



ANT+ Device Profile

Bicycle Power



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Revision History

| Revision | Effective Date | Description |
|----------|--------------------|--|
| 1.0 | July 3, 2007 | Initial Release |
| 1.1 | July 2007 | Corrected accumulated power description |
| 1.2 | July 31, 2007 | Made all message names general |
| 1.3 | August 1, 2007 | Made it clear that 2 byte fields are little endian |
| 1.4 | September 13, 2007 | Revised a typo – all standard torque fields are 1.32 resolution |
| 1.5 | November 14, 2007 | Corrected formatting. Corrected equation 10 (Torque Frequency) |
| 1.6 | February 6, 2008 | Added clarification for calibration of bike power sensors |
| 1.7 | March 5, 2008 | Modified 0x11 and 0x12 messages |
| 1.8 | March 11, 2008 | Modified 0x10 Added Auto Zero Message Added Notes for best practice |
| 1.9 | March 17, 2008 | Corrected constants in Eq. 2 (Speed) Revised Calibration messages and Auto Zero flowchart |
| 1.95 | May 8, 2008 | Corrected byte order for offset data in Calibration Responses |
| 2.00 | September 16, 2008 | New formatting |
| 2.1 | August 2010 | Re-format, added common page descriptions and new calibration criteria |
| 2.2 | November 10, 2011 | Edited 'Copyright Information and Usage Notice' section Added Custom Calibration Parameters to calibration messages (optional) Added 'Set/Get' Bicycle Parameters page (optional) Removed use of forward direction acknowledged messages |
| 2.3 | April 2012 | Corrected typo in Section on Set/Get parameters |
| 3.0 | February 2012 | Added page 0x13 (Torque Effectiveness and Pedal Smoothness metrics) Updated section 13 to clarify that sensors may not send acknowledged messages Added section explaining the requirements to be met before using the icons Updated section 3.3 to include CTF-only Receiver Implementation Updated section 7.1 Event Count. Updated figures in section 13. Updated section 16.2.1 to reflect current version of Common Pages document. Added section 16.2.4: Common Page 82 (0x52): Battery Status Added section 17.3 Handling Invalid Values Clarified background page transmission pattern requirements. Added description of extended device numbers to transmission type field. Added note that sensors may send forward direction calibration messages. Updated template to 2013 version and added CTF icon to front page |
| 4.0 | August 2013 | Added Measurement Output Data Page 0x03 Updated Calibration Sequence diagrams in section 14 Updated section 14.3 to remove outdated references to torque Updated Figure 14-11. Coasting Offset Calibration Example |

| | | |
|-----|---------------|---|
| | | <p>Updated Table 7-1, Table 7-2 and Table 7-3 to include messages 0x02 and 0x03.</p> <p>Added custom calibration status flag to data page 0x02.</p> <p>Updated Common Page 82 to reflect latest version of common pages document. Removed common pages 80 and 81 and referred to the common pages document.</p> <p>Clarified CTF calibration requirements</p> <p>Clarified rollover power rollover values as 65.536kW</p> <p>Specified default messages should be sent at least 2 out of 4 messages</p> <p>Updated section 18.2 to clarify the method for handling rollovers.</p> |
| 4.1 | June 2014 | Minor fix: Fixed table of contents bookmarks for PDF. Updated copyright. |
| 4.2 | October 2015 | <p>Clarifications to crank length setting and reporting</p> <p>Two-Sided sensor system network key considerations</p> |
| 5.0 | November 2016 | <p>Added Advanced Capabilities Sub Page to Get/Set</p> <p>Added verification tests, requirement markers</p> <p>Added 'Using This Document' section</p> |
| 5.1 | January 2019 | <p>Cycling Dynamics</p> <p>Pedal additions to Measurement Output Page</p> <p>8 Hz transmission requirements</p> |

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2 Related Documents

Refer to current versions of the listed documents. To ensure you are using the current versions, check the ANT+ website at www.thisisant.com or contact your ANT+ representative.

1. ANT Message Protocol and Usage
2. ANT+ Common Pages
3. SimulANT+ User Guide
4. SimulANT+ Profile Verification Suite User Guide

3 Using This Document

This profile document defines the requirements, recommendations, best practices, and allowances for certified ANT+ products. As a developer, use the document to identify requirements that need to be met to make your product ANT+ compliant. Use the SimulANT+ Profile Verification Suite with the certification requirement markers (Figure 3-1) in this document to test that requirements are met before submitting your product for ANT+ certification.



Figure 3-1. ANT+ Certification Requirement Marker

Each requirement in the profile is marked with a test number in bold square brackets [**XX_XXXX**]. Profile verification tests for master (sensor) devices are prefixed with '**MD_**' whereas slave (display) devices are marked as '**SD_**'. As you run the tests on SimulANT+, you can check back to the requirements in this document to understand and fix test failures. Section 23 outlines the tests that you can run using SimulANT+ to verify your product's ANT+ compliance, and points to the sections in the document that explain the individual requirements covered in each test. Requirements marked as [**self-verify**] do not have a related SimulANT+ Profile Verification Test and must be verified manually.



4 Typical Use Case of Bicycle Power Sensors

A bike power sensor is a sensor that is mounted on a bicycle and that allows the cyclist to measure his or her power output, which is the force required to move the bike forward and is measured in Watts. The power meter transmits the information to a display device. The display device can be a bike mounted display unit, watch, cell phone, piece of fitness equipment, or other personal display device. The purpose of the ANT+ Bicycle Power device profile is to provide a robust means of interoperable communication between bicycle power sensors and display units that are produced by separate manufacturers.

This document provides channel configuration information, message definitions, and outlines interaction sequences to explain how sensors transmit bike power information and how display units properly interpret that information. The specification covers the main power information from a variety of supported bike power sensor types as well as the interaction between the display and sensor for calibration. Figure 4-1 illustrates how a bike meter is typically used. The sensor transmits the user's power information and responds to calibration requests. Some device-specific information is transmitted at a slower rate in common data pages. The ANT+ bicycle power device profile describes messages that perform three main functions:

- Power information is transmitted from the sensor to the display in main data pages.
- Interaction occurs between the sensor and display for servicing calibration or configuration requests.
- Background support and status is passed periodically from the power sensor to the display in common data pages.

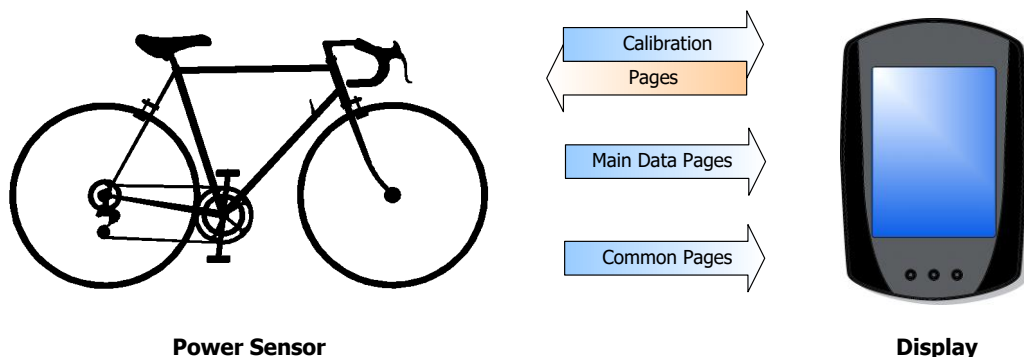


Figure 4-1. Standard Use Case of an ANT+ Bike Power sensor

4.1 Bicycle Power Sensor Types

Bike power sensors vary in two ways: in the method used to measure power, and in the conditions and interval used to update and broadcast power information.

4.1.1 Power Measurement Types

The ANT+ message definition currently supports power sensors that:

- measure power directly
- measure torque and rotational velocity at the crank (includes pedal sensors)
- measure torque and rotational velocity at the wheel

Future power sensors may require additional messages. For displays to be compatible with future devices refer to section 6.

4.1.2 Power Information Update Types

All of the broadcast power messages have an Update Event Counter that is used by the receiver to calculate information accurately. There are two methods used by bicycle power sensors for information updates: event-synchronous and time-synchronous.

4.1.2.1 Event-Synchronous Update

The sensor calculates data and updates messages after detecting a rotation event, such as crank or wheel revolution. The elapsed time between each event fluctuates but the number of motion events in each update is constant.

Example: The power information is updated each time the power sensor detects a new crank rotation.

4.1.2.2 Time-Synchronous Update

The sensor calculates data and updates messages at a fixed time interval, regardless of the number of motion events.

Example: The power information is updated at 1Hz.

4.2 Messages Transmitted from the ANT+ Bike Power Sensor

ANT+ bike power data pages support various types of bike power sensors. It is the goal of ANT+ to support both a basic power format common across all power sensors, as well as to provide the ability to extract more detailed information from the power sensor. The basic power format is implemented using a simple Power-Only message transmitted at a slow rate along with more detailed main power messages at a higher data rate. Main power messages are specific to the power methods used; there are four currently supported methods. Other non-time-critical messages, such as battery status and device identification, are grouped as background common data pages and are sent at the slow rate. Each data message has an indicator associated with it describing the data that is being transmitted in that message.

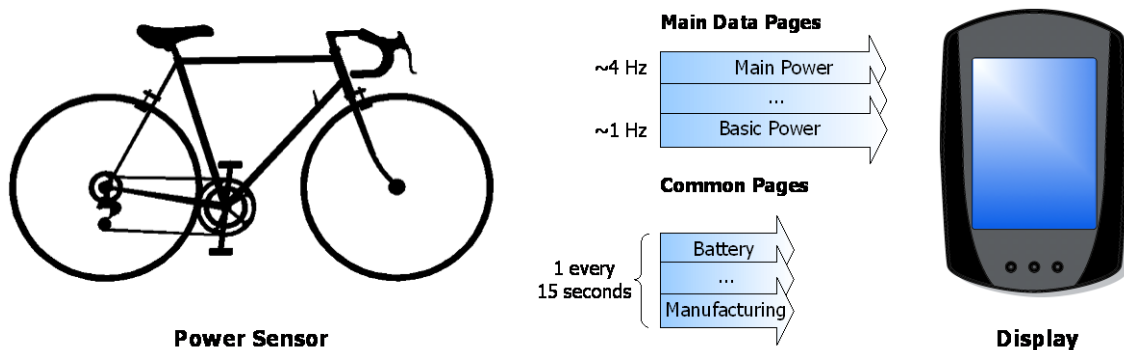


Figure 4-2. Timing of ANT+ Bike Power Sensor Message Formats

4.3 ANT+ Bike Power Sensor Receiver Implementation

In a full receiver implementation, the display can receive and interpret all messages from the power sensor; to provide the best features and data, most bicycle-specific displays use a full receiver implementation. A simple receiver that interprets only the basic power-only message may be implemented using a smaller amount of memory. The simple implementation allows cost-reduced, non-bicycle specific or resource-constrained ANT+ devices to receive bicycle power messages. In cases where the power sensor is broadcasting messages that are newer than the display, the simple receiver can interpret at least the basic power-only messages. Alternatively, a CTF-Only Receiver Implementation is permitted, which allows displays to receive from Crank Torque Frequency sensors only. If a display only supports PWR, it **shall [SD_PWR_005]** handle CTF sensors gracefully. If a display only supports CTF sensors, it **shall [SD_PWR_005]** handle PWR sensors gracefully.

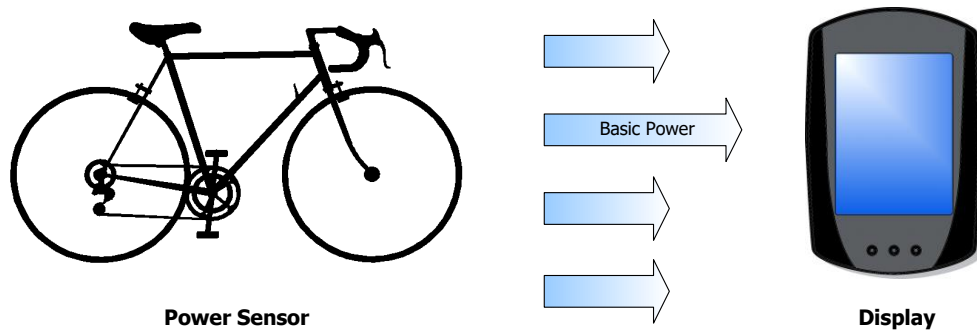


Figure 4-3. Simple Receiver Implementation

A summary of the differences between the simple and full receiver implementations is shown below in Table 4-1. At minimum, the display **shall [SD_0006]** display changing power and cadence values.

Table 4-1. Bike Power Receiver Implementation Comparison

| Simple Receiver Implementation (PWR) | CTF-Only Receiver Implementation | Full Receiver Implementation (PWR and CTF) |
|---|--|--|
| Receives the basic Power-Only message (0x10) | Receives CTF Main Data Page (0x20) | Receives all ANT+ messages |
| Message contains instantaneous power and cadence | Message contains detailed information such as torque and cadence. | Messages contain detailed information such as torque, cadence, and wheel speed |
| No calculations required to retrieve data from messages | Calculations are required to retrieve data from the messages | Calculations are required to retrieve data from messages |
| Data updated at 0.4Hz minimum; supports only time-synchronous updates | Messages support fine-time resolution of event data; e.g. an event-synchronous crank torque meter can capture every single pedal stroke up to 240RPM | Messages support fine-time resolution of event data; e.g. an event-synchronous crank torque meter can capture every single pedal stroke up to 240RPM |
| Allows receive-only implementation | Provides calibration and configuration interaction | Provides calibration and configuration interaction |
| Does not support calibration interaction | Support for manual CTF calibration is required as described in section 14.5 | Full support for manual calibration |
| Does not support Torque Frequency message. Optional support for TE & PS message | Does not support Power-Only message | Support for background messages and (optional) support for extended features such as Auto Zero configuration |
| No protection for RF outage | Accuracy maintained during loss of RF reception; average power can be accurately calculated over an RF outage lasting up to 30s | Accuracy maintained during loss of RF reception; average power can be accurately calculated over an RF outage lasting up to 30s |

4.4 Calibration Interaction

Another important feature of the ANT+ bike power device profile is defining the interaction between the power sensor and the display during calibration operations.

Most power sensors require occasional calibration or offset re-zeroing. An example of the interaction between the sensor and display for a manual calibration operation is shown in Figure 4-4.

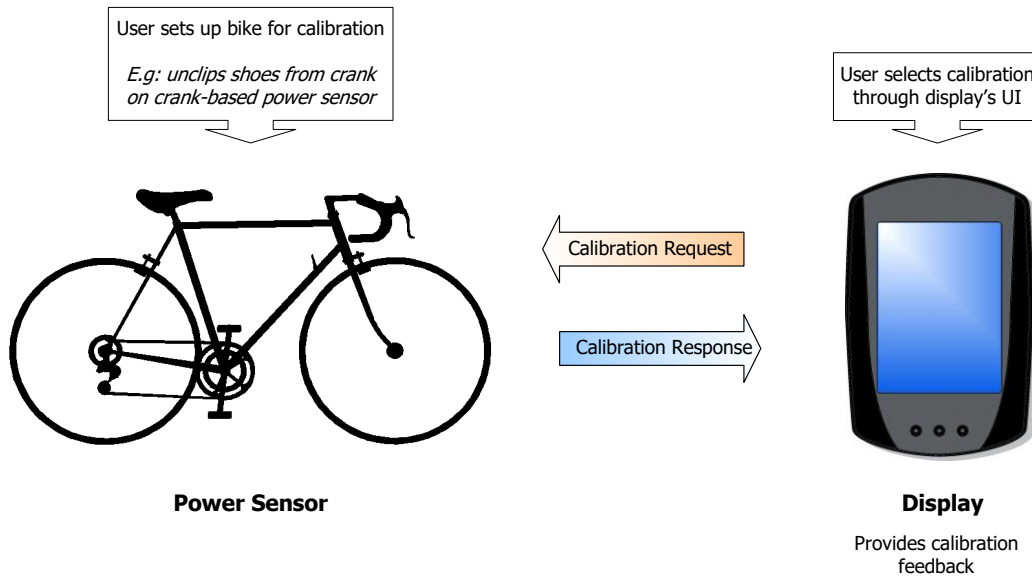


Figure 4-4. A Typical Manual Calibration Operation

Calibration request and response messages are detailed in Section 14.

4.5 Cycling Dynamics

Cycling dynamics consist of four distinct elements:

Power Phase – describes where a cyclist is generating power during a crank cycle. Power phase describes the angles at which positive torque begin and end during a crank cycle, giving insight into a user's pedal form. The peak power phase is also transmitted, documenting the angles between which applied torque is at its greatest during a crank cycle. On power meters that support both left and right power phase, the left and right phases can be compared to detect any imbalances between a rider's left and right legs and allow the user to train for balance.

PCO (Platform Center Offset) – describes where the center of force is applied across the pedal platform during a crank cycle. PCO may be used to help with injury rehabilitation and prevention.

Rider Position – describes the user's current form as either standing or sitting. The rider position helps users better understand their power and Cycling Dynamics with respect to their positioning on the bike.

Torque Barycenter – describes the angle which is the barycenter of the torque – including both negative and positive torque. This element may be used to determine the optimum position of an oval chain ring, or to gather biometric data about a rider's barycenter between rides.

The ANT+ Bike Power profile allows the display device to enable/disable these characteristics individually if they are supported by the sensor.

4.5.1 Pre-requisites

Because of the nature of power phase, PCO, rider position, and torque barycenter, not all types of power meters can compute Cycling Dynamics. If a power meter supports any one of the Cycling Dynamics, Advanced Capabilities page 2 **shall** [MD_PWR_010] be supported, with the appropriate capabilities set. If the power meter supports power phase, both get and set Power Phase Configuration commands **shall** [MD_PWR_010] be supported. If the power meter supports rider position, both get and set Rider Position Configuration commands **shall** [MD_PWR_010] be supported.

4.5.2 Enabling Cycling Dynamics

The following procedure is required to enable Cycling Dynamics characteristic(s) from a display device paired to a bike power sensor.

1. Request Get Subpage Advanced Capabilities 2. If the subpage is not received, no advanced capability is supported by the sensor.
2. Send Set Subpage Advanced Capabilities 2 with 8Hz enabled, and the Cycling Dynamic(s) that should be enabled, if the set page claims to support them. The sensor will now begin transmitting Cycling Dynamics pages.
3. Change receiving channel period to 8Hz. The sensor will be interleaving Cycling Dynamics pages into its transmission pattern and they can be received and decoded at the display.

5 Channel Configuration

The channel configuration parameters of the bike power sensor and all other ANT-enabled devices are defined by the ANT protocol. Refer to the ANT Message Protocol and Usage document for definitions of the various channel parameters.

5.1 Slave Channel Configuration

The device expected to receive data from an ANT+ bike power sensor **shall [SD_0001]** configure an ANT channel with the parameters listed in Table 5-1.

Table 5-1. ANT Channel Configuration for Receiving Bike Power Sensor Information

| Parameter | Value | Comment |
|----------------------|----------------------------|--|
| Channel Type | Receive (0x00) | Power sensors require bi-directional communication for calibration and manufacturing purposes. |
| Network Key | ANT+ Managed Network Key | The ANT+ Managed Network key is governed by the ANT+ Managed Network licensing agreement. |
| RF Channel Frequency | 57 | RF Channel 57 (2457 MHz) is used for the ANT+ bike power sensor. |
| Transmission Type | 0 for pairing | The transmission type must be set to 0 for a pairing search. Once the transmission type is learned, the receiving device should remember the type for future searches. To be future compatible, any returned transmission type is valid. Future versions of this spec may allow additional bits to be set in the transmission type. |
| Device Type | 11 (0x0B) | The device type shall [SD_0001] be set to 11 (0x0B) when searching to pair to an ANT+ bike power sensor. Please see the ANT Message Protocol and Usage document for more details. |
| Device Number | 1-65535 0 for searching | The transmitting sensor contains a 16-bit number that uniquely identifies its transmissions. Set the Device Number parameter to zero to allow wildcard matching. Once the device number is learned, the receiving device should remember the number for future searches. Please see the ANT Message Protocol and Usage document for more details. |
| Channel Period | 8182 counts | Data is transmitted from most bike power sensors every 8182/32768 seconds (approximately 4.00 Hz). This channel period shall [SD_0003] be used by default. |
| | 4091 | Some bike power sensors transmit at 4091/32768 messages per second. A bike power display may use this channel period for these sensors only. See section 15.2.2 for details. |
| Search Timeout | (Default = 30 seconds) | The default search timeout is set to 30 seconds in the receiver. This timeout is implementation specific and can be set by the designer to the appropriate value for the system. |

5.1.1 Transmission Type

The most significant nibble of the transmission type may optionally be used to extend the device number from 16 bits to 20 bits. In this case, the most significant nibble of the transmission type becomes the most significant nibble of the extended 20 bit device number. Therefore, a wildcard pairing scheme **shall [SD_0002]** always be used by a display that does not know the transmission type of the power sensor that it is searching for.



5.1.2 Channel Period

All receivers **shall [SD_0003]** use the 8182/32768 channel period (~4.00 Hz) to ensure reliable performance when pairing to new bike power sensors. When reconnecting to a pre-paired sensor that is known to transmit at 4091 counts, then the channel may be opened using either 8182 or 4091 counts. See section 15.2.2 for details.

5.1.3 Minimum Receiver Requirements for Full Compliance with the ANT+ Bike Power Specification

The following conditions must be met for a receiver to be fully compliant with the ANT+ Bike Power profile:

- Receive all power messages
- Provide the user a means to initiate and confirm a manual zero-offset calibration procedure (0x01). See Section 14.2.1
- Receive Manufacturer Information (ANT Common Data Page)
- Receive Product Information (ANT Common Data Page)

5.1.4 Optional Receiver Functions

The following messages may be supported but are not required for the minimum level of compliance with the ANT+ bike power specification.

- Auto Zero configuration (0x01, Calibration ID: 0xAB)
- Torque Effectiveness and Pedal Smoothness data page (0x13)
- Battery Status (ANT Common Data Page)

5.1.5 Power-Only Receiver Implementation

It is possible to receive basic data from most ANT+ power sensors by receiving the Power-Only message, and optionally the Torque Effectiveness and Pedal Smoothness message. No calculations are required – instantaneous power and cadence measurements are available directly in the message. However, the resolution of the data available from this message is not as high as that available from the torque at wheel and torque at crank data pages.

In addition:

- There is no protection for RF outage, and the update period may be as long as 2.25 seconds (maximum).
- Power-Only receivers are not compatible with torque frequency sensors.

5.2 Master Channel Configuration

The ANT+ bike power sensor **shall** [MD_0001] [MD_0002] [MD_0003] establish its ANT channel as shown in Table 5-2.

Table 5-2. ANT Channel Configuration for Transmitting Bike Power sensor Information

| Parameter | Value | Comment |
|-------------------|--|---|
| Channel Type | Master (0x10) | Power sensors require bi-directional communication for calibration and manufacturing purposes |
| Network Key | ANT+ Managed Network Key | The ANT+ Managed Network key is governed by the ANT+ Managed Network licensing agreement |
| RF Channel | 57 | Channel 57 is used for the ANT+ bike power sensor |
| Transmission Type | Set MSN to 0 (0x0) or MSN of extended device number. Set LSN to 5 (0x5) | ANT+ devices follow the transmission type definition as outlined in the ANT protocol. This transmission type cannot use a shared channel address and must be compliant with the global data messages defined in the ANT protocol |
| Device Type | 11 (0x0B) | The device shall [MD_0001] transmit its device type as 11 (0x0B) Please see the ANT Message Protocol and Usage document for more details |
| Device Number | 1-65535 | This is a two-byte field that allows for a unique identification of a given bike power sensor. It is imperative that the implementation allow for a unique device number to be assigned to a given device. An example of a method to implement a unique device ID is to use the lowest 2 bytes of the device's serial number. NOTE: The device number for the transmitting sensor must not be 0x0000 |
| Channel Period | 8182 | Data is transmitted every 8182/32768 seconds (approximately 4.0049Hz). Period chosen for compatibility with ANT devices |

5.2.1 Channel Type

As communication in two directions is required, the channel type **shall** [MD_0004] be set to bidirectional master (0x10). The bidirectional master channel is also used to enable the interference avoidance features inherent to the ANT protocol.

5.2.2 Transmission Type

The most significant nibble of the transmission type may optionally be used to extend the device number from 16 bits to 20 bits. In this case, the most significant nibble of the transmission type becomes the most significant nibble of the 20 bit device number.

5.2.3 Device Number

The device number needs to be as unique as possible across production units. An example of achieving this specification is to use the lowest two bytes of the serial number of the device for the device number of the ANT channel parameter.

The device number of the bicycle power sensor **shall** [self-verify] not be 0x0000. Be careful if the device number is derived from the lower 16-bits of a larger serial number that multiples of 0x10000 (65536) do not cause the device number to be set to 0.

6 General Bike Power Message Payload Format

An ANT channel configured as described in section 5 delivers bike power sensor messages. An 8-byte broadcast data packet payload is received every channel period.

It is important to note that all of the ANT+ messages sent by the bike power sensor — main data pages and common data pages — use page numbers to distinguish the different data page formats; the first byte of the data payload is always used to indicate the data page number. The ANT+ bike power specification provides multiple data page numbers to meet the requirements of the various ANT+ compatible power sensors.

All ANT messages have an 8-byte payload. For ANT+ bike power messages the first byte contains the data page number and the remaining 7 bytes are used for sensor-specific data.

Table 6-1. ANT+ Bike Power General Message Format

| Byte | Description | Length |
|------|------------------|---------|
| 0 | Data Page Number | 1 Byte |
| 1-7 | Data | 7 Bytes |

6.1 Data Page Number

The data page number is a single byte, which identifies to the host the type of power sensor and the format of the power message including any special data. Data page numbers may be extended to include new power sensors and different message types.

6.2 Data

The data portion of the power message usually includes an update event counter, a time stamp, and an accumulated power value. The time stamp and update event counter are used together to allow the receiver to accurately calculate power over an interval that may include missed messages.

6.3 Byte Order

Standard ANT messages are little endian for multi-byte fields; an exception is the Crank Torque-Frequency message format, which is big endian. All byte fields are explicitly defined in each message format.

There are three main types of bike power sensors. This section will describe the different sensor types and the data that these sensors transmit. A more detailed description of data pages for the different sensors will be provided in later sections of the device profile.

7 Bicycle Power Sensor Types

There are three types of bicycle power sensors and they have differing abilities to transmit information. This section will give an overview of what types of sensors can transmit certain types of data. The following sections will detail each type of sensor and the data that is available for transmission.

7.1 Overview of Defined Bike Power Data Pages

The following main data pages are defined for ANT+ bike power messages. Pages not defined in Table 7-1 are reserved for future use.

Table 7-1. ANT+ Bike Power Sensor Data Pages

| Data Page Number | Sensor Type | Direction | Message Description |
|------------------|-------------------------|--------------------------------------|--|
| 0x01 | All | Sensor → Display Display → Sensor | Calibration Messages |
| 0x02 | Standard | Display → Sensor Sensor → Display | Get/Set Parameters |
| 0x03 | Standard/ Power-Only | Sensor → Display | Measurement Output |
| 0x10 | Standard/ Power-Only | Sensor → Display | Standard – Power Only |
| 0x11 | Standard | Sensor → Display | Standard – Torque at Wheel |
| 0x12 | Standard | Sensor → Display | Standard – Torque at Crank |
| 0x13 | Standard/ Power-Only | Sensor → Display | Standard – Torque Effectiveness & Pedal Smoothness |
| 0x20 | CTF | Sensor → Display | Crank Torque-Frequency Message |
| 0xE0 | Standard Crank | Sensor → Display | Right Force Angle |
| 0xE1 | Standard Crank | Sensor → Display | Left Force Angle |
| 0xE2 | Standard Crank | Sensor → Display | Pedal Position Data |

7.2 Power-Only Sensors

Power-Only sensors measure power, but not torque or rotational speed. More details on power-only sensors can be found in section 8.

Update Method for all main data pages: Time-synchronous only. All Power-Only messages **shall [MD_PWR_003]** be updated at regular time intervals (and not event-synchronously).



Table 7-2. Power-Only Sensor Messages

| Function | Page Number | | Message | Details |
|--|-------------|--------|--|---|
| <i>Required</i> Power Main Data Page | 0x10 | | Standard Power Only | Default broadcast message |
| <i>Optional</i> TE & PS Main Data Page | 0x13 | | Torque Effectiveness and Pedal Smoothness | Minimum: Interleave every 5 messages (1.25s) |
| <i>Required</i> Common Data Page | 0x50 | | Manufacturer's Information | Minimum: Interleave every 121 messages (30.25 s) |
| <i>Required</i> Common Data Page | 0x51 | | Product Information | Minimum: Interleave every 121 messages (30.25s) |
| <i>Optional</i> Common Data Page | 0x52 | | Battery Voltage | Minimum: Interleave every 61 messages (15.25s) |
| Calibration Function | Page | Cal ID | Message | Details |
| <i>Required</i> Manual Calibration (Zero Offset) Page | 0x01 | 0xAA | Rx: Calibration request (0xAA) | Service calibration request when received from display. See section 14 for details. |
| | | 0xAC | Tx: Acknowledge (0xAC) | |
| | | 0xAF | Tx: Fail (0xAF) | |
| <i>Optional</i> Auto Zero | 0x01 | 0xAB | Rx: Autozero configuration (0xAB) | Service autozero configuration request when received from display (for sensors that self-monitor zero offset) |
| | | 0xAC | Tx: Acknowledge (0xAC) | |
| | | 0xAF | Tx: Fail (0xAF) | |
| <i>Optional</i> Custom Calibration Parameters | 0x01 | 0xBA | Custom Cal Parameter Request | Set custom calibration parameters See section 14 for details. |
| | | 0xBB | Custom Cal Parameter Response | |
| | | 0xBC | Custom Cal Parameter Update | |
| | | 0xBD | Custom Cal Parameter Update Response | |
| <i>Optional</i> Auto Zero Support | 0x01 | 0x12 | Tx: Auto zero status | Minimum: Interleave every 121 messages (30.25s) |
| <i>Optional</i> Get/Set Parameters | 0x02 | | Allows the display to get and set parameters on the sensor | Requested by display |
| <i>Optional</i> Measurement Output | 0x03 | | Allows raw measurement values, and progress to be sent to the display during calibration | Sent as part of calibration process only |

7.3 Torque Sensors

Torque may be measured at the bicycle crank or wheel. A separate message ID is used to identify the location of the torque sensor so that rotational velocity may be properly interpreted as either cadence or wheel speed. More details on torque sensors can be found in sections 9 and 10.

