Communications Protocol

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It is based on *Qi Specification version 2.0, Communications Protocol* and was submitted as a Fast-Track document.

The text of this International Standard is based on the following documents:

| Draft | Report on voting |
|---|---|
| 100/4251/FDIS | 100/4281/RVD |

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

The structure and editorial rules used in this publication reflect the practice of the organization which submitted it.

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WIRELESS POWER
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# Qi Specification

## *Communications Protocol*

Version 2.0

April 2023

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## RELEASE HISTORY

| Specification Version | Release Date | Description |
|---|---|---|
| v2.0 Final Draft | April 2023 | Initial release of the v2.0 Qi Specification. |

# Table of Contents

# 1 General

The Wireless Power Consortium (WPC) is a worldwide organization that aims to develop and promote global standards for wireless power transfer in various application areas. A first application area comprises flat-surface devices such as mobile phones and chargers in the Baseline Power Profile (up to 5 W) and Extended Power Profile (above 5 W).

## 1.1 Structure of the Qi Specification

**General documents**

- Introduction
- Glossary, Acronyms, and Symbols

**System description documents**

- Mechanical, Thermal, and User Interface
- Power Delivery
- Communications Physical Layer
- Communications Protocol
- Foreign Object Detection
- NFC Tag Protection
- Authentication Protocol

## 1.2 Scope

The *Qi Specification, Communications Protocol* (this document) defines the messaging between a Power Transmitter and a Power Receiver. The primary purpose of this messaging is to set up and control the power transfer. As a secondary purpose, it provides a transport mechanism for higher-level applications such as Authentication. The communications protocol comprises both the required order and timing relations of successive messages.

## 1.3 Compliance

All provisions in the *Qi Specification* are mandatory, unless specifically indicated as recommended, optional, note, example, or informative. Verbal expression of provisions in this Specification follow the rules provided in ISO/IEC Directives, Part 2.

**Table 1: Verbal forms for expressions of provisions**

| Provision | Verbal form |
|---|---|
| requirement | “shall” or “shall not” |
| recommendation | “should” or “should not” |
| permission | “may” or “may not” |
| capability | “can” or “cannot” |

## 1.4 References

For undated references, the most recently published document applies. The most recent WPC publications can be downloaded from http://www.wirelesspowerconsortium.com.

## 1.5 Conventions

### 1.5.1 Notation of numbers

- Real numbers use the digits 0 to 9, a decimal point, and optionally an exponential part.
- Integer numbers in decimal notation use the digits 0 to 9.
- Integer numbers in hexadecimal notation use the hexadecimal digits 0 to 9 and A to F, and are prefixed by "0x" unless explicitly indicated otherwise.
- Single bit values use the words ZERO and ONE.

### 1.5.2 Tolerances

Unless indicated otherwise, all numeric values in the *Qi Specification* are exactly as specified and do not have any implied tolerance.

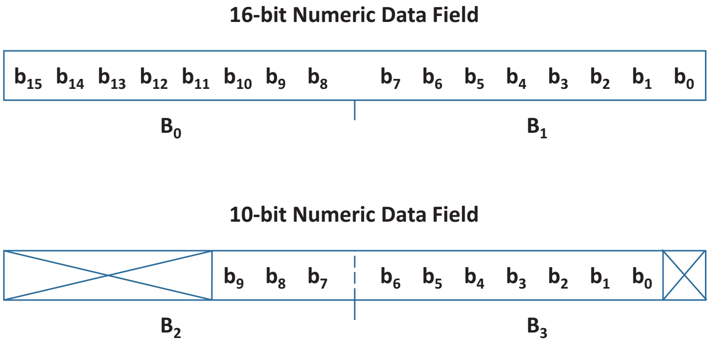
### 1.5.3 Fields in a data packet

A numeric value stored in a field of a data packet uses a big-endian format. Bits that are more significant are stored at a lower byte offset than bits that are less significant. Table 2 and Figure 1 provide examples of the interpretation of such fields.

**Table 2: Example of fields in a data packet**

<table>
<tr><th></th><th>$b_7$</th><th>$b_6$</th><th>$b_5$</th><th>$b_4$</th><th>$b_3$</th><th>$b_2$</th><th>$b_1$</th><th>$b_0$</th></tr>
<tr><td>$B_0$</td><td colspan="8" rowspan="2">(msb) 16-bit Numeric Data Field (lsb)</td></tr>
<tr><td>$B_1$</td></tr>
<tr><td>$B_2$</td><td colspan="5">Other Field</td><td colspan="3">(msb)</td></tr>
<tr><td>$B_3$</td><td colspan="7">10-bit Numeric Data Field (lsb)</td><td>Field</td></tr>
</table>

**Figure 1. Examples of fields in a data packet**



### 1.5.4 Notation of text strings

Text strings consist of a sequence of printable ASCII characters (i.e. in the range of 0x20 to 0x7E) enclosed in double quotes ("). Text strings are stored in fields of data structures with the first character of the string at the lowest byte offset, and are padded with ASCII NUL (0x00) characters to the end of the field where necessary.

**EXAMPLE:** The text string “WPC” is stored in a six-byte fields as the sequence of characters 'W', 'P', 'C', NUL, NUL, and NUL. The text string “M:4D3A” is stored in a six-byte field as the sequence 'M', ':', '4', 'D', '3', and 'A'.

### 1.5.5 Short-hand notation for data packets

In many instances, the *Qi Specification* refers to a data packet using the following shorthand notation:

<MNEMONIC>/<modifier>

In this notation, <MNEMONIC> refers to the data packet's mnemonic defined in the *Qi Specification, Communications Protocol*, and <modifier> refers to a particular value in a field of the data packet. The definitions of the data packets in the *Qi Specification, Communications Protocol*, list the meanings of the modifiers.

For example, EPT/cc refers to an End Power Transfer data packet having its End Power Transfer code field set to 0x01.

## 1.6 Power Profiles

A Power Profile determines the level of compatibility between a Power Transmitter and a Power Receiver. Table 3 defines the available Power Profiles.

- *BPP PTx*: A Baseline Power Profile Power Transmitter.
- *EPP5 PTx*: An Extended Power Profile Power Transmitter having a restricted power transfer capability, i.e. $P_{\mathrm{L}}^{(\mathrm{pot})}$ = 5 W.
- *EPP PTx*: An Extended Power Profile Power Transmitter.
- *BPP PRx*: A Baseline Power Profile Power Receiver.
- *EPP PRx*: An Extended Power Profile Power Receiver.

**Table 3: Capabilities included in a Power Profile**

| **Feature** | **BPP PTx** | **EPP5 PTx** | **EPP PTx** | **BPP PRx** | **EPP PRx** |
|---|---|---|---|---|---|
| A*x* or B*x* design | Yes | Yes | No | N/A | N/A |
| MP-A*x* or MP-B*x* design | No | No | Yes | N/A | N/A |
| Baseline Protocol | Yes | Yes | Yes | Yes | Yes |
| Extended Protocol | No | Yes | Yes | No | Yes |
| Authentication | N/A | Optional | Yes | N/A | Optional |

# 2 Overview

When a user places a Power Receiver within the Operating Volume of a Power Transmitter, the two start to communicate with the aim to configure and control the power transfer. The Power Signal provides the carrier for all communications. The *Qi Specification, Communications Physical Layer* defines the low-level formats of data bits, data bytes, and data packets. The *Qi Specification, Communications Protocol* (this document) defines the payloads of the data packets and their use in the power control protocols.

## 2.1 Protocol phases

The *Qi Specification* defines two communications protocols.

- *Baseline Protocol*—the original protocol introduced in version 1.0 of the Qi Power Class 0 Specification, which uses Power Receiver to Power Transmitter communications only.
- *Extended Protocol*—added in version 1.2 of the Qi Power Class 0 Specification to support bi-directional communications and enhanced Foreign Object Detection (FOD) features. Version 1.3 of the *Qi Specification* adds data transport stream functionality and authentication options.

As shown in Figure 2, the communications protocol comprises several phases. The negotiation phase is not present in the Baseline Protocol.

**Figure 2. Protocol phases**

- *Ping phase.* The Power Transmitter tries to establish communications with a Power Receiver. Before doing so, it typically performs measurements to determine if there are objects such as bankcards, coins or other metals, which can damage or heat up during the power transfer. These measurements proceed without waking up the Power Receiver. See the *Qi Specification, Power Delivery,* for restrictions on such measurements.

  **NOTE:** The Power Transmitter typically postpones a conclusion whether detected metals are Foreign Objects or Friendly Metals to the negotiation phase, after obtaining design information from the Power Receiver. See the *Qi Specification, Foreign Object Detection,* for details about recommended methods.

- *Configuration phase.* The Power Receiver sends basic identification and configuration data to the Power Transmitter. Both sides use this information to create a baseline Power Transfer Contract. Moreover, the Power Transmitter and Power Receiver decide whether to continue with the Baseline Protocol or the Extended Protocol.

  **NOTE:** A Power Receiver can only make use of features such as enhanced FOD, data transport streams, and authentication if it implements the Extended Protocol.

- *Negotiation phase.* This phase is not present in the Baseline Protocol. The Power Transmitter and Power Receiver establish an extended Power Transfer Contract containing additional settings and limits. The Power Receiver also provides design information to the Power Transmitter, which the latter can use to complete FOD before switching to the power transfer phase. See the *Qi Specification, Foreign Object Detection,* for details about this information.
- *Power transfer phase.* This is the phase in which the power transfer to the Power Receiver's Load occurs. In the Extended Protocol, the Power Transmitter and Power Receiver perform a system calibration at the start of this phase. See the *Qi Specification, Foreign Object Detection,* for details about calibration. Occasional interruptions of this phase may occur to renegotiate an element of the Power Transfer Contract. However, the power transfer continues during such renegotiations.

Table 4 summarizes the main features of the two protocol variants.

**Table 4: Comparison of the Baseline Protocol and the Extended Protocol**

| Feature | Baseline Protocol | Extended Protocol |
|---|---|---|
| Power Transmitter design | Type *Ax* and type B*x* designs only | All designs |
| Power Receiver to Power Transmitter Communications | Load modulation at a fixed 2 kHz clock | Load modulation at a fixed 2 kHz clock |
| Power Transmitter to Power Receiver Communications | N/A | Frequency shift keying at a frequency dependent clock of $f_{op}/512$ |
| Operating phases | Ping, configuration, and power transfer | Ping, configuration, negotiation, and power transfer |
| Power level calibration | N/A | At the start of the power transfer phase |
| Authentication | N/A | Using data transport streams in the power transfer phase |

## 2.2 Power Transfer Contract

A Power Transfer Contract comprises the settings and limits governing the power transfer. The Power Receiver sets up an initial Power Transfer Contract as applicable to the Baseline Protocol. The first part of Table 5 shows the elements of this initial (or baseline) Power Transfer Contract. The Power Transmitter receives all information to duplicate the baseline Power Transfer Contract in the configuration phase of the protocol.

Some elements of the Power Transfer Contract are negotiable, enabling the Power Transmitter and Power Receiver to determine new values for these elements in the negotiation phase of the protocol (Extended Protocol only). In the Baseline Protocol, all elements of the Power Transfer Contract keep their values until the power transfer ends.

The Extended Protocol makes use of an extended Power Transfer Contract that contains the additional elements shown in the second part of Table 5. See the *Qi Specification, Power Delivery*, and *Section 6, Negotiation phase*, for details about the use of these elements.

**Table 5: Power Transfer Contract**

| Element | Symbol | Unit | Negotiable | Comment |
|---|---|---|---|---|
| *Elements of a baseline Power Transfer Contract* | | | | |
| Reference Power | $P_{\mathrm{r}}^{(\mathrm{ref})}$ | W | Yes* | The reference power level for RP8 and RP data packets. The CFG data packet provides the initial value. See Section 8.14, *Received Power—RP8 (0x04; status update)*, for an example of its usage. |
| Received Power window size | $t_{\mathrm{window}}$ | ms | No | The properties of the time window for measuring the Received Power. The CFG data packet provides these values. See Figure 62 in *Section 7.3, Power transfer phase timings*. |
| Received Power window offset | $t_{\mathrm{offset}}$ | ms | No | |
| Power Control Hold-off | $t_{\mathrm{delay}}$ | ms | No | The delay between the CE data packet and the power level adjustment window. Defaults to 5 ms. See Figure 61 in *Section 7.3, Power transfer phase timings*. |
| Received Power reporting resolution | N/A | N/A | Yes* | The resolution of the reported Received Power. Defaults to 8 bit (RP8 data packet). |
| *Additional elements of an extended Power Transfer Contract* | | | | |
| FSK polarity, modulation depth, and number of cycles per bit | N/A | N/A | Yes | Power Transmitter to Power Receiver communications parameters. The CFG data packet provides the initial values for the polarity and modulation depth. The number of cycles per bit defaults to 512. |
| Potential Load Power | $P_{\mathrm{L}}^{(\mathrm{pot})}$ | W | No | The highest Guaranteed Load Power level the Power Transmitter can negotiate. No default. See *Section 2.2.1, Load Power level negotiation*, and the *Qi Specification, Power Delivery*, for details. |

Table 5: Power Transfer Contract (Continued)

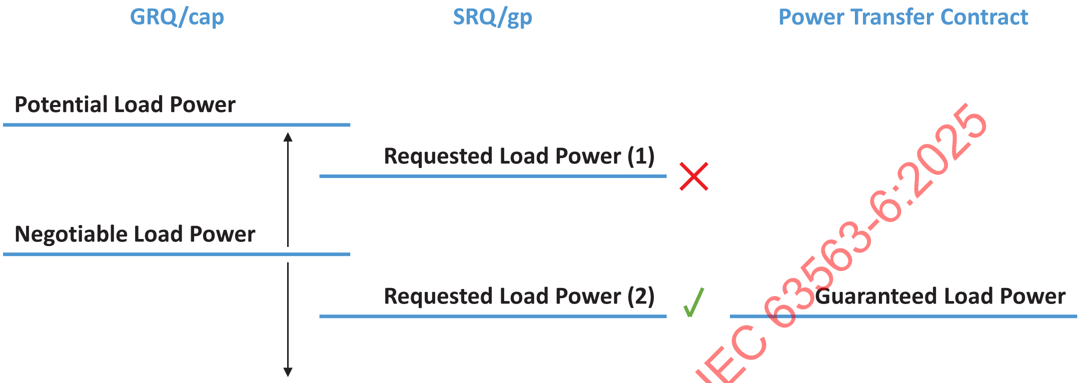
| Element | Symbol | Unit | Negotiable | Comment |
|---|---|---|---|---|
| Guaranteed Load Power | $P_{\mathrm{L}}^{(\mathrm{gtd})}$ | W | Yes | The negotiated power level. Defaults to 5 W. See Section 2.2.1, *Load Power level negotiation*, and the *Qi Specification, Power Delivery,* for details. |
| Re-ping delay | $t_{\mathrm{reping}}$ | ms | Yes | The delay between an EPT/rep data packet and the next Digital Ping. Defaults to 12.6 second. |

*In the negotiation phase of the Extended Protocol

### 2.2.1 Load Power level negotiation

A Power Receiver can typically operate at multiple target power levels. To determine the most appropriate one, the Power Receiver negotiates a Guaranteed Load Power level with the Power Transmitter. Figure 3 shows the steps involved.

**Figure 3. Load Power levels**



The Potential Load Power level is the highest Load power level the Power Transmitter can negotiate at any time. The Negotiable Load Power level is the highest Load power level the Power Transmitter is willing to negotiate at a given time. Usually, the Negotiable Load Power level is equal to the Potential Load Power level. However, in some conditions, the Power Transmitter may set the Negotiable Load Power level to a lower value. A first example of such a condition is an operating temperature that can cause the Power Transmitter to overheat when transferring power at the highest level. A second example is an insufficiently capable power supply driving the Power Transmitter. The Power Receiver can retrieve the Potential Load Power level and the Negotiable Load Power level from the Power Transmitter using a GRQ/cap data packet.

The Requested Load Power is the Load power level at which the Power Receiver intends to operate. It provides this power level to the Power Transmitter using an SRQ/gp data packet. If the Requested Load Power level is less than or equal to the Negotiable Load Power level, the power level negotiation is successful, and both the Power Transmitter and Power Receiver store the Requested Load Power level as a Guaranteed Load Power level in their copies of the Power Transfer Contract.

*Section 6, Negotiation phase*, *Section 8.18.3, SRQ/gp—Guaranteed Load Power: parameter field and responses*, and *Section 9.4, Power Transmitter Capabilities—CAP (0x31)*, provide details and examples of power level negotiation sequences.

The Load Power level a Power Transmitter can support depends on several factors.

- The designs of the Power Transmitter and Power Receiver
- The position of the Power Receiver in the Operating Volume
- The power supply of the Power Transmitter
- The Load of the Power Receiver
- The operating temperature

The Potential Load Power, Negotiable Load Power, and Requested Load Power levels used in the negotiation process are meaningful only if the Power Receiver has a design that is “similar” to one the reference designs listed in Table 6. See the *Qi Specification, Power Delivery,* for details.

**NOTE:** A Power Receiver may attempt to draw more power than the Guaranteed Load Power level, and a Power Transmitter may provide more power than the Guaranteed Load Power level or Potential Load Power level. However, the system operation is undefined in those cases. See the *Qi Specification, Power Delivery,* for details.

**Table 6: Power Levels**

| Power Level | Reference Power Receiver* |
|---|---|
| 5 W | Power Receiver example 1,<br>Power Receiver example 2 |
| 8 W | Power Receiver example 3 |
| 12 W | Power Receiver example 5 |
| 15 W | Power Receiver example 4 |

## 2.2.2 Examples

Table 7, Table 8, and Table 9 provide examples of Power Transfer Contracts. In the Extended Protocol, the initial Power Transfer Contract contains the elements of the baseline Power Transfer Contract plus the elements of the extended Power Transfer Contract.

**Table 7: Example of a baseline Power Transfer Contract when leaving the configuration phase**

| Element | Symbol | Power Receiver Value | Power Transmitter Value |
|---|---|---|---|
| Reference Power | $P_r^{(ref)}$ | 5 W | 5 W |
| Received Power window size | $t_{window}$ | 8 ms | 8 ms |
| Received Power window offset | $t_{offset}$ | 8 ms | 8 ms |
| Power Control Hold-off | $t_{delay}$ | 5 ms | 5 ms |
| Received Power reporting resolution | N/A | 8 bit | 8 bit |

Table 8: Example of an extended Power Transfer Contract when entering the negotiation phase

| Element | Symbol | Power Receiver Value | Power Transmitter Value |
|---|---|---|---|
| Reference Power | $P_\mathrm{r}^\mathrm{(ref)}$ | 5 W | 5 W |
| Received Power window size | $t_\mathrm{window}$ | 8 ms | 8 ms |
| Received Power window offset | $t_\mathrm{offset}$ | 8 ms | 8 ms |
| Power Control Hold-off | $t_\mathrm{delay}$ | 5 ms | 5 ms |
| Received Power reporting resolution | N/A | 8 bit | 8 bit |
| FSK polarity, modulation depth, and number of cycles per bit | N/A | Positive / Category 0/512 | Positive / Category 0/512 |
| Potential Load Power | $P_\mathrm{L}^\mathrm{(pot)}$ | Unknown | 15 W |
| Guaranteed Load Power | $P_\mathrm{L}^\mathrm{(gtd)}$ | 5 W | 5 W |
| Re-ping delay | $t_\mathrm{reping}$ | 1000 ms | 1000 ms |

Table 9: Example of an extended Power Transfer Contract when leaving the negotiation phase

| Element | Symbol | Power Receiver Value | Power Transmitter Value |
|---|---|---|---|
| Reference Power | $P_\mathrm{r}^\mathrm{(ref)}$ | 10 W | 10 W |
| Received Power window size | $t_\mathrm{window}$ | 8 ms | 8 ms |
| Received Power window offset | $t_\mathrm{offset}$ | 8 ms | 8 ms |
| Power Control Hold-off | $t_\mathrm{delay}$ | 5 ms | 5 ms |
| Received Power reporting resolution | N/A | 16 bit | 16 bit |
| FSK polarity, modulation depth, and number of cycles per bit | N/A | Positive / Category 0/512 | Positive / Category 0/512 |
| Potential Load Power | $P_\mathrm{L}^\mathrm{(pot)}$ | 15 W or unknown* | 15 W |
| Guaranteed Load Power | $P_\mathrm{L}^\mathrm{(gtd)}$ | 8 W | 8 W |
| Re-ping delay | $t_\mathrm{reping}$ | 500 ms | 500 ms |

* If the Power Receiver does not request the CAP data packet in the Extended Protocol, the Potential Load Power remains unknown in the Power Receiver’s copy of the Power Transfer Contract.

## 2.3 Data packet types

Whereas the Power Transmitter starts the communications protocol by applying a Digital Ping (at the end of the ping phase), the Power Receiver drives the execution of the remaining phases of the protocol. This means that the Power Receiver initiates all data packet communications, and that the Power Transmitter waits to send a data packet or Response Pattern until explicitly invited to do so.

**NOTE:** Although it is the Power Receiver that drives the communications protocol, the Power Transmitter may adjust the power level or stop the power transfer completely at any time if it considers that necessary to ensure safe system operation. For additional information, see the *Qi Specification, Power Delivery.*

The Power Receiver can send four kinds of data packets:

- *Status update*—the Power Transmitter does not reply to these data packets.
- *Power control*—the Power Transmitter adjusts the power level in response to these data packets.
- *Simple query*—invites the Power Transmitter to reply with a Response Pattern (ACK, NAK, ND, ATN).
- *Data request*—invites the Power Transmitter to reply with a full data packet.

**NOTE:** The Baseline Protocol uses status update and power-control data packets only.

The Power Transmitter should not respond to data packets that suffer from communications errors. The reason is that data packet corruption could result in the Power Transmitter providing the wrong type of response, confusing the Power Receiver. The lack of a response is a clear signal to the Power Receiver that something went wrong and that it should resend the data packet.

## 2.4 High-level messages and data transport streams

The purpose of most communications in the protocol is to configure and control the power transfer. However, the Extended Protocol also supports data transport streams, which can pass high-level messages (often unrelated to the power transfer) between the Power Transmitter and Power Receiver. Examples of such messages include the authentication messages that the Power Transmitter and Power Receiver can use to verify each other's credentials in a tamper-resistant manner.

**NOTE:** The goal of authentication is to ensure that the Power Transmitter and/or the Power Receiver have passed independent tests certifying safe operation.

A Power Receiver to Power Transmitter data transport stream consists of a sequence of simple-query data packets, with the payloads of these data packets carrying the high-level message data. The Power Receiver can initiate a data transport stream at any time in the power transfer phase. Conversely, when a Power Transmitter has a high-level message to send to the Power Receiver—and has ensured that the latter can process that message—it can draw the Power Receiver's attention by responding with an ATN Response Pattern to an incoming simple-query data packet in the power transfer phase. This signals the Power Receiver to transmit a series of data-request data packets enabling the Power Transmitter to send a data transport stream.

## 2.5 Backward compatibility

Table 10 summarizes the key differences between previous versions and version 1.3 of the *Qi Specification, Communications Protocol* (this document), other than those associated with the new data transport stream and authentication functionalities. Power Transmitters and Power Receivers should examine their counterpart's version number to handle these differences appropriately.

**NOTE:** Prior to version 1.3, the definition of the communications protocol was contained in section 5 of the *Qi Wireless Power Transfer System, Power Class 0 Specification, Parts 1 and 2, Interface Definitions.*

**Table 10: Backward compatibility**

| Version | Backward compatibility notes |
|---|---|
| 1.0.*x* | Baseline Protocol differences to version 1.3<br>▪ The value contained in an RP8 data packet represents a rectified power level rather than a Received Power level. |
| 1.1.*x* | — |
| 1.2.*x* | No Baseline Protocol differences to version 1.3<br>Extended Protocol differences to version 1.3<br>▪ A Power Transmitter does not support a defined delay between the removal of the Power Signal and the next Digital Ping<br>▪ A Power Transmitter does not support a Power Receiver aborting the negotiation phase and proceeding to the power transfer phase of the baseline protocol<br>▪ A Power Transmitter does not support FOD/rf data packets (but it should be resilient to receiving such data packets)<br>▪ In the negotiation phase, a Power Transmitter responds with ND to simple-query data packets having one or more reserved bits set to ONE rather than ignoring those bits<br>▪ A Power Transmitter does not accept additional SRQ/en data packets after sending an ACK Response Pattern to the first SRQ/en data packet at the end of the negotiation phase. If a Power Receiver sends a second SRQ/en data packet, the Power Transmitter interrupts the power transfer. Note that there is no power transfer interruption when both the Power Receiver and Power Transmitter are v1.3 compliant.<br>▪ A Power Receiver does not recognize ATN Response Patterns. Accordingly it will not send DSR data packets inviting the Power Transmitter to send CAP data packets with the aim to trigger the Power Receiver into renegotiating.<br>▪ A Power Transmitter may send CHS, PROP, and/or reserved data packets while calibrating (that is, before sending its first RP/0 or RP/4 data packet in the power transfer phase). |
| 1.3.x | Extended protocol differences to version 2.0<br>▪ A Power Transmitter does not support a reduced number of cycles per FSK bit. |

# 3 Power Receiver and Power Transmitter identification

A Power Receiver identifies itself to a Power Transmitter with the following information.

- The version of the *Qi Specification* with which the Power Receiver complies.
- A Power Receiver Manufacturer Code (PRMC) identifying the Power Receiver's manufacturer.
- A basic device identifier identifying the Power Receiver among multiple Power Receiver's present in the Operating Volume.

  **NOTE:** The basic identifier may change from time to time as defined in Section 8.11, *Identification—ID (0x71; status update)*.
- An optional extended device identifier providing additional information.
- Optionally a Wireless Power ID (WPID). See Section 6.4, *Wireless power ID*, for details.

In the Extended Protocol, the Power Receiver can request the Power Transmitter to identify itself to the Power Receiver with the following information.

- The version of the *Qi Specification* with which the Power Transmitter complies.
- A Power Transmitter Manufacturer Code (PTMC) identifying the Power Transmitter's manufacturer.
- A Power Transmitter Certificate. See *Qi Specification, Authentication Protocol*, for details.

**NOTE:** In the Baseline Protocol, a Power Receiver cannot retrieve a PTMC from the Power Transmitter. However, this does not mean that the latter does not have an associated PTMC. The product registration of the WPC requires the manufacturer of the Power Transmitter to submit a self-declaration form listing the PTMC.

A Power Transmitter shall not use the PRMC in any way that limits the design freedom of the Power Receiver. Conversely, a Power Receiver shall not use the PTMC in any way that limits the design freedom of the Power Transmitter.

The purpose of the PRMC and PTMC is to enable Power Transmitters and Power Receivers of the same manufacturer recognize Proprietary (PROP) data packets more easily.

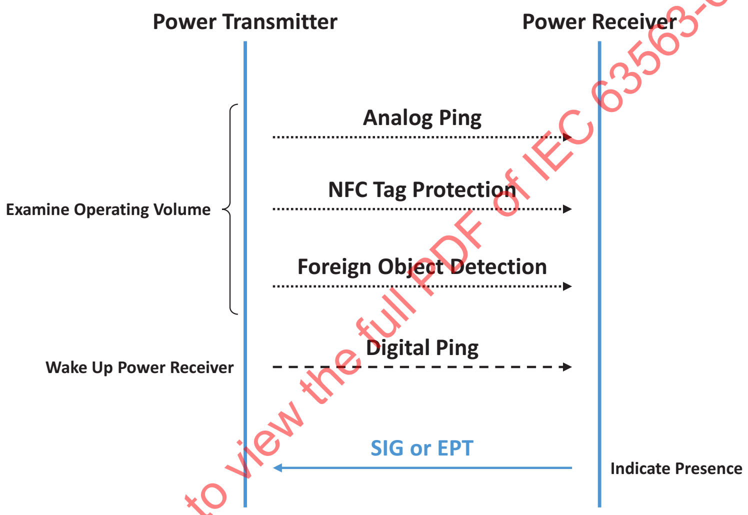
As an example, a manufacturer can have multiple Power Receiver Products with substantially different design properties such as coupling factor, Friendly Metal arrangement, etc. When using knowledge of the PRMC only, a Power Transmitter can therefore easily make incorrect assumptions about these properties. By adjusting its operation based on its assumptions, such as adjusting thresholds etc., interoperability failure is likely to occur.

# 4 Ping phase

At the start of the ping phase, the Power Transmitter does not yet know whether a Power Receiver is present within its Operating Volume. The Power Receiver is not aware of the Power Transmitter either, because its systems are typically inactive due to the lack of a Power Signal.

Figure 4 illustrates the stages of the ping phase. In the first three stages (dotted arrows), the Power Receiver is not active. Moreover, the Power Transmitter should ensure that any signals it uses in these phases do not wake up the Power Receiver. In the fourth stage (dashed arrow), the Power Transmitter attempts to wake up the Power Receiver. In the last stage (solid arrow), the Power Receiver starts its communications.

