NVM Express® Technical Proposal for New Feature

Technical Proposal ID	TP4119a Rx Phy Eye Opening Measurement (EOM)
Change Date	2023-04-06
Builds on Specification	NVM Express NVMe over PCIe Transport Specification 1.0b NVM Express Base Specification 2.0b NVM Express Management Interface Specification 1.2b
References Specification	

Technical Proposal Author(s)

Name	Company
Gerry Houlder, Jim Hatfield	Seagate
Austin Bolen	Dell EMC
Lee Prewitt	Microsoft
Curtis Ballard	HPE

This proposal intends to:

For the NVM Express Base Specification 2.0b

This proposal defines methods to:

a) Start the measurement process in a transport-agnostic, and implementation-agnostic manner; and
b) Report the measurement result in a transport-agnostic, and implementation-agnostic manner.

For the NVM Express NVMe over PCIe Transport Specification 1.0b

This proposal defines methods to:

a) Pass selection parameters to start the measurement process in a transport-specific, but implementation-agnostic manner; and
b) Return measurement results in an PCIe-specific, but implementation-agnostic manner.

For the NVM Express Management Interface Specification 1.2b

This proposal adds a new log to the list of supported logs.

Revision History

Revision Date	Change Description
2021.08.12	Initial phase 2 revision
2021.08.19	Comments from 2021.08.19 meeting
2021.08.26	Comments from 2021.08.26 meeting
2021.11.05	Resynched to NVMe 2.0a, PCIe transport 1.0a Got rid of 'primary/secondary' controller verbiage Expanded header and added time estimates for good/better/best Added generation number
2021.11.19	Responded to comments from Mike Allison, Austin Bolen, and the Technical WG meeting of Nov. 18, 2021 - Removed the 'Port' field - Replaced Action='establish context' with 'start measurement' - Replaced Action='release context' with 'abort measurement and clear log' - Added to the header: in process indicator, header length, specified for all fields what value is returned if no measurement has been done
2022.01.11	Changed copyright date from 2021 to 2022
2022.01.31	1. Addressed editorial comments from Mike Allison 2. addressed what to do if any lanes failed to be measured 3. addressed what to do if the measurement process is interrupted by I/O 4. updated base references to 'b' revisions 5. marked headings for the search window.
2022.02.03	1. Accepted all changes and removed resolved comments 2. EOM header: inserted a current link speed field, a reserved field, and shifted fields that followed to larger offsets 3. the EOM Lane Descriptor: added Status field (success/fail)
2022.02.09	1. Resolved many editorial and technical comments from Austin Bolen (making it very clean for Phase 3) 2. Added Figures 198, NewZ
2022.02.10	1. changed 'in process' to 'in progress' 2. Revised the text about 'quiescing' in 3.new.B.x 3. Swapped the columns in figure NewZ 4. Named the PCIe register containing the Current Link Speed
2022.03.02	1. Addressed editorial (phase 3 type) comments from Mike Allison 2. Addressed technical comments from Mike Allison adding clarification to multiple fields in the log page. 3. Synched to 'b' versions of the affected specs 4. Addressed the scope as all physical controllers associated with the same PCIe port.
2022.03.10	1. Removed most of the changes to the base spec, per new style guidelines for command specific logs (Mike Allison) 2. Changed the wording about 'physical controller' to say 'controller… that supports this log' 3. Numerous editorial corrections suggested by Austin Bolen 4. Corrected math errors in the offset column of Figure www, including removing the need for the VSOFF field. 5. Removed the Version field in the EOM Lane descriptor. Having one version for the log is sufficient.

2022.03.24	1. Entered phase 3
	2. Renamed
	    Header Length (HLEN) -> Header Size (HSIZE)
	    Log Version -> Log Revision
	3. Changed the polarity of the Measurement Successful bit
	4. Removed the Measurement In Process bit in the EOM descriptor, and changed the dependencies of fields there to use the EOMIP field instead.
	5. Reworded the VSLEN field description to not say 'supported', but instead to just say it is the number of bytes.
	6. Adjusted the scope of the log page in 3.new.B.x, per a suggestion from Austin Bolen.
	7. Resolved all previous comments.