Update Method for all main data pages: Time-synchronous or event-synchronous

Table 7-3. Torque Sensor Messages

| Function | Page Number | | Message | Details |
|--|--------------|--------|--|--|
| Required Torque Main Data Page | 0x11 0x12 | | Tx: Standard Torque At Wheel OR Tx: Standard Torque At Crank | Default broadcast message |
| Required Power Main Data Page | 0x10 | | Standard Power Only | Minimum: Interleave every 9th message Preferred: Interleave every 5th message |
| Optional TE & PS Main Data Page | 0x13 | | Torque Effectiveness and Pedal Smoothness | Minimum: Interleave every 5 messages (1.25s) |
| Required Common Data Page | 0x50 | | Manufacturer’s Information | Minimum: Interleave every 121 messages (30.25s) |
| Required Common Data Page | 0x51 | | Product Information | Minimum: Interleave every 121 messages (30.25s) |
| Optional Common Data Page | 0x52 | | Battery Voltage | Minimum: Interleave every 61 messages (15.25s) |
| Calibration Function | Page | Cal ID | Message | Details |
| Required Manual Calibration (Zero Offset) Page | 0x01 | 0xAA | Rx: Calibration request (0xAA) | Service calibration request when received from display. See section 14 for details. |
| | | 0xAC | Tx: Acknowledge (0xAC) | |
| | | 0xAF | Tx: Fail (0xAF) | |
| Optional Auto Zero | 0x01 | 0xAB | Rx: Auto zero configuration (0xAB) | Service auto zero configuration request when received from display (for sensors that self-monitor zero offset) |
| | | 0xAC | Tx: Acknowledge (0xAC) | |
| | | 0xAF | Tx: Fail (0xAF) | |
| Optional Custom Calibration Parameters | 0x01 | 0xBA | Custom Cal Parameter Request | Set custom calibration parameters See section 14 for details. |
| | | 0xBB | Custom Cal Parameter Response | |
| | | 0xBC | Custom Cal Parameter Update | |
| | | 0xBD | Custom Cal Parameter Update Response | |
| Optional Auto Zero Support | 0x01 | 0x12 | Tx: Auto zero status | Minimum: Interleave every 121 messages (30.25s) |
| Optional Get/Set Parameters | 0x02 | | Allows the display to get and set parameters on the sensor | Requested by display |
| Optional Measurement Output | 0x03 | | Allows raw measurement values, and progress to be sent to the display during calibration | Sent as part of calibration process only |

7.4 Crank Torque Frequency Sensors

Crank torque frequency (CTF) power sensors are a special case for ANT+ power messages. They are not designed to convert torque to power at the sensor, they cannot broadcast the Power-Only main data page, and they do not broadcast any ANT+ common pages. For more details on crank torque frequency sensors refer to section 12.

Update Method: Event-synchronous only

Table 7-4. Crank Torque Frequency Sensor Messages

| Function | Page Number | | Message | Details |
|---|-------------|--------|---------------------------------|---|
| <i>Required</i> CTF Main Data Page | 0x20 | | Tx: Crank Torque Frequency | Default broadcast message |
| Calibration Function | Page | Cal ID | Message | Details |
| <i>Required</i> Manual Calibration (Zero Offset) Page | 0x01 | 0xAA | Rx: Calibration request (0xAA) | Service calibration request when received from display. See section 14 for details. |
| | | 0x10 | Tx: CTF offset data (0x10) | |
| <i>Optional</i> Save Slope to Flash | 0x01 | 0x20 | Rx: Save new slope value (0x20) | |
| | | 0xAC | Tx: Acknowledge (0xAC) | |

7.5 Dual Sided Sensors

Dual Sided sensors included crank based, pedal based and cleat based power systems that measure power exerted by each leg independently. These types of power meters appear as a single unit to a display device and may use power-only or crank torque messages. Communication between the left and the right parts of the system may be achieved using ANT, however the ANT+ key and frequency **shall not [MD_PWR_007]** be used. Instead developers may request the use of the ANT+ private key.

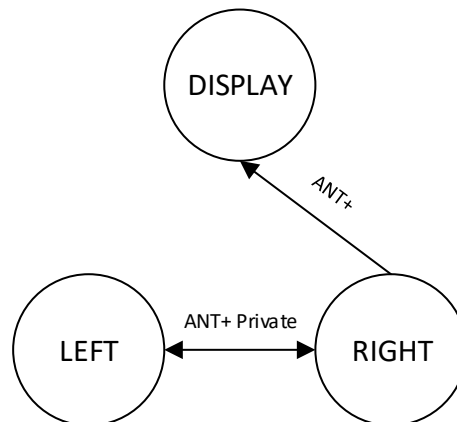


Figure 7-1. Use of ANT+ Private Key for Dual Sided Power Systems

7.5.1 ANT+ Private Key

The ANT+ private key is an unregulated ANT network key that may be used for communication between sensor elements of a power system (such as between the left and right pedals). ANT+ members may request this network key by sending a request to support@thisisant.com. Applicants must agree to, sign and submit the 'ANT+ Private Network Allocation Agreement' upon which they will receive the ANT+ Private key, an assigned frequency and channel device type. Manufacturers may specify their required channel period, however they must disclose this to ANT+ and not change it

without first informing ANT+. The payload used for communication is not regulated by ANT+ and may be defined by the manufacturer.

8 Standard Power-Only Main Data Page (0x10)

The standard power-only page is used to transmit power output directly in Watts. There are no conversions, calibrations, or calculations required. An accumulated power field is provided for greater reliability in degraded RF conditions. All fields in this message **shall [MD_0010]** be set as described in Table 8-1.

All power sensors (except CTF sensors) are required to support the standard power-only message in addition to any torque-based messages. Power-Only messages **shall [MD_0008]** be interleaved at least once in every 9 messages but interleaving at least once in every 5 messages is preferred. Byte 2 is an optional data field that **shall [MD_PWR_007]** be set to an invalid value when the sensor can only determine power on one pedal. Byte 2 is also a newer feature and may not be supported by all displays.

Table 8-1. Power-Only Message Format

| Byte | Description | Length | Value | Units | Rollover or Range |
|------|-------------------------|---------|---|-----------|-------------------|
| 0 | Data Page Number | 1 Byte | 0x10: standard Power-Only message | N/A | N/A |
| 1 | Update Event Count | 1 Byte | Power event count | N/A | 256 |
| 2 | Pedal Power | 1 Byte | Bit 7: Pedal Differentiation 1 - Right Pedal Power Contribution 0 – Unknown Pedal Power Contribution Bits 0-6: Pedal Power Percent Special Values: 0xFF – pedal power not used | % | 0-100% |
| 3 | Instantaneous Cadence | 1 Byte | Crank cadence – if available Otherwise: 0xFF indicates invalid | RPM | 0-254rpm |
| 4 | Accumulated Power LSB | 2 Bytes | Accumulated power 1-watt resolution | 1 Watt | 65.536kW |
| 5 | Accumulated Power MSB | | | | |
| 6 | Instantaneous Power LSB | 2 Bytes | Instantaneous power 1-watt resolution | 1 Watt | 0-65.535kW |
| 7 | Instantaneous Power MSB | | | | |

The instantaneous power value can be used by the receiver directly and has 1-watt resolution. No calculations are required to interpret the power.

8.1 Update Event Count

The update event count field is incremented each time the information in the message is updated. There are no invalid values for update event count. For Power-only sensors (refer to section 7.2) the time period of the update count depends on the system but must be a regular interval for accurate averaging.

The update event count in this message refers to updates only to the fields of this message. This update event count value is also used by the optional Torque Effectiveness and Pedal Smoothness data page (0x13). The values in data page 0x13 must correspond to those sent in a Power-only page and **shall [MD_PWR_003]** include the update event count value of the related Power-only page (See section 12).

Note that it is not permissible to send two different Torque Effectiveness and Pedal Smoothness data pages using the same update event counter value. Therefore, the Power-only page must be calculated at least as often as the TE & PS page, and care must be taken with interleaving. The Power-only page and /or the Torque Effectiveness and Pedal Smoothness page must be sent each time the update event counter is incremented. This is to ensure that the display is able to identify missed messages.

8.2 Pedal Power

The pedal power data field provides the user's power contribution (as a percentage) between the left and right pedals, as measured by a pedal power sensor. For example, if the user's power was evenly distributed between the left and right pedals, this value would read 50%. If the power was not evenly distributed, for example if the pedal power measured 70%, some sensors may or may not know which pedal has the greater power contribution. The most significant bit is used to indicate if the pedal power sensor is capable of differentiating between the left and right.

8.2.1 Pedal Differentiation Bit

This bit is used to indicate the pedal power sensor's ability to determine between the left and right pedals. If this bit is set to 1, then the value stored in bits 0 – 6 represent the percent power contribution applied to the *right* pedal, and the remaining percent (i.e. 100% - value) is the percent power contribution applied to the left pedal.

If the pedal power sensor is unable to differentiate between the left and right pedals, this bit is set to zero.

8.2.2 Pedal Power Percent

This data field represents the user's power contribution to a single pedal and is an integer value representing percent. If the pedal differentiation bit is set to 1, this value corresponds to the percent contribution applied to the *right* pedal.

8.3 Instantaneous Cadence

The instantaneous cadence field is used to transmit the pedaling cadence recorded from the power sensor. This field is an instantaneous value only; it does not accumulate between messages.

The value 0xFF is sent in this field to indicate that the power sensor cannot measure pedaling cadence. 0xFF is interpreted as an invalid value and is ignored by the display.

8.4 Accumulated Power

Accumulated power is the running sum of the instantaneous power data and is incremented at each update of the update event count. The accumulated power field rolls over at 65.535kW. At 2Hz power event updates, there are sufficient buffers over all power levels.

Table 8-2. Time to Buffer Overflow for a Given Power

| Power (Watts) | Time to Buffer Overflow (seconds) |
|------------------|--------------------------------------|
| 100 | 327 |
| 500 | 65 |
| 2000 | 16 |

8.5 Average Power Calculations

In the following formula, N refers to the most recent message received, and $N-1$ refers to the received message immediately preceding N .

$$AveragePower = \frac{\Delta AccumulatedPower}{\Delta EventCount} = \frac{AccumulatedPower_N - AccumulatedPower_{N-1}}{EventCount_N - EventCount_{N-1}}$$

Equation 1. Average Power Calculation

Under normal conditions with complete RF reception, average power equals instantaneous power. In conditions where packets are lost, average power accurately calculates power over the interval between the received messages.



9 Standard Wheel Torque Main Data Page (0x11)

The standard wheel torque page is used to send event timing information and torque values from a power sensor that measures torque on the rear wheel. Timing is based on a 2048Hz clock and torque is transmitted in Newton meters. All fields in this message **shall [MD_0010]** be set as described in Table 9-1.

Table 9-1. Wheel Torque Message Format

| Byte | Description | Length | Value | Units | Rollover or Valid Range |
|------|------------------------|---------|---|-------------------|-------------------------|
| 0 | Data Page Number | 1 Byte | 0x11 – sensor measures torque at wheel | N/A | N/A |
| 1 | Update Event Count | 1 Byte | Event counter increments with each information update. | N/A | 256 |
| 2 | Wheel Ticks | 1 Byte | Wheel tick count increments with each wheel revolution. | Wheel revolutions | 256 (~550 meters) |
| 3 | Instantaneous Cadence | 1 byte | Crank cadence – if available Otherwise: 0xFF indicates invalid | RPM | 0-254rpm |
| 4 | Wheel Period LSB | 2 bytes | Accumulated wheel period (updated each event) | 1/2048s | 32s |
| 5 | Wheel Period MSB | | | | |
| 6 | Accumulated Torque LSB | 2 bytes | Accumulated torque (updated each event) | 1/32Nm | 2048Nm |
| 7 | Accumulated Torque MSB | | | | |

9.1 Update Event Count

The update event count is incremented each time the information in the data page is updated. There are no invalid values for update event count.

Rollover: Power sensors may update information at a fixed time interval (time-synchronous updates) or each time a wheel rotation event occurs (event-synchronous update). The Wheel Torque message works for both update methods.

The update event count in time-synchronous update systems rolls over at a fixed time interval equal to 256 times the update period.

Table 9-2. Time to Update Event Counter Rollover for a Given Update Rate

| Fixed Update Rate (Hz) | Time to Rollover (seconds) |
|------------------------|----------------------------|
| 1 | 256 |
| 4 | 64 |

Alternately, the update event count may increment with each complete wheel revolution. The update event counter rolls over at 256 events; based on typical speeds this ranges between 20 seconds and three minutes as outlined in Table 9-3.

Table 9-3. Time to Update Event Counter Rollover for a Given Speed

| Speed (km/h) | Time to Rollover (seconds) |
|--------------|----------------------------|
| 10 | 192 |
| 30 | 64 |
| 60 | 32 |
| 80 | 24 |

9.2 Wheel Ticks

The wheel ticks field increments with each wheel revolution and is used to calculate linear distance traveled. The wheel ticks field rolls over every 256 wheel revolutions, which is approximately 550 meters assuming a 2m wheel circumference. There are no invalid values for this field.

For event-synchronous systems, the wheel ticks and update event count increment at the same rate.

9.3 Instantaneous Cadence

The instantaneous cadence field is used to report the pedaling cadence recorded from the power sensor. This is an instantaneous value only and does not accumulate between messages. The value 0xFF is sent in this field to indicate that the power sensor cannot measure pedaling cadence. 0xFF is interpreted as an invalid value and is ignored by the display.

9.4 Accumulated Wheel Period

The accumulated wheel period is used to indicate the average rotation period of the wheel during the last update interval, in increments of 1/2048s. This frequency is chosen because it is a factor of the common 32.768kHz crystal and because it provides a practical balance between resolution and available data bandwidth.

Each Wheel Period tick represents a 488-microsecond interval. In event-synchronous systems, the accumulated wheel period time stamp field rolls over in 32 seconds. In fixed time interval update systems, the time to rollover depends on wheel speed but is greater than 32 seconds.

As a rider increases velocity, the period of each revolution decreases and the uncertainty due to the resolution of the wheel period time interval becomes a proportionally larger part of the calculated speed. This means that the resolution of speed measurement changes with speed. For a practical speed range between 20 and 50km/h, the speed resolution is finer than 0.2km/h; for speeds as high as 80km/h the resolution is less than 0.5km/h.

Table 9-4. Speed Measurement Resolution for a Given Speed

| Speed (km/h) | Seconds Per Revolution (seconds) | Wheel Rotation Ticks Per Revolution | Speed Measurement Resolution (km/h) |
|--------------|----------------------------------|-------------------------------------|-------------------------------------|
| 2 | 3.88 | 7937 | 0.00 |
| 20 | 0.38 | 774 | 0.03 |
| 60 | 0.13 | 129 | 0.23 |
| 80 | 0.09 | 97 | 0.41 |

9.4.1 Interpreting Zero Speed from Standard Wheel Torque Data

9.4.1.1 Time-synchronous Update

To indicate zero rotational velocity, do not increment the accumulated wheel period and do not increment the wheel ticks. The update event count continues incrementing to indicate that updates are occurring, but since the wheel is not rotating the wheel ticks do not increase. Displays should interpret a zero change in accumulated wheel period as zero speed.

9.4.1.2 Event-synchronous Update

If the wheel is not rotating in an event-synchronous system, new power updates cannot occur and the sensor continues to broadcast the last message. Displays should interpret repeated messages as zero rotational velocity. The number of seconds of repeated messages before interpreting zero speed is left to the manufacturer.

9.5 Accumulated Torque

The accumulated torque is the cumulative sum of the average torque measured every update event count. The accumulated torque field is 2 bytes. The resolution of power measurement changes with speed, but stays below the 1-watt level for the most useful speed range.

Table 9-5. Power Resolution for a Given Speed

| Speed (km/h) | Power Resolution (Watts) |
|-----------------|-----------------------------|
| 20 | 0.5 |
| 40 | 0.8 |
| 60 | 1.0 |
| 80 | 1.6 |

The amount of time required to reach the rollover value of the accumulated torque field (2048Nm) varies with power output.

Table 9-6. Time to Accumulated Torque Rollover for a Given Power Output

| Power (Watts) | Time to Rollover (seconds) |
|------------------|-------------------------------|
| 200 | 64 |
| 400 | 32 |
| 1000 | 13 |

9.6 Speed and Distance Computations

To calculate speed and distance, the receiving device requires knowledge of the wheel circumference in meters. This value is entered by the user. N refers to the most recent message received, and $N-1$ refers to the received message immediately preceding N .

$$Speed_{AVE} = \frac{3600}{1000} \cdot \frac{Circumference \cdot (UpdateEventCount_N - UpdateEventCount_{N-1})}{\left(\frac{WheelPeriod_N - WheelPeriod_{N-1}}{2048} \right)} [km / h]$$

Equation 2. Average Speed Calculation for Wheel Torque Sensor

$$\Delta Dist = Circumference \cdot (WheelTicks_N - WheelTicks_{N-1}) [m]$$

Equation 3. Distance Calculation for Wheel Torque Sensor

NOTE: Do **not** use wheel ticks to calculate linear speed.

9.7 Power Calculations

See Section 11 for details.



10 Standard Crank Torque Main Data Page (0x12)

The standard crank torque page is used to send event timing information and torque values from a power sensor that measures torque at the crank. Timing is based on a 2048Hz clock and torque is transmitted in Newton meters. All fields in this message **shall** [MD_0010] be set as described in Table 10-1.

Table 10-1. Crank Torque Message Format

| Byte | Description | Length | Value | Units | Rollover or Valid Range |
|------|------------------------|---------|--|-------------------|-------------------------|
| 0 | Data Page Number | 1 Byte | 0x12 – sensor measures torque at crank | N/A | N/A |
| 1 | Update Event Count | 1 Byte | Event counter increments with each information update. | N/A | 256 |
| 2 | Crank Ticks | 1 Byte | Crank ticks increment with each crank revolution. | Crank Revolutions | 256 |
| 3 | Instantaneous Cadence | 1 Byte | Crank cadence – if available Otherwise: 0xFF | RPM | 0-255rpm |
| 4 | Crank Period LSB | 2 Bytes | Accumulated crank period (updated each event) | 1/2048s | 32s |
| 5 | Crank Period MSB | | | | |
| 6 | Accumulated Torque LSB | 2 Bytes | Accumulated torque (updated each event) | 1/32Nm | 2048Nm |
| 7 | Accumulated Torque MSB | | | | |

10.1 Update Event Count

The update event count is incremented each time the information in the message is updated. There are no invalid values for update event count.

Rollover: Power sensors may update information on a fixed frequency (time-synchronous) or with each rotation event (event-synchronous).

If the power sensor uses a fixed period for updates (time-synchronous system), the event count increments each time an update is available and rolls over at a rate equal to the update period times 256.

Table 10-2. Time to Update Event Count Rollover for a Given Update Rate

| Fixed Update Rate (Hz) | Time to Rollover (seconds) |
|------------------------|----------------------------|
| 1 | 256 |
| 4 | 64 |

Alternatively, in event-synchronous systems, the update event count increments with every complete crank revolution. Even at extreme cadences, there is more than one minute of buffer before a rollover occurs.

Table 10-3. Time to Update Event Count Rollover for a Given Cadence

| Cadence (RPM) | Time to Rollover (mm:ss) |
|----------------------|---------------------------------|
| 20 | 12:45 |
| 60 | 4:15 |
| 120 | 2:33 |
| 240 | 1:03 |

10.2 Crank Ticks

The crank ticks increment with each crank revolution and indicates a full rotation of the crank. The crank ticks field rolls over every 256 crank revolutions. There are no invalid values for crank ticks.

For systems that update synchronously with crank events (event-synchronous), the crank ticks and update event count increment at the same rate.

10.3 Instantaneous Cadence

The instantaneous cadence field is used to report the pedaling cadence recorded from the power sensor. This is an instantaneous value only and does not accumulate between messages. The value 0xFF is sent in this field to indicate that the power sensor cannot measure pedaling cadence. 0xFF is interpreted as an invalid value and is ignored by the display.

10.4 Accumulated Crank Period

The accumulated crank period is used to indicate the average rotation period of the crank during the last update interval, in increments of 1/2048s. This frequency is chosen because it is a factor of the common 32.768kHz crystal and because it provides a practical balance between resolution and available data bandwidth. Refer to section 10.4.1 for information on how to handle zero cadence situations.

Each crank period tick represents a 488-microsecond interval. In event-synchronous systems, the accumulated crank period field rolls over in 32 seconds. In fixed update (time-synchronous) systems the time to rollover depends on wheel speed, but is greater than 32 seconds.

Table 10-4. Cadence Resolution for a Given Cadence

| Cadence (RPM) | Seconds Per Revolution | Ticks Per Revolution | Cadence Resolution (RPM) |
|----------------------|-------------------------------|-----------------------------|---------------------------------|
| 0 (by definition) | - | 16384 (0x4000) | 0.00 |
| 8 | 7.5 | 15360 | 0.00 |
| 20 | 3 | 6144 | 0.00 |
| 60 | 1 | 2048 | 0.03 |
| 120 | 0.5 | 1024 | 0.12 |
| 240 | 0.25 | 512 | 0.47 |

As a rider pedals faster, the period of each crank revolution decreases and the uncertainty in the Crank Period interval due to timing resolution becomes a proportionally larger part of the calculated cadence. The cadence resolution remains finer than 0.5 RPM for the entire practical input range.

10.4.1 Interpreting Zero Cadence from Standard Crank Torque Data

10.4.1.1 Time-synchronous Update

To indicate zero rotational velocity, the accumulated crank period should not be incremented. The update event count continues to be incremented to indicate that updates are occurring, but since the crank is not rotating, the crank ticks do not increase. Displays should interpret a zero change in accumulated crank period as zero cadence.

10.4.1.2 Event-synchronous Update

If the crank is not rotating in an event-synchronous system, new power updates cannot occur and the sensor continues to broadcast the last message. Displays should interpret repeated messages as zero cadence. The number of seconds of repeated messages that must occur before interpreting zero cadence is left to the manufacturer to decide.

10.5 Accumulated Torque

The accumulated torque is the cumulative sum of the average torque measured every crank rotation event. The accumulated torque field is 2 bytes.

Table 10-5. Crank Power Resolution for a Given Cadence

| Cadence (RPM) | Power Resolution (Watts) |
|---------------|--------------------------|
| 60 | 0.2 |
| 80 | 0.3 |
| 100 | 0.3 |
| 120 | 0.4 |

The time required to reach the rollover value of the accumulated torque field (2048Nm) varies with power output.

Table 10-6. Time to Accumulated Torque Rollover for a Given Cadence Power Output

| Power (Watts) | Time to Rollover (seconds) |
|---------------|----------------------------|
| 200 | 64 |
| 400 | 32 |
| 1000 | 13 |

10.6 Cadence Computation

The average cadence in RPM is computed from the update event count and elapsed time. N refers to the most recent message received, and $N-1$ refers to the received message immediately preceding N .

$$Cadence_{AVE} = 60 \cdot \frac{(UpdateEventCount_N - UpdateEventCount_{N-1})}{\left(\frac{CrankPeriod_N - CrankPeriod_{N-1}}{2048} \right)} [RPM]$$

Equation 4. Average Cadence Computation for Crank Torque Sensor

10.7 Power Calculations

See Section 11 for details.

11 Computing Power from Standard Torque Data Messages

The device that is receiving the standard torque data messages must apply the following calculations to properly derive and display the computed bike power.

The period, update event count, and cumulative torque are used to calculate angular velocity and power. In the calculations that follow N refers to the most recent message received, and $N-1$ refers to the message immediately preceding N . The following calculations apply to the standard wheel torque message and the standard crank torque message.

NOTE: If the wheel or crank is revolving at less than 240RPM (4Hz), multiple messages may arrive that describe the same event.

11.1 Average Angular Velocity

The average angular velocity (rad/s) between two received messages is computed from the number of rotation events divided by the rotation period.

$$AngularVel_{AVE} = \frac{2\pi \cdot (UpdateEventCount_N - UpdateEventCount_{N-1})}{\left(\frac{Period_N - Period_{N-1}}{2048} \right)} [radians / s]$$

Equation 5. Calculation of Angular Velocity

11.2 Average Torque

The average torque between two received messages is computed from the difference in accumulated torque, divided by the number of rotation events. Accumulated torque is broadcast in 1/32Nm, which must be factored back out.

$$Torque_{AVE} = \frac{(AccumulatedTorque_N - AccumulatedTorque_{N-1})}{32 \cdot (UpdateEventCount_N - UpdateEventCount_{N-1})} [Nm]$$

Equation 6. Calculation of Average Torque

11.3 Average Power

The average power in Watts between two received messages is the product of average torque and average angular velocity over the interval.

$$Power_{AVE} = Torque_{AVE} \cdot AngularVel_{AVE} [Watts]$$

Equation 7. Calculation of Average Power 1

If average torque and angular velocity are not used, the average power in Watts can be calculated directly from the accumulated torque and period.

$$Power_{AVE} = 128\pi \frac{(AccumulatedTorque_N - AccumulatedTorque_{N-1})}{Period_N - Period_{N-1}} [Watts]$$

Equation 8. Calculation of Average Power 2

12 Torque Effectiveness and Pedal Smoothness Main Data Page (0x13)

This data page is an optional page that can be used by power-only or torque sensors, as described in section 7. It is used to send the instantaneous values of left and right Torque Effectiveness and either left and right, or combined, Pedal Smoothness from the sensor. This page should be interleaved with other messages such that it is sent at least once every 5 messages. Calculations may be performed by the display to create averaged values if desired. All fields in this message **shall [MD_0010]** be set as described in Table 12-1.

Table 12-1. Torque Effectiveness and Pedal Smoothness Message Format

| Byte | Description | Length | Value | Units | Rollover or Valid Range |
|------|-------------------------------------|---------|---|-------|-------------------------|
| 0 | Data Page Number | 1 Byte | 0x13 – Torque Effectiveness and Pedal Smoothness percentages | N/A | N/A |
| 1 | Update Event Count | 1 Byte | Event counter increments with each power-only information update. This value is tied to the event counter on the Power Only page. | N/A | 256 |
| 2 | Left Torque Effectiveness | 1 Byte | Left leg torque effectiveness 0xFF: Invalid or negative values | 1/2% | 0-100% |
| 3 | Right Torque Effectiveness | 1 Byte | Right leg torque effectiveness 0xFF: Invalid or negative values | 1/2% | 0-100% |
| 4 | Left (or combined) Pedal Smoothness | 1 Byte | Left pedal smoothness, or combined pedal smoothness if byte 5 is set to 0xFE 0xFF: Invalid | 1/2% | 0-100% |
| 5 | Right Pedal Smoothness | 1 Byte | Right pedal smoothness FE: Combined pedal smoothness being sent in byte 4 0xFF: Invalid | 1/2% | 0-100% |
| 6-7 | Reserved | 2 Bytes | Set to 0xFF | N/A | N/A |

NOTE: The sensor must transmit 0xFF for all byte fields marked as 'Reserved'. The receiver must not interpret these values.

12.1 Update Event Count

The update event count value in this data page is tied to the value used in the standard power-only page. There are no invalid values for update event count. This is described in section 8.1.

12.2 Torque Effectiveness

Values for left and right torque effectiveness can be sent in bytes 2 and 3 (Table 12-1). As torque effectiveness cannot be measured on combined systems, then any sensors that cannot distinguish between the torque applied to the left and right crank arms should set these bytes to invalid (0xFF).

In addition, although it is possible to measure negative values of torque effectiveness (for example if a cyclist resists the pedal more than they push it) it is expected that the range of interesting values will lie between 0 – 100%. Therefore negative values of torque effectiveness **shall [self-verify]** be sent as invalid (0xFF).



12.2.1 Calculating Torque Effectiveness

The Torque Effectiveness is calculated for each crank arm based on the positive (clockwise) and negative (anti-clockwise) torque applied to the crank over each revolution. Figure 12-1 shows a typical torque curve, where P_+ represents the positive power applied to the bike and is the sum of the instantaneous power measurements. Similarly, P_- is the sum of the negative instantaneous power measurements (i.e. power lost from the bike as negative torque is applied to the pedals).

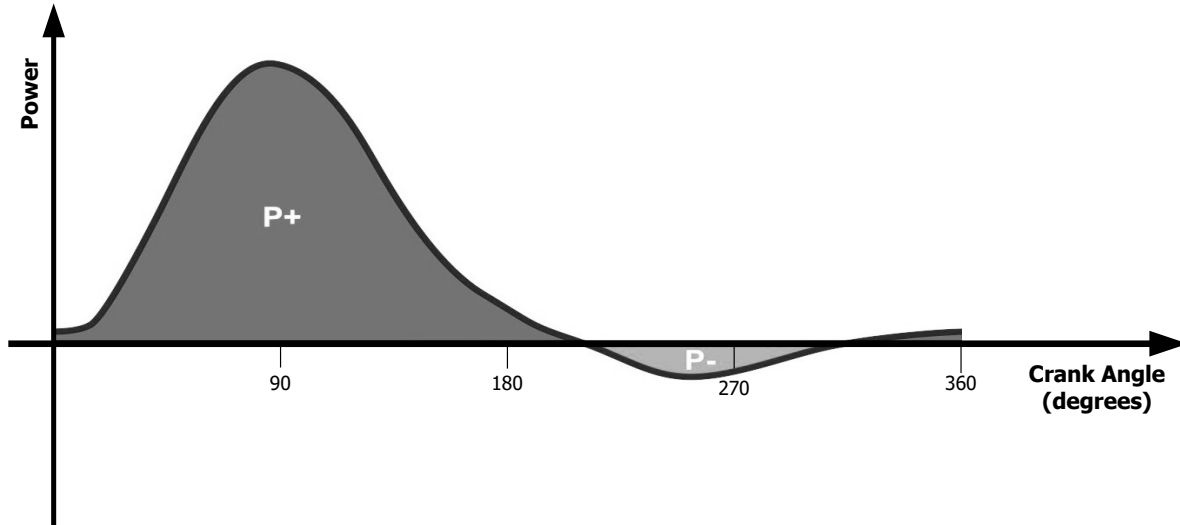


Figure 12-1 Instantaneous Power vs. Crank Angle

Equation 9 defines Torque Effectiveness in terms of P_+ and P_- (note that P_- will be a negative value):

$$\text{Torque Effectiveness} = \frac{100 \times (P_+ + P_-)}{P_+}$$

Equation 9. Calculation of Torque Effectiveness

12.3 Pedal Smoothness

If the sensor is able to distinguish between the left and right leg's Pedal Smoothness values, then the appropriate values should be sent according to Table 12-1. If the Pedal Smoothness is calculated as a combined value across both pedals, then the resulting value should be sent in byte 4, and byte 5 should be set to 0xFE. If a single sensor is in use that measures either left or right pedal smoothness, then pedal smoothness should be sent in either the byte 4 or byte 5 respectively, and the unused byte should be set to invalid (0xFF).

