VESA High-performance Monitor and Display Compliance Test Specification (DisplayHDR CTS)

Version 1.0

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www.vesa.org

Purpose

The purpose of this Specification is to provide performance guidance to manufacturers of HDR PCs, including laptops, All-in-Ones, and desktop monitors, to facilitate a DisplayHDR user-facing logo program that defines a publicly shared set of standards that are represented by a series of logos.

Summary

This Specification describes HDR, why VESA created a DisplayHDR logo program, and the compliance test requirements that are necessary for a device manufacturer to self-certify a device as meeting one or more of the VESA DisplayHDR logo performance tiers.

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Support for this Specification

Clarifications and application notes might exist that further support this Specification. To obtain the latest Specification and any support documentation, contact VESA.

If you have a product that incorporates the DisplayHDR logo program, ask the company that manufactured your product for assistance. If you are a manufacturer, VESA can assist you with any clarification that you might require.

Submit all comments or reported errors to support@vesa.org.

Acknowledgments

This document would not have been possible without the efforts of VESA's Display Performance Metrics (DPM) Task Group. In particular, Table 1 lists the individuals and their companies that contributed significant time and knowledge to this version of the Specification.

Table 1: Main Contributors

Company	Name	Contribution
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Revision History

Table 2: Revision History

Date	Version	Description
November 27, 2017	1.0	Initial release of the Specification.

1 Overview

1.1 Summary

This Specification describes HDR, why VESA created a DisplayHDR logo program, and the compliance test requirements that are necessary for a device manufacturer to self-certify a device as meeting one or more of the VESA DisplayHDR logo performance tiers.

1.2 Introduction

As of 2017, within the market place for televisions, there is an array of high dynamic range (HDR) logos and standards, none of which provide a complete set of technical performance specifications or fully publish their testing methodology. Thus, a user cannot easily compare one device with another.

By contrast, the PC industry has historically been far more specification-based, openly publishing performance specifications. The DPM Task Group was founded to establish a standard that could be used for personal computer (PC) displays, for both laptops and desktops, that would clearly convey a robust performance level as indicated by the specification level and associated logo for each performance level.

The DPM Task Group developed this Specification to meet the following goals:

- **Define multiple tiers of HDR performance standards.** The initial goal was to establish the standard with three tiers, but to also anticipate additional tiers that can be added later as display performance improves. A set of logos will be developed that can be used by device manufactures for user products that meet each of the respective tiered performance levels.
- **Define and openly publish a set of standardized tests.** This will enable low-cost self-certification for device manufacturers. In addition, simplified use of the test process, by reviewers, retailers, and users will encourage appropriate application of the logo and standard.
- **Define any necessary interface and communication protocols that may be deemed necessary to define as part of the standard.** For example, define bit depth, color gamut container, and/or other requirements necessary for communication between the graphics processing unit (GPU) and display, thereby leveraging existing VESA groups to drive any changes necessary within related Standards.

The initial three tiers and their associated label names are listed below. The test criteria for each tier is discussed throughout the remainder of this Specification.

- DisplayHDR-400
- DisplayHDR-600
- DisplayHDR-1000

1.3 Scope

Although this Specification defines device display performance, it cannot it its entirety be applied to individual display components. Specifically, many of the tests require the combination of display panel, backlighting, timing controller (TCON), GPU, operating system, and potentially a scaler to evaluate performance.

The defined specifications are designed for LCD, which is currently the predominant display technology for the PC industry. As OLED and other display technologies become more common, VESA may develop alternative specifications for those technologies.

The following features are explicitly excluded from this Specification (see Section 9 for further details):

- Resolution
- Aspect ratio
- Audio

1.4 Terms, Abbreviations, Acronyms, and Initialisms

Table 1-1: Terms, Abbreviations, Acronyms, and Initialisms Used in this Specification

Term	Description
BLU	Back Light Unit. Illumination unit behind the LCD open-cell glass panel.
cd/m^2	Candela per square meter (formerly referred to as “nits”).
DisplayID	Display IDentification.
DPM	Display Performance Metrics.
EDID	Extended Display Identification Data. Legacy VESA structure, superseded by the DisplayID structure.
E-EDID	Enhanced Extended Display Identification Data. Legacy VESA structure, superseded by the DisplayID structure.
EOTF	Electro-Optical Transfer Function.
FPS	Frames Per Second.
FRC	Frame Rate Converter.
GPU	Graphics Processing Unit.
HDR	High Dynamic Range. References displays that have the ability to show a greater contrast ratio than what is typically considered SDR. ***Note:*** *There is no definition of the minimum ratio of HDR in general. In this Specification, the first tier evaluates to a ratio of 4000:1. For the purposes of this Specification, this ratio could therefore be considered as the HDR starting point.*
HLG	Hybrid Log Gamma.
MaxCLL	Maximum Content Light Level. Maximum luminance level of the entire content clip (e.g., in a movie, it is the maximum luminance pixel within the entire movie). Contained with an HDR file as metadata.
PC	Personal Computer.
rise time	Length of time that the display takes to transition from **black** to **white**.
SDR	Standard Dynamic Range. Represented by a contrast ratio from **black** to **white**, typical panels range from 500:1 to approximately 1500:1.
TCON	Timing Controller.

1.5 Conventions

1.5.1 Precedence

If there is a conflict between text, figures, and tables, the precedence shall be tables, figures, and then text.

1.6 Reference Documents

Table 1-2 lists the various reference documents that are used within this Specification. Users of this Specification are advised to ensure that they have the latest versions/revisions of reference standards/specifications and documents.

Table 1-2: Reference Documents

Document	Version/ Revision[a]	Publication Date	Referenced As
Adobe® RGB (1998) Color Image Encoding	Version 2005-05	May 2005	*Adobe RGB*
BT.709, Parameter values for the HDTV standards for production and international programme exchange[b]	Version 6	June 2015	*ITU-R BT.709*
Recommendation ITU-R BT.1886, Reference electro-optical transfer function for flat panel displays used in HDTV studio production[b]		March 2011	*ITU-R BT.1886*
BT.2020, Parameter values for ultra-high definition television systems for production and international programme exchange[b]	Version 2	October 2015	*ITU-R BT.2020*
CIE 1931 xy Chromaticity Diagram	1931	1931	*CIE 1931*
CIE Illuminant D65	1964	1964	*CIE D65*
*CIE ISO 11664-5:2016, Colorimetry – Part 5: CIE 1976 L*u*v* Colour Space and u', v' Uniform Chromaticity Scale Diagram*	Revision 2016	September 2016	*CIE 1976*
CTA-861.3, HDR Static Metadata Extension – (formerly known as *CEA-861.3*)[c]	Version 3A	July 1, 2016	*CTA-861.3*
High-Definition Multimedia Interface (HDMI) Specification[d]	Version 1.4b Version 2.0b	October 11, 2011 March 3, 2016	*HDMI v1.4b* *HDMI v2.0b* *HDMI Specification*
IEC 61966-2-1:1999, Multimedia systems and equipment – Colour measurement and management – Part 2-1: Colour management – Default RGB colour space - sRGB	1999	October 18, 1999	*IEC 61966-2-1*
Information Display Measurements Standard[e]	Version 1.03	June 1, 2012	*IDMS v1.03*
SMPTE RP 431-2, D-Cinema Quality – Reference Projector and Environment[f]	2011	April 6, 2011	*SMPTE RP 431-2*
SMPTE ST 2084, Dynamic Range Electro-Optical Transfer Function of Mastering Reference Displays[f]	2014	August 16, 2014	*SMPTE ST 2084*

Table 1-2: Reference Documents (Continued)

Document	Version/ Revision[a]	Publication Date	Referenced As
VESA DisplayID Standard[h]	Version 2.0	September 11, 2017	*DisplayID Standard*
VESA Enhanced Extended Display Identification Data (E-EDID) Standard[g]	Version A.2	September 25, 2006	
VESA Glossary of Terms and Acronyms Specification[h]	Current	Current	

a. *All references include subsequently published errata, specification change notices or engineering change notices, etc.*
b. *Published by the International Telecommunication Union (ITU). See www.itu.int.*
c. *Published by ANSI Accredited Standards Developer and Consumer Technology Association (ANSI/CTA). See global.ihs.com.*
d. *See www.hdmi.org*
e. *Published by the International Committee for Display Metrology (ICDM) and Society for Information Display (SID). See www.icdm-sid.org.*
f. *Published by the Society of Motion Picture and Television Engineers. See www.smpte.org/digital-library.*
g. *Included as legacy support for users that have PC devices that include E-EDID (or EDID). Superseded by DisplayID Standard.*
h. *See www.vesa.org/vesa-member/downloads/.*

2 Specification Summary

Table 2-1 summarizes the high-level specifications documented by this Specification. The sections that follow further detail how each of these display performance features are measured.