**Figure 4. Stages of the ping phase**



Before initiating a Digital Ping to solicit a response from a Power Receiver, the Power Transmitter should go through the following stages.

- Detect objects. For this purpose, the Power Transmitter can use Analog Pings or a variety of alternative methods. The *Qi Specification, Power Delivery*, provides a number of examples.
- Optionally apply NFC tag protection as defined in the *Qi Specification, NFC Tag Protection*.

The *Qi Specification, NFC Tag Protection*, provides recommendations about how to execute the above steps.

**NOTE:** Instead of performing NFC tag detection, a Power Transmitter may limit the Power Signal throughout the power transfer to levels that do not damage NFC tags. The *Qi Specification, NFC Tag Protection*, provides guidelines and methods to determine safe power levels.

- Collect information that helps to decide whether Foreign Objects are present in addition to a Power Receiver. For this purpose, the Power Transmitter can use a variety of methods commonly known as pre-power FOD methods. The *Qi Specification, Foreign Object Detection*, defines these methods.

After performing the above steps and determining that there potentially is a Power Receiver in its operating Volume, the Power Transmitter initiates a Digital Ping to solicit a response from the Power Receiver, which is either a Signal Strength (SIG) data packet or an End Power Transfer (EPT) data packet. If there is no such response, the Power Transmitter stays in the ping phase and should repeat the above steps.

**NOTE:** Power Transmitters employing multiple coils to enable a greater positioning freedom for a Power Receiver typically initiate a Digital Ping multiple times using different coil. Typically, such Power Transmitters abort the protocol after receiving the SIG data packet from the Power Receiver until they have determined the optimum coil to use for the power transfer. The *Qi Specification, Power Delivery*, provides examples of this approach.

## 4.1 Ping phase state diagram

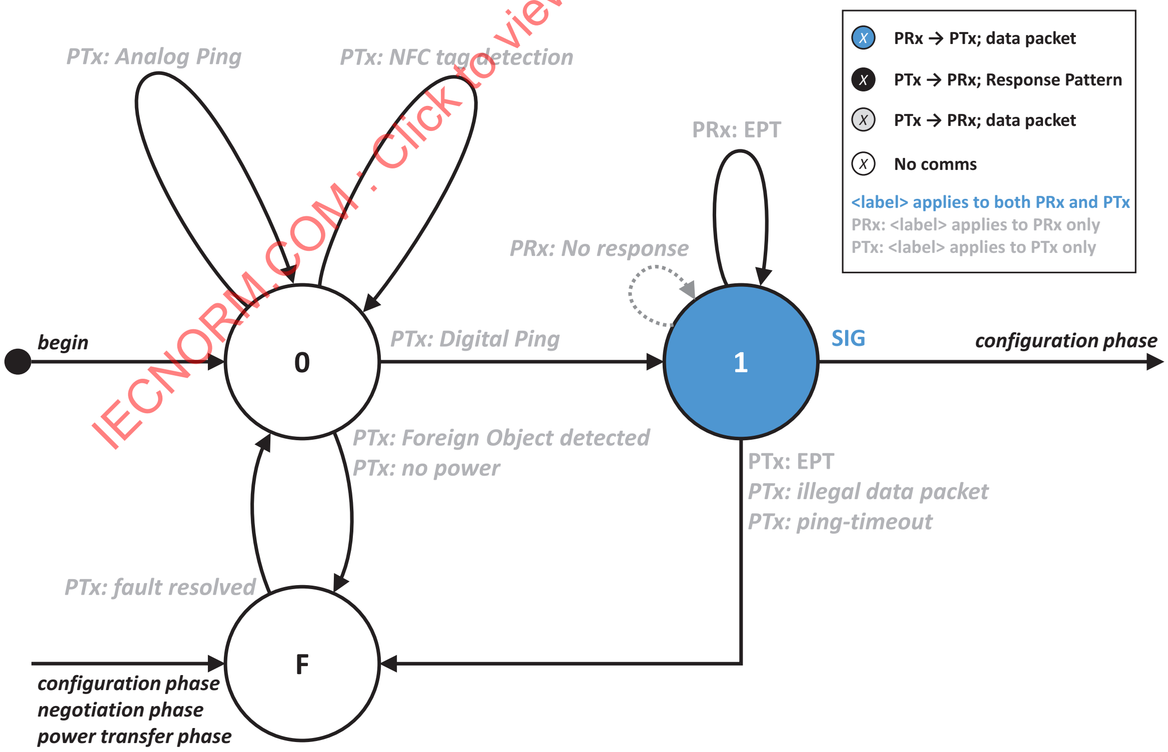
The *Qi Specification, Communications Protocol* (this document) describes the protocol using state diagram that apply to both the Power Transmitter and the Power Receiver. In most states, the Power Transmitter or Power Receiver can send or receive a data packet. Depending on this data packet, the Power Transmitter and Power Receiver switch to the next state. In the case of communications errors, the Power Transmitter and Power Receiver can switch to different states. The power transfer protocol provides mechanisms to resynchronize the Power Transmitter and Power Receiver to the same state.

Some state transitions apply only to the Power Transmitter or only to the Power Receiver, as indicated by their labels. Most of these transitions relate to error conditions such as timeouts or unexpected content in a received data packet. Additionally, some state transitions list multiple conditions. Satisfying any one of those conditions is sufficient to follow such a transition to the next state.

The description of state transitions that apply to both the Power Transmitter and the Power Receiver use the data packet sender's perspective. The data packet receiver's perspective of these transitions simply is to have received the data packet correctly. If the data packet receiver does not receive the data packet correctly, a transition that is associated with an appropriate timeout applies.

The state diagram shown in Figure 5 applies to both the Baseline Protocol and the Extended Protocol.

**Figure 5. State diagram of the ping phase**



### 4.1.1 Transitions from state 0

State 0 is the first state of the protocol. The Power Transmitter switches to this state after completing its power-up initialization functions. In this state, the Power Transmitter attempts to detect the presence of a Power Receiver, NFC tags, and Foreign Objects. The following transitions are possible from this state.

- *PTx: Analog Ping.* The Power Transmitter has attempted to detect objects using an Analog Ping or an alternative method. See the *Qi Specification, Power Delivery*, for details.
- *PTx: NFC tag detection*. The Power Transmitter has attempted to detect NFC tags in the Operating Volume. See the *Qi Specification, NFC Tag Protection*, for the recommended approach.
- *PTx: Digital Ping*. The Power Transmitter has found an object that is likely to contain a Power Receiver and therefore has initiated a Digital Ping.
- *PTx: Foreign Object detected*. The Power Transmitter has detected a Foreign Object, or NFC tag, which prevents it from initiating a Digital Ping. See the *Qi Specification, Foreign Object Detection*, for examples.
- *PTx: no power.* The Power Transmitter has discovered that it cannot sustain a power transfer to the Power Receiver.

  **NOTE:** The Power Transmitter may conclude that it cannot sustain a power transfer when the Power Receiver repeatedly requests it to terminate the power transfer using EPT/nr or EPT/an data packets (in the negotiation phase and/or power transfer phase). For example, the Power Transmitter cannot sustain a power transfer is when the Power Transmitter is plugged into an underrated USB power source.

### 4.1.2 Transitions from state 1

State 1 is the first state of the protocol in which the Power Receiver participates actively. The following transitions are possible from this state.

- *SIG*. The Power Receiver has sent a SIG data packet.
- *PRx: EPT.* The Power Receiver has sent an EPT data packet.
- *PTx: EPT*. The Power Transmitter has received an EPT data packet.
- *PTx: illegal data packet*. The Power Transmitter has received a data packet other than SIG or EPT.
- *PTx: ping timeout*. The Power Transmitter has not detected the start of a data packet before the Digital Ping timeout $t_{\text{ping}}$. See Section 4.2.3, *Digital Ping timeout*, for the timeout value.
- *PRx: no response*. In exceptional cases, the Power Receiver may choose not to respond to a Digital Ping.

### 4.1.3 Transitions from state F

In state F, the Power Transmitter resolves any fault condition that can occur in execution of the protocol. The Power Transmitter can reach this state from any of the other protocol phases, in particular when

- It receives an EPT data packet.
- It times out on a data packet from the Power Receiver.
- It detects a protocol error (e.g. on receiving an unexpected data packet).
- It decides to abort the protocol for internal reasons (e.g. when executing consecutive Digital Pings on multiple coils).

**NOTE:** Reception of an EPT data packet does not necessarily mean that a fault has occurred. For example, it can involve a request from the Power Receiver to delay restarting the protocol. See Section 8.8, *Extended Identification—XID (0x81; status update)*, for a list of error codes.

Upon entering state F, the Power Transmitter shall remove the Power Signal within the time window $t_{\text{terminate}}$.

- *PTx: fault resolved*: The Power Transfer has resolved the fault conditions and is ready to restart execution of the protocol.

## 4.2 Ping phase timings

Table 11 provides an overview of the timing constraints that apply to the ping phase.

**Table 11: Timing constraints in the ping phase**

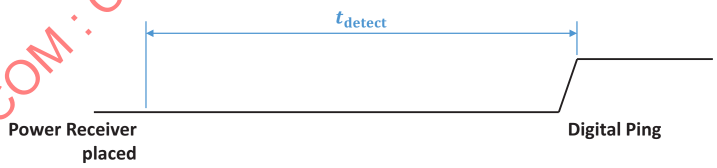
| Parameter | Side | Symbol | Minimum | Target | Maximum | Unit |
|---|---|---|---|---|---|---|
| Detection time window | PTx | $t_{\text{detect}}$ | N/A | N/A | 5,000 | ms |
| Wake-up window | PRx | $t_{\text{wake}}$ | 19 | 40 | 64 | ms |
| Digital Ping timeout | PTx | $t_{\text{ping}}$ | 65 | 65 | 70 | ms |
| Power termination window | PTx | $t_{\text{terminate}}$ | N/A | N/A | 28 | ms |
| Reset window | PRx | $t_{\text{reset}}$ | N/A | 25 | 28 | ms |
| No Power Signal window | PTx | $t_{\text{nopower}}$ | 32 | N/A | N/A | ms |
| Next Digital Ping window | PTx | $t_{\text{nextping}}$ | See Table 25 in Section 8.7, *End Power Transfer—EPT (0x02; power control)* | | | |

For the timing details and other properties of the Analog Pings the Power Transmitter may use to detect objects, see the *Qi Specification, Power Delivery*.

### 4.2.1 Power Receiver detection

The Power Transmitter shall initiate a Digital Ping at $t_{\text{detect}}$ from the user placing a Power Receiver within its Operating Volume.

**Figure 6. Detection time window**



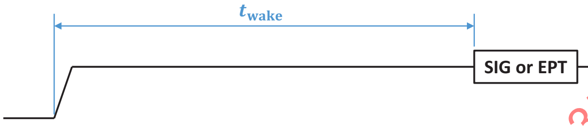
**NOTE:** The black line represents the Power Signal, which initially is zero and increases when the Power Transmitter initiates the Digital Ping. The Power Transmitter may apply Analog Pings before initiating the Digital Ping. Such Analog Pings would show as brief departures of the black line from the zero level.

### 4.2.2 Power Receiver wake-up

If the Power Receiver intends to engage with the Power Transmitter, it shall send a SIG data packet at $t_{\mathrm{wake}}$ after the Power Transmitter has initiated the Digital Ping. If the Power Receiver does not intend to engage with the Power Transmitter, it shall either send an EPT data packet at $t_{\mathrm{wake}}$ after the Power Transmitter has initiated a Digital Ping, or not respond at all.

**NOTE:** A Power Transmitter may use multiple Digital Pings to enhance the positioning freedom of a Power Receiver. A Power Receiver should therefore respond consistently with a SIG data packet to such Digital Pings. See Section 8.17, *Signal Strength—SIG (0x01; status update)*, for an explanation of how the Power Receiver should determine the Signal Strength Value in the SIG data packet.

**Wake-up window**

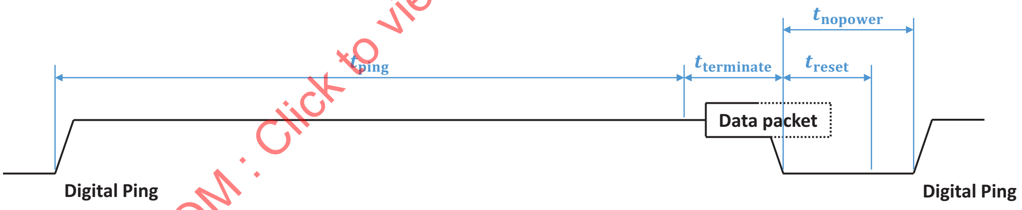


**NOTE:** See the *Qi Specification, Communications Physical Layer*, for the reference time of the start of a data packet.

### 4.2.3 Digital Ping timeout

If the Power Transmitter has not detected the start of a data packet at $t_{\mathrm{ping}}$, it shall remove the Power Signal at $t_{\mathrm{terminate}}$. The start of the Digital Ping timeout is the application of the Power Signal.

**Figure 7. Digital Ping timeout**

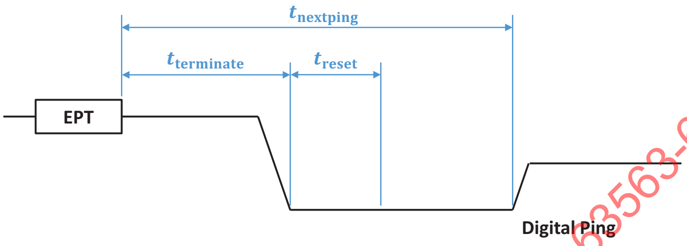


**NOTE:** See Section 4.2.5, *Power Receiver reset*, for details about $t_{\mathrm{reset}}$ and $t_{\mathrm{nopower}}$.

### 4.2.4 End Power Transfer (EPT) data packet

A Power Transmitter shall remove the Power Signal at $t_{\text{terminate}}$ from the end of an EPT data packet and switch to state F of the ping phase, regardless of the End Power Transfer Code contained in the data packet. After removing the Power Signal, the Power Transmitter shall initiate a first Digital Ping at $t_{\text{nextping}}$ from the end of the EPT data packet. The value of $t_{\text{nextping}}$ depends on the value contained in the EPT data packet.

**Figure 8. End Power Transfer data packet timing**



After sending a first EPT data packet, the Power Receiver should continue to send EPT data packets while the Power Signal is present. The transmission of these data packets shall comply with the timing constraints for consecutive data packets provided in Section 5.2.2, *Consecutive data packets*.

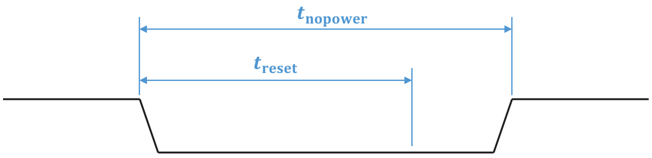
**NOTE:** Consecutive EPT data packets may contain different values in their End Power Transfer Code fields.

### 4.2.5 Power Receiver reset

The Power Transmitter shall not apply an Analog Ping or initiate a Digital Ping in the time window $t_{\text{nopower}}$ after removing the Power Signal. The Power Receiver shall discard the Power Transfer Contract at $t_{\text{reset}}$ after the Power Transmitter removes the Power Signal. If the Power Signal reappears before the Power Receiver has discarded the Power Transfer Contract, it may continue with the protocol from the state it was in when the Power Signal disappeared.

**NOTE:** The time window $t_{\text{nopower}}$ applies in particular to consecutive Digital Pings in Power Transmitters that use multiple coils to enable a greater positioning freedom for Power Receivers.

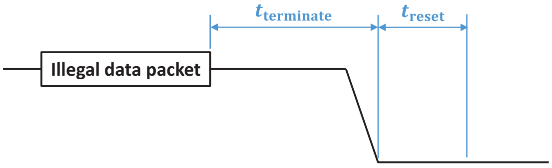
**Figure 9. Reset time window**



### 4.2.6 Illegal data packet

The Power Transmitter shall remove the Power Signal at $t_{\text{terminate}}$ after receiving an illegal data packet.

**Figure 10. Illegal data packet timeout**



**NOTE:** If the time to receive the first data packet in the ping phase takes longer than the time to receive a SIG or EPT data packet, the Power Transmitter should treat that data packet as an illegal data packet and remove the Power Signal without waiting to receive the remainder of the data packet.

# 5 Configuration phase

The configuration phase is the part of the protocol in which:

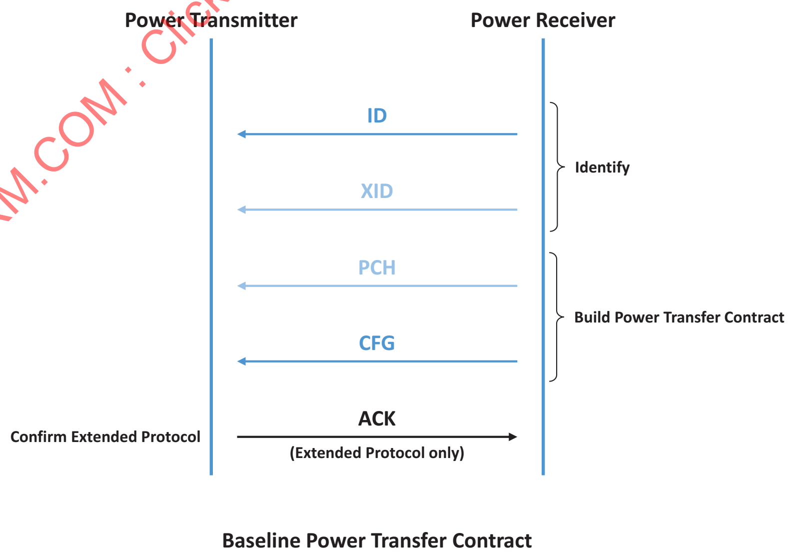
- The Power Receiver identifies itself to the Power Transmitter.
- The Power Receiver and Power Transmitter establish a baseline Power Transfer Contract. See Section 2, *Overview*, for details about the information contained in the Power Transfer Contract.
- The Power Receiver and Power Transmitter determine the protocol variant to use in the power transfer.

In the configuration phase, the Power Transmitter and Power Receiver continue to operate using the Digital Ping parameters. This means that the power and current levels in both the Power Transmitter and Power Receiver change only if a user moves the Power Receiver from its position within the Operating Volume.

**NOTE:** Multi-coil Power Transmitters may proceed into the configuration phase to obtain the Power Receiver's identification data before executing a new Digital Ping with a different coil configuration. This enables such Power Transmitters to discriminate between multiple Power Receivers located within their Operating Volumes. See the *Qi Specification, Power Delivery*, for examples of this approach.

Figure 11 summarizes the data flow in the configuration phase. The Power Receiver identifies itself using an Identification (ID) data packet and optionally an Extended Identification (XID) data packet. It provides data for use in the Power Transfer Contract using an optional Power Control Hold-off (PCH) data packet and a Configuration (CFG) data packet. In the final step, the Power Transmitter acknowledges Extended Protocol (if applicable).

**Figure 11. Data flow in the configuration phase**

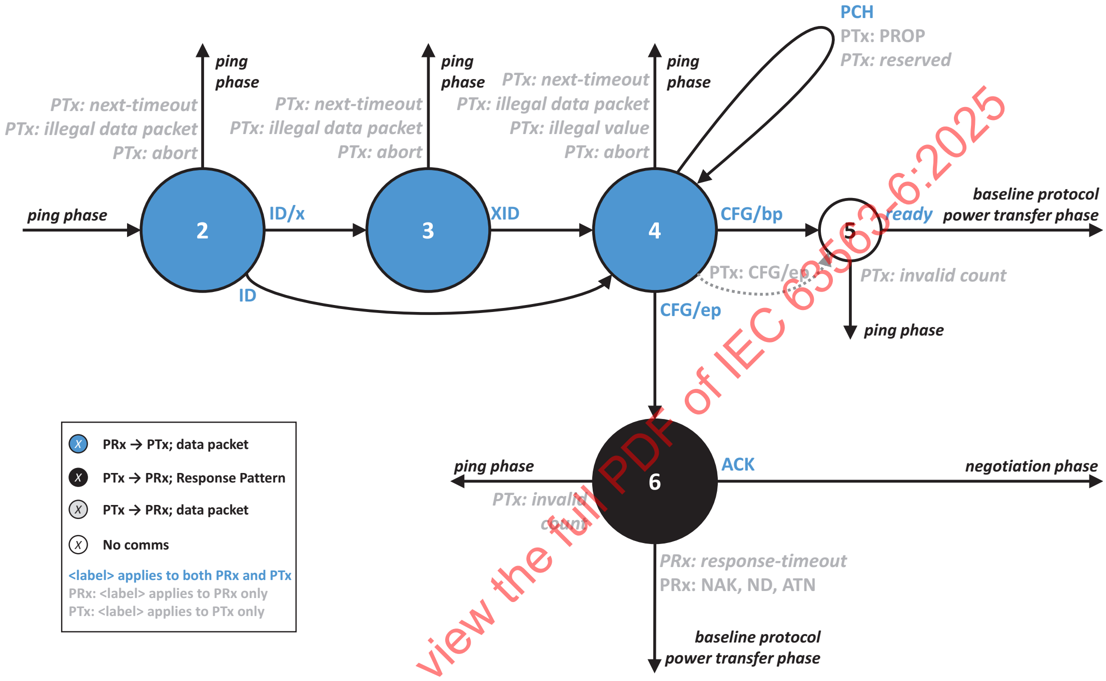


## 5.1 Configuration phase state diagram

The state diagram shown in Figure 12 applies to both the Baseline Protocol and the Extended Protocol.

**NOTE:** For details about how to interpret this diagram, see Section 4.1, *Ping phase state diagram*.

Figure 12. State diagram of the configuration phase



### 5.1.1 Transitions from state 2

In state 2, the Power Receiver identifies itself to the Power Transmitter. The following transitions are possible from this state.

- *ID*. The Power Receiver has sent an ID data packet with its Ext bit set to ZERO. See Section 8.11, *Identification—ID (0x71; status update)*, for the meaning of the Ext bit.
- *ID/x*. The Power Receiver has sent an ID data packet having its Ext bit set to ONE.
- *PTx: illegal data packet*. The Power Transmitter has received a data packet other than ID.
- *PTx: next-timeout*. The Power Transmitter has not detected the start of a data packet from the Power Receiver before the next data packet timeout $t_{\text{next}}$. See Section 5.2.2, *Consecutive data packets*.
- *PTx: abort*. The Power Transmitter may abort further execution of the protocol for internal reasons. For example, a multi-coil Power Transmitter may execute Digital Pings on several coils in order to determine the optimum coil configuration for the power transfer, aborting the protocol after receiving the SIG data packet. See Section 5.1.6, *Examples*, for details.

When switching to the ping phase, the Power Transmitter enters state F (and removes the Power Signal).

### 5.1.2 Transitions from state 3

In state 3, the Power Receiver provides optional extended identification data. The following transitions are possible from this state.

- *XID*. The Power Receiver has sent an XID data packet.
- *PTx: illegal data packet*. The Power Transmitter has received a data packet other than XID.
- *PTx: next-timeout*. The Power Transmitter has not detected the start of a data packet from the Power Receiver before the next data packet timeout $t_{\mathrm{next}}$. See Section 5.2.2, *Consecutive data packets*, for the timeout value.
- *PTx: abort*. The Power Transmitter may abort further execution of the protocol for internal reasons. For example, a multi-coil Power Transmitter may execute Digital Pings on several coils in order to determine the optimum coil configuration for the power transfer, aborting the protocol after receiving the ID data packet. See Section 5.1.6, *Examples*, for details.

When switching to the ping phase, the Power Transmitter enters state F (and removes the Power Signal).

### 5.1.3 Transitions from state 4

In state 4, the Power Receiver provides the elements of the baseline Power Transfer Contract to the Power Transmitter. The following transitions are possible from this state.

- *PCH.* The Power Receiver has sent a PCH data packet.
- *PTx: PROP*. The Power Transmitter has received a PROP data packet. See Table 17 in Section 8, *Power Receiver data packets*, for the list of proprietary data packets. The Power Transmitter shall ignore all unsupported PROP data packets, but still include them in the count of optional data packets.

**NOTE:** The state diagram does not provision for the Power Receiver to send proprietary data packets in the configuration phase. The requirement that the Power Transmitter ignore all proprietary data packets enables a future enhancement of the protocol in which the Power Receiver may send proprietary data packets in the configuration phase. However, plans for such an enhancement of the protocol do not currently exist.

- *PTx: reserved*. The Power Transmitter has received a reserved data packet. See Table 17 in Section 8, *Power Receiver data packets*, for the list of defined data packets and reserved data packets. The Power Transmitter shall ignore all reserved data packets, but still include them in the count of optional data packets.
- *CFG/bp*. The Power Receiver has sent a CFG data packet with its Neg bit set to ZERO. This means that the Power Receiver supports the Baseline Protocol only.
- *CFG/ep*. The Power Receiver has sent a CFG data packet with its Neg bit set to ONE. This means that the Power Receiver supports both the Baseline Protocol and the Extended Protocol.
- *PTx: illegal data packet*. The Power Transmitter has received a data packet not listed on any one of the transitions of state 4.

- *PTx: illegal value*. The Power Transmitter has received a PCH data packet containing a Power Control Hold-off Time outside the allowed range. See Section 8.12, *Power Control Hold-off—PCH (0x06; status update)*, for the allowed range. The Power Transmitter has received a CFG data packet that does not comply with the format defined in Section 8.4, *Configuration—CFG (0x51; simple query)*. See Section 5.2.4, *Illegal value in a data packet*, for the timeout value.
- *PTx: next-timeout*. The Power Transmitter has not detected the start of a data packet from the Power Receiver before the next data packet timeout $t_{\text{next}}$. See Section 5.2.2, *Consecutive data packets*, for the timeout value.
- *PTx: abort*. The Power Transmitter may abort further execution of the protocol for internal reasons. For example, a multi-coil Power Transmitter may execute Digital Pings on several coils in order to determine the optimum coil configuration for the power transfer, aborting the protocol after receiving the Identification (ID) or Extended Identification (XID) data. See Section 5.1.6, *Examples*, for details.
- *PTx: CFG/ep*. A Power Transmitter that does not support the Extended Protocol shall switch to state 5, regardless of the value of the NEG bit in the CFG data packet. In exceptional cases, a Power Transmitter that does support the Extended Protocol may decide to continue in the Baseline Protocol (not sending an ACK Response Pattern), even if the Power Receiver indicates that it supports the Extended Protocol.

**NOTE:** In this case, the Power Receiver goes through state 6 to the power transfer phase of the Baseline Protocol.

When switching to the ping phase, the Power Transmitter enters state F (and removes the Power Signal).

### 5.1.4 Transitions from state 5

In state 5, the Power Transmitter verifies the Count field of the received CFG data packet. The Power Receiver follows the ready transition (unconditionally). The following transitions are possible from this state.

- *Ready*. The Power Receiver and the Power Transmitter switch to the power transfer phase of the Baseline Protocol. Prior to switching, the Power Transmitter shall verify that the Count field of the CFG data packet matches the number of PCH, PROP and reserved data packets received in state 4.
- *PTx: invalid count*. The Power Transmitter has received a CFG data packet containing a Count field that does not match the number of optional data packets received in state 4. See Section 5.2.4, *Illegal value in a data packet*, for the timeout value.

When switching to the ping phase, the Power Transmitter enters state F (and removes the Power Signal).

### 5.1.5 Transitions from state 6

In state 6, the Power Transmitter decides whether to use the Baseline Protocol or the Extended Protocol. The following transitions are possible from this state.

- ACK. The Power Transmitter has agreed to continue using the Extended Protocol.

  **NOTE:** The Power Transmitter may decide to use the Baseline Protocol and not send an ACK, even if it supports the Extended Protocol.

  **NOTE:** If the Power Transmitter responds to the CFG data packet with ACK, it switches to the negotiation phase of the Extended Protocol. However, if the Power Receiver does not receive the ACK correctly, it times out and switches to the power transfer phase of the Baseline Protocol. As a result, there is an operating phase mismatch between the Power Transmitter and Power Receiver. But when the Power Receiver sends its first data packet in the power transfer phase (e.g. a CE data packet), the Power Transmitter discovers the mismatch and switches to the power transfer phase of the Baseline Protocol as well. See Figure 22 in Section 6.6, *Negotiation phase state diagram*, for additional details on this mechanism. Alternatively, the Power Transmitter may switch to state F in the ping phase (and remove the Power Signal) to resolve the mismatch.

