Recording Bike Power Data

ANT+ Application Note

Copyright Information and Usage Notice

Revision History

Revision	Effective Date	Description
1.0	October 2015	Initial Release

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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.

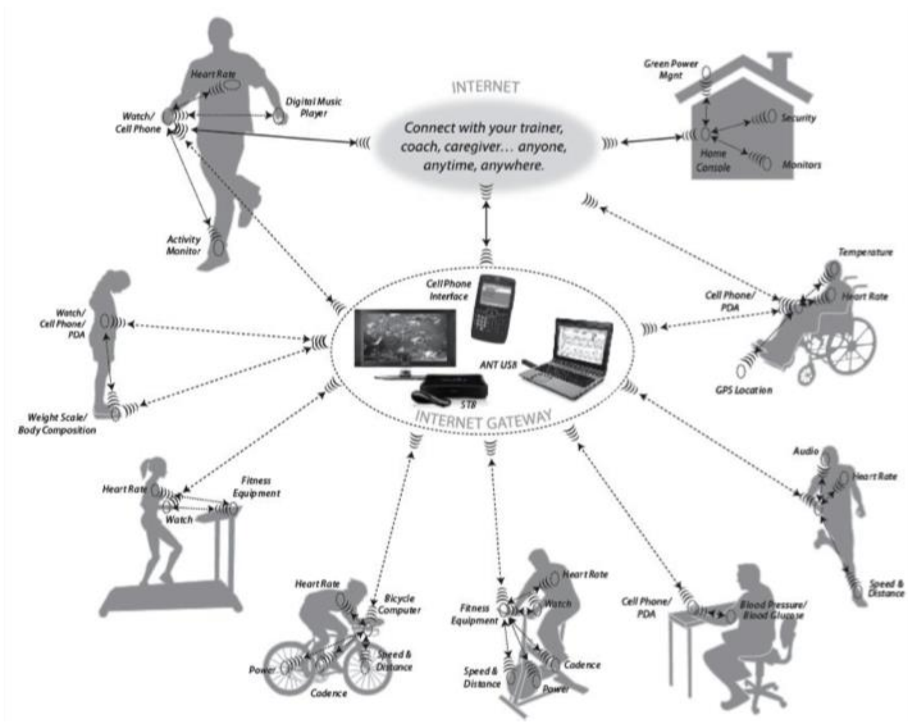


Figure 1-1. ANT+ Device Ecosystem

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 the terms and conditions of the Adopter's Agreement and have downloaded the ANT+ Managed network key. By accepting the Adopter's 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 and Software

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+ Bicycle Power Device Profile
3. ANT+ Common Data Pages

Additional software tools for use with those provided in this application note package include:

4. SimulANT+ (zip file including the simulator, manual, scripts, and scripting help)
5. FIT SDK (including a CSV to FIT file converter)
6. ANT Library Package (Windows and Mac OSX available)

3 Introduction

The purpose of this application note is to provide a clear and consistent approach to saving bike power data received from ANT+ bike power meters of various types. This document describes the method and available toolset to aid implementation such that bike power displays and other recording units are able to store bike power data without introducing inconsistency into the data.

A method and toolset are provided for storing sampled power data:

- With a configurable sampling interval, OR,
- Store all new events

It is also possible to simply store every received message, if the receiving unit has sufficient memory available.

Best practice recommendations are provided for detecting coasting and stop events and handling data outages.

3.1 Displaying vs. Recording Data

Figure 3-1 highlights the dual role typically performed by a bike computer, or equivalent display, relating to the handling of ANT+ sensor data. In this example, data is received from an ANT+ power meter and displayed to the cyclist in real-time during the ride. Typically data will also be received from an ANT+ heart rate monitor and ANT+ bike speed and/or cadence sensors; this may be supplemented with data from an increasing number of other ANT+ sensors including muscle oxygen monitors, temperature sensors, suspension sensors, and shifting state indicators.

The key data is displayed to the cyclist during the ride based on user preferences; typically simplified to a smaller number of metrics. In order to present this in a way that is usable during a ride, this data is also smoothed so that the numbers do not change too fast to be legible. If there is a gap in received data, it may be more helpful to the cyclist for the bike computer to display the last received value rather than blank the display. Similarly the last received power value is typically displayed for a few seconds after it is received at the end of a ride so that cyclists have time to breath before looking down to check their performance.

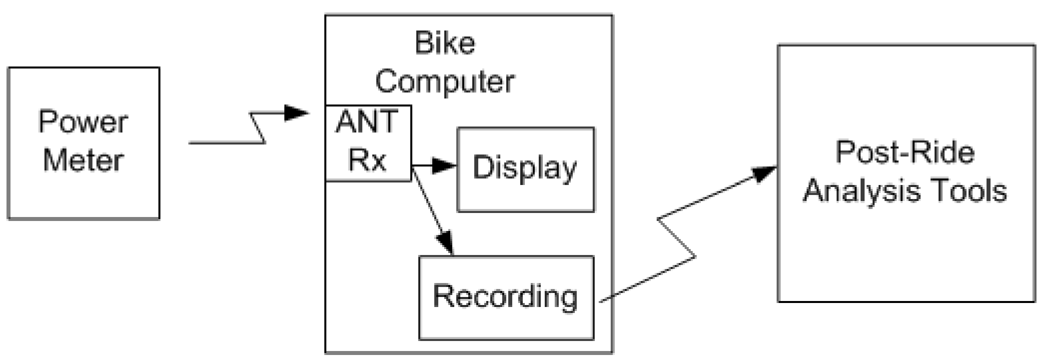


Figure 3-1. Dual Functions of a Bike Computer

In contrast, data that is recorded for post-ride analysis is more tolerant to variable receive rates but requires integrity to be maintained with respect to the timestamp of each data point. Simply sampling the displayed value and recording this in a data file is unlikely to produce satisfactory results. Instead a separate variable set must be maintained by the bike computer for the purposes of displaying and recording data. The remainder of this application note focuses solely on the recording of received data.

3.2 Motivation

Recording bike power data correctly is critical to meeting consumer expectations relating to both power meters and displays. Bike power meter purchases usually represent a significant investment to the user. The accuracy, repeatability and reliability of the bike power meter are therefore expected to meet exacting standards. Almost all bike power meter users will record this data and view it using post-ride data analysis tools. The data that the user views therefore includes the errors introduced by the bike power meter, and any errors introduced by the bike computer when recording the data.

Modern bike power meters can record and transmit bike power that is accurate to +/- 2%, and repeatable to 2%. The errors introduced by poor data recording practices can introduce an additional inaccuracy in the order of ~3%. This application note has therefore been provided to outline the best practices that ensure needless errors are not introduced to bike power data, and users are able to gain the accurate, repeatable data that they expect.

4 Processing Incoming Data

Most bike power displays store bike power data in records showing the average power over each second of the ride i.e. with a recording interval of 1 second. The recording interval can be shortened to yield higher resolution data or lengthened to reduce the memory required to store the data from a ride.