2022.03.25	1. Resolved editorial comments from Austin Bolen
2022.07.25	1. Integrated
2022.08.10	1. Resolved editorial comments from Mike Allison, Jim Hatfield, and Austin Bolen.
2022.08.26	1. Modified Base spec Figure 202

2022.08.27	1. Added notes in Figure ttt for the "Maximum Top Bottom" and "Maximum Left Right" EOM Header fields to say "The value reported is the maximum value from the center point to the outside of the eye diagram. This is not a measured value."
2022.08.29	1. Added changes to Base spec figures 24, 29, and 33 2. Added Gerry Houlder as a co-author from Seagate 3. Figure 202: changed reference from specifically the PCIe transport, to 'the appropriate transport specification'
2022.09.07	1. Integrated changes from 2022.08.26, 2022.08.27, and 2022.08.29
2022.09.07	Corrected figure numbering and references.
2023.01.24	Initial updates for TP4119a. 1. Editorial updates. 2. Added Physical Interface Receiver Eye Opening Measurement to the list of log pages that use the Log Specific Identifier. 3. Explicitly state that the measurements are performed as a background operation. 4. TP4119 requires the EOM Lane Descriptors to be sorted in order of increasing lane number. Clarified that it is increasing lane number from lowest offset to highest offset. 5. Increased the Log Revision from 1h to 2h. 6. Stated explicitly that the Optional Data Present field and the Number of Descriptors field is zero if a measurement has not been completed since the log was initialized. 7. Stated explicitly that the MAXTB, MAXLR, Top, Bottom, Left, Right, Number of Rows, and Number of Columns fields are only non-zero if the Printable Eye Field Present bit is set to '1'. 8. Clarified that the Printable Eye field is only present if the Printable Field Present bit is set to '1'. 9. Clarified that the estimated times to complete the measurements are static values. 10. Clarified that the Lane field is numbered per the PCIe Base Specification prior to any lane reversal. 11. For PAM4, changed it from having a separate EOM Lane Descriptor per eye to having a single EOM Lane Descriptor that contains the measurement data for all three eyes for that lane. 12. Clarified that the Vendor Specific Length field is only non-zero if the Vendor Specific Field Present bit is set to '1'. 13. Clarified that the Vendor Specific field is only present if the Vendor Specific Field Present bit is set to '1'.
2023.02.16	1. In the EOM Lane Descriptor, specified how to number the eyes, added back the separate EOM Lane Descriptor per eye, and added a statement that for PAM4, the three eyes must be in a specific order with no overlaps or gaps in the rows of consecutive eyes of a given lane. 2. Added an implementation note that strongly recommends the Vendor Specific field be populated with any data required to evaluate the signal integrity of the receiver. 3. Clarified in the intro section that the log is applicable to the port associated with the specified Target Controller. 4. Clarified that if a lane measurement fails, then the EOM Lane Descriptor for each eye of the lane reports a failure. 5. Editorial updates.
2023.02.21	1. Clarified that traffic needs to be quiesced on all controllers associated with the PCIe port being measured. 2. The text stated that KATO should be longer than the estimated time. Added clarified that it should be longer than the estimated time to complete the measurement. 3. Clarified that Current Link Speed is the value of the PXLS register at the time the Get Log Page command is process vs when the measurement is started because there was no value specified for the field prior to measurement starting. 4. Clarified that MAXTB and MAXLR apply to each EOM Lane Descriptor. 5. Editorial updates.

2023.02.23	1. Renamed the Vendor Specific field to the Eye Data field. 2. Clarified that the steps in the Start Measurement and Read Log Data field shall be performed in the order listed. 3. Changed name of the Current Link Speed field to the Measurement Link Speed field and clarified that the filed is 0h if no measurement has been performed since the log page was initialized. 4. Clarified that the host should quiesce all other activity on the PCIe port being measured while the measurement is in progress, including all commands, for at least the estimated time to perform the measurement. 5. Clarified that the estimated times for the measurement apply to all supported PCIe lanes on the PCIe port, are typical times, and assume that the host has quiesced other activity on the PCIe port while the measurement is in progress. 6. Editorial updates.
2023.03.02	1. Editorial updates based on workgroup feedback.
2023.04.06	1. Editorial updates based on 30-day member review and workgroup feedback.

