ANT+ Device Profile

Bicycle Power

ANT+ Managed Network Document
D00001086 Rev 2.2
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Revision History

Revision	Effective Date	Description
1.0	July 3, 2007	Initial Release
1.1		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 AutoZero 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 Pedal Power added Offset and raw torque removed from auto zero page
2.2	January 28, 2011	Edited "Copyright Information and Usage Notice" section

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1 Overview of ANT+

The ANT+ Managed Network is comprised of a group of devices that use the ANT radio protocol and ANT+ Device Profiles to determine and standardize wireless communication between individual devices. This management of device communication characteristics provides interoperability between devices in the ANT+ network.

Developed specifically for ultra low power applications, the ANT radio protocol provides an optimal balance of RF performance, data throughput and power consumption.

ANT+ Device Profiles have been developed for devices used in personal area networks and can include, but are not limited to, devices that are used in sport, fitness, wellness, and health applications. Wirelessly transferred data that adheres to a given device profile will have the ability to interoperate with different devices from different manufacturers that also adhere to the same standard. Within each device profile, a minimum standard of compliance is defined. Each device adhering to the ANT+ Device Profiles must achieve this minimum standard to ensure interoperability with other devices.

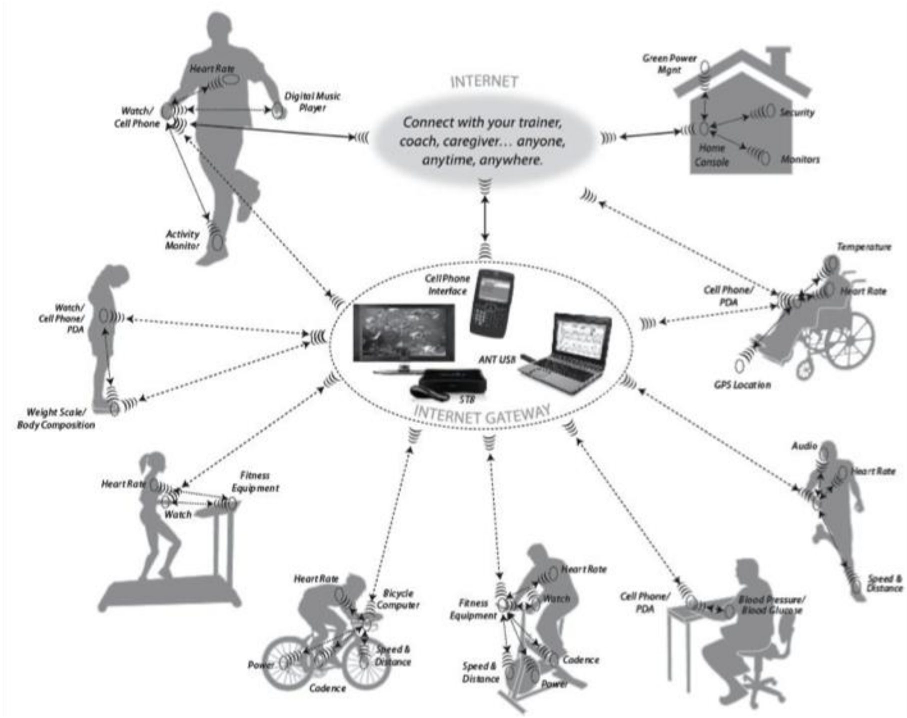

Figure 1-1. ANT+ Device Ecosystem

This document details the wireless communication between devices adhering to this ANT+ Device Profile. The typical use case of the device(s), wireless channel configuration, data format(s), minimum compliance for interoperability, and implementation guidelines are also detailed.

IMPORTANT:

> **If you have received this document you have agreed to, and signed, the ANT+ Managed Network license agreement and have received the ANT+ Managed Network Key. By signing the license agreement and receiving the ANT+ device profiles you agree to:**
>
> - **Implement and test your product to this specification in its entirety**
> - **To implement only ANT+ defined messages on the ANT+ managed network**

2 Related Documents

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

- ANT Message Protocol and Usage
- ANT Reference Design User Manual
- ANT+ Common Data Pages

3 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 meter transmits the information to a display device; the 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 information, message definitions, and sample code 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 3-1 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.

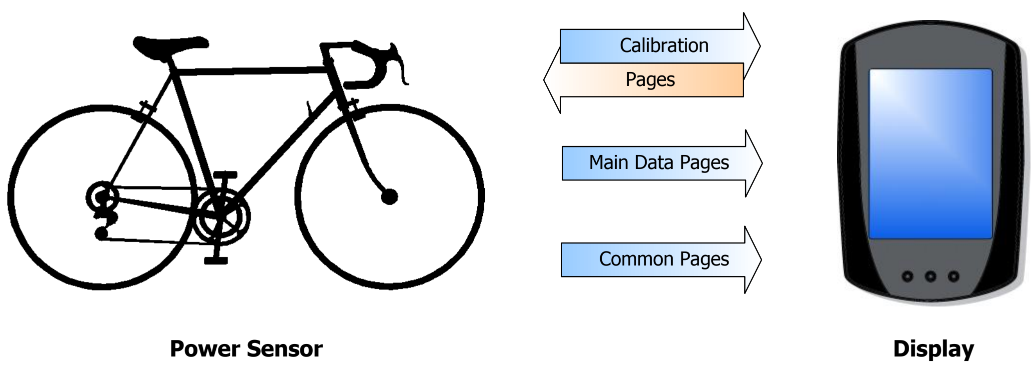

Figure 3-1. Standard Use Case of an ANT+ Bike Power sensor

3.1 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.

3.1.1 Power Measurement Types

The ANT+ message definition currently supports power sensors that:

- measure power directly
- measure torque and rotational velocity at the crank
- 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 5.

3.1.2 Power Information Update Types

All of the broadcast power messages have an Update Event Counter which 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.

3.1.2.1 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.

3.1.2.2 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.

3.2 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.

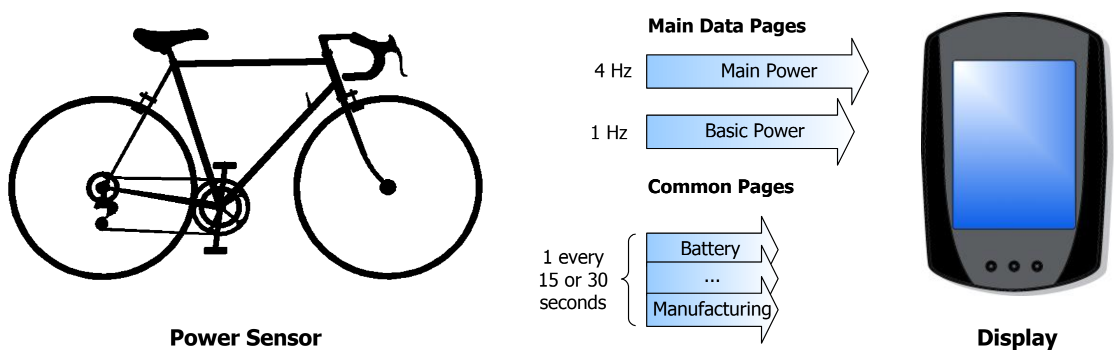

Figure 3-2. Timing of ANT+ Bike Power Sensor Message Formats

3.3 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.