The rate at which actual crank revolutions or wheel revolutions (for hub based power meters) occur varies based on the cyclist's cadence, and is unrelated to the recording interval or the rate at which data pages are transmitted from the power meter. This is illustrated in Figure 4-1.

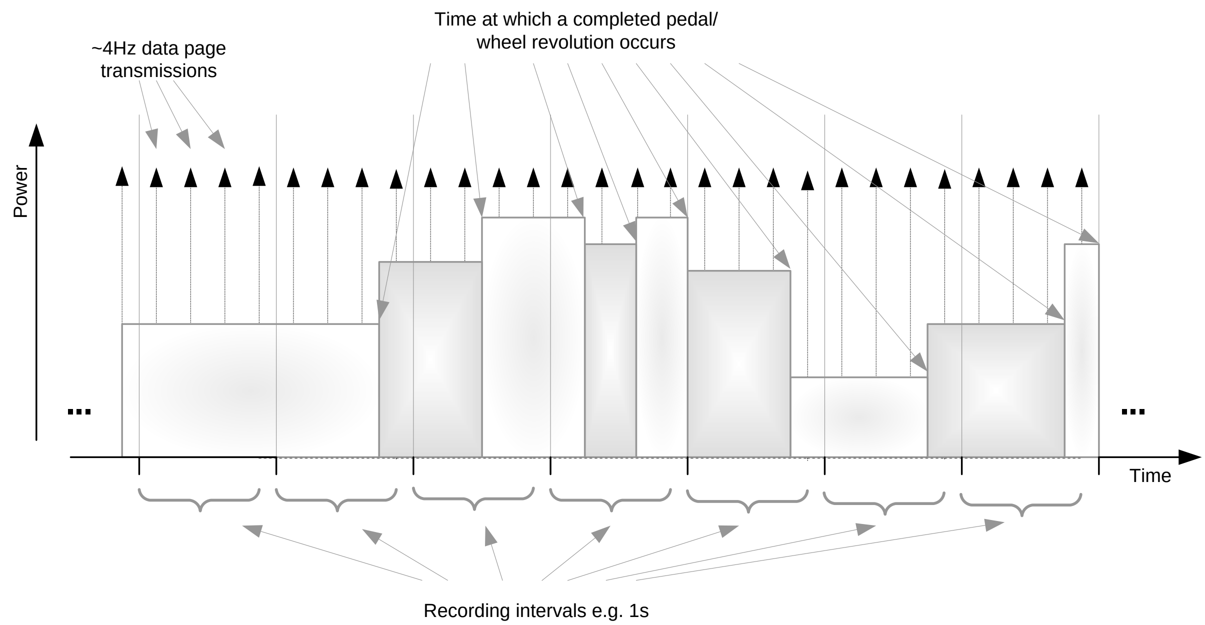


Figure 4-1. Example Timing of Events, Data Page Transmissions and Recording Intervals

The pattern shown in Figure 4-1 applies regardless of the type of power meter used. However the content of the data pages transmitted does behave differently depending on the event update method: event-synchronous, or time-synchronous.

4.1 Event-Synchronous vs Time-Synchronous Power Meters

Event-synchronous power meters include some crank torque meters and crank torque frequency (CTF) meters. CTF meters are always event-synchronous.

Event-synchronous power meters update the contents of the transmitted data pages each time a revolution is completed. This is indicated by incrementing the update event count. Therefore the update event count and crank ticks field increment at the same time.

When the bike crank moves faster, the time taken to complete each revolution is reduced and the corresponding update events occur more frequently. When a revolution period is shorter than the time between data page transmissions then the update event count will increase by more than one between each received data page.

When the bike crank moves slower, the time taken to complete each event increases and the corresponding events occur less frequently. When a revolution period is longer than the time between data page transmissions then the previous data page will be repeatedly interleaved until the current revolution completes.

A detailed example of processing event-synchronous data is provided in section 4.3

Note that in event-synchronous systems, all main data pages including the power-only page are event-synchronous.

Time-synchronous power meters include some crank torque meters, wheel torque meters and power-only meters. Wheel torque and power-only meters are always time-synchronous.

Time-synchronous power meters update the contents of the transmitted data pages at a constant time interval (e.g. update interval = 0.5 seconds), which is not affected by the speed at which the bike crank (or wheel) moves. The update event count increases at a constant rate, and the crank (or wheel) ticks field increases at an unrelated rate.

Recording data messages in a log file can be executed at regular intervals when time-synchronous data pages are received. Note that the event update interval for the power meter in question must be known in order to process the data efficiently.

4.2 Interpreting Power Data Based on Power Meter Type

The figure below summarises the types of power meter available and indicates which set of assumptions should be used to interpret the data received from each one.

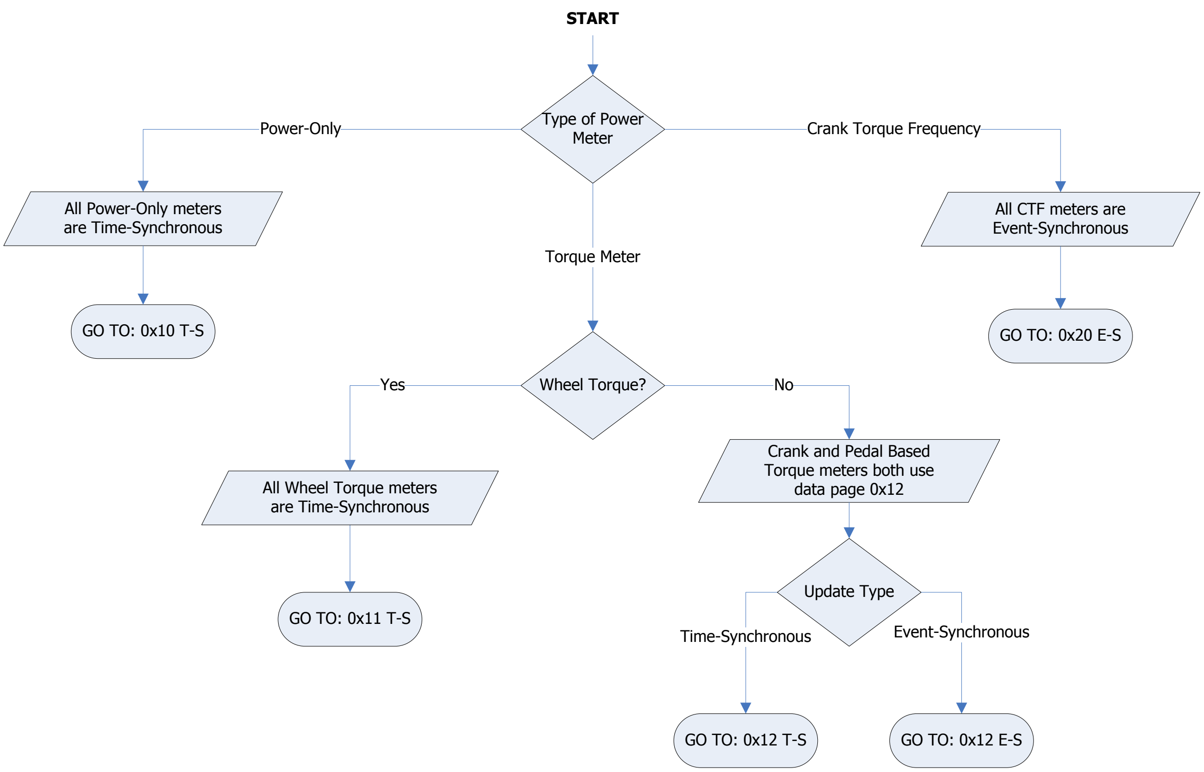


Figure 4-2. Choosing Interpretation Method Based on Power Meter Type

4.2.1 Determining Whether a Power Meter is Event- or Time-Synchronous

Most power meters can be identified as a particular type based on the data pages that they transmit. However crank torque meters can be either time-synchronous or event-synchronous. To distinguish between crank torque meters, it is recommended that the power meter is operated at varying pedalling cadences, while the data is received by SimulANT+ (or similar software) such that a log of the raw data can be viewed.

