

USB4 2.0 ENGINEERING CHANGE NOTICE FORM

Title: Receiver Multi Error-Bursts Test Adjustments (Gen2& Gen3 only)

Applied to: USB4 Specification Version 2.0

Brief description of the functional changes:

Modify the error-bursts restart test definition and change from normative to informative
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Benefits as a result of the changes:

Remove setup related issues and simplify the characterization method by enabling a dedicated compliance tool
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An assessment of the impact to the existing revision and systems that currently conform to the USB specification:
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None

An analysis of the hardware implications:
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None

An analysis of the software implications:
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None

An analysis of the compliance testing implications:
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Changing the error-bursts restart test setup and define as informative
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Actual Change

(a). Section 3.5.3 (USB4 1.0), Section 3.1.4.3 (USB4 2.0)

From Text:

3.1.4.3 Receiver Multi Error-Bursts Testing

When a receiver employs DFE with more than one tap, it shall take steps to limit the probability that a burst of errors is restarted right after the reception of one or more correct bits (see Section 3.1.1.2). The receiver multi error-burst probability shall be characterized as follows:

- Definitions:
 - N is a parameter that defines the observation window for burst restart. It also defines the interval between error bursts. N shall be at least 32 bits.
 - An Error Capture is an observation window that starts with the detection of a bit error which is preceded by at least N consecutive bits without errors.
 - A Burst Restart Event is an Error Capture that contains an error burst of one or more consecutive errors followed by one or more correct bits and then by one or more errors within the observation window.
- Initialize the receiver test setup with "Case 2" configuration used for testing the uncoded BER with periodic jitter component of 100 MHz (see Section 3.1.4.2). PRBS31 test pattern shall be used and neither Forward Error Correction nor Pre-Coding shall be applied.
- After initialization, the periodic jitter magnitude shall be increased to the point where uncoded BER of 1E-8 is observed.
- The receiver under test shall trigger on random bit-errors and capture errors that follow. This shall be done using the method described above for Error Captures. At least N consecutive bits shall be examined for errors starting from the initial trigger.
- The probability for obtaining Burst Restart Events shall not exceed 5E-7 (i.e. one error burst restart per 2 million error captures on average).
- Error Captures and Burst Restart Events shall be counted and reported out as detailed in Section 8.3.2.2.3 and Section 8.3.2.2.4. The Burst Restart Count shall not increment more than once in an Error Capture.

To Text:

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3.1.4.3 Receiver Multi Error-Bursts Testing

When a receiver employs DFE with more than one tap, it shall take steps to limit the probability that a burst of errors is restarted right after it ends with the reception of one or more correct bits (see Section 3.1.1.2). The probability of Error-Burst Restart Events should not exceed 5E-7 (less than one restart event per 2 million error bursts on average). The combination of an uncoded BER of 1E-12 and an Error-Burst Restart probability of 5E-7 supports an uncoded BER of 1E-19. In cases where the actual uncoded BER is less than 1E-12 at a certain ratio, the Error-Burst Restart probability can be larger than 5E-7 at this same ratio, since the coded BER depends on the product of the two terms.

It is recommended that the receiver multi error-bursts probability shall be characterized using the compliance post-processing tool (Informative):

- Definitions:

- N is a parameter that defines the observation window for burst restart. It also defines the interval between error bursts. N shall be at least 32 bits.
- An Error Capture is an observation window that starts with the detection of a bit error which is preceded by at least N consecutive bits without errors.
- A Burst Restart Event is an Error Capture that contains an error burst of one or more consecutive errors followed by one or more correct bits and then by one or more errors within the observation window.

- Initialize Construct the receiver “Case 2” uncoded BER test setup with “Case 2” configuration used for testing the uncoded BER with periodic jitter component of 100 MHz, and run the test as described in (see Section 3.1.4.2.). PRBS31 test pattern shall be used and neither Forward Error Correction nor Pre-Coding shall be applied.
- Extract the receiver vertical noise CDF function (vertical “bathtub” curve), and the converged values of the receiver DFE taps and evaluate the error burst-restart probability and the estimated coded BER using a compliance post-processing tool. Background and information on the compliance post-processing tool may be found at: <https://groups.usb.org/wg/usb4electrical/document/folder/1421>.
- After initialization, the periodic jitter magnitude shall be increased to the point where uncoded BER of 1E-8 is observed.
- The receiver under test shall trigger on random bit errors and capture errors that follow. This shall be done using the method described above for Error Captures. At least N consecutive bits shall be examined for errors starting from the initial trigger.
- The probability for obtaining Burst Restart Events shall not exceed 5E-7 (i.e., one error burst restart per 2 million error captures on average).
- Error Captures and Burst Restart Events shall be counted and reported out as detailed in Section 8.3.3.2.3 and Section 8.3.3.2.4. The Burst Restart Count shall not increment more than once in an Error Capture.

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The following pseudocode example describes how to update the Error Capture Count and the Burst Restart Count:

```
Start: Wait for N consecutive bits without errors  
  
Wait for a bit with error  
  
Start an observation window of N bits  
  
Increment Error Capture Count by 1  
  
If a transition from a bit without errors to a bit with error is  
detected within the observation window, increment Burst Restart  
Count by 1  
  
Wait for end of observation window  
  
Go to Start
```

The following is an example Error Capture (N=32):

```
No burst restart (Error Capture Count shall be incremented by 1, Burst Restart Count  
shall not change):  
captured_data[31:0]=000000000000000000000000000000001111111111  
  
Burst restart (Error Capture Count shall be incremented by 1, Burst Restart Count shall  
be incremented by 1):  
captured_data[31:0]=00000000000000000000000000000000111001111111
```

where '1' represents a bit error and '0' represents a correct bit, as expected from "exclusive-or" (XOR) operation between the received bits and the synchronized reference PRBS31 pattern. captured_data[0] corresponds to the initial error event trigger.