Description for NVM Express Base Specification 2.0b Changes Document

Feature Enhancement

- Added log page 19h to the Get Log Page command allowing a host to request that a controller perform a receiver eye measurement process in a transport-agnostic, and implementation-agnostic manner; and provide a way for the host to read the measurement results in a transport-agnostic, and implementation-agnostic manner.

Description for NVM Express NVMe over PCIe Transport Specification 1.0b Changes Document

Feature Enhancement

- Added log page 19h with PCIe transport-specific content, allowing a host to pass selection parameters to start the measurement process in a transport-specific, but implementation-agnostic manner, and to return measurement results in an PCIe-specific, but implementation-agnostic manner.

Description for NVM Express Management Interface Specification 1.2b Changes Document

Feature Enhancement

- Added log page 19h to the list of supported logs.

Markup Conventions:

Black: Unchanged (however, hot links are removed)

~~Red Strikethrough~~: Deleted

Blue: New

Blue Highlighted: TBD values, anchors, and links to be inserted in new text.

\<Green Bracketed\>: Notes to editor

Description of Specification Changes for NVM Express Base Specification 2.0b:

Modify a portion of section 3.1.2.1.2 as shown below:

\<add a log to the list of logs supported for I/O controllers\>

3.1.2.1.2 Log Page Support

Figure 24 defines log pages that are mandatory, optional, and prohibited for an I/O controller. I/O Command Set specific log page support requirements are described within individual I/O Command Set specifications.

Figure 24: I/O Controller – Log Page Support

Log Page Name	Log Page Support Requirements [1]
…	
Physical Interface Receiver Eye Opening Measurement	O[4]
…	

Notes:
1. O/M/P definition: O = Optional, M = Mandatory, P = Prohibited
2. Mandatory for controllers that support Fixed Capacity Management (refer to section 8.3.2).
3. Optional for NVM Express revision 1.4 and earlier.
4. If this log page is not described for a specific physical interface (refer to the applicable NVM Express transport specification), then this log page is prohibited for that transport.

\<add a log to the list of logs supported for Administrative controllers\>

3.1.2.2.2 Log Page Support

Figure 29 defines log pages that are mandatory, optional, and prohibited for an Administrative controller.

Figure 29: Administrative Controller – Log Page Support

Log Page Name	Command Support Requirements [1]
…	
Physical Interface Receiver Eye Opening Measurement	O[5]
…	

Notes:
1. O/M/P definition: O = Optional, M = Mandatory, P = Prohibited
2. Optional if Set Features command is not supported (refer to Figure 28).
3. Optional if NVMe-MI Send command and NVMe-MI Receive command is not supported (refer to Figure 28).
4. Optional for NVM Express revision 1.4 and earlier.
5. If this log page is not described for a specific physical interface (refer to the applicable NVM Express transport specification), then this log page is prohibited for that transport.

3.1.2.3.3   Log Page Support

The Discovery controller shall support the Discovery Log Page. The log pages that a Discovery controller may support are shown in Figure 33.

Figure 33: Discovery Controller – Log Page Support

Log Page Name	Command Support Requirements [1]
…	
Physical Interface Receiver Eye Opening Measurement	P
…	
Notes	

Notes
1.   O/M/P definition: O = Optional, M = Mandatory, P = Prohibited
2.   Optional if Set Features command is not supported (refer to Figure 32).
3.   Optional if NVMe-MI Send command and NVMe-MI Receive command is not supported (refer to refer to Figure 32).
4.   Optional for versions 1.1 and earlier of the NVMe over Fabrics specification.

5.16 Get Log Page command

…

Figure 198: Get Log Page – Command Dword 11

Bits	Description
31:16	**Log Specific Identifier:** This field specifies an identifier that is required for a particular log page. The log pages that require a log specific identifier are indicated in the table below. <table><tr><td>**Log Page**</td><td>**Identifier**</td></tr><tr><td>Endurance Group Information</td><td rowspan="2">Endurance Group Identifier (refer to section 3.2.3)</td></tr><tr><td>Rotational Media Information</td></tr><tr><td>Predictable Latency Per NVM Set</td><td>NVM Set Identifier (refer to section 3.2.2)</td></tr><tr><td>Media Unit Status</td><td>Domain Identifier (refer to section 3.2.4) [1]</td></tr><tr><td>Supported Capacity Configuration List</td><td>Domain Identifier (refer to section 3.2.4) [1]</td></tr><tr><td>Physical Interface Receiver Eye Opening Measurement</td><td>Target Controller (refer to the applicable NVM Express transport specification)</td></tr></table>
15:00	**Number of Dwords (NUMDU):** This field specifies the most significant 16 bits of the number of dwords to return unless otherwise specified.
NOTES:	

NOTES:
1.   If the NVM subsystem does not support multiple domains, then this field is reserved. If this field specifies a non-zero Domain Identifier that is not reported in the Domain List (refer to section 5.17.2.17), then the controller shall abort the command with Invalid Field in Command.