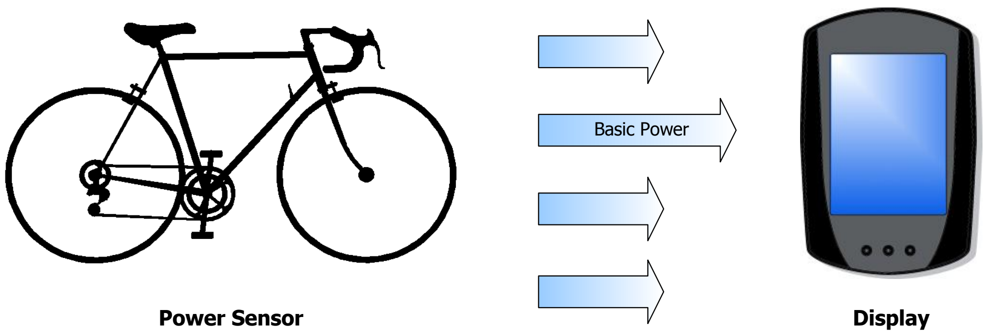

Figure 3-3. Simple Receiver Implementation

A summary of the differences between simple and full receiver implementations is shown below in Table 3-1.

Table 3-1. Bike Power Receiver Implementation Comparison

Simple Receiver Implementation	Full Receiver Implementation
Receives the basic Power-Only message	Receives all ANT+ messages
Messages contain instantaneous power 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 messages
Data updated at 0.5Hz minimum; supports only time-synchronous updates	Messages support fine-time resolution of event data; for example an event-synchronous crank torque meter can capture every single pedal stroke up to 240RPM
Allows receive-only implementation	Provides calibration and configuration interaction
Does not support calibration interaction	Support for manual calibration
Does not support Torque Frequency 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; for example average power can be accurately calculated over an RF outage lasting up to 30s

3.4 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 3-4.

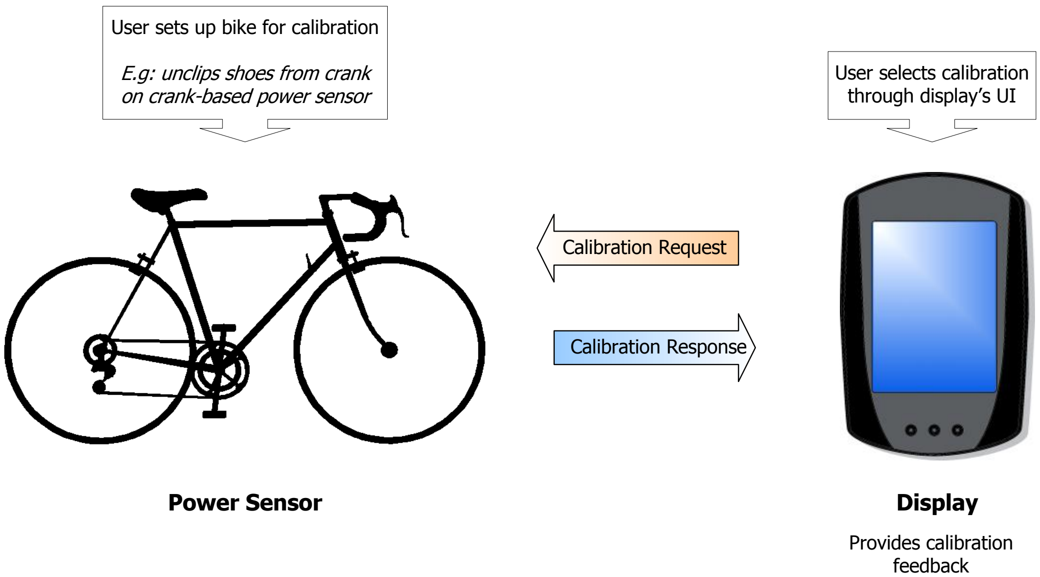

Figure 3-4. A Typical Manual Calibration Operation

Calibration request and response messages are detailed in Section 12.

4 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.

4.1 Slave Channel Configuration

The device expected to receive data from an ANT+ bike power sensor must configure an ANT channel with the parameters listed in Table 4-1.0

Table 4-1. 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 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 which 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 the bike power sensor every 8182/32768 seconds (approximately 4.00 Hz)
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.

4.1.1 Channel Period

All receivers shall use the 8182/32768 channel period (~4.00 Hz) to ensure reliable performance.

4.1.2 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 (0x10, 0x11, 0x12, 0x20)
- Provide the user a means to initiate and confirm a manual zero-offset calibration procedure (0x01). See Section 12.2.1
- Receive Manufacturer Information (ANT Common Data Page)
- Receive Product Information (ANT Common Data Page)

4.1.3 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
- Raw Torque message
- Battery Status (ANT Common Data Page)

4.1.4 Power-Only Receiver Implementation

It is possible to receive basic data from most Ant+ power sensors by receiving the Power-Only message. No calculations are required – instantaneous power and cadence measurements are available directly in the message.

- There is no protection for RF outage, and the update period may be as long as 2 seconds (maximum).
- Power-Only receivers are not compatible with torque frequency sensors.

4.2 Master Channel Configuration

The ANT+ bike power sensor shall establish its ANT channel as shown in Table 4-2.

Table 4-2. 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	5 (0x05)	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 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

4.2.1 Channel Type

The transmit channel type (0x10) is used instead of a transmit only channel type (0x50) for a number of reasons. The most compelling reason to use the transmit channel (0x10) is that this channel uses the interference avoidance features inherent to the ANT protocol. A transmit only channel (0x50) does not use these features and is much more susceptible to interference from other 2.4GHz sources including other ANT and ANT+ devices. Also, calibration pages use acknowledged message types which require bidirectional channels.

4.2.2 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 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.

5 General Bike Power Message Payload Format

An ANT channel configured as described in Section 4 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 5-1. ANT+ Bike Power General Message Format

Byte	Description	Length
0	Data Page Number	1 byte
1-7	Data	7 bytes

5.1 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.

5.2 Data

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

5.3 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.

6 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.

6.1 Defined Bike Power Main Data Pages

The following main data pages are defined for ANT+ bike power messages. Pages not defined in Table 6-1 are reserved for future use.

Table 6-1. ANT+ Bike Power sensor Main Data Pages

Data Page Number	Sensor Type	Direction	Message Description
0x01	All	Sensor -> Display Display -> Sensor	Calibration Messages
0x10	Standard	Sensor -> Display	Standard – Power Only
0x11	Standard	Sensor -> Display	Standard –Torque At Wheel
0x12	Standard	Sensor-> Display	Standard – Torque At Crank
0x20	CTF	Sensor-> Display	Crank Torque-Frequency Message

6.2 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 7.