From this data, observe whether the event count always increases at regular time intervals and is therefore from a time-synchronous power meter; or whether it increases at higher rates when the cadence is high and is an event-synchronous power meter.

4.2.2 Determining the Fixed Time Update Interval for Time-Synchronous Power Meters

The other key piece of data required to store data successfully from an ANT+ power meter is the fixed time update interval. This can be obtained from the relevant capabilities data page (TO BE ADDED TO THE DEVICE PROFILE).

Alternatively, it can be obtained by contacting the manufacturer, or by observing the data stream:

To obtain the fixed time update interval from the power meter, collect a set of log data using SimulANT+ or a similar software. It is important that the data covers a substantial length of time in order to yield an accurate result. The fixed time update interval can then be calculated by dividing the duration of the test by the number of event count increments that occurred in that time.

4.2.3 Assumption Sets

The following sections detail the assumptions that can be made regarding the data received from each power meter type.

4.2.3.1 0x10 T-S (Power-Only)

Power-only meters send main data page 0x10, but not pages 0x11 or 0x12. They may optionally interleave other data pages such as 0x13 (Torque Effectiveness and Pedal Smoothness).

Key Assumption: Each standard power-only main data page update describes a fixed time interval.

Key Variables: The length of the update time interval (refer to section 4.2.2).

The number of rotations described by each update is not specified.

The data in the standard power-only main data page applies for the time interval indicated in Table 4-1.

Table 4-1. Power-Only Message Fields

Field	Value	Time Applicability
Data Page Number	0x10 – standard Power-Only message	N/A
Update Event Count	Power event count	Fixed Time Interval
Pedal Power	Bit 7: Pedal Differentiation 1 - Right Pedal Power Contribution 0 – Unknown Pedal Power Contribution	Permanent: This describes a capability of the sensor.
	Bits 0-6: Pedal Power Percent	Fixed Time Interval
Instantaneous Cadence	Crank cadence – if available Otherwise: 0xFF indicates invalid	
Accumulated Power	Accumulated power 1-watt resolution	
Instantaneous Power	Instantaneous power 1-watt resolution	

The number of revolutions that the time interval describes can be calculated if a valid cadence is specified. In this case:

$$\textit{Number of rotations described} = \frac{\textit{Cadence (rpm)}}{60} \times \textit{Update Time Interval (s)}$$

Equation 4-1. Obtaining the Number of Revolutions per Data Update

If transmitted, the data in the torque effectiveness and pedal smoothness page applies for the time taken to complete exactly one revolution back from the point at which the page was updated. The page is updated at the same time as the power-only page and the update event count values are tied. This is illustrated in Figure 4-3.

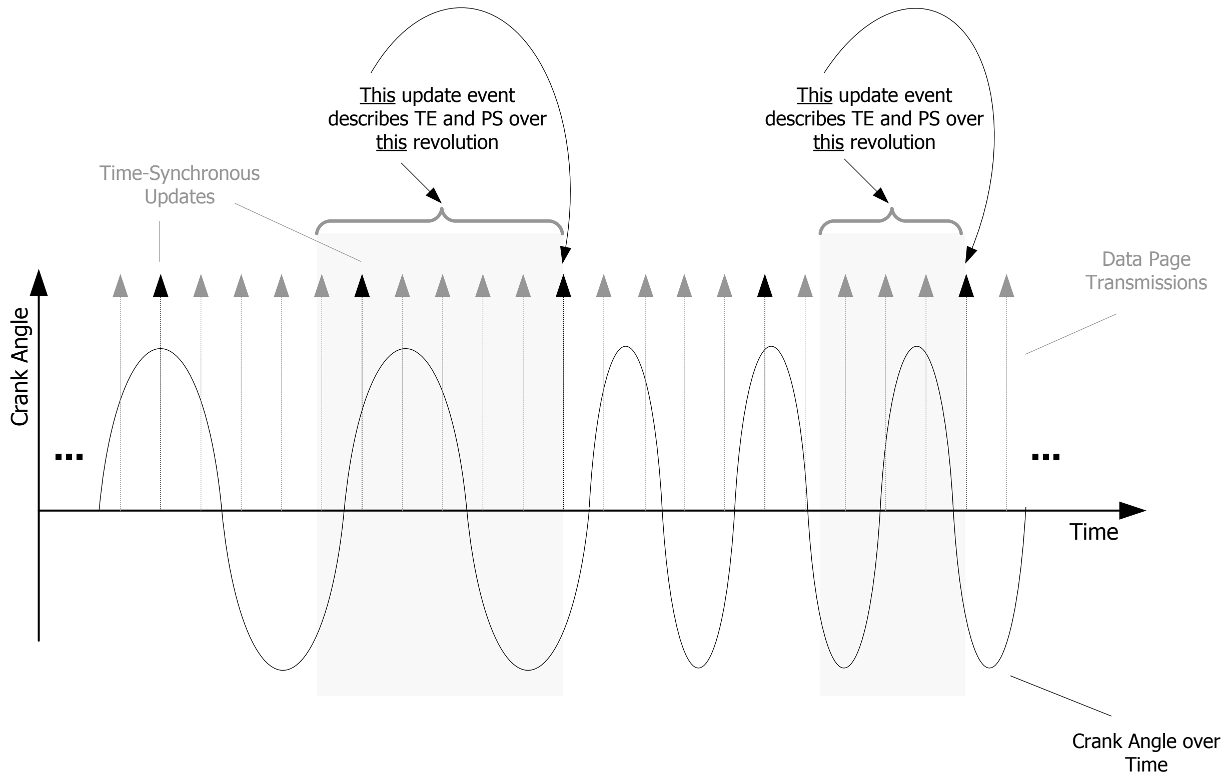


Figure 4-3. Time Applicability of Torque Effectiveness and Pedal Smoothness Data

Table 4-2 summarises the applicability of torque effectiveness and pedal smoothness fields in time-synchronous systems.