12.3.1 Calculating Pedal Smoothness

P_{avg} is the mean power averaged across 1 crank cycle and P_{max} is the peak power applied during that cycle, as shown in Figure 12-2. These values can be used to calculate pedal smoothness, as defined as in Equation 10. The shape of the power curve and the resulting value of pedal smoothness will vary depending on the style of riding, and on whether the power is measured per crank arm (i.e. in left-right systems) or for the whole system.

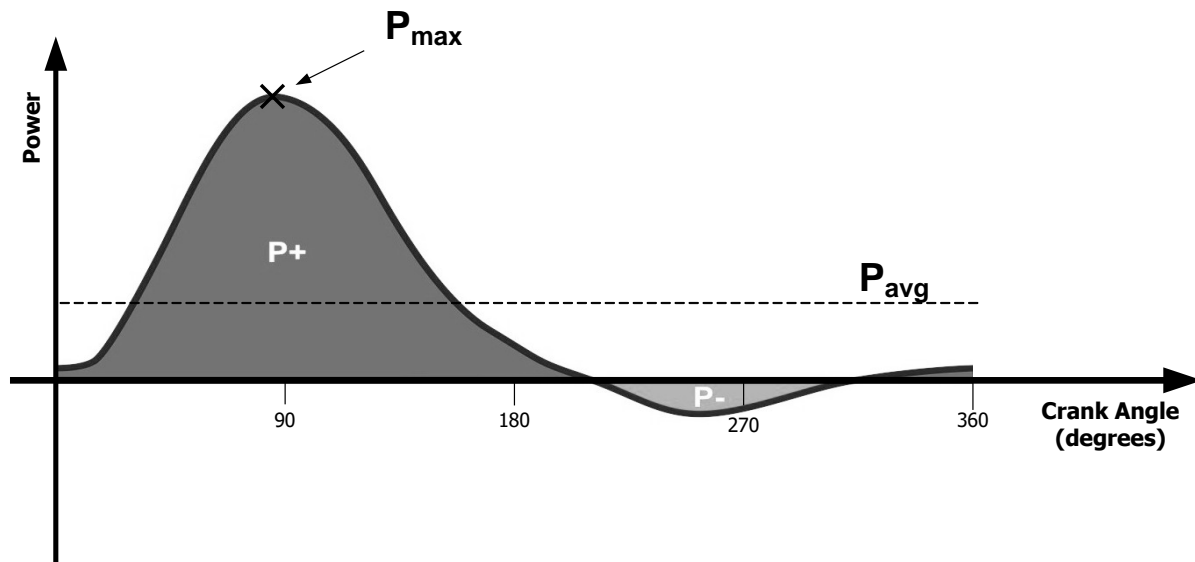


Figure 12-2. Values used to calculate Pedal Smoothness

$$\text{Pedal Smoothness} = \frac{P_{avg}}{P_{max}}$$

Equation 10. Calculation of Pedal Smoothness



13 Crank Torque Frequency Main Data Page (0x20)

Crank Torque Frequency main data pages for power sensors are similar in form to the other main data pages, but allow the power sensor to transmit torque as a frequency. Currently only one Crank Torque Frequency main data page is defined. The necessary calibration values are passed such that the receiver can calculate power from the time stamp and torque ticks stamp. Time stamping uses a 2000Hz clock. All fields in this message **shall [MD_0010]** be set as described in Table 13-1.

NOTE: Crank torque-frequency messages are big endian. The byte order for multi-byte fields in these messages is reversed with respect to standard ANT+ messages.

Table 13-1. Crank Torque Frequency Message Format

| Byte | Description | Length | Value | Units | Rollover or Valid Range |
|------|------------------------|---------|---|------------|-------------------------|
| 0 | Data Page Number | 1 Byte | 0x20 – Crank Torque Frequency | N/A | N/A |
| 1 | Update Event Count | 1 Byte | Rotation event counter increments with each completed pedal revolution. | N/A | 256 |
| 2 | Slope MSB | 2 Bytes | Slope defines the variation of the output frequency. | 1/10 Nm/Hz | 100 – 500 |
| 3 | Slope LSB | | | | |
| 4 | Time Stamp MSB | 2 Bytes | Time of most recent rotation event | 1/2000s | 32.7s |
| 5 | Time Stamp LSB | | | | |
| 6 | Torque Ticks Stamp MSB | 2 Bytes | Count of most recent torque event | N/A | 65536 ticks |
| 7 | Torque Ticks Stamp LSB | | | | |

13.1 Update Event Count

The update event count increments with each complete pedal stroke. The update event count is used to indicate the number of cadence events that have occurred between two consecutively received messages. Even at extreme cadences there is more than one minute of buffer before a rollover occurs.

Table 13-2. Time to Crank Torque Frequency Rollover for a Given Cadence

| Cadence (RPM) | Time to Rollover (mm:ss) |
|---------------|--------------------------|
| 20 | 12:45 |
| 60 | 4:20 |
| 120 | 2:05 |
| 240 | 1:05 |

NOTE: After 3 seconds without a new cadence event, the display should change the displayed cadence to zero.

13.2 Slope Value

The slope is a configuration value required by the display to convert torque ticks into units of Newton metres. It is saved to the power sensor's flash memory during manufacturing. Slope ranges in value from 10.0Nm/Hz to 50.0Nm/Hz. To send slope as an integer, the slope field is sent in units of 1/10 Nm/Hz, with values ranging between 100 and 500. Slope is included in every message so that special messaging is not required at startup to retrieve it.

13.3 Time Stamp

The crank torque-frequency message uses a 2000Hz clock to time cadence events. The time stamp field indicates the time of the most recent cadence event. Each time stamp tick represents a 500-microsecond interval. The time stamp field rolls over every 32.7 seconds.

Table 13-3. Cadence Resolution for a Given Cadence

| Cadence (RPM) | Seconds Per Revolution | Ticks Per Revolution | Cadence Resolution (RPM) |
|---------------|------------------------|----------------------|--------------------------|
| 20 | 3 | 6000 | 0.0 RPM |
| 60 | 1 | 2000 | 0.0 RPM |
| 120 | 0.5 | 1000 | 0.1 RPM |
| 240 | 0.25 | 500 | 0.5 RPM |

As a rider pedals faster, the period of each revolution decreases and the uncertainty in time stamp interval becomes a proportionally larger part of the calculated cadence or speed. At cadences below 120 RPM, the timing resolution is finer than the required display resolution.

13.4 Torque Ticks Stamp

The torque ticks stamp represents the most recent value of torque ticks since the last registered revolution. The amount of time that the torque ticks stamp provides protection against RF outage depends on torque, cadence, and calibration values. Under the most extreme conditions, with maximum slope (50Nm/Hz) and maximum offset (1000Hz) there is adequate buffer for transmission loss.

Table 13-4. Time until Overflow of Torque Ticks for a Given Cadence

| Cadence (RPM) | Time until Overflow (seconds) for Output of 1000W | Time until Overflow (seconds) for Output of 300W |
|---------------|---|--|
| 60 | 7 | 19 |
| 80 | 9 | 23 |
| 100 | 11 | 27 |
| 120 | 13 | 30 |
| 240 | 22 | 41 |

13.5 Encoding Crank Torque Frequency Messages

The torque ticks stamp is incremented every 2kHz clock cycle. When a cadence event occurs the current update event count is incremented by one, the time stamp of the 2kHz clock is recorded, and the value of the torque accumulator is incremented. At each channel period the information from the most current cadence event is broadcast.

13.6 Power Calculations Using Crank Torque Frequency Messages

The device that is receiving the Crank Torque Frequency main data pages must apply the following calculations to properly derive and display the computed bike power.

The ANT+ protocol calculates the average power and cadence over the pedal strokes that have occurred between the two most recently received messages. In most cases, this refers to a single crank rotation, since the received messages are consecutive. When degraded RF transmission results in packet loss, the ANT+ protocol maintains an accurate measurement of average power and cadence during the RF interruption.

In the following calculations, N refers to the most recent message received, and $N-1$ refers to the message immediately preceding N .

13.6.1 Calculating Cadence

$$CadencePeriod = \frac{Timestamp_N - TimeStamp_{N-1}}{EventCount_N - EventCount_{N-1}} \times 0.0005s[s]$$

$$Cadence = round(60 / CadencePeriod)[rpm]$$

Equation 11. Calculation of Cadence using Crank Torque Frequency

13.6.2 Calculating Torque

$$ElapsedTime = (Timestamp_N - TimeStamp_{N-1}) \times 0.0005s$$

$$TorqueTicks = TorqueTicksStamp_N - TorqueTicksStamp_{N-1}$$

Equation 12. Calculations for Elapsed Time and Torque Ticks

The average torque per revolution of the pedal is calculated using the calibrated Offset parameter.

Equation 13. Calculation of Torque Frequency

Torque in Nm is calculated from torque rate (Torque Frequency) using the calibrated sensitivity Slope.

$$TorqueFrequency = \left(\frac{1}{\frac{ElapsedTime}{TorqueTicks}} - Offset \right) [Hz]$$

Equation 14. Calculation of Torque from the Torque Rate

Finally, power is calculated from the cadence and torque.

$$Torque = \left(\frac{TorqueFrequency}{\frac{Slope}{10}} \right) [Nm]$$

$$Power = \left(Torque \cdot Cadence \cdot \frac{\pi}{30} \right) [Watts]$$

Equation 15. Calculation of Power using Torque

13.7 Cadence Time

When the user stops pedaling, the update event count field in broadcast messages does not increment. After receiving 12 messages with the same update event count (approximately 3 seconds), the receiving device should change the cadence and power displays to zero.

14 Calibration Main Data Pages

Most power sensors have a procedure for periodic recalibration. ANT+ calibration data pages provide a standard means for a user-initiated calibration sequence to be coordinated between the sensor and display. For the crank torque frequency power sensor, calibration messages are used to assign or check configuration values in the power sensor memory.

Users may optionally initiate calibration via a display or directly from the sensor, for example by back pedaling or coasting during a ride. Therefore it is recommended that displays should accept spontaneous forward direction calibration messages, and display the calibration result to the user.

Because it is important to know that these messages have been received, all calibration messages sent from the display **shall [SD_PWR_001] [SD_PWR_002]** use ANT acknowledged messages. Firmware in the display device should be written so that messages are re-sent when ANT responds with EVENT_TRANSFER_TX_FAILED from the acknowledged message as there are no automatic retries using the acknowledged data transfers. **Note that the sensor shall [MD_PWR_001] [MD_PWR_002] respond to the calibration request using broadcast messages only. The sensor shall [MD_0006] never send an acknowledged message to the display.** Firmware on the display should also account for the possibility of the devices becoming unsynchronized during a calibration request. In this case, a timeout for acknowledged messages is required.

Using ANT acknowledged messages means that calibration messages may be re-sent multiple times if they are not acknowledged. The sensor side must correctly handle repeated messages.

14.1 Standard Calibration Message Format

The standard calibration message format is shown below in Table 14-1.

Table 14-1. Standard Calibration Message Format

| Byte | Description |
|------|--|
| 0 | Data Page Number |
| 1 | Calibration ID |
| 2-7 | Calibration data (defined by Calibration ID) |

14.1.1 Calibration ID

The calibration ID is used to identify the operation requested and how to interpret the remaining contents of the message.

Table 14-2. Currently Defined Calibration IDs

| Value | Description |
|-------|---|
| 0xAA | Calibration Request: Manual Zero |
| 0xAB | Calibration Request: Auto Zero Configuration |
| 0xAC | Calibration Response: Manual Zero Successful |
| 0xAF | Calibration Response: Failed |
| 0x10 | Crank Torque Frequency (CTF) Power sensor Defined Message |
| 0x12 | Auto Zero Support |
| 0xBA | Custom Calibration Parameter Request |
| 0xBB | Custom Calibration Parameter Response |
| 0xBC | Custom Calibration Parameter Update |
| 0xBD | Custom Calibration Parameter Update Response |

14.2 General Calibration Main Data Pages

In the most general case, a calibration request sent from the display device to the power sensor instructs the power sensor to begin calibration. The instructions required by the sensor for calibration vary for each manufacturer. The power sensor responds to the request with a calibration response message - the calibration was successful or the calibration failed. The sensor returns up to two bytes of calibration data.

14.2.1 General Calibration Request Main Data Page (0xAA)

Different power sensors may have different procedures for self-calibration, but in general they require the user to put the sensors in a known state. For example, a user with a crank-mounted power sensor might turn on the sensor without clipping his/her pedals in so that no torque is applied to the pedals.

The generic calibration request page (Table 14-3) is sent from the display device to the sensor to indicate that the specific conditions required for calibration have been met and that a calibration is requested. All fields in this message **shall** [MD_0010] be set as described in Table 14-3.

Table 14-3. General Calibration Request Message Format

| Byte | Description | Length | Value | Units |
|------|------------------|---------|--------------------------------|-------|
| 0 | Data Page Number | 1 Byte | 0x01 (calibration message) | N/A |
| 1 | Calibration ID | 1 Byte | 0xAA (calibration request) | N/A |
| 2 | Reserved | 6 Bytes | 0xFF (reserved for future use) | N/A |
| 3 | Reserved | | | |
| 4 | Reserved | | | |
| 5 | Reserved | | | |
| 6 | Reserved | | | |
| 7 | Reserved | | | |

14.2.2 Auto Zero Configuration Main Data Page (0xAB)

In addition to manually resetting offset values, some power sensors are able to maintain their offset values automatically. Settings for auto zero features are controlled using the Auto Zero Configuration page and are reported in all calibration responses. All fields in this message **shall** [SD_PWR_002] be set as described in Table 14-4.

Table 14-4. Auto Zero Configuration Message Format

| Byte | Description | Length | Value | Units |
|------|------------------|---------|---|-------|
| 0 | Message ID | 1 Byte | 0x01 (Calibration Message) | N/A |
| 1 | Calibration ID | 1 Byte | 0xAB (Calibration Request: auto zero configuration) | N/A |
| 2 | Auto Zero Status | 1 Byte | 0x00 – Auto Zero OFF 0x01 – Auto Zero ON 0xFF – Auto Zero Not Supported | N/A |
| 3 | Reserved | 5 Bytes | 0xFF (reserved for future use) | N/A |
| 4 | Reserved | | | |
| 5 | Reserved | | | |
| 6 | Reserved | | | |
| 7 | Reserved | | | |

The Auto Zero Configuration page is used to change the auto zero settings on the power sensor. The power sensor must indicate that auto zero features are enabled for this feature to be supported properly at the display. It is recommended that the auto zero capable power sensors regularly interleave Torque Meter Capabilities data page (0x12) (see Section 14.3).

- Displays are not required to support Auto-Zero configuration messages in the user interface. If auto zero configuration is not provided, the user cannot adjust auto zero with that display.
- Note that Auto Zero status is contained in all calibration messages, because the use of manual operations and the use of automatic operations are not exclusive.

14.2.3 General Calibration Response Main Data Page (0xAC/0xAF)

The general calibration response page is shown in Table 14-5. The power sensor transmits this page to the display device in response to a calibration request. All fields in this message **shall [MD_PWR_002]** be set as described in Table 14-5.

Table 14-5. General Calibration Response Message Format

| Byte | Description | Length | Value | Units |
|------|----------------------|---------|--|-------|
| 0 | Data Page Number | 1 Byte | 0x01 (Calibration Message) | N/A |
| 1 | Calibration ID | 1 Byte | 0xAC (Calibration Response Successful) 0xAF (Calibration Response Failed) | N/A |
| 2 | Auto Zero Status | 1 Byte | 0x00 – Auto Zero Is OFF 0x01 – Auto Zero Is ON 0xFF – Auto Zero Is Not Supported | N/A |
| 3 | Reserved | 3 Bytes | Set to 0FFFFFFF | N/A |
| 4 | Reserved | | | |
| 5 | Reserved | | | |
| 6 | Calibration Data LSB | 2 Bytes | This is a signed two-byte number allowing for values ranging from -32768 to +32767 | N/A |
| 7 | Calibration Data MSB | | | |

The last two bytes of this message are defined as the Calibration Data and are sent whether or not the Calibration ID is responding with a successful calibration response (0xAC) or a failure response (0xAF). This value is passed back from the sensor to the display to provide an indication to the user about the quality of the calibration. The Calibration Data bytes do not have units and may vary for each manufacturer. This value is a signed number allowing for both negative and positive data.

For example, upon completing calibration a torque-sensing power sensor could save the current zero-offset to the calibration data. A display can then show this value to the user each time a calibration is requested. In the case of a failed calibration, the sensor could use the calibration data bytes to report an error code.

NOTE: The calibration data is not used by the display to calculate or correct the power messages received by the sensor. It is intended to indicate the result of the calibration to the user. If the calibration data value is significantly different from the number the user is accustomed to seeing, it may indicate to the user that calibration should be performed again or that the power sensor requires service.



14.2.4 General Calibration Process Data Flow

Figure 14-1 describes the calibration data flow expected between the bike power sensor and the display device.

NOTE: The acknowledgement portion of the message, labeled 'ANT Ack*', is automatically sent by ANT. No application level code is required to send the acknowledgement; however, instead of waiting for the EVENT_TX message, the EVENT_TRANSFER_TX_COMPLETED or EVENT_TRANSFER_TX_FAILED is used as an event. Refer to the ANT Message Protocol and Usage document for more details.

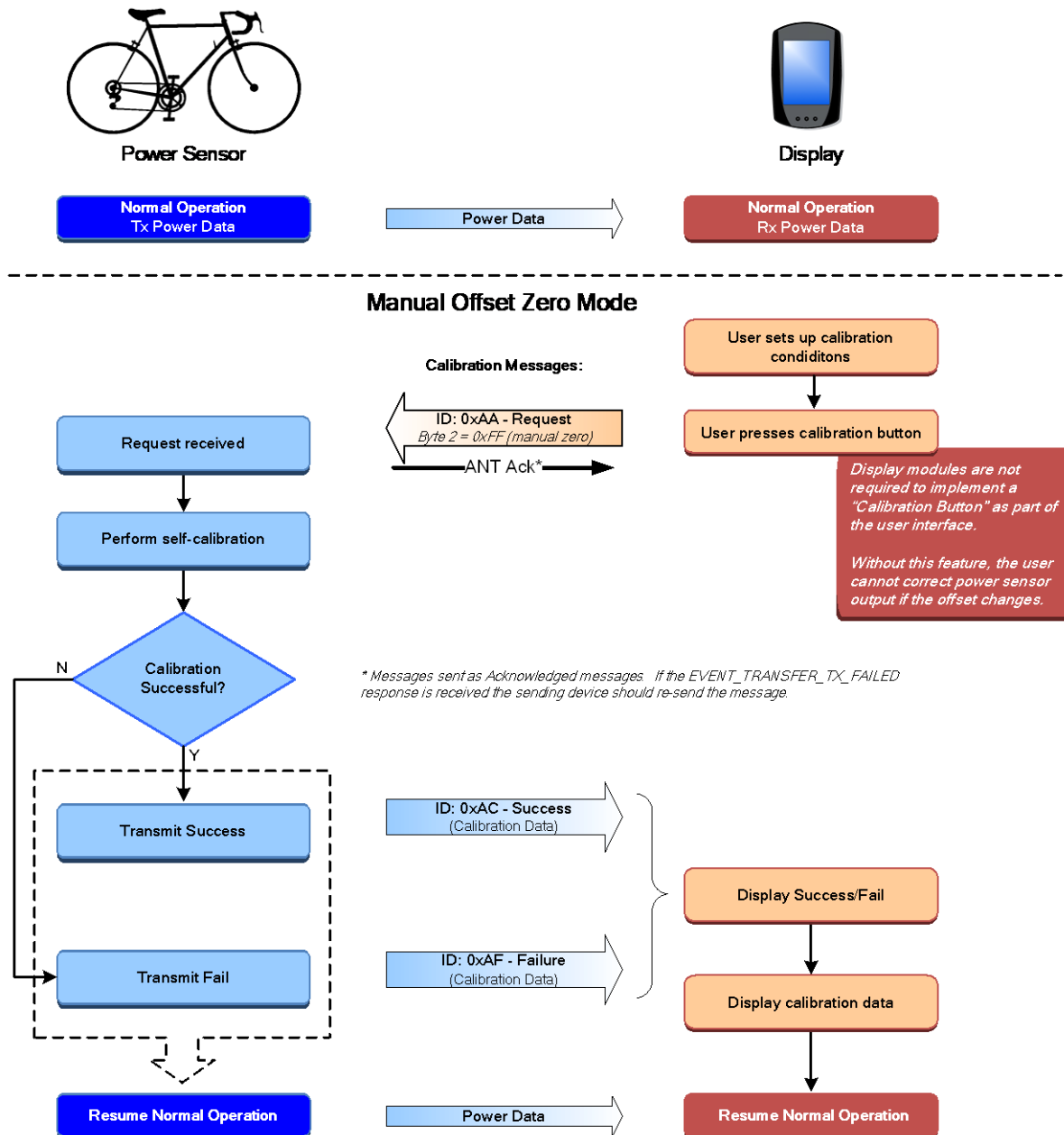


Figure 14-1. General Calibration Process Flow Chart

In Figure 14-2 the sequence diagram shows the same procedure as shown in the previous flow chart to give a different representation of the same procedure. In the event that the Display does not receive either an



EVENT_TRANSFER_TX_SUCCESS or EVENT_TRANSFER_TX_FAILED, the display **shall [self-verify]** resend the calibration request.

Note: Previous revisions of this profile described using acknowledged data types when sending calibration responses from the power sensor. Forward direction acknowledgement from sensor to display should be avoided as it introduces race conditions in the one-to-many network topology that this profile is designed to support. Messages sent from the Sensor to the Display should use broadcast data types only.

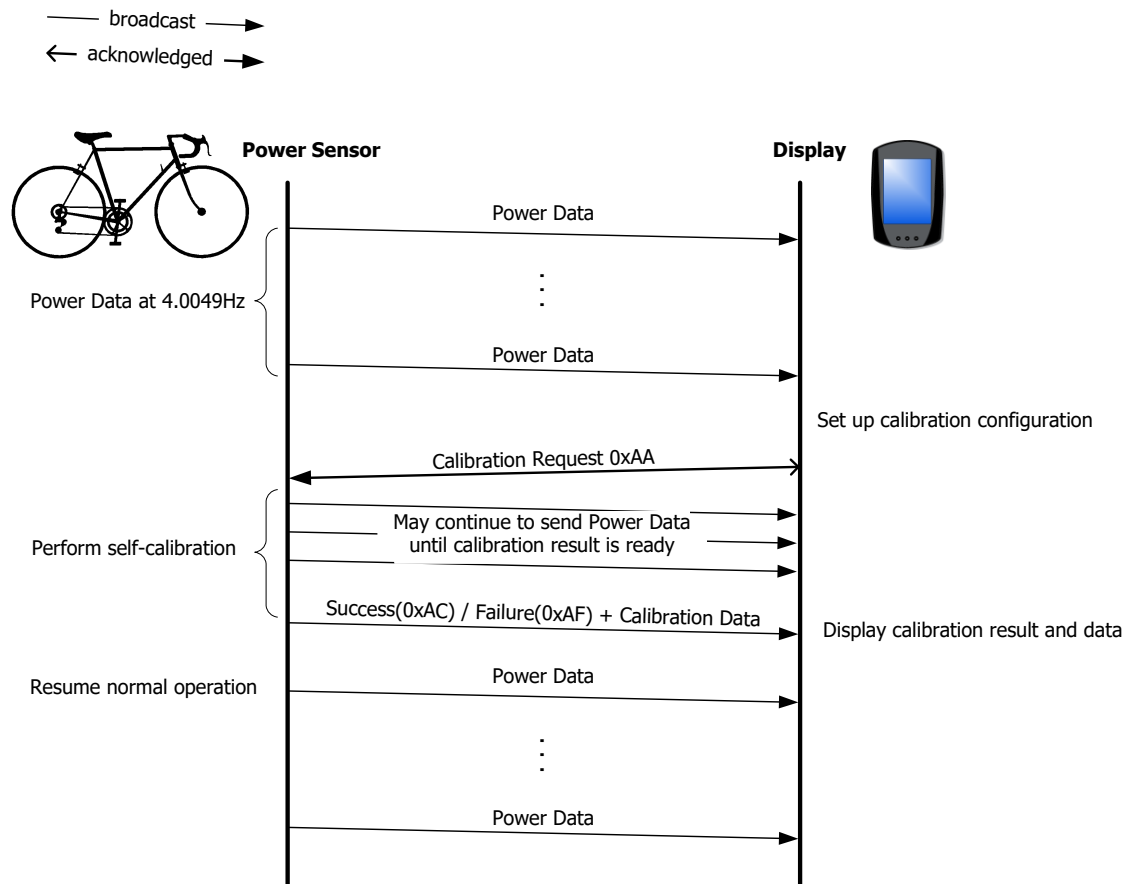


Figure 14-2. Calibration Process Sequence Diagram

14.2.5 Auto Zero Configuration Data Flow

Figure 14-3 describes the data flow expected between the bike power sensor and the display device for setting the Auto Zero configuration. It is important to note that the acknowledged portion of the message, labeled 'ANT Ack*', is automatically sent by ANT. No application level code is required to send the acknowledgement; however, instead of waiting for the EVENT_TX message, the EVENT_TRANSFER_TX_COMPLETED or EVENT_TRANSFER_TX_FAILED is used as an event. Refer to the ANT Message Protocol and Usage document for more details.

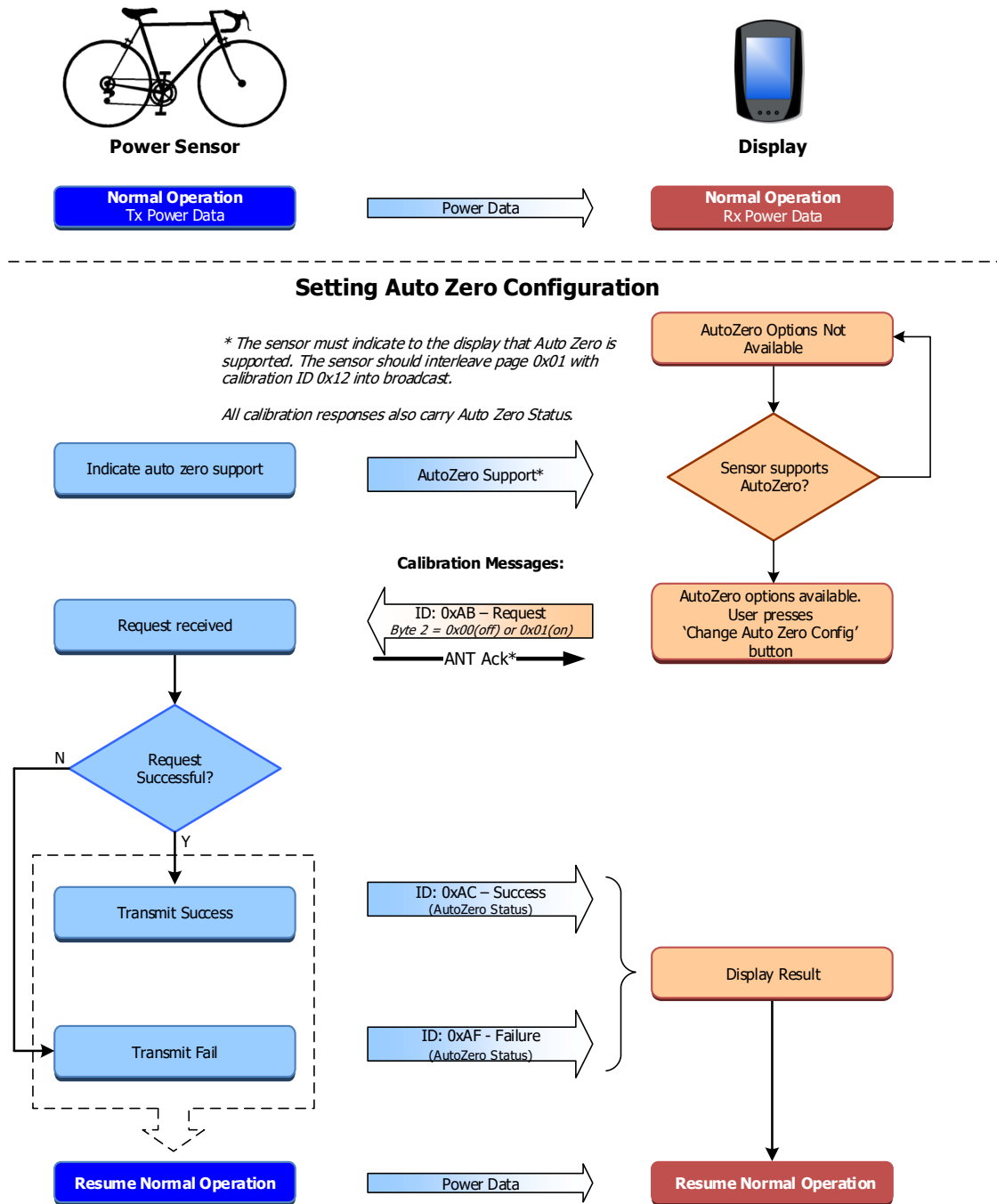


Figure 14-3. Auto Zero Configuration Flow Chart

Figure 14-4 shows the message flow that is also described in Figure 14-3. It illustrates the display receiving the calibration message described in section 14.3, which shows that the power sensor supports Auto Zero, and indicates whether it is currently on or off. The display therefore allows the user to change the auto zero settings and receives a success or failure response from the power sensor, before resuming normal operation.