Note: A burst of errors contains one or more consecutive bit errors.

(b). Section 3.6.5 (USB4 1.0), Section 3.1.5.5 (USB4 2.0)

From Text:

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3.1.5.5 Captive Device Receiver Multi Error-Bursts Testing

When a Captive Device's receiver employs DFE with more than one tap, it shall take steps to limit the probability that a burst of errors is restarted right after the reception of one or more correct bits (see Section 3.1.1.2). The receiver multi error-burst probability shall be characterized as follows:

- Definitions:
 - N is a parameter that defines the observation window for burst restart. It also defines the interval between error bursts. N shall be at least 32 bits.
 - An Error Capture is an observation window that starts with the detection of a bit error which is preceded by at least N consecutive bits without errors.
 - A Burst Restart Event is an Error Capture that contains an error burst of one or more consecutive errors followed by one or more correct bits and then by one or more errors within the observation window.
- Initialize the receiver test setup as configured for testing the uncoded BER with periodic jitter component of 100 MHz (see Section 3.1.5.4). PRBS31 test pattern shall be used and neither Forward Error Correction nor Pre-Coding shall be applied.
- After initialization, the periodic jitter magnitude shall be increased to the point where uncoded BER of 1E-8 is observed.
- The receiver under test shall trigger on random bit-errors and capture errors that follow. This shall be done using the method described above for Error Captures. At least N consecutive bits shall be examined for errors starting from the initial trigger.
- The probability for obtaining Burst Restart Events shall not exceed 5E-7 (i.e. one error burst restart per 2 million error captures on average).
- Error capture events and error-burst restart events shall be counted and reported out as detailed in Section 8.3.2.2.3 and Section 8.3.2.2.4. The Burst Restart Count shall not increment more than once in an Error Capture.

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3.1.5.5 Captive Device Receiver Multi Error-Bursts Testing

When a Captive Device's receiver employs DFE with more than one tap, it shall take steps to limit the probability that a burst of errors is restarted right after it ends with the reception of one or more correct bits (see Section 3.1.1.2). The probability of Error-Burst Restart Events should not exceed $5E-7$ (less than one restart event per 2 million error bursts on average). The combination of an uncoded BER of $1E-12$ and an Error-Burst Restart probability of $5E-7$ supports an uncoded BER of $1E-19$. In cases where the actual uncoded BER is less than $1E-12$ at a certain ratio, the Error-Burst Restart probability can be larger than $5E-7$ at this same ratio, since the coded BER depends on the product of the two terms.

It is recommended that the receiver multi error-bursts probability be characterized using the compliance post-processing tool (Informative):

- Definitions:

- N is a parameter that defines the observation window for burst restart. It also defines the interval between error bursts. N shall be at least 32 bits.
- An Error Capture is an observation window that starts with the detection of a bit error which is preceded by at least N consecutive bits without errors.
- A Burst Restart Event is an Error Capture that contains an error burst of one or more consecutive errors followed by one or more correct bits and then by one or more errors within the observation window.

- Initialize-Construct the receiver **uncoded BER** test setup ~~as configured for testing the uncoded BER~~ with periodic jitter component of 100 MHz, ~~and run the test as described in (see Section 3.1.5.4.)~~. PRBS31 test pattern shall be used and neither Forward Error Correction nor Pre-Coding shall be applied.
- Extract the receiver vertical noise CDF function (vertical "bathtub" curve), and the converged values of the receiver DFE taps and evaluate the error burst-restart probability and the estimated coded BER using a compliance post-processing tool. Background and information on the compliance post-processing tool may be found at: <https://groups.usb.org/wg/usb4electrical/document/folder/1421>.

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- After initialization, the periodic jitter magnitude shall be increased to the point where uncoded BER of $1E-8$ is observed.
- The receiver under test shall trigger on random bit errors and capture errors that follow. This shall be done using the method described above for Error Captures. At least N consecutive bits shall be examined for errors starting from the initial trigger.
- The probability for obtaining Burst Restart Events shall not exceed $5E-7$ (i.e., one error burst restart per 2 million error captures on average).
- Error capture events and error burst restart events shall be counted and reported out as detailed in Section 8.3.3.2.3 and Section 8.3.3.2.4. The Burst Restart Count shall not increment more than once in an Error Capture.

The following pseudo-code example describes how to update the Error Capture Count and the Burst Restart Count:

```
Start: Wait for N consecutive bits without errors

Wait for a bit with error

Start an observation window of N bits

Increment Error Capture Count by 1

If a transition from a bit without errors to a bit with error is
detected within the observation window, increment Burst Restart
Count by 1

Wait for end of observation window
```

The following is an example analysis:

No burst restart (Error Capture Count shall be incremented by 1, Burst Restart Count shall not change): _____

captured_data[31:0]=0000000000000000000000001111111111

Burst restart (Error Capture Count shall be incremented by 1, Burst Restart Count shall be incremented by 1): _____

captured_data[31:0]=000000000000000000000000111001111111

where '1' represents a bit error and '0' represents a correct bit, as expected from "exclusive or" (XOR) operation between the received bits and the synchronized reference PRBS31 pattern. captured_data[0] corresponds to the initial error event trigger.

Note: A burst of errors contains one or more consecutive bit errors.