Update Method: Time-synchronous only. All Power-Only messages must be updated at regular time intervals.

Table 6-2. Power-Only Sensor Messages

Function	Message ID		Message	Details
Required Power Main Data Page	0x10		Standard Power Only	Standard broadcast message
Required Common Data Page	0x50		Manufacturer's Information	Interleave every 121 messages (30.25 s)
Required Common Data Page	0x51		Product Information	Interleave every 121 messages (30.25s)
Optional Common Data Page	0x52		Battery Voltage	Interleave every 61 messages (15.25s)
Calibration Function	**Message ID**	**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 12 for details.
		0xAC	Tx: Acknowledge (0xAC)	
		0xAF	Tx: Fail (0xAF)	
Optional 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)	
Optional Auto Zero Support	0x01	0x12	Tx: Auto zero status	Interleave every 121 messages (30.25s)

6.3 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 8 and 9.

Update Method: Time-synchronous or event-synchronous

Table 6-3. Torque Sensor Messages

Function	Message ID		Message	Details
Required Torque Main Data Page	0x11 0x12		Tx: Standard Torque At Wheel OR Tx: Standard Torque At Crank	Standard broadcast message
Required Power Main Data Page	0x10		Standard Power Only	Minimum: Interleave every 9th message Preferred: Interleave every 5th message
Required Common Data Page	0x50		Manufacturer's Information	Interleave every 121 messages (30.25 s)
Required Common Data Page	0x51		Product Information	Interleave every 121 messages (30.25s)
Optional Common Data Page	0x52		Battery Voltage	Interleave every 61 messages (15.25s)
Calibration Function	**Message ID**	**Cal ID**	**Message**	**Details**
Required Manual Calibration (Zero Offset) Page	0x01	0xAA	Rx: Calibration request (0xAA)	Service calibration request when received from display. Use acknowledged method and handle resends. See section 12 for details.
		0xAC	Tx: Acknowledge (0xAC)	
		0xAF	Tx: Fail (0xAF)	
Optional Auto Zero	0x01	0xAB	Rx: Auto zero 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)	
Optional Auto Zero Support	0x01	0x12	Tx: Auto zero status	Interleave every 121 messages (30.25s)

6.4 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 data pages. For more details on crank torque frequency sensors refer to section 11.

Update Method: Event-synchronous only

Table 6-4. Crank Torque Frequency Sensor Messages

Function	Message ID		Message	Details
Required CTF Main Data Page	0x20		Tx: Crank Torque Frequency	Standard broadcast message
Calibration Function	**Message ID**	**Cal ID**	**Message**	**Details**
Required Manual Calibration (Zero Offset) Page	0x01	0xAA 0x10	Rx: Calibration request (0xAA) Tx: CTF offset data (0x10)	Service calibration request when received from display. Use acknowledged method and handle resends. See section 12 for details.

7 Standard Power-Only Main Data Page

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 power sensors are recommended to support the standard power-only message in addition to any torque-based messages. Power-Only messages should be interleaved at least once every 2 seconds, preferably at 1Hz. Byte 2 is an optional data field that shall be set to an invalid value if not used. Byte 2 is also a newer feature and may not be supported by all displays.

Table 7-1. Power-Only Message Format

Byte	Description	Length	Description	Units	Rollover
0	Data Page Number	1 byte	0x10: standard Power-Only message	N/A	N/A
1	Event Count	1 byte	Power event count	N/A	256 count
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	Max=254RPM
4	Accumulated Power LSB	2 bytes	Accumulated power 1-watt resolution	1 Watt	65.5kW
5	Accumulated Power MSB				
6	Instantaneous Power LSB	2 bytes	Instantaneous power 1-watt resolution	1 Watt	Max=65.5kW
7	Instantaneous Power MSB				

NOTE: The sensor must transmit 0xFF for all byte fields marked as “Reserved”. These values must **not** be interpreted by the receiver.

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

7.1 Event Count

The event count is incremented each time the information in the message is updated. There are no invalid values for event count. The time period of the update count depends on the system but must be a regular interval for accurate averaging.

The event count in this message refers **only** to updates of the standard Power-Only main data page (0x10). It should never be used with the event count of other data pages.

7.2 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 were evenly distributed between the left and right pedals, this value would read 50%. If the power were not evenly distributed, for example if the pedal power measured 70%, some sensors may or may not know which pedal has the greatest power contribution. The most significant bit is used to indicate if the pedal power sensor is capable of differentiating between the left and right.

7.2.1 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.

7.2.2 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.

7.3 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.

7.4 Accumulated Power

Accumulated power is the running sum of the instantaneous power data and is incremented at each update of the event count. The accumulated power field overflows at 65.53kW. At 2Hz power event updates, there are sufficient buffers over all power levels.

Table 7-2. Time to Buffer Overflow for a Given Power

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

7.5 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*.

$$AveragePower = \frac{\Delta AccumulatedPower}{\Delta EventCount} = \frac{AccumulatePower_N - AccumulatePower_{N-1}}{EventCount_N - EventCount_{N-1}}$$

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.

8 Standard Wheel Torque Main Data Page

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.

Table 8-1. Wheel Torque Message Format

Byte	Description	Length	Description	Units	Rollover or Valid Range
0	Data Page Number	1 byte	0x11 – sensor measures torque at wheel	N/A	N/A
1	Update Event Counter	1 byte	Event counter increments with each information update.	N/A	256 events
2	Wheel Ticks	1 byte	Wheel tick count increments with each wheel revolution.	Wheel revolutions	256 ticks ~550 meters
3	Instantaneous Cadence	1 byte	Crank cadence – if available Otherwise: 0xFF indicates invalid	RPM	Max=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				

8.1 Event Count

The event count is incremented each time the information in the data page is updated. There are no invalid values for event count. The event count in this message refers **only** to updates of the standard Wheel Torque main data page (0x11). It should never be used with the event count of other data pages.

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

Table 8-2. Time to Event Counter Rollover for a Given Update Rate

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

Alternately, the event count may increment with each complete wheel revolution. The event counter rolls over at 256 events; based on typical speeds this ranges between 20 seconds and three minutes as outlined in Table 8-3.

Table 8-3. Time to Event Counter Rollover for a Given Speed

Byte	Description
0	Data Page Number
1	Update Event Counter
2	Wheel Ticks
3	Instantaneous Cadence

8.2 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 event count increment at the same rate.

8.3 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.

8.4 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 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 8-4. 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

8.4.1 Interpreting Zero Speed from Standard Wheel Torque Data

8.4.1.1 Time-synchronous Update

To indicate zero rotational velocity, do not increment the accumulated wheel period and do not increment the wheel ticks. The 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.

8.4.1.2 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.

8.5 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 8-5. 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 8-6. Time to Accumulated Torque Rollover for a Given Power Output

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

8.6 Speed and Distance Computations

To calculate speed and distance, the receiving device requires knowledge of the wheel circumference in meters. *N* refers to the most recent message received, and *N-1* refers to the received message immediately preceding *N*.