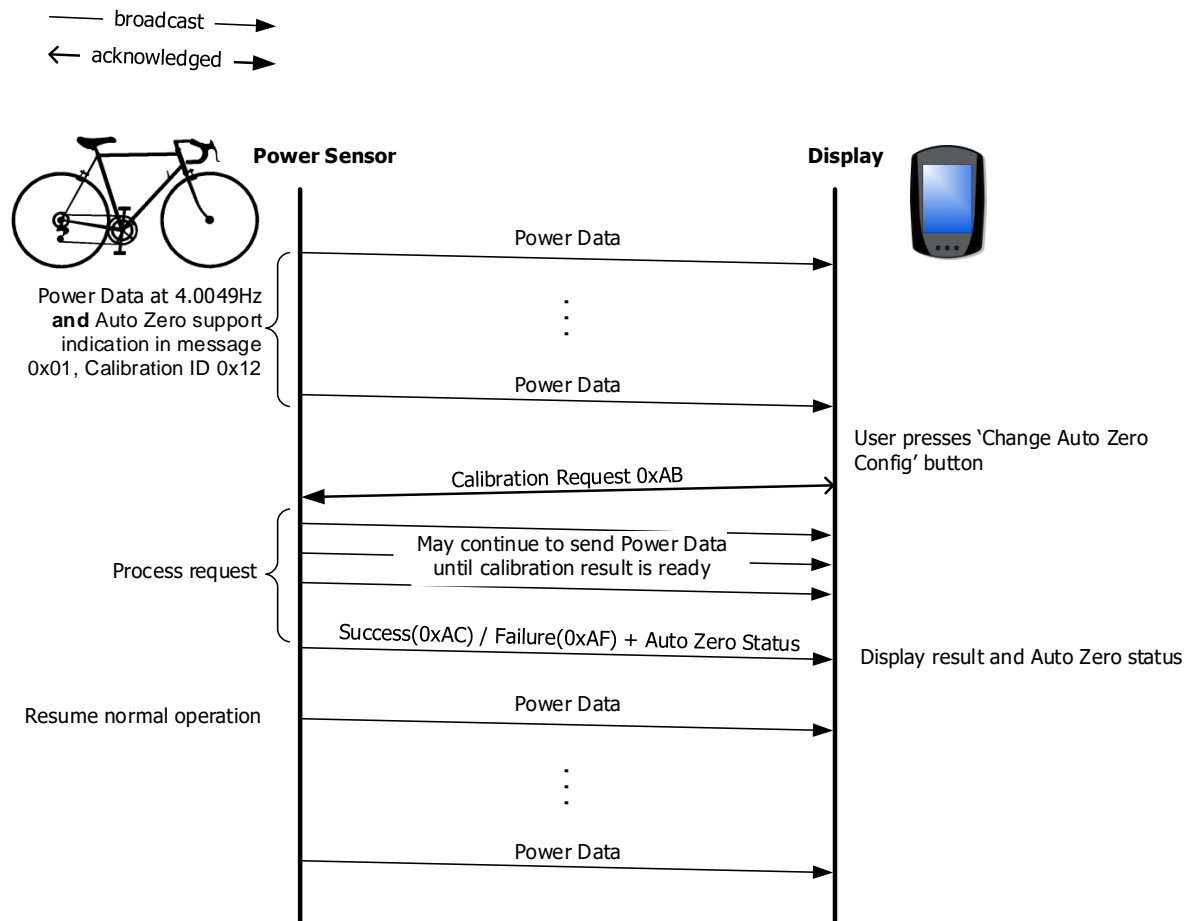


Figure 14-4. Auto Zero Configuration Sequence Diagram



14.3 Auto Zero Support Main Data Page

The Torque Meter Capabilities page is defined to allow extended information to be passed from the sensor to the display. The message provides status information on auto zero functions. The information does not need to be interpreted by the display for proper calculation of power. All fields in this message **shall [MD_PWR_002]** be set as described in Table 14-6.

For the display to support auto zero functions, the Torque Meter Capabilities main data page should be interleaved at least once every 121 messages.

Table 14-6. Auto Zero Support Message Format

| Byte | Description | Length | Value | | Units |
|------|--|---------|--------------------------------|-------------------|-------|
| 0 | Data Page Number | 1 Byte | 0x01 (Calibration Message) | | N/A |
| 1 | Calibration ID | 1 Byte | 0x12 Auto Zero Support message | | N/A |
| 2 | Sensor Configuration Descriptive Bit Field | 1 Byte | 0 – Auto Zero Enable | 0 – Not Supported | |
| | | | | 1 – Supported | |
| | | | 1 – Auto Zero Status | 0 – Auto Zero Off | |
| | | | | 1 – Auto Zero On | |
| | | | 2 – 7 – Reserved | Value = 0 | |
| 3 | Reserved | 5 Bytes | 0xFF (reserved for future use) | | N/A |
| 4 | Reserved | | | | |
| 5 | Reserved | | | | |
| 6 | Reserved | | | | |
| 7 | Reserved | | | | |

14.3.1 Reserved Bytes

In earlier revisions of this device profile, bytes 3 through 6 were specified as raw and offset torque values. These values were not in use in the field and have been removed from this page.

14.3.2 Sensor Configuration

Byte 2 of the message is a bit field providing information about the power sensor, including whether the power sensor supports auto zero functions.

14.4 Get/Set Custom Calibration Parameters

Some power sensors may support custom calibration parameters that can be set by a display to customize performance. The 'Custom Calibration Parameters' messages provide a common method for requesting and setting custom calibration data on the power sensor. All fields in this message **shall [MD_0010]** be set as described in Table 14-7.

Support for this messaging is optional, and the interpretation of the custom calibration parameters is controlled by the manufacturer, not ANT+. Table 14-7 lists the available custom calibration messages.

Table 14-7. Custom Parameter Request

| Byte | Description | Length | Value | Units |
|------|------------------|---------|--|-------|
| 0 | Data Page Number | 1 Byte | 0x01 (Calibration Message) | N/A |
| 1 | Calibration ID | 1 Byte | 0xBA (Request Custom Calibration Parameters) 0xBB (Custom Calibration Parameter Response) 0xBC (Set Custom Calibration Parameter) 0xBD (Set Custom Parameters Successful) | N/A |
| 2 | Reserved | 6 Bytes | Manufacturer Specific | N/A |
| 3 | Reserved | | | |
| 4 | Reserved | | | |
| 5 | Reserved | | | |
| 6 | Reserved | | | |
| 7 | Reserved | | | |

Figure 14-5 below describes the expected data flow between the bike power sensor and display for requesting or setting the custom calibration parameters. Note, this process makes use of acknowledged messages. Note that ANT automatically handles the acknowledgement (ANT Ack*). The application does not need additional code to send the acknowledgement; however, instead of waiting for the EVENT_TX message, EVENT_TRANSFER_TX_COMPLETED or EVENT_TRANSFER_TX_FAILED will be received and should be handled accordingly. Refer to the ANT Message and Protocol and Usage document for more details.

Note: If the 'Set Parameters' request is not successful, a 'Calibration Failed' (0xAF) is returned.



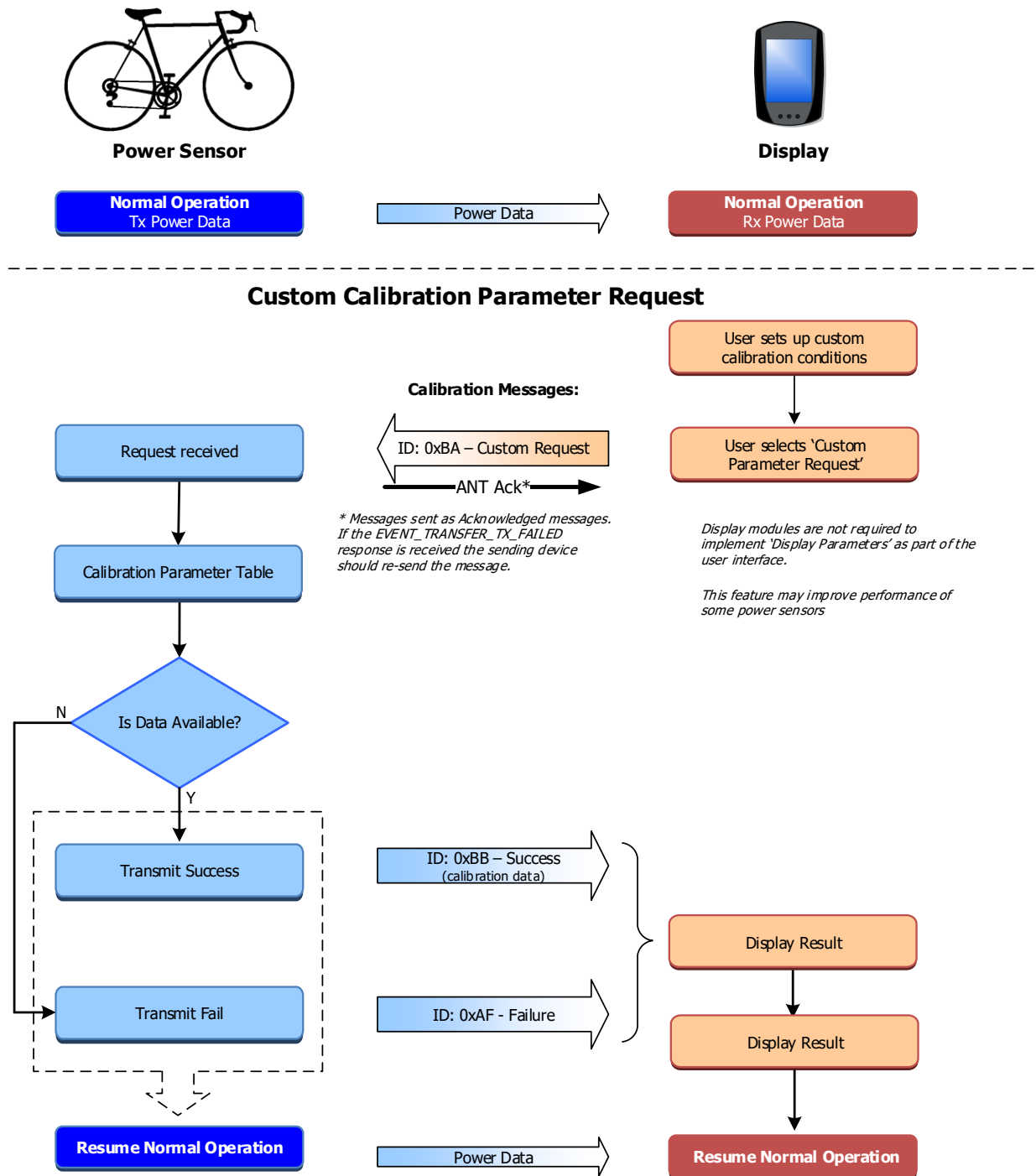


Figure 14-5. Request Custom Parameter Process Flow Chart

Figure 14-6 shows the sequence diagram of the same request custom calibration parameter procedure. Note that normal operation does not resume until the calibration result is successfully received by the power meter sensor.

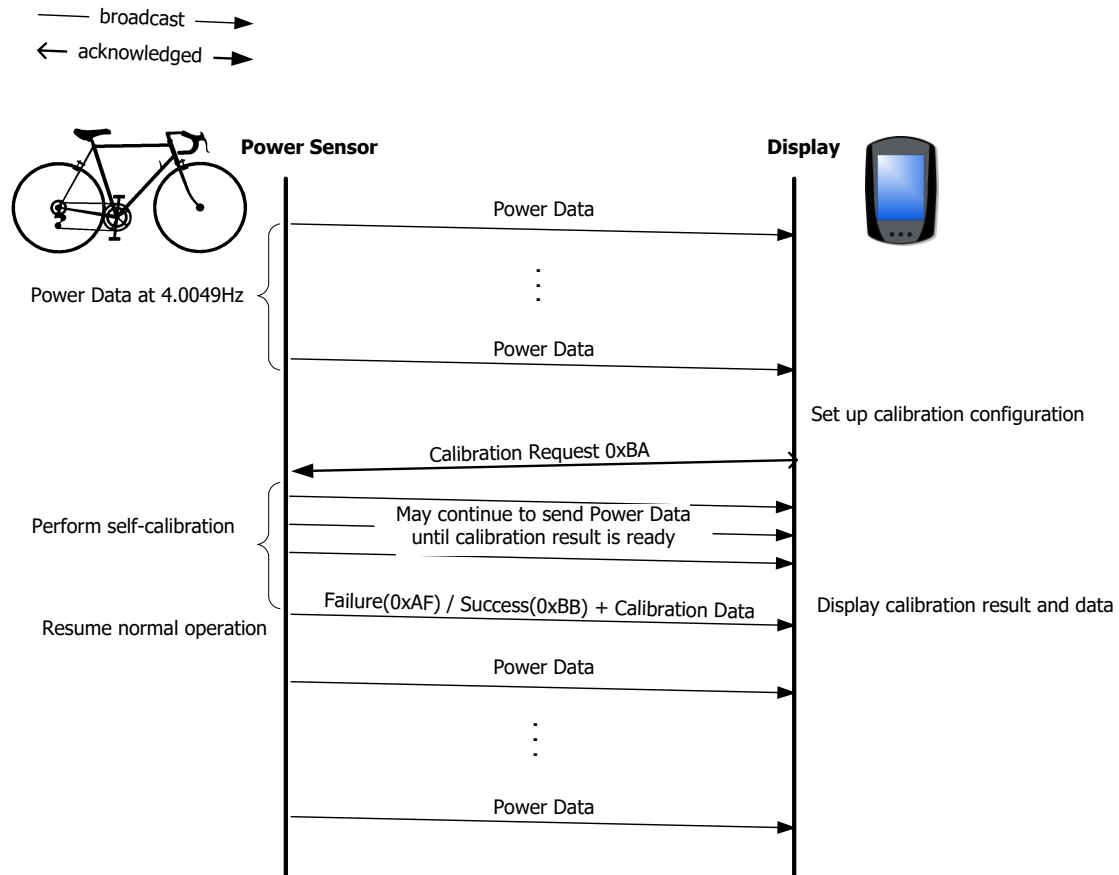


Figure 14-6. Custom Calibration Request Sequence Diagram

Figure 14-7 and Figure 14-8 show the flow chart and sequence diagram of the set custom calibration parameter procedure.

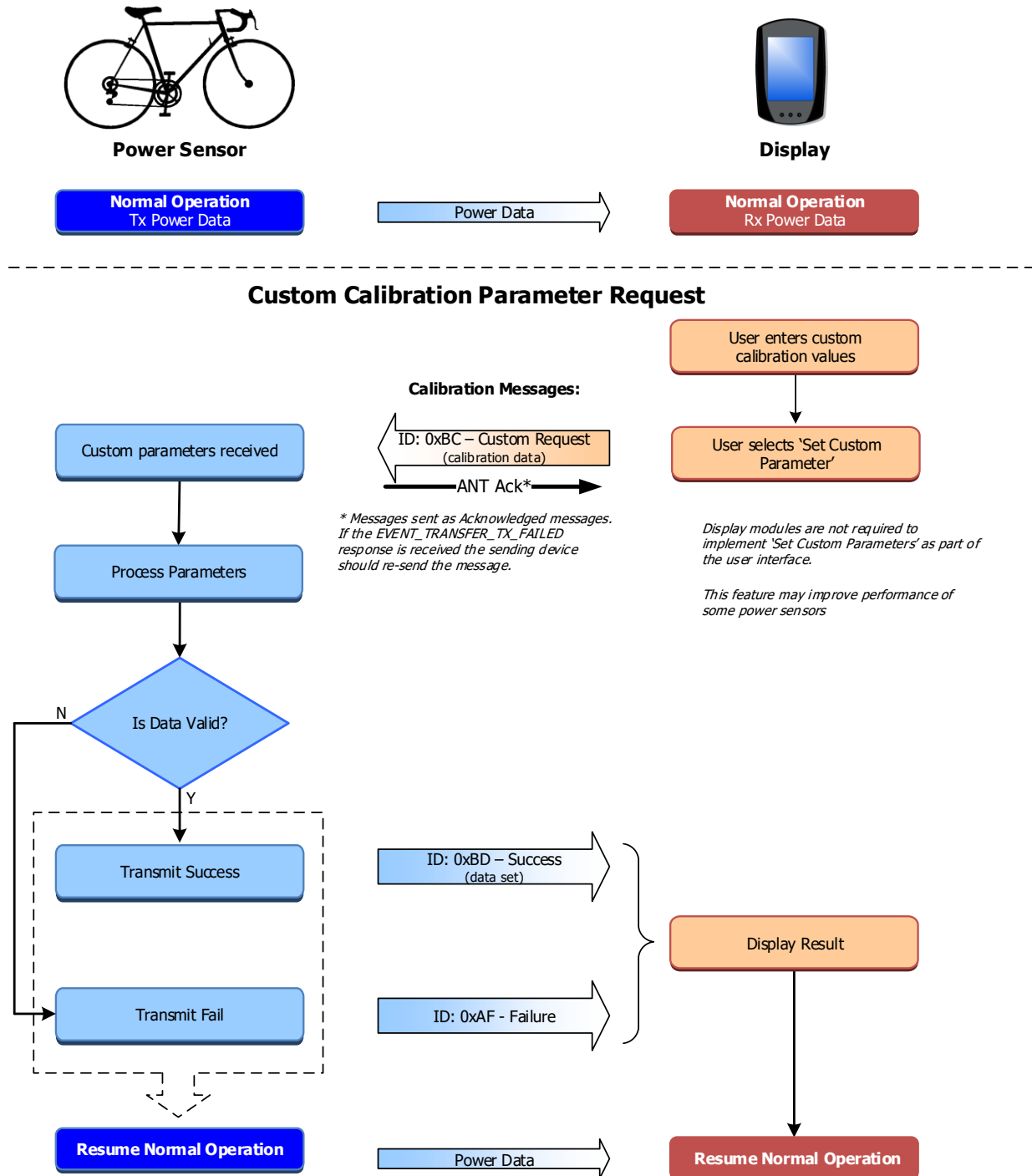
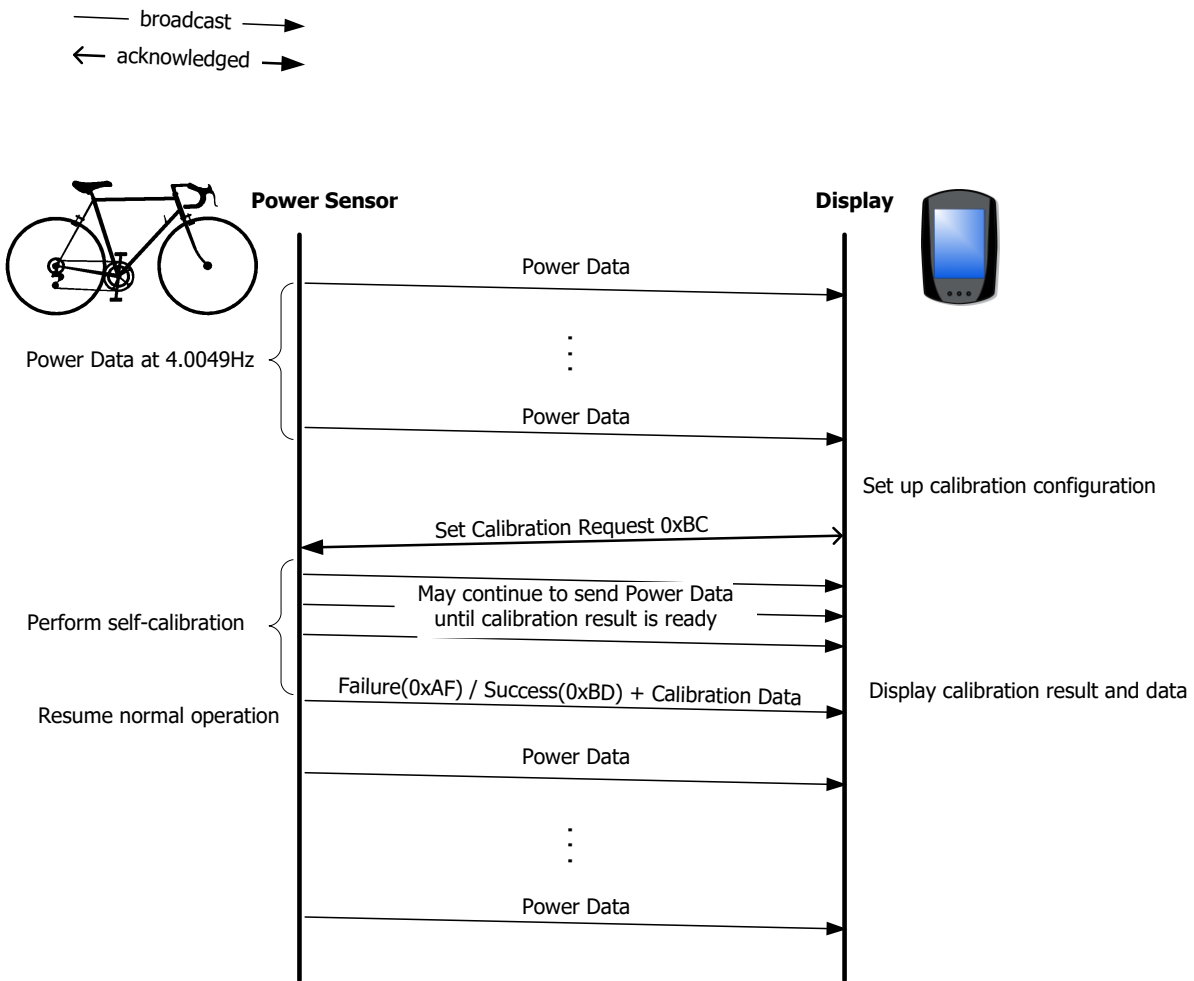


Figure 14-7. Set Custom Parameter Process Flow Chart

**Figure 14-8. Set Custom Calibration Sequence Diagram**

14.5 Torque-Frequency Defined Calibration Main Data Pages

Calibration pages specific to crank torque-frequency type power sensors (CTF) are used to pass the serial number, slope, and offset information. The second byte (Byte 1) of the calibration message specifies the type of data being sent (i.e. CTF defined message). The Request for CTF calibration data is sent using an acknowledged message from the display. The power sensor **shall [MD_0006]** respond using broadcast messages. Byte 2 is used to identify the CTF defined message that is being sent. Currently, only four CTF Defined messages are supported, but this may be expanded in the future.

NOTE: All Torque-Frequency Defined calibration messages are big endian. The power sensor must transmit the value 0xFF for all byte fields marked as 'Reserved'. The receiver must not interpret these values.

Table 14-8. CTF Defined Calibration Messages

| Calibration Parameter | CTF Defined ID | Value | Units |
|-----------------------|----------------|-----------|------------|
| Offset | 0x01 | 0 – 65535 | Hz |
| Slope | 0x02 | 100 – 500 | 1/10 Nm/Hz |
| Serial Number | 0x03 | 0 – 65535 | N/A |
| Acknowledgement | 0xAC | N/A | N/A |

14.5.1 Calibration Process for a Torque-Frequency Power Sensor

There are two ways to put a CTF power sensor into calibration mode:

- the display sends a calibration request page and the power sensor responds with calibration data
- the power sensor automatically sends calibration data when the bike has been coasting for more than 5 seconds.

When the display requests the calibration, it will send the request data page shown in Table 14-3. On receiving the request, the power sensor responds for 10 seconds with a Torque Frequency Calibration Response page. All fields in this message **shall [MD_0010]** be set as described in Table 14-9.

Table 14-9. Torque Frequency Calibration Response Message Format

| Byte | Description | Length | Value | Units |
|------|------------------|---------|--------------------------------|-------|
| 0 | Data Page Number | 1 Byte | 0x01 (calibration message) | N/A |
| 1 | Calibration ID | 1 Byte | 0x10 (CTF defined message) | N/A |
| 2 | CTF Defined ID | 1 Byte | 0x01 (Zero Offset) | N/A |
| 3 | Reserved | 3 Bytes | 0xFF (reserved for future use) | N/A |
| 4 | Reserved | | | |
| 5 | Reserved | | | |
| 6 | Offset MSB | 2 Bytes | 0 – 65535 | N/A |
| 7 | Offset LSB | | | |

If the sensor has not detected a cadence event when the 10-second period expires, the power unit shuts off.

NOTE: Previous revisions of this device profile described using acknowledged messages for CTF offset response pages. To prevent possible race conditions in a one to many topology, only broadcast messages **shall [MD_0006]** be sent from a power sensor.

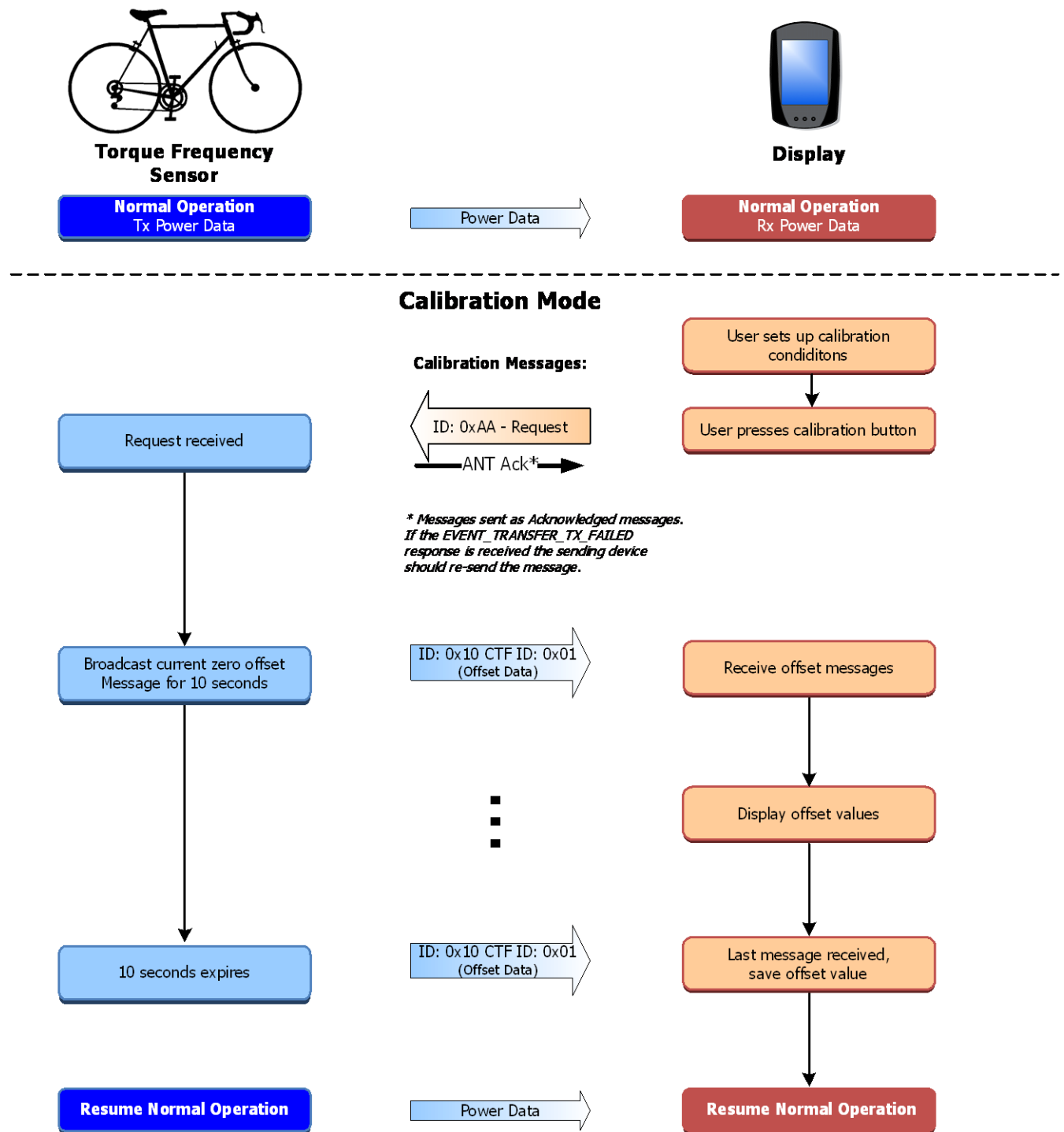
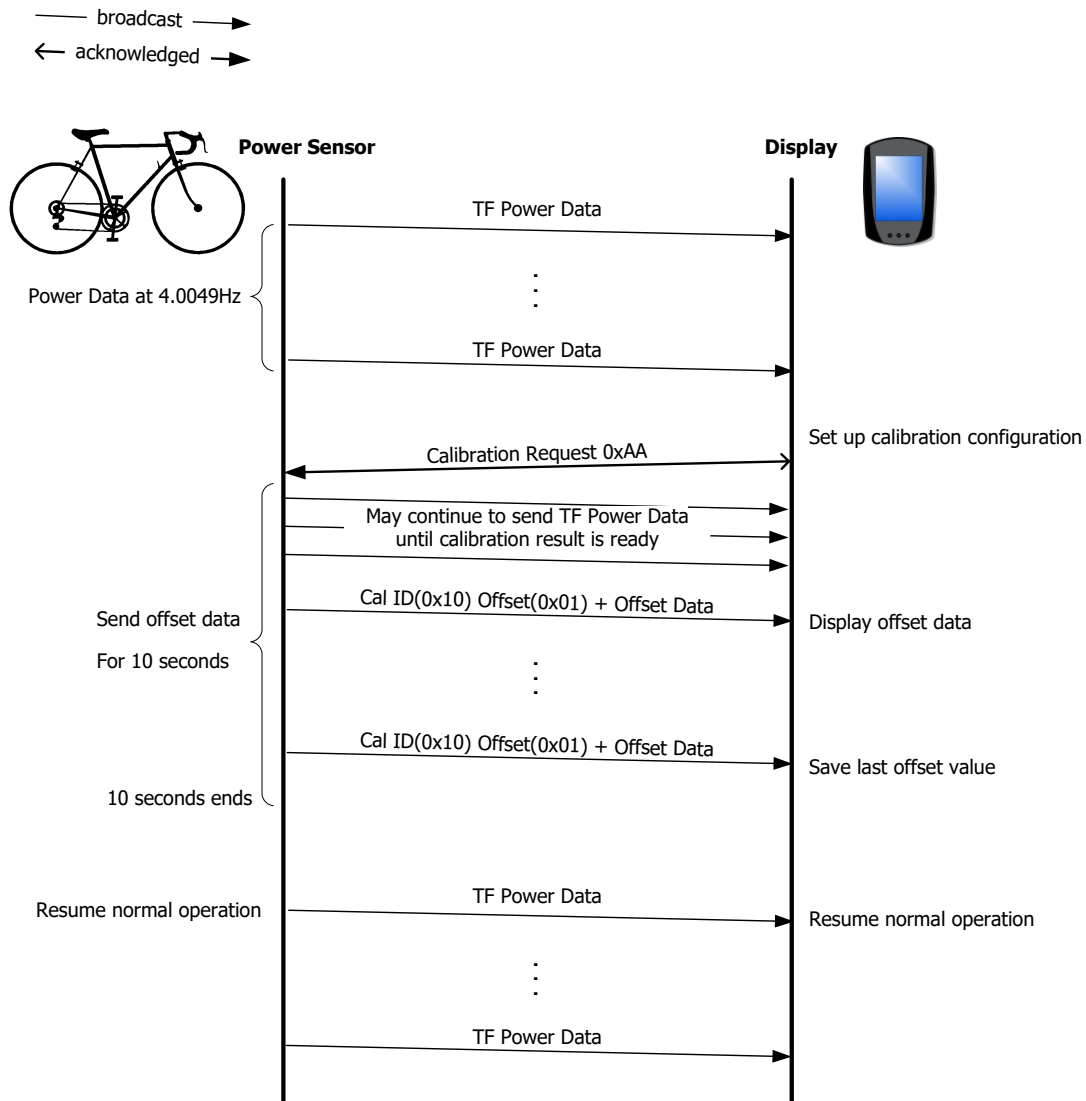


Figure 14-9. Torque Frequency Calibration Flow Chart

**Figure 14-10. Torque Frequency Calibration Process Sequence Diagram**

The second calibration use case is when the bike is coasting for more than 5 seconds. Coasting is defined as zero pedal events, and speed must be 5 km/h or greater over during the calibration period (i.e. bike must be moving the entire time). After 5 seconds of coasting, the power sensor will send the Torque Frequency Calibration Response page as outlined in Table 14-9 and shown in Figure 14-11.