Table 4-2. Torque Effectiveness and Pedal Smoothness Message Fields

Field	Value	Time Applicability
Data Page Number	0x13 – Torque Effectiveness and Pedal Smoothness	N/A
Update Event Count	Event counter increments with each power-only information update. This value is tied to the event counter on the Power Only page.	Fixed Time Interval
Left Torque Effectiveness	Left leg torque effectiveness 0xFF: Invalid or negative values	Time varies based on cadence. Data applies for the duration of the crank revolution that completed at the moment the page was updated.
Right Torque Effectiveness	Right leg torque effectiveness 0xFF: Invalid or negative values	
Left (or combined) Pedal Smoothness	Left pedal smoothness, or combined pedal smoothness if byte 5 is set to 0xFE. 0xFF: Invalid	
Right Pedal Smoothness	Right pedal smoothness FE: Combined pedal smoothness being sent in byte 4 0xFF: Invalid	

The time period that the torque effectiveness and pedal smoothness data applies for can be calculated when the cadence is known. Assuming that the period is shorter than the update time interval, the approximate period is:

$$Period\ (s) = \frac{60}{Cadence\ (rpm)}$$

Equation 4-2. Obtaining the Time Period for 1 Revolution

Note that if the crank period is longer than the update time interval, then the appropriate cadence value should be used for each time section.

Data records are written to store this data in different ways depending on the relative size of the fixed time interval between data page updates, and the recording interval. Refer to the detailed example in section 4.4.

4.2.3.2 0x11 T-S (Wheel Torque)

Time-synchronous wheel torque meters send main data pages 0x10 and 0x11, but not 0x12. These power meters do not use the torque effectiveness and pedal smoothness page as it is impractical to measure these values from the bicycle wheel.

Key Assumption: Each standard wheel torque / power-only main data page update describes a fixed time interval.

Key Variables: The length of the update time interval (refer to section 4.2.2).

The number of rotations described by each update is not specified (the wheel ticks field does not include fractional values).

The data in the standard wheel torque data page applies as indicated in Table 4-3 and should be used to generate the torque, power and cadence data records. The data in the standard power-only data page provides the power balance field which should be used to supplement the wheel torque data (Table 4-1). It should be noted that the update event counts for the wheel torque and power-only data pages are not tied, and the time intervals described by each data page could therefore be offset. The update time interval is the same for all data pages.

Table 4-3. Wheel Torque Message Fields

Field	Value	Time Applicability
Data Page Number	0x11 – sensor measures torque at wheel	N/A
Update Event Count	Event counter increments with each information update.	Fixed Time Interval
Wheel Ticks	Wheel tick count increments with each wheel revolution.	Describes the current value at the instant the page was updated.
Instantaneous Cadence	Crank cadence – if available Otherwise: 0xFF indicates invalid	Fixed Time Interval
Wheel Period	Accumulated wheel period	Fixed Time Interval
Accumulated Torque	Accumulated torque	Fixed Time Interval

If transmitted, the data in the torque effectiveness and pedal smoothness page applies for the time taken to complete exactly one crank revolution back from the point at which the page was updated. The page is updated at the same time as the power-only page and the update event count values are tied. Refer to section 4.2.3.1 for the time applicability of this page.

Data records are written to store this data in different ways depending on the relative size of the fixed time interval between data page updates, and the recording interval. Refer to the detailed example in section 4.4.

4.2.3.3 0x12 T-S (Crank Torque)

Time-synchronous crank torque meters send main data pages 0x10 and 0x12, but not 0x11. They may optionally interleave other data pages such as 0x13 (Torque Effectiveness and Pedal Smoothness).

Key Assumption: Each standard crank torque / power-only main data page update describes a fixed time interval.

Key Variables: The length of the update time interval (refer to section 4.2.2).

The number of rotations described by each update is not specified.

The data in the standard crank torque data page applies as indicated in Table 4-5 and should be used to generate the torque, power and cadence data records. The data in the standard power-only data page provides the power balance field which should be used to supplement the crank torque data (Table 4-1). It should be noted that the update event counts for the crank torque and power-only data pages are not tied, and the time intervals described by each data page could therefore be offset. The update time interval is the same for all data pages.

Table 4-4. Crank Torque Message Fields

Field	Value	Time Applicability
Data Page Number	0x12 – sensor measures torque at crank	N/A
Update Event Counter	Event counter increments with each information update.	Fixed Time Interval
Crank Ticks	Crank ticks increment with each crank revolution.	Describes the current value at the instant the page was updated.
Instantaneous Cadence	Crank cadence – if available Otherwise: 0xFF	Fixed Time Interval
Period	Accumulated crank period	Fixed Time Interval
Accumulated Torque	Accumulated torque	Fixed Time Interval

If transmitted, the data in the torque effectiveness and pedal smoothness page applies for the time taken to complete exactly one crank revolution back from the point at which the page was updated. The page is updated at the same time as the power-only page and the update event count values are tied. Refer to section 4.2.3.1 for the time applicability of this page.

Data records are written to store this data in different ways depending on the relative size of the fixed time interval between data page updates, and the recording interval. Refer to the detailed example in section 4.4.

4.2.3.4 0x12 E-S (Crank Torque)

Event-synchronous crank torque meters send main data pages 0x10 and 0x12, but not 0x11. They may optionally interleave other data pages such as 0x13 (Torque Effectiveness and Pedal Smoothness).

Key Assumption: Each standard crank torque / power-only main data page update describes one crank revolution.

The data in the both the standard crank torque main data page and the standard power-only main data page describes the whole crank revolution, as indicated in Table 4-5 and Table 4-6. The standard crank torque data should be used to generate the torque, power and cadence data records. The power-only data provides the power balance field which should be used to supplement the crank torque data. It should be noted that the update event counts for the crank torque and power-only data pages are not tied, and may indicate different values despite incrementing at the same rate. The time period that each update describes is indicated by the crank period.

Table 4-5. Crank Torque Message Fields

Field	Value	Time Applicability
Data Page Number	0x12 – sensor measures torque at crank	N/A
Update Event Counter	Event counter increments with each information update.	Time varies based on crank period. Data applies for one complete revolution back from the time at which the page was updated.
Crank Ticks	Crank ticks increment with each crank revolution.	
Instantaneous Cadence	Crank cadence – if available Otherwise: 0xFF	
Period	Accumulated crank period	
Accumulated Torque	Accumulated torque	

Table 4-6. Power-Only Message Fields

Field	Value	Time Applicability
Data Page Number	0x10 – standard Power-Only message	N/A
Update Event Count	Power event count	Time varies based on crank period. Data applies for one complete revolution back from the time at which the page was updated.
Pedal Power	Bit 7: Pedal Differentiation 1 - Right Pedal Power Contribution 0 – Unknown Pedal Power Contribution	Permanent: This describes a capability of the sensor.
	Bits 0-6: Pedal Power Percent	Time varies based on crank period. Data applies for one complete revolution back from the time at which the page was updated.
Instantaneous Cadence	Crank cadence – if available Otherwise: 0xFF indicates invalid	
Accumulated Power	Accumulated power 1-watt resolution	
Instantaneous Power	Instantaneous power 1-watt resolution	

If transmitted, the data in the torque effectiveness and pedal smoothness page applies for the time taken to complete exactly one crank revolution back from the point at which the page was updated (i.e. the same time period as pages 0x10 and 0x12). The page is updated at the same time as the power-only page and the update event count values are tied.