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

Equation 2. Average Speed Calculation for Wheel Torque Sensor

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

Equation 3. Distance Calculation for Wheel Torque Sensor

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

8.7 Power Calculations

See Section 10 for details.

9 Standard Crank Torque Main Data Page

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.

Table 9-1. Crank Torque Message Format

Byte	Description	Length	Description	Units	Rollover or Valid Range
0	Data Page Number	1 byte	0x12 – sensor measures torque at crank	N/A	N/A
1	Update Event Counter	1 byte	Event counter increments with each information update.	N/A	256 events
2	Crank Ticks	1 byte	Crank ticks increment with each crank revolution.	Crank Revolutions	256 crank ticks
3	Instantaneous Cadence	1 byte	Crank cadence – if available Otherwise: 0xFF	RPM	0-254 RPM
4	Period LSB	2 bytes	Accumulated crank period (updated each event)	1/2048s	32s
5	Period MSB				
6	Accumulated Torque LSB	2 bytes	Accumulated torque (updated each event)	1/32Nm	2048Nm
7	Accumulated Torque MSB				

NOTE: The sensor must transmit 0xFF for all byte fields marked as "Reserved". These values must **not** be interpreted by the receiver.

9.1 Event Count

The event count is incremented each time the information in the message is updated. There are no invalid values for event count. The event count in this message refers **only** to updates of the Crank Torque main data page (0x12). It should never be used with the event count of other data pages.

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

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

Alternately, in event-synchronous systems, the 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 9-3. Time to 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

9.2 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 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 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.

Each crank period tick represents a 488-microsecond interval. In event-synchronous systems, the time stamp 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 9-4. 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.

9.4.1 Interpreting Zero Cadence from Standard Crank Torque Data

9.4.1.1 Time-synchronous Update

To indicate zero rotational velocity, the accumulated crank period should not be incremented. The 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.

9.4.1.2 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 before interpreting zero cadence is left to the manufacturer.

9.5 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 9-5. 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 9-6. Time to Accumulated Torque Rollover for a Given Cadence Power Output

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

9.6 Cadence Computation

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

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

Equation 4. Average Cadence Computation for Crank Torque Sensor

9.7 Power Calculations

See Section 10 for details.

10 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, 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.

10.1 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

10.2 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

10.3 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

11 Crank Torque Frequency Main Data Pages

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. 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.

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

Table 11-1. Crank Torque Frequency Message Format

Byte	Description	Length	Description	Units	Rollover or Valid Range
0	Data Page Number	1 byte	0x20 – Crank Torque Frequency	N/A	N/A
1	Event Counter	1 byte	Rotation event counter increments with each completed pedal revolution.	N/A	256 events
2	Slope MSB	2 bytes	Slope defines the variation of the output frequency.	1/10 Nm/Hz	6.55 kNm/Hz
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	65535 ticks
7	Torque Ticks Stamp LSB				

11.1 Event Count

The event count increments with each complete pedal stroke. The 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 11-2. 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.

11.2 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.

11.3 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 11-3. 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.

11.4 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 11-4. Time until Overflow of Torque Ticks for a Given Cadence

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

11.5 Encoding Crank Torque Frequency Messages

The torque ticks stamp is incremented every 2kHz clock cycle. When a cadence event occurs the current 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.

11.6 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*.

11.6.1 Calculating Cadence

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

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

Equation 9. Calculation of Cadence using Crank Torque Frequency

11.6.2 Calculating Torque

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

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

Equation 10. Calculations for Elapsed Time and Torque Ticks

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

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

Equation 11. Calculation of Torque Frequency

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

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

Equation 12. Calculation of Torque from the Torque Rate

Finally, power is calculated from the cadence and torque.

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

Equation 13. Calculation of Power using Torque

11.7 Cadence Time Out

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

12 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. Because it is important to know that these messages have been received, all calibration messages shall be sent using ANT acknowledged messages. Firmware in both the sensor and display devices 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. 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 receiving side must correctly handle repeated messages.

12.1 Standard Calibration Message Format

The standard calibration message format is shown below in Table 12-1.

Table 12-1. Standard Calibration Message Format

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

12.1.1 Calibration ID

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

Table 12-2. 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	Torque Meter Capabilities (Power sensor Torque and Auto Zero Support)

12.2 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.

12.2.1 General Calibration Request Main Data Page

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 12-4) 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.

Table 12-3. 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			

12.2.2 Auto Zero Configuration Main Data Page

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.

Table 12-4. 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 12.3).

- 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.

12.2.3 General Calibration Response Main Data Page

The general calibration response page is shown in Table 12-5. The power sensor transmits this page to the display device in response to a calibration request.

Table 12-5. 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		
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.

12.2.4 General Calibration Process Data Flow

Figure 12-1 describes the calibration data flow expected between the bike power sensor and the display device communicating with the sensor. The actions for the display device are shown in blue and the actions for the sensor are shown in green. The orange communication arrows represent the acknowledged data transfers between devices.

NOTE: The acknowledged portion of the message, labeled "ANT Acknowledge (AUTO)", is automatically sent by ANT. The implementation does not need to write code 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.