- PTx: invalid count. The Power Transmitter has received a CFG data packet containing a Count field that does not match the number of optional data packets received in state 4. See Section 5.2.4, *Illegal value in a data packet*, for the timeout value.
- PRx: response-timeout. The Power Receiver has not detected an ACK response to its CFG data packet before the response timeout $t_{\text{responsetimeout}}$, presumably because the Power Transmitter does not support the Extended Protocol. See Section 5.2.3, *Configuration (CFG) data packet*, for the timeout value.
- PRx: NAK/ND/ATN. The Power Receiver has received an unexpected response.

When switching to the ping phase, the Power Transmitter enters state F (and removes the Power Signal).

## 5.1.6 Examples

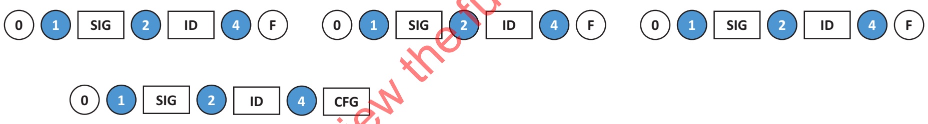
### 5.1.6.1 Optimum coil selection in a multi-coil Power Transmitter

Figure 13 and Figure 14 provide examples of communications sequences of a multi-coil Power Transmitter executing multiple Digital Pings to select an optimum coil for the power transfer. In the example of Figure 13, the Power Transmitter repeatedly goes through state 0 (executing a Digital Ping), state 1 (receiving a SIG data packet), state 2 (storing the Signal Strength data and aborting the Digital Ping), and state F (resolving the issue, which in this case means selecting a different coil for the next Digital Ping). Eventually, the Power Transmitter has collected a sufficient number of Signal Strength Values from multiple coils. It then selects the optimum coil for the power transfer for use in the final sequence, in which it continues to receive the CFG data packet.

In the example of Figure 14, the Power Transmitter retrieves ID data packets (in addition to SIG data packets), in order to discriminate between multiple Power Receivers that can be positioned in its Operating Volume.

**Figure 13. Example of a communications sequence in a multi-coil Power Transmitter to select a coil**

**Figure 14. Another example of a communications sequence in a multi-coil Power Transmitter to select a coil**



## 5.2 Configuration phase timings

Table 12 provides an overview of the timing constraints that apply to the communications and other actions in the configuration phase.

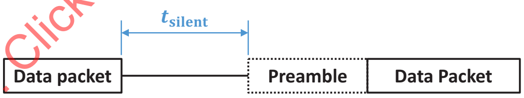
**Table 12: Timing constraints in the configuration phase**

| Parameter | Side | Symbol | Minimum | Target | Maximum | Unit |
|---|---|---|---|---|---|---|
| Silent window | PRx | $t_{\text{silent}}$ | 6 | 7 | N/A | ms |
| Next data packet window | PRx | $t_{\text{start}}$ | 11.5 | N/A | 19 | ms |
| Next data packet timeout | PTx | $t_{\text{next}}$ | 22 | N/A | 25 | ms |
| Power termination window | PTx | $t_{\text{terminate}}$ | See Table 11 in Section 4.2, *Ping phase timings* | | | |
| Reset window | PRx | $t_{\text{reset}}$ | See Table 11 in Section 4.2, *Ping phase timings* | | | |
| Response start window | PTx | $t_{\text{response}}$ | See Table 14 in Section 6.7, *Negotiation phase timings* | | | |
| Response timeout | PRx | $t_{\text{responsetimeout}}$ | | | | |

### 5.2.1 Generic constraints

A Power Receiver shall start to transmit the preamble of a next data packet at $t_{\text{silent}}$ from the end of the data packet directly preceding it.

**Figure 15. Generic timing constraints**



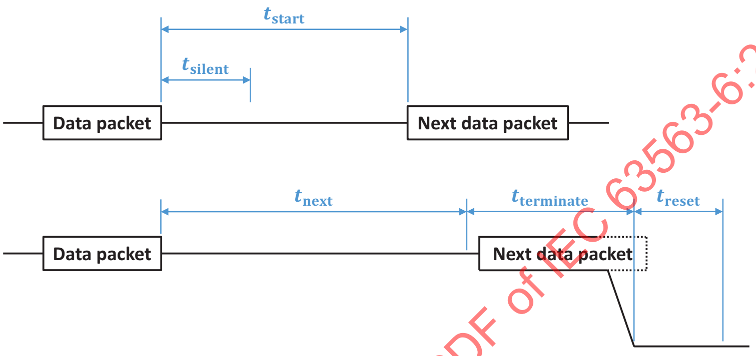
**NOTE:** Most figures in the *Qi Specification, Communications Protocol* (this document) do not show the preamble explicitly. See the *Qi Specification, Communications Physical Layer*, for the reference times defining the start and end of a data packet.

### 5.2.2 Consecutive data packets

A Power Receiver shall start sending the next data packet at $t_{\text{start}}$ from the end of the preceding data packet. The SIG data packet sent in the ping phase counts as a preceding data packet. See the *Qi Specification, Communications Physical Layer*, for the reference times defining the start and end of a data packet.

If the Power Transmitter has not detected the start of a data packet at $t_{\text{next}}$, it shall remove the Power Signal at $t_{\text{terminate}}$.

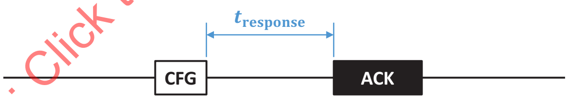
**Figure 16. Timing of consecutive data packets**



### 5.2.3 Configuration (CFG) data packet

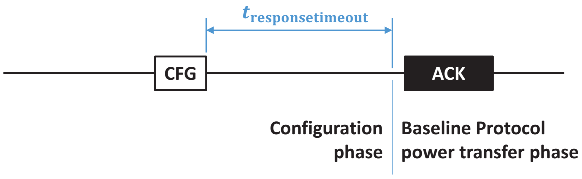
A Power Transmitter shall start to transmit its response at $t_{\text{response}}$ from the end of a simple-query data packet or a data-request data packet.

**Figure 17. Power Transmitter response timing**



If a Power Receiver has not detected the start of a Response Pattern or data packet at $t_{\text{responsetimeout}}$ from the end of a simple-query or data-request data packet, it shall switch to the power transfer phase of the Baseline Protocol.

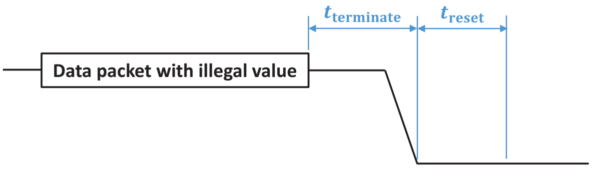
**Figure 18. Power Receiver response timeout**



### 5.2.4 Illegal value in a data packet

The Power Transmitter shall remove the Power Signal at $t_{\text{terminate}}$ after receiving a data packet containing an illegal value.

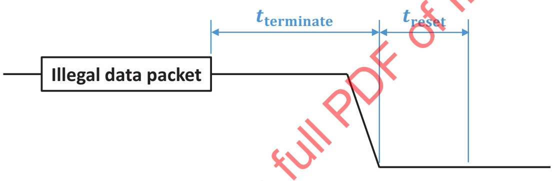
**Figure 19. Illegal value timeout**



### 5.2.5 Illegal data packet

The Power Transmitter shall remove the Power Signal at $t_{\text{terminate}}$ after receiving an illegal data packet.

**Figure 20. Illegal data packet timeout**



# 6 Negotiation phase

The negotiation phase is the part of the Extended Protocol in which the Power Transmitter and Power Receiver can make changes to the Power Transfer Contract. There are two flavors of this phase:

- Negotiation phase. The negotiation phase follows directly on the Configuration phase and serves to create the initial extended Power Transfer Contract. It also serves to complete the pre-power FOD functionality; see the *Qi Specification, Foreign Object Detection* for details. The length of the negotiation phase is not restricted.
- Renegotiation phase. A renegotiation phase may interrupt the power transfer phase multiple times, and typically serves to adjust a single element of the Power Transfer Contract. The FOD/qf, FOD/rf, and SRQ/rpr data packets are illegal in a renegotiation phase. The constraints on the CE data packets of the power transfer phase limit the length of a renegotiation phase; see Section 7.3.2, *Control Error (CE) data packets*, for details.

The Power Receiver negotiates changes to the elements of the extended Power Transfer Contract using a question and answer approach, wherein the Power Receiver sends a simple-query data packet and the Power Transmitter replies with a Response Pattern. For example, the Power Receiver can ask whether the Power Transmitter supports a particular power level, and the Power Transmitter responds with yes (ACK) or no (NAK).

If the Power Transmitter and Power Receiver cannot successfully negotiate a new Power Transfer Contract, they may abort the negotiation phase and switch to the power transfer phase without making any change to the Power Transfer Contract. Aborting the negotiation phase means that the power transfer phase continues using the Baseline Protocol and the baseline Power Transfer Contract. Aborting a renegotiation phase means a switch back to the power transfer phase of the Extended Protocol and an unchanged Power Transfer Contract.

**NOTE:** Aborting the negotiation phase and switching to the power transfer phase of the Baseline Protocol implies that renegotiation at a later stage is not possible, unless the power transfer is terminated and restarted from the selection phase.

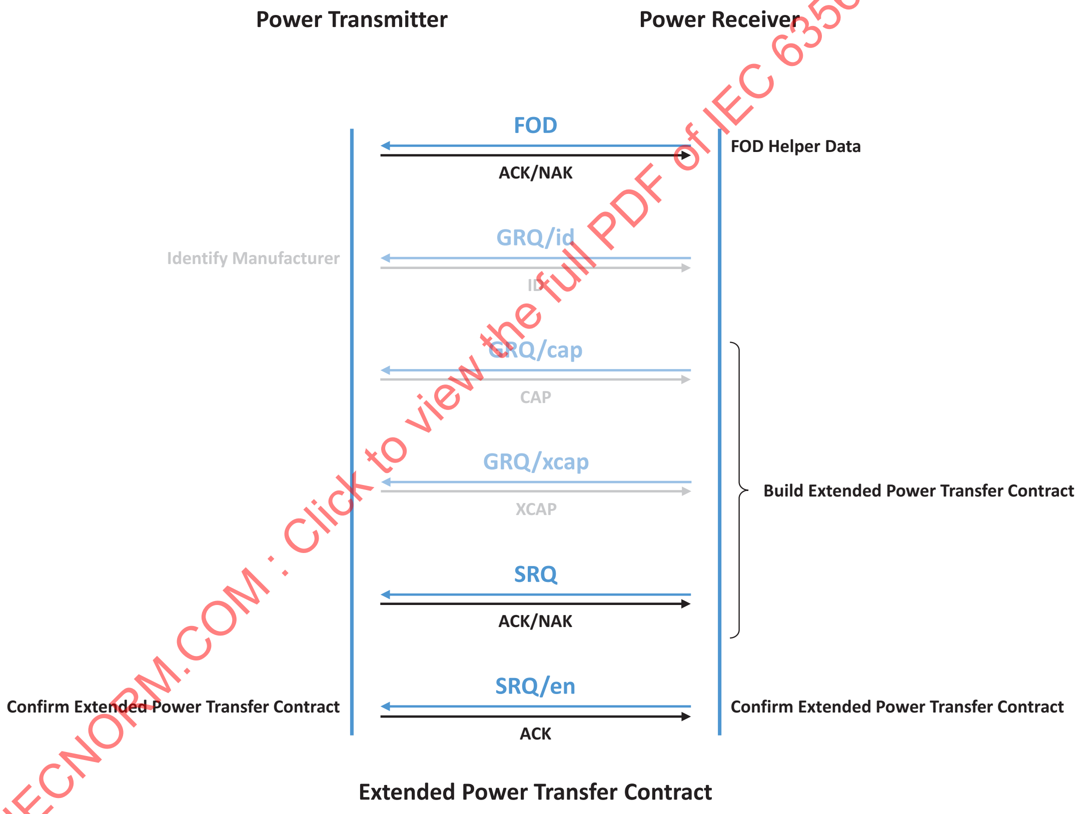
In addition to simple queries, the Power Receiver can use data-request data packets to retrieve more information from the Power Transmitter. For example, the Power Receiver can request that the Power Transmitter provide its identification (GRQ/id), its capabilities (GRQ/cap), and its extended capabilities (GRQ/xcap).

**NOTE:** The Power Transmitter's ID data packet provides information about the version of the *Qi Specification* to which it is compliant. The Power Receiver should verify that the version number is at least 1.3 before attempting to use data transport stream functionality.

Figure 21 summarizes the data flow in the negotiation phase. The Power Receiver uses FOD Status (FOD) data packets to inform the Power Transmitter about the effect its presence has on the selected properties of a reference Power Transmitter. The Power Transmitter can use this information to configure its FOD functionality as explained in the *Qi Specification, Foreign Object Detection*. The Power Receiver can optionally use a General Request (GRQ) data packet to retrieve the identity of the Power Transmitter's manufacturer in a Power Transmitter Identity (ID) data packet. The Power Receiver and Power Transmitter build the extended Power Transfer Contract using GRQ/cap and GRQ/xcap data packets (recommended) and one or more Specific Request (SRQ) data packets. To confirm the extended Power Transfer Contract and end the negotiation phase, the Power Receiver uses an SRQ/en data packet.

**NOTE:** Figure 21 does not imply any particular required order or number of occurrences order of the data packets used in the negotiation phase (except for the SRQ/en data packet).

Figure 21. Data flow in the negotiation phase



The Power Receiver may send an EPT data packet at any time in the negotiation phase to disengage from the Power Transmitter (not shown in Figure 21).

## 6.1 Negotiable elements of the Power Transfer Contract

The Power Transmitter and Power Receiver can negotiate the following elements of the Power Transfer Contract:

- *Reference Power*. The CFG data packet provides the initial Reference Power level. For compatibility with Power Transmitters supporting the Baseline Protocol only, this factor is at most 5 W.

  **NOTE:** A Reference Power level of 5 W in the Power transfer Contract corresponds to a value of 10 in the CFG and SRQ/rp data packets, see Section 8.4, *Configuration—CFG (0x51; simple query)* and Section 8.18.7, *SRQ/rp—Reference Power: parameter field and responses*. The RP8 and RP data packets are limited to report a Received Power level up to twice the Reference Power level. A Power Receiver intending to operate at a target power level of 10 W should therefore negotiate a Reference Power level close to 10 W (e.g. using a value of 20 in the SRQ/rp data packet).

- *FSK Polarity and Modulation depth*. The CFG data packet provides the initial FSK properties. The Power Receiver should choose initial properties that optimize FSK communications in the negotiation phase. In the latter phase, the Power Receiver may adjust the FSK properties to optimize FSK communications in the power transfer phase.

  **NOTE:** The Power Receiver should renegotiate the FSK properties when it encounters communications issues in the power transfer phase.

- *Number of cycles per FSK bit.* A lower number of cycles per FSK bit increases the throughput of Power Transmitter to Power Receiver communications. The Power Receiver should negotiate a lower value when it intends to retrieve a substantial amount of data from the Power Transmitter (such as during authentication, see the *Qi Specification, Authentication Protocol*).

- *Received Power reporting data packet*. The Extended Protocol uses a 16-bit Received Power resolution. Since the initial Power Transfer Contract has this element set to 8-bit, it is necessary to update this element in the negotiation phase using an SRQ/rpr data packet.

- *Guaranteed Power*. The Power Receiver can use two approaches to negotiate an appropriate Guaranteed Load Power level. In the recommended approach, it requests the CAP data packet to determine the highest level the Power Transmitter is willing to negotiate. In the alternative approach, it uses a trial-and-error approach, requesting several levels using SRQ/gp data packets until the Power Transmitter agrees to a requested level. The *Qi Specification, Power Delivery*, provides details about approaches to determine the appropriate Guaranteed Load Power level.

  **NOTE:** The alternative approach leaves the Potential Load Power level in the Power Receiver's copy of the Power Transfer Contract unknown. A Power Receiver should therefore not use this approach.

- *Re-ping delay*. The Power Receiver can set a re-ping delay if it expects to have to interrupt the power transfer temporarily. An example of a reason to interrupt the power transfer temporarily is that a Power Receiver intends to use NFC communications, which the Power Signal can distort.

## 6.2 Updating the Power Transfer Contract

Both the Power Receiver and the Power Transmitter shall keep track of the elements of the Power Transfer Contract that have changed. One way to do this is for both to duplicate the Power Transfer Contract and apply the changes to one of the copies only. See Table 13 for an example.

**Table 13: Example of duplication of an extended Power Transfer Contract**

| Element | Old value | New value |
|---|---|---|
| Reference Power | 10 W | *15 W (negotiated)* |
| Received Power window size | 8 ms | 8 ms |
| Received Power window offset | 8 ms | 8 ms |
| Power Control Hold-off | 5 ms | 5 ms |
| Received Power resolution | 8 bit | *16 bit (negotiated)* |
| FSK polarity, modulation depth, and number of cycles per bit | Positive/Category 0/ 512 | *Positive/Category 1/64 (negotiated)* |
| Potential Load Power | 15 W | 15 W |
| Guaranteed Load Power | 8 W | *12 W (negotiated)* |
| Re-ping delay | 500 ms | 500 ms (not negotiated) |

When the Power Receiver exits the negotiation or a renegotiation phase using an SRQ/en data packet, it compares the two copies, counts the elements that are different between the two, and uses this count as a parameter to the SRQ/en data packet. In the example of Table 13, the count is four. When the Power Transmitter has verified that it has the same change count (by comparing its own two copies), it shall acknowledge the SRQ/en data packet. Moreover, it shall start to use the copy containing the changes as the new Power Transfer Contract when it receives a data packet from the power transfer phase. The Power Receiver shall start to use the copy containing the changes when it has received the ACK Response Pattern following the SRQ/en data packet.

**NOTE:** A change to one or more of the FSK polarity, modulation depth, and number of cycles per bit counts as a single change.

When aborting the negotiation phase, both the Power Transmitter and the Power Receiver continue to use the copy that does not contain the changes, i.e. they continue to use the existing Power Transfer Contract.

## 6.3 Foreign Object Detection support

In the negotiation phase, the Power Receiver supplies the Power Transmitter with design information, which the latter can use to determine whether Foreign Objects are present within its Operating Volume. The Power Receiver shall send FOD/qf and FOD/rf data packets to provide this information. See the *Qi Specification, Foreign Object Detection*, for recommended methods.

## 6.4 Wireless power ID

In addition, to the identification data the Power Receiver provides in the configuration phase, it may also send its unique Wireless Power ID (using WPID/hi and WPID/lo data packets). The Power Transmitter may use this Wireless Power ID for various purposes.

**NOTE:** The WPC is not currently managing the uniqueness of the Wireless Power ID. Accordingly, any use of this functionality is proprietary.

## 6.5 NFC tag protection support

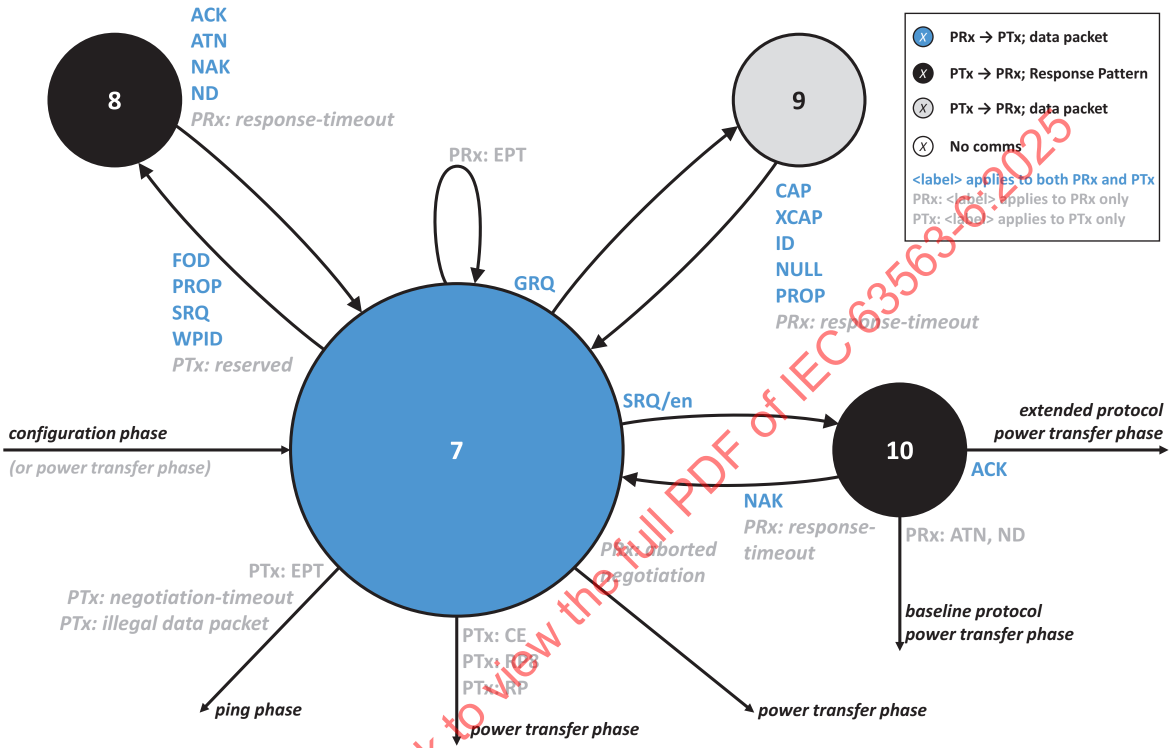
In the negotiation phase, the Power Receiver may request the GRQ/xcap data packet to determine whether the Power Transmitter supports NFC tag protection, whether it has performed NFC tag protection, and whether it has detected an NFC tag in the Operating Volume. The Power Receiver may also perform NFC tag protection. See the *Qi Specification, NFC Tag Protection*, for specific details of the protocol steps involved.

## 6.6 Negotiation phase state diagram

The state diagram shown in Figure 22 applies to the Extended Protocol only.

**NOTE:** For details about how to interpret this diagram, see Section 4.1, *Ping phase state diagram*.

Figure 22. State diagram of the negotiation phase (Extended Protocol only)



### 6.6.1 Transitions from state 7

State 7 is the main state of the negotiation phase. In this state, the Power Receiver can send data packets to negotiate properties of the extended Power Transfer Contract. In addition, it can send data packets to provide other miscellaneous functionality. The following transitions are possible from this state.

- *SRQ*. The Power Receiver has sent a SRQ data packet. The Power Receiver shall send at least one SRQ/rpr data packet in the negotiation phase. It shall not send an SRQ/rpr data packet in a renegotiation phase. See Section 6, *Negotiation phase*, for the differences between the negotiation phase and a renegotiation phase.
- *FOD*. The Power Receiver has sent an FOD/qf or FOD/rf data packet. See the *Qi Specification, Foreign Object Detection*, for details about the use of this data packet. The Power Receiver shall send both FOD/qf and FOD/rf data packets in the negotiation phase. It shall not send a FOD/qf or FOD/rf data packets in a renegotiation phase. See Section 6, *Negotiation phase*, for the differences between the negotiation phase and a renegotiation phase.
- *WPID*. The Power Receiver has sent a WPID/hi or WPID/lo data packet. A Power Receiver shall send either both or none of the WPID data packets
- *PROP*. The Power Receiver has sent a PROP data packet.
- *PTx*: *reserved*. The Power Transmitter has received a reserved data packet.
- *PRx: EPT*. The Power Receiver has sent an EPT data packet, requesting the Power Transmitter to remove the Power Signal.
- *GRQ*. The Power Receiver has requested the Power Transmitter to send a specific data packet.
- *SRQ/en*. The Power Receiver has sent an SRQ/en data packet to finalize the negotiated Power Transfer Contract.
- *PTx: EPT*. The Power Transmitter has received an EPT data packet.
- *PRx: aborted negotiation*. This transition applies in four cases:
    - The Power Receiver has not been able to terminate a renegotiation phase successfully before timing out on the Control Error interval $t_{\mathrm{interval}}$ or Received Power interval $t_{\mathrm{received}}$; see Section 7.3.2, *Control Error (CE) data packets*, and Section 7.3.3, *Received Power (RP and RP8) data packets*. The Power Receiver shall switch to the power transfer phase of the Extended Protocol.

      **NOTE:** If the Power Receiver has sent an SRQ/en data packet to finalize a renegotiation phase but has not received an ACK Response Pattern, the renegotiated elements of the Power Transfer Contract can differ between the Power Receiver and the Power Transmitter. Accordingly, the Power Receiver should renegotiate these elements again in a next renegotiation phase. For an example, see Section 6.6.5.10 , *Resolution of a renegotiation failure (alternative approach)*.

  - The Power Receiver has received a Response Pattern that violates the requirements provided in *Qi Specification, Communications Protocol* (this document). The Power Receiver shall switch to the power transfer phase without updating the Power Transfer Contract. See Section 8, *Power Receiver data packets*, for the permitted Response Patterns per data packet.

    **NOTE:** The above requirement implies that if the violation occurs in the negotiation phase directly following the configuration phase the Power Receiver switches to the power transfer phase of the Baseline Protocol.

  - The Power Receiver has detected an unrecoverable error in the negotiation phase. For example, it has not been able to conclude the negotiation phase successfully within reasonable time.

- PTx: CE/RP/RP8. The Power Transmitter has received a CE or RP8 data packet, which indicates that the Power Receiver has aborted the negotiation phase. Alternatively, the Power Transmitter has received an RP data packet, which indicates that the Power Receiver has aborted the renegotiation phase. The Power Transmitter shall discard all changes to the Power Transfer Contract and switch to the power transfer phase.

  **NOTE:** If the Power Receiver has aborted the negotiation phase, the Power Transmitter switches to the power transfer phase of the Baseline Protocol. If the Power Receiver has aborted a renegotiation phase, the Power Transmitter switches to the power transfer phase of the Extended Protocol.

- PTx: negotiation-timeout. The Power Transmitter has not detected the start of a data packet from the Power Receiver before the negotiation timeout $t_{\text{negotiate}}$. See Section 6.7.1, *Consecutive data packets*, for the timeout value.

  **NOTE:** The negotiation time out is similar to the next data packet timeout $t_{\text{next}}$ in the configuration phase.

- PTx: illegal data packet. The Power Transmitter has received a data packet not listed on any one of the transitions of state 7.

When switching to the ping phase, the Power Transmitter enters state F (and removes the Power Signal).

## 6.6.2 Transitions from state 8

In state 8, the Power Transmitter sends an appropriate Response Pattern, replying to a simple-query data packet. The following transitions are possible from this state.

- *ACK/ATN/NAK/ND*. The Power Transmitter has replied to the last received data packet. See the data packet definitions in Section 8, *Power Receiver data packets*, for the appropriate responses. If the received data packet is a reserved data packet or an unsupported PROP data packet, the Power Transmitter shall reply with ND.

In a renegotiation phase, the Power Transmitter shall send ND when the last received data packet was an SRQ/rpr, FOD/qf or FOD/rf data packet.

- *PRx: response-timeout*. The Power Receiver has not detected a reply to its simple query data packet before the response timeout $t_{\mathrm{responsetimeout}}$, presumably because the Power Transmitter did not receive the data packet correctly. See Section 6.7.2, *Simple-query and data-request data packets*, for the timeout value.

## 6.6.3 Transitions from state 9

In state 9, the Power Transmitter sends an appropriate data packet in response to the GRQ data packet. The following transitions are possible from this state.

- *CAP/XCAP/ID/PROP*. The Power Transmitter has replied to the GRQ data packet with the requested data packet.
- *NULL*. The Power Transmitter has returned the NULL data packet because the requested data packet is not a CAP, ID, or PROP data packet.
- *PRx: response-timeout*. The Power Receiver has not detected a reply to its GRQ data packet before the response timeout $t_{\mathrm{responsetimeout}}$, presumably because the Power Transmitter did not receive it correctly. See Section 6.7.2, *Simple-query and data-request data packets*, for the timeout value.

### 6.6.4 Transitions from state 10

In state 10, the Power Transmitter sends an appropriate Response Pattern, replying to the SRQ/en data packet. The following transitions are possible from this state.

- *ACK*. The Power Transmitter has verified that
  - It has received and acknowledged an SRQ/rpr data packet.
  - It has received and acknowledged FOD/qf and FOD/rf data packets.
  - The count value in the SRQ/en data packet is equal to the number of elements of the Power Transfer Contract that have changed.

  After switching to the power transfer phase, it shall use the updated Power Transfer Contract.
- *NAK*. The Power Transmitter has determined that the conditions for sending an ACK Response have not been satisfied. It shall discard all changes to the Power Transfer Contract (and stay in the negotiation phase).
- *PRx: ND/ATN*. The Power Receiver shall abort the negotiation phase, discard all changes to the Power Transfer Contract, and proceed to the power transfer phase of the Baseline Protocol. Alternatively, the Power Receiver shall abort the renegotiation phase, discard all changes to the Power Transfer Contract, and proceed to the power transfer phase of the Extended Protocol.
- *PRx: response-timeout*. The Power Receiver has not detected a reply to its SRQ/en data packet before the response timeout $t_{\text{responsetimeout}}$, presumably because the Power Transmitter did not receive it correctly. See Section 6.7.2, *Simple-query and data-request data packets*, for the timeout value.