Table 4-7. Torque Effectiveness and Pedal Smoothness Message Fields

Field	Value	Time Applicability
Data Page Number	0x13 – Torque Effectiveness and Pedal Smoothness percentages	N/A
Update Event Count	Event counter increments with each power-only information update. This value is tied to the event counter on the Power Only page.	Time varies based on crank period. Data applies for one complete crank revolution back from the time at which the page was updated.
Left Torque Effectiveness	Left leg torque effectiveness 0xFF: Invalid or negative values	
Right Torque Effectiveness	Right leg torque effectiveness 0xFF: Invalid or negative values	
Left (or combined) Pedal Smoothness	Left pedal smoothness, or combined pedal smoothness if byte 5 is set to 0xFE 0xFF: Invalid	
Right Pedal Smoothness	Right pedal smoothness FE: Combined pedal smoothness being sent in byte 4 0xFF: Invalid	

Data records are written to store this data in different ways depending on the relative size of the crank period and the recording interval. Refer to the detailed example in section 4.3.

4.2.3.5 0x20 E-S (CTF)

Crank torque frequency power meters send main data page 0x20 on every message period except during calibration. No other pages are interleaved.

Key Assumption: Each crank torque frequency main data page update describes one crank revolution.

The data crank torque frequency main data page applies for the whole crank revolution, or permanently, as indicated in Table 4-8. The time period that each update describes is indicated by the difference between the message timestamps. This value equates to the crank period for messages describing successive events.

Table 4-8. Crank Torque Frequency Message Fields

Field	Value	Time Applicability
Data Page Number	0x20 – Crank Torque Frequency	N/A
Update Event Count	Rotation event counter increments with each completed pedal revolution.	Time varies based on crank period. Data applies for one complete revolution back from the time at which the page was last updated.
Slope	Slope defines the variation of the output frequency.	Permanent: This is set by the manufacturer.
Time Stamp	Time of most recent rotation event	Time varies based on crank period. Data applies for one complete revolution back from the time at which the page was last updated.
Torque Ticks Stamp	Count of most recent torque event	

Refer to the ANT+ bike power device profile for the calculations required to convert the transmitted data into power.

Data records are written to store the power data in different ways depending on the relative size of the crank period and the recording interval. Refer to the detailed example in section 4.3.

4.3 Detailed Example of Processing Event-Synchronous Data

Because the cadence of the cyclist affects the rate at which data updates are transmitted by event-synchronous power meters it may not be possible to write a new record every recording interval. Records can only be written once all the event data has arrived covering the entire record interval. This is illustrated below.

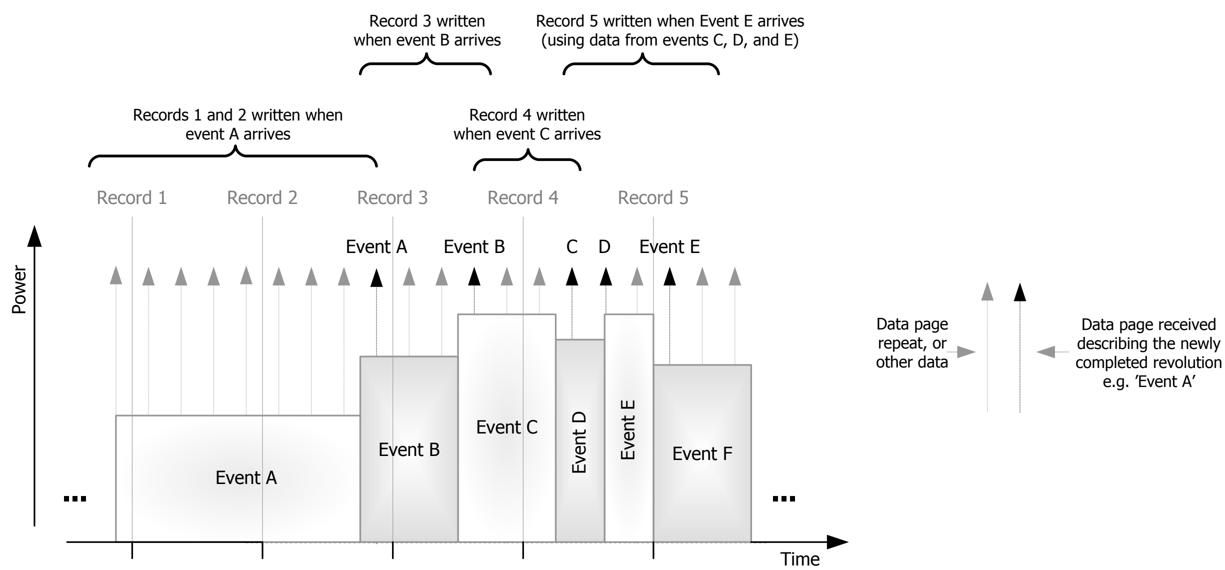
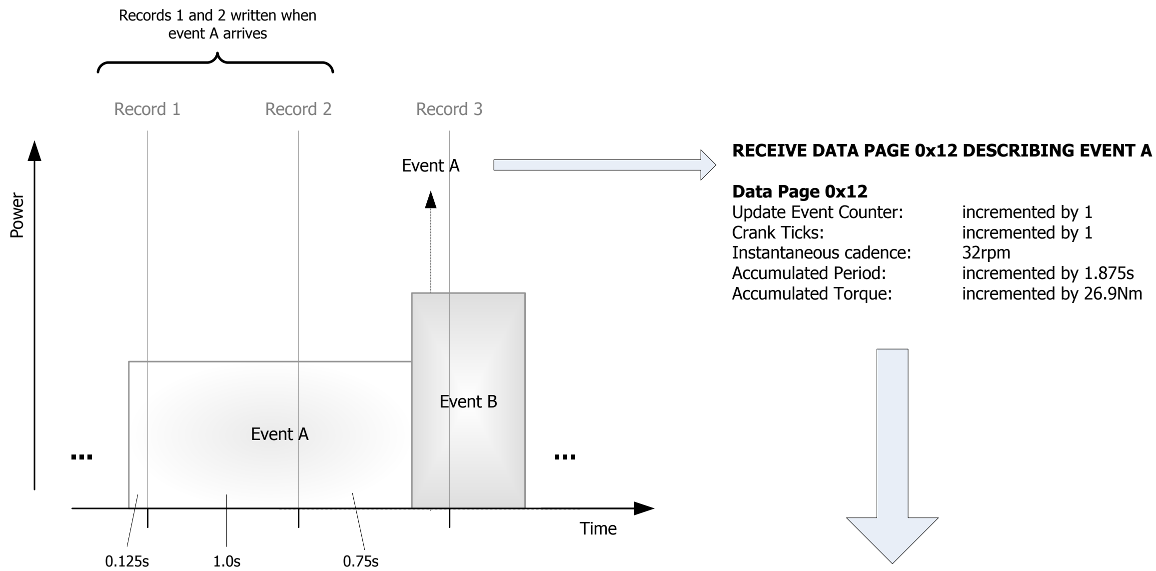


Figure 4-4. Writing of Records based on Event-Synchronous Data

Note that the diagram above has been simplified to show the event description arriving in the next data page to be transmitted after the completion of the event. This is accurate in that the next relevant data page (e.g. the next standard crank torque main data page 0x12) will contain this data. However, other data pages (such as battery status page 0x52) may be transmitted first in accordance with the transmission pattern in use.