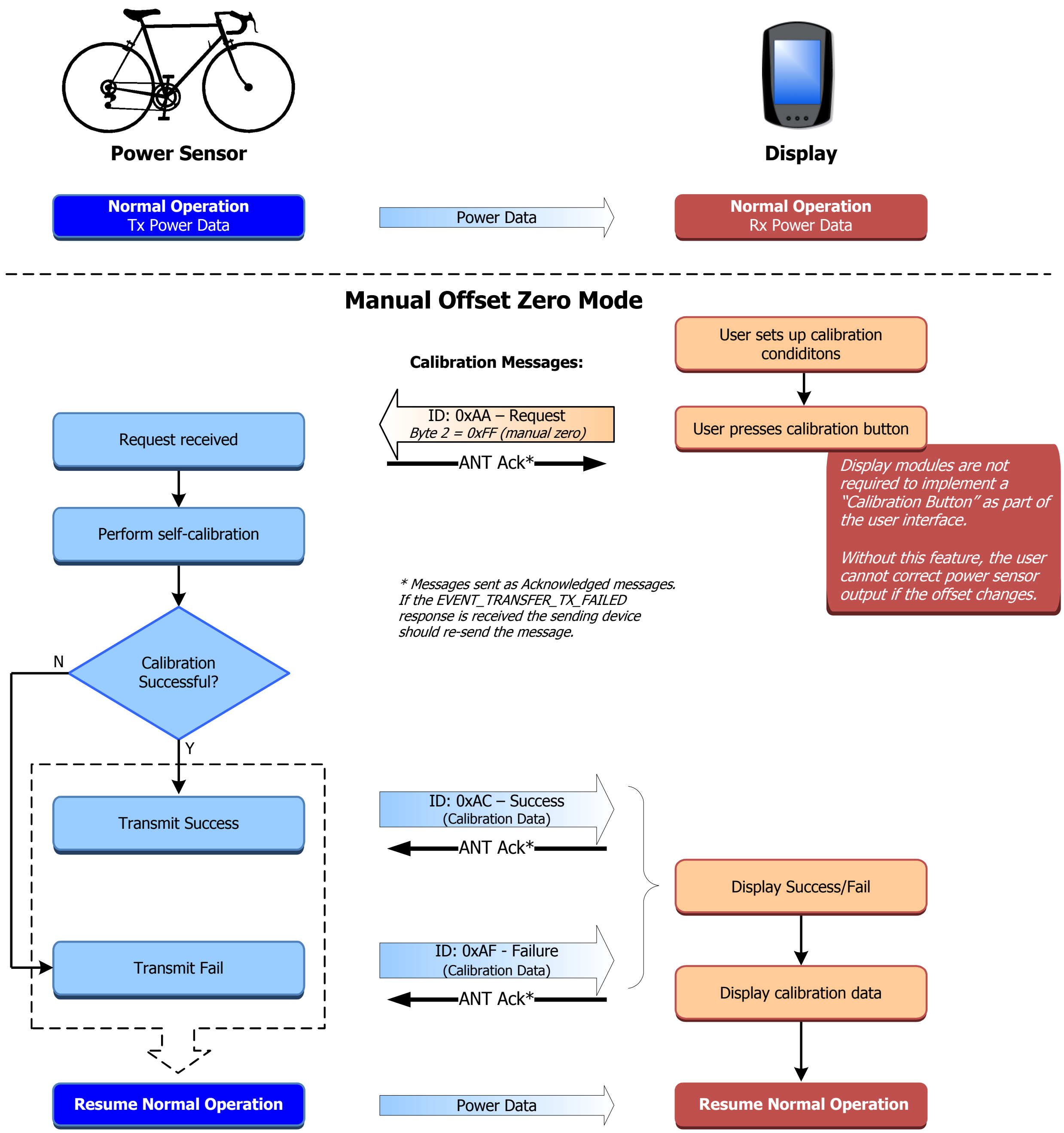

Figure 12-1. General Calibration Process Flow Chart

In Figure 12-2 the sequence diagram shows the same procedure as shown in the previous flow chart to give a different representation of the same procedure. Note that the normal operation does not resume after the calibration process is complete until the acknowledgement from the last calibration process is received by the power sensor sensor.

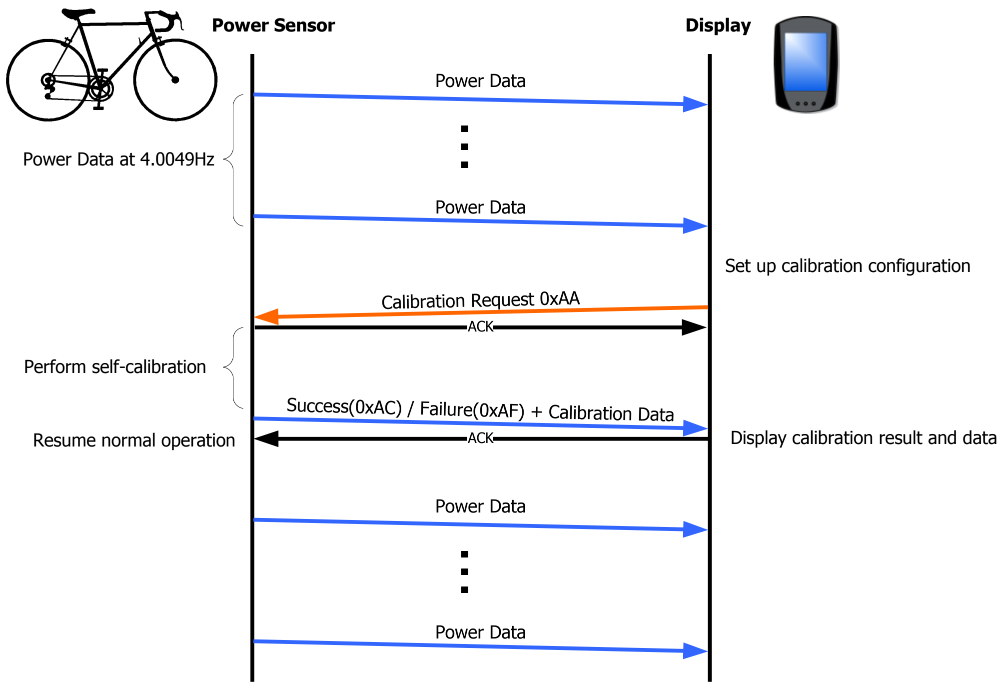

Figure 12-2. Calibration Process Sequence Diagram

12.2.5 Auto Zero Configuration Data Flow

Figure 12-3 describes the data flow expected between the bike power sensor and the display device communicating with the sensor for setting the Auto Zero configuration. The actions for the display device are shown in blue and the actions for the sensor are shown in green. The orange communication arrows represent the acknowledged data transfers between devices. It is important to note that the acknowledged portion of the message, labeled "ANT Acknowledge (AUTO)", is automatically sent by ANT. The implementation does not need to write code 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.