  This timeout results in an operating phase mismatch, with the Power Receiver remaining in the negotiation phase and the Power Transmitter switching to the power transfer phase. The Power Receiver shall resolve this mismatch by repeating the SRQ/en data packet until it receives an ACK or NAK response. In a renegotiation phase, repeating the SRQ/en data packet may lead to a violation of the timing constraints on the transmission of CE and/or RP/0 data packets.

  **NOTE:** If the Power Receiver has to resend the SRQ/en data packet too often, it should start sending EPT/an data packets. It is the Power Receiver's decision how many times it will retry the SRQ/en data packet.

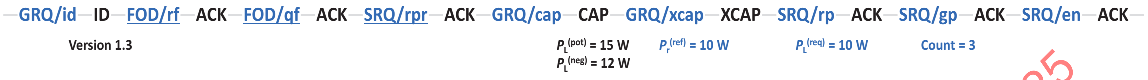
See Section 6.2, *Updating the Power Transfer Contract*, for information about when to start using the updated parameters.

## 6.6.5 Examples

### 6.6.5.1 Recommended negotiation approach

Figure 23 shows an example of a data packet sequence in the negotiation phase. The underlined data packets are mandatory in the negotiation phase. All other data packets are optional.

Figure 23. Recommended negotiation approach



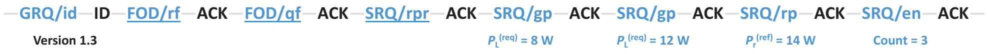
In this example, the Power Receiver uses the GRQ/id data packet as the first data packet in the negotiation phase. The purpose hereof is to determine whether the Power Transmitter's version supports the FOD/rf data packet. Next, the Power Receiver sends the FOD/rf and FOD/qf data packets to help the Power Transmitter discriminate between Foreign Objects and Friendly Metals. The Power Transmitter acknowledges both data packets, meaning that it did not detect a Foreign Object. Subsequently, the Power Receiver sends the following data packets:

- An SRQ/rpr data packet to set the Received Power resolution in the Power Transfer Contract to 16 bit.
- A GRQ/cap data packet to retrieve the Power Transmitter's capabilities such as its Potential Load Power level $P_{\mathrm{L}}^{(\mathrm{pot})}$ and Negotiable Load Power level $P_{\mathrm{L}}^{(\mathrm{neg})}$.
- A GRQ/xcap data packet to retrieve the Power Transmitter's additional capabilities, such as its NFC tag protection information and status.
- An SRQ/rp to send an appropriate Reference Power level $P_{\mathrm{r}}^{(\mathrm{ref})}$.
- An SRQ/gp data packet to request a particular Guaranteed Load Power level $P_{\mathrm{L}}^{(\mathrm{req})}$ (based on the information obtained from the CAP data packet).
- An SRQ/en data packet to exit the negotiation phase. (In the example, the count is three because of the updates to three elements of the Power Transfer Contract, namely the Received Power resolution, the Reference Power level, and the Guaranteed Load Power level.)

### 6.6.5.2 Alternative negotiation approach (not recommended)

Figure 24 shows an example of the alternative approach to negotiate a Guaranteed Load Power level.

**Figure 24. Alternative negotiation approach**



The first four data packets sent in this sequence are the same as in the previous example. Instead of retrieving the Power Transmitters' capabilities, the Power Receiver uses a trial and error approach to determine an appropriate Guaranteed Load Power level by sending the following data packets:

- A first SRQ/gp data packet to select a Guaranteed Load Power level of $P_L^{(gtd)}$ = 8 W, which the Power Transmitter accepts.
- A second SRQ/gp data packet to select a higher Guaranteed Load Power level of $P_L^{(gtd)}$ = 12 W, which the Power Transmitter accepts as well.
- An SRQ/rp data packet to set the Reference Power level at $P_r^{(ref)}$ = 14 W.
- An SRQ/en data packet to exit the negotiation phase. (Similar to the preceding example, the count is three even though the sequence updates the Guaranteed Load Power level twice.)

### 6.6.5.3 Abort to the Baseline Protocol because of an FOD trigger

Figure 25 shows an example of an aborted negotiation sequence in which the Power Receiver decides to continue with the Baseline Protocol, because the Power Transmitter has indicated that it detected a Foreign Object by responding with a NAK Response Pattern to an FOD/qf or FOD/rf data packet. To avoid that the Power Transmitter removes the Power Signal, the Power Receiver switches to the power transfer phase of the Baseline Protocol.

**NOTE:** In the latter phase, the Power Transmitter continues FOD and may still remove the Power Signal if necessary.

**Figure 25. Aborted to the Baseline Protocol because of an FOD trigger**

### 6.6.5.4 Resolution of an operating-phase mismatch

Figure 26 shows an example of a negotiation sequence in which the Power Receiver times out on a corrupted ACK response to the SRQ/en data packet. In this case, the Power Receiver repeats the SRQ/en data packet until it receives the ACK from the Power Transmitter correctly and only then switches to the power transfer phase. The Power Transmitter has already switched to the power transfer phase after it ACK'ed the first SRQ/en data packet.

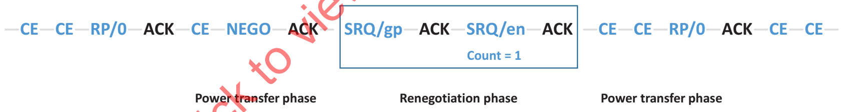
**NOTE:** Once Power Receiver has sent an SRQ/en data packet and times out on the response, the protocol does not allow the Power Receiver to fall back to the Baseline Protocol (see the requirement in the *PRx: aborted negotiation transition from state 7*.) The reason is that the Power Transmitter may have already switched to the power transfer phase of the Extended Protocol. However, the Power Receiver can fall back to the Baseline Protocol by restarting the power transfer by sending an appropriate EPT data packet.

Figure 26. Resolution of an operating-phase mismatch

### 6.6.5.5 Power-Receiver initiated renegotiation

Figure 27 shows an example of a renegotiation sequence, in which the Power Receiver quickly updates an element of the Power Transfer Contract and resumes with the power transfer phase.

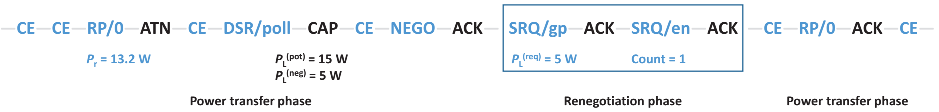
Figure 27. Power Receiver initiated renegotiation



### 6.6.5.6 Power-Transmitter initiated renegotiation

Figure 28 shows an example of a renegotiation sequence initiated by the Power Transmitter. In this example, the Guaranteed Load Power level in the Power Transfer Contract is $P_L^{(gtd)}$ = 12 W (not shown in Figure 28) and the system operates at a Received Power level of about $P_r$ = 13 W. When Power Transmitter needs the Power Receiver to reduce its power consumption because it is about to overheat, it requests permission to communicate by responding to an RP/0 data packet with ATN. The Power Receiver grants this permission by sending a DSR/poll data packet, enabling the Power Transmitter to send its CAP data packet. Because the Negotiable Load Power level reported in this data packet is lower than the Guaranteed Load Power level in the Power Transfer Contract), the Power Receiver initiates a renegotiation phase to update the Guaranteed Load Power level in the Power Transfer Contract.

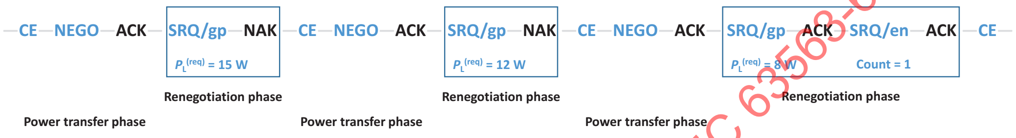
Figure 28. Power Transmitter initiated renegotiation



### 6.6.5.7 Repeated renegotiation

Figure 29 shows an example of a repeated renegotiation sequence. The Power Receiver can use a sequence like this to determine if a higher Guaranteed Load Power level is possible again after the Power Transmitter has reduced it to avoid overheating (see the preceding example). The Power Receiver uses multiple attempts to increase the Guaranteed Load Power level in the Power Transfer Contract. After each unsuccessful attempt, the Power Receiver switches back to the power transfer phase in order to satisfy the constraints on the CE data-packet timeout $t_{\text{interval}}$; see Section 7.3, *Power transfer phase timings*, for details. The Power Receiver does not end the first and second of the renegotiation phases in the sequence with SRQ/en because it did not make changes to the Power Transfer Contract.

Figure 29. Repeated renegotiation

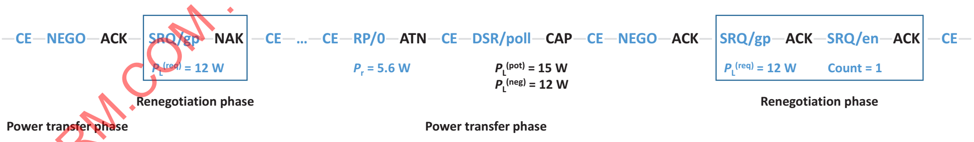


### 6.6.5.8 Renegotiating to a higher power level

Figure 30 shows an example of a renegotiation phase, in which the Power Receiver attempts to update the Guaranteed Load Power level in the Power Transfer Contract. In this example, the Power Transmitter denies the update. The reason for this denial could be that the Power Transmitter needs some time to reconfigure its power supply. When the Power Transmitter is ready to grant the request, it asks for permission to communicate by responding to an RP/0 data packet with ATN. The Power Receiver then enables the Power Transmitter to send its CAP data packet, which the Power Receiver takes as a signal to reattempt negotiating the Guaranteed Load Power level.

**NOTE:** The Power Receiver does not use an SRQ/en data packet to terminate the aborted negotiation.

Figure 30. Renegotiating to a higher power level



### 6.6.5.9 Resolution of a renegotiation failure (recommended approach)

**NOTE:** This section applies only if the Power Receiver aborts the renegotiation phase after sending one or more SRQ/en data packets and before receiving an ACK Response Pattern.

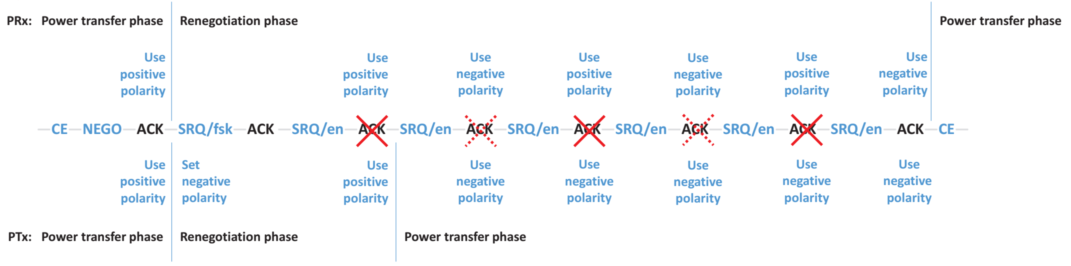
Figure 31 and Figure 32 shows examples of renegotiation sequences in which communications errors can result in a mismatch between the Power Transmitter Contracts of the Power Transmitter and the Power Receiver. In the data packet sequence of Figure 31 a mismatch initially occurs because the Power Transmitter sends its ACK Response Pattern and starts using the new Power Transfer Contract, while the Power Receiver does not receive the Response Pattern correctly and therefore continues to use the old Power Transfer Contract. To resolve the mismatch, the Power Receiver should resend its SRQ/en data packet as often as necessary to obtain a Response Pattern. As indicated in Section 7.3.2, *Control Error (CE) data packets*, and Section 7.3.3, *Received Power (RP and RP8) data packets*, the Power Receiver may violate the timing constraints on CE and RP data packets to resolve the renegotiation failure. However, when failing to obtain a Response Pattern after five or six retransmissions of the SRQ/en data packet, the Power Receiver should send EPT/rep data packets to restart the power transfer.

**NOTE:** When restarting the power transfer following an EPT/rep data packet, the Power Transmitter should suppress potentially distracting user interface events than can alarm the user, see Section 8.7, *End Power Transfer—EPT (0x02; power control)*. The Power Receiver should do likewise to silently resolve the issue.

When there is a communications error when ending a renegotiation phase in which the Power Receiver changes the properties of the FSK communications channel, the Power Receiver should alternate between the new properties and the old properties of the channel when resolving the failure. The reason is that the missed ACK Response Pattern can also result from a communications error in the SRQ/en data packet itself, see Figure 32.

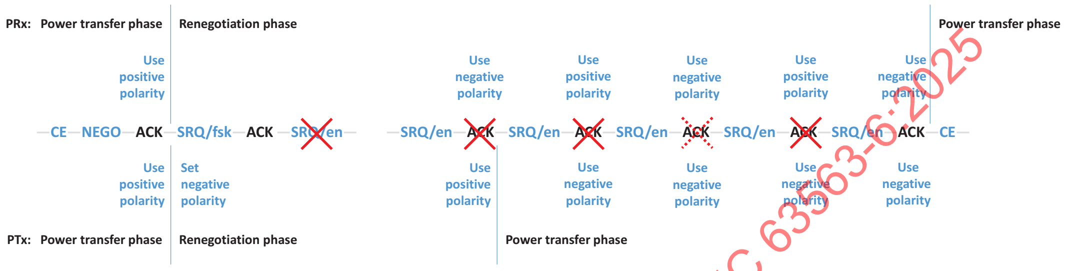
As a detailed explanation of the examples, in Figure 31, the Power Transmitter receives the SRQ/en data packet and sends its ACK Response Pattern. Subsequently, it returns to the power transfer phase and starts to use the negative FSK polarity. However, the Power Receiver has not received the ACK Response Pattern and therefore continues in the renegotiation phase. Because it knows there can be a mismatch in the power transfer contracts, it starts to use alternate between negative and positive FSK polarity when receiving a Response Pattern. When the Power Receiver uses a positive FSK polarity, it does not receive the Response Pattern, and a new communications error occurs. However, when it uses a negative FSK polarity, it can receive the Response Pattern correctly, unless there are further communications errors (as indicated by the dashed crosses).

Figure 31. Resolution of a communications error at the end of a renegotiation phase (I)



In the example of Figure 32, there is initially no mismatch because the Power Transmitter does not receive the SRQ/en at packet terminating the renegotiation phase. However, because the Power Receiver cannot distinguish this case from the example in Figure 31, it starts to alternate between the negative and positive FSK polarity. This decision causes a mismatch to occur with the Power Transmitter returning to the power transfer phase and starting to use the negative FSK polarity, and the Power Receiver staying in the renegotiation phase until it receives the ACK Response Pattern (which it eventually does).

Figure 32. Resolution of a communications error at the end of a renegotiation phase (II)

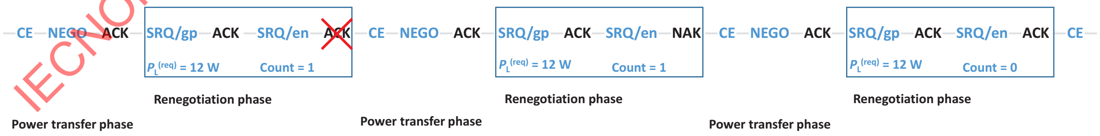


## 6.6.5.10 Resolution of a renegotiation failure (alternative approach)

**NOTE:** This section applies only if the Power Receiver aborts the renegotiation phase after sending one or more SRQ/en data packets and before receiving an ACK Response Pattern.

Figure 33 shows an example of an aborted renegotiation sequence, which results in a mismatch between the Power Transfer Contracts of the Power Transmitter and Power Receiver. In the first renegotiation phase, the Power Receiver requests the Power Transmitter to change the Guaranteed Load Power level to 12 W. Due to a communications error, the Power Receiver does not receive the ACK Response Pattern to the SRQ/en data packet confirming that the Power Transmitter has updated its Power Transfer Contract. Because of the timing constraint on the CE data packet (see Section 7.3.2, *Control Error (CE) data packets*, for details), the Power Receiver cannot retransmit its SRQ/en data packet. Accordingly, the Power Receiver aborts the renegotiation phase without changing its Power Transfer Contract, and a mismatch occurs between the two Power Transfer Contracts.

Figure 33. Resolution of a renegotiation failure



To repair the mismatch, the Power Receiver engages in a new renegotiation phase immediately after sending the CE data packet. In this example, the Power Receiver repeats its request to change the Guaranteed Load Power level to 12 W. Because the Power Transmitter has already changed the Guaranteed Load Power level in its Power Transfer Contract (it has sent an ACK Response Pattern to the SRQ/en data packet in the initial renegotiation sequence), the Power Transmitter sends a NAK Response Pattern in the second renegotiation sequence. The Power Receiver may take this as a signal to change the Guaranteed Load Power level in its Power Transfer Contract, resolving the mismatch that occurred due to the communications error. To make completely sure, the Power Receiver engages in a third renegotiation sequence and repeats its request for a Guaranteed Load Power level of 12 W one more time. Because the Guaranteed Load Power level in its Power Transfer Contract is set to12 W already, it terminates the renegotiation sequence with a Count value of zero in the SRQ/en data packet. Since the Power Transfer Contract of the Power Transmitter also contains a Guaranteed Load Power level of 12 W, and no change occurs, the Power Transmitter sends an ACK Responds Pattern in this renegotiations sequence.

## 6.7 Negotiation phase timings

Table 14 provides an overview of the timing constraints that apply to the communications and other actions in the negotiation phase.

**Table 14: Timing constraints in the negotiation phase**

| Parameter | Side | Symbol | Minimum | Target | Maximum | Unit |
|---|---|---|---|---|---|---|
| Silent window | PRx | $t_{\text{silent}}$ | See Table 12 in Section 5.2, *Configuration phase timings*. | | | |
| Next data packet window | PRx | $t_{\text{start}}$ | | | | |
| Negotiation timeout | PTx | $t_{\text{negotiate}}$ | 300 | N/A | 500 | ms |
| Response start window[*] | PTx | $t_{\text{response}}$ | 3 | N/A | 10 | ms |
| Response timeout | PRx | $t_{\text{responsetimeout}}$ | 15 | N/A | N/A | ms |
| Power termination window | PTx | $t_{\text{terminate}}$ | See Table 11 in Section 4.2, *Ping phase timings*. | | | |
| Reset window | PRx | $t_{\text{resset}}$ | | | | |
| FOD grace window | PTx | $t_{\text{FOD}}$ | N/A | N/A | 5,000 | ms |

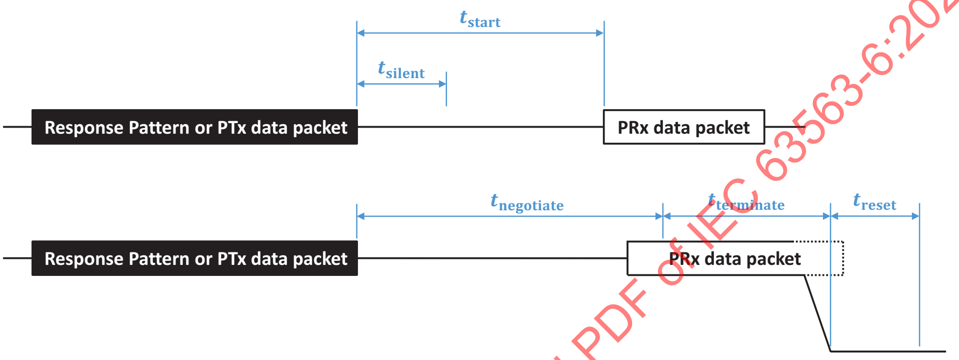
[*] The number of cycles the Power Receiver can use to determine the operating frequency $f_{\text{op}}$ before the start of the Response Pattern is $N_{\text{cycles}} = 3 \cdot f_{\text{op}}$, with $f_{\text{op}}$ in kilohertz. For example, at $f_{\text{op}} = 125$ kHz, $N_{\text{cycles}} = 375$.

### 6.7.1 Consecutive data packets

A Power Receiver shall start to transmit the preamble of a next data packet at $t_{\text{silent}}$ from the end of the data packet directly preceding it. See the *Qi Specification, Communications Physical Layer*, for the reference times defining the start and end of a data packet. See Section 5.2, *Configuration phase timings*, for an illustration.

A Power Receiver shall start sending the next data packet at $t_{\text{start}}$ from the end of the preceding Response Pattern or Power Transmitter data packet. The ACK response sent to the CFG data packet counts as a preceding Response Pattern.

Figure 34. Timing of consecutive data packets

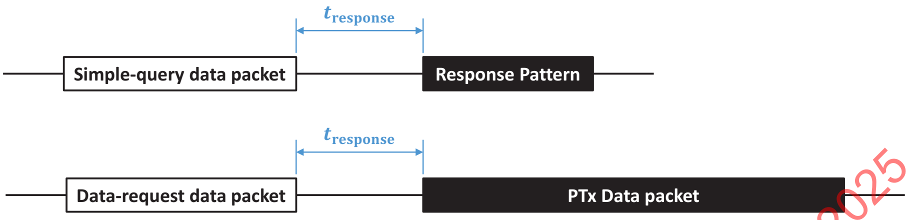


If the Power Transmitter has not received a data packet at $t_{\text{negotiate}}$, it shall remove the Power Signal at $t_{\text{terminate}}$.

## 6.7.2 Simple-query and data-request data packets

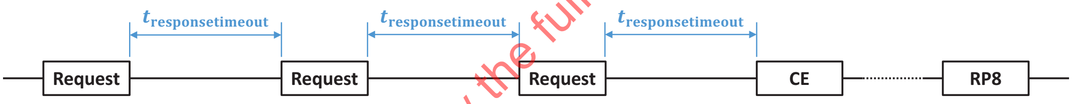
A Power Transmitter shall start to transmit its response at $t_{response}$ from the end of a simple-query data packet or a data-request data packet.

Figure 35. Power Transmitter response timing



If a Power Receiver has not detected the start of a Response Pattern or data packet at $t_{responsetimeout}$ from the end of a simple-query or data-request data packet, it should assume the Power Transmitter did not receive its data packet. In that case, it should retry sending its simple-query or data-request data packet at least once. If it has not detected a Response Pattern after two retries, it should abort the negotiation phase and proceed to the power transfer phase of the Baseline Protocol. Alternatively, if it has not detected a Response Pattern after two retries, it should abort the renegotiation phase and proceed to the power transfer phase of the Extended Protocol.

Figure 36. Power Receiver response timeout (recommended behavior)



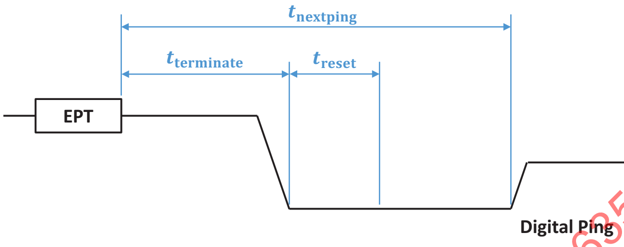
**NOTE:** When the Power Receiver fails to detect the Response Pattern or Power Transmitter data packet, there is a risk of collisions between further Power Transmitter and Power Receiver communications. The Power Transmitter and Power Receiver should take the following precautions to prevent such collisions:

- (Power Receiver) Delay sending the next data packet until after the expected end of the failed Response Pattern or Power Transmitter data packet
- (Power Receiver) Continuously monitor the FSK communications channel and delay sending the next data packet until there are no FSK communications ongoing
- (Power Transmitter) Continuously monitor the Power Signal for an incoming data packet and abort any FSK communications after detecting a preamble

### 6.7.3 End Power Transfer (EPT) data packet

A Power Transmitter shall remove the Power Signal at $t_{\text{terminate}}$ from the end of an EPT data packet and switch to state F of the ping phase, regardless of the End Power Transfer Code contained in the data packet. After removing the Power Signal, the Power Transmitter shall initiate a first Digital Ping at $t_{\text{nextping}}$ from the end of the EPT data packet. The value of $t_{\text{nextping}}$ depends on the value contained in the EPT data packet.

**Figure 37. End Power Transfer data packet timing**



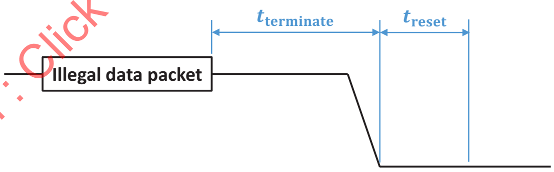
After sending a first EPT data packet, the Power Receiver should continue to send EPT data packets while the Power Signal is present. The transmission of these data packets shall comply with the timing constraints for consecutive data packets provided in Section 5.2.2, *Consecutive data packets*.

**NOTE:** Consecutive EPT data packets may contain different values in their End Power Transfer Code fields.

### 6.7.4 Illegal data packet

The Power Transmitter shall remove the Power Signal at $t_{\text{terminate}}$ after receiving an illegal data packet.

**Figure 38. Illegal data packet timeout**



### 6.7.5 FOD grace window

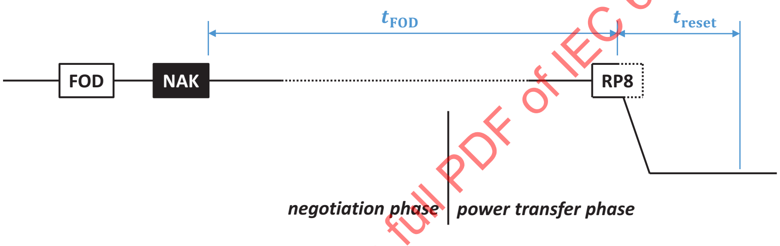
A Power Transmitter shall remove the Power Signal at $t_{\mathrm{FOD}}$ when:

- the Power Transmitter has replied with a NAK Response Pattern to one or more FOD/qf or FOD/rf data packets, indicating that it has detected a Foreign Object; and
- the Power Receiver has not switched to the power transfer phase of the Baseline Protocol in response to the first NAK Response Pattern. Reception of an RP8 data packet is a clear indication to the Power Transmitter that the Power Receiver has made this switch.

**NOTE:** The Power Receiver can switch to the power transfer phase by following the *PRx: aborted negotiation* transition from state 7 in the state diagram shown in Figure 22 in Section 6.5, *NFC tag protection support*.

Figure 39 shows an RP8 data packet arriving too late for the Power Transmitter to receive it within the FOD grace window $t_{\mathrm{FOD}}$. Accordingly, the Power Transmitter removes the Power Signal.

**Figure 39. FOD grace window timeout**



# 7 Power transfer phase

The power transfer phase is the part of the protocol in which actual power transfers to the Power Receiver's Load. The power transfer proceeds subject to the conditions in the Power Transfer Contract created in the negotiation phase. The Power Receiver controls the power level by sending control error data, which is a measure for the deviation between the Power Receiver's target and actual operating points. The Power Transmitter and Power Receiver aim to drive the control error data to zero, at which point the system is operating at its target power level. See the *Qi Specification, Power Delivery*, for details about power control.

In addition to control error data, the Power Transmitter and Power Receiver exchange information intended to facilitate FOD. The Power Receiver regularly reports the amount of power it receives—the Received Power level—and the Power Transmitter can signal whether it has detected a Foreign Object. The recommended method for FOD in the power transfer phase is power-loss accounting. In this approach, the Power Transmitter compares the Received Power level as reported by the Power Receiver with the amount of power it transmits—the Transmitted Power level—and signals the Power Receiver when the difference exceeds a threshold. See the *Qi Specification, Foreign Object Detection*, for details about FOD in the power transfer phase.

If circumstances so require, the Power Transmitter or the Power Receiver may request renegotiation of the Power Transfer Contract. Examples of such changed circumstances include:

- The Power Receiver requires (substantially) more power than previously negotiated.
- The Power Transmitter has detected that it is operating at a low efficiency.
- The Power Transmitter is no longer able to sustain the current power level because of an increased operating temperature (or vice versa, it allows the Power Receiver to operate at a higher power level after cooling down sufficiently).

The Power Transmitter and Power Receiver can exchange application-level data throughout the power transfer phase by initiating data transport streams. An important common application is authentication, where both sides can verify their counterpart's credentials in a tamper resistant manner.

For example, a Power Receiver may want to verify the credentials of a Power Transmitter to ensure that it can trust the latter to operate safely at elevated power levels—having the proper credentials implies having passed compliance testing.

Accordingly, a recommended approach to the power transfer is to start at a low power level (e.g. at a Load Power of $P_\mathrm{L} \leq 5\ \mathrm{W}$), and control the power to a higher level only after successfully completing the authentication protocol.

**NOTE:** It is recommended that the Power transmitter and Power Receiver first negotiate a Power Transfer Contract for the low power level, and after successful authentication renegotiate a Power Transfer Contract for the higher power level.