The following figures illustrate the sequence of calculations used to write the data records on receipt of each standard crank torque data page describing a new pedal stroke event. Notice that data from each event is split into time-based chunks and used to write past records directly and/or contribute towards future records.



Calculate Record 1

Power = Torque x Angular Velocity => Power (Event A) = 26.9 x 32 x $\frac{2\pi}{60}$ *= 90 W* (Convert from rpm to rad/s)

Power assumed constant for the whole pedal stroke

=> Power contributed towards Record 1 = 90 W for 0.125 s

Record 1 Power = $\frac{(90 \times 0.125) + (\text{power from previous record 1 events} \times \text{time spent at each power level})}{\text{Recording Interval}}$

By definition: Rotations for Event A = 1 revolution

Cadence assumed constant for the whole pedal stroke

=> Revolutions contributed to Record 1 = $\frac{1 \times 0.125}{1.875}$ *= time portion of event A completed in recording interval 1*

Record 1 Revolutions = $\frac{1 \times 0.125}{1.875}$ *+ any previous revolutions that occured in recording interval 1*

WRITE: Record 1: Power= (90W x 0.125) + previous contribution, Rotations= 0.06 + previous contribution

Calculate Record 2

=> Power contributed towards Record 2 = 90 W for 1 s

Record 2 Power = $\frac{(90 \times 1.0)}{1}$ *= 90 W*

=> Revolutions contributed to Record 2 = $\frac{1 \times 1.0}{1.875}$ *= time portion of event A completed in recording interval 2*

Record 2 Revolutions = $\frac{1 \times 1.0}{1.875}$ *= 0.53 revolutions*

WRITE: Record 2: Power= 90W, Rotations= 0.53

Calculate Contribution Towards Record 3

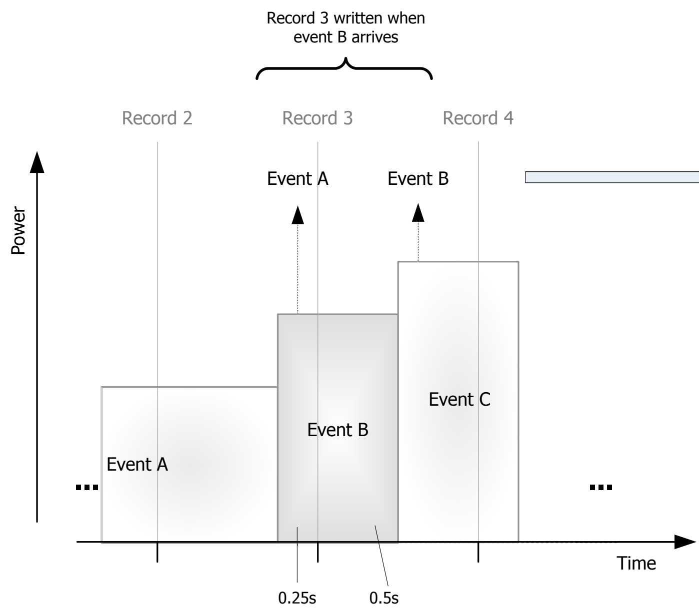
=> Power contributed towards Record 3 = 90 W for 0.75 s = $\frac{(90 \times 0.75)}{1}$ *= 67.5 W*

=> Revolutions contributed to Record 3 = $\frac{1 \times 0.75}{1.875}$ *= 0.4 revolutions*

WAIT TO WRITE RECORD 3 UNTIL EVENT B ARRIVES

Figure 4-5. Writing Records on Receipt of 'Event A'

Accumulated data from event A is temporarily stored and used in the calculation of record 3 that takes place when the data page describing event B arrives.



RECEIVE DATA PAGE 0x12 DESCRIBING EVENT B

Data Page 0x12

Update Event Counter:	incremented by 1
Crank Ticks:	incremented by 1
Instantaneous cadence:	80rpm
Accumulated Period:	incremented by 0.75s
Accumulated Torque:	incremented by 16.1Nm

Calculate Record 3

Power = Torque x Angular Velocity => Power (Event B) = $16.1 \times 80 \times \frac{2\pi}{60} = 135$ *W* (Convert from rpm to rad/s)

Power assumed constant for the whole pedal stroke

=> Power contributed towards Record 3 = 135 W for 0.25 s

Record 3 Power = $\frac{(135 \times 0.25) + (\text{power from previous record 3 events} \times \text{time spent at each power level})}{\text{Recording Interval}}$

$= \frac{(135 \times 0.25) + (90 \times 0.75)}{1.0} = 101.25W$ (From event A)

By definition: Rotations for Event B = 1 revolution

Cadence assumed constant for the whole pedal stroke

=> Revolutions contributed to Record 3 = $\frac{1 \times 0.25}{0.75}$ *= time portion of event B completed in recording interval 3*

Record 3 Revolutions = $\frac{1 \times 0.25}{0.75}$ *+ any previous revolutions that occured in recording interval 3*

$= \frac{1 \times 0.25}{0.75} + 0.4 = 0.73$ *revolutions* (From event A)

WRITE: Record 3: Power= 101.25W, Rotations= 0.73

Calculate Contribution Towards Record 4

=> Power contributed towards Record 4 = 135 W for 0.5 s = $\frac{(135 \times 0.5)}{1} = 67.5$ *W*

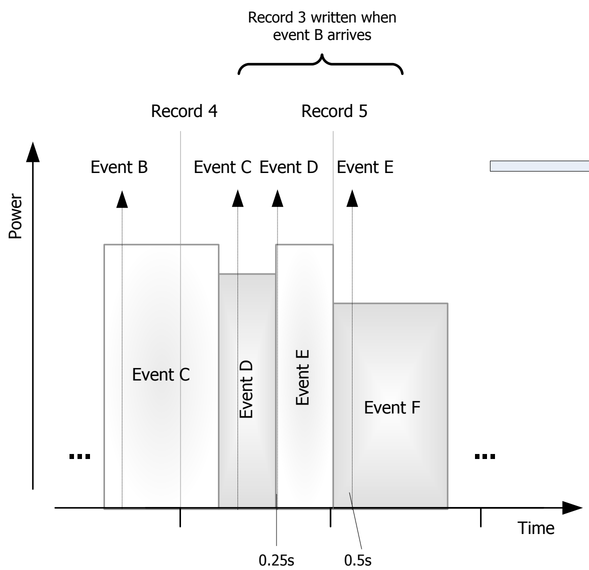
=> Revolutions contributed to Record 4 = $\frac{1 \times 0.5}{0.75} = 0.66$ *revolutions*

WAIT TO WRITE RECORD 4 UNTIL EVENT C ARRIVES

Figure 4-6. Writing Record 4 on Receipt of 'Event B'

The data from Event C is handled in the same way as event B. Data page 0x12 arrives describing the new event as follows: Cadence = 90rpm, Torque = 19.1Nm. This implies a power level of 160W can be assumed as the constant value for the revolution. The event period is 0.75s. Record 4 is therefore written as Power: 147.5W Revolutions: 1.33. (0.25x160W) and 0.33 revolutions are accumulated towards record 5.