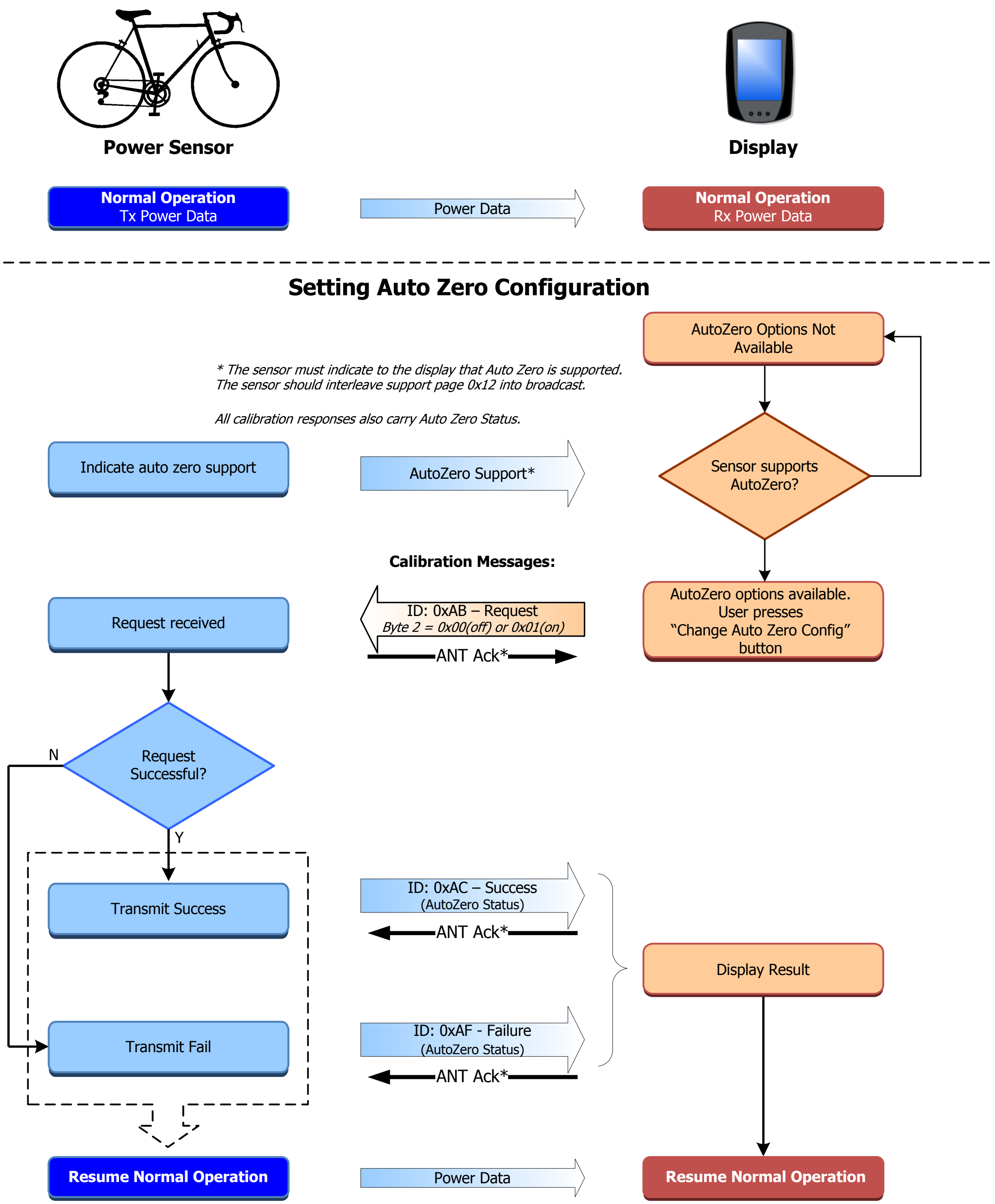

Figure 12-3. Auto Zero Configuration Flow Chart

12.3 Torque Sensor Capabilities Main Data Page
(Power sensor Torque and Auto Zero Calibration Support Message)

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 and sends an output of raw and offset torque values. The information does not need to be interpreted by the display for proper calculation of power.

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

Table 12-6. Torque Meter Capabilities Support Message Format

<table>
<tr><th>Byte</th><th>Description</th><th>Length</th><th colspan="2">Value</th><th>Units</th></tr>
<tr><td>0</td><td>Data Page Number</td><td>1 byte</td><td colspan="2">0x01 (calibration message)</td><td>N/A</td></tr>
<tr><td>1</td><td>Calibration ID</td><td>1 byte</td><td colspan="2">0x12 Torque Meter Capabilities message</td><td>N/A</td></tr>
<tr><td rowspan="5">2</td><td rowspan="5">Sensor Configuration Descriptive Bit Field</td><td rowspan="5">1 byte</td><td rowspan="2">0 – Auto Zero Enable</td><td>0 – Not Supported</td><td rowspan="5"></td></tr>
<tr><td>1 - Supported</td></tr>
<tr><td rowspan="2">1 – Auto Zero Status</td><td>0 – Auto Zero Off</td></tr>
<tr><td>1 – Auto Zero On</td></tr>
<tr><td>2 – 7 – Reserved</td><td>Value = 0</td></tr>
<tr><td>3</td><td>Reserved</td><td rowspan="5">5 bytes</td><td colspan="2" rowspan="5">0xFF (reserved for future use)</td><td rowspan="5">N/A</td></tr>
<tr><td>4</td><td>Reserved</td></tr>
<tr><td>5</td><td>Reserved</td></tr>
<tr><td>6</td><td>Reserved</td></tr>
<tr><td>7</td><td>Reserved</td></tr>
</table>

12.3.1 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.

12.3.2 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.

12.4 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). CTF defined messages are acknowledged by the receive side. Byte 2 is used to identify the CTF defined message that is being acknowledged. Currently, only four data types are used, but this set may be expanded.

NOTE: All Torque-Frequency Defined calibration messages are big endian. The sensor must transmit the value 0xFF for all byte fields marked as "Reserved". These values must not be interpreted by the receiver.

Table 12-7. Currently Supported CTF Defined Calibration Messages

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

12.4.1 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 12-3. On receiving the request, the power sensor responds for 10 seconds with a Torque Frequency Calibration Response page as outlined in Table 12-8.

Table 12-8. 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: Like all calibration messages, the offset data messages should use the acknowledge method. However, since it is preferred to send the most recent offset measurement; unacknowledged messages should not be resent.