Figure 40 and Figure 41 summarize the data flow in the power transfer phase as explained above. The Power Receiver typically sends Control Error (CE) data packets several times per second. It sends Received Power data packets (RP8 in the Baselines Protocol and RP in the Extended Protocol) typically once every 1.5 second.

In the Extended Protocol, the Power Transmitter may reply to an RP data packet with an Attention (ATN) Response Pattern to request permission to send a data packet.

The Power Transmitter and Power Receiver may use Data Stream Response (DSR), Power Transmitter Capability (CAP), and Renegotiate (NEGO) data packets to initiate renegotiation of an element in the Power Transfer Contract (typically the Guaranteed Load Power). Finally, they may use Auxiliary Data Control (ADC), Auxiliary Data Transport (ADT), and DSR data packets to exchange application-level data.

Figure 40. Data flow in the power transfer phase (Baseline Protocol)

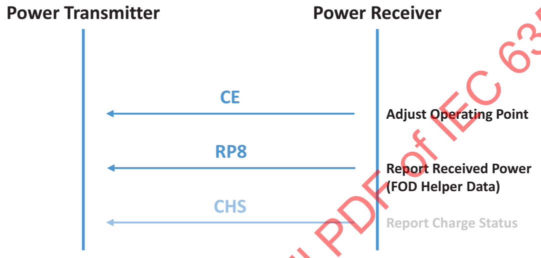
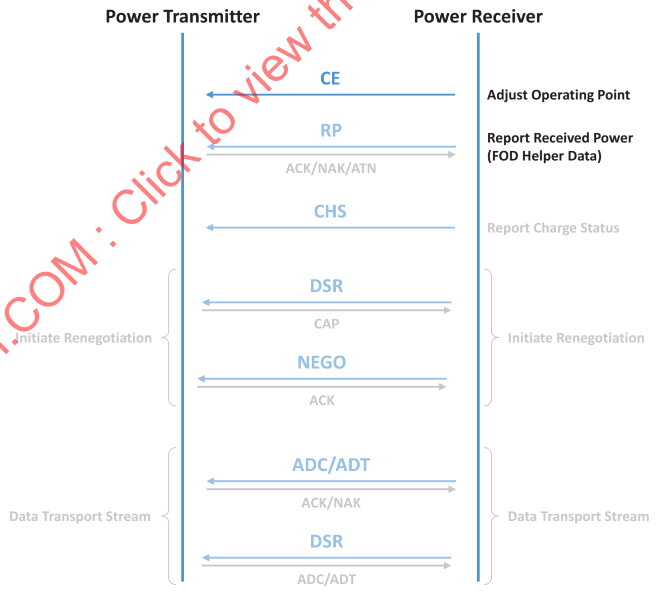


Figure 41. Data flow in the power transfer phase (Extended Protocol)



**NOTE:** Figure 40 and Figure 41 do not imply any particular required order or number of occurrences of the data packets used in the power transfer phase.

## 7.1 Power transfer state diagram

Figure 42 and Figure 43 show the state diagrams governing the Baseline Protocol and Extended Protocol, respectively. Apart from the additional features available in the Extended Protocol, there are a few differences between the two:

- In the Baseline Protocol, the power transfer phase follows the configuration phase. In the Extended Protocol, it follows the negotiation phase.
- In the Baseline Protocol, the Power Receiver uses short RP8 data packets. In the Extended Protocol, it uses long RP data packets.

**NOTE:** For details about how to interpret this diagram, see Section 4.1, *Ping phase state diagram*.

**Figure 42. State diagram of the power transfer phase (Baseline Protocol)**

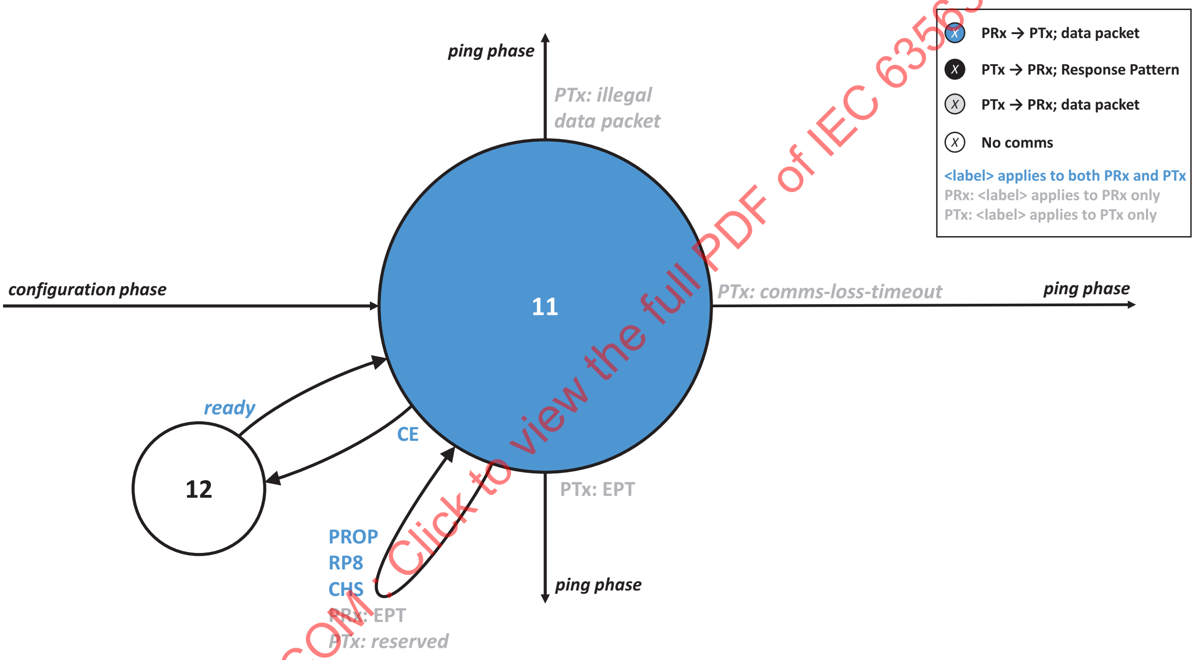
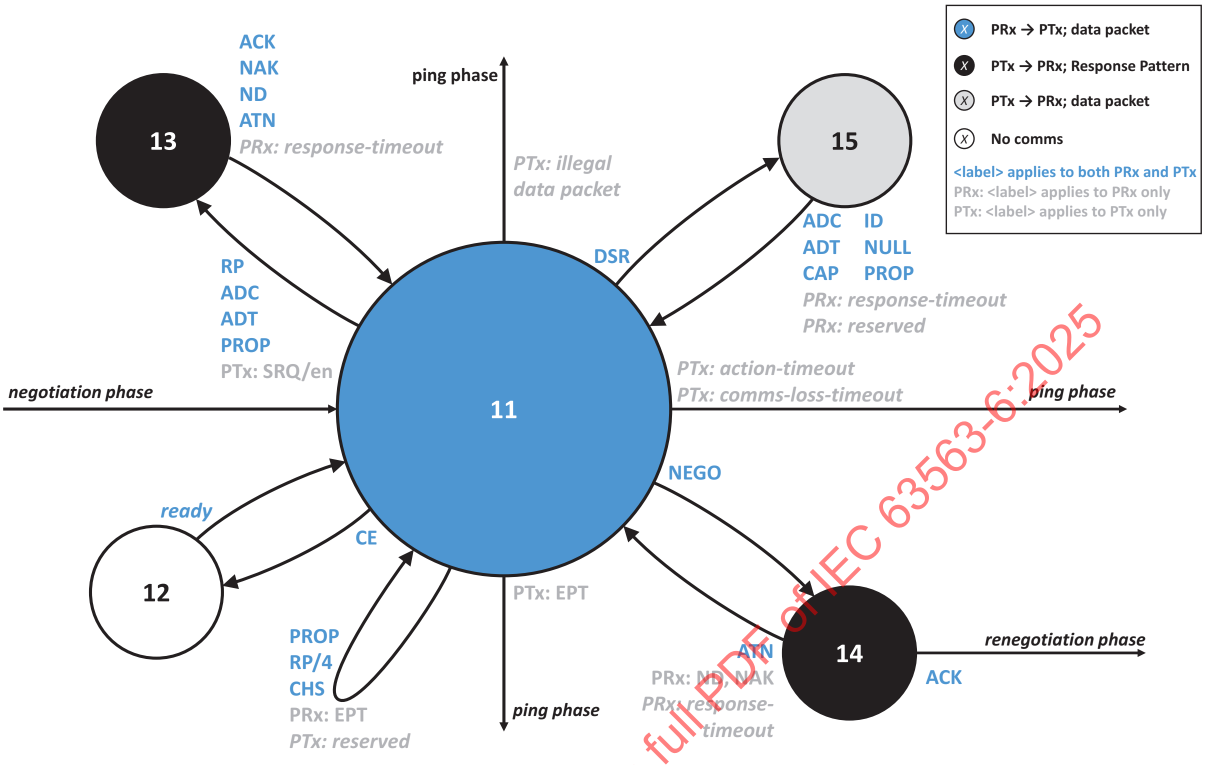


Figure 43. State diagram of the power transfer phase (Extended Protocol)



## 7.1.1 Transitions from state 11

State 11 is the main state in the power transfer phase. In this state, the Power Receiver can send data packets to control the power and provide data transport stream functionality. The following transitions are possible from this state.

**NOTE:** See the *Qi Specification, Foreign Object Detection*, for restrictions on the use of data packets at certain stages of the power transfer phase.

- *CE*. The Power Receiver has sent a CE data packet. See Section 7.3, *Power transfer phase timings*, for the timing requirements.
- *RP8*. The Power Receiver has sent a short RP8 data packet. See Section 7.3, *Power transfer phase timings*, for the timing requirements.

  **NOTE:** This transition exists in the Baseline Protocol only.
- *RP/4*. The Power Receiver has sent an RP/4 data packet. See Section 7.3, *Power transfer phase timings*, for the timing requirements.

  **NOTE:** This transition exists in the Extended Protocol only.
- *CHS*. The Power Receiver has sent a CHS data packet.
- *PROP*. The Power Receiver has sent a PROP data packet. The Power Transmitter shall ignore all unsupported PROP data packets.

  **NOTE:** In the case of proprietary data packets that the Power Transmitter does support, it may switch to state 13 or state 15, depending on the intended use of the proprietary data packet.

- *PRx: EPT*. The Power Receiver has sent an EPT data packet, requesting the Power Transmitter to remove the Power Signal. The Power Receiver should set an appropriate error code to enable the Power Transmitter taking appropriate corrective action.
- *PTx: reserved*. The Power Transmitter shall ignore all reserved data packets.
- PTx: EPT. The Power Transmitter has received an EPT data packet
- *PTx: comms-loss-timeout*. The Power Transmitter has not correctly received a CE, RP8, or RP data packet from the Power Receiver before the associated timeouts. See Section 7.3.6, *Comms-loss-timeout (Power Transmitter)*, for the timeout values.
- *PTx: illegal data packet*. The Power Transmitter has received a data packet not listed on any one of the transitions of state 11.

  **NOTE:** The Power Transmitter can receive an illegal data packet when a user quickly replaces the Power Receiver with another one. In this scenario, the other Power Receiver starts the protocol from the ping phase, typically sending the following data packet sequence: SIG—ID—CFG—... To avoid damaging the Power Receiver due to too high a Power Signal, the Power Transmitter should stop the power transfer as quickly as possible if it detects a Power Receiver swap.
- *RP*. The Power Receiver has sent an RP data packet. See Section 7.3, *Power transfer phase timings*, for the timing requirements.

  **NOTE:** See the *Qi Specification, Foreign Object Detection*, for the use of other modes of the RP data packet.
- *ADC*. The Power Receiver has sent an ADC data packet to control the transmission of a data transport stream. See Section 7.2.1, *Data transport stream format*, for the format of a data transport stream, and Section 8.1, *Auxiliary Data Control—ADC (0x25; simple query)*, for the available control options.
- *ADT*. The Power Receiver has sent an ADT data packet in a Power Receiver to Power Transmitter data transport stream. See Section 7.2.1, *Data transport stream format*, for the format of a data transport stream. This section also provides details about the odd/even header mechanism used to recover from communications errors.

  **NOTE:** The odd/even states associated with the mechanism shown in the state diagram of Figure 48 in Section 7.2.1, *Data transport stream format*, represent two manifestations of states 11 and 13. To avoid clutter, Figure 43 does not show these odd/even states explicitly.
- *PTx: SRQ/en*. The Power Transmitter has received an SRQ data packet to end the negotiation phase. In state 13, it shall send an ACK Response Pattern.

  **NOTE:** The Power Transmitter receives this data packet only in the case of an operating phase mismatch, with the Power Receiver still being in the negotiation phase.
- *DSR*. The Power Receiver has sent a DSR data packet to progress a Power Transmitter to Power Receiver data transport stream. See Section 7.2.1, *Data transport stream format*, for more information about data transport streams.
- *NEGO*. The Power Receiver has sent a NEGO data packet to request permission to enter a renegotiation phase.

- *PTx: action-timeout*. The Power Transmitter has not observed the Power Receiver taking the expected action in response to:
  - A NAK'ed RP data packet.
  - An ATN response to a simple-query data packet.
  - A Power Transmitter data packet sent in response to a DSR data packet (e.g. DSR/ack—ADT).
  - A request for renegotiation.

  **NOTE:** A Power Transmitter can request the Power Receiver to initiate a renegotiation phase by transmitting a CAP data packet in response to a DSR data packet. See Section 6.6.5.6 , *Power-Transmitter initiated renegotiation*, for an example.

  See Section 7.3.7, *Action-timeout*, for the expected actions and associated timings.

When switching to the ping phase, the Power Transmitter enters state F (and removes the Power Signal).

## 7.1.2 Transitions from state 12

In state 12, the Power Transmitter adjusts the power level based on the control error data it received. The Power Receiver waits until the Power Transmitter has finished controlling the power level. See the *Qi Specification, Power Delivery*, for details about the power control. The following transition is possible from this state.

- *Ready*. The Power Transmitter has finished adjusting the power level.

**NOTE:** The Power Receiver can use a timer to determine when the Power Transmitter has finished adjusting the power level because the length of the time window for adjusting the power level is fixed. See Section 7.3.2, *Control Error (CE) data packets*, for the length of the time window.

## 7.1.3 Transitions from state 13

In state 13, the Power Transmitter sends an appropriate Response Pattern, replying to a simple-query data packet. The following transitions are possible from this state.

- *ACK/NAK/ND*. The Power Transmitter has replied to the received data packet. See Section 8.18.5, *SRQ/rcs—Recalibration support: parameter field and responses*, Section 8.1, *Auxiliary Data Control—ADC (0x25; simple query)*, and Section 8.2, *Auxiliary Data Transport—ADT (multiple header codes; simple query)* for the appropriate responses.
- *ATN*. The Power Transmitter has requested attention from the Power Receiver, e.g. because it has a data packet to send.

  **NOTE:** When giving this reply, the Power Transmitter should ignore the contents of the received data packet because it cannot give an appropriate ACK, NAK or ND response. The Power Receiver should retransmit its data packet later (e.g., after it has given the Power Transmitter the opportunity to send its data packet).

- *PRx: response-timeou*t. The Power Receiver has not detected a reply to its simple query data packet before the response timeout $t_{\text{responsetimeout}}$, presumably because the Power Transmitter did not receive the data packet correctly. See *Section 6.7, Negotiation phase timings*, for the timeout value.

### 7.1.4 Transitions from state 14

In state 14, the Power Transmitter sends an appropriate Response Pattern, replying to a simple-query data packet. The following transitions are possible from this state.

- *ACK*. The Power Transmitter has agreed to switch to a renegotiation phase of the protocol.
- *ATN*. The Power Transmitter has requested attention from the Power Receiver, e.g. because it has a data packet to send. Both the Power Receiver and the Power Transmitter shall remain in the power transfer phase.
- *PRx: response-timeout*. The Power Receiver has not detected a reply before the response timeout $t_{\text{responsetimeout}}$, presumably because the Power Transmitter did not receive the NEGO data packet correctly. See *Section 6, Negotiation phase*, for the timeout value.

  **NOTE:** If the Power Receiver did not receive the ACK Response Pattern, a mismatch occurs between the operating states of the Power Transmitter and Power Receiver. They automatically resynchronize their states when the Power Receiver sends its next CE or RP data packet, because either of the latter data packets result in an aborted renegotiation phase, as defined in *Section 6, Negotiation phase*.

- *NAK/ND*. The Power Receiver shall ignore these Response Patterns and stay in the power transfer phase.

### 7.1.5 Transitions from state 15

In state 15, the Power Transmitter sends an appropriate data packet, replying to a data-request data packet. The following transitions are possible from this state.

- *ADC/ADT/CAP*. The Power Transmitter has replied to the DSR data packet with an appropriate data packet of its own choice. See Section 7.2.1, *Data transport stream format*, on how to construct a Power Transmitter to Power Receiver data transport stream using ADC and ADT data packets. This section also provides details about the odd/even header mechanism used to recover from communications errors.

  **NOTE:** The odd/even states associated with the this mechanism shown in the state diagram of Figure 49 in Section 7.2.1, *Data transport stream format*, represent two manifestations of states 11 and 15. To avoid clutter, Figure 43 does not show these odd/even states explicitly.

- *NULL*. The Power Transmitter has returned the NULL data packet because it does not support the requested data packet.

  **NOTE:** The main use of the NULL data packet is replying to the DSR/ack data packet that the Power Receiver uses to acknowledge closure of a Power Transmitter to Power Receiver data stream when the Power Transmitter has no further data to send. See Section 7.2.1, *Data transport stream format*, for an example.

- *PROP*. The Power Transmitter has sent responses to PROP data packets it recognizes.

- *PRx: response-timeout*. The Power Receiver has not detected a reply to its data request packet before the response timeout $t_{\text{responsetimeout}}$, presumably because the Power Transmitter did not receive the data packet correctly. See *Section 6, Negotiation phase* for the timeout value.
- *PRx: reserved*. The Power Receiver has received a reserved data packet. It shall ignore the contents of this data packet.

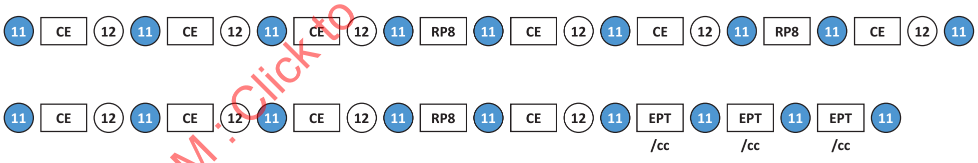
**NOTE:** The requirement given in Section 7.3.7, *Action-timeout*, with respect to the timing of the transmission of the next DSR data packet still applies, however.

## 7.1.6 Examples

### 7.1.6.1 Baseline Protocol

Figure 44 provides an example of a communications sequence in the power transfer phase of the Baseline Protocol. The numbers in the circles refer to the states defined in Figure 43. The rectangles represent data packets sent from those states. The sequence starts from state 11, in which the Power Receiver sends a CE data packet. Next, the system proceeds to state 12, in which the Power Transmitter adjust its coil current as necessary. When the adjustments are ready, the system proceeds to state 11, and the process can repeat. The majority of the data packets sent by the Power Receiver consists of CE data packets. At least once every few seconds, the Power Receiver sends an RP8 data packet, proceeding back to state 11 after completing the transmission. At the end of the sequence, the Power Receiver starts to send EPT/cc data packets to indicate that it is ready with the power transfer.

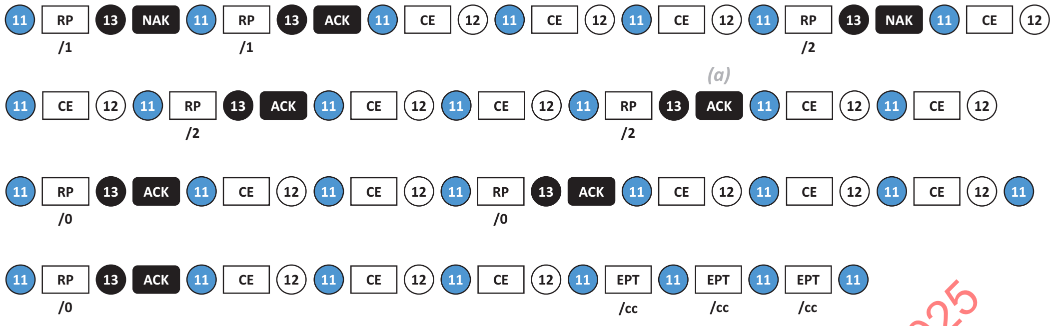
Figure 44. Example of a communications sequence in the power transfer phase of the Baseline Protocol



### 7.1.6.2 Extended Protocol

Figure 45 provides an example of a communications sequence in the power transfer phase of the Extended Protocol. In the top two rows, the initial two-point power level calibration happens; see the *Qi Specification, Foreign Object Detection*, for details. At position (a) the initial calibration is ready. Subsequently, the Power Receiver sends CE and RP/0 data packets to sustain the power transfer until it is ready with the power transfer, at which point it starts to send EPT/cc data packets.

Figure 45. Example of a communications sequence in the power transfer phase of the Extended Protocol



For examples involving renegotiation of the Power Transfer Contract, see Section 6.6.5, *Examples*. For examples involving data transport streams, see Section 7.2.4, *Examples*.

## 7.2 Data transport stream

Data transport streams serve to pass application-level data from a Data Stream Initiator to a Data Stream Responder. Version 1.3 of the Qi Specification supports two applications, namely:

- Authentication, as defined in the *Qi Specification, Authentication Protocol*.
- Proprietary (general-purpose) applications.

### 7.2.1 Data transport stream format

A Power Receiver and a Power Transmitter can pass application-level data by means of a data transport stream. The latter consists of a sequence of data packets with the following structure:

- An initial ADC data packet opening the stream.
    - The type of the message contained in the stream.
    - The number of data bytes in the stream.
- A sequence of ADT data packets containing the actual message.
- A final ADC/end data packet closing the stream.

**NOTE:** Other data packets, such as CE data packets, may intermix with those of a data transport stream. These data packets are not part of the transport data stream.

**NOTE:** The maximum number of data bytes in a data transport stream is limited to 2047.

A Power Transmitter—and by implication a Power Receiver—can have at most one outgoing and one incoming data transport stream open at a time. After acknowledging the initial ADC data packet and having received the first ADT data packet, the recipient of a data transport stream shall consider the latter open until

- it has sent an ACK response to the final closing ADC data packet, or
- a timeout has occurred on a next ADT or ADC data packet in the stream.

A Data Stream Initiator may prematurely close the stream by sending ADC/end before it has sent the number of data bytes indicated in the opening ADC data packet. In this case, the Data Stream Responder should discard all data bytes received in the data stream.

**NOTE:** A Data Stream Initiator may refuse to open an incoming data transport stream until it has closed its outgoing stream.

Figure 46 shows two examples of proprietary data transport streams containing two ADT data packets. The Power Receiver and Power Transmitter communicate the gray data packets as well, but these data packets are not part of the data transport streams. However, some of these data packets support the continued flow of the data transport stream, as shown in Table 15. See Section 8, *Power Receiver data packets*, and Section 9, *Power Transmitter data packets*, for details about the data packet names used in the figure.

**Figure 46. Example of a data transport stream**

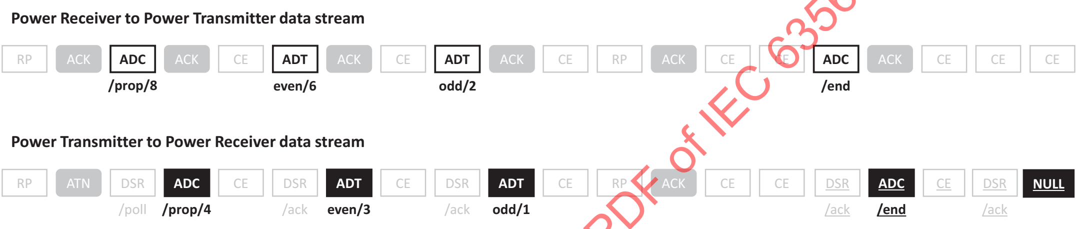


**Table 15: Data packets and Response Patterns supporting the transport stream**

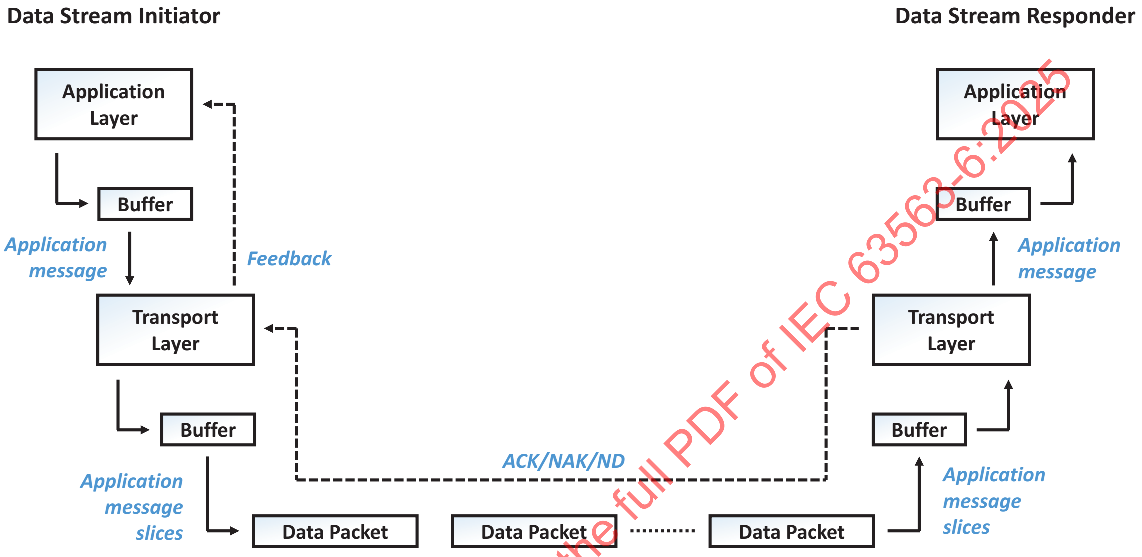
| Power Receiver | Power Transmitter |
|---|---|
| *Data packets that are part of a data transport stream* | |
| ADC | ADC |
| ADT | ADT |
| *Data packets and Response Patterns that support a data transport stream, but are not part of the latter* | |
| DSR | ACK/NAK/ND/ATN |

**NOTE:** When selecting ADT data packet sizes for transmission in a data transport stream, the Power Transmitter and Power Receiver should ensure not to violate the timing requirements on CE and RP data packet. See Section 7.3, *Power transfer phase timings*, for these requirements.

## 7.2.2 Data model

Figure 47 shows a typical layered architecture for communicating application messages from a Data Stream Initiator to a Data Stream Responder. The architecture includes an application layer providing specialized functionality such as authentication, and a transport layer providing the means to communicate messages.

**Figure 47. Data model**



Transmission of an application-level message from a Data Stream Initiator to a Data Stream Responder typically proceeds as follows.

1. The application layer in the Data Stream Initiator creates the message and stores it in a buffer.
2. The application layer submits the message in its buffer to the transport layer.
3. The transport layer stores the message in a local buffer.
4. The transport layer attempts to send the message to the Data Stream Responder using a data transport stream.

   The transport layer may retransmit any one of the data packets in the stream as necessary to address communications errors or errors reported by the Data Stream Responder. It should limit the number of retransmissions to at most four times. Moreover, it should provide feedback to the application layer whether it was able to transfer the message successfully.
5. When the Data Stream Initiator has closed the data transport stream, the transport layer of the Data Stream Responder considers the message complete and forwards it to its application layer.