Record 5 is written when event E arrives, as shown in Figure 4-7 below. Note that no records can be written on receipt of event D as a full recording interval has not elapsed by the time this event completes.



RECEIVE DATA PAGE 0x12 DESCRIBING EVENT D

Data Page 0x12

Update Event Counter:	incremented by 1
Crank Ticks:	incremented by 1
Instantaneous cadence:	185rpm
Accumulated Period:	incremented by 0.375s
Accumulated Torque:	incremented by 8.5Nm

RECEIVE DATA PAGE 0x12 DESCRIBING EVENT E

Data Page 0x12

Update Event Counter:	incremented by 1
Crank Ticks:	incremented by 1
Instantaneous cadence:	185rpm
Accumulated Period:	incremented by 0.375s
Accumulated Torque:	incremented by 9.5Nm

Calculate Record 5

Power = Torque x Angular Velocity => Power (Event D) = $8.5 \times 185 \times \frac{2\pi}{60} = 143\ W$

Convert from rpm to rad/s

=> Power (Event E) = $9.5 \times 185 \times \frac{2\pi}{60} = 160\ W$

Power assumed constant for the whole pedal stroke

=> Power contributed towards Record 5 = 143 W for 0.375 s and 160 W for 0.375 s

Record 5 Power = $\frac{(143 \times 0.375) + (160 \times 0.375) + (\text{power from previous record 5 events} \times \text{time})}{\text{Recording Interval}}$

$= \frac{(143 \times 0.375) + (160 \times 0.375) + (160 \times 0.25)}{1.0} = 154W$

From event C

By definition: Rotations for Event D, Event E = 1 revolution per event.

Record 5 Revolutions = 1 + 1 + any previous revolutions that occured in recording interval 5

=1 + 1 + 0.33 = 2.33 revolutions

From events D, E From event C

WRITE: Record 5: Power= 154W, Rotations= 2.33

Calculate Contribution of Event E Towards Record 6

Event E completes during recording interval 5

=> Power contributed towards Record 6 = 0 W

=> Revolutions contributed to Record 6 = 0 revolutions

WAIT TO WRITE RECORD 6 UNTIL EVENT F ARRIVES

Figure 4-7. Writing Record 5 on Receipt of 'Event E'

4.4 Detailed Example of Processing Time-Synchronous Data

Because time-synchronous data updates are transmitted at regular time intervals the corresponding data records can be written regularly. Each record can be written when data page s have arrived that describe the whole recording interval. The figure below shows a scenario where the fixed time interval is ~493ms (i.e. two channel periods), and the recording interval is 1s.

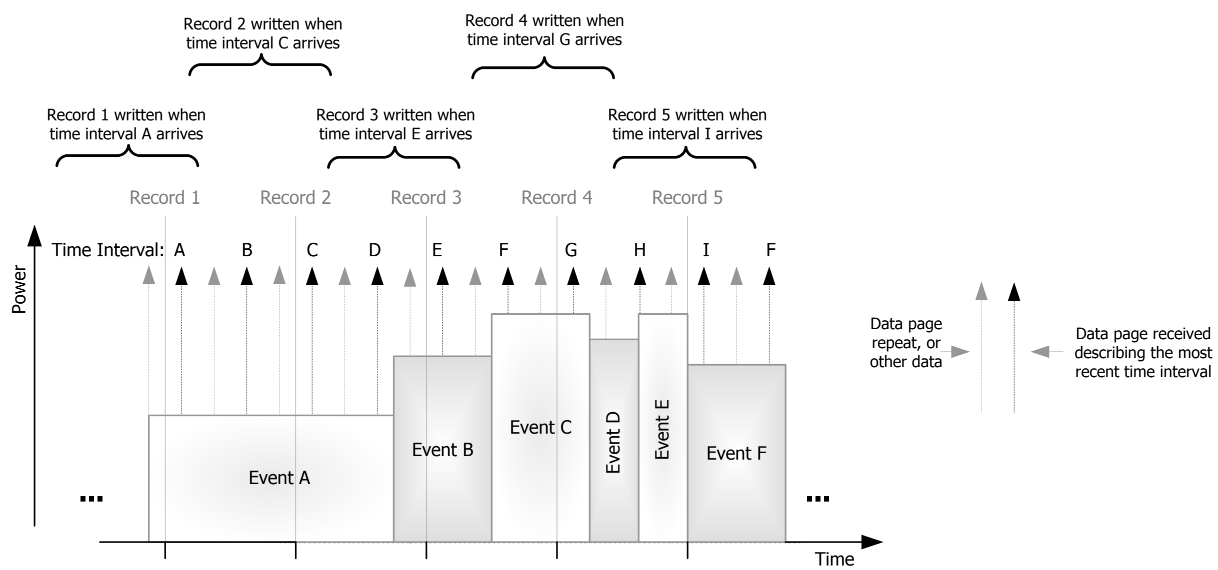


Figure 4-8. Writing of Records based on Time-Synchronous Data

Note that the diagram above has been simplified to show the new data arriving in the next data page to be transmitted after the completion of each time interval. This is accurate in that the next relevant data page (e.g. the next standard wheel torque main data page 0x11) will contain this data. However, other data pages (such as battery status page 0x52) may be transmitted first in accordance with the transmission pattern in use.

4.5 Outages vs. Zero Data

It is important to distinguish between data outages and data that show zero power and cadence. A data outage occurs when wireless interference or environmental factors prevent data page transmissions from being received by the bike computer (or similar display). This could occur at any time and may last for varying periods. Data outages are unpredictable and are just as likely to occur during a high power sprint, as during light pedalling or coasting. Assuming that power and cadence are zero during a data outage is likely to lead to reduced average power numbers, and any graphs produced for post-race analysis will show obvious errors. This may reduce consumer confidence in the recording device. Instead short data outages should be backfilled using accumulated data, and longer data outages should leave record gaps or show invalid, rather than zero.

In contrast, when the bike has stopped or is coasting then the power and cadence are genuinely zero and should be recorded as such. The recommended approach for detecting coast or stop events and recovering from data outages is outlined in the sections below. Data should never be discarded as a result of a coast or stop condition.

4.5.1 Detecting When the Bike has Stopped Moving or is Coasting

When either a coast or stop is detected, the data records that describe the applicable time interval should be written to show zero power and zero cadence.