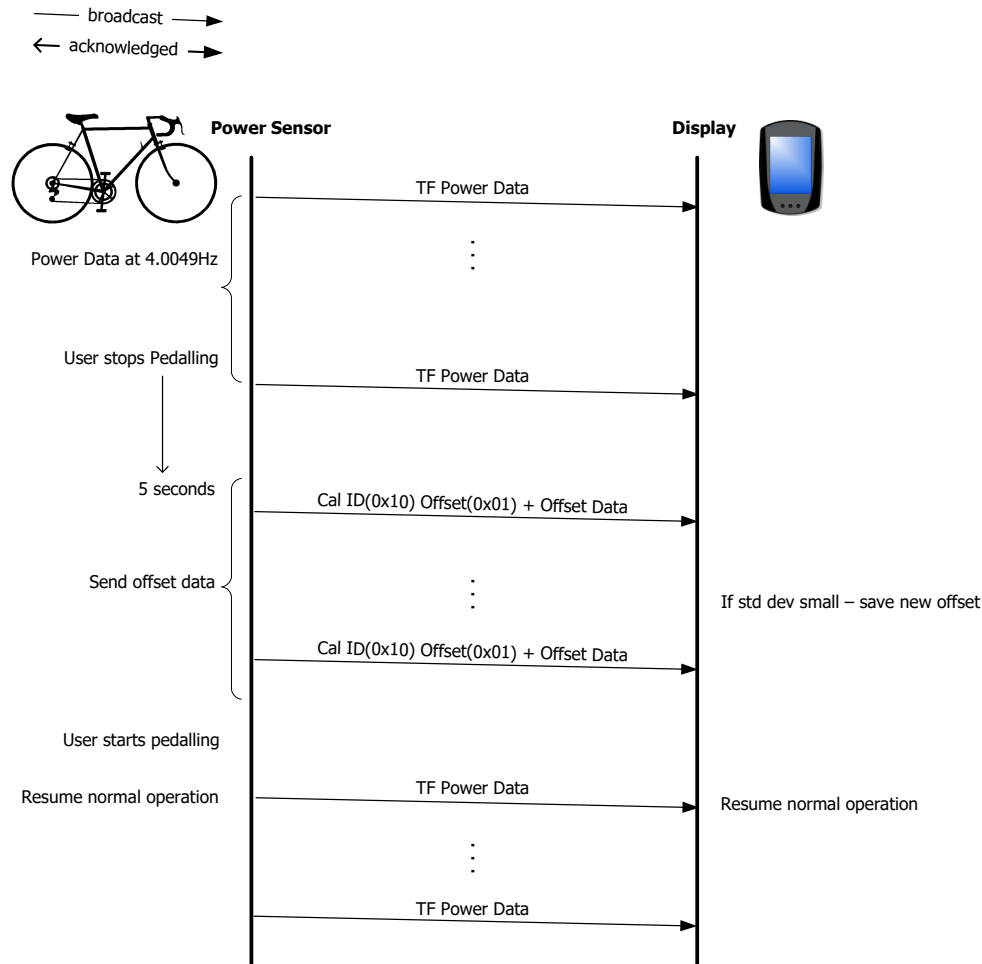


Figure 14-11. Coasting Offset Calibration Example

The transmitted offset value should be averaged over at least 5 samples during the coasting period. The standard deviation between the previous and current sample should be within +/- 4Hz. If the standard deviation of the received messages is within this +/- 4Hz range, the display **shall [SD_CTF_001]** save the sampled average as the new offset value.



14.5.2 Save Slope to Flash Main Data Page

To save a new value for slope to the power sensor flash, the display unit sends a CTF defined calibration message for slope to the power sensor. All fields in this message **shall [MD_0010]** be set as described in Table 14-10.

Table 14-10. Torque Frequency Calibration Request for Slope Message Format

| Byte | Description | Length | Value | Units |
|------|------------------|---------|--------------------------------|---------------|
| 0 | Data Page Number | 1 Byte | 0x01 (calibration message) | N/A |
| 1 | Calibration ID | 1 Byte | 0x10 (CTF defined message) | N/A |
| 2 | CTF Defined ID | 1 Byte | 0x02 (Slope) | NA |
| 3 | Reserved | 3 Bytes | 0xFF (reserved for future use) | N/A |
| 4 | Reserved | | | |
| 5 | Reserved | | | |
| 6 | Slope MSB | 2 Bytes | 100–500 | 1/10 Nm/Hz |
| 7 | Slope LSB | | | |

When the power sensor receives the set slope value it responds with the CTF acknowledgement message (Table 14-11), which is sent as a broadcast message to the display device. All fields in this message **shall [MD_0010]** be set as described in Table 14-11.

Table 14-11. Torque Frequency Calibration Response for Slope Message Format

| Byte | Description | Length | Value | Units |
|------|-------------------|---------|--------------------------------|-------|
| 0 | Data Page Number | 1 Byte | 0x01 (calibration message) | N/A |
| 1 | Calibration ID | 1 Byte | 0x10 (CTF defined message) | N/A |
| 2 | CTF Defined ID | 1 Byte | 0xAC (Acknowledgement) | N/A |
| 3 | CTF ACKed Message | 1 Byte | 0x02 (Slope CTF message) | N/A |
| 4 | Reserved | 4 Bytes | 0xFF (reserved for future use) | N/A |
| 5 | Reserved | | | |
| 6 | Reserved | | | |
| 7 | Reserved | | | |

NOTE: The successful setting of slope data can also be confirmed by checking the slope value in the next regular power message.

14.5.3 CTF: Save Serial to Flash

To save a new serial number to the power sensor flash, the display device sends a CTF defined message for serial number to the power sensor. All fields in this message **shall [MD_0010]** be set as described in Table 14-12.

NOTE: this message is intended only for use by CTF sensor manufacturers. It is not recommended that other CTF displays support this message.

Table 14-12. Torque Frequency Request to Save Serial Number in Flash Message Format

| Byte | Description | Length | Value | Units |
|------|-------------------|---------|--------------------------------|-------|
| 0 | Message ID | 1 Byte | 0x01 (calibration message) | N/A |
| 1 | Calibration ID | 1 Byte | 0x10 (CTF defined message) | N/A |
| 2 | CTF Defined ID | 1 Byte | 0x03 (Serial Number) | N/A |
| 3 | Reserved | 3 Bytes | 0xFF (reserved for future use) | N/A |
| 4 | Reserved | | | |
| 5 | Reserved | | | |
| 6 | Serial Number MSB | 2 Bytes | 0 - 65535 | N/A |
| 7 | Serial Number LSB | | | |

When the power sensor receives the set value it responds with the CTF acknowledgement message (Table 14-13), which is sent as a broadcast message to the display device. All fields in this message **shall [MD_0010]** be set as described in Table 14-13.

Table 14-13. Torque Frequency Response to Save Serial Number in Flash Message Format

| Byte | Description | Length | Value | Units |
|------|-------------------|---------|--------------------------------|-------|
| 0 | Data Page Number | 1 Byte | 0x01 (calibration message) | N/A |
| 1 | Calibration ID | 1 Byte | 0x10 (CTF defined message) | N/A |
| 2 | CTF Defined ID | 1 Byte | 0xAC (Acknowledgement) | N/A |
| 3 | CTF ACKed Message | 1 Byte | 0x03 (Serial Number) | N/A |
| 4 | Reserved | 4 Bytes | 0xFF (reserved for future use) | N/A |
| 5 | Reserved | | | |
| 6 | Reserved | | | |
| 7 | Reserved | | | |

15 Bicycle Power Meter Get/Set Parameters (Page 0x02)

The Get/Set Bicycle Parameters page is used to pass ANT+ defined common information between a display and sensor. It is similar in purpose to the 'Custom Calibration Parameters', but the information is defined by ANT+ and contains common information that may be relevant to multiple manufacturers.

The display may set common bicycle parameters, such as Crank Length, by sending this page to the power meter sensor. The display may also request this data using the Request Data Page (common page 70).

Support for the Get/Set Parameters page is not required for interoperability. Power meter sensors that do not support this page **shall [MD_PWR_004]** ignore the request. Displays **shall [SD_PWR_003]** handle this lack of response gracefully.



15.1 Basic Format

The Get/Set Parameters page uses sub-paging to provide extensibility. The content of the remaining 6 bytes is defined by the subpage number as shown in Table 15-1.

Table 15-1. Get/Set Parameter Page Format

| Byte | Description | Length | Value | Units | Rollover or Valid Range |
|------|----------------------|---------|--|-------|-------------------------|
| 0 | Data Page Number | 1 Byte | 0x02 – Get/Set Bicycle Parameters | N/A | N/A |
| 1 | Subpage Number | 1 Byte | Subpage Number | N/A | N/A |
| 2-7 | Subpage Defined Data | 6 Bytes | Data contents defined by Subpage number. Refer section 15.2. | N/A | N/A |

15.1.1 Setting Parameters

To set parameters on the power meter sensor, the display **shall [SD_PWR_003]** send a data page 0x02 containing the desired data and the relevant subpage. Any subpage fields that are read only will be ignored by the sensor and should be set to 0x00. The read only fields are set by the sensor and are populated when sent from the sensor to the display (i.e. in a Get command). The Set message should be sent from the display using an acknowledged message. After receiving the Set message, the sensor does not send any messages to confirm that the values have been changed. To confirm the values on the sensor, the display will use the standard Request Data Page (common page 70).



15.1.2 Requesting Parameters

To confirm or query parameters on the sensor, the display may send a Request Data Page (using common page 70). Refer to the ANT+ Common Pages document for more details.

An example of the Request Data Page (page 70) for a display requesting subpage 0x01 or 0xFD is shown in Table 15-2.

Table 15-2. Common Page 70 Format for Requesting Parameters

| Byte | Description | Length | Value | Units |
|------|---------------------------------|--------|---|-------|
| 0 | Command ID | 1 Byte | 70 (0x46) – Data Page Request | N/A |
| 1 | Reserved | 1 Byte | Value = 0xFF | N/A |
| 2 | Reserved | 1 Byte | Value = 0xFF | N/A |
| 3 | Descriptor Byte 1 | 1 Byte | 1 (0x01) for requesting subpage 1 (i.e. crank parameters) 253 (0xFD) for requesting subpage 253 (i.e. advanced capabilities) | N/A |
| 4 | Descriptor Byte 2 | 1 Byte | Invalid: 255 (0xFF) | N/A |
| 5 | Requested Transmission Response | 1 Byte | This field is application specific. It is recommended that at least 2 broadcast messages are requested from the sensor. Note: a display may not request acknowledged data from the power sensor | N/A |
| 6 | Requested Page Number | 1 Byte | 0x02 for requesting the Get/Set Parameter page | N/A |
| 7 | Command Type | 1 Byte | Value = 1 (0x01) for Requesting a Data Page | N/A |

15.2 Subpages

15.2.1 Subpage 0x01 – Crank Parameters

The Crank Parameters subpage allows the length of the user's crank to be set in 0.5 mm increments from 110 to 236.5 mm. When this page is requested by the display, the sensor **shall** [MD_PWR_004] communicate its current Crank Length value. It can also report the status of firmware on systems with multiple sensors (such as pedal, cleats, or cranks). All fields in this message **shall** [MD_PWR_004] [SD_PWR_003] be set as described in Table 15-3.



Table 15-3. Subpage 1 - Crank Parameters Format

| Byte | Description | Length | Value | Units | Rollover or Valid Range |
|------|---------------------|---------|--|--------|-------------------------|
| 0 | Data Page Number | 1 Byte | 0x02 – Set/Get Bicycle Parameters | N/A | N/A |
| 1 | Subpage Number | 1 Byte | 0x01 Crank Parameters | N/A | N/A |
| 2 | Reserved | 2 Bytes | 0xFF Reserved | N/A | N/A |
| 3 | Reserved | | | | |
| 4 | Crank Length Value | 1 Byte | CL Value = (Full Crank Length – 110mm)/0.5 Set to 0xFF if invalid. Display sets to 0xFE to request AutoCrank | 0.5 mm | 110.0 – 236.5mm |
| 5 | Sensor Status | 1 Byte | From Display: Read only, set to 0x00 From Sensor: Status bit field. Refer Table 15-4. | N/A | N/A |
| 6 | Sensor Capabilities | 1 Byte | From Display: Read only, set to 0x00 | N/A | N/A |

| | | | | | |
|---|----------|--------|---|-----|-----|
| | | | From Sensor: Sensor capabilities bit field. Refer to Table 15-5 | | |
| 7 | Reserved | 1 Byte | Reserved: 0xFF | N/A | N/A |

15.2.1.1 Crank Length

Byte 4 of the Crank Parameters subpage describes the length of the user's crank in millimeters. This field may be calculated in real-time by the sensor, or some systems may require the user to set this value.

The scale of the crank length value is 0.5 mm, and an offset of 110 mm must be added to the received value to calculate full crank length.

Examples:

- (1) To indicate that the crank length is 172.5, the value in the Crank Length field is sent as 125.

$$(172.5 \text{ mm} - 110.0 \text{ mm}) / 0.5 \text{ mm} = 125.$$

- (2) A value of 130 is received in the Crank Length field. The length of the crank is 175 mm

$$130 * 0.5 \text{ mm} + 110.0 \text{ mm} = 175 \text{ mm}$$

Special Values

The value 0xFF is used to set the crank length to invalid.

A value of 0xFE is used by a display to set the calculation of crank length to be automatically determined by the sensor. This is used only by sensors that indicate automatic crank length support in the capabilities bit field described in Section 15.2.1.3.

15.2.1.2 Sensor Status Bit Field

Byte 5 of the Crank Parameters subpage describes the status of sensors in a two sensor system; including which sensors are present, whether they have matching firmware and the method used to set the crank length. Byte 5 is read only, and **shall [SD_PWR_003]** be set to 0x00 when this subpage is sent by the display. The following table describes the bit field.

Table 15-4. Sensor Status Bit Field Description

| Bit | Description | Value | Usage Notes |
|---|---------------------|--|---|
| 0 | Crank Length Status | 00 - Crank length Invalid | Used when no crank length has been set. A display should respond by setting the crank length*. |
| | | 01 - Default crank length used | Used when the reported crank length is the factory default. A display may override this setting if desired*. |
| 10 - Crank length manually set | | Used when the crank length has been set by the display. A display may override this setting if desired*. | |
| 1 | | 11 - Crank length automatically set OR fixed | The crank length has either been set automatically by the power meter, or is a fixed value that cannot be changed. A display should not attempt to override this value unless 'auto crank length' support is set to 1 in the sensor capabilities bit field. |
| | 2 | Sensor SW Mismatch Status | 00 - Undefined |
| 01 - SW mismatch, Right sensor is older | | | Used by left-right systems when a SW mismatch exists. Display should warn user and/or apply a software update. |



| | | | |
|---|----------------------------|--|---|
| 3 | | 10 - SW Mismatch, Left sensor is older | Used by left-right systems when a SW mismatch exists. Display should warn user and/or apply a software update. |
| | | 11 - SW on left and right sensor is the same | Used by left-right sensor systems when no SW mismatch exists. |
| 4 | Sensor Availability Status | 00 – Undefined | Used by single-sensor power meters. |
| | | 01 – Left Sensor Present | Used when only the left sensor is present but the right sensor is also expected. Display should warn user that a sensor is missing. |
| 5 | | 10 – Right Sensor Present | Used when only the right sensor is present but the left sensor is also expected. Display should warn user that a sensor is missing. |
| | | 11 – Left and Right Sensor Present | Used by left-right sensor systems when both sensors are present. |
| 6 | Custom Calibration Status | 00 – Undefined | Used by power meters that do not support custom calibration. |
| | | 01 – Custom calibration not required | Used by power meters that support custom calibration, but do not require the display to initiate it. |
| 7 | | 10 – Custom calibration required | Used by power meters that support custom calibration, and require the display to initiate it. |
| | | 11 – Reserved for future use | Reserved |

*Either by requesting auto crank length or sending a crank length specified by the user.

15.2.1.3 Sensor Capabilities

Byte 6 of the Crank Parameters subpage describes the capabilities of the sensor related to Crank Parameters. Bit 0 describes whether the sensor is capable of determining the length of the crank automatically; all other bits are reserved.

Byte 6 is read-only and **shall [MD_PWR_003]** be set to 0x00 when this subpage is sent by the display. The following table describes the bit field.

Table 15-5. Sensor Capabilities Bit Field

| Bit | Description | Value |
|-----|-------------------|--|
| 1:7 | Reserved | Set to 0. Do not interpret. |
| 0 | Auto Crank Length | 0: The sensor is NOT capable of automatically determining crank length 1: The sensor is capable of automatically determining crank length |

15.2.1.4 Setting and Reporting Crank Length

Sensors may support three modes of operation specific crank length.

- 1) **Read or Write:** Sensors utilizing this mode of operation are capable of reporting their crank length to a display and allow the display to override the setting with a custom crank length value. Typically pedal and cleat based systems would operate in this mode.
- 2) **Read-only:** Sensors that are read-only will only allow reporting of the crank length to the display. The display may not, and should not try to, change the crank length on these types of sensor systems. Typically a crank based system would use this mode of crank length operation.



- 3) **Auto:** Sensors that operate in Auto mode are capable of dynamically calculating the crank length of a system. A display device should display the calculated crank length to the user indicating that it was calculated automatically. The display device should allow the user the option of enabling and disabling auto mode and allowing the user to override the auto setting should they choose to do so. Typically pedal or cleat based systems would have the capability to determine crank length automatically.

The default mechanism for setting and reporting crank length is defined by the Get/Set message Sub Page 1. The sensor capabilities and crank length status bit fields indicate whether the display should set the crank length on the power sensor.

If the crank length status indicates b00 (Invalid) then the crank length has not been set either manually or in the factory. A status value of b01 (Default) indicates that the sensor is using a default value that was set in the factory. A status value of b10 (Manual) is used to indicate that the crank length has been set manually by a display device. The interpretation of a status value set to b11 depends on the state being reported in the capabilities field. If the capabilities indicates that Auto Crank is not available then a status of b11 indicates that the crank length on the sensor is read-only. Conversely if the capabilities indicates that Auto Crank is available then a status of b11 indicates that the crank length has been computed automatically. This behavior is summarized in Crank Length Status.

Table 15-6. Summary Guidance for Setting Crank Length

| Crank Length Status | Auto Crank Length | |
|------------------------|---|--|
| | 0 | 1 |
| 00 (Invalid) | Display SHOULD set the crank length to enable the sensor to report power accurately | |
| 01 (Default) | Display may update the crank length if desired | |
| 10 (Manual) | Display may update the crank length if desired | |
| 11 (Fixed/Auto) | Display SHOULD NOT update the crank length | Display may update the crank length if desired |

The display should always request the Get/Set message Sub Page 1 prior to attempting to change the crank length. The crank length, status and capabilities fields provide the necessary information to the display to determine actions required on the crank length. This is summarized in the figure below.

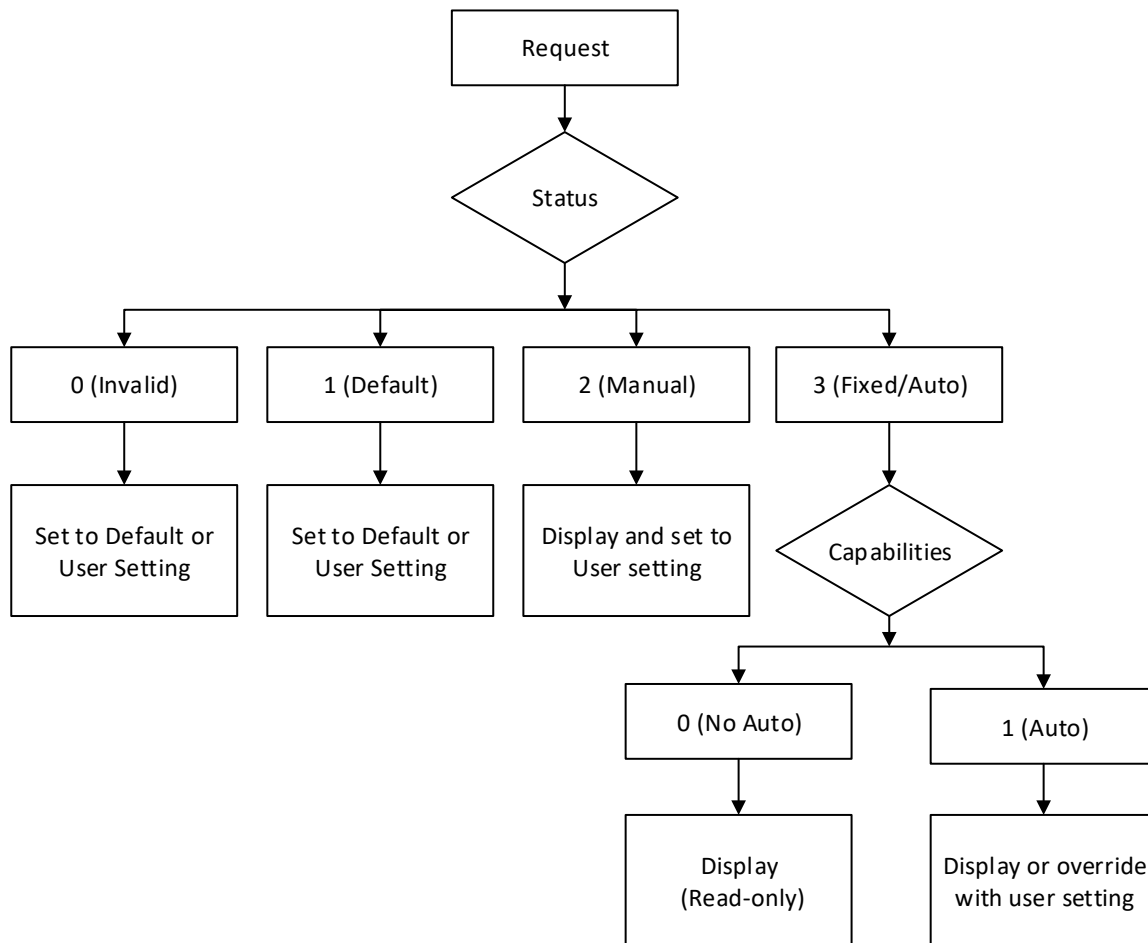


Figure 15-1. Display Decision Tree for Crank Length Setting

15.2.2 Subpage 0x02 – Power Phase Configuration

This page is used to get and set parameters related to the power phase.

Table 15-7. Subpage 0x02 – Power Phase Configuration Format

| Byte | Description | Length | Value | Units | Range or Rollover |
|------|-----------------------|--------|---|-------|-------------------|
| 0 | Data Page Number | 1 Byte | Data Page Number = 2 (0x02) | N/A | N/A |
| 1 | Subpage Number | 1 Byte | 0x02 Advanced Settings | N/A | N/A |
| 2 | Peak Torque Threshold | 1 Byte | The percentage of total torque considered to be peak. 201-255 – Reserved | 0.5% | 0-100% |
| 3 | Reserved | 1 Byte | Set to 0xFF | N/A | N/A |
| 4 | Reserved | 1 Byte | Set to 0xFF | N/A | N/A |
| 5 | Reserved | 1 Byte | Set to 0xFF | N/A | N/A |
| 6 | Reserved | 1 Byte | Set to 0xFF | N/A | N/A |
| 7 | Reserved | 1 Byte | Set to 0xFF | N/A | N/A |

15.2.2.1 Peak Torque Threshold

The percentage of the total applied torque during a time interval which is considered to be peak. Setting this value to a low percentage such as 1% will yield start and end peak torque angles in the left and right force angle pages that more closely approximate torque barycenter. At 100%, Peak Torque equals Total Torque.

Power meters should default to 50%.

15.2.3 Subpage 0x04 – Rider Position Configuration

Table 15-8. Subpage 0x02 – Power Phase Configuration Format

| Byte | Description | Length | Value | Units | Range or Rollover |
|------|------------------------|--------|--|-------|-------------------|
| 0 | Data Page Number | 1 Byte | Data Page Number = 2 (0x02) | N/A | N/A |
| 1 | Subpage Number | 1 Byte | 0x02 Advanced Settings | N/A | N/A |
| 2 | Transition Time Offset | 1 Byte | The time interval the seated/standing detection can be in transition state | s | 0-255 |
| 3 | Reserved | 1 Byte | Set to 0xFF | N/A | N/A |
| 4 | Reserved | 1 Byte | Set to 0xFF | N/A | N/A |
| 5 | Reserved | 1 Byte | Set to 0xFF | N/A | N/A |
| 6 | Reserved | 1 Byte | Set to 0xFF | N/A | N/A |
| 7 | Reserved | 1 Byte | Set to 0xFF | N/A | N/A |

15.2.3.1 Transition Time Offset

A transition state is a state in which the power meter has detected a change from standing to sitting or sitting to standing but is uncertain whether that change is a true transition or if the transition detected is a false positive. The transition time offset specifies the time-period between when a transition is first detected until when a determination can be made as to whether the transition was successful or not. A bike power meter which supports rider position **shall [MD_PWR_010]** enter transition state upon detecting a position transition and remain in that state for the interval specified by the transition time offset before reporting the final transitioned to rider position. This time offset provides the bike power meter with time to determine if the transition was true or whether it was a false positive.

If a display attempts to set the transition time offset to a value below what is minimally supported, the power meter **shall [MD_PWR_010]** ignore the setting and respond with its current transition time offset settings.

15.2.4 Subpage 0xFD – Advanced Capabilities 1

The advanced capabilities subpage is an optional data page that may be interleaved in the regular transmission pattern and/or sent on request from the power sensor to describe its capabilities and indicate its current configuration (e.g. channel period set to 4Hz or 8Hz). When this page is requested by the display, the sensor should communicate its current configuration.

This page may also be sent from the display device to the power sensor in order to change the configuration of the power sensor. All fields in this message **shall [MD_PWR_005] [SD_PWR_004]** be set as described in Table 15-9.



Table 15-9. Subpage 0xFD – Advanced Capabilities Format

| Byte | Description | Length | Value | Units | Range or Rollover |
|------|------------------|--------|-----------------------------|-------|-------------------|
| 0 | Data Page Number | 1 Byte | Data Page Number = 2 (0x02) | N/A | N/A |
| 1 | Subpage Number | 1 Byte | 0xFD Advanced Settings | N/A | N/A |

| | | | | | |
|---|----------------------------------|--------|--|-----|-----|
| 2 | Interoperable Properties | 1 Byte | Interoperable properties bit field. See Table 15-10 for details. | N/A | N/A |
| 3 | Custom Properties | 1 Byte | Manufacturer Specific | N/A | N/A |
| 4 | Interoperable Capabilities Mask | 1 Byte | Capabilities bit field. See Table 15-11 for details. | N/A | N/A |
| 5 | Custom Capabilities Mask | 1 Byte | Manufacturer Specific Capabilities Mask | N/A | N/A |
| 6 | Interoperable Capabilities Value | 1 Byte | Interoperable Capabilities bit field. See Table 15-12 for details. | N/A | N/A |
| 7 | Custom Capabilities | 1 Byte | Manufacturer Specific Capabilities value | N/A | N/A |

15.2.4.1 Properties

Properties define read-only settings of the sensor. The sensor **shall [self-verify]** ignore these bits from the display. The display must not attempt to change these values. The Custom Properties field is manufacturer specific and may be set as desired by the sensor manufacturer. The Interoperable Properties field is managed by ANT+ and defines interoperable properties of the sensor. These properties are described in Table 15-10.