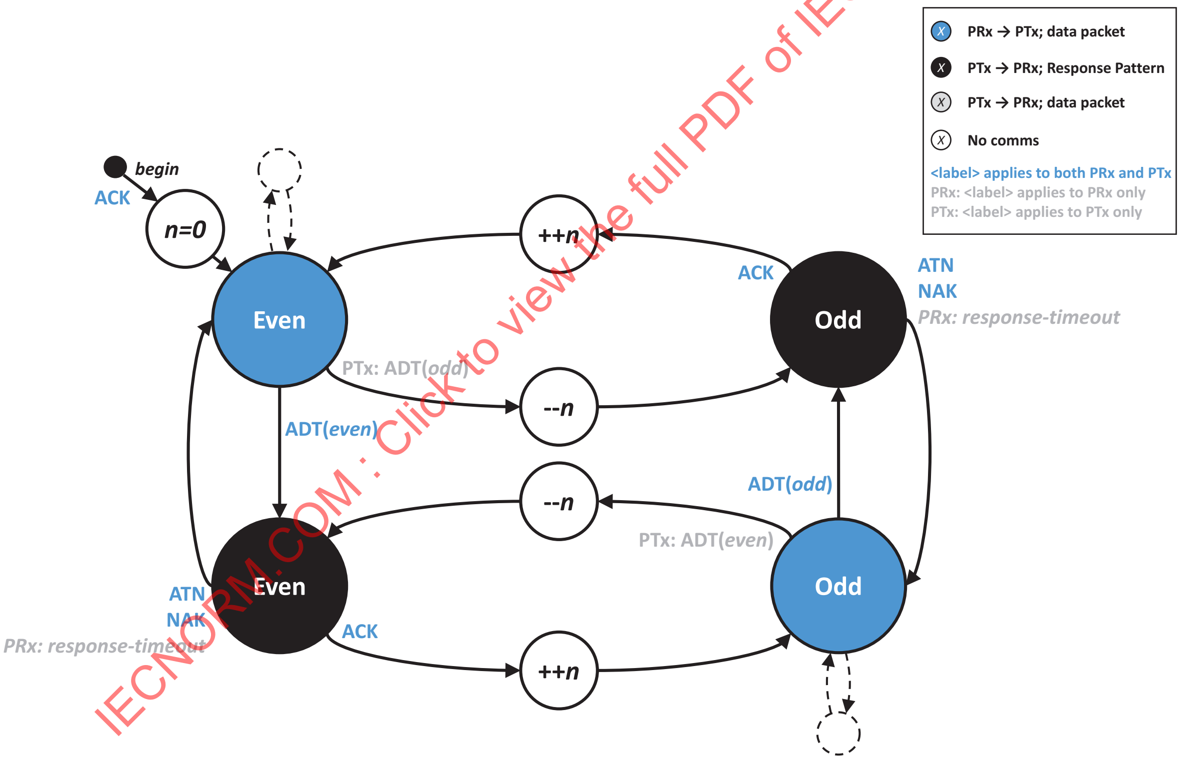
The transport layer should provide a buffer size of 67 bytes or more.

### 7.2.3 Even/odd ADT header mechanism

To ensure the integrity of a data transport stream, a Power Transmitter shall confirm proper reception of all ADT data packets in the stream using ACK Response Patterns. A Power Receiver shall use DSR/ack data packets for the same purpose. ADT data packets as well as their confirmations can get lost due to noise on the Power Signal. For example, sudden load changes during the transmission of a data packet or Response Pattern can cause variations in the Power Signal that hamper communications. To help the system to recover from such communications errors, the ADT data packets in the data transport stream alternately use odd and even headers. If a recipient sees two or more ADT data packets in a row with the same header, it knows that retransmissions have occurred due to communications errors.

The state diagram in Figure 48 illustrates this mechanism for a Power Receiver to Power Transmitter data transport stream. Later in this section, Figure 49 provides a similar state diagram for a Power Transmitter to a Power Receiver data stream.

**Figure 48. Odd/even mechanism (Power Receiver to Power Transmitter data transport stream)**



**NOTE:** The ACK transition from the begin state to the n=0 state represents the acknowledgement of the ADC data packet opening the data transport stream.

The variables *n* and *m* in the diagrams represent the sequence number of the next ADT data packets in the streams to send or receive. The Power Transmitter and Power Receiver do not share these variables; each holds its own copy. Specifically, in the Power Receiver, the variable *n* represents the sequence of the next ADT data packet to send; and in the Power Transmitter, the variable *n* represents the next ADT data packet to receive. Likewise, in the Power Transmitter, the variable *m* represents the sequence of the next ADT data packet to send; and in the Power Receiver, the variable *m* represents the next ADT data packet to receive. Communications errors can cause the Power Receiver and Power Transmitter to have different values in their variables (e.g. the value of the Power Transmitter's variable n can be one larger than the Power Receiver's variable *n*). The odd/even header mechanism enables the Power Transmitter and Power Receiver to restore their variables to the same value. Section 7.2.4, *Examples*, provides examples.

### Transitions from the blue Even state

In the blue Even state, the Power Receiver sends the next even-headered ADT data packet. The following transitions are possible from this state.

**NOTE:** The blue Even state corresponds to state 11 in Figure 43 The dashed parts of Figure 48 represent the other transitions possible from state 11. An example of such a transition is the transmission of a CE data packet.

**NOTE:** The first ADT data packet in the data transport stream uses an even-header ($n$ = 0.)

- *ADT(even)*. The Power Receiver has sent the $n^{th}$ even-headered ADT data packet in its open data transport stream.

  **NOTE:** If the Power Transmitter does not correctly receive the ADT data packet, e.g. due to a communications error, it does not execute the transition. At this point, the synchronization between the Power Transmitter and Power Receiver is lost. The examples below show how corrective action based on the odd/even mechanism restores synchronization.

- *PTx: ADT(odd)*. The Power Transmitter has received an odd-headered ADT data packet.

  **NOTE:** The Power Transmitter can receive an odd-headered ADT data packet in this state if the Power Receiver has not received the ACK to the previous even-headered ADT data packet due to a communications error. It should discard the data from the previously received odd-headered data packet, replacing it with the data received in the current odd-headered data packet.

### Transitions from blue Odd state

Identical to the blue Even state but with even and odd reversed.

### Transitions from the black Even state

In the black Even state, the Power Transmitter sends the appropriate Response Pattern, replying to the incoming ADT data packet. The following transitions are possible from this state.

**NOTE:** The black Even state corresponds to state 13 in Figure 43.

- *ACK*. The Power Transmitter has acknowledged proper receipt of the even-headered ADT data packet.
- *ATN*. The Power Transmitter has requested permission to communicate because it has a data packet to send.

  **NOTE:** Sending the ATN Response Pattern causes the Power Receiver to resend its even-headered ADT data packet later because it did not receive an ACK.
- *NAK*. The Power Transmitter has indicated that it was not able to process the ADT data packet.

  **NOTE:** If the Power Transmitter does not receive the ADT data packet correctly due to a communications error, it should not send a response as explained in Section 2, *Overview*.
- *PRx*: response-timeout. The Power Receiver has not detected a Response Pattern before the response timeout $t_{\text{responsetimeout}}$. See Section 7.3, *Power transfer phase timings*, for the timeout value.

### Transitions from the black Odd state

Identical to the black Even state but with even and odd reversed.

### ++*n* states

The Power Transmitter and Power Receiver increment their local variables *n* by one and proceed to the next state.

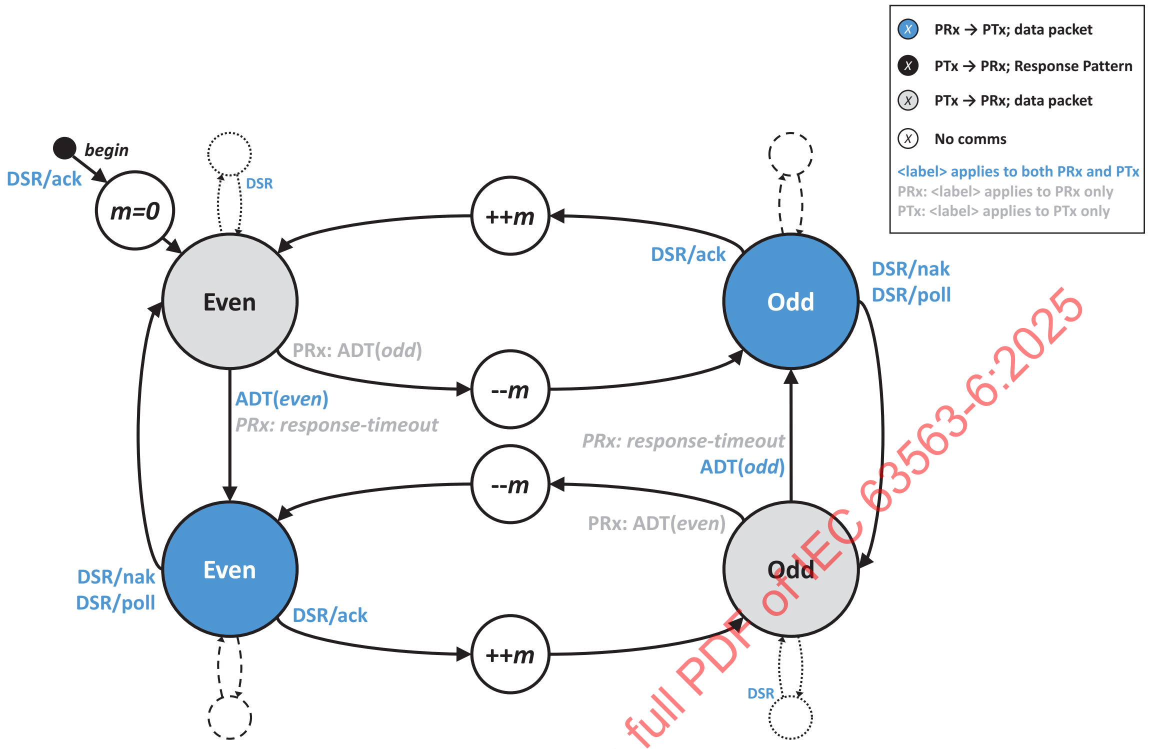
### --*n* states

If $n = 0$, the Power Transmitter shall discard all data received from the incoming data transport stream, close the latter and send an ND Response pattern.

**NOTE:** Figure 48 does not show this error condition.

Otherwise, the Power Transmitter decrements its local variable *n* by one and proceed to the next state.

Figure 49. Odd/even mechanism (Power Transmitter to Power Receiver data transport stream)



**NOTE:** The DSR/ack transition from the begin state to the m=0 state represents the acknowledgement of the ADC data packet opening the data transport stream.

### Transitions from the gray Even state

In the gray Even state, the Power Transmitter sends the next even-headered ADT data packet. The following transitions are possible from this state.

**NOTE:** The gray Even state corresponds to state 15 in Figure 43. The dotted parts of Figure 49 represent the Power Transmitter having sent other data packets than ADT; see state 15 for details.

**NOTE:** The first ADT data packet in the data transport stream uses an even-header ($m$ = 0).

- *ADT(even)*. The Power Transmitter has sent the $m^{\text{th}}$ even-headered ADT data packet in its open data transport stream.

  **NOTE:** The Power Transmitter sends this data packet as a reply to the Power Receiver's DSR/ack data packet from the blue odd state or as a reply to the DSR/poll data packet from the blue even state.

  **NOTE:** If the Power Receiver does not correctly receive the ADT data packet, e.g. due to a communications error, it does not execute the transition. At this point, the synchronization between the Power Transmitter and Power Receiver is lost. The examples below show how corrective action based on the odd/even mechanism restores synchronization.

- *PRx: ADT(odd)*. The Power Receiver has received an odd-headered ADT data packet.

  **NOTE:** The Power Receiver can receive an odd-headered ADT data packet in this state if the Power Receiver has not received a reply to the previous DSR/ack data packet due to a communications error. It should discard the data from the previously received odd-headered data packet, replacing it with the data received in the current odd-headered data packet.

- *Response-timeout—Power Receiver only*: The Power Receiver has not detected an ADT data packet before the response timeout $t_{\text{response}}$ (see Section 7.3, *Power transfer phase timings*, for the timeout value).

### Transitions from the gray Odd state

Identical to the gray Even state, but with even and odd reversed.

### Transitions from the blue Even state

In the blue Even state, the Power Receiver sends the appropriate DSR data packet, replying to the incoming ADT data packet. The following transitions are possible from this state.

**NOTE:** The blue Even state corresponds to state 11 in Figure 43. The dashed parts of Figure 49 represent the other transitions possible from state 11. An example of such a transition is the transmission of a CE data packet.

- *DSR/ack*. The Power Receiver has acknowledged proper receipt of the last received ADT data packet—or ADC data packet.

  **NOTE:** The first DSR/ack data packet acknowledges the ADC data packet opening the data transport stream.

- *DSR/nak*. The Power Receiver has indicated that it was not able to process the last received ADT data packet.
- *DSR/poll*. The Power Receiver has invited the Power Transmitter to send a data packet.

  **NOTE:** The Power Receiver should send a DSR/poll packet after it has experienced a timeout in receiving the Power Transmitter's reply to a previous DSR data packet.

  **NOTE:** See the action timeout in Section 7.3, *Power transfer phase timings*, for requirements on the timing of these transitions.

### Transitions from the blue Odd state

Identical to the blue Even state but with even and odd reversed.

### ++*m* states

The Power Transmitter and Power Receiver increment their local variables *m* by one and proceed to the next state.

### --*m* states

If $m = 0$, the Power Receiver shall discard all data received from the incoming data transport stream, close the latter and send a DSR/nd data packet.

**NOTE:** Figure 49 does not show this error condition.

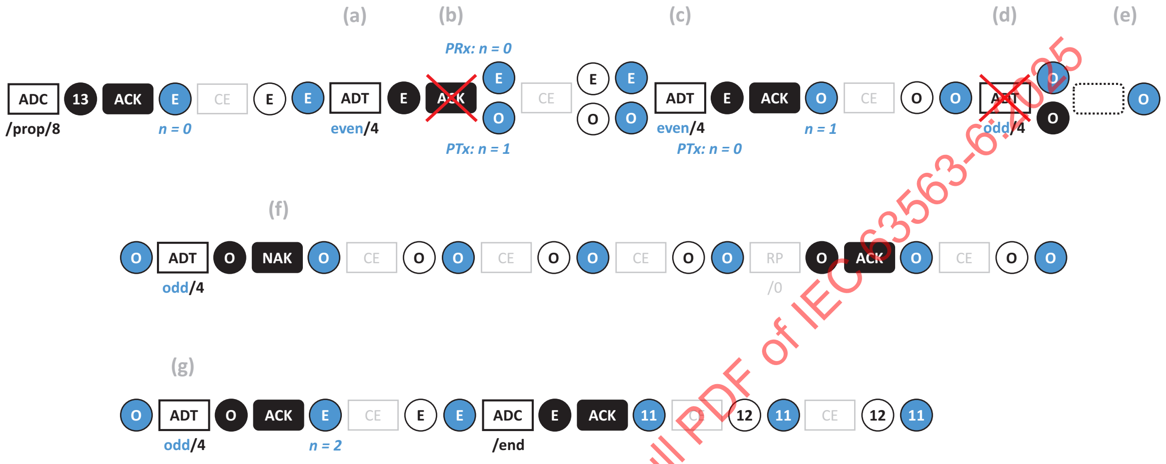
Otherwise, the Power Receiver decrements its local variable *m* by one and proceeds to the next state.

## 7.2.4 Examples

### 7.2.4.1 Proprietary Power Receiver to Power Transmitter data transport stream

The first example (Figure 50) comprises an eight-byte proprietary Power Receiver to Power Transmitter data transport stream containing two ADT data packets.

Figure 50. Resynchronization example; Power Receiver to Power Transmitter data transport stream



To show how the resynchronization mechanism works, the red crosses in positions (b) and (d) indicate incorrectly received data packets.

**NOTE:** Figure 50 shows states 11, 12, and 13 with Even and Odd while the data transport stream is open. Whether an Even or Odd state is state 11, 12, and 13 can be determined from its color-coding.

When the Power Receiver opens the data transport stream, both the Power Transmitter and Power Receiver initialize their local variables *n* to zero.

At **transition (a)**, the Power Receiver transmits the first ADT data packet in the stream.

At **transition (b)**, the Power Transmitter acknowledges the even ADT data packet and increments its local variable *n*. However, the ACK Response Pattern is lost, desynchronizing the Power Transmitter and Power Receiver states (as well as their *n* values).

At **transition (c)**, the Power Transmitter detects that the Power Receiver retransmitted the previous ADT data packet, because it received an even-headered ADT data packet while being in the odd state. Accordingly, it decrements *n* and goes back to the black even state from where it acknowledges the retransmitted ADT data packet. This restores the synchronization with the Power Receiver's state (and the *n* values).

The synchronization remains in place until the next communications error at **transition (d)**, where the Power Receiver's ADT data packet is lost.

There is no loss of synchronization this time because the lost ADT data packet also results in a missing response (response-timeout) at **position (e)**.

At **position (f)**, the Power Transmitter NAK's the odd ADT data packet from the Power Receiver, presumably because it is busy.

**NOTE:** The Power Transmitter received the odd ADT correctly, but it was busy and could not process its content. If the Power Transmitter was too busy to receive data packets, it should have remained silent until it would have been ready to receive data packets again. The Power Receiver can resolve this situation in the same way as shown at positions (d) and (e).

After a suitable delay in which the Power Receiver sends a number of CE data packets as well as an RP/0 data packet, the Power Receiver resends the odd ADT data packet again at position (g). From that position onward, the data transport stream runs to a successful conclusion without further communications errors or delays.

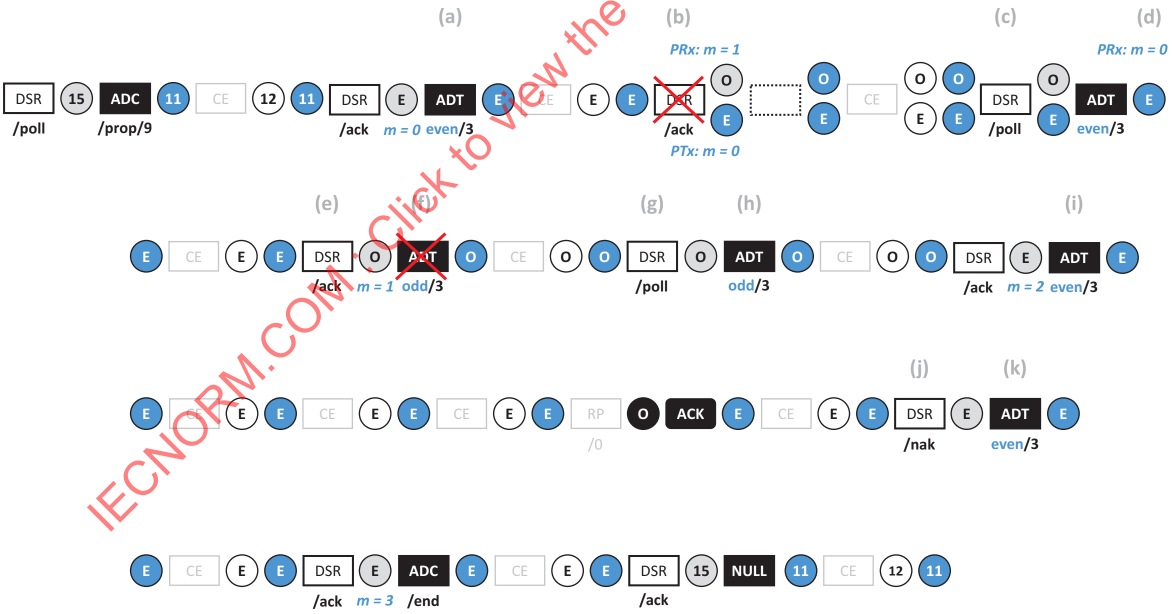
**NOTE:** It is up to the Power Receiver to determine the length of the delay. It may find that the Power Transmitter ignores or NAK's its ADT data packet multiple times if it retries sending the data packet too quickly.

### 7.2.4.2 Proprietary Power Transmitter to Power Receiver data transport stream

The second example (Figure 51) comprises a nine-byte proprietary Power Transmitter to Power Receiver data transport stream containing three ADT data packets. Similar to the previous example, the Power Transmitter and Power Receiver initialize their local variables *m* to zero when Power Transmitter opens the data transport stream.

**NOTE:** Figure 51 shows states 11, 12, 13 and 15 with Even and Odd while the data transport stream is open. Whether an Even or Odd state is state 11, 12, 13 or 15 can be determined from its color-coding.

**Figure 51. Resynchronization example; Power Transmitter to Power Receiver data transport stream**



At transition (a), the Power Transmitter transmits the first ADT data packet in the stream.

The Power Receiver's response is lost at position (b), desynchronizing the Power Transmitter and Power Receiver states. The *m* values are also desynchronized because the Power Receiver—having acknowledged the even ADT data packet—increments its *m* value, whereas the PTx does not do so because it had not received the acknowledgement.

At transition (c), the Power Receiver transmits a DSR/poll data packet because it did not receive a response to the DSR/ack data packet. This DSR/poll data packet invites the Power Transmitter to send its ADT/even data packet again.

At transition (d), the Power Receiver receives the previous (even headered) ADT data packet in the odd state. Accordingly, it decrements its local variable *m* and goes back to the blue even state. This restores the resynchronization with the Power Transmitter's state (as well as its *m* value).

At transition (e), the Power Transmitter receives the acknowledgement and moves on to the next (odd-headered) ADT data packet in the stream. At transition (f), this next ADT data packet is lost, but there is no desynchronization as the Power Receiver proceeds to the odd state through the response-timeout transition.

At transition (g), the Power Receiver enables the Power Transmitter to continue the stream by transmitting a DSR/poll data packet, enabling the Power Transmitter to resend the lost odd-headered ADT data packet.

At transition (h), the Power Receiver sees that synchronization is still correct.

At position (i), the Power Receiver receives the final even ADT data packet. However, it is too busy at this time to process its content.

Accordingly, it delays its DSR/nak data packet until it is ready again to receive data packets from the Power Transmitter at position (j).

The latter resends the even ADT data packet at position (k), after which the data transport stream runs to a successful conclusion.

#### 7.2.4.3 Recovery from communications errors when opening a data transport stream

Figure 52 and Figure 53 show how the Power Transmitter and Power Receiver can recover from communications errors when opening a data transport stream. There are two cases for streams in either direction. In the first case, the Data Stream Responder did not receive the ADC/auth data packet, and therefore did not take any action. In the second case, the acknowledgement got lost and the Data Stream Responder did not consider the stream to be open. In both cases, the Data Stream Initiator resends its ADC/auth data packet—potentially multiple times—until it receives acknowledgement that the Data Stream Responder has opened the stream.

Figure 52. Communications error opening a Power Receiver to Power Transmitter data transport stream

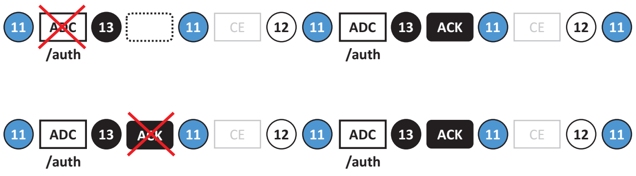
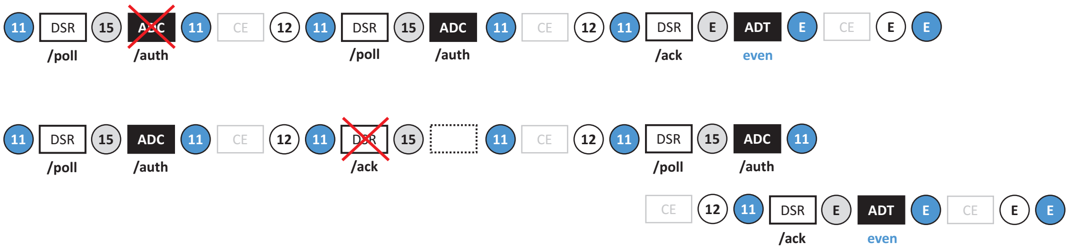


Figure 53. Communications error opening a Power Transmitter to Power Receiver data transport stream



### 7.2.4.4 Recovery from communications errors when closing a data transport stream

Figure 54 and Figure 55 show how the Power Transmitter and Power Receiver can recover from communications errors when closing a data transport stream. There are two cases for streams in either direction. In the first case, the Data Stream Responder did not receive the ADC/end data packet, and therefore did not close the stream. In the second case, the recipient of the stream closed the latter, but its acknowledgement thereof got lost. In both cases, the Data Stream Initiator resends its ADC/end data packet—potentially multiple times—until it receives acknowledgement that the Data Stream Responder has closed the stream.

**NOTE:** Attempting to close a data transport stream that is not open is not an error.

Figure 54. Communications error closing a Power Receiver to Power Transmitter data transport stream

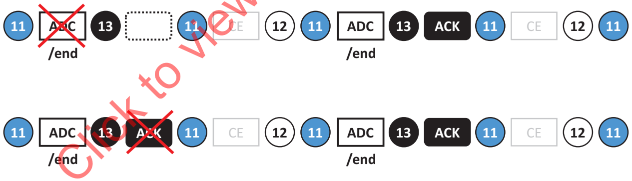
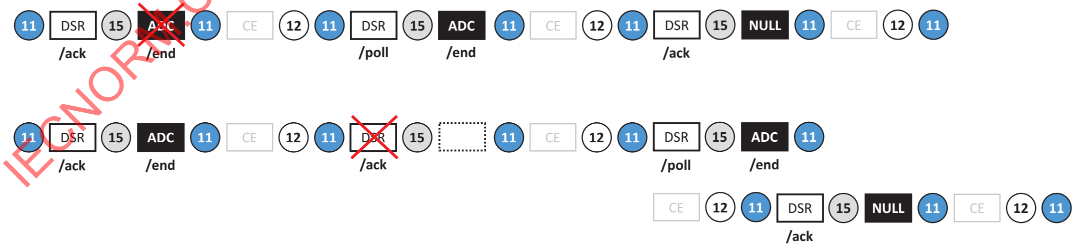


Figure 55. Communications error closing a Power Transmitter to Power Receiver data transport stream



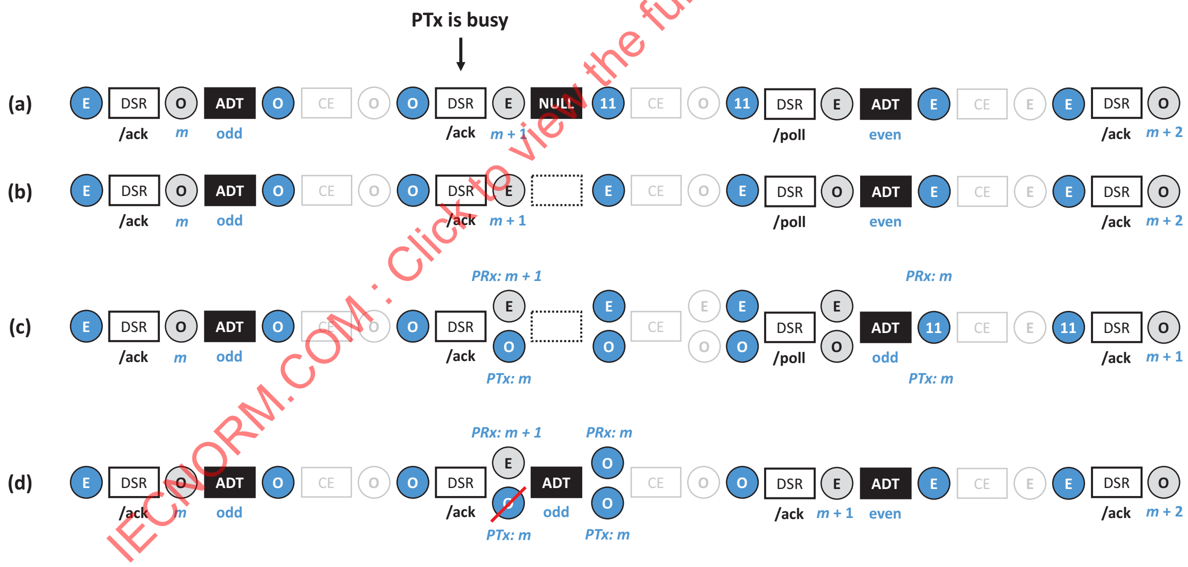
#### 7.2.4.5 Power Transmitter busy scenarios

Figure 56 shows four data packet sequences that may occur in a Power Transmitter to Power Receiver data stream in the case that a Power Transmitter is busy and does not have data available upon receiving a DSR data packet.

In sequence (a), the Power Transmitter sends a NULL data packet instead of the next, even-headered, ADT data packet in the data transport stream. The Power Receiver notices the interruption, and at a later point in time enables the Power Transmitter to resume sending ADT data packets by sending a DSR/poll data packet. The Power Receiver may send multiple CE, RP, or other data packets before sending the DSR data packet. Alternatively, it may wait for an ATN Response Pattern from the Power Transmitter before sending the DSR data packet.

In sequence (b), the Power Transmitter receives and processes the DSR/ack data packet, but does not send a response. The Power Receiver should treat the missing response a communications error, and recover by sending a DSR/poll data packet later. See Section 7.2.4.2 , *Proprietary Power Transmitter to Power Receiver data transport stream*, for a more detailed description. When the Power Transmitter resumes sending ADT data packets, starting with an even-headered ADT data packet, the Power Receiver learns that the Power Transmitter did receive and process the DSR/ack data packet to which there was no response.

**Figure 56. Power Transmitter busy scenarios (Power Transmitter to Power Receiver data transport stream)**



In sequence (c), the Power Transmitter receives the DSR/ack data packet, but does not process it. The Power Receiver should treat the missing response a communications error, and recover by sending a DSR/poll data packet later. See Section 7.2.4.2 , *Proprietary Power Transmitter to Power Receiver data transport stream*, for a more detailed description. When the Power Transmitter resumes sending ADT data packets, starting with an odd-headered ADT data packet, the Power Receiver learns that the Power Transmitter did not receive and process the DSR/ack data packet to which there was no response.