Figure 202: Get Log Page – Log Page Identifiers

Log Identifier	Scope	Log Page Name	Reference Section
…			
19h	Refer to the applicable NVM Express transport specification		
…			

KEY:
Namespace = The log page contains information about a specific namespace.
Endurance Group = The log page contains information about a specific Endurance Group.
Controller = The log page contains information about the controller that is processing the command.
Domain = The log page contains information about the Domain.
NVM subsystem = The log page contains information about the NVM subsystem.
Vendor Specific = The log page contains information that is vendor specific.

NOTES:
1.   For namespace identifiers of 0h or FFFFFFFFh.
2.   For namespace identifiers other than 0h or FFFFFFFFh.
3.   Bit 0 is cleared to '0' in the DSTO field in the Identify Controller data structure (refer to Figure 275).
4.   Bit 0 is set to '1' in the DSTO field in the Identify Controller data structure.

...

<add a transport-specific log page, and a new Admin commands section>

3.new Admin Commands

3.new.B Get Log Page command

3.new.B.x Physical Interface Receiver Eye Opening Measurement (Log Identifier 19h)

The Physical Interface (Phy) Receiver (Rx) Eye Opening Measurement (EOM) log page contains an EOM Lane Descriptor for each eye of each active lane of the PCIe port associated with the specified controller. Each EOM Lane Descriptor contains information that provides a general indication of how well the controller receiver is seeing or receiving the signal by providing a set of data indicating general information about the eye opening measurement and:

a) an optional Printable Eye field that indicates the basic shape of the eye; and
b) an optional Eye Data field that may contain a more comprehensive eye diagram than what is able to be indicated using the Printable Eye field as well as any other information useful for evaluating the signal integrity of the receiver.

This log page shall not be supported for secondary controllers.

The scope of the log page shall be a PCIe port. If this log page is supported, then all non-secondary controllers (i.e., non-SR-IOV controllers and SR-IOV primary controllers) associated with the same PCIe port shares the same log page.

If a lane measurement cannot be made (e.g., due to transport errors), then the Measurement Successful bit for each EOM Lane Descriptor associated with that lane shall be cleared to '0' to indicate that an error occurred (refer to Figure www).

Once a measurement has been started on a PCIe port, the host should quiesce all other activity on that PCIe port (e.g., all commands) for at least the estimated time to complete the measurement (refer to the Estimated Time for Good Quality, Estimated Time for Good Quality, and Estimated Time for Good Quality fields).

The Action field in the Log Specific Parameter field (refer to Figure NEWa) specifies whether:

a) the controller returns the current contents of the log page;
b) the controller starts the measurement process and returns log page data; or
c) the controller aborts any measurement in progress and initializes the log page header.

The Physical Interface Receiver Eye Opening Measurement log page for a PCIe port shall be initialized if any controller associated with that PCIe port processes:

a) a Get Log Page command requesting the Physical Interface Receiver Eye Opening Measurement log page with the Action field (refer to Figure NEWa) set to:

    a. 01b (i.e., Start Measurement and Read Log Page Data); or
    b. 10b (i.e., Abort Measurement and Clear Log);

    or

b) a Controller Level Reset.

Figure NewZ specifies the size of the log page.

Figure NewZ: Size of Physical Interface Receiver Eye Opening Measurement Log Page

Value of EOMIP	Size of Log Page (bytes)
0h	HSIZE
1h	HSIZE
2h	HSIZE + (DS * ND)
Note: The EOMIP field, the HSIZE field, the DS field, and the ND field are defined in Figure ttt.	