Table 15-10. Subpage 0xFD – Interoperable Properties

| Bit | Description | Meaning when sent from power sensor |
|-----|-----------------------|--|
| 0 | Default crank length | 0 – The crank length is set to the sensor's default value 1 – The crank length is not set to the sensor's default value |
| 1 | Requires crank length | 0 – The sensor requests that the crank length be set 1 – The sensor does not request that the crank length be set |
| 2 | Reserved | 0 – Reserved. Do not use 1 – Always set to 1. |
| 3 | Reserved | 0 – Reserved. Do not use 1 – Always set to 1. |
| 4 | Reserved | 0 – Reserved. Do not use 1 – Always set to 1. |
| 5 | Reserved | 0 – Reserved. Do not use 1 – Always set to 1. |
| 6 | Reserved | 0 – Reserved. Do not use 1 – Always set to 1. |
| 7 | Reserved | 0 – Reserved. Do not use 1 – Always set to 1. |

15.2.4.1.1 Default Crank Length

This bit specifies if the crank length is set to the default value of the sensor.

15.2.4.1.2 Requires Crank Length

This bit specifies whether the sensor needs to have its crank length set by the display.

15.2.4.2 Capabilities

Capabilities are defined by Mask/Value pairs. Separate fields are available for Custom (manufacturer specific) and Interoperable capabilities.

From the sensor: The mask indicates which capabilities the sensor supports. The value indicates the current setting of the capability.

From the display: The mask indicates which capabilities the head unit is attempting to set. The value indicates the new setting of the capability being set by the display.

Table 15-11. Subpage 0xFD – Interoperable Capabilities Mask

| Bit | Description | Meaning when sent from power sensor | Meaning when sent from display |
|-----|-------------------------|--|--------------------------------|
| 0 | 4Hz | 0 – Supports transmitting at 4Hz | 0 – Apply bit 0 in byte 6 |
| | | 1 – Does not support transmitting at 4Hz | 1 – Ignore bit 0 in byte 6 |
| 1 | 8Hz | 0 – Supports transmitting at 8Hz | 0 – Apply bit 1 in byte 6 |
| | | 1 – Does not support transmitting at 8Hz | 1 – Ignore bit 1 in byte 6 |
| 2 | Reserved for future use | 0 – Reserved. Do not use | 0 – Reserved. Do not use |
| | | 1 – Always set to 1. | 1 – Always set to 1 |
| 3 | Reserved for future use | 0 – Reserved. Do not use | 0 – Reserved. Do not use |
| | | 1 – Always set to 1. | 1 – Always set to 1 |
| 4 | Auto zero | 0 – Supports auto zero | 0 – Apply bit 4 in byte 6 |
| | | 1 – Does not support auto zero | 1 – Ignore bit 4 in byte 6 |
| 5 | Auto crank length | 0 – Supports auto crank length | 0 – Apply bit 5 in byte 6 |
| | | 1 – Does not support auto crank length | 1 – Ignore bit 5 in byte 6 |
| 6 | TE and PS | 0 – Supports TE and PS | 0 – Apply bit 6 in byte 6 |
| | | 1 – Does not support TE and PS | 1 – Ignore bit 6 in byte 6 |
| 7 | Reserved for future use | 0 – Reserved. Do not use | 0 – Reserved. Do not use |
| | | 1 – Always set to 1 | 1 – Always set to 1 |

Table 15-12. Subpage 0xFD – Interoperable Capabilities Value

| Bit | Description | Meaning when sent from power sensor | Meaning when sent from display |
|-----|-------------------------|--|--------------------------------|
| 0 | 4Hz | 0 – Transmitting at 4Hz | 1 – Do not transmit at 4Hz |
| | | 1 – Not transmitting at 4Hz | 0 – Transmit at 4Hz |
| 1 | 8Hz | 0 – Transmitting at 8Hz | 1 – Do not transmit at 8Hz |
| | | 1 – Not transmitting at 8Hz | 0 – Transmit at 8Hz |
| 2 | Reserved for future use | 0 – Reserved. Do not use | 1 – Always set to 1 |
| | | 1 – Always set to 1. | 0 – Reserved. Do not use |
| 3 | Reserved for future use | 0 – Reserved. Do not use | 1 – Always set to 1 |
| | | 1 – Always set to 1. | 0 – Reserved. Do not use |
| 4 | Auto zero | 0 – Auto zero enabled | 1 – Disable auto zero |
| | | 1 – Auto zero disabled | 0 – Enable auto zero |
| 5 | Auto crank length | 0 – Auto crank length enabled | 1 – Disable auto crank length |
| | | 1 – Auto crank length disabled | 0 – Enable auto crank length |
| 6 | TE and PS page | 0 – TE and PS included in transmission pattern | 1 – Do not send TE and PS page |

| | | | |
|---|-------------------------|--------------------------|---|
| | | 1 – TE and PS not sent | 0 – Include TE and PS in transmission pattern |
| 7 | Reserved for future use | 0 – Reserved. Do not use | 1 – Always set to 1 |
| | | 1 – Always set to 1 | 0 – Reserved. Do not use |

15.2.4.2.1 4Hz and 8Hz Capabilities

The Advanced Capabilities page allows the display to change the channel period from 8182 (4Hz) to 4091 (8Hz) and vice versa. Care should be taken to ensure that bits 0 and 1 are set in tandem. For example, the display should not attempt to set the 8Hz bit without turning off the 4Hz mode otherwise undefined behavior may result. Sensor should not enter the 8Hz state unless instructed to do so by a display device. On reset or wake up sensors should default to 4Hz operation.

In order to maintain compatibility between 4Hz receivers and 8Hz transmitters the transmission pattern of an 8Hz transmitter **shall [MD_PWR_005]** interleave correct transmission patterns of two 4Hz transmitters. However, optional data pages may be different on both data streams allowing the sensor to send more data pages than possible at 4Hz

Other considerations:

4Hz Receiver - 8Hz Transmitter

When a 4Hz display is receiving from an 8Hz sensor it will receive every second message from the sensor. As the sensor must interleave two correct 4Hz transmission patterns in its 8Hz transmission pattern the 4Hz receiver will not suffer any degradation of performance and will be able to correctly decode the power information from the 8Hz sensor. However, care must be taken when requesting messages from the sensor. The sensor will respond to message requests on each of its channel periods. Therefore the display will only receive half of the messages that it requests. For example, if the display requested 4 broadcast messages it would only receive 2 broadcast messages in return. If only one message is requested then the display will not receive any of the requested messages.

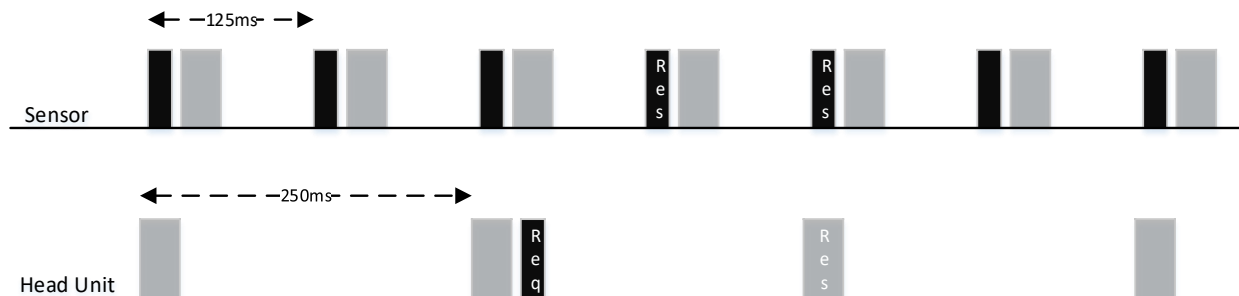


Figure 15-2. 4Hz Head Unit with 8Hz Sensor – Requesting Messages

For example in Figure 15-2 a display operating at 4Hz requests 2 messages from a sensor that is operating at 8Hz. The first response from the sensor will not be received by the display, however the second response will succeed. Therefore as best practice displays should request at least two messages from sensors to ensure success.

8Hz Receiver - 4Hz Transmitter

A display configured to receive at 8Hz will function with a sensor that is transmitting at 4Hz. It will miss every second message resulting an EVENT_RX_FAIL event from the ANT stack every other message. Problems may arise if the display is connected to other ANT+ sensors with channel periods slightly offset from the ANT+ Bike Power channel period. As the sensors collide in the time domain they may cause the connection to the bike power sensor to be lost forcing the receiver to go into search.



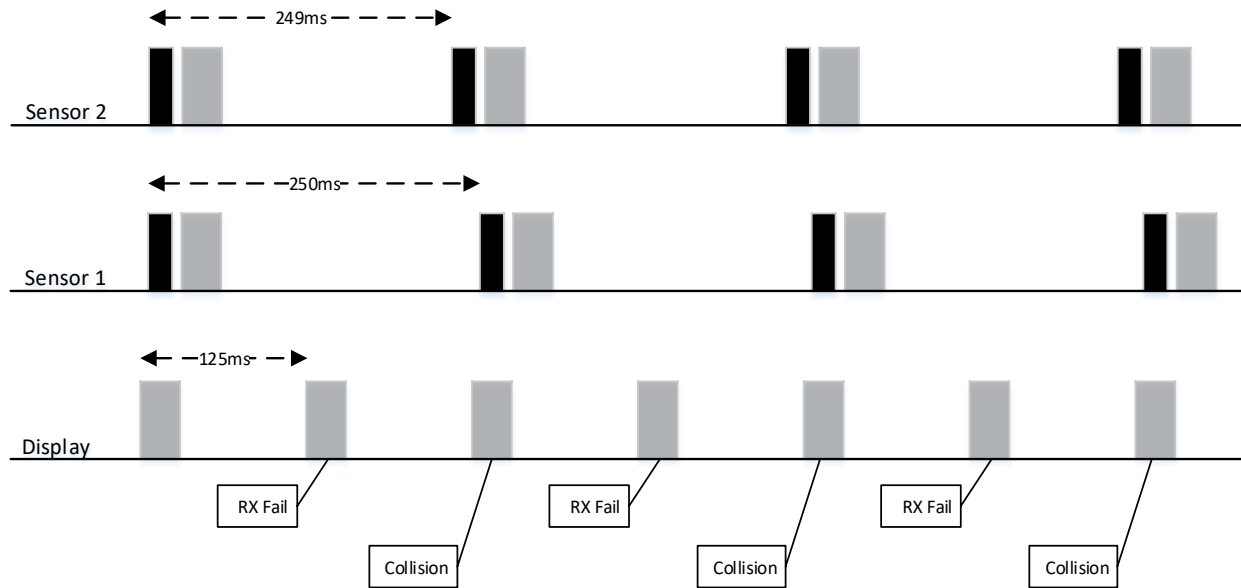


Figure 15-3. 8Hz Head Unit with Multiple ~4Hz Sensors Bike Sensors

To prevent the bike power channel from being interrupted by other channels connected to the display it is recommended that the sensor transmit the Advanced Capabilities page in its transmission pattern. When the display detects that the sensor is transmitting at 4Hz it may either force the sensor into 8Hz or fall back to a 4Hz channel period itself, thereby preventing prolonged message loss.

15.2.5 Subpage 0xFE – Advanced Capabilities 2

The advanced capabilities subpage is an optional data page that may be interleaved in the regular transmission pattern and/or sent on request from the power sensor to describe its capabilities and indicate its current configuration (e.g. channel period set to 4Hz or 8Hz). When this page is requested by the display, the sensor should communicate its current configuration.

This page may also be sent from the display device to the power sensor in order to change the configuration of the power sensor. All fields in this message **shall** [MD_PWR_005] [SD_PWR_004] be set as described in Table 15-13.

Advanced Capabilities 2 is an extension of Advanced Capabilities 1. See section 15.2.4 for more information about Advanced Capabilities.



Table 15-13. Subpage 0xFE – Advanced Capabilities 2 Format

| Byte | Description | Length | Value | Units | Range or Rollover |
|------|----------------------------------|--------|--|-------|-------------------|
| 0 | Data Page Number | 1 Byte | Data Page Number = 2 (0x02) | N/A | N/A |
| 1 | Subpage Number | 1 Byte | 0xFE Advanced Settings | N/A | N/A |
| 2 | Reserved | 1 Byte | Set to 0xFF | N/A | N/A |
| 3 | Reserved | 1 Byte | Set to 0xFF | N/A | N/A |
| 4 | Interoperable Capabilities Mask | 1 Byte | Capabilities bit field. See Table 15-14 for details. | N/A | N/A |
| 5 | Reserved | 1 Byte | Set to 0xFF | N/A | N/A |
| 6 | Interoperable Capabilities Value | 1 Byte | Interoperable Capabilities bit field. See Table 15-15 for details. | N/A | N/A |
| 7 | Reserved | 1 Byte | Set to 0xFF | N/A | N/A |

15.2.5.1 Capabilities

Capabilities are defined by Mask/Value pairs. Separate fields are available for Custom (manufacturer specific) and Interoperable capabilities.

From the sensor: The mask indicates which capabilities the sensor supports. The value indicates the current setting of the capability.

From the display: The mask indicates which capabilities the head unit is attempting to set. The value indicates the new setting of the capability being set by the display.

Table 15-14. Subpage 0xFE – Interoperable Capabilities Mask

| Bit | Description | Meaning when sent from power sensor | Meaning when sent from display |
|-----|--------------------------|--|--------------------------------|
| 0 | 4Hz | 0 – Supports transmitting at 4Hz | 0 – Apply bit 0 in byte 6 |
| | | 1 – Does not support transmitting at 4Hz | 1 – Ignore bit 0 in byte 6 |
| 1 | 8Hz | 0 – Supports transmitting at 8Hz | 0 – Apply bit 1 in byte 6 |
| | | 1 – Does not support transmitting at 8Hz | 1 – Ignore bit 1 in byte 6 |
| 2 | Reserved for future use | 0 – Reserved. Do not use | 0 – Reserved. Do not use |
| | | 1 – Always set to 1. | 1 – Always set to 1 |
| 3 | Power Phase – 8Hz | 0 – Supports power phase when transmitting at 8 Hz | 0 – Apply bit 3 in byte 6 |
| | | 1 – Does not support power phase when transmitting at 8 Hz | 1 – Ignore bit 3 in byte 6 |
| 4 | PCO – 8 Hz | 0 – Supports PCO when transmitting at 8 Hz | 0 – Apply bit 4 in byte 6 |
| | | 1 – Does not support PCO when transmitting at 8 Hz | 1 – Ignore bit 4 in byte 6 |
| 5 | Rider Position – 8 Hz | 0 – Supports rider position when transmitting at 8 Hz | 0 – Apply bit 5 in byte 6 |
| | | 1 – Does not support rider position when transmitting at 8 Hz | 1 – Ignore bit 5 in byte 6 |
| 6 | Torque Barycenter – 8 Hz | 0 – Supports torque barycenter when transmitting at 8 Hz | 0 – Apply bit 6 in byte 6 |
| | | 1 – Does not support torque barycenter when transmitting at 8 Hz | 1 – Ignore bit 6 in byte 6 |
| 7 | Reserved for future use | 0 – Reserved. Do not use | 0 – Reserved. Do not use |
| | | 1 – Always set to 1 | 1 – Always set to 1 |

Table 15-15. Subpage 0xFE – Interoperable Capabilities Value

| Bit | Description | Meaning when sent from power sensor | Meaning when sent from display |
|-----|-------------------------|--|--------------------------------|
| 0 | 4Hz | 0 – Transmitting at 4Hz | 1 – Do not transmit at 4Hz |
| | | 1 – Not transmitting at 4Hz | 0 – Transmit at 4Hz |
| 1 | 8Hz | 0 – Transmitting at 8Hz | 1 – Do not transmit at 8Hz |
| | | 1 – Not transmitting at 8Hz | 0 – Transmit at 8Hz |
| 2 | Reserved for future use | 0 – Reserved. Do not use | 1 – Always set to 1 |
| | | 1 – Always set to 1. | 0 – Reserved. Do not use |
| 3 | Power Phase – 8 Hz | 0 – Power phase enabled when transmitting at 8 Hz | 1 – Disable power phase |
| | | 1 – Power phase disabled when transmitting at 8 Hz | 0 – Enable power phase |
| 4 | PCO – 8 Hz | 0 – PCO enabled when transmitting at 8 Hz | 1 – Disable PCO |
| | | 1 – PCO disabled when transmitting at 8 Hz | 0 – Enable PCO |
| 5 | Rider Position – 8 Hz | 0 – Rider position enabled when transmitting at 8 Hz | 1 – Disable rider position |

| | | | |
|---|--------------------------|--|-------------------------------|
| | | 1 – Rider position disabled when transmitting at 8 Hz | 0 – Enable rider position |
| 6 | Torque Barycenter – 8 Hz | 0 – Torque barycenter enabled when transmitting at 8 Hz | 1 – Disable torque barycenter |
| | | 1 – Torque barycenter disabled when transmitting at 8 Hz | 0 – Enable torque barycenter |
| 7 | Reserved for future use | 0 – Reserved. Do not use | 1 – Always set to 1 |
| | | 1 – Always set to 1 | 0 – Reserved. Do not use |

15.2.5.1.1 4Hz and 8 Hz Capabilities

See section 15.2.4.2.1 for information about the 4Hz and 8Hz capabilities. Note that Advanced Capabilities Page 2 **shall [self-verify]** duplicate the 4Hz and 8Hz setting in Advanced Capabilities Page 1. Setting 4Hz and 8Hz using either page **shall [self-verify]** apply the setting to the whole bike power system, and be reported on both Advanced Capabilities pages.



15.2.5.1.2 Power Phase

This capability allows the transmission of the left and right force angle pages (0xE0 and 0xE1). 8 Hz mode **shall [SD_PWR_006]** be enabled when power phase is enabled. The pages **shall [MD_PWR_010]** be interleaved in a manner that allows all pages to be received by a 4 Hz transmitter.

15.2.5.1.3 PCO and Rider Position

These capabilities allows the transmission of the Pedal Position Data page (0xE2). 8 Hz mode **shall [SD_PWR_006]** be enabled when PCO or rider position is enabled. The pages **shall [MD_PWR_010]** be interleaved in a manner that allows all pages to be received by a 4 Hz transmitter.

15.2.5.1.4 Torque Barycenter

This capability allows the transmission of the Torque Barycenter Data page (0x14). 8 Hz mode **shall [SD_PWR_006]** be enabled when torque barycenter is enabled. The pages **shall [MD_PWR_010]** be interleaved in a manner that allows all pages to be received by a 4 Hz transmitter.

16 Measurement Output Data Page (0x03)

The measurement output data page is an optional page that may be used by PWR sensors (including power-only, torque at wheel and torque at crank). It is intended to provide a richer user experience during the calibration process by providing raw system measurements and/or an indication of progress. **The measurement output data page shall [MD_PWR_001] only be sent as a broadcast message from the sensor to the display.**

Display manufacturers are encouraged to display the values sent using this page to give the user feedback during calibration and provide access to additional diagnostic information available from the sensor. For example, this page may be used to send countdown values while the sensor is processing a calibration request, enabling the display to indicate to the user how far the sensor has progressed through the calibration process e.g. using a progress bar. Other measurement output messages may also be sent both during and after calibration is completed. Refer to section 16.6 for an example message flow. All fields in this message **shall [MD_PWR_001]** be set as described in Table 16-1.

The sensor **shall [self-verify]** return to sending power data in the normal transmission pattern when triggered by any one of the following events:

- The user begins to pedal (recommended as best practice)
- A time-out occurs (optional)
- The sensor receives a request for page 0x10 e.g. in response to user input as described in section 19.2.1 (mandatory)

This data page shall [MD_0008] not be sent as part of the normal power data transmission pattern.

If a sensor needs to send several different values, this message can be updated to rotate through those values. In this case the display may optionally make a multi-field display available, or allow the user to scroll through the values. **Note that sensors shall [MD_PWR_001] not send more than one variable of a given data type at any one time.**

Table 16-1. Measurement Output Message Format

| Byte | Description | Length | Value | Units | Rollover or Valid Range |
|------|--------------------------------|---------|--|----------------|-------------------------|
| 0 | Data Page Number | 1 Byte | 0x03 – Measurement Output | N/A | N/A |
| 1 | Bits 0-3: Number of Data Types | 4 Bits | Set to the number of data types currently being transmitted. Refer to section 16.1 | N/A | 1-11 |
| | Reserved | 4 Bits | Reserved for future use, set to 0x00 | N/A | N/A |
| 2 | Data Type | 1 Byte | Data type and engineering units applicable to the measurement value. Refer to Table 16-2 | N/A | N/A |
| 3 | Scale Factor | 1 Byte | Binary decimal justification | 2 ^x | -127 to 127 |
| 4 | Timestamp LSB | 2 Bytes | Timestamp corresponding to the measurement instant | 1/2048s | 32s |
| 5 | Timestamp MSB | | | | |
| 6 | Measurement Value LSB | 2 Bytes | Data value, signed | As specified | -32768 to 32767 |
| 7 | Measurement Value MSB | | | | |

Note: all fields in the measurement output data page are required fields.

16.1 Number of Data Types

Number of data types is a required field that allows the display to format the data it receives effectively. This field should be set to the number of data types currently being transmitted from the sensor. I.e. if the sensor is only sending measurement output data pages containing a countdown value, it should be set to 1. Or if the sensor is currently sending measurement output data pages containing torque, force, zero offset and temperature values, then this field should be set to 4.

16.2 Data Type

The data type field specifies the parameter that is encoded in the measurement value field as described in Table 16-2.

Table 16-2. Currently Defined Data Types

| Value | Data Type | Units | Description |
|-------|--------------------------|--------------|--|
| 0 | Countdown (progress bar) | % | Percentage of process remaining until process is complete. |
| 1 | Countdown (time) | s | Seconds remaining until process is complete. |
| 2-7 | Reserved | N/A | Reserved for future use |
| 8 | Torque (whole sensor) | Nm | Forward driving torque is represented as positive, back-peddalling torque is represented as negative |
| 9 | Torque (left) | Nm | Torque applied to the left pedal. Forward driving torque is represented as positive, back-peddalling torque is represented as negative |
| 10 | Torque (right) | Nm | Torque applied to the right pedal. Forward driving torque is represented as positive, back-peddalling torque is represented as negative |
| 11 | Torque (y-axis) | Nm | Torque with reference to middle of pedal about the y-axis. See Figure 16-1 and Figure 16-2. 0x8000 - Invalid |
| 12 | Torque (outboardness) | Nm | Torque with reference to middle of pedal about the x-axis. Describes whether more force is applied with the inner or outer side of the foot. Outboard applied downward force results in a positive value. See Figure 16-1 and Figure 16-2. 0x8000 - Invalid |
| 13-15 | Reserved | N/A | Reserved for future use |
| 16 | Force (whole sensor) | N | Forward driving force is represented as positive, back-peddalling force is represented as negative |
| 17 | Force (left) | N | Force applied to the left pedal. Forward driving force is represented as positive, back-peddalling force is represented as negative |
| 18 | Force (right) | N | Force applied to the right pedal. Forward driving force is represented as positive, back-peddalling force is represented as negative |
| 19 | Reserved | N/A | Reserved for future use |
| 20 | Crank Angle | 2 byte brads | The angle of the crank |
| 21 | Crank Angle Left | 2 byte brads | The angle of the left crank |
| 22 | Crank Angle Right | 2 byte brads | The angle of the right crank |
| 23 | Reserved | N/A | Reserved for future use |
| 24 | Zero-offset | No units | Scalar value representing the zero offset |
| 25 | Temperature | degC | Sensor temperature |
| 26 | Voltage | V | Voltage measured within the sensor |
| 27-31 | Reserved | N/A | Reserved for future use |
| 32 | Force Forward (left) | N | Force applied to left pedal in line with its x-axis. See Figure 16-1. 0x8000 - Invalid |
| 33 | Force Forward (right) | N | Force applied to right pedal in line with its x-axis. See Figure 16-2. |

| | | | |
|--------|------------------------|---------|---|
| | | | 0x8000 - Invalid |
| 34 | Force Downward (left) | N | Force applied to left pedal in line with its y-axis. See Figure 16-1. 0x8000 - Invalid |
| 35 | Force Downward (right) | N | Force applied to right pedal in line with its y-axis. See Figure 16-2. 0x8000 - Invalid |
| 36-39 | Reserved | N/A | Reserved for future use |
| 40 | Pedal Angle (left) | degrees | As derived from g-sensor. Angle with reference to horizon, where toe downward is a positive angle. See Figure 16-3. 0x8000 - Invalid |
| 41 | Pedal Angle (right) | degrees | As derived from g-sensor. Angle with reference to horizon, where toe downward is a positive angle. See Figure 16-3. 0x8000 - Invalid |
| 42-255 | Reserved | N/A | Reserved for future use. |

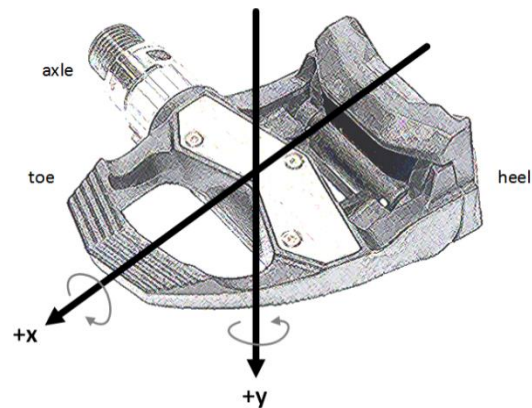


Figure 16-1. Left Pedal Axes

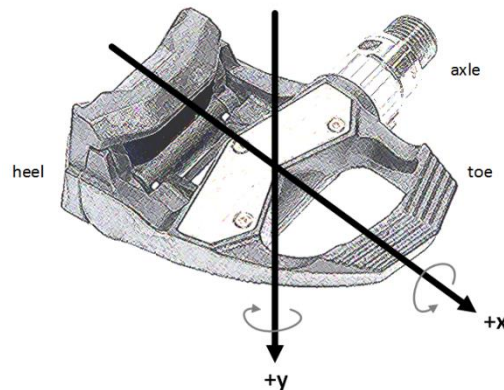


Figure 16-2. Right Pedal Axes

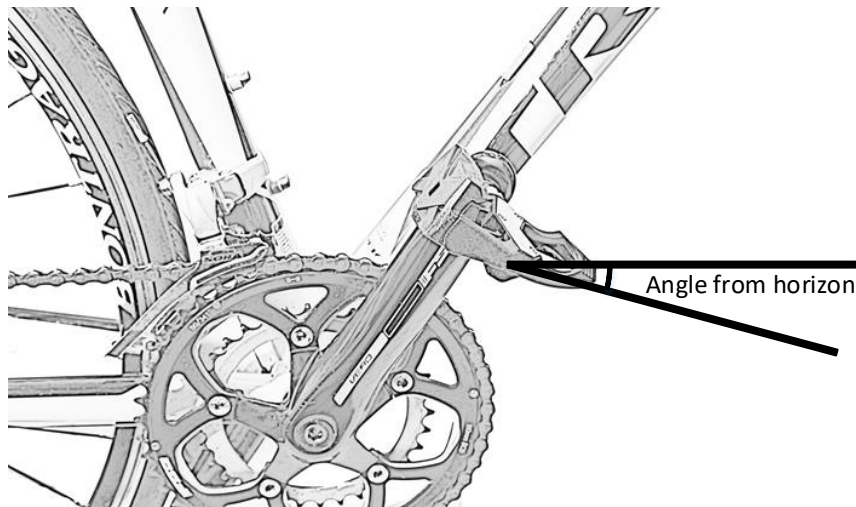


Figure 16-3. Pedal Angle

16.3 Scale Factor

The scale factor field describes the location of the binary decimal point in the data value. A positive scale factor x implies that the measurement value should be multiplied by 2^x to obtain the desired parameter value, while a negative scale factor $-x$ implies that the measurement value has a fractional component of x bits.

Example: To encode a value of 3.375 Nm with 5 bits of fractional significance, the scale factor is set to -5 and the measurement value is set to 108, as illustrated in Figure 16-4. Example showing how to send a Scaled Value.

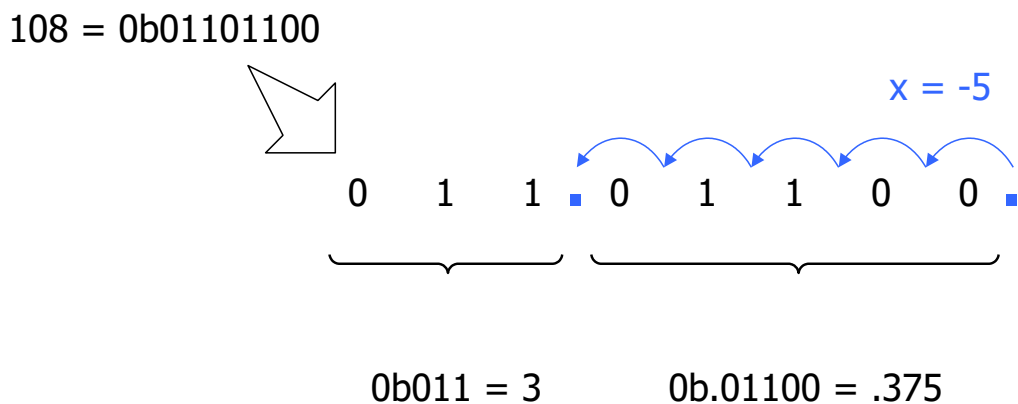


Figure 16-4. Example showing how to send a Scaled Value

16.4 Timestamp

The timestamp field is used to report the time instant of the measurement. This can be useful in the case where the measurement value is changing as a function of time.

16.5 Measurement Value

The measurement value field is used to encode the desired parameter. The value is signed; values larger than 32767 or with fractional significance can be encoded using the scale factor field as described in Section 16.3.

16.6 Use of the Measurement Output Data Page

Figure 16-5. Example Message Flow Diagram illustrating the use of Data Page 0x03 shows an example usage of the measurement output data page, and illustrates how this data can be displayed to the user. This message flow provides an optional alternative to the standard calibration process message flow described in Figure 14-2.