In sequence (d), the Power Transmitter receives the DSR/ack data packet, but resends the odd-headered ADT data packet. This is a violation of the state diagram provided in Figure 49. The Power Receiver should recover from this violation by discarding the data from the first received odd-headered ADT data packet, keeping the data from the resent odd-headered ADT data packet, switching back to the blue odd state, decrementing its *m* value, and sending a DSR/ack data packet.

### 7.2.4.6 Two interleaved data transport streams

Figure 57 provides an example of an 8-byte Power Receiver to Power Transmitter data transport stream, interleaved with a 6-byte Power Transmitter to Power Receiver data transport stream.

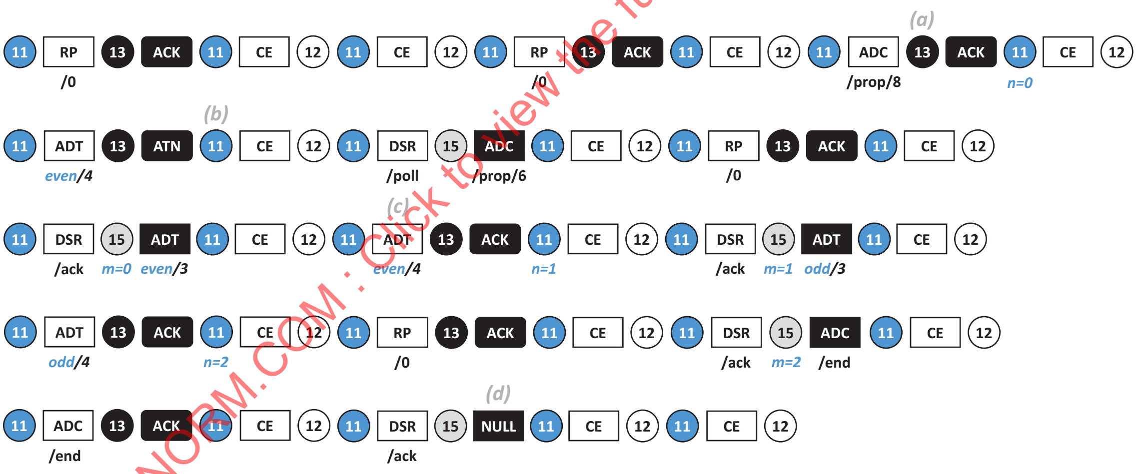
The Power receiver opens its stream at position (a).

The Power Transmitter requests attention at position (b) and opens its stream when the Power Receiver enables the Power Transmitter to talk using the DSR/poll data packet.

Since the Power Receiver did not receive an acknowledgement of its even ADT data packet, it repeats this data packet at position (c).

At position (d), the Power Transmitter has no further information to send, so it responds with the NULL data packet to the DSR/ack data packet, which the Power Receiver sends to confirm that the Power Transmitter has closed its stream.

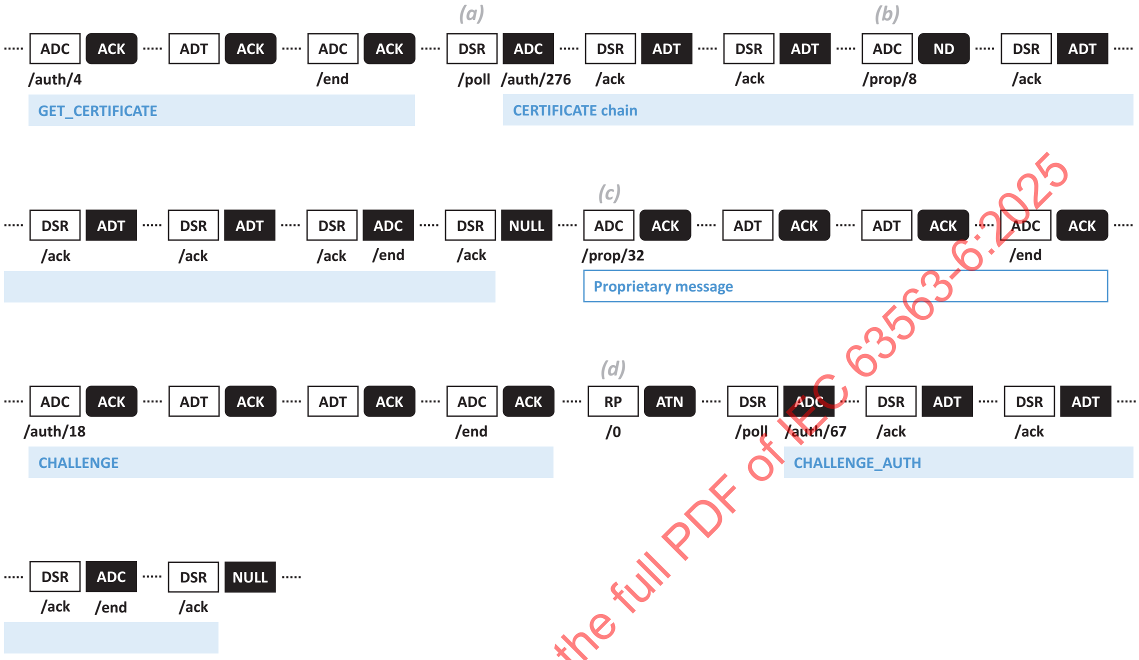
**Figure 57. Example of two interleaved data transport streams**



### 7.2.4.7 Authentication

The example provided in Figure 58 shows the use of data transport streams to execute the authentication protocol.

**Figure 58. Simple authentication, Power Receiver authenticating a Power Transmitter**



**NOTE:** For clarity of illustration, Figure 58 shows only the data packets and responses that are relevant to the data transport streams, leaving out any data packets that go in between. Furthermore, the figure does not show the states that the system runs through, nor does it show all ADT data packets that are part of the streams.

The authentication protocol starts with the Power Receiver opening a data transport stream to send a GET_CERTIFICATE message to the Power Transmitter. After closing this stream, at position (a) the Power Receiver sends a DSR/poll data packet, inviting the Power Transmitter to send its certificate chain. If the Power Transmitter is not ready to send its certificate data at this time, it may respond with a NULL data packet. In this case, the Power Receiver should repeat its DSR/poll data packet later. Alternatively, the Power Receiver may wait until the Power Transmitter sends an ATN Response Pattern, which serves as a trigger for the Power Receiver to send a DSR/poll data packet.

In this example, the Power Receiver requests that the Power Transmitter send its certificate chain in a single data transport stream. Alternatively, the Power Receiver may use multiple GET_CERTIFICATE messages in separate data transport streams to retrieve the Power Transmitter's certificate chain in separate segments.

While the Power Transmitter is sending its certificate chain, at position (b) the Power Receiver tries to open a proprietary data transport stream. However, this Power Transmitter does not support concurrent outgoing and incoming data transport streams, and therefore responds with ND. The Power Transmitter already has an incoming and/or outgoing data transport stream open or does not support the requested data transport stream type; see Section 8.1, *Auxiliary Data Control—ADC (0x25; simple query)*.

The Power Receiver therefore delays its proprietary message to position (c) after the NULL data packet indicates that the Power Transmitter has no more data to send. Following the proprietary message, the Power Receiver continues with the authentication protocol and sends a CHALLENGE message. Subsequently, it waits for the Power Transmitter to send an ATN Response Pattern, which indicates that the Power Transmitter has finished its cryptographic calculations.

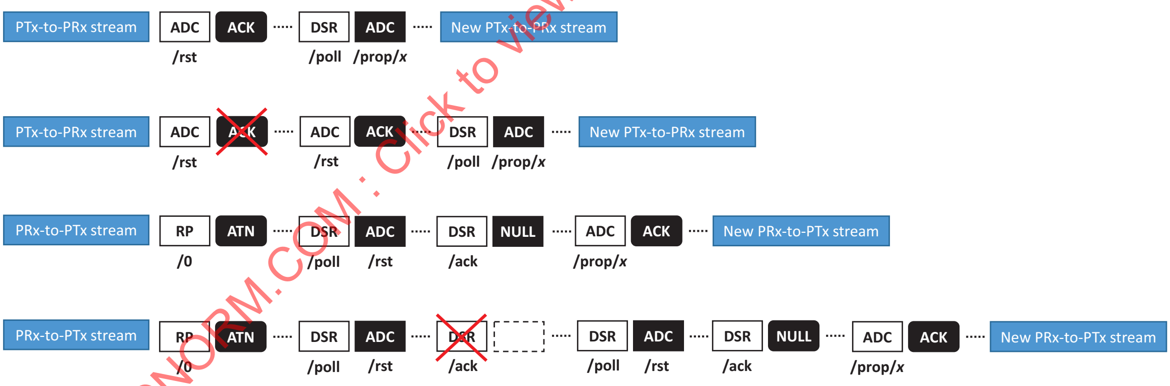
Finally, the Power Receiver sends a CHALLENGE_AUTH message to retrieve the Power Transmitter's response. See the *Qi Specification, Authentication Protocol*, for details of the authentication protocol, including recommendations on how to proceed with the power transfer if authentication fails.

As an alternative to waiting for an ATN Response Pattern, the Power Receiver may send DSR/poll data packets to check if the Power Transmitter is ready calculating (with the Power Transmitter responding with a NULL data packet as long as it is not).

### 7.2.4.8 Data transport stream control

In the case of an unrecoverable error while processing a data transport stream, the Power Transmitter and Power Receiver can send an ADC/rst data packet to reset and close all open streams, repeating the ADC/rst data packet until they receive acknowledgement. Both the Power Transmitter and the Power Receiver should discard all data associated with their incoming and outgoing data streams when they send or receive an ADC/rst data packet. Figure 59 provides a graphical illustration.

**Figure 59. Data transport stream reset**



## 7.3 Power transfer phase timings

Table 16 provides an overview of the timing constraints that apply to the communications and other actions in the power transfer phase.

**Table 16: Timing constraints in the power transfer phase**

| Parameter | Side | Symbol | Minimum | Target | Maximum | Unit |
|---|---|---|---|---|---|---|
| Silent window | PRx | $t_{silent}$ | See Table 12 in Section 5.2, *Configuration phase timings*. | | | |
| Control Error interval | PRx | $t_{interval}$ | N/A | 250 | 350[*] | ms |
| | | | | | 700[†] | ms |
| Control Error timeout | PTx | $t_{timeout}$ | 800 | 1,500 | 1,828 | ms |
| Power control window | PRx | $t_{control}$ | 24[‡] | N/A | N/A | ms |
| Power control window | PTx | $t_{active}$ | N/A | 20 | 21 | ms |
| Received Power interval (RP8) | PRx | $t_{received}$ | N/A | 1,500 | 4,050 | ms |
| Received Power interval[**] (RP/0 and RP/4) | PRx | $t_{received}$ | N/A | 1,500 | 2,050 | ms |
| Received Power timeout | PTx | $t_{power}$ | 8,000 | 23,000 | 24,028 | ms |
| Power termination window | PTx | $t_{terminate}$ | See Table 11 in Section 4.2, *Ping phase timings*. | | | |
| Reset window | PRx | $t_{reset}$ | See Table 11 in Section 4.2, *Ping phase timings*. | | | |
| Response start window | PTx | $t_{response}$ | See Table 14 in Section 6.7, *Negotiation phase timings*. | | | |
| Response timeout | PRx | $t_{responsetimeout}$ | | | | |
| NAK window | PRx | $t_{nak}$ | N/A | N/A | 1,000 | ms |
| ATN window | PRx | $t_{atn}$ | N/A | N/A | 500 | ms |
| DSR window | PRx | $t_{dsr}$ | N/A | N/A | 1,000 | ms |
| Data transport stream window | Both | $t_{dts}$ | N/A | N/A | 1,500 | ms |
| Data transport stream timeout | Both | $t_{dtstimeout}$ | 2,000 | N/A | N/A | ms |
| Renegotiation window | PRx | $t_{renegotiate}$ | N/A | N/A | 5,000 | ms |

[*] Applies to the Baseline Protocol. Applies to the Extended Protocol as well when one or both of the Power Transmitter and Power Receiver report version 1.2 or lower in their ID data packets.

[†] Applies to the Extended Protocol when the Power Transmitter and Power Receiver both report version 1.3 or higher in their ID data packets. A Power Receiver should use $t_{interval} > 350$ ms only when necessary to accommodate data packets sent by the Power Transmitter.

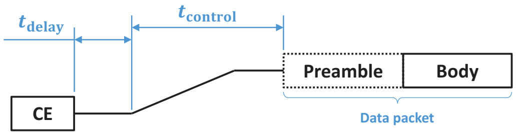
[‡] For RP8 and RP data packets, add $t_{window} + t_{offset} - n \cdot 0.5$ ms to the minimum value. Here, $t_{window}$ and $t_{offset}$ represent the Window Size and Window Offset values provided in the CFG data packet, and $n$ represents the number of preamble bits in the data packet.

[**] See the *Qi Specification, Foreign Object Detection*, for the timings related to the power-loss calibration part of the protocol.

## 7.3.1 Generic timing constraints

A Power Receiver shall start to transmit the preamble of a next data packet at $t_{\text{delay}}$ +$t_{\text{control}}$ from the end of a CE data packet directly preceding it, where $t_{\text{delay}}$ represents the power control hold-off value contained in the Power Transfer Contract. See Figure 60 for an illustration. The Power Receiver shall start to transmit the preamble of a next data packet at $t_{\text{silent}}$ from the end of any other data packet or Response Pattern directly preceding it. See the *Qi Specification, Communications Physical Layer*, for the reference times defining the start and end of a data packet. See Section 5.2, *Configuration phase timings*, and Section 6.7, *Negotiation phase timings*, for illustrations.

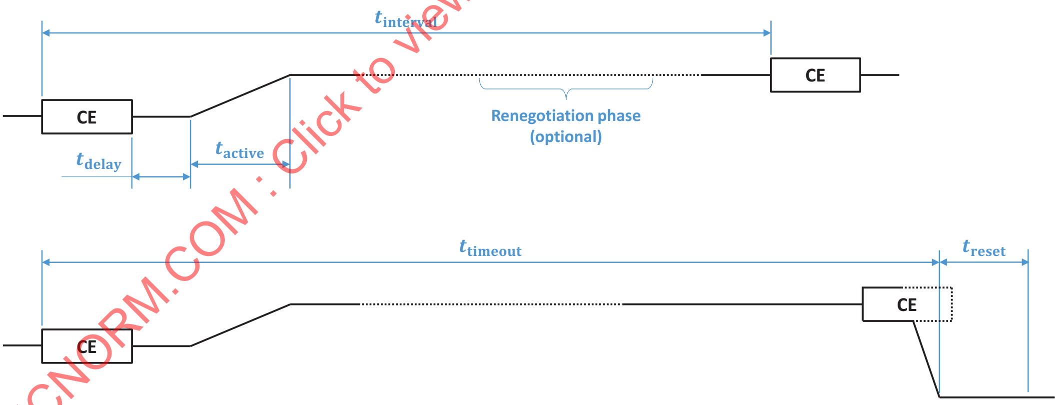
**Figure 60. Generic timing constraints**



## 7.3.2 Control Error (CE) data packets

A Power Receiver shall send the first CE data packet at $t_{\text{interval}}$ from the start of the power transfer phase. It shall continue to send CE data packets throughout the power transfer phase with a time interval $t_{\text{interval}}$ between the starts of consecutive CE data packets. This $t_{\text{interval}}$ constraint on consecutive CE data packets also applies if the Power Receiver switches to and returns from a renegotiation phase in between those data packets.

**Figure 61. CE data packet timing**



The following rules apply with respect to the timing of CE data packets.

- With respect to transmission of the first CE data packet in the Baseline Protocol, the reference time for the start of the power transfer phase is the start of the CFG data packet. In the Extended Protocol, the reference time is the start of the SRQ/en data packet.
- The time interval $t_{\text{interval}}$ does not need to be constant and may vary within the limits provided in Table 16.
- Two CE data packets are consecutive even if the Power Receiver sends other types of data packets in between these two data packets.
- A Power Receiver may violate the timing constraint on the CE data packets when it has to repeat sending SRQ/en data packets due to communications errors. See state 10 in Section 6.5, *NFC tag protection support*, as well as the example in Figure 26 (in Section 6.6.5.4 , *Resolution of an operating-phase mismatch*).

A Power Transmitter should adjust the power level in the time window $t_{\text{active}}$. This time window is located at $t_{\text{delay}}$ from the end of the CE data packet, where $t_{\text{delay}}$ represents the power control hold-off value contained in the Power Transfer Contract. The purpose of the power transfer control hold-off delay is to provide a time window for the coil current to stabilize after the communications.

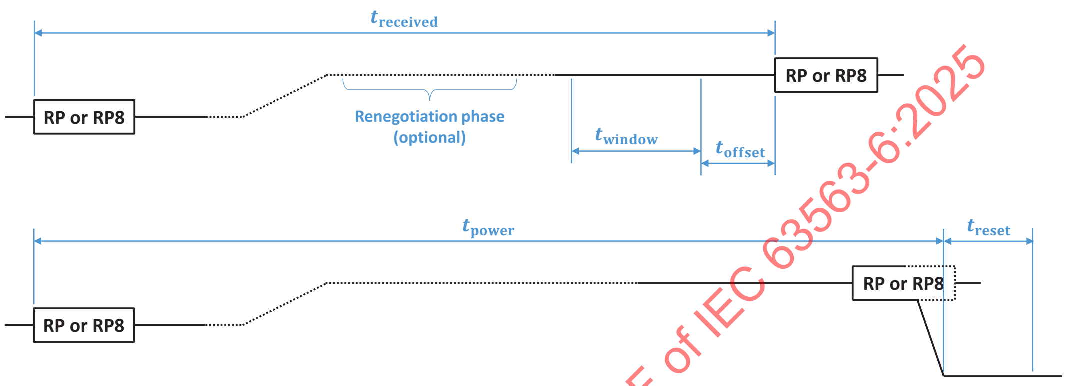
A Power Transmitter shall remove the Power Signal at $t_{\text{timeout}}$ from the start of the last received CE data packet. Accordingly, the Power Transmitter should restart any timer associated with $t_{\text{timeout}}$ at the start of each CE data packet it receives.

**NOTE:** $t_{\text{timeout}}$ is part of the comms-loss-timeout transition shown in the state diagram of the power transfer phase (Figure 42 and Figure 43).

### 7.3.3 Received Power (RP and RP8) data packets

A Power Receiver shall send the first RP or RP8 data packet at $t_{\text{received}}$ from the start of the power transfer phase. It shall continue to send RP or RP8 data packets throughout the power transfer phase with a time interval $t_{\text{received}}$ between the starts of consecutive RP or RP8 data packets. This $t_{\text{received}}$ constraint on consecutive RP or RP8 data packets also applies if the Power Receiver switches to and returns from a renegotiation phase in between those data packets.

**Figure 62. Received Power data packet timing**



The following rules apply with respect to the timing of RP and RP8 data packets.

- With respect to transmission of the first RP data packet in the Baseline Protocol, the reference time for the start of the power transfer phase is the start of the CFG data packet. In the Extended Protocol, the reference time is the start of the SRQ/en data packet.
- The time interval $t_{\text{received}}$ does not need to be constant and may vary within the limits provided in Table 16.
- Two Received Power data packets are consecutive even if the Power Receiver sends other types of data packets in between these two data packets.
- A Power Receiver may violate the timing constraint on the RP data packets when it has to repeat sending SRQ/en data packets due to communications errors. See state 10 in Section 6.5, *NFC tag protection support*, as well as the example in Figure 26 (also in Section 6.5, *NFC tag protection support*).

A Power Transmitter shall remove the Power Signal at $t_{\text{power}}$ from the start of the last received RP or RP8 data packet.

**NOTE:** The Power Transmitter should restart any timer associated with $t_{\text{power}}$ at the start of each RP or RP8 data packet it receives.

**NOTE:** This timeout is part of the comms-loss-timeout transition shown in the state diagram of the power transfer phase (Figure 42 and Figure 43).

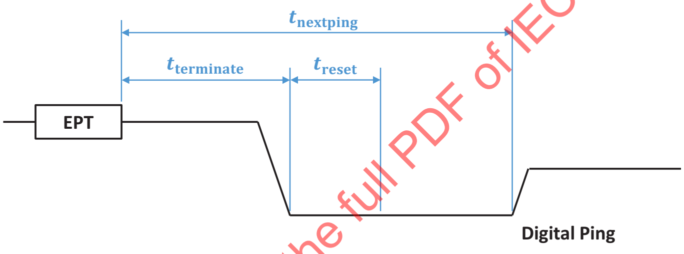
The Power Receiver shall determine its Received Power level in the time window $t_{\text{window}}$. This time window is located at an offset $t_{\text{offset}}$ before the start of the RP or RP8 data packet and shall not overlap with the preamble of the data packet directly following it. The Power Receiver provides the values of $t_{\text{window}}$ and $t_{\text{offset}}$ in its CFG data packet.

The Power Transmitter should determine its Transmitted Power level in the same time window. See the *Qi Specification, Foreign Object Detection*, for details.

## 7.3.4 End Power Transfer (EPT) data packet

A Power Transmitter shall remove the Power Signal at $t_{\text{terminate}}$ from the end of an EPT data packet and switch to state F of the ping phase, regardless of the End Power Transfer Code contained in the data packet. After removing the Power Signal, the Power Transmitter shall initiate a first Digital Ping at $t_{\text{nextping}}$ from the end of the EPT data packet. The value of $t_{\text{nextping}}$ depends on the value contained in the EPT data packet.

**Figure 63. End Power Transfer data packet timing**



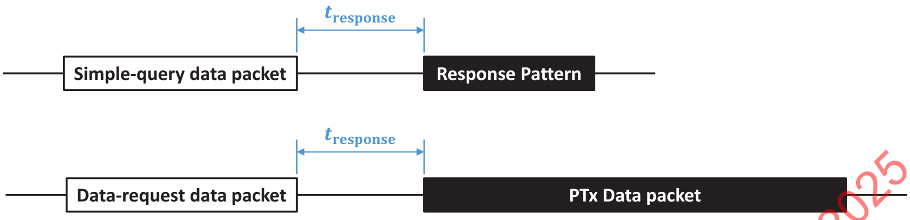
After sending a first EPT data packet, the Power Receiver should continue to send EPT data packets while the Power Signal is present. The transmission of these data packets shall comply with the timing constraints for consecutive data packets provided in Section 5.2.2, *Consecutive data packets*.

**NOTE:** Consecutive EPT data packets may contain different values in their End Power Transfer Code fields.

### 7.3.5 Simple-query and data-request data packets

A Power Transmitter shall start to transmit its response at $t_{response}$ from the end of a simple-query data packet or a data-request data packet.

Figure 64. Power Transmitter response timing



If a Power Receiver has not detected the start of a Response Pattern or data packet at $t_{responsetimeout}$ from the end of a simple-query or data-request data packet, it should assume the Power Transmitter did not receive its Response Pattern or data packet. In that case, it should retry sending its simple-query or data-request data packet at least once.

### 7.3.6 Comms-loss-timeout (Power Transmitter)

This is a composite timeout consisting of the CE data packet timeout value $t_{timeout}$ and the RP or RP8 data-packet timeout value $t_{power}$. See the timing constraints on CE, RP and RP8 data packets above.

### 7.3.7 Action-timeout

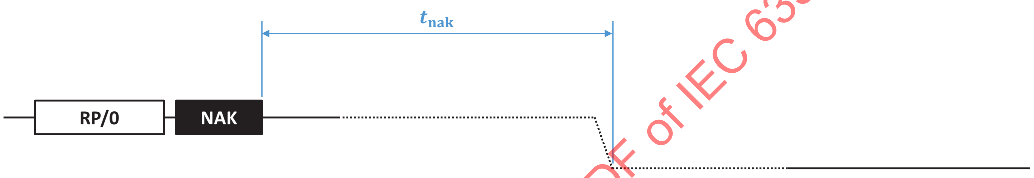
#### Power Reduction following a NAK response to an RP/0 data packet

The Power Transmitter may reply with NAK to an RP/0 packet if it can no longer support the negotiated power level, e.g. because of an increased ambient temperature.

As shown in Figure 65, a Power Receiver should reduce its power consumption at $t_{\mathrm{nak}}$ after receiving a NAK Response Pattern to an RP/0 data packet. After reducing its power consumption, the Power Receiver should request renegotiation using the NEGO data packet to determine the appropriate power level. Prior to switching to a renegotiation phase, the Power Receiver should enable the Power Transmitter to transmit its CAP data packet by sending a DSR/poll data packet.

**NOTE:** For the recommended method of renegotiating the power level, see Section 6.6.5.6, *Power-Transmitter initiated renegotiation*.

Figure 65. Timings associated with a NAK'ed RP/0 data packet

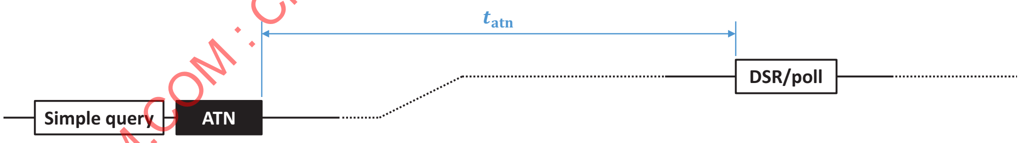


If the Power Receiver has not reduced its power consumption sufficiently at $t_{\mathrm{nak}}$, the Power Transmitter may remove the Power Signal.

#### DSR data packet following an ATN Response

A Power Receiver shall send a DSR/poll data packet at $t_{\mathrm{atn}}$ after receiving an ATN Response Pattern to a simple-query data packet.

Figure 66. Timings associated with an ATN Response Pattern



#### Next DSR data packet following a PTx data packet

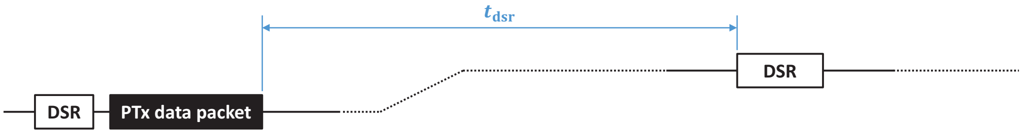
As shown in Figure 67, a Power Receiver shall send a DSR data packet at $t_{\mathrm{dsr}}$ after receiving a data packet from the Power Transmitter (in response to a preceding DSR data packet). The following exceptions apply:

- The Power Transmitter sends a CAP data packet. In this case, the Power Receiver may send a NEGO data packet instead of a DSR data packet. (See below for additional details.)
- The Power Transmitter sends a NULL data packet. In this case, the Power Receiver does not have to send a DSR data packet.

**NOTE:** The purpose of the next DSR data packet is to provide an ACK or NAK the Power Transmitter's data packet.

**NOTE:** The Power Transmitter should not respond with ATN to an RP data packet when it has an outgoing data transport stream open.

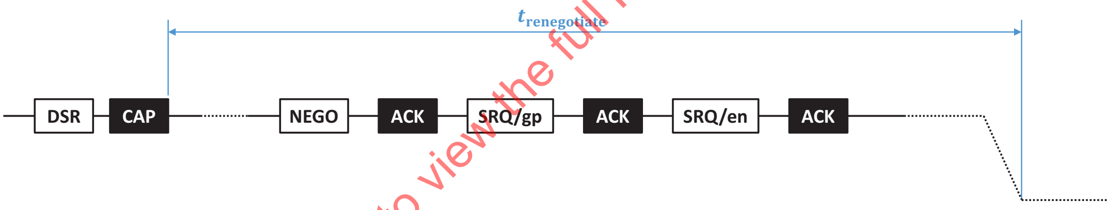
Figure 67. Timings associated with a DSR data packet



### Response to a renegotiation request

The Power Transmitter may request the Power Receiver to initiate a renegotiation phase by providing a CAP data packet in response to a DSR data packet. If the Negotiable Load Power level $P_{\mathrm{L}}^{(\mathrm{neg})}$ in this CAP data packet is less than the Guaranteed Load Power level $P_{\mathrm{L}}^{(\mathrm{gtd})}$ in the Power Transfer Contract, i.e. $P_{\mathrm{L}}^{(\mathrm{neg})} < P_{\mathrm{L}}^{(\mathrm{gtd})}$, the Power Receiver shall reduce its power consumption within $t_{\mathrm{renegotiate}}$ after receiving the CAP data packet. Hereto, it shall either negotiate a new Guaranteed Load Power level such that $P_{\mathrm{L}}^{(\mathrm{gtd})} \leq P_{\mathrm{L}}^{(\mathrm{neg})}$, or send an EPT/nul data packet. For an additional example, see Section 6.6.5.6 , *Power-Transmitter initiated renegotiation*. If the Power Receiver does not renegotiate a new Guaranteed Load Power level, the Power Transmitter may reduce the power level or remove the Power Signal.