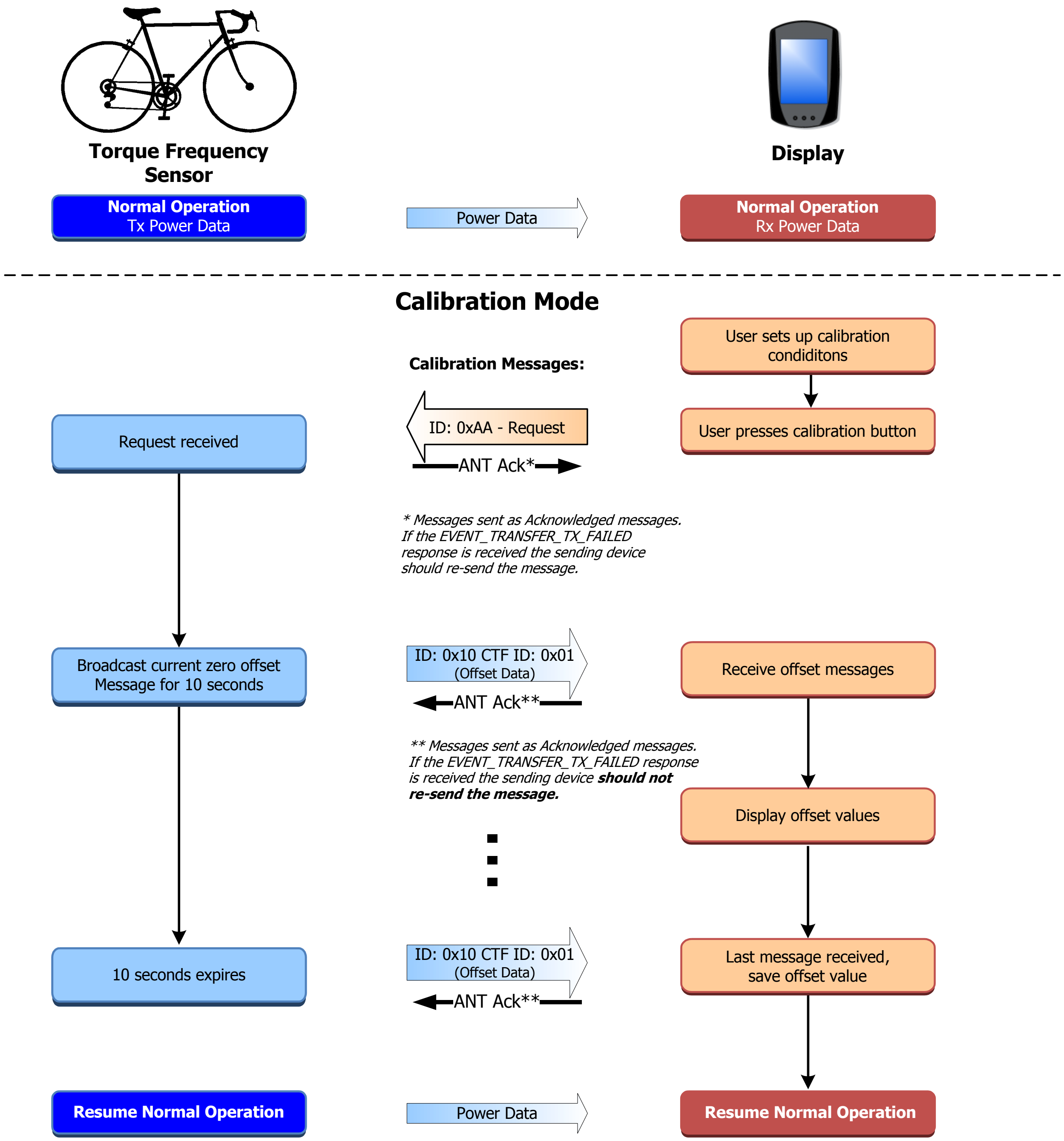

Figure 12-4. Torque Frequency Calibration Flow Chart

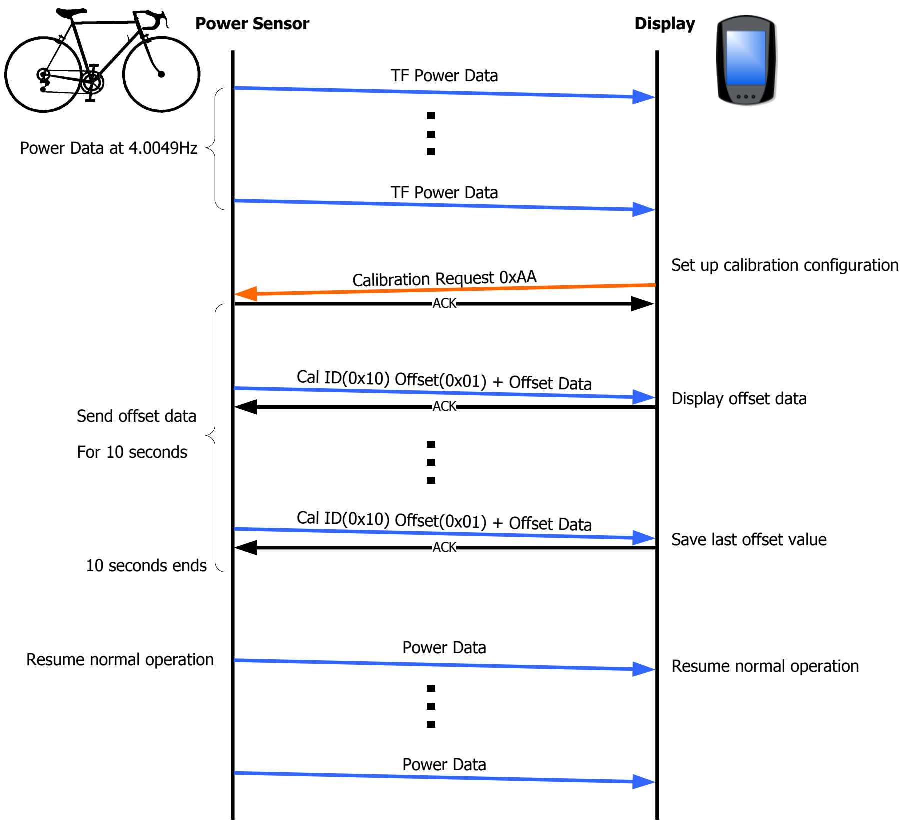

Figure 12-5. Torque Frequency Calibration Process Sequence Diagram

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 12-8 and shown in Figure 12-6.

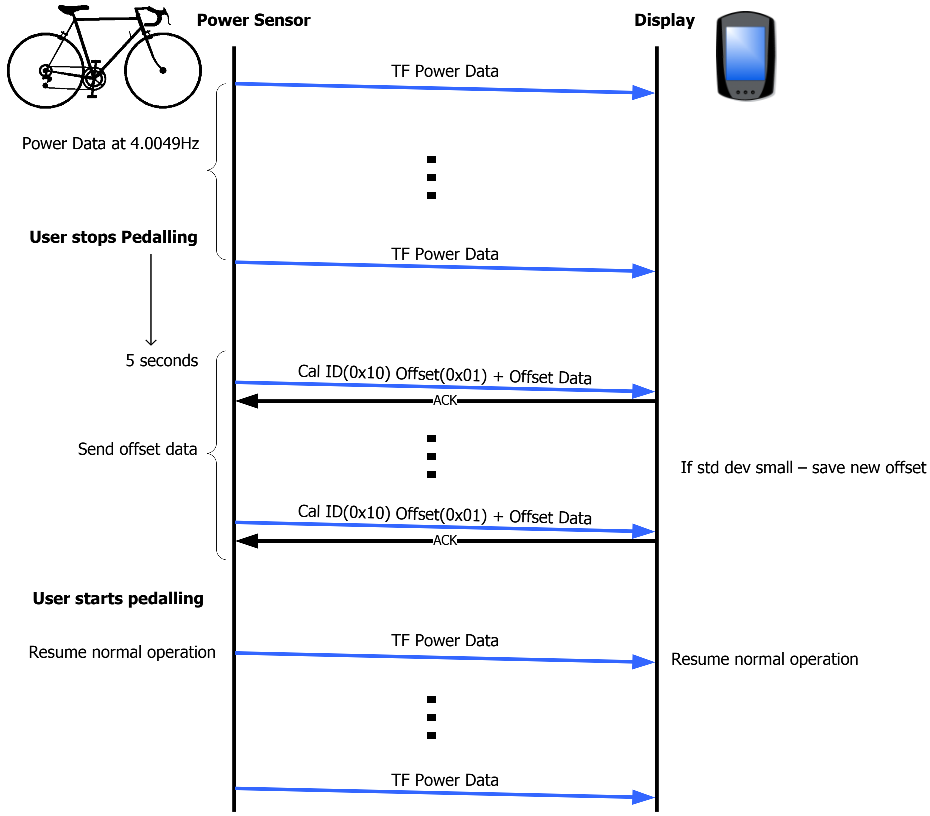

Figure 12-6. Coasting Offset calibration example

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 save the sampled average as the new offset value.

12.4.2 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.

Table 12-9. 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 acknowledge message to the display device.

Table 12-10. 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.

12.4.3 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.

Table 12-11. 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 No. MSB	2 bytes	0 - 65535	N/A
7	Serial No. LSB			

When the power sensor receives the set value it responds with the CTF acknowledge data message to the display device.