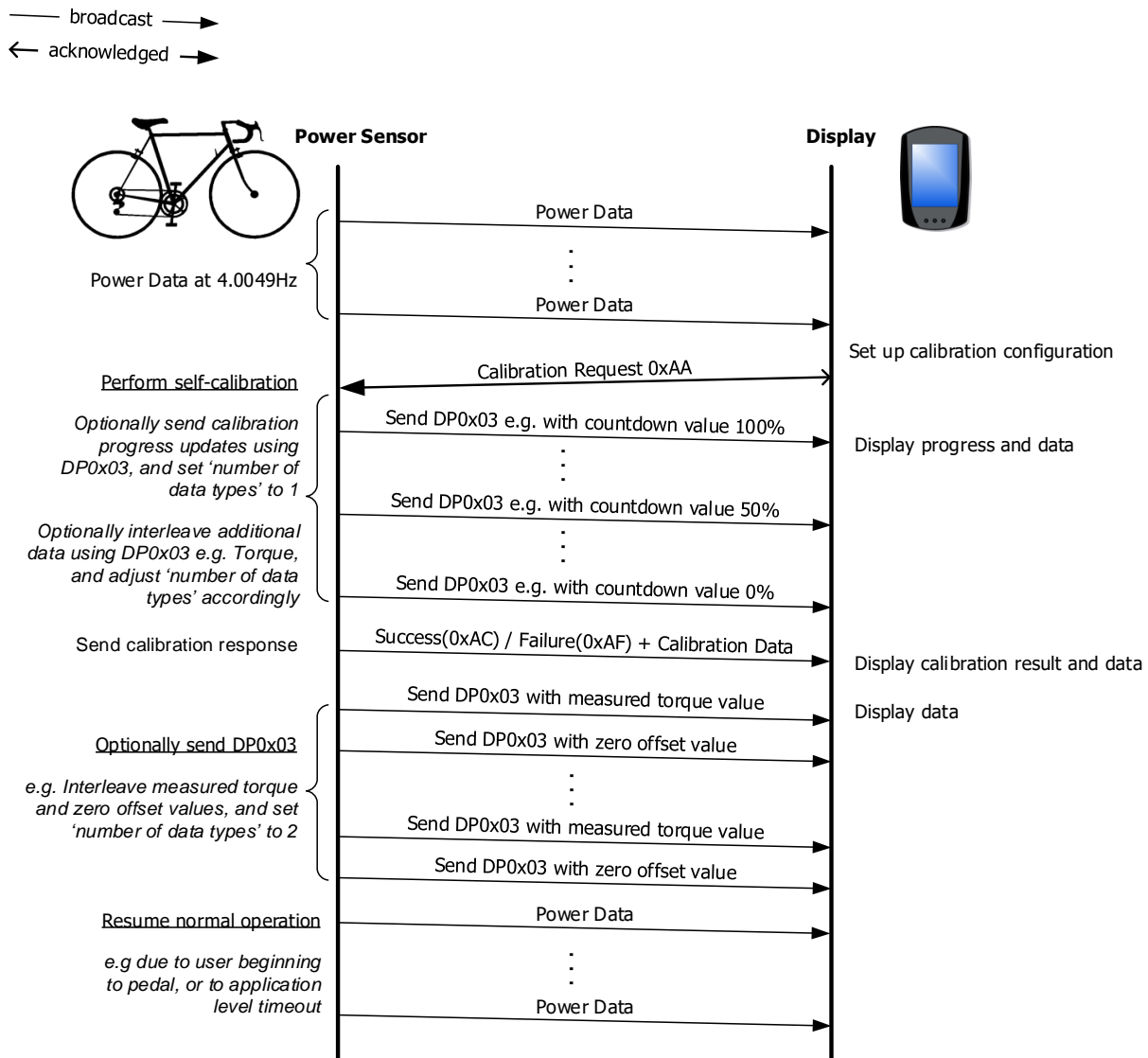


Figure 16-5. Example Message Flow Diagram illustrating the use of Data Page 0x03

17 Cycling Dynamics Data Pages

17.1 Right Force Angle (0xE0)

This page is an element of Cycling Dynamics. It can be enabled by a display through get/set parameters subpage 0xFE, and **shall [MD_PWR_010]** be transmitted if 8 Hz mode is enabled, AND Power Phase is enabled. It **shall [MD_PWR_010]** stop transmitting when Power Phase is disabled. The page should be interleaved such that the page may be received by a 4 Hz transmitter at a regular interval. If only single pedal is supported, and the side of the pedal is unknown, transmit the Left Force Angle page. If both Left and Right Force Angles are supported, the pages should be transmitted together – one after the other.

Table 17-1. Right Pedal Force Angle Message Format

| Byte | Description | Length | Value | Units | Rollover or Valid Range |
|------|------------------|--------|--|-------|-------------------------|
| 0 | Data Page Number | 1 Byte | 0xE0 – Right Pedal Force Angle Page | N/A | N/A |
| 1 | Event Count | 1 Byte | Event counter increments with each information update. | N/A | 256 |
| 2 | Start Angle | 1 Byte | The angle at which the positive torque begins for the right pedal. Set to 0x00 if positive torque occurs through the whole pedal stroke. 0xC0 – indicates invalid if End Angle also set to 0xC0. | brads | 0-255 |
| 3 | End Angle | 1 Byte | The angle at which the positive torque ends for the right pedal. Set to 0xFF if positive torque occurs through the whole pedal stroke. 0xC0 – indicates invalid if Start Angle also set to 0xC0. | brads | 0-255 |
| 4 | Start Peak Angle | 1 Byte | The angle at which, between it and the end peak angle, peak torque is achieved. Set to 0x00 if peak torque is achieved through the whole pedal stroke (i.e., Peak Torque Threshold is set to 100%). | brads | 0-255 |

| | | | | | |
|---|----------------|---------|---|---------|-----------|
| | | | 0xC0 – indicates invalid if End Peak Angle also set to 0xC0. | | |
| 5 | End Peak Angle | 1 Byte | <p>The angle at which, between it and the start peak angle, peak torque is achieved.</p> <p>Set to 0xFF if peak torque is achieved through the whole pedal stroke (i.e., Peak Torque Threshold is set to 100%).</p> <p>0xC0 – indicates invalid if Start Peak Angle also set to 0xC0.</p> | brads | 0-255 |
| 6 | Torque LSB | 2 Bytes | The average torque during this event interval. | 1/32 Nm | 0-2047.97 |
| 7 | Torque MSB | | | | |

17.1.1 Update Event Count

The update event count field is incremented each time the information in the message is updated. There are no invalid values for update event count. For Power-only sensors (refer to section 7.2) the time-period of the update count depends on the system but must be a regular interval for accurate averaging. The update event count in this message refers to updates only to the fields of this message.

17.1.2 Start and End Torque Angle

The angle at which the positive torque begins and ends. The axis used by the start and end torque angle is shown in figure Figure 17-1, clockwise starting from normal. See Figure 17-2 for a graph explaining start and end torque angles.

If positive torque occurs through the whole pedal stroke, the sensor shall set Start Angle to 0x00 and End Angle to 0xFF.

If the sensor cannot determine or does not support Start and End Torque Angle, it shall set both Start Angle and End Angle to 0xC0.

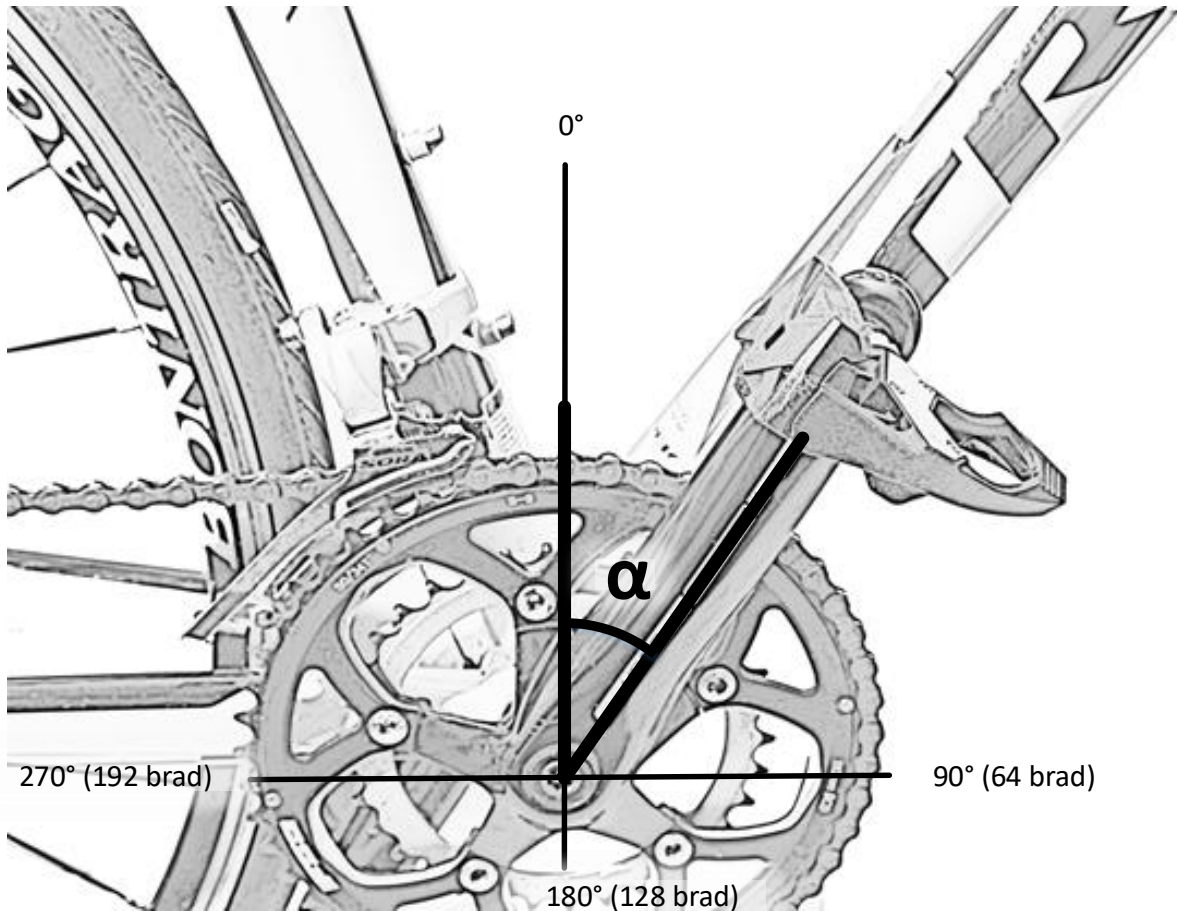


Figure 17-1. Crank Angle

17.1.3 Start and End Peak Torque Angle

The start and end peak angle define the angles between which peak torque is outputted. The axis used by the start and end peak torque angle is shown in figure Figure 17-1, clockwise starting from normal. By default, peak torque is defined as 50% of the total torque in an event interval. The peak torque threshold percentage configured may be requested and set using the Bicycle Power Meter Get/Set Parameters Subpage Power Phase Configuration. See Figure 17-2 for a graph explaining start and end peak torque angles.

If peak torque is achieved through the whole pedal stroke, the sensor shall set Start Peak Angle to 0x00 and End Peak Angle to 0xFF.

If the sensor cannot determine or does not support Start and End Peak Torque Angle, it shall set both Start Peak Angle and End Peak Angle to 0xC0.

17.1.3.1 Calculating Start and End Peak Torque Angle

This section explains of how the peak torque threshold configured using Get/Set Subpage 2 Power Phase Configuration is used to derive start and end peak torque angles.

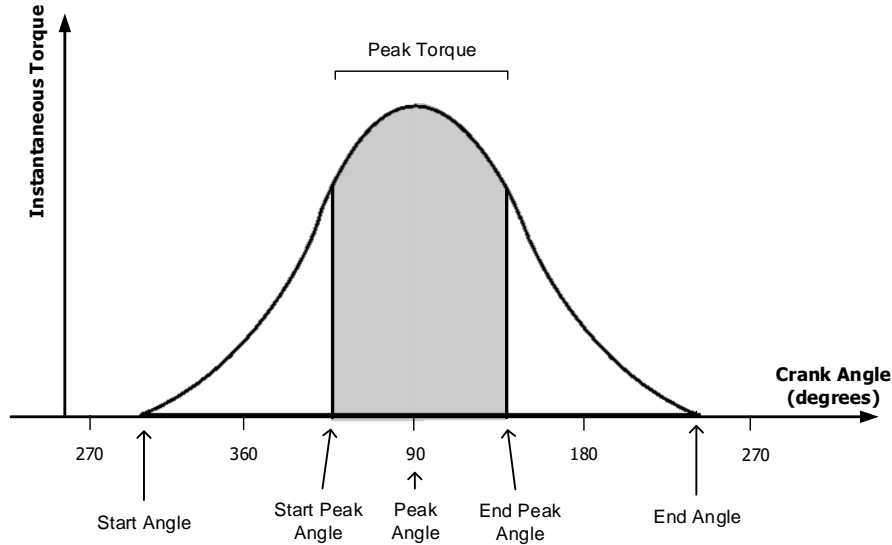


Figure 17-2. Instantaneous Torque vs. Crank Angle

The curve in Figure 17-2 describes the relationship between instantaneous torque and crank angle. The area under the curve is the total positive torque applied over the course of the crank cycle. The shaded area represents the peak torque. Equation 16 defines peak torque as a function of the total torque over the course of a crank cycle, and the configured peak torque threshold percentage. Peak angle is the angle at which the instantaneous torque is at its maximum over the course of a crank cycle. Ideally, this angle will be around 90°. These two values together can be used together to determine the start and end angles of the peak torque as explained in Equation 18, or a discrete approximation thereof.

$$\text{Peak Torque} = \text{Total Torque} \times \frac{\text{threshold}}{100}$$

Equation 16. Peak Torque Calculation

$$\text{Peak Angle} = \text{Torque Angle Curve (Maximum Instantaneous Torque)}$$

Equation 17. Peak Torque Angle Calculation

$$\frac{\text{Peak Torque}}{2} = \int_{\text{peak angle}}^{\text{end angle}} \text{Torque Angle Curve} = \int_{\text{start angle}}^{\text{peak angle}} \text{Torque Angle Curve}$$

Equation 18. Start and End Peak Torque Angle Calculation

17.2 Left Force Angle (0xE1)

This page is an element of Cycling Dynamics. It can be enabled by a display through get/set parameters subpage 0xFE, and **shall [MD_PWR_010]** be transmitted if 8 Hz mode is enabled, AND Power Phase is enabled. It **shall [MD_PWR_010]** stop transmitting when Power Phase is disabled. The page should be interleaved such that the page may be received by a 4 Hz transmitter at a regular interval.

Table 17-2. Left Pedal Force Angle Message Format

| Byte | Description | Length | Value | Units | Rollover or Valid Range |
|------|------------------|--------|--|-------|-------------------------|
| 0 | Data Page Number | 1 Byte | 0xE1 – Left Pedal Force Angle Page | N/A | N/A |
| 1 | Event Count | 1 Byte | Event counter increments with each information update. | N/A | 256 |
| 2 | Start Angle | 1 Byte | The angle at which the positive torque begins for the left pedal. Set to 0x00 if positive torque occurs through the whole pedal stroke. 0xC0 – indicates invalid if End Angle also set to 0xC0. | brads | 0-255 |
| 3 | End Angle | 1 Byte | The angle at which the positive torque ends for the left pedal. Set to 0xFF if positive torque occurs through the whole pedal stroke. 0xC0 – indicates invalid if Start Angle also set to 0xC0. | brads | 0-255 |
| 4 | Start Peak Angle | 1 Byte | The angle at which, between it and the end peak angle, peak torque is achieved. Set to 0x00 if peak torque is achieved through the whole pedal stroke (i.e., Peak Torque Threshold is set to 100%). 0xC0 – indicates invalid if End Peak Angle also set to 0xC0. | brads | 0-255 |
| 5 | End Peak Angle | 1 Byte | The angle at which, between it and the start peak angle, peak torque is achieved. Set to 0xFF if peak torque is achieved through the whole pedal stroke (i.e., Peak Torque Threshold is set to 100%). 0xC0 – indicates invalid if Start Peak Angle also set to 0xC0. | brads | 0-255 |

| | | | | | |
|---|------------|---------|--|---------|-----------|
| 6 | Torque LSB | 2 Bytes | The average torque during this event interval. | 1/32 Nm | 0-2047.97 |
| 7 | Torque MSB | | | | |

17.2.1 Event Count

The update event count field is incremented each time the information in the message is updated. There are no invalid values for update event count. For Power-only sensors (refer to section 7.2) the time-period of the update count depends on the system but must be a regular interval for accurate averaging. The update event count in this message refers to updates only to the fields of this message.

17.2.2 Start and End Torque Angle

See section 17.1.2.

17.2.3 Start and End Peak Torque Angle

See section 17.1.3.

17.3 Pedal Position Data (0xE2)

This page is an element of Cycling Dynamics. It can be enabled by a display through get/set parameters subpage 0xFE, and **shall** [MD_PWR_010] be transmitted if 8 Hz mode is enabled, AND either Rider Position OR PCO is enabled. It **shall** [MD_PWR_010] stop transmitting when both Rider Position AND PCO are disabled. The page should be interleaved such that the page may be received by a 4 Hz transmitter at a regular interval – for example by transmitting the page every X pages where X is an odd number. The exact frequency of transmission is left up to the manufacturer.

Table 17-3. Pedal Position Data Message Format

| Byte | Description | Length | Value | Units | Rollover or Valid Range |
|------|------------------|--------------|--|-------|-------------------------|
| 0 | Data Page Number | 1 Byte | 0xE2 – Pedal Position Data | N/A | N/A |
| 1 | Event Count | 1 Byte | Crank Cycle count | N/A | 256 |
| 2 | Reserved | 6 bits (0:5) | Set to 0x20 | N/A | N/A |
| | Rider Position | 2 bits (6:7) | 0 – Seated (or cannot determine) 1 – Transition to Seated 2 – Standing 3 – Transition to Standing | N/A | 0-3 |
| 3 | Cadence | 1 Byte | The average number of revolutions of the crank per minute during this event interval. 255 - Invalid | rpm | 0-254 |
| 4 | Right PCO | 1 Byte | Right Platform Center Offset -128 - Invalid | mm | + -127 |
| 5 | Left PCO | 1 Byte | Left Platform Center Offset -128 - Invalid | mm | + -127 |
| 6 | Reserved | 1 Byte | Set to 0xFF | | |
| 7 | Reserved | 1 Byte | Set to 0xFF | | |

17.3.1 Event Count

The update event count field is incremented each time the information in the message is updated. There are no invalid values for update event count. For Power-only sensors (refer to section 7.2) the time-period of the update count depends on the system but must be a regular interval for accurate averaging. The update event count in this message refers to updates only to the fields of this message.

17.3.2 Rider Position

The current position of the rider as either standing or seated or whether the rider is in a transition. The Bicycle Power Meter Get/Set Parameters Rider Position Configuration Subpage indicates how long after detecting a transition the power meter should remain in transition state before indicating the new valid detected state. Rider position is often used by displays and post-processing applications to differentiate power output while standing vs. while sitting.

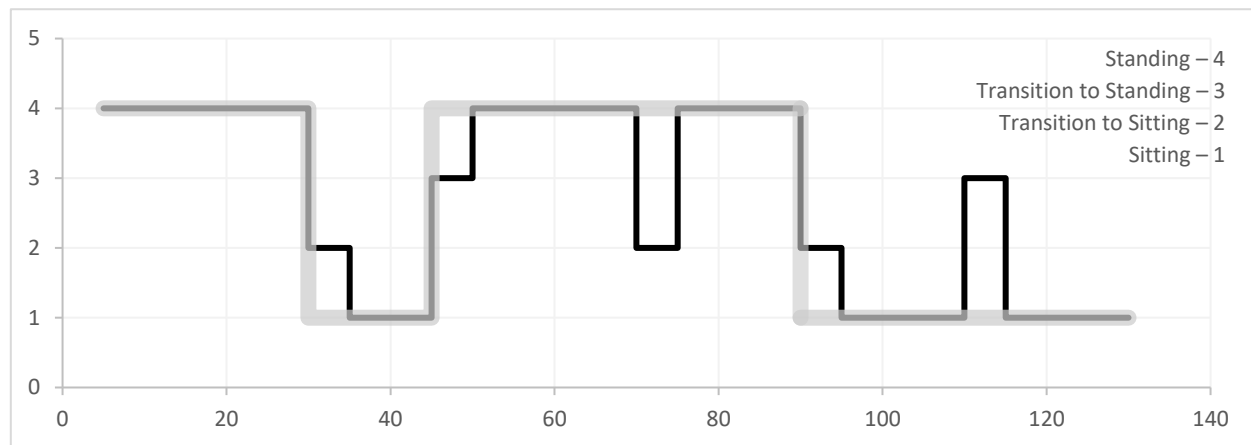
17.3.2.1 Interpreting Rider Position Transitions

A transition state is a state in which the power meter has detected a change from standing to sitting or sitting to standing, but is uncertain whether that change is a true transition to the subsequent state or if the transition detected is a false positive. Because power often spikes when a rider transitions from sitting to standing, accounting the transition states as sitting vs. standing correctly is important when attempting to compare power while sitting to standing. Table 17-4 explains how to properly attribute transition states in post-processing to provide riders with the most accurate picture of the detected transitions. Figure 17-3 graphically illustrates how to interpret transitions.

Table 17-4. Attribution of Transition States

| State 1 | State 2 | State 3 | Attribution of State 2 |
|----------|------------------------|----------|------------------------|
| Seated | Transition to Standing | Standing | Standing |
| Seated | Transition to Standing | Seated | Seated |
| Standing | Transition to Seated | Seated | Seated |
| Standing | Transition to Seated | Standing | Standing |

While this approach provides the most accurate interpretation of rider position transitions, it may be difficult to implement on displays since it requires back calculating transition information. A more simplistic approach may also be taken when interpreting rider position such as to interpret all transitions as sitting, or to interpret all transitions as successful transitions to the next state.

**Figure 17-3. Interpreting Rider Position Transitions**

17.3.3 Cadence

The average number of revolutions per minute during this event interval.

17.3.4 Platform Center Offset

The number of mm away from the center of the pedal body cleat platform (in the direction outward from the bicycle) the center of rider's pedal force is applied.

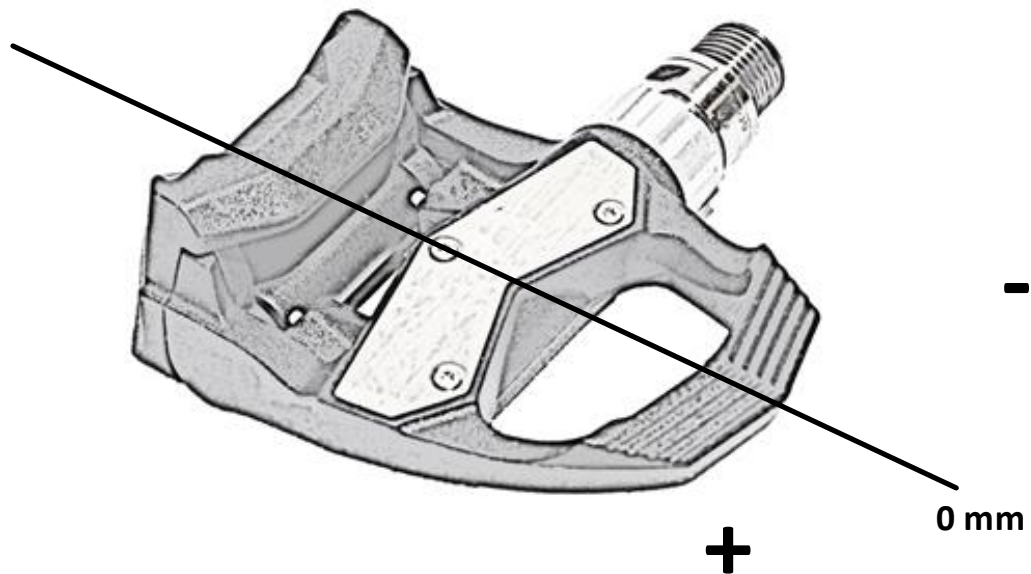


Figure 17-4. Platform Center Offset

17.4 Torque Barycenter Data Page (0x14)

This page is an element of Cycling Dynamics. It can be enabled by a display through get/set parameters subpage 0xFE, and **shall [MD_PWR_010]** be transmitted if 8 Hz mode is enabled, AND Torque Barycenter is enabled. It **shall [MD_PWR_010]** stop transmitting when Torque Barycenter is disabled. The page should be interleaved such that the page may be received by a 4 Hz transmitter at a regular interval.

This page allows oval chain ring users to display data over the course of their ride and determine the optimal positioning of their chain ring. All fields in this message **shall [MD_0010]** be set as described in Table 17-5.

Table 17-5. Torque Barycenter Message Format

| Byte | Description | Length | Value | Units | Rollover or Valid Range |
|------|-------------------------|---------|---|-------|-------------------------|
| 0 | Data Page Number | 1 Byte | 0x14 – Torque Barycenter | N/A | N/A |
| 1 | Torque Barycenter Angle | 1 Byte | The barycenter of the torque (or force) graph of both pedals for each pedal stroke. In 0.5° starting at 30°. | 0.5° | 30° - 157° |
| 2-7 | Reserved | 6 Bytes | Set all bytes to 0xFF | N/A | N/A |

17.4.1 Torque Barycenter Angle

The barycenter of the torque (or force) graph for each pedal stroke. This metric can be used to determine the optimum chain ring position of an oval ring. It is measured in 0.5° starting at 30°. The value is encoded with an offset of 30°.

Examples:

- (1) To indicate that the torque barycenter angle is 45°, the value in the Torque Barycenter Angle field is sent as 30.

$$(45^{\circ} - 30^{\circ})/0.5^{\circ} = 30.$$

- (2) A value of 230 is received in the Torque Barycenter Angle field. The torque barycenter angle is 145°.

$$230 * 0.5^{\circ} + 30^{\circ} = 145^{\circ}$$

The torque barycenter angle is based on composite data from the left and right pedal strokes. Each pedal stroke typically includes regions of positive and negative torque. The net torque values during a crank cycle can be plotted in a polar graph as seen in Figure 17-5. The angle of this graph's barycenter is the torque barycenter angle.



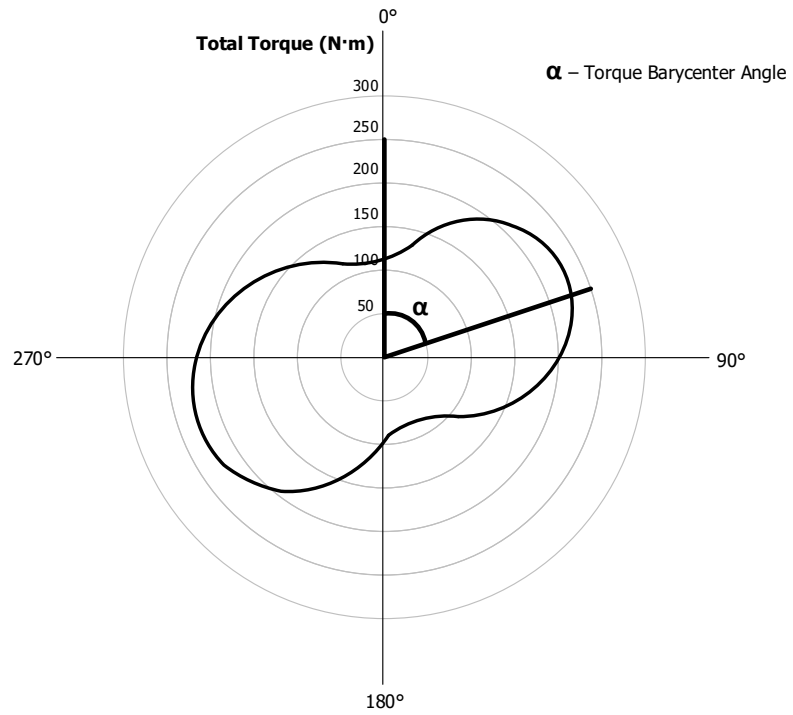


Figure 17-5. Torque Graph Illustrating Torque Barycenter Angle

17.4.1.1 Torque Barycenter Angle Calculation

Equation 19-Equation 25 demonstrate how to calculate the torque barycenter angle.

In these equations, TBA is the torque barycenter angle, T is the instantaneous torque or force, and θ is the angle at which T is applied. Angles are measured from the top of the pedal stroke (see angle α in Figure 17-1).

Note that the torque barycenter angle is calculated slightly differently in the cases of single leg measurement (Equation 19 & Equation 20) and combined leg measurement (Equation 21 & Equation 22). In the case of combined leg measurement, the angle θ must be adjusted to be in the range of 0°-180°. Equation 23-Equation 25 are applicable to both single leg and combined leg measurement.

$$TBA_{xi} = T_i^3 \cdot \cos(\theta_i)$$

Equation 19. x-Component of Torque Barycenter Angle at Angle Theta – Single Leg Measurement

$$TBA_{yi} = T_i^3 \cdot \sin(\theta_i)$$

Equation 20. y-Component of Torque Barycenter Angle at Angle Theta – Single Leg Measurement

$$\begin{aligned} TBA_{xi} &= T_i^3 \cdot & (\theta \leq 180^\circ) \\ TBA_{xi} &= T_i^3 \cdot \cos(\theta_i - 180^\circ) & (\theta > 180^\circ) \end{aligned}$$

Equation 21. x-Component of Torque Barycenter Angle at Angle Theta – Combined Leg Measurement

$$\begin{aligned} TBA_{yi} &= T_i^3 \cdot & (\theta \leq 180^\circ) \\ TBA_{yi} &= T_i^3 \cdot \sin(\theta_i - 180^\circ) & (\theta > 180^\circ) \end{aligned}$$

Equation 22. y-Component of Torque Barycenter Angle at Angle Theta – Combined Leg Measurement

$$TBA_x = \sum TBA_{xi}$$

Equation 23. Total x-Component of Torque Barycenter Angle

$$TBA_y = \sum TBA_{yi}$$

Equation 24. Total y-Component of Torque Barycenter Angle

$$TBA = \arctan\left(\frac{TBA_x}{TBA_y}\right)$$

Equation 25. Torque Barycenter Angle

17.4.1.2 Comparison to Peak Torque Angle

Torque barycenter angle differs from peak angle by including both positive and negative torque. If the graph of a single pedal's stroke has the same shape and orientation for positive and negative torque, the torque barycenter angle for that pedal stroke is the same as its peak angle. However, if the positive and negative torque differ in shape or orientation, torque barycenter angle is affected while peak angle is not.