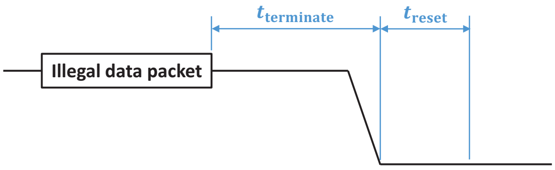
Figure 68. Timings associated with a Power Transmitter initiated renegotiation request



## 7.3.8 Illegal data packet

The Power Transmitter shall remove the Power Signal at $t_{\mathrm{terminate}}$ after receiving an illegal data packet.

Figure 69. Illegal data packet timeout



### 7.3.9 Data transport stream timing

The initiator of a data transport stream shall send the data packets comprising the stream with a time interval of $t_{\mathrm{dts}}$ between consecutive data packets.

**NOTE:** The time interval $t_{\mathrm{dts}}$ does not need to be constant and may vary within the limits provided in Table 16.

If the recipient of a data transport stream has not received the next data packet in the stream at $t_{\mathrm{dtstimeout}}$, it should close the data transport stream and discard all data received therein.

**Figure 70. PRx-to-PTx data transport stream timing**

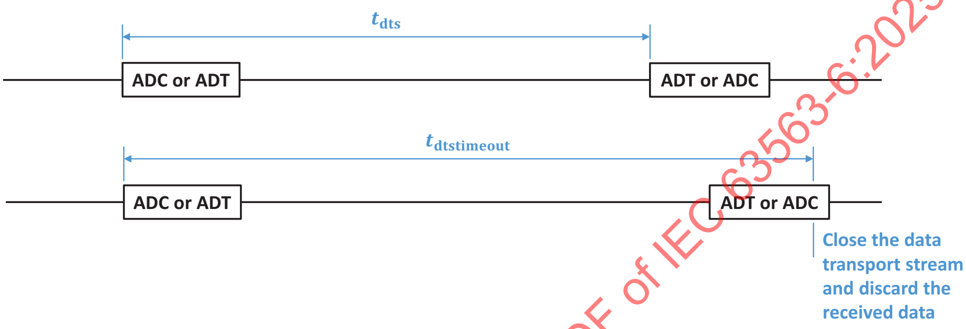
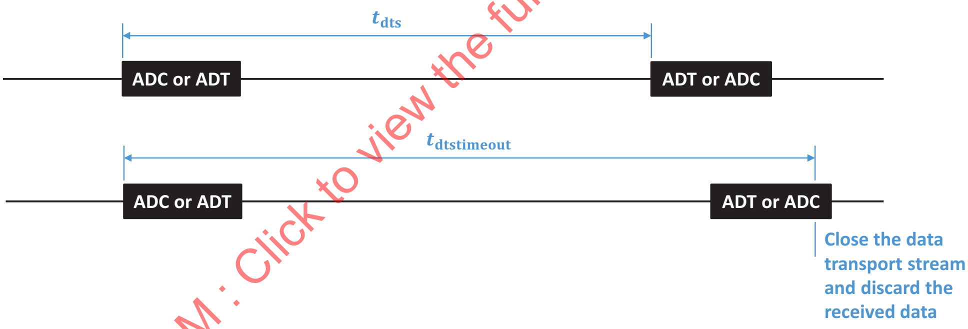


**Figure 71. PTx-to-PRx data transport stream timing**



# 8 Power Receiver data packets

Table 17 lists all defined Power Receiver data packets.

**Table 17: Power Receiver data packets**

| Header* | Mnemonic | Name | Type | Size |
|---|---|---|---|---|
| 0x01 | SIG | Signal Strength | Status update | 1 |
| 0x02 | EPT | End Power Transfer | Power control | 1 |
| 0x03 | CE | Control Error | Power control | 1 |
| 0x04 | RP8 | Received Power (8 bit) | Status update | 1 |
| 0x05 | CHS | Charge Status | Status update | 1 |
| 0x06 | PCH | Power Control Hold-off | Status update | 1 |
| 0x07 | GRQ | General Request | Data request | 1 |
| 0x09 | NEGO | Renegotiate | Simple query | 1 |
| 0x15 | DSR | Data Stream Response | Data request | 1 |
| 0x16 | ADT/1e | Auxiliary Data Transport (even) | Simple query | 1 |
| 0x17 | ADT/1o | Auxiliary Data Transport (odd) | Simple query | 1 |
| 0x18 | PROP/1e | Proprietary | Multiple | 1 |
| 0x19 | PROP/1o | Proprietary | Multiple | 1 |
| 0x20 | SRQ | Specific Request | Simple query | 2 |
| 0x22 | FOD | FOD Status | Simple query | 2 |
| 0x25 | ADC | Auxiliary Data Control | Simple query | 2 |
| 0x26 | ADT/2e | Auxiliary Data Transport (even) | Simple query | 2 |
| 0x27 | ADT/2o | Auxiliary Data Transport (odd) | Simple query | 2 |
| 0x28 | PROP/2e | Proprietary | Multiple | 2 |
| 0x29 | PROP/2o | Proprietary | Multiple | 2 |
| 0x31 | RP | Received Power (16 bit) | Simple query | 3 |
| 0x36 | ADT/3e | Auxiliary Data Transport (even) | Simple query | 3 |
| 0x37 | ADT/3o | Auxiliary Data Transport (odd) | Simple query | 3 |
| 0x38 | PROP/3 | Proprietary | Multiple | 3 |
| 0x46 | ADT/4e | Auxiliary Data Transport (even) | Simple query | 4 |
| 0x47 | ADT/4o | Auxiliary Data Transport (odd) | Simple query | 4 |
| 0x48 | PROP/4 | Proprietary | Multiple | 4 |

Table 17: (Continued)Power Receiver data packets

| Header[*] | Mnemonic | Name | Type | Size |
|---|---|---|---|---|
| 0x51 | CFG | Configuration | Simple query | 5 |
| 0x54 | WPID | Wireless Power ID (most significant bits) | Multiple | 5 |
| 0x55 | WPID | Wireless Power ID (least significant bits) | Simple query | 5 |
| 0x56 | ADT/5e | Auxiliary Data Transport (even) | Simple query | 5 |
| 0x57 | ADT/5o | Auxiliary Data Transport (odd) | Simple query | 5 |
| 0x58 | PROP/5 | Proprietary | Multiple | 5 |
| 0x66 | ADT/6e | Auxiliary Data Transport (even) | Simple query | 6 |
| 0x67 | ADT/6o | Auxiliary Data Transport (odd) | Simple query | 6 |
| 0x68 | PROP/6 | Proprietary | Multiple | 6 |
| 0x71 | ID | Identification | Status update | 7 |
| 0x76 | ADT/7e | Auxiliary Data Transport (even) | Simple query | 7 |
| 0x77 | ADT/7o | Auxiliary Data Transport (odd) | Simple query | 7 |
| 0x78 | PROP/7 | Proprietary | Multiple | 7 |
| 0x81 | XID | Extended Identification | Status update | 8 |
| 0x84 | PROP/8 | Proprietary | Multiple | 8 |
| 0xA4 | PROP/12 | Proprietary | Multiple | 12 |
| 0xC4 | PROP/16 | Proprietary | Multiple | 16 |
| 0xE2 | PROP/20 | Proprietary | Multiple | 20 |

[*] Header values not listed in this table are reserved and shall not be used

## 8.1 Auxiliary Data Control—ADC (0x25; simple query)

ADC data packets control the transmission of data transport streams. Table 18 defines the format of the ADC data packet.

**Table 18: Message field of an Auxiliary Data Control (ADC) data packet**

| | $b_7$ | $b_6$ | $b_5$ | $b_4$ | $b_3$ | $b_2$ | $b_1$ | $b_0$ |
|---|---|---|---|---|---|---|---|---|
| $B_0$ | Request | | | | | (msb) | | |
| $B_1$ | Parameter | | | | | | | (lsb) |

**Request** Set to one of the following values:

*0—ADC/end*—close the outgoing data transport stream to the Power Transmitter.

*2—ADC/auth*—open an authentication data transport stream to the Power Transmitter.

*5—ADC/rst*—reset all incoming and outgoing data transport streams.

**NOTE:** The requested action involves discarding all data received in any open incoming data transport stream, and subsequently closing the latter. It also involves closing any outgoing data transport stream without sending an ADC/end data packet.

*0x10…0x1F—ADC/prop*—open a proprietary data transport stream to the Power Transmitter

**NOTE:** The WPC does not manage the use of these values. Accordingly, the Power Receiver should verify the type and make of the Power Transmitter before using proprietary data transport streams.

All other values are reserved. The Power Receiver shall not use those values.

**Parameter** For proprietary (ADC/prop) and authentication (ADC/auth) data transport streams: the number of data bytes in the stream. Set this field to zero in ADC/end and ADC/rst data packets.

**Response Pattern**

- *ACK*: The Power Transmitter has executed the request successfully.
- *NAK*: The Power Transmitter has not executed the request.

  **NOTE:** Examples of reasons for not executing the request comprise the Power Transmitter already having received one or more ADT data packets in an open incoming data transport stream; the Power Transmitter having an open outgoing data transport stream and not supporting simultaneous incoming and outgoing data transport streams; the Power Transmitter being busy.
- *ND*: The Power Transmitter does not support the requested data transport stream type.
- *ATN*: The Power Transmitter requests permission to communicate.

  **NOTE:** If the Power Transmitter responds with ATN, it has not executed the request.

## 8.2 Auxiliary Data Transport—ADT (multiple header codes; simple query)

ADT data packets carry the application layer messages sent in a data transport stream to a Power Transmitter. Table 19 defines the format of an Auxiliary ADT data packet. ADT data packet sizes from 1 to 7 are available and each size is available with an odd and an even header. See Table 17.

**Table 19: Message field of an Auxiliary Data Transport (ADT) data packet**

|  | $b_7$ | $b_6$ | $b_5$ | $b_4$ | $b_3$ | $b_2$ | $b_1$ | $b_0$ |
|---|---|---|---|---|---|---|---|---|
| $B_0$ | Data |  |  |  |  |  |  |  |
| … |  |  |  |  |  |  |  |  |
| $B_n$ |  |  |  |  |  |  |  |  |

**Data** Defined by the appropriate application layer.

**Response Pattern**

- *ACK*: The Power Transmitter has processed the data in the packet correctly.
- *NAK*: The Power Transmitter has not been able to process the data in the packet.

  **NOTE:** A Power Transmitter can use this Response Pattern if it busy or if it is unable to buffer the data.
- *ND*: The Power Transmitter does not have an incoming data transport stream open.
- *ATN*: The Power Transmitter requests permission to communicate.

  **NOTE:** The Power Transmitter should discard the data received in the packet when using this Response Pattern.

## 8.3 Charge Status—CHS (0x05; status update)

CHS data packets provide the charging level of a battery in the Load.

**NOTE:** It is optional for a Power Receiver to send this data packet.

**Table 20: Message field of a Charge Status (CHS) data packet**

| | $b_7$ | $b_6$ | $b_5$ | $b_4$ | $b_3$ | $b_2$ | $b_1$ | $b_0$ |
|---|---|---|---|---|---|---|---|---|
| $B_0$ | Charge Status Value | | | | | | | |

**Charge Status Value** May have one of the following values:

*0…100*—a percentage of the fully charged level. A value of 100 means that the battery is fully charged.

*0xFF*—the load does not contain a battery, or the Power Receiver is not able to obtain charge level data.

All other values are reserved. The Power Receiver shall not use those values.

## 8.4 Configuration—CFG (0x51; simple query)

The CFG data packet provides basic configuration data:

- All parameters governing the power transfer in the Baseline Protocol.
- All FSK communications parameters used in the Extended Protocol.
- Additional capabilities of the Power Receiver.

**Table 21: Message field of a Configuration (CFG) data packet**

| | $b_7$ | $b_6$ | $b_5$ | $b_4$ | $b_3$ | $b_2$ | $b_1$ | $b_0$ |
|---|---|---|---|---|---|---|---|---|
| $B_0$ | ‘00’ | | Reference Power | | | | | |
| $B_1$ | Reserved | | | | | | | |
| $B_2$ | ZERO | AI | Reserved | OB | ZERO | Count | | |
| $B_3$ | Window Size | | | | | Window Offset | | |
| $B_4$ | Neg | Pol | Depth | | Buffer Size | | | Dup |

A Power Receiver shall set all reserved bits to ZERO. A Power Transmitter shall ignore all reserved bits.

**Reference Power** Shall be set to $\frac{P_\mathrm{r}^{(\mathrm{ref})}}{0.5\ \mathrm{W}}$. The value contained in this field shall be at most 10, i.e. $P_\mathrm{r}^{(\mathrm{ref})} \leq 5\ \mathrm{W}$.

**NOTE:** Section 8.14, *Received Power—RP8 (0x04; status update)*, and Section 8.15, *Received Power—RP (0x31; simple query)*, provide details about the use of the Reference Power level. A Power Receiver can report Received Power levels up to (but not including) $2 \cdot P_\mathrm{r}^{(\mathrm{ref})}$. The Received Power level of a Power Receiver should stay below this highest reportable level to avoid false FOD events from occurring (see the *Qi Specification*, *Foreign Object Detection*, for details). In the negotiation phase of the Extended Protocol, the Power Receiver can reconfigure the Reference Power level to a higher value using an SRQ/rp data packet.

**AI** Authentication functionality is supported (ONE) or not supported (ZERO).

**OB** Out-of-band communications functionality is supported (ONE) or not supported (ZERO).

**NOTE:** Version 1.3 of the *Qi Specification* does not define an out-of-band communications channel.

**Count** The number of optional data packets present in the configuration phase.

**NOTE:** All optional data packets contribute to the count, even those that are present multiple times.

**Window Size** Shall be set to $\frac{t_\mathrm{window}}{4\ \mathrm{ms}}$. The value contained in this field shall be at least 2, i.e. $t_\mathrm{window} \geq 8\ \mathrm{ms}$.

**NOTE:** The Received Power window size $t_\mathrm{window}$ and Received Power window offset $t_\mathrm{offset}$ determine the time window in which the Power Receiver measures its Received Power. These values are elements of the Power Transfer Contract. See Figure 62 in Section 7.3, *Power transfer phase timings*, for details about the position of this window relative to the RP8 or RP data packet directly following it.

**Window Offset** Shall be set to a whole number greater than $n/8$, where $n$ represents the maximum number of preamble bits used in any RP8 or RP data packet.

**NOTE:** The Received Power windows offset $t_{\text{offset}}$ in the Power Transfer Contract is equal to the value contained in this field times 4 ms.

**NOTE:** An 11-bit preamble yields a Window Offset of at least 2 (i.e. $t_{\text{offset}}$ = 8 ms); a 16-bit preamble yields a Window Offset of at least 3 (i.e. $t_{\text{offset}}$ = 12 ms); and a 24-bit preamble yields a Window Offset of at least 4 (i.e. $t_{\text{offset}}$ = 16 ms).

**Neg** The Extended Protocol is supported (ONE) or not supported (ZERO). If the Neg bit is set to ZERO, all bits of the AI, OB, Dup, Buffer Size, Pol, and Depth fields shall be set to ZERO as well.

**NOTE:** CFG/ep indicates that the Neg bit is set to ONE, and CFG/bp indicates that the Neg bit is set to ZERO.

**Pol** The FSK polarity is positive (ZERO) or negative (ONE).

**Depth** The FSK modulation to use. See the *Qi Specification, Communications Physical Layer*, for the defined modulation depths.

**NOTE:** The FSK polarity and modulation depth are elements of the Power Transfer Contract.

**Buffer Size** The size of the transport-layer buffer for receiving a data transport stream in the model provided in Section 7.2.2, *Data model*. The number of bytes in the buffer is equal to $16 \cdot 2^n$, with $n$ the value contained in the Buffer Size field.

**Dup** Simultaneous incoming and outgoing data streams are supported (ONE) or not supported (ZERO).

## Response Pattern

- *ACK*: The Power Transmitter has switched to the negotiation phase of the Extended Protocol. Use only if the Neg bit is set to ONE.

  **NOTE:** The Power Receiver can still decide to switch to the power transfer phase of the Baseline Protocol instead switching to the negotiation phase.

- *No response*: The Power Transmitter has switched to the power transfer phase of the Baseline Protocol.

  **NOTE:** The Power Transmitter may refrain from responding with ACK, even if it supports the Extended Protocol and the Power Receiver has set the Neg bit to ONE.

- *NAK, ND, or ATN*: The Power Transmitter shall not use these Response Patterns.

  **NOTE:** The Power Receiver switches to the power transfer phase of the Baseline Protocol when it receives one of these Response Patterns; see Section 5.1.5, *Transitions from state 6*.

## 8.5 Control Error—CE (0x03; power control)

CE data packets provide feedback about the desired power level.

**Table 22: Message field of a Control Error (CE) data packet**

|  | $b_7$ | $b_6$ | $b_5$ | $b_4$ | $b_3$ | $b_2$ | $b_1$ | $b_0$ |
|---|---|---|---|---|---|---|---|---|
| $B_0$ | Control Error Value |  |  |  |  |  |  |  |

**Control Error Value** A two's complement signed integer value that is a relative measure for the deviation between the actual and target operating points of the Power Receiver.

A positive value indicates that the actual operating point is below the target operating point and requests the Power Transmitter to increase the Power Signal. A negative value indicates that the actual operating point is above the target operating point and requests the Power Transmitter to reduce the Power Signal. See the *Qi Specification, Power Delivery*, for details on how to determine this value.

## 8.6 Data Stream Response—DSR (0x15; data request)

DSR data packets sustain the transmission of a data transport stream from the Power Transmitter.

**Table 23: Message field of a Data Stream Response (DSR) data packet**

| | $b_7$ | $b_6$ | $b_5$ | $b_4$ | $b_3$ | $b_2$ | $b_1$ | $b_0$ |
|---|---|---|---|---|---|---|---|---|
| $B_0$ | Type | | | | | | | |

**Type** Set to one of the following values:

*0x00—DSR/nak*—indicates that the last received Power Transmitter data packet has been rejected.

*0x33—DSR/poll*—invites the Power Transmitter to send any data packet.

*0x55—DSR/nd*—indicates that the last received Power Transmitter data packet was not expected.

*0xFF—DSR/ack*—confirms that the last received Power Transmitter data packet has been processed properly.

All other values are reserved. The Power Receiver shall not use those values.

**NOTE:** For additional details, see the definition of the Power Transmitter data packets in Section 9, *Power Transmitter data packets*.

### Response

The Power Transmitter shall reply with a data packet. For a list of Power Transmitter data packets, see Table 43 in Section 9, *Power Transmitter data packets*.

## 8.7 End Power Transfer—EPT (0x02; power control)

EPT data packets provide a request to stop the power transfer and a reason for the request. The Power Receiver should send this data packet with an appropriate reason if it detects an error condition.

**NOTE:** The EPT data packet is considered a power-control data packet because it requests the Power Transmitter to change the power level (to zero).

**Table 24: Message field of an End Power transfer (EPT) data packet**

| | $b_7$ | $b_6$ | $b_5$ | $b_4$ | $b_3$ | $b_2$ | $b_1$ | $b_0$ |
|---|---|---|---|---|---|---|---|---|
| $B_0$ | End Power Transfer Code | | | | | | | |

**End Power Transfer Code** The reason for requesting to stop the power transfer:

*0x00—EPT/nul*—use if none of the other codes is appropriate.

*0x01—EPT/cc*—charge complete; use to indicate that the battery is full.

*0x02—EPT/if*—internal fault; use if an internal logic error has been encountered.

*0x03—EPT/ot*—over temperature; use if (e.g.) the battery temperature exceeds a limit.

*0x04—EPT/ov*—over voltage; use if a voltage exceeds a limit.

*0x05—EPT/oc*—over current; use if the current exceeds a limit.

*0x06—EPT/bf*—battery failure; use if the battery cannot be charged.

*0x08—EPT/nr*—no response; use if the target operating point cannot be reached.

*0x0A—EPT/an*—aborted negotiation; use if a suitable Power Transfer Contract cannot be negotiated.

*0x0B—EPT/rst*—restart; use to restart the power transfer.

**NOTE:** Typically, a Power Transmitter engages in FOD after stopping the power transfer and before restarting it. For details about this procedure, see the *Qi Specification, Foreign Object Detection*.

*0x0C—EPT/rep*—re-ping; use to restart the power transfer after a specified delay (the re-ping delay $t_{\text{reping}}$). The Power Transmitter should suppress potentially distracting user interface events associated with restarting the power transfer.

**NOTE:** A Power Receiver should use this End Power Transfer Code only if it has verified that the Power Transmitter complies with version 1.3 or higher of the *Qi Specification*. A typical use case is to interrupt the power transfer to establish an NFC link between the Power Receiver Product and Power Transmitter Product.

*0x0D—EPT/nfc*—NFC tag; use if an NFC tag has been detected.

*0x0E—EPT/ptxnfc*—refer to the *Qi Specification, NFC Tag Protection* for further information.

All other values are reserved. The Power Receiver shall not use those values.

Table 25 provides the delay $t_{nextping}$ until the next Digital Ping after an EPT data packet. See Section 4.2.4, *End Power Transfer (EPT) data packet*, for details.

**Table 25: Digital Ping delay time $t_{nextping}$**

| EPT Code | Mnemonic | Minimum | Typical | Maximum | Unit |
|---|---|---|---|---|---|
| 0x00 | EPT/nul | Implementation dependent | | | |
| 0x01 | EPT/cc | 7,000 | 900,000 | N/A | ms |
| 0x02 | EPT/if | Implementation dependent | | | |
| 0x03 | EPT/ot | 300,000 | 900,000 | N/A | ms |
| 0x04 | EPT/ov | 1,000 | 2,000 | N/A | ms |
| 0x05 | EPT/oc | | | | |
| 0x06 | EPT/bf | No Digital Ping until the user has removed the Power Receiver | | | |
| 0x07 | N/A | No Digital Ping until the user has removed the Power Receiver | | | |
| 0x08 | EPT/nr | 60 | After the third attempt, no Digital Ping until the user has removed the Power Receiver | | ms |
| 0x09 | N/A | No Digital Ping until the user has removed the Power Receiver | | | |
| 0x0A | EPT/an | 60 | After the third attempt, no Digital Ping until the user has removed the Power Receiver | | ms |
| 0x0B | EPT/rst | 60 | N/A | 500 | ms |
| 0x0C | EPT/rep | 80% · $t_{reping}$ | $t_{reping}$ | 120% · $t_{reping}$ | ms |
| 0x0D | EPT/nfc | Implementation dependent | | | |
| 0x0E | EPT/ptxnfc | Implementation dependent | | | |
| 0x0F...0xFF | N/A | No Digital Ping until the user has removed the Power Receiver | | | |

## 8.8 Extended Identification—XID (0x81; status update)

The XID data packet contains additional identification data.

**Table 26: Message field of an Extended Identification (XID) data packet**

| | $b_7$ | $b_6$ | $b_5$ | $b_4$ | $b_3$ | $b_2$ | $b_1$ | $b_0$ |
|---|---|---|---|---|---|---|---|---|
| $B_0$ | (msb) | Extended Device Identifier | | | | | | |
| $B_1$ | | | | | | | | |
| $B_2$ | | | | | | | | |
| $B_3$ | | | | | | | | |
| $B_4$ | | | | | | | | |
| $B_5$ | | | | | | | | |
| $B_6$ | | | | | | | | |
| $B_7$ | | | | | | | | (lsb) |

| | |
|---|---|
| **Extended Device Identifier** | Provides additional information about the Power Receiver's identity. |

## 8.9 FOD Status—FOD (0x22; simple query)

The FOD Status data packet contains information that can help the Power Transmitter to determine whether a Foreign Object is present before the power transfer starts. See the *Qi Specification, Foreign Object Detection*, for more information about pre-power transfer FOD.

**Table 27: Message field of an FOD Status (FOD) data packet**

| | $b_7$ | $b_6$ | $b_5$ | $b_4$ | $b_3$ | $b_2$ | $b_1$ | $b_0$ |
|---|---|---|---|---|---|---|---|---|
| $B_0$ | Reserved | | | | | | Type | |
| $B_1$ | FOD Support Data | | | | | | | |

A Power Receiver shall set all reserved bits to ZERO. A Power Transmitter shall ignore all reserved bits.

**Type** Set to one of the following values:

*0—FOD/qf*—the FOD Support Data field contains the Reference Quality Factor $Q_{\mathrm{t}}^{(\mathrm{ref})}$, rounded to the nearest whole number. The *Qi Specification, Foreign Object Detection*, defines how to determine the Reference Quality Factor.

*1—FOD/rf*—the FOD Support Data field contains the Reference Resonance Frequency, encoded as $\frac{f_{\mathrm{t}}^{\prime(\mathrm{ref})}}{0.5\ \mathrm{kHz}} - 72$ rounded to the nearest whole number. The *Qi Specification, Foreign Object Detection*, defines how to determine the Reference Resonance Frequency.

**NOTE:** A value of zero corresponds to a Reference Resonance Frequency in the range of 35.75 kHz up to (but not including) 36.25 kHz, and a value of 255 corresponds to a Reference Resonance Frequency in the range of 163.25 up to (but not including) 163.75 kHz.

All other values are reserved. The Power Receiver shall not use those values.

**FOD Support Data** Depends on the value contained in the Type field.

### Response Pattern

Negotiation phase.

- *ACK*: The Power Transmitter considers it unlikely that a Foreign Object is present in its Operating Volume.
- *NAK*: The Power Transmitter considers it likely that a Foreign Object is present in its Operating Volume.

  **NOTE:** See the Qi Specification, Foreign Object Detection, for additional information about combining the Response Patterns to multiple FOD Status data packets into a single verdict about the likelihood of a Foreign Object being present.
- *ND*: The Power Transmitter does not recognize the Type value.

- *ATN*: The Power Transmitter shall not use this Response Pattern.

  **NOTE:** The Power Receiver switches to the power transfer phase of the Baseline Protocol when it receives this Response Pattern; see Section 6.6.1, *Transitions from state 7*.

Renegotiation phase.

- *ND*: The Power Transmitter shall use this Response Pattern.
- *ACK, NAK,* and *ATN*: The Power Transmitter shall not use these Response Patterns.

## 8.10 General Request—GRQ (0x07; data request)

The GRQ data packet requests the Power Transmitter to respond with the indicated data packet.

**Table 28: Message field of a General Request (GRQ) data packet**

|  | $b_7$ | $b_6$ | $b_5$ | $b_4$ | $b_3$ | $b_2$ | $b_1$ | $b_0$ |
|---|---|---|---|---|---|---|---|---|
| $B_0$ | Requested Power Transmitter Data Packet |  |  |  |  |  |  |  |

**Requested Power Transmitter Data Packet** One of the Power Transmitter Data packet headers listed in Table 43 in Section 9, *Power Transmitter data packets*.

### Response

The Power Transmitter shall respond with the requested data packet.

**NOTE:** The Power Transmitter responds with the NULL data packet if it does not support the Requested Power Transmitter data packet; see Section 6.6.3, *Transitions from state 9*.

## 8.11 Identification—ID (0x71; status update)

The ID data packet identifies the Power Receiver.

**Table 29: Message field of an Identification (ID) data packet**

| | $b_7$ | $b_6$ | $b_5$ | $b_4$ | $b_3$ | $b_2$ | $b_1$ | $b_0$ |
|---|---|---|---|---|---|---|---|---|
| $B_0$ | Major Version | | | | Minor Version | | | |
| $B_1$ | (msb) | Manufacturer Code | | | | | | |
| $B_2$ | | | | | | | | (lsb) |
| $B_3$ | Ext | (msb) | Basic Device Identifier | | | | | |
| $B_4$ | | | | | | | | |
| $B_5$ | | | | | | | | |
| $B_6$ | | | | | | | | (lsb) |

**Major Version** Shall be set to 1.

**Minor Version** Shall be set to 3 in the Extended Protocol, and to 1, 2, or 3 in the Baseline Protocol.

**Manufacturer Code** Shall contain the PRMC that the Power Receiver's manufacturer has registered with the WPC.

**Ext** Indicates the presence (ONE) or absence (ZERO) of an XID data packet in the configuration phase.

**NOTE:** ID/x indicates that the Ext bit is set to ONE, and ID indicates that the Ext bit is set to ZERO.

**Basic Device Identifier** In combination with the Manufacturer Code, this identifier enables a multi-coil Power Transmitter to recognize the Power Receiver within a set of Power Receivers present in its Operating Volume. To enable such recognition, the Basic Device Identifier should comprise a 20-bit serial number. To preserve user privacy, the Power Receiver may dynamically generate the Basic Identifier. However, if the Power Receiver generates this identifier dynamically, it shall not change it within two seconds after losing the Power Signal.