Table 2-1: DisplayHDR Performance Tier Summary

Tier	Minimum-white Luminance Test – 10% Center Patch and Full-screen Flash Tests Minimum Requirement (cd/m^2)[a]	Minimum-white Luminance – Test Full-screen Long-duration Test Minimum Requirement (cd/m^2)[b]	Corner Box Test – Black-level Test Maximum (cd/m^2)[c]	Tunnel Test – Black-level Test Maximum (cd/m^2)[d]	Minimum Color Gamut in *CIE 1976* u', v' Format [e]	Minimum Bit Depth[f]
400	400	320	0.40	0.10	95% *ITU-R BT.709*	• 10-bit image processing in dimming processor • 8-bit driver IC
600	600	350	0.10	0.10	99% *ITU-R BT.709* and 90% DCI-P3 D65 (*SMPTE RP 431-2*)	• 10-bit image processing in dimming processor • 8b + 2b dithering in display pipeline • 8-bit driver IC
1000	1000	600	0.05	0.10	99% *ITU-R BT.709* and 90% DCI-P3 D65 (*SMPTE RP 431-2*)	• 10-bit image processing in dimming processor • 8b + 2b dithering in display pipeline • 8-bit driver IC

a. See Section 5.1.1 and Section 5.1.2 for further details.
b. See Section 5.1.3 for further details.
c. See Section 5.2.1 for further details.
d. See Section 5.2.2 for further details.
e. See Section 6 for further details.
f. See Section 7.1 for further details.

3 Test Environment

3.1 Ambient Temperature

The expectation of a User-Facing Logo program is that users can duplicate the tests at home and achieve results that indicate compliance with the DisplayHDR logo's performance specification. As such, a fairly wide range of usage environments should be considered as "within range," and testing the devices in ambient temperatures within this range should have successful results.

The required supported ambient temperature range is 15 through 30°C (59 through 86°F). Manufacturing should perform testing at 21°C (70°F).

3.2 Colorimeter/Sensor Usage

It should be anticipated that users and/or reviewers will use colorimeters of two predominant form factors:

- Those that hang on a USB cable over the top of the display, and rest against the screen, –or–
- Those that are handheld and touched to the screen with a soft surround

In both cases, it should be assumed that:

- No significant source of ambient light leaks around the sensor's edge, into the measuring device
- Sensors are effectively flush against the screen and baffled to prevent light leakage from the sides

Additionally, a darkened room should be used for testing, thereby minimizing direct lighting from reflecting on the screen.

Except where noted, the sensor shall be placed in the center of the screen for all tests.

While pushing the sensor flush to the screen, take care to ensure that the panel is not being deformed because deformation will impact test performance.

3.3 System Warm-up Time

The device under test should be provided 30 minutes of warm-up time. In addition, the device's screen savers should be disabled so that the display is active for 30 minutes prior to testing.
To ensure testing consistency, the display should be warmed up using full-screen "**paper-white**" at 180cd/m^2 for this 30-minute warm-up period.

3.4 Colorimeter Requirements

The colorimeter's quality and capabilities may limit the user's ability to accurately test HDR displays. It is necessary that the colorimeter be able to reliably measure and report luminance that exceeds the limit being tested. Ideally, the colorimeter should be able to record levels above 1000cd/m^2 because some panels with the DisplayHDR-1000 specification will naturally perform above 1000cd/m^2.

Furthermore, the colorimeter and associated gamut calculation method need to be able to operate in the *CIE 1976* coordinate system, resulting in u', v' values and providing a calculation of color gamut coverage in both *ITU-R BT.709* and DCI-P3 D65 (*SMPTE RP 431-2*).

The darkest black-level measurement in VESA tests extends to 0.05cd/m^2; therefore, to accurately measure this, the colorimeter needs to be able to take measurements down to at least this level.

3.5 Hardware and Software for Semi-automated Testing

An HDR10-ready PC using DisplayPort™ or HDMI® can be used to connect to the HDR10-enabled monitor and/or display hardware. The display will not be considered HDR10-compliant unless there are *CTA-861.3*-conformant DisplayID (or legacy EDID+CTA) data blocks. A test application is available from Microsoft® for free, by way of the Microsoft Store. Temporarily, the beta version of the test application is available in the VESA Kavi workspace (www.vesa.org/vesa-member/downloads/) in the compressed ZIP file, **DPMTest-2017-*MM-DD*.zip**.

The test application is **not** integrated with colorimeter input and monitoring; thus, a second computer is required to be connected to the colorimeter to record the colorimeter data.

Graphics hardware that supports HDR10 is required. The following suggested options are known to work with Windows®:

- Using discrete graphics (AMD® or NVIDIA® cards):
  - Microsoft Windows Creators Edition (RS2, Version 1703, Build 15063 or higher)
  - AMD Radeon Rx 5xx series and Radeon Rx Vega, –or–
  - NVIDIA GeForce GTX 10-Series video drivers and graphics cards (current versions)
  - HDR Test application, **WindowsDisplayColorPerformance.exe**
- Using integrated graphics (7th Generation Intel® Core™ processors):
  - Using a 7th Generation processor with Intel HD Graphics 630 or higher, this includes all 7th Generation desktop Core i7 and Core i5 processors, and all mobile Core i7 and many Core i5 processors
  - Microsoft Windows Fall Creators Edition (RS3, Version 1709, Build 16299 or higher)
  - Intel Redstone 3 video driver (Version 15.60.4832 or higher)
  - HDR Test application, **WindowsDisplayColorPerformance.exe**

3.6 Test Suite and Test Files

Section 5 through Section 8 describe the tests that are necessary to be performed to evaluate which performance tier a display device supports. Appendix B provides the specifications for each test image. Appendix C illustrates a variety of sample DisplayIDs.

4 Video Signal Input Processing

4.1 HDR10

HDR video on the PC uses the HDR10 format; thus, the minimum requirement for a device to be considered HDR-compliant is that the device must be able to process HDR10 video.

For monitors, this means that a scaler must be used to accept HDR10 input, including a 10-bit signal, EOTF *SMPTE ST 2084*, and *ITU-R BT.2020* color container. What happens between the scaler and TCON, and between the TCON and Driver IC, is undefined, other than the driver IC's bit-depth resolution, which is defined as part of this Specification.

For laptops, because their panel and GPU are tightly integrated, HDR10 video processing can be handled anywhere within the display pipeline. Therefore, the HDR10, *ITU-R BT.2020*, and EOTF signals are not required to go beyond the GPU. Again, as with monitors, the Driver IC's bit-depth resolution is defined as part of this Specification.

Note: *Although this Specification provides flexibility with regard to where a laptop decodes HDR10 (e.g., in the GPU, the TCON, or possibly a scaler or similar chip), MovieLabs (movielabs.com) has defined robust security requirements for 4K playback, HDR, and protected movie content. Because of this, it is not been confirmed whether the necessary histogram analysis required for local dimming can be done in the GPU while meeting the MovieLabs security requirements that are necessary for protected movie playback.*

4.2 HLG

Hybrid Log Gamma (HLG), rather than EOTF *SMPTE ST 2084*, was deemed optional and therefore not included as part of this Specification. This is because no operating system vendors have indicated plans to output HLG from the operating system (by way of the GPU) to the display.

This is not to say that PCs do not support HLG – there are websites with HLG content that can be played on the PC; however, the video signal that is sent from the GPU to the display is converted to EOTF *SMPTE ST 2084*.

4.3 White Point

Throughout this Specification, all references to "**white**" in the DCI-P3 D65 (*SMPTE RP 431-2*) color space assume the *CIE D65* definition. D65 is intended to represent average daylight and has a correlated color temperature of approximately 6500K. *CIE D65* should be used in all colorimetric calculations that require representative daylight, unless there are specific reasons for using a different illuminant.

5 Luminance Specifications

5.1 Minimum-white Luminance Level Specifications

Table 5-1 lists the three kinds of minimum-white luminance level tests, each of which is designed to ensure performance levels as a proxy for various typical PC usages, and further described in the sections that follow.

Table 5-1: Minimum-white Luminance Level Specifications

Minimum-white Luminance Level Test	Description
Minimum-white Luminance – 10% Center Patch Test	Tests that the display can deliver a minimum luminance level for 10% of the screen for a long duration. This is used as a proxy for long-term static images that have a high brightness level (e.g., photo editing of an HDR image that has the sun located within the image).
Minimum-white Luminance – Full-screen Flash Test	In gaming, there are many cases in which the games author's creative intent is to stun the user (e.g., an explosion within a game). While the duration may be brief, the display must be able to drive full power across a full-**white** screen for 2 seconds. It should also be noted that many movies also contain brief scenes of exceptionally high power levels. Today, most TVs fail to deliver the original creative intent of the movie. By specifying the delivery of full power across a full-**white** screen for 2 seconds, it should be possible to deliver most gaming and movies to expected performance levels.
Minimum-white Luminance – Full-screen Long-duration Test	Although the usage is mostly applicable to laptops that are used outside, this test applies to all PC device types. This test is mostly the non-HDR usage model of processing email outside, in bright lighting. For example, although it is not being used for HDR video playback, a user that has purchased a premium HDR display will expect the display to perform better outside than a laptop that has a standard dynamic range (SDR) display. Thus, the required minimum brightness of a full-**white** screen under long duration is defined.

In the two cases above where "long duration" is defined, the intent and expectation is that this could be an all-day usage scenario, and that the display must be designed to not only meet these specifications, but also work after being delivered to a user who may apply these types of uses for many hours a day. To save time while testing, however, the test is applied for only 30 minutes as a proxy for "all day" as a steady state for power delivery, and thermal impact will be achieved within those 30 minutes.

Note: *The code values mentioned throughout this section are the EOTF SMPTE ST 2084 lookup values. See Appendix A for a complete list of code values as they relate to luminance levels. For ease of reference, the values in this section are hyperlinked to the lookup table values listed in Appendix A.*

Microsoft Windows Note: *When using the Windows test tool, if an EOTF* ***SMPTE ST 2084*** *code value is higher than the maximum luminance level reported by DisplayID (or legacy E-EDID or EDID), the test tool will tone map the higher-than-maximum luminance levels to that of the display's maximum reported luminance. Specifically, for all references in this section to tests with an EOTF code value of 1023 (representing 10,000cd/m^2), when testing a 600cd/m^2 display, the test tool would tone map these EOTF code values down from 1023 to 712 (corresponding to a luminance level of 600cd/m^2).*

5.1.1 Minimum-white Luminance – 10% Center Patch Test

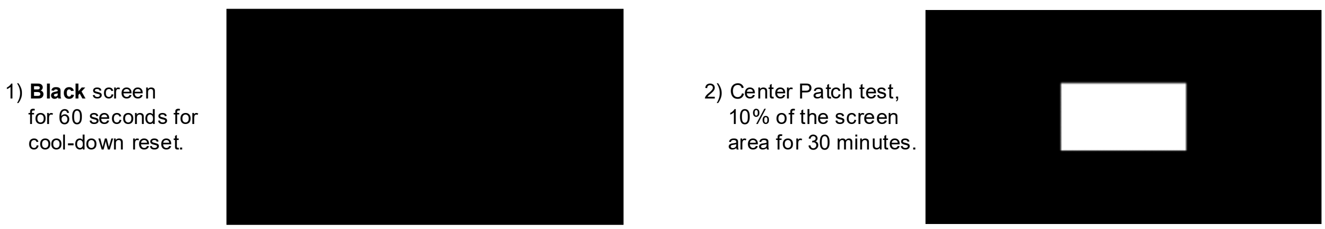

Figure 5-1: 10% Center Patch Test Sequence

- **Black** video signal is provided for 60 seconds, code value 0. Actual backlight power would thus be determined by scaler/TCON/GPU.
- Bright **white**, code value 1023. Center Patch test is assumed to reach "steady state," from a power delivery and thermal perspective, within 30 minutes. Thus, there is no need to repeat the test more than once.
- Luminance is measured at the screen's center once per minute for 30 measurements, over 30 minutes, using the same panel. The first measurement should be obtained within 5 seconds of when the **white** box begins to display.
- All 30 measurements must be measured at a level that is higher than the Minimum Required Luminance specified in Table 5-2.

Table 5-2: 10% Center Patch Test Performance Requirements

DisplayHDR Performance Tier	Minimum Luminance Level (cd/m^2)
400	400
600	600
1000	1000

- Luminance delta between the highest and lowest of the 30 measurements must be less than 10%. The highest measurement divided by the lowest measurement must have a ratio less than 1.1:1.

5.1.2 Minimum-white Luminance – Full-screen Flash Test

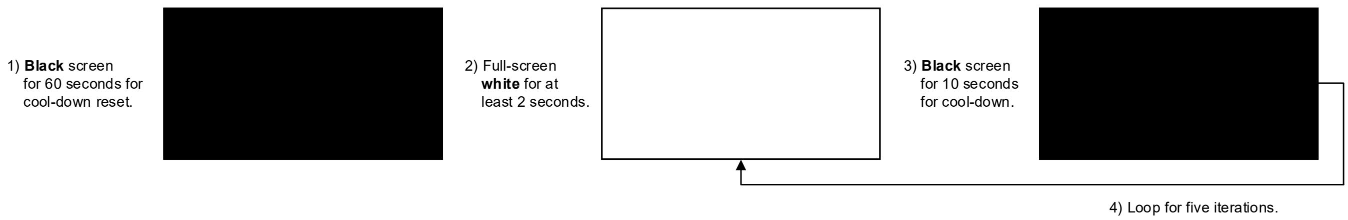

Figure 5-2: Full-screen Flash Sequence

- **Black** video signal is provided for 60 seconds, code value 0. Actual backlight power would thus be determined by scaler/TCON/GPU.
- Full-screen **white**, code value 1023, displays for 2 seconds.

  If your measuring tools are unable to respond within 2 seconds, you can display full-screen **white** for a length of time that is sufficient for your tools to respond; however, that makes the test much more difficult from a power delivery and thermal perspective, so is not required as part of this Specification.
- Luminance is measured at the screen's center once per iteration, for five iterations on the same panel.
- All five measurements must be measured at a level that is higher than the Minimum Required Luminance specified in Table 5-2.

Table 5-3: Full-screen Flash Test Performance Requirements

DisplayHDR Performance Tier	Minimum Luminance Level (cd/m^2)
400	400
600	600
1000	1000

- Due to the inability to reliably ensure that user tools are capable of measuring at the same point during the 2 seconds, this Specification does not define requirements with respect to luminance variance between the five measurements.

5.1.3 Minimum-white Luminance – Full-screen Long-duration Test

Figure 5-3: Full-screen Long-duration Sequence

- **Black** video signal is provided for 60 seconds, code value 0. Actual backlight power would thus be determined by scaler/TCON/GPU.
- Full-screen long-duration sequence displays a full screen, code value 1023. This is expected to briefly run at maximum luminance, become either power or thermally limited, and to progressively drop the luminance level.
- Luminance is measured at the screen's center once per minute for 30 measurements, using the same panel. The first measurement should be obtained within 5 seconds of when the **white** box begins to display.
- All 30 measurements must be measured at a level that is higher than the Minimum Required Luminance specified in Table 5-4.

Table 5-4: Full-screen Long Duration Performance Requirements

DisplayHDR Performance Tier	Minimum Luminance Level (cd/m^2)
400	320
600	350
1000	600

- Display brightness is expected to decline during the 30-minute test; therefore, this Specification does not define requirements with respect to luminance-level delta.

5.2 Maximum Black-level Test Specifications

Table 5-5 lists the two kinds of **black**-level tests, each of which tests for different display performance features. Both are described in the sections that follow.

Table 5-5: Maximum Black-level Test Specifications

Test	Description
Corner Box	Uses a **black** screen, code value 0, with **white** corners. Corners are not full **white** (i.e., code value 1023), and are specified and different for each DisplayHDR performance tier. The single measurement for this test is the **black** level at the screen's center. This is used as a nominal contrast comparison versus the **white** corners.
Tunnel	Ensures that either the native panel contrast ratio is at least 4000:1, –or– that local or global dimming has been implemented.

5.2.1 Corner Box Test – Black-level Test

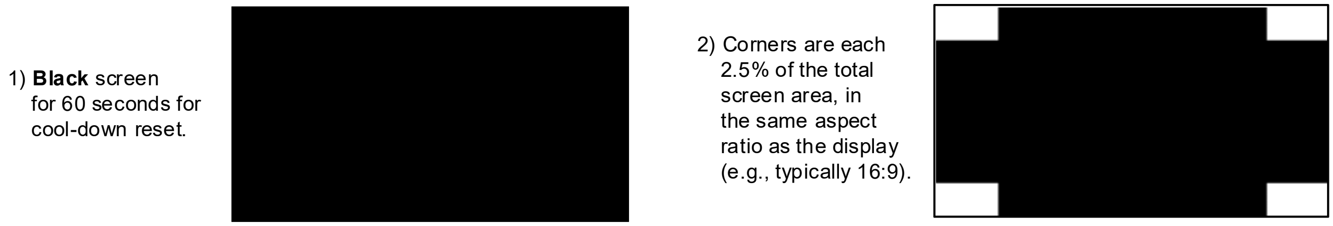

Figure 5-4: Corner Box Test – Black-level Test Sequence

- **Black** video signal is provided for 60 seconds, code value 0. Actual backlight power would thus be determined by scaler/TCON/GPU.
- **White** corners, each 2.5% of the total screen area, match the screen's aspect ratio (e.g., typically 16:9). The **white** level of the corners are specified in Table 5-6.

Table 5-6: Corner Box Test File and Maximum Luminance Requirements[a]

DisplayHDR Performance Tier	Video Signal Corner Box Luminance Level (cd/m^2)	Corner (Full Range) Code Value	MaxCLL (Full Range) Code Value	Screen Center, Maximum Luminance Level (cd/m^2)
400	400	668	668	0.40
600	600	712	712	0.10
1000	600	712	712	0.05

a. *Listed values are code values for systems with DisplayID (or legacy EDID+CTA) values indicating a Maximum Luminance of 400, 600, or 1000cd/m^2.*

*For displays with a Maximum Luminance between 400 and 600cd/m^2, the code value used for the corner box **white** would match the corresponding EOTF SMPTE ST 2084 code value for the stated Maximum Luminance value. Thus, the EOTF SMPTE ST 2084 code values would range from 668 to 712. For Maximum Luminance of 600cd/m^2 or higher, a fixed code value of 712 is used for the corner box **white**.*

- Luminance is measured only at the screen's center. The measurement should be obtained within 5 seconds of when the corner boxes begin to display.
- Luminance levels at the screen corners is not measured:
  - Stated luminance levels at the screen corners is that of the video signal from the GPU to the HDR processing unit.
  - Actual screen corner output is not measured. This test measures only the **black** level at the screen's center.

5.2.2 Tunnel Test – Black-level Test

1) **Black** screen for 60 seconds for cool-down reset.

2) Thirty-two steps from code value 515 at the edges, down to **black** in the screen's center.

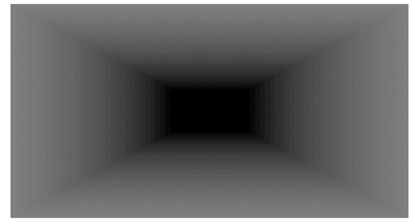

Figure 5-5: Tunnel Test – Black-level Test Sequence

- **Black** video signal is provided for 60 seconds, code value 0. Actual backlight power would thus be determined by scaler/TCON/GPU.
- Uses *IDMS v1.03* Image-Signal-Black chart with 32 steps, from code value full range 515 (approximately 95cd/m^2) down to **black**.
- Luminance is measured at the screen's center. The measurement should be obtained within 5 seconds of when the tunnel begin to display.

Table 5-7 lists the maximum permitted luminance at the screen's center for each performance tier.

Table 5-7: Tunnel Test Performance Requirements

DisplayHDR Performance Tier	Maximum Luminance Level (cd/m^2)
400	0.10
600	0.10
1000	0.10

Note: *Figure 5-5 and the luminance levels (**black**) listed in Table 5-7 demonstrate the image that is sent from the GPU, as well as the image that should be the display's final output. However, because of local or global dimming, the internal process may be significantly different.*

5.2.2.1 Global Dimming – Simplified Principals

As previously stated in Section 4.1, the local or global dimming calculation of the backlight and its corresponding transparency adjustment must be performed in the scaler or TCON for a monitor. In laptops, which do not have a scaler present, this calculation can usually be done in the GPU or TCON.

For simplicity, to aid in explaining global dimming, this sub-section describes a model in which the GPU sends HDR10 data to a monitor in which the scaler performs the histogram analysis and transparency adjustment.

The GPU sends the gray-tone tunnel image to the scaler, as illustrated in Figure 5-6. The scaler is then expected to apply global dimming.

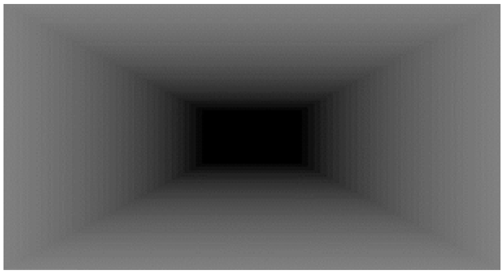

Figure 5-6: Tunnel Test – Original Image Sent from GPU

A simple example of global dimming is that the process will detect that the brightest pixel is only code value 515 (approximately 95cd/m^2). Assuming that the panel is a 400cd/m^2 panel, only a 24% power level is needed to drive 95cd/m^2, as illustrated in Figure 5-7.

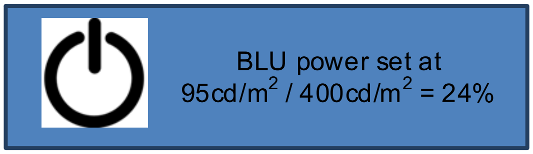

Figure 5-7: Tunnel Test – BLU Power Level Adjusted by Local/Global Dimming

However, the process also requires the scaler (for monitors) or TCON/GPU (for laptops) to increase the image's transparency to accommodate for the lower backlight. Thus, on a DisplayHDR-400 display, with this particular source image (which has a maximum luminance level of code value 515), the image's transparency will be increased by 400/96 = 4.167. The image sent from the scaler to the TCON to the panel (in the case of monitors), –or– from the TCON/GPU to the panel (in the case of All-in-Ones and laptops), will then range from Full **White** at the screen's edge, and to **Black** at the screen's center, as illustrated in Figure 5-8.

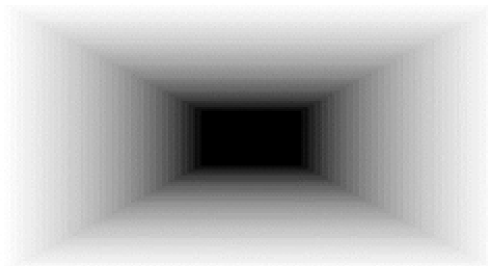

Figure 5-8: Tunnel Test – After Histogram Analysis, Image Transparency Is Adjusted to Compensate for Backlight Power Modification, and then Image Is Sent to the Panel

Combining this now Full **White** to **Black** image along with the 24% BLU power will result in an image that is approximately 95cd/m^2 at the edge, and with improved **black** levels in the middle – targeting 0.10cd/m^2, as illustrated in Figure 5-9.

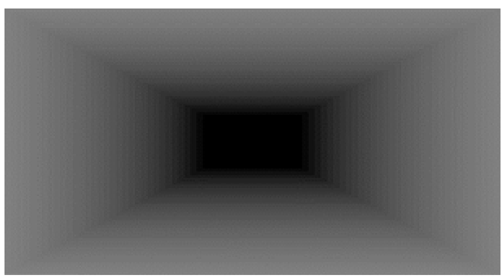

Figure 5-9: Tunnel Test – Combining BLU Power and Transparency – End Result Matches the Original GPU Output

Note: *Due to typical/common edge luminance loss, the measured brightness at the screen's edges may be less than 95cd/m^2; however, testing is not performed for 95cd/m^2. This is merely the input video signal.*

6 Color Gamut Specifications

All specifications are stated in *CIE 1976* u', v' format (see Table 6-1) because this provides for a perceptually more-linear color space than *CIE 1931* (x, y) format.

All specifications defined within this section also speak to actual coverage as a percentage of the specified color gamut, and not merely a proportional adjacent color gamut area.

Table 6-1: Color Gamut Requirements

<table>
<tr><th>DisplayHDR Performance Tier</th><th colspan="2">ITU-R BT.709 Coverage (CIE 1976 u', v' Format)</th><th colspan="2">DCI-P3 D65[a] Coverage (CIE 1976 u', v' Format)</th></tr>
<tr><td>400</td><td>95%</td><td rowspan="3">Minimum</td><td colspan="2">Not specified</td></tr>
<tr><td>600</td><td>99%</td><td>90%</td><td rowspan="2">Minimum</td></tr>
<tr><td>1000</td><td>99%</td><td>90%</td></tr>
</table>

a. Defined in SMPTE RP 431-2.

Testing for color gamut will be performed using three separate tests, each full-screen images of **Red**, **Green**, and **Blue**, as illustrated in Figure 6-1.

Figure 6-1: RGB Color Gamut Test

- RGB luminance levels are tested at a **white** level-equivalent illumination of $300cd/m^2$. Specifically, this means that if all three color components were being simultaneously illuminated, the color would be **white**, and the illumination level would be $300cd/m^2$. Thus, for any of the individual R, G, and B tests, the single color illumination level will be significantly less than $300cd/m^2$.
- **Red**, **Green**, and **Blue** full-screen images will be the *ITU-R BT.2020* color primaries. This is the color definition of the test values within the test application.
- Windows test application will clip the original images to the display's maximum color gamut, as stated in the display's DisplayID (or legacy E-EDID or EDID).
- *CIE 1976* u', v' measurement values for **Red**, **Green**, and **Blue** shall be obtained by colorimeter from the screen's center.

In Figure 6-2, the **black** line illustrates the DCI-P3 D65 (*SMPTE RP 431-2*) gamut, and the **yellow** line is an illustrative example of a potential screen's gamut. The example illustrates a screen with good, but skewed, **green** coverage, and relatively poor **red** and **blue** coverage. In this particular case, Figure 6-2 illustrates a panel that may have been optimized for *Adobe RGB*, which yields more **green** than DCI-P3 D65, but less **red** and **blue**.

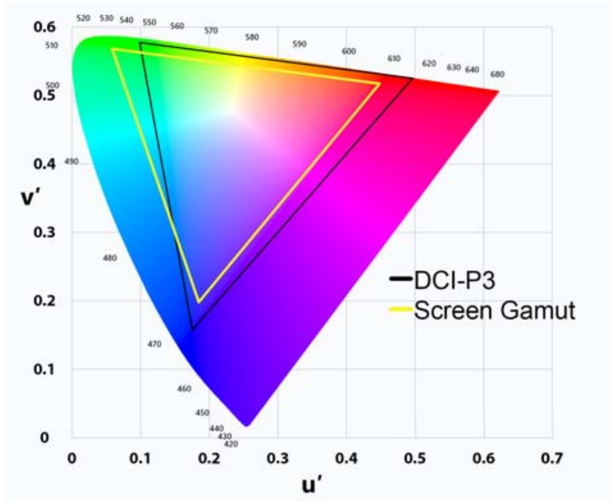

Figure 6-2: Comparison between Target DCI-P3 D65 Gamut and Example Screen's Gamut

In Figure 6-3, the **black** triangle represents the full area of the DCI-P3 D65 color gamut. In this example, DCI-P3 D65 is the target gamut, and the area of this triangle is used when comparing the screen's gamut that lies within the target compared to the area of the target gamut.

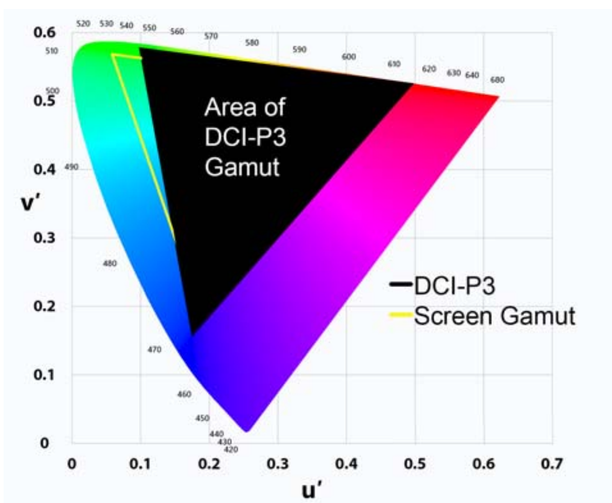

Figure 6-3: Gamut Area Represented by DCI-P3 D65 Color Gamut (Shown in Black)

In Figure 6-4, the **white** polygon represents the area of the example screen's gamut that is contained **within** the target gamut (i.e., DCI-P3 D65 in the figure). Note that much of the extended **green** area beyond that of DCI-P3 D65 is excluded from the gamut coverage area calculation because only the screen's gamut within the target gamut is included.

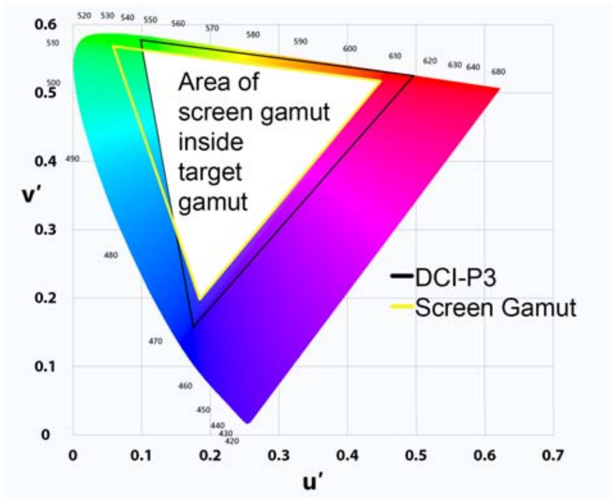

Figure 6-4: Example of Screen's Gamut Contained within Target Gamut (Shown in White)

In Figure 6-5, the relative size of the **white** polygon, which represents the target screen's gamut area that is within DCI-P3 D65, compared to the size of the **black** triangle, the full DCI-P3 D65 gamut area, is the percentage of coverage that is used by this Specification.

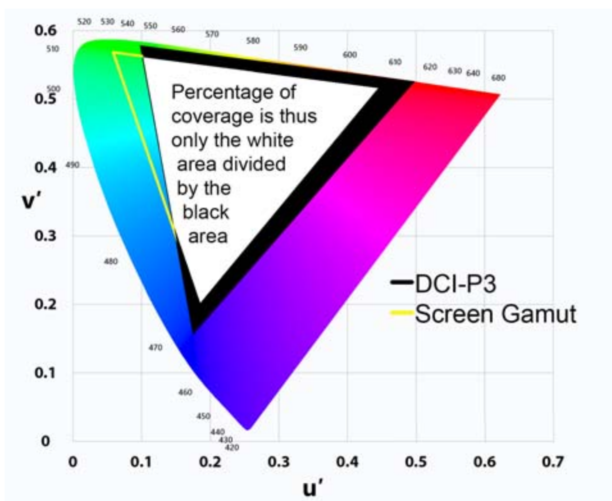

Figure 6-5: Example of Included Gamut (Shown in White) Ratio Compared to Target Gamut (Shown in Black)

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7 Bit Depth

7.1 Bit-depth Specification

Table 7-1 lists the minimum requirements that are necessary to ensure a minimum level of quality for both video processing and final video output. Internal processing in the scaler, GPU, TCON, or alternative chip is intentionally undefined. Vendors are recommended to select a sufficiently high bit depth to prevent visual banding.

Table 7-1: Minimum Bit Depth Requirements

Minimum Requirement	Description	DisplayHDR Performance Tier		
		400	600	1000
10-bit video signal, per channel	Required of HDR10, and is required as the input video signal to the local or global dimming processing unit. Depending on the system design, this may be the scaler, GPU, TCON, or alternative chip; however, the requirement is simply that 10-bit input is required of the unit that is calculating the histogram and corresponding video transparency.	✔	✔	✔
Temporal or spatial dithering	Ideally the display pipeline can operate at true 10-bit throughout the entire pipeline; however, for cost saving, this tier permits conversion down to a minimum of 8-bit, but not 6b + 2b FRC. The requirement is that the video data is maintained at a minimum of 8 bits through the scaler (if present), TCON, and driver IC.	✔		
	Ideally, the display pipeline can operate at true 10-bit throughout the entire pipeline; however, for cost saving, these tiers permit simulated 10-bit using a minimum of 8-bit plus dithering, typically referred to as "8b + 2b FRC," which simulates an additional two bits of resolution within the display pipeline. Typically, the 8b + 2b FRC will be implemented in the TCON for display pipelines that do not have a scaler, or the dithering could be done by the GPU outputting 8 bits to the TCON. However, for display pipelines that have a scaler, 8b + 2b FRC will typically be implemented in the scaler; the TCON and driver IC could operate at 8 bits.		✔	✔
Minimum 8-bit digital-to-analog conversion	The driver IC, which is responsible for converting the digital video signal to an analog voltage to drive the liquid crystal, is required to operate at a minimum of 8-bit resolution, with 256 discrete values, represented at sufficient voltage accuracy to record each unique value.	✔	✔	✔
Backlight control	To eliminate checkerboard patterning that may occur on segmented local dimming panels, backlight control needs be driven to an 8-bit accuracy level, but does not necessarily need to implement all 256 potential levels of dimming. This high level of backlight power control accuracy is **not** required for panels without segmented backlights.	✔	✔	✔

7.2 Bit-depth Testing

Bit-depth testing does **not** use a colorimeter. Rather, the testing is performed by the user observing test patterns as they appear on the screen.

7.2.1 Simulated Bit-depth Test

This test enables a user to distinguish between 6-, 8-, and 10-bit depths. A static image with five gradient ramp bars from left to right (see Figure 7-1) enables a user to identify the screen's bit-depth performance level.

Figure 7-1: Gradient Ramp Bars to Illustrate Simulated Bit Depth

Note: *The screen capture shown in Figure 7-1 has been brightened for illustrative purposes to make it easier to see the gradient steps in this Specification. The actual image in the test tool uses darker gray tones.*

The static image is structured from top to bottom with the following ramp bars:

- 6-bit quantization
- Display-native
- 8-bit quantization
- Display-native
- 10-bit quantization

For displays that use dithering, it is anticipated that the user should be able to identify "shimmer" and movement that closely, but not identically, matches the true bit-depth level-stepped ramp bars.

8 Rise-time Specifications

8.1 Explaining the User Need for Rise-time Specifications

It is important for displays that include local or global dimming to be able to quickly respond to changes in brightness. The Rise-time specification provides tests that ensure a minimum level of performance with regard to display responsiveness to changes of brightness from full OFF to full ON.

Intentional hysteresis, and thus delay, may be introduced to the speed at which the BLU will change brightness level to eliminate visible flicker. It is assumed that this will typically be the largest contributor to Rise-time delay.

Table 8-1 describes two simple usage scenarios that highlight the need for a quick rise-time.

Table 8-1: Rise-time Usage Scenarios

Scenario	Description
Local dimming panel, **black** desktop background, mouse pointer being moved in a large circle	The screen is broken into multiple 2D local dimming segments that are not illuminated until the mouse pointer moves into the zone, and then the zone takes a long time to illuminate that the mouse pointer has already left that zone. In this scenario, only the mouse pointer, while circling around the screen, is illuminated by light leakage from adjacent zones. In a well-baffled screen, this could cause the mouse pointer to entirely disappear.
Movie with fireworks at night in an otherwise clear **black** sky	The fireworks may enter the scene and quickly explode to full luminance level, and then fade so quickly afterward that the backlight never reaches full luminance level before the fireworks are gone. The sparkle and benefit of HDR fireworks is thus detrimentally affected and the benefit of HDR is lost. In fact, in a worst-case scenario, HDR fireworks could look worse on an HDR display than on an SDR display.

8.2 Rise-time Definition

For the purposes of this Specification, “rise time” is the length of time that the display takes to transition from **black** to **white**. More specifically, it is the length of time that the display takes to transition from minimum luminance to the required 10% center patch peak luminance that is specified for the panel (i.e., 400, 600, or 1000cd/m^2).

There are multiple contributors to the rise-time latency – processing by the scaler, GPU, TCON, LED power driver ramp, and LED warm-up time. However, the largest contributor of rise-time latency is usually any algorithmic application of hysteresis, which is typically used for reducing display flicker.

Because the flicker-reduction algorithm and consequential hysteresis is expected to be a frame-based algorithm, the rise-time test requirement is defined as a maximum number of frames, rather than as a fixed-time duration.

Figure 8-1 illustrates the duration, in frames, that are counted as "rise time":

- **Red line** – Shows the GPU signal transitioning from **black** to **white** on the fourth video frame within Figure 8-1.
- **Green line** – Shows a two-frame processing delay (referred to as "display latency" (DL)). The actual latency is not of consideration for this test; however, it is included in Figure 8-1 to clearly distinguish between display latency and rise time. Rise time is measured as the time from when the **green** line starts to transition from **black** to **white**, and ends when it has achieved the panel's maximum luminance. In Figure 8-1, the rise time (RT) is 4.5 frames.

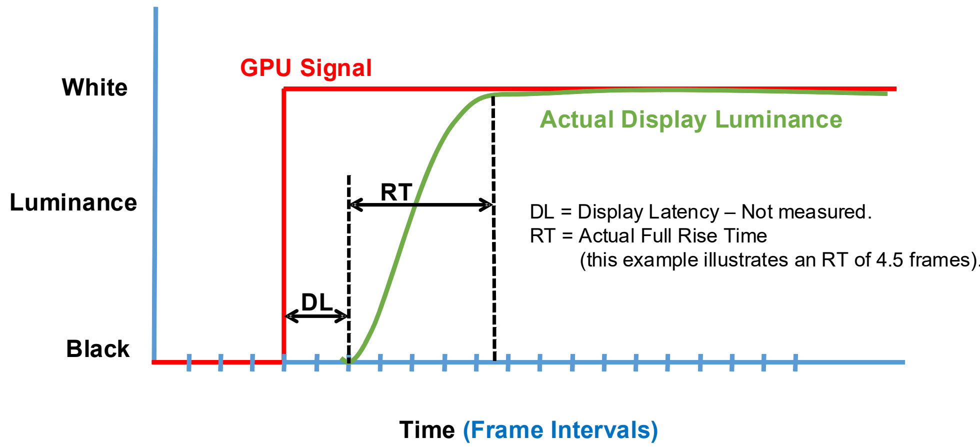

Figure 8-1: Example Actual Full Rise-time Duration

Although Figure 8-1 illustrates the full duration of the actual rise time, there are complexities with determining exactly where the signal starts rising from 0, and when the signal finally achieves 100%. Some backlight designs use a strobing/pulsing illumination, and there may be long tails getting to 100% that are not visibly noticeable, but would significantly change the rise-time measurement results. Therefore, the industry standard method for measuring rise time is to measure from the 10 to 90% luminance levels, and consider that the measured rise time. This Specification uses this methodology, and defines the measured rise time as illustrated in Figure 8-2.

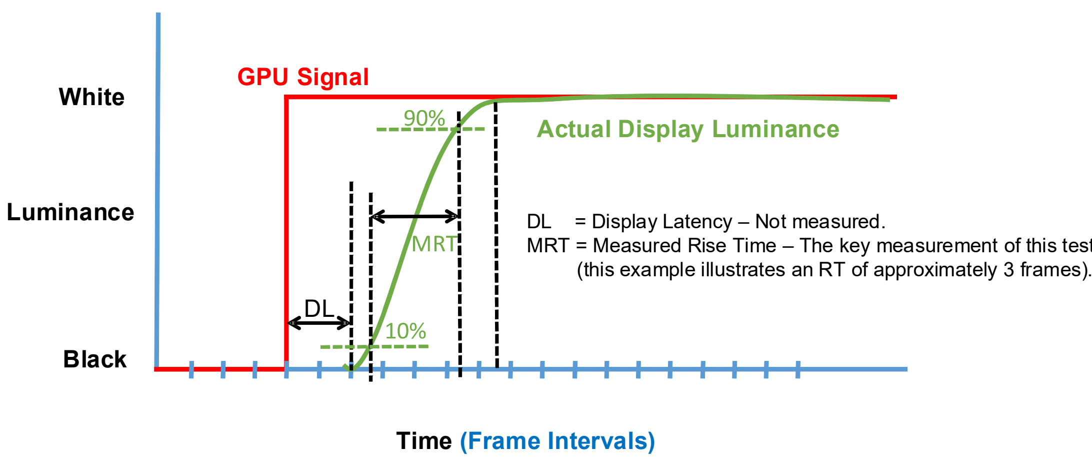

Figure 8-2: Measured Rise-time Illustration

8.3 Rise-time Requirement

The measured rise time (i.e., time from 10 to 90%) should be a maximum of 8 frames for all frame rates that the display supports.

Testing must be performed at 60Hz, thereby requiring that the maximum rise time at 60Hz display refresh shall be a maximum of 8 frames, and thus a maximum of 133ms.

Table 8-2: Examples of Maximum Rise Times for a Sampling of Panel Refresh Rates

Display Refresh Rate (Hz)	Maximum Number of Frames for Rise from Black to Maximum Luminance		Time (ms)	
24	8	Recommended	333	Recommended
60	8	**Required**	133	**Required**
144	8	Recommended	56	Recommended
200	8	Recommended	40	Recommended

8.4 Measuring Rise Time

This section discusses the highly accurate and official method for rise-time measurement, and an **optional** (non-binding) approximation test that can be used with low-cost hardware.

8.4.1 High-precision Rise-time Measurement

To obtain a high-precision rise-time measurement, a photo diode, or photosensor amplifier (e.g., Hamamatsu® C6386-01), can be used by sampling the voltage at 1-ms intervals. By sampling the voltage and then pre-testing the voltage for **10% (dark gray)** and **90% (light gray)**, an oscilloscope can be used to determine how many milliseconds the rise time takes to achieve the known voltage swing from 10 to 90% luminance levels.

8.4.2 Low-cost Rise-time Measurement (Low Accuracy)

This section defines an **optional**, non-binding, low-cost test that can be used to approximate rise-time measurement.

The user should record the screen with a video camera that is set to the same frame rate as the screen (e.g., 60Hz), along with a manually adjustable video shutter speed that matches the frame rate's reciprocal (i.e., 1/60th second for 60Hz). (Using cinematographic terms this is referred to as a "360-degree shutter.")

Example hardware includes the GoPro® HERO5, and most consumer camcorders that provide options for manual shutter-speed settings and recording at 60Hz. It is important that the shutter, aperture, and ISO speed be manually set and not in Auto mode to thus defeat any auto-exposure image processing that would invalidate the test. The user can record the display illumination, and then step through the recorded video to observe how many frames it takes to rise from **black** to full **white**. The user will need to approximate which frame appears to reach "maximum luminance" so that there is some variability.

Furthermore, it must be noted that it will be nearly impossible for the consumer to visually determine the 10 and 90% points; thus, the rise time that this test will yield is likely to be from the 0 to 100% points, which will of course take longer than the 10 to 90% range that is the official definition of this Specification. This low-cost test can be used only as an approximation and **cannot** be used to determine whether a panel meets or does not meet compliance specifications.

9 Undefined Features

Table 9-1 lists features that are explicitly excluded from this Specification, which enables manufacturers and designers to have complete freedom of choice in each of these areas.

Table 9-1: Undefined Features

Undefined Feature	Reason for Not Defining
Resolution	Recognizing the vast range of how PCs are used, the VESA Display Performance Metrics Task Group acknowledges that resolution is an entirely independent metric from HDR performance, and has therefore chosen to not include resolution as part of this Specification.
Aspect Ratio	The PC ecosystem continues to show an impressive range of aspect ratios, with widescreen monitors used in vertical orientation showing 9x16, all the way to ultra-wide horizontal displays showing up to 32x9. Thus, the task group saw no benefit in including aspect ratios as part of this Specification.
Audio	Unrelated, so therefore undefined.

A EOTF *SMPTE ST 2084* (Perceptual Quantizer) to Luminance Level Lookup Table (Informative)

Table A-1: EOTF *SMPTE ST 2084* to Luminance Level Lookup Table

EOTF *SMPTE ST 2084* 10-bit Perceptual Quantizer Code Value	Luminance Level[a] (cd/m^2)
0	0
153	1.0
193	2.0
206	2.5
254	5.0
307	10.0
365	20
429	40
497	80
515	95
569	160
592	200
636	300
643	320
653	350
668	400
712	600
769	1000
846	2000
923	4000
1023	10000

a. *Also referred to as "intensity."*

B Test File Specification (Informative)

This appendix defines the test image specifications. In most cases, the automated VESA DPM Test Tool can be used because it includes the complete test sequence. However, if it is necessary to test the display using a fully automated manufacturing process, signal generator, and/or other non-Windows 10 signal source, the test files can be created using the specifications defined in this appendix.

The DPM Test Tool provides two versions of several of the tests. Specifically, there are two versions of each of the three **white** luminance tests and the color gamut test (Tests B.1, B.2, B.3, and B.6, respectively). In each case, the two versions of the test differ, as follows:

- DisplayID (or legacy EDID) values are used to tone-map and gamut adjust the tests
- Original test images and test metadata are passed through to the display for the display to perform the tone-mapping function

In each case, the test tool indicates its output results, as follows:

- Tests B.1a, B.2a, B.3a, and B.6a use the DisplayID (or legacy EDID) values
- Tests B.1b, B.2b, B.3b, and B.6b use the values specified in this appendix

In cases where two versions of the test are provided, the better of the two results is expected to be used when determining the display's performance level**.**

B.1 Minimum-white Luminance – 10% Center Patch Test

Table B-1: Minimum-white Luminance – 10% Center Patch Test Specifications

Specification	Description
Image	• **Black** full-screen image, EOTF *SMPTE ST 2084*, code value of 0. • **White** rectangular box, EOTF *SMPTE ST 2084*, code value of 1023, that matches the aspect ratio of the full screen, comprising 10% of the screen's area, centered and placed on top of the **black** background. The rectangular box is thus 31.62% of the screen's pixel height, and 31.62% of the screen's pixel width.
Metadata	• MaxCLL 10000cd/m^2 • MasteringLuminance 10000cd/m^2 • MaxFALL[a] 1000cd/m^2 • Chromaticity Should be maximum *ITU-R BT.2020* values

a. *MaxFALL is only 1000cd/m^2 because the* **white** *box is only 10% of the screen.*

B.2 Minimum-white Luminance – Full-screen Flash Test

Table B-2: Minimum-white Luminance – Full-screen Flash Test Specifications

Specification	Description
Image	• **White** full-screen image, EOTF *SMPTE ST 2084*, code value of 1023
Metadata	• MaxCLL 10000cd/m^2 • MasteringLuminance 10000cd/m^2 • MaxFALL[a] 10000cd/m^2 • Chromaticity Should be maximum *ITU-R BT.2020* values

a. *MaxFALL is now 10000cd/m^2 because the* **white** *box is 100% of the screen.*

B.3 Minimum-white Luminance – Full-screen Long-duration Test

This test uses the same image as for the Full-screen Flash Test (see Section B.2).

B.4 Corner Box Test – Black-level Test

Table B-3: Corner Box Test – Black-level Test Specifications

Specification	Description
Image	• **Black** full-screen image, EOTF *SMPTE ST 2084*, code value of 0. • Four **white** rectangular boxes, EOTF *SMPTE ST 2084*, code value of 712, that each match the aspect ratio of the full screen, each comprising 2.5% of the screen's area (10% total). The four **white** rectangular boxes are "snapped" to the four corners of the **black** background, with two adjacent sides of the **white** boxes touching two of the **black** background's edges. Each **white** rectangular box is thus 15.81% of the screen's pixel height, and 15.81% of the screen's pixel width.
Metadata	• MaxCLL 600cd/m^2 • MasteringLuminance 600cd/m^2 • MaxFALL[a] 60cd/m^2 • Chromaticity Should be maximum *ITU-R BT.2020* values

a. *MaxFALL is only 60cd/m^2 because the four corners at 600cd/m^2 total only 10% of the screen.*

B.5 Tunnel Test – Black-level Test

Table B-4: Tunnel Test – Black-level Test Specifications

Specification	Description
Image	• **Black** rectangle, EOTF *SMPTE ST 2084*, code value of 0, centered in the image, exactly 20% of screen pixel height, and 20% of screen pixel width (i.e., 4% of the screen area). • Surrounding the **black** centered box are 32 concentric rectangles, matching the screen's aspect ratio, increasing in luminance from the center to the edge in 32 equal steps of increasing EOTF *SMPTE ST 2084* code values, per Table B-5. Each of the 32 rectangles increase in width and height by an equal amount. • Left and right visible width of each of the 32 concentric rectangles is 1.25% of the screen's pixel width. The top and bottom visible widths of each of the 32 concentric rectangles is 1.25% of the screen's pixel height. For example, a screen of size 3840x2160 would use a **black** box in the middle of the screen that is 768 pixels wide and 432 pixels high. Each of the 32 rectangles around it would show a left and right visible bar thickness of 48 pixels on each side, and a top and bottom bar thickness of 27 pixels each.
Metadata	• MaxCLL 96cd/m^2 • MasteringLuminance 96cd/m^2 • MaxFALL[a] 26cd/m^2 • Chromaticity Should be maximum *ITU-R BT.2020* values

a. *MaxCLL is 96cd/m^2 because the outer rectangle with EOTF SMPTE ST 2084 code value 515 is 95.5cd/m^2. However, MaxFALL is the screen luminance average, which is calculated to 25.xcd/m^2. Both MaxCLL and MaxFALL are rounded up to the next integer.*

Table B-5: EOTF *SMPTE ST 2084* Code Values for each of the Tunnel Test Steps

Step Number from Inner Box	Full Range Code Values	Step Number from Inner Box	Full Range Code Values
1	16	17	274
2	32	18	290
3	48	19	306
4	64	20	322
5	80	21	338
6	97	22	354
7	113	23	370
8	129	24	386
9	145	25	402
10	161	26	418
11	177	27	435
12	193	28	451
13	209	29	467
14	225	30	483
15	241	31	499
16	258	32	515

B.6 RGB Color Gamut Test

Table B-6: RGB Color Gamut Test Specifications

Specification	Description
Image	• Three full-screen separate image files, one each for **Red**, **Green**, and **Blue**. each set to maximum color gamut, at a luminance level of a **white** equivalent at 300cd/m^2 is used • To maximize the DCI-P3 D65 (*SMPTE RP 431-2*) color gamut from the display, the following *ITU-R BT.2020* EOTF color values are used: • **Red** (636, 0, 0) • **Green** (0, 636, 0) • **Blue** (0, 0, 636)
Metadata	• MaxCLL 300cd/m^2 • MasteringLuminance 300cd/m^2 • MaxFALL 300cd/m^2 • Chromaticity *ITU-R BT.2020* is used

B.7 Gradient Ramp Bars Used for Simulated Bit-depth Test

The Gradient Ramp Bars test is a visual inspection, showing five rows across the screen, each taking 20% of the screen's height and the screen's full width. The ramp bars are dark shadow tones, ranging from dark on the left, to moderately dark on the right. Table B-7 lists how each of the gradient ramp bars is displayed.

Table B-7: Gradient Ramp Bars Used for Simulated Bit-depth Test

Row	Description
1	Ramp bar is truncated to 6-bit precision.
2	Ramp bar uses native display capability.
3	Ramp bar is truncated to 8-bit precision.
4	Ramp bar uses native display capability (same as Row 2).
5	Ramp bar is truncated to 10-bit precision.

The image is created algorithmically, using the following logic:

1 Generate a linear gradient, from left (0.0) to right (1.0):

```
float c = normalizedPosition.x;
```

2 Pre-shape with gamma of 2.2:

```
c = pow(c,0.45454);
```

3 Focus on dark levels:

```
c = c*0.25;
```

4 Quantize first strip (top 20% of screen) to 6-bit:

```
c = trunc(c*64.0f)/64.0f;
```

5 Quantize third strip (middle 20% of screen) to 8-bit:

```
c = trunc(c*256.0f)/256.0f;
```

6 Quantize fifth strip (bottom 20% of screen) to 10-bit:

```
c = trunc(c*1024.0f)/1024.0f;
```

7 Revert back to gamma:

```
c = pow(c,2.2f);
```

8 Replicate to all color channels to make gray:

```
Final color = {c, c, c, 1.0f};
```

B.8 Rise-time Test

This test uses the same image as for the 10% Center Patch Test (see Section B.1), switching on for 10 seconds, switching off for 10 seconds, and then looping indefinitely.

C Sample DisplayIDs (Informative)

This appendix illustrates a variety of sample DisplayIDs, with GPU processing of HDR for local panel laptop, TCON processing of HDR for a local panel laptop, and an HDR10 monitor:

- Sample C.1 illustrates an example DisplayID block for an embedded panel with a TCON that supports 8-bit input and sRGB EOTF on the interface. The panel is natively 8 bit, has a DCI-P3 D65 (*SMPTE RP 431-2*) color space, and uses Gamma 2.2. This DisplayID would be suitable for a panel in which HDR processing occurs in the GPU.
- Sample C.2 illustrates an example DisplayID block for an embedded panel with a TCON that supports both 8- and 10-bit input, sRGB EOTF, *ITU-R BT.2020*, and EOTF *SMPTE ST 2084* on the interface. The panel is natively 8 bit, has a DCI-P3 D65 color space, and uses Gamma 2.2. This DisplayID would be suitable for a panel in which HDR processing is expected to occur in the TCON.
- Sample C.3 illustrates an example DisplayID block for a monitor that supports both 8- and 10-bit input, sRGB EOTF, *ITU-R BT.2020*, and EOTF *SMPTE ST 2084* on the interface. The panel is natively 8 bit, has a DCI-P3 D65 color space, and uses Gamma 2.2. This DisplayID would be suitable for a monitor in which HDR processing is expected to occur in the scaler.

C.1 Sample DisplayID for a TCON That Supports DisplayHDR-400 with GPU HDR Processing

```
[DISPLAYID RAW DATA]
    |00|01|02|03|04|05|06|07|08|09|0A|0B|0C|0D|0E|0F|
----+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
00 |20 5f 04 00 20 00 19 12 34 56 34 12 78 56 34 12
 10 |2a 11 0d 50 43 20 48 44 52 20 53 61 6d 70 6c 65
 20 |21 00 1d 1c 0c d6 06 00 0a a0 05 80 e1 ea 51 3d
 30 |a4 b0 66 52 0f fd 34 54 00 5d 40 5e 66 36 12 78
 40 |26 00 09 02 00 00 00 00 00 01 00 00 22 00 14 5d
 50 |94 03 08 ff 09 4f 00 07 80 1f 00 9f 05 28 00 00
 60 |00 07 00 34


[DISPLAYID]
  [General Info]
  Version..................: 2
  Revision.................: 0
  Section Size.............: 95
  Product type identifier...: Desktop Productivity
  Extension Count..........: 0
  Checksum.................: 0x34

  [Datablock 0: Product Identification]
  Vendor ID................: 12-34-56
  Product Code.............: 0x1234
  Serial Number............: 0x12345678
  Week of Manufacture.......: 42
  Year of Manufacture.......: 2017
  Product ID String Size....: 13
  Product ID String ........: PC HDR Sample

  [Datablock 1: Display Parameters]
  Horizontal Image Size..............: 310.0 mm
  Vertical Image Size................: 175.0 mm
  Horizontal Pixel Count.............: 2560
  Vertical Pixel Count...............: 1440
  Scan Orientation...................: Left to Right, Top to Bottom
  Luminance Information..............: Exposed as Minimum Guaranteed
  Color Information..................: CIE 1931
  Audio Integrated Into Display.......: No
  Color 1 Chromaticity...............: X: 0.680 Y: 0.320
  Color 2 Chromaticity...............: X: 0.265 Y: 0.690
  Color 3 Chromaticity...............: X: 0.150 Y: 0.060
  White Point Chromaticity...........: X: 0.312 Y: 0.329
  Full Max Luminance.................: 320.00 CD/M^2
  10 Percent Rect Max Luminance.......: 400.00
  Min Luminance......................: 0.40 CD/M^2
  Native Color Depth.................: 8 BPC
  Device Technology..................: ACTIVE MATRIX LCD
```

```
Gamma..............................: 2.20

[Datablock 2: Display Interface Features]
            | 6-bpc | 8-bpc | 10-bpc | 12-bpc | 14-bpc | 16-bpc |
            +-------+-------+--------+--------+--------+--------+
        RGB |   N       Y       N        N        N        N
YCbCr 4:4:4 |   N       N       N        N        N        N
YCbCr 4:2:2 |  n/a      N       N        N        N        N
YCbCr 4:2:0 |  n/a      N       N        N        N        N

Minimum Pixel Rate at Which YCbCr 4:2:0 Is Supported.........: 0 MP/s

Audio at 48-kHz Supported....................................: No
Audio at 44.1-kHz Supported..................................: No
Audio at 32-kHz Supported....................................: No

sRGB Color Space and EOTF Supported..........................: Yes

[Datablock 3: Type VII Timing - Detailed]
Detailed Timing 1
 2560 x 1440 Progressive, 234.59MHz
```

C.2 Sample DisplayID for a TCON That Supports DisplayHDR-400 with HDR10 Support in the TCON

```
[DISPLAYID RAW DATA]
    |00|01|02|03|04|05|06|07|08|09|0A|0B|0C|0D|0E|0F|
----+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
00 |20 5f 04 00 20 00 19 12 34 56 34 12 78 56 34 12
 10 |2a 11 0d 50 43 20 48 44 52 20 53 61 6d 70 6c 65
 20 |21 00 1d 1c 0c d6 06 00 0a a0 05 80 e1 ea 51 3d
 30 |a4 b0 66 52 0f fd 34 54 00 5d 40 5e 66 36 12 78
 40 |26 00 09 06 00 00 00 00 00 61 00 00 22 00 14 5d
 50 |94 03 08 ff 09 4f 00 07 80 1f 00 9f 05 28 00 00
 60 |00 07 00 d0


[DISPLAYID]
  [General Info]
  Version..................: 2
  Revision.................: 0
  Section Size.............: 95
  Product type identifier...: Desktop Productivity
  Extension Count..........: 0
  Checksum.................: 0xD0

  [Datablock 0: Product Identification]
  Vendor ID................: 12-34-56
  Product Code.............: 0x1234
  Serial Number............: 0x12345678
  Week of Manufacture.......: 42
  Year of Manufacture.......: 2017
  Product ID String Size....: 13
  Product ID String ........: PC HDR Sample

  [Datablock 1: Display Parameters]
  Horizontal Image Size...............: 310.0 mm
  Vertical Image Size.................: 175.0 mm
  Horizontal Pixel Count..............: 2560
  Vertical Pixel Count................: 1440