Figure NEWa: Physical Interface Receiver Eye Opening Measurement Log Specific Parameter Field

Bits	Description
14:12	Reserved
11:10	**Action**: This field specifies the action that the controller shall take during processing this Get Log Page command.
		Value	Definition	

Figure NEWa: Physical Interface Receiver Eye Opening Measurement Log Specific Parameter Field

Bits		Description
	00b	**Read Log Data**: The controller shall return the Physical Interface Receiver Eye Opening Measurement log page starting at the address specified by the LPOU field and the LPOL field in the Get Log Page command.
	01b	**Start Measurement and Read Log Data**: The controller shall perform the following operations in the order listed: 1) if a measurement is in progress, then the previous measurement shall be terminated; 2) begin to perform the eye opening measurements as a background operation on all active lanes of the PCIe port associated with the specified Target Controller (refer to Figure NewB); and 3) return the Physical Interface Receiver Eye Opening Measurement log page starting at the offset indicated by the LPOU field and the LPOL field in the Get Log Page command.
	10b	**Abort Measurement and Clear Log**: The controller shall abort any measurement in progress and shall initialize the log page header to indicate that no measurement is reported (i.e., the EOMIP field shall be cleared to 0h). It is not an error if the controller processes a Get Log Page command with this value while no measurement in progress.
	11b	Reserved
09:08		**Measurement Quality:** If the Action field is set to 01b, then this field specifies the relative quality of the measurement and the relative degree of effort to that the host requests to spend on performing the measurements. The measurement qualities are relative and vendor specific, but: Good quality <= Better quality <= Best quality If the Action field is not set to 01b, then this field shall be ignored by the controller. Note: Higher quality measurements may require more time to complete the measurement than lower quality measurements. <table><tr><th>Value</th><th>Definition</th></tr><tr><td>00b</td><td>Good quality</td></tr><tr><td>01b</td><td>Better quality</td></tr><tr><td>10b</td><td>Best quality</td></tr><tr><td>11b</td><td>Reserved</td></tr></table>

Figure NEWb: Physical Interface Receiver Eye Opening Measurement Log Specific Identifier Field

Bits	Description
15:00	**Target Controller**: This field specifies the Controller ID of the controller associated with the PCIe port to be measured.

The log page returned is described in Figure yyy. The EOM Lane Descriptors described in Figure yyy shall be sorted starting at the byte offset following the EOM Header in order of:

1. increasing lane number; and
2. then increasing eye number.

Figure yyy: Physical Interface Receiver Eye Opening Measurement Log Page

Bytes	Description
HSIZE-1:00	EOM header (refer to Figure ttt)
DS+(HSIZE-1):HSIZE	EOM Lane Descriptor 0 (refer to Figure www)
…	…
(DS*ND)+(HSIZE-1):(DS*(ND-1))+HSIZE	EOM Lane Descriptor ND-1
Note: DS is the value of the Descriptor Size field in Figure ttt. ND is the value of the Number of Descriptors field in Figure ttt.	

Figure ttt describes the EOM header data.