Table 12-12. 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			

13 Common Data 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 Data Pages document.

13.1 Required Common Data Pages

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

Common data page 80 transmits the manufacturer's ID, model number, and hardware revision.

Table 13-1. Common Data Page 80

Byte	Description	Length	Value	Units	Rollover
0	Data Page Number	1 Byte	0x50 – Common Page 80	N/A	N/A
1	Reserved	1 Byte	Value = 0xFF	N/A	N/A
2	Reserved	1 Byte	Value = 0xFF		
3	HW Revision	1 Byte	To be set by the manufacturer.	N/A	N/A
4	Manufacturer ID LSB	2 Bytes	Contact the ANT+ Alliance for a current list of manufacturing IDs, or to be assigned a manufacturing ID.	N/A	N/A
5	Manufacturer ID MSB				
6	Model Number LSB	2 Bytes	To be set by the manufacturer.	N/A	N/A
7	Model Number MSB				

For the current list of Manufacturer Identification values, or if you wish to be added to this list, please contact the ANT+ Alliance at antalliance@thisisant.com.

13.1.2 Common Page 81 (0x51) – Product Information

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

Table 13-2. Common Data Page 81

Byte	Description	Length	Value	Units	Rollover
0	Data Page Number	1 Byte	0x51 – Common Page 81	N/A	N/A
1	Reserved	1 Byte	Value = 0xFF	N/A	N/A
2	Reserved	1 Byte	Value = 0xFF	N/A	N/A
3	SW Revision	1 Byte	To be set by the manufacturer.	N/A	N/A
4	Serial Number (Bits 0 – 7)	4 Bytes	The lowest 32 bits of the serial number. Value 0xFFFFFFFF to be used for devices without serial numbers.	N/A	N/A
5	Serial Number (Bits 8 – 15)				
6	Serial Number (Bits 16 – 23)				
7	Serial Number (Bits 24 – 31)				

13.2 Other Common Data Pages

Other common data pages that are listed in the ANT+ Common Data 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.

14 Guidelines for Best Practice

14.1 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 should 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.

14.2 Handle Stop and Coasting Conditions

It is important that the display properly handle the display of power, speed, and cadence in cases when the bicycle is stopped and when the bicycle is coasting.

14.2.1 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.

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.

14.2.2 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.

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

15 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: Add only positive values to message fields that are accumulated.
- Receivers: Use modulo operations in calculations for message fields that are accumulated.
- Receivers: Use average values to properly calculate and store data after RF reception loss.

15.1 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 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 14.

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

Equation 14. Example of Accumulating a Value

Each message field has a maximum value, after which the running sum rolls over, as shown in Figure 15-1. Note that a rollover makes it possible for the Accumulated Value N to be less than it was in the previous message.

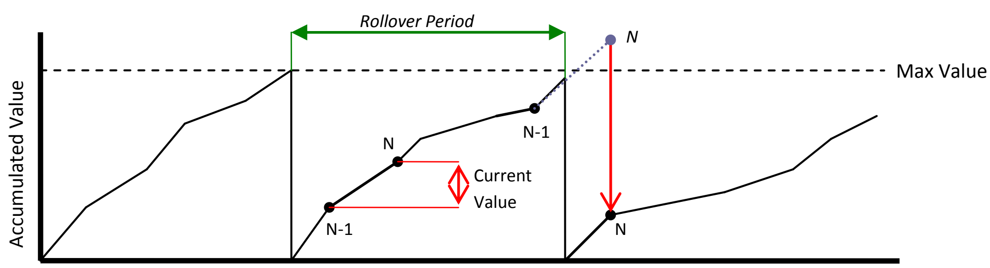

Figure 15-1. Accumulating Values

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.

15.2 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 Event Counts between the two messages.

$$CurrentValue = \frac{\Delta AccumulatedValue}{\Delta EventCount}$$

Equation 15. 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.

To properly span rollovers, the calculations on the receiver side must be implemented using a modulo operation as shown in Equation 16. In the following, *N* refers to the most recent message received, and *N-1* refers to the message immediately preceding *N*.

$$CurrentValue = \frac{Modulo(AccumulatedValue_N - AccumulatedValue_{N-1}, MaxValue)}{Modulo(EventCount_N - EventCount_{N-1}, MaxEvent)}$$

Equation 16. Calculating a Value over a Rollover Event

15.3 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 15-2 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.

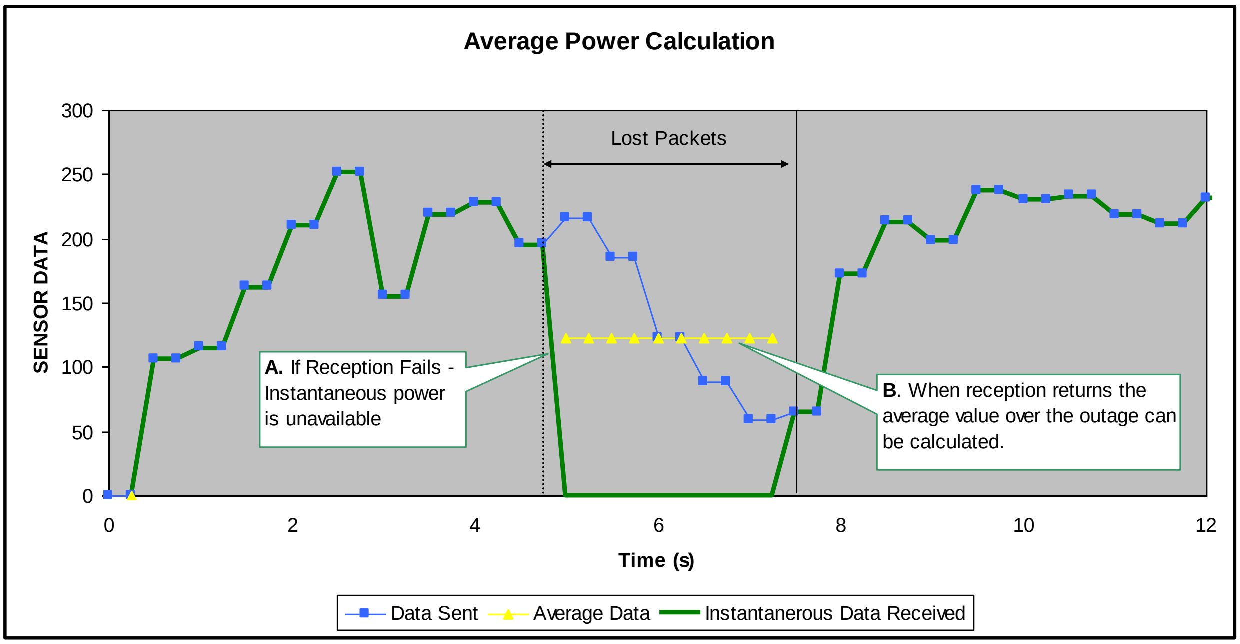

Figure 15-2. Averaging Power through an RF Outage