This is illustrated in Figure 17-6 and Figure 17-7, where the grey ellipses represent positive torque and the interior white ellipses represent negative torque over a pedal stroke. Total torque is the area represented by subtracting the area of the negative torque from the area of the positive torque. The torque barycenter angle divides the graph into two halves with the same area.

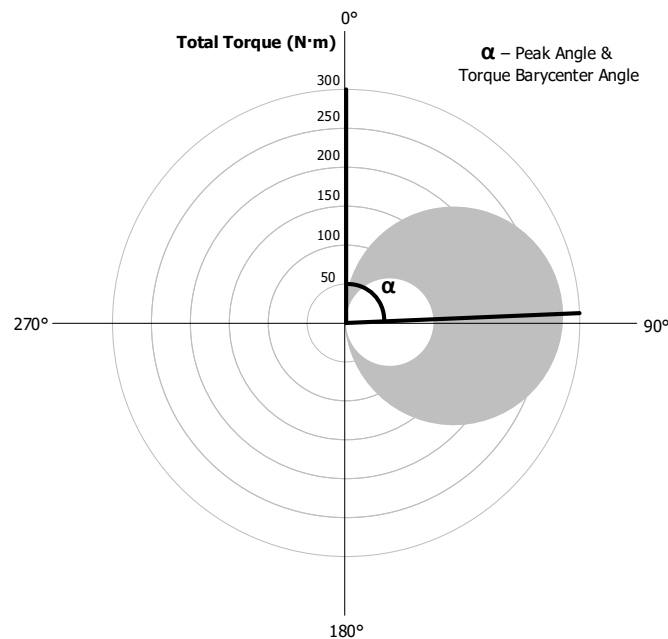


Figure 17-6. Single Pedal Stroke with Equal Peak Angle and Torque Barycenter Angle

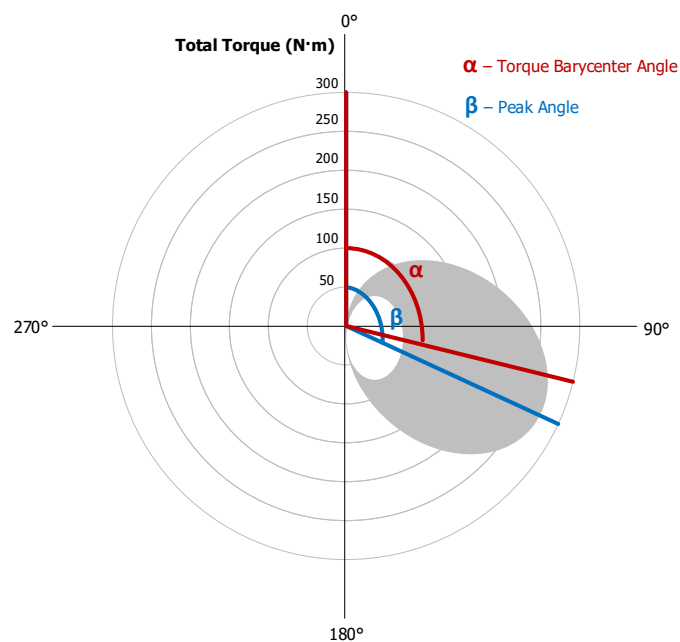


Figure 17-7. Single Pedal Stroke with Unequal Peak Angle and Torque Barycenter Angle

18 Reserved Range

Pages 4-15, 21-31, and 33-111 are reserved for future use. These pages **shall [MD_0007]** not be transmitted.

19 Common Pages

Data page numbers above 0x40 are globally defined across all ANT devices. Formats exist to provide information about battery status and operating hours as well as hardware and software versions. These common data pages may be interleaved with the power messages to provide the display with information about the sensor's status.

For more detailed information, refer to the ANT+ Common Pages document.

19.1 Required Common Pages

19.1.1 Common Page 80 (0x50) – Manufacturer's Identification

Common data page 80 **shall** [MD_0009] transmits the manufacturer's ID, model number, and hardware revision.

Refer to the ANT+ Common Pages document for details of this page.

19.1.2 Common Page 81 (0x51) – Product Information

Common data page 81 transmits the device's software revision and its 32-bit serial number.

Refer to the ANT+ Common Pages document for details of this page.



19.2 Optional Common Pages

19.2.1 Common Page 70 (0x46): Request Data Page

Common Data Page 70 allows an ANT+ device to request a specific data page from another ANT+ device; in this case, it allows the display to request the Get/Set Parameters pages from the ANT+ power meter. The request data page **shall [self-verify]** be sent using an acknowledged message by the display and **shall [self-verify]** be formatted as shown in Table 19-1.

This is an optional data page. Power meter sensors that do not support this page **shall [MD_0013]** ignore the request. Displays **shall [self-verify]** handle this lack of response gracefully.

Table 19-1. Common Data Page 70 Format

| Byte | Description | Length | Value | Units |
|------|---------------------------------|--------|---|-------|
| 0 | Command ID | 1 Byte | 70 (0x46) – Data Page Request | N/A |
| 1 | Reserved | 1 Byte | Value = 0xFF | N/A |
| 2 | Reserved | 1 Byte | Value = 0xFF | N/A |
| 3 | Descriptor Byte 1 | 1 Byte | Allows subpages to be requested within the requested data page. Valid Values: 0 – 254 Invalid: 255 (0xFF) | N/A |
| 4 | Descriptor Byte 2 | 1 Byte | Allows subpages to be requested within the requested data page. Valid Values: 0 – 254 Invalid: 255 (0xFF) | N/A |
| 5 | Requested Transmission Response | 1 Byte | Describes transmission characteristics of the data requested. Bit 0-6: Number of times to transmit requested page. Bit 7: Setting the MSB means the device replies using acknowledged messages if possible. Special Values: 0x80 - Transmit until a successful acknowledge is received. 0x00 – Invalid | N/A |
| 6 | Requested Page Number | 1 Byte | Page number to transmit. | N/A |
| 7 | Command Type | 1 Byte | Value = 1 (0x01) for Request Data Page | N/A |

19.2.1.1 Descriptor Bytes 1 & 2

The descriptor byte fields are used to describe requested subpages and **shall [self-verify]** be populated when requesting data page 0x01 or 0x02. Refer to section 15.1.2 for an example. Otherwise these bytes are set to invalid (e.g. when requesting data page 0x10).

19.2.1.2 Requested Transmission Response

The power meter **shall [MD_0013]** be able to support all requested transmission response types; however, the ANT+ bicycle power device profile further stipulates that **the display shall [self-verify] only request broadcast messages from a power meter sensor.**

Refer to the ANT+ Common Pages document for more details on the request data page and possible requested transmission response types.

19.2.2 Common Page 82 (0x52): Battery Status

Common data page 82 transmits the device's battery voltage and status. If this page is sent by power sensors that contain more than one battery (e.g. in left-right pedal systems), then this page should be populated to represent the values from the battery with the lowest voltage.

This is an optional data page; however if it is used, then it shall [MD_0008] be interleaved at least once every 61 messages.



Table 19-2. Global Data Page 82 - Battery Status

| Byte | Description | Length | Value | Units | Rollover |
|------|-------------------------------|---------|---|-------------------------------|------------------------|
| 0 | Data Page Number | 1 Byte | 82 (0x52) – Battery Status | N/A | N/A |
| 1 | Reserved | 1 Byte | Value = 0xFF | N/A | N/A |
| 2 | Battery Identifier | 1 Byte | Identifies the battery in the system to which this battery status pertains and specifies how many batteries are available in the system. Bits 0-3: Number of Batteries Bits 4-7: Identifier Set to 0xFF if not used. | N/A | N/A |
| 3 | Cumulative Operating Time LSB | 3 Bytes | This will give the cumulative operating time of the device and should be reset on insertion of a new battery. | 2 seconds or 16 seconds | 1.1 years 8.5 years |
| 4 | Cumulative Operating Time | | | | |
| 5 | Cumulative Operating Time MSB | | | | |
| 6 | Fractional Battery Voltage | 1 Byte | Value = 0 – 255 (0x00 – 0xFF) | 1/256 (V) | N/A |
| 7 | Descriptive Bit Field | 1 Byte | Refer to ANT+ Common Pages | Binary | N/A |

19.2.2.1 6.7.1 Battery Identifier

The battery identifier is used by systems that are made up of components and have a need to report battery status information from multiple batteries. The upper nibble of this field is used identify the battery in the system to which this message pertains while the lower nibble is used to indicate the total number of batteries in the system.

Identifier: Identifies battery in system to which this message pertains.

Number of batteries: Total number of batteries in the system needing to report battery status.

Only the battery with the lowest battery level should be broadcast in the regular common page transmission pattern. This ensures that display devices that do not support the device identifier field still show a consistent and meaningful value. The display may request battery information of all other devices individually using the Request Data Page (Common Page 70), and setting descriptor byte 1 to the value of the desired identifier.

For bicycle power sensors, identifier values 0 and 1 are reserved for the right and left pedal batteries respectively. For example, a pedal based power meter may report power for both the right and the left pedals by setting the 'Identifier' field to 0 for the right pedal battery and 1 for the left pedal battery while setting the 'Number of batteries' field to 2. If the left pedal battery had the lower voltage its value would be reported in the regular transmission for the Battery Status page. The display may request the battery status of the right pedal to get a better picture of the entire system's battery status.

If this field is not used its value should be set to 0xFF.

19.3 Other Common Pages

Other common data pages that are listed in the ANT+ Common Pages document can be sent from the ANT+ bike power sensor. Other common data pages are implemented in the bike power sensor at the discretion of the developer.

20 Guidelines for Best Practice

20.1 Accumulate Positive Values Only

The ANT+ data page definitions make use of accumulated values to maintain accuracy in the event of packet loss. All of these accumulated values are scalar quantities and **shall [MD_0011]** be incremented only by positive amounts. If a negative number is added to an accumulated value, it cannot be interpreted correctly on the receive side.

20.2 Handle Stop and Coasting Conditions

The display **shall [MD_PWR_009]** properly handle the display of power, speed, and cadence in cases when the bicycle is stopped and when the bicycle is coasting as described in the sections below.

20.2.1 Event-synchronous Updates

Since no wheel (crank) events are occurring, no updates occur. The last page is repeated until either a rotation event occurs or the unit shuts down. The display should recognize that an extended period of repeated messages indicates a stop or coasting. (For torque frequency sensors refer to section 13.7.)

It is recommended that event-synchronous power sensors self-detect coasting or stopped conditions and force an update to explicitly indicate this state to the display.

20.2.2 Time-synchronous Updates

If the wheel (or crank) is not moving in a system with fixed interval updates, the update count increases but the accumulated Wheel Ticks (crank ticks) and Accumulated Wheel (Crank) Period do not increase. The display should interpret a zero increase in these values as a stop or coasting. For Power-only sensors (i.e. sensors that only send data page 0x10) a stop or coasting condition is indicated by the accumulated power remaining constant while the event updates continue to increment.

How and when the display handles these cases is up to the individual manufacturer.

20.3 Handling Invalid Values

If a display receives an invalid value from the sensor, it is recommended that this is indicated to the user by clearing the display field or showing dashes, rather than leaving the last valid value in place.



21 Using Accumulated Values

The ANT+ data page definitions make use of accumulated values to maintain accuracy in the event of packet loss. This section explains how to properly transmit and receive accumulated data:

- Transmitters **shall [MD_0011]** add only positive values to message fields that are accumulated.
- Receivers **shall [SD_0008]** reconstruct accumulated values from rollover fields as described in section 21.2.
- Receivers should use average values to properly calculate and store data after RF reception loss.



21.1 Transmitting Data in Accumulated Values

Instantaneous values from the sensor, such as power and wheel period, are calculated during each update period and added to a running sum. The update event count and the accumulated sum are then transmitted in the next broadcast message. For example, during update event N the data field would be accumulated as in Equation 26.

$$AccumulatedValue_N = AccumulatedValue_{N-1} + CurrentValue$$

Equation 26. Example of Accumulating a Value

Each message field has a maximum value, after which the running sum rolls over, as shown in Figure 21-1. Note that a rollover makes it possible for the Accumulated Value N to be less than it was in the previous message.

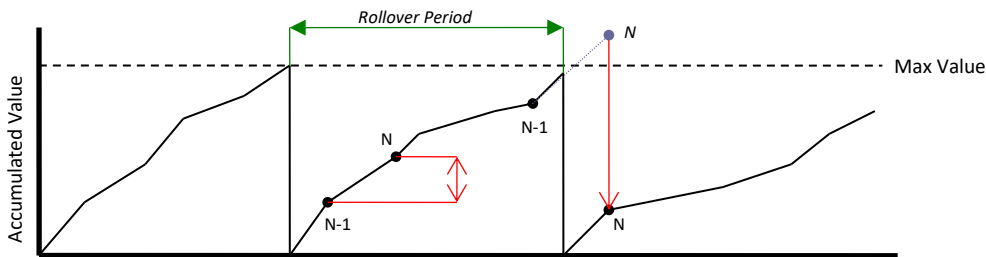


Figure 21-1. Accumulating Values

NOTE: All accumulating message fields must use only positive values.

A decrease in an accumulated value is interpreted by the receiver as a rollover event. For this reason, negative values cannot be added to accumulated fields as they will be incorrectly calculated at the receive side.

The expected amount of time separating rollover events is called the rollover period. This is the maximum amount of time that accuracy in calculations can be maintained during an interruption of RF reception. Rollover periods vary by application and are described in the data page sections.

21.2 Receiving and Calculating Data from Accumulated Values

When messages are received by the display, the current value can be determined by subtracting the data from the previous message, and dividing by the difference in update event counts between the two messages.

NOTE: The following calculations assume signed numbers are used.

To properly span rollovers, the calculations on the receiver side must first reconstruct the accumulated value and the event count from the received values, as shown:

1. Initialize AccumulatedValue to 0; initialize PreviousReceivedValue to the value received in the first data message.
2. For each subsequent data message:
 - a. $\text{AccumulatedValue} += \text{ReceivedValue} - \text{PreviousReceivedValue}$
 - b. If $\text{PreviousReceivedValue} > \text{ReceivedValue}$

$$\{ \text{AccumulatedValue} += 256 \}$$
 - c. $\text{PreviousReceivedValue} = \text{ReceivedValue}$

Note that the event count is reconstructed in exactly the same way as the accumulated value. The current value can then be calculated from the reconstructed accumulated value and the reconstructed event count as shown in Equation 27. In the following, N refers to the most recently calculated value, and $N-1$ refers to the calculation immediately preceding N .

$$\text{CurrentValue} = \frac{(\text{AccumulatedValue}_N - \text{AccumulatedValue}_{N-1})}{(\text{AccumulatedEventCount}_N - \text{AccumulatedEventCount}_{N-1})}$$

Equation 27. Calculating a Value from Two Messages

During normal RF conditions, every message is received and the calculated value is equal to the instantaneous value.

When RF reception is compromised, the calculated value is the average value over the period of the RF outage.

21.3 Handling Data during RF Reception Loss

An important benefit of using accumulated values in message fields is that accuracy can be maintained during RF reception loss. Under normal operating conditions with adequate RF reception, instantaneous values are calculated at the receiver. When reception is interrupted, the average value of the data is automatically reconstructed.

Figure 21-2 shows bicycle power data that is sent during a period of RF reception loss. During the outage (A), the instantaneous value is unavailable and the display may choose to show the most recent power value or to indicate that messages are not being received.

After reception resumes (B), the first value calculated at the receiver is the average power over the period of the outage. It is important that display units properly calculate the average power over the interval and then save these values correctly into memory and into any summary statistics. Storing either zeros or the last received data before the loss results in inaccurate data.

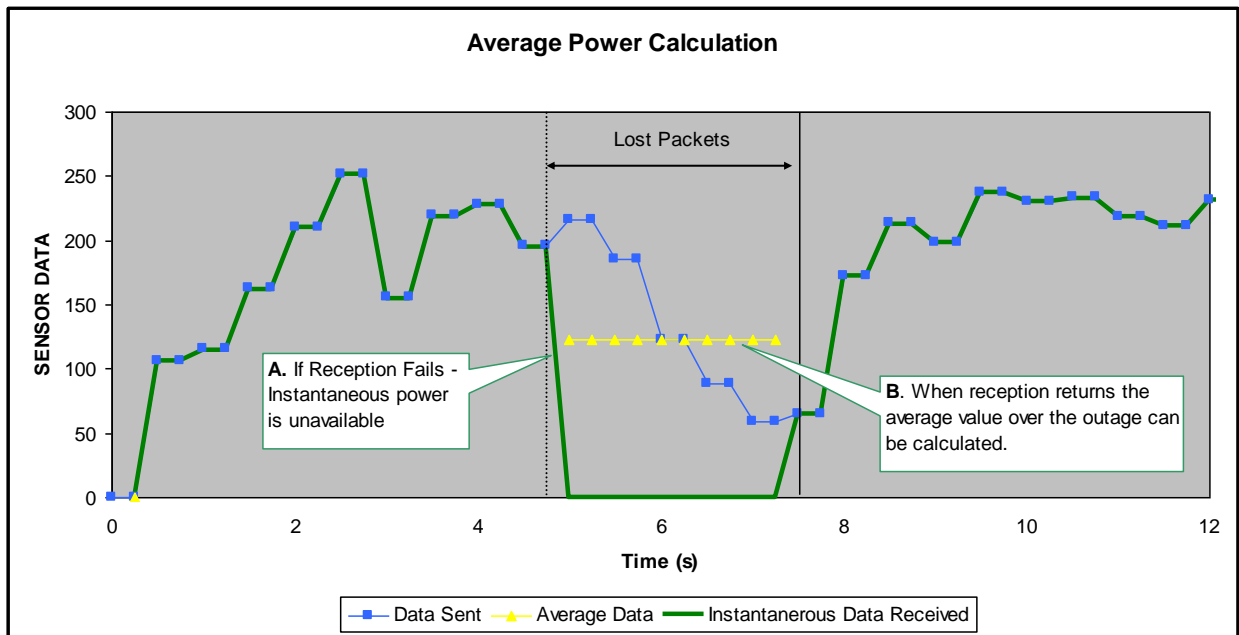


Figure 21-2. Averaging Power through an RF Outage

22 Minimum Requirements

The ANT+ Bicycle Power Device Profile divides bicycle power sensors into two groups: standard PWR sensors (including power-only, torque at wheel and torque at crank sensors), and CTF sensors. Each of these types must meet a set of minimum transmission requirements, and is associated with a distinct interoperability icon, as described below.

22.1 Minimum Transmission Requirements for ANT+ Bicycle Power Sensors and Displays

22.1.1 Sensor requirements (PWR)

ANT+ Bicycle Power (PWR) sensors must behave as described in either section 7. The pages marked as required in Table 22-1 **shall [MD_0006]** be sent, and comply with the timing requirements. Any optional pages used **shall [MD_0008] [MD_0010]** also comply.

When operating in 8 Hz mode, the minimum transmission pattern outlined in Table 22-2 **shall [self-verify]** be used.

Table 22-1. Minimum Transmission Requirements for ANT+ Bicycle Power Sensors at 4 Hz (PWR)

| Function | Page Number | Message | Details | |
|--|--------------|---|--|--|
| Optional Torque Main Data Page | 0x11 0x12 | Tx: Standard Torque At Wheel OR Tx: Standard Torque At Crank | Default broadcast message (if used) interleave at least twice every 4 messages | |
| Required Power Main Data Page | 0x10 | Standard Power Only | Default broadcast message, interleave at least twice every 4 messages OR if page 0x11 or 0x12 is in use, then: Minimum: Interleave every 9 messages Preferred: Interleave every 5 messages OR if page 0x13 is in use, then: Minimum: Interleave as often as page 0x13 | |
| Optional TE & PS Main Data Page | 0x13 | Torque Efficiency and Pedal Smoothness | Minimum: Interleave every 5 messages (1.25s) | |
| Required Common Data Page | 0x50 | Manufacturer’s Information | Minimum: Interleave every 121 messages (30.25s) | |
| Required Common Data Page | 0x51 | Product Information | Minimum: Interleave every 121 messages (30.25s) | |
| Optional Common Data Page | 0x52 | Battery Voltage | Minimum: Interleave every 61 messages (15.25s) | |
| Calibration Function | Page | Cal ID | Message | Details |
| Required Manual Calibration (Zero Offset) Page | 0x01 | 0xAA | Rx: Calibration request (0xAA) | Service calibration request when received from display. See section 14 for details. |
| | | 0xAC | Tx: Acknowledge (0xAC) | |
| | | 0xAF | Tx: Fail (0xAF) | |
| Optional Auto Zero | 0x01 | 0xAB | Rx: Auto zero configuration (0xAB) | Service auto zero configuration request when received from display (for sensors that self-monitor zero offset) |
| | | 0xAC | Tx: Acknowledge (0xAC) | |
| | | 0xAF | Tx: Fail (0xAF) | |
| Optional Custom Calibration Parameters | 0x01 | 0xBA | Custom Cal Parameter Request | Set custom calibration parameters See section 14 for details. |
| | | 0xBB | Custom Cal Parameter Response | |
| | | 0xBC | Custom Cal Parameter Update | |



| | | | | |
|----------------------------|------|------|--------------------------------------|---|
| | | 0xBD | Custom Cal Parameter Update Response | |
| Optional Auto Zero Support | 0x01 | 0x12 | Tx: Auto zero status | Minimum: Interleave every 121 messages (30.25s) |

Table 22-2. Minimum Transmission Requirements for ANT+ Bicycle Power Sensors at 8 Hz (PWR)

| Function | Page Number | Message | Details |
|-----------------------------------|--------------|---|---|
| Optional Torque Main Data Page | 0x11 0x12 | Tx: Standard Torque At Wheel OR Tx: Standard Torque At Crank | Default broadcast message (if used) interleave at least 4/15 messages. Recommended: Interleave 8/29 messages |
| Required Power Main Data Page | 0x10 | Standard Power Only | Default broadcast message, interleave at least 4/15 messages OR if page 0x11 or 0x12 or 0x13 is in use, then: Minimum: Interleave 3/29 messages |
| Optional TE & PS Main Data Page | 0x13 | Torque Efficiency and Pedal Smoothness | Minimum: Interleave 3/29 messages |
| Required Common Data Page | 0x50 | Manufacturer's Information | Minimum: Interleave every 243 messages (30.25s) |
| Required Common Data Page | 0x51 | Product Information | Minimum: Interleave every 243 messages (30.25s) |
| Optional Common Data Page | 0x52 | Battery Voltage | Minimum: Interleave every 123 messages (15.25s) |
| Cycling Dynamics | | | |
| Optional Right Force Angle Page | 0xE0 | Right Force Peak Torque Angle | Minimum: Interleave 3/29 messages |
| Optional Left Force Angle Page | 0xE1 | Left Force Peak Torque Angle | Minimum: Interleave 3/29 messages |
| Optional Pedal Position Data Page | 0xE2 | Pedal Position | Minimum: Interleave 3/29 messages |
| Optional Torque Barycenter Page | 0x14 | Torque Barycenter | Minimum: Interleave 3/29 messages |

22.1.2 Display Requirements (PWR)

To qualify as an ANT+ Bicycle Power (PWR) display the device must implement the Simple Receiver Implementation (PWR) described in Table 4-1 as a minimum. However the Full Receiver Implementation is preferred as it offers a greater feature set to the user.

22.2 Minimum Transmission Requirements for ANT+ Crank Torque Frequency Sensors and Displays**22.2.1 Sensor requirements (CTF)**

To qualify as an ANT+ Crank Torque Frequency sensor the device must behave as described in section 7.4.

22.2.2 Display Requirements (CTF)

To qualify as an ANT+ Crank Torque Frequency (CTF) display the device must implement the CTF-only Receiver Implementation described in Table 4-1 as a minimum. However, the Full Receiver Implementation is preferred as it offers a greater feature set to the user.

22.3 Additional Requirements

In addition to the requirements outlined in sections 22.1 and 22.2, the following general requirements apply:

- A sensor **shall [MD_0006]** only send broadcast messages to the display and **shall [MD_0006]** never send acknowledged or burst messages. However, a display **shall [SD_0010]** decode (and display) data sent as acknowledged messages from the sensor.
- A display **shall [SD_0009]** not decode any unexpected burst messages that are sent from the sensor and **shall [SD_0009]** handle this situation gracefully.
- A display **shall [SD_0007]** not decode reserved bytes in received data pages.
- The display **shall [SD_0005]** handle gracefully the receipt of undefined data pages.
- A sensor **shall [MD_0014]** not open any other master channel on the ANT+ Network Key except that the channel conforms to an ANT+ Device Profile.



22.4 ANT+ Device Interoperability Icons

The ANT+ interoperability icons inform the end user of the product's capabilities. These icons indicate to the user that this specific device will transmit/receive bicycle power or crank torque frequency information, and that it is interoperable with other devices that carry the same icon. The use of these icons is optional for certified devices (and prohibited for uncertified devices), however it is strongly recommended that they are used because consumers may not otherwise be able to distinguish between PWR and CTF devices. Devices that have been certified against both sets of requirements (e.g. displays using the Full Receiver Implementation) can use both icons.

An ANT+ Bicycle Power sensor or display that meets the minimum compliance specifications and has been certified may use the icon shown in Figure 22-1 on packaging, documentation, and marketing material.



Figure 22-1. ANT+ Bicycle Power Device Interoperability Icons

An ANT+ Crank Torque Frequency sensor or display that meets the minimum compliance specifications and has been certified may use the icon shown in Figure 22-2 on packaging, documentation, and marketing material.



Figure 22-2. ANT+ Crank Torque Frequency Device Interoperability Icons

23 Profile Verification Tests

Table 23-1. Profile Verification Tests for the Bike Power Sensor

| <input checked="" type="checkbox"/> | Certification Test | Relevant Document Sections |
|-------------------------------------|---|---|
| | MD_0001 ANT Channel Parameter Test | 5 Channel Configuration |
| | MD_0002 Transmission Type | 5.2 Master Channel Configuration |
| | MD_0003 Channel Period | 5.2 Master Channel Configuration |
| | MD_0004 Channel Type | 5.2.1 Channel Type |
| | MD_0006 Tx Required Data Page | 22.3 Additional Requirements |
| | MD_0007 Tx Invalid Data Page | Reserved Range |
| | MD_0008 Transmission Pattern | 8 Standard Power-Only Main Data Page (0x10) 16 Measurement Output Data Page (0x03) 19.2.2 Common Page 82 (0x52): Battery Status 22.1.1 Sensor requirements (PWR) |
| | MD_0009 Manufacturer ID | 19.1.1 Common Page 80 (0x50) – Manufacturer's Identification |
| | MD_0010 Page Format | 22.1.1 Sensor requirements (PWR) |
| | MD_0011 Rollover | 20.1 Accumulate Positive Values Only 21 Using Accumulated Values |
| | MD_0013 Request Data Page | 19.2.1 Common Page 70 (0x46): Request Data Page |
| | MD_0014 Network Traffic | 22.3 Additional Requirements |
| | MD_PWR_001 Manual Calibration Request | 14 Calibration Main Data Pages 16 Measurement Output Data Page (0x03) |
| | MD_PWR_002 Auto Zero Calibration Request | 14 Calibration Main Data Pages |
| | MD_PWR_003 Update Event Count | 8.1 Update Event Count 15.2.1.3 Sensor Capabilities |
| | MD_PWR_004 Get/Set Crank Parameters | 15.2.1 Subpage 0x01 – Crank Parameters |
| | MD_PWR_005 Get/Set Advanced Capabilities | 15.2.5 Subpage 0xFE – Advanced Capabilities 2 15.2.4 Subpage 0xFD – Advanced Capabilities 1 |
| | MD_PWR_007 Dual Sided Sensors | 7.5 Dual Sided Sensors 8 Standard Power-Only Main Data Page (0x10) |
| | MD_PWR_009 Stopping & Coasting | 20.2 Handle Stop and Coasting Conditions |
| | MD_PWR_010 Cycling Dynamics | 4.5 Cycling Dynamics 17 Cycling Dynamics Data Pages |

| | |
|--------------------|--|
| Self-verify | 5.2.3 Device Number 12.2 Torque Effectiveness |
|--------------------|--|

Table 23-2. Profile Verification Tests for the Bike Power Display

| <input checked="" type="checkbox"/> | Certification Test | Relevant Document Sections |
|-------------------------------------|---|--|
| | SD_0001 ANT Channel Parameter Test | 5.1 Slave Channel Configuration |
| | SD_0002 Transmission Type | 5.1.1 Transmission Type |
| | SD_0003 Channel Period | 5.1.2 Channel Period |
| | SD_0005 Rx Undefined Data Page | 22.3 Additional Requirements |
| | SD_0006 Sweep | 4.3 ANT+ Bike Power Sensor Receiver Implementation |
| | SD_0007 Rx Reserved Fields | 22.3 Additional Requirements |
| | SD_0008 Rollover | 21 Using Accumulated Values |
| | SD_0009 Ignore Burst | 22.3 Additional Requirements |
| | SD_0010 Rx Ack | 22.3 Additional Requirements |
| | SD_0015 Valid Data Displayed | 20.3 Handling Invalid Values |
| | SD_PWR_001 Manual Calibration Request | 14 Calibration Main Data Pages |
| | SD_PWR_002 Auto Zero Calibration Request | 14 Calibration Main Data Pages |
| | SD_PWR_003 Get/Set Crank Parameters | 15.2.1 Subpage 0x01 – Crank Parameters |
| | SD_PWR_004 Get/Set Advanced Capabilities | 15.2.5 Subpage 0xFE – Advanced Capabilities 2 15.2.4 Subpage 0xFD – Advanced Capabilities 1 |
| | SD_PWR_005 Sensor Support | 4.3 ANT+ Bike Power Sensor Receiver Implementation |
| | SD_PWR_006 Cycling Dynamics | 15.2.5 Subpage 0xFE – Advanced Capabilities 2 |
| | SD_CTF_001 Calibration Request | 14.5 Torque-Frequency Defined Calibration Main Data Pages |
| | Self-verify | 15.2.4.1 Properties 15.2.5.1.1 4Hz and 8 Hz Capabilities 19.2.1 Common Page 70 (0x46): Request Data Page |