Figure ttt: EOM Header

Bytes	Description
0	**Log Identifier:** This field shall be set to 19h.
1	**EOM In Progress (EOMIP):** This field shall indicate the measurement progress for the PCIe port. | Value	Description | |---|---| | 0h | No measurement has been started since this log page was initialized. | | 1h | A measurement is in progress. | | 2h | A measurement has completed since this log page was initialized. | | 3h to FFh | Reserved |
3:2	**Header Size (HSIZE):** This field shall indicate the number of bytes in the EOM Header data structure and shall be set to 64.
7:4	**Result Size**: This field shall indicate the number of bytes in this log page. Refer to Figure NewZ.
8	**EOM Data Generation Number:** This field shall be incremented each time the Physical Interface Receiver Eye Opening Measurement log page is read with the Action field (refer to Figure NEWa) set to Start Measurement and Read Log Data (i.e., 01b). If the value of this field is set to FFh, then this field shall be cleared to 0h when incremented (i.e., rolls over to 0h).
9	**Log Revision:** This field shall indicate the version of this log page. This field shall be set to 2h.
10	**Optional Data Present:** This field indicates which optional fields are present in the log page. If the EOMIP field is not set to 2h, then this field shall cleared to 0h. | Bits	Description | |---|---| | 7:2 | Reserved | | 1 | **Eye Data Field Present:** If the Eye Data field in the EOM Lane Descriptor data structure is present, then this bit shall be set to '1'. If the Eye Data field is not present, then this bit shall be cleared to '0'. | | 0 | **Printable Eye Field Present:** If the Printable Eye field in the EOM Lane Descriptor data structure is present, then this bit shall be set to '1'. If the Printable Eye field is not present, then this bit shall be cleared to '0'. |
11	**Lanes:** This field shall indicate the number of lanes configured for this port.
12	**Eyes Per Lane:** This field shall indicate the number of eyes per lane (e.g., the value of this field is set to 1h for NRZ signaling and the value of this field is set to 3h for PAM4 signaling).
13	**Log Specific Parameter Field Copy:** This field contains additional log specific information. | Bits	Description | |---|---| | 7 | Reserved | | 6:0 | **Log Specific Parameter Field Value:** This field shall indicate the value of the Log Specific Parameter field in CDW10 (refer to Figure NewA) for the Get Log Page command that started the measurement (i.e., the Action field was set to 10b). If no measurement has been started since the log page was initialized, then this field shall be cleared to 0h. |
14	**Link Information:** This field contains information about the PCIe link. | Bits	Description | |---|---| | 7:4 | Reserved | | 3:0 | **Measurement Link Speed:** This field shall indicate the value of the Current Link Speed field in the PXLS register (refer to Figure 55) at the time the measurement was started. If no measurement has been started since the log page was initialized, then this field shall be cleared to 0h. |
17:15	Reserved
19:18	**Log Specific Identifier Copy:** This field shall indicate the value of the Log Specific Identifier field in CDW11 for the Get Log Page command that started the measurement (i.e., the Action field was set to 10b). If no measurement has been started since the log page was initialized, then this field shall be 0h.
23:20	**Descriptor Size (DS):** This field shall indicate the number of bytes in each EOM Lane Descriptor (refer to Figure www).
25:24	**Number of Descriptors (ND):** This field shall indicate the number of EOM Lane Descriptors returned (refer to Figure www). There are no EOM Lane Descriptors returned for lanes that are not implemented or are not active. If no measurement has completed since this log page was initialized (i.e., the EOMIP field is not set to 2h), then this field shall be cleared to 0h.
27:26	**Maximum Top Bottom (MAXTB):** If the Printable Eye Field Present bit is set to '1', then this field shall indicate the maximum value for the Top and Bottom fields in each EOM Lane Descriptor. If the Printable Eye Field Present bit is cleared to '0', then this field shall be cleared to 0h. The value reported is the maximum number of rows from the center point to the outside top or bottom edge of the eye diagram in the Printable Eye field of any EOM Lane Descriptor. This is not a measured value.
29:28	**Maximum Left Right (MAXLR)**: If the Printable Eye Field Present bit is set to '1', then this field shall indicate the maximum value for the Left and Right fields in each EOM Lane Descriptor. If the Printable Eye Field Present bit is cleared to '0', then this field shall be cleared to 0h. The value reported is the maximum number of columns from the center point to the outside left or right edge of the eye diagram in the Printable Eye field of any EOM Lane Descriptor. This is not a measured value.
31:30	**Estimated Time for Good Quality (ETGOOD):** This field indicates the estimated typical time in seconds to complete the measurement of all supported lanes on the PCIe port (refer to the Maximum Link Width field for the number of supported lanes) with the Measurement Quality field (refer to Figure NewA) cleared to a value of 00b. The value indicated by this field may be exceeded if the host does not quiesce all other activity on the PCIe port being measured while the measurement is in progress. A value of 0h indicates less than one second.

Bytes	Description
33:32	**Estimated Time for Better Quality (ETBETTER)**: This field indicates the estimated typical time in seconds to complete the measurement of all supported lanes on the PCIe port (refer to the Maximum Link Width field for the number of supported lanes) with the Measurement Quality field set to a value of 01b. The value indicated by this field may be exceeded if the host does not quiesce all other activity on the PCIe port being measured while the measurement is in progress. A value of 0h indicates less than one second.
35:34	**Estimated Time for Best Quality (ETBEST)**: This field indicates the estimated time in seconds to complete the measurement of all supported lanes on the PCIe port (refer to the Maximum Link Width field for the number of supported lanes) with the Measurement Quality field set to a value of 10b. The value indicated by this field may be exceeded if the host does not quiesce all other activity on the PCIe port being measured while the measurement is in progress. A value of 0h indicates less than one second.
63:36	Reserved

Figure www describes the EOM Lane Descriptor that is returned for each eye of each lane measured. The length is reported in the Descriptor Size field (refer to Figure ttt).

Figure www: EOM Lane Descriptor

Bytes	Description
0	Reserved
1	**Measurement Status:** This field shall indicate the measurement status for the lane indicated by the Lane field. | Bits	Description
7:1	Reserved
0	**Measurement Successful**: If the measurement was successful, then this bit shall be set to '1'. If the measurement failed, then this bit shall be cleared to '0'.	
2	**Lane**: This field shall indicate the lane number associated with this measurement for this port. The lanes shall be numbered as described in the PCI Express Base Specification prior to any lane reversal.
3	**Eye**: This field indicates the eye number associated with this measurement for this lane. The eyes for each lane shall be numbered incrementally starting at 0 where the eye at the lowest voltage for each lane is numbered 0, the eye at the second lowest voltage for each lane (if applicable) is numbered 1, etc.
5:4	**Top**: If the Printable Eye Field Present bit is set to '1', then this field shall indicate the absolute value of the number of rows in the Printable Eye field from the center of the eye to the top edge of the eye. This field shall be less than or equal to MAXTB. If the Printable Eye Field Present bit is cleared to '0', then this field shall be cleared to 0h.
7:6	**Bottom**: If the Printable Eye Field Present bit is set to '1', then this field shall indicate the absolute value of the number of rows in the Printable Eye field from the center of the eye to the bottom edge of the eye. This field shall be less than or equal to MAXTB. If the Printable Eye Field Present bit is cleared to '0', then this field shall be cleared to 0h.
9:8	**Left**: If the Printable Eye Field Present bit is set to '1', then this field shall indicate the absolute value of the number of columns in the Printable Eye field from the center of the eye to the left edge of the eye. This field shall be less than or equal to MAXLR. If the Printable Eye Field Present bit is cleared to '0', then this field shall be cleared to 0h.
11:10	**Right**: If the Printable Eye Field Present bit is set to '1', then this field shall indicate the absolute value of the number of columns in the Printable Eye field from the center of the eye to the right edge of the eye. This field shall be less than or equal to MAXLR. If the Printable Eye Field Present bit is cleared to '0', then this field shall be cleared to 0h.
13:12	**Number of Rows (NROWS)**: If the Printable Eye Field Present bit is set to '1', then this field shall indicate the number of rows in the Printable Eye field. If the Printable Eye Field Present bit is cleared to '0', then this field shall be cleared to 0h.
15:14	**Number of Columns (NCOLS)**: If the Printable Eye Field Present bit is set to '1', then this field shall indicate the number of columns in the Printable Eye field. If the Printable Eye Field Present bit is cleared to '0', then this field shall be cleared to 0h.
17:16	**Eye Data Length (EDLEN)**: If the Eye Data Field Present bit is set to '1', then this field shall indicate the number of bytes present in the Eye Data field. If the Eye Data Field Present bit is cleared to '0', then this field shall be cleared to 0h.
31:18	Reserved
End of EOM Lane Descriptor Header	

Bytes	Description

(NROWS*NCOLS+32)-1:32	**Printable Eye**: If the Printable Eye Field Present bit is set to '1', then this field shall indicate an eye diagram as a series of rows of printable ASCII characters representing the vertical and horizontal position of the eye boundary.
	
	If the Printable Eye Field Present bit is cleared to '0', then:
	  a) the Printable Eye field is not present; and
	  b) the Eye Data field, if present, immediately follows the EOM Lane Descriptor Header.
	
	The ASCII character of each byte in this field shall be:
	  a) "1" (i.e., 31h) if the position is outside of the eye; and
	  b) "0" (i.e., 30h) if the position is on or inside the eye.
	
	If there is more than one eye per lane, then there shall be no gap or overlap between the rows of consecutive Printable Eye fields for a given lane such that the unified diagram of all eyes in the lane is able to be constructed by concatenating the eye diagram in the Printable Eye field for each eye in the lane on top of each other from lowest numbered eye to highest numbered eye.
	
	The information in this field, the header for the EOM Lane Descriptor, and the EOM Header provides enough information to print a rudimentary eye diagram which shows the general shape of the eye. To evaluate the signal integrity of the receiver, additional information is required which may be provided by the Eye Data field).
	
	<table><tr><th>Bytes</th><th>Row</th></tr><tr><td>((Row+1)*NCOLS)-1:0</td><td>0</td></tr><tr><td>((Row+1)*NCOLS)-1:Row*NCOLS</td><td>1</td></tr><tr><td>…</td><td>…</td></tr><tr><td>((Row+1)*NCOLS)-1:Row*NCOLS</td><td>NROWS-1</td></tr></table>

(NROWS*NCOLS+32)+VSLEN-1:(NROWS*NCOLS+32)	**Eye Data**: If the Eye Data Field Present bit is set to '1', then this field shall indicate vendor specific data related to this measurement. If the Eye Data Field Present bit is cleared to '0', then this field is not present. The information in the other fields of this log page do not contain enough information to evaluate the signal integrity of the receiver. To evaluate the signal integrity of the receiver, additional information is required such as time resolution, voltage resolution, bit error rate (BER) threshold, equalization values (e.g., settings related to continuous time linear equalization (CTLE), variable gain amplifier (VGA), decision feedback equalization (DFE), and boost). It is strongly recommended that this field be present and include all information required to evaluate the signal integrity of the receiver. This field may also contain a more comprehensive eye diagram than is able to be represented in the Printable Eye field (e.g., a diagram that is in color and shows contour lines for different BERs).
(DS-1):(NROWS*NCOLS+32)+VSLEN	**Padding**: The controller shall pad with all bytes cleared to 0h to a Dword boundary, where DS is the data structure size described in Figure yyy. If the data structure is already Dword aligned, then this field is not present.

shows an example of an eye diagram in the Printable Eye field with:

    Number of Rows   = 32;
    Number of Columns   = 22;
    MAXTB   = 16;
    MAXLR   = 11;
    Top   = 14;
    Bottom   = 16;
    Left   = 11; and
    Right   = 9.

Note: Coloring has been added for emphasis in this example but is not part of the log page.

Figure zzz: Example of an Eye Diagram in the Printable Eye Field

Row / Col	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1
4	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	1	1	1	1	1	1	1
6	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
7	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
8	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
9	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
10	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1
11	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1
12	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
13	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
14	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1
23	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1
24	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
25	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
26	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
27	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1
28	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1
29	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1
30	1	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1
31	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1

...

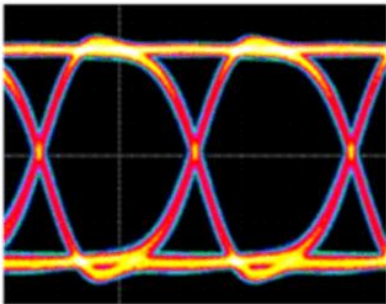**\<Modify portions of NVM Express Management Interface Specification 1.2b as shown below\>**
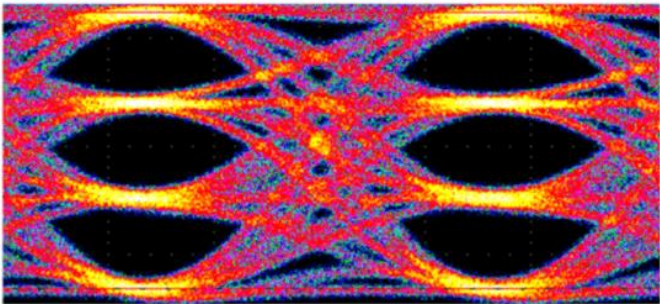
6.3 Get Log Page

\<add a log to figure 122\>

<u>**Figure 122: Management Endpoint – Log Page Support**</u>

<u>**Log Page Name**</u>[3]	<u>**Log Identifier**</u>	<u>**Requirements**</u>[1]	
		<u>**NVMe Storage Device**</u>	<u>**NVMe Enclosure**</u>
<u>...</u>			
Physical Interface Receiver Eye Opening Measurement	19h	O	O
<u>...</u>			

<these diagrams are not part of the proposal, but are here for discussion and background>

NRZ

PAM4