For most types of power meter, it is impossible to distinguish between a bike that is stopped and a bike that is coasting by analyzing the transmitted data. However, most bike computers use GPS and/or ANT+ speed sensors to determine speed. If these sources indicate that the bike is still moving, then the bike is coasting; otherwise it has stopped.

For power-only sensors, or time-synchronous crank torque sensors a stop or coasting condition is indicated by the accumulated power, (or accumulated crank ticks, accumulated crank period, and accumulated torque) remaining constant while the update event count continues to increment. The instantaneous cadence field will indicate zero (if a valid value is being sent). Data records should be written as normal, with the appropriate fields populated as zero.

For wheel torque sensors, the update count increases but the accumulated wheel ticks and accumulated wheel period will not increase when the bike has stopped. However if these values continue to increase, but the instantaneous cadence value is zero (or invalid) and the accumulated torque value does not increase, then the bike is coasting. Data records should be written as normal, with the appropriate fields populated as zero.

For event-synchronous crank torque sensors, or CTF sensors the update event count stops increasing when the user stops pedaling as there are no new events.

Some event-synchronous sensors force a single data update when no events are occurring. This appears as an incremented update event count with no corresponding increase in the crank ticks (or timestamp) fields. This is a recommended best practice for sensor manufacturers as it prevents the loss of data associated with a partial revolution at the end of a session.

The last page is repeated until either a rotation event occurs or the unit shuts down. If a new rotation event occurs, then the data records describing the coast/stop interval can be written as normal (note that this may result in a very small amount of power being spread over many data records if the power meter did not force an update). If the unit shuts down, then the display should assume that zero power was accumulated after the last event received, and write the data records accordingly. No data received by the display should be discarded.

4.5.2 Handling Invalid Values

Power meters may transmit 'invalid' in place of a defined value for the certain fields including cadence, pedal power (i.e. left-right balance), torque effectiveness and pedal smoothness. In this case a display may omit these fields from data records, or may populate the fields with 'invalid'. **The fields should not be populated with zero**. If the crank period is known, then the cadence may be calculated and included in the data records.

4.5.3 Handling Data Outages

An important benefit of using accumulated values in message fields is that accuracy can be maintained during RF reception loss. The recorded data can maintain correct average power values provided that data outages are handled correctly, and the length of the data outage is not too long.

Figure 4-9 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 **display** the most recent power value or to indicate that messages are not being received. However, no data records should be **written** during the data outage.

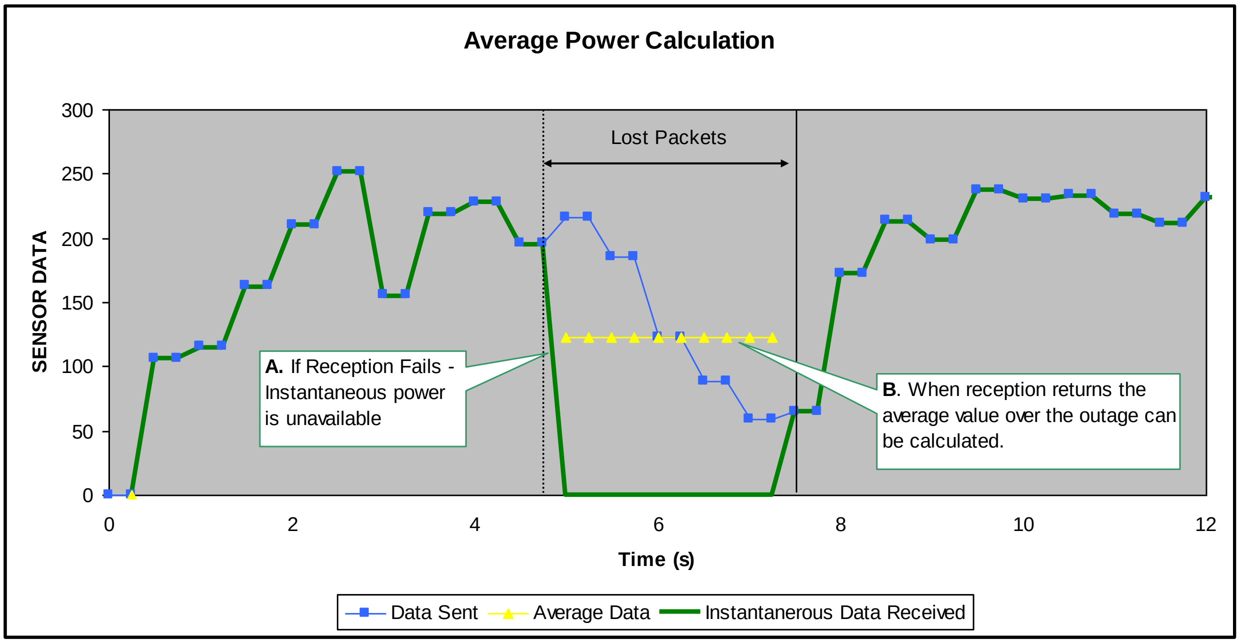


Figure 4-9. Averaging Power through an RF Outage

When reception resumes, the length of the outage should be checked to ensure it is safe to assume that no more than one rollover per field has occurred. Typically data records can be backfilled for outages of up to 10 seconds, although this number may need to be reduced for extremely powerful cyclists, and/or if the system is time-synchronous and the update time interval is 250ms or less.

The example in Figure 4-9 shows a short data outage, where the data records can be backfilled. This is done by calculating the average power and cadence over the outage interval based on the accumulated values received. Note that the data record immediately following the start of the outage should also include any calculated data contributed by previous events.

Storing either zeros or the last received data before the loss will result in inaccurate data and should be avoided.

If the data outage is too long, then it is recommended that either no data records are written for the relevant time period, or that any data records that are written contain invalid values. When data transmission resumes after a long data outage the display should use the first data page to reinitialize the accumulated values. Valid data records can then be written as subsequent data page updates are received.

5 Toolset

The toolset provided with this application note package includes a set of SimulANT+ scripts to demonstrate the intended approach and to allow developers to test their implementations. In addition a Command Line tool is provided based on the power decoder library that may either be incorporated into product or used as a reference design.

C99 was selected for this purpose because it is both portable and widely used, and therefore provides the greatest convenience for the majority of bike power display manufacturers. Developers using alternative technology for their products may use this document as a starting point for the code.

5.1 Power Decoder Library

The power decoder library is written in C99 and provides the main engine for interpreting incoming ANT+ bike power data and outputting data records.

5.1.1 Command Line Tool

A command line tool is provided that uses the power decoder library (and the ANT library) to receive ANT+ bike power data via an ANT USB, and generates CSV or FIT file output. The input data can be generated live from an ANT+ bike power meter or simulated using SimulANT+ or AutoANT/ANTwareII.

5.1.2 Power Decoder Library API

The PowerDecoder.h file acts as the power decoder library API to allow for the use of the power decoder library within embedded product. The code has been optimised for production level efficiency and has also been thoroughly commented to aid understanding. Refer to the software licence for warranty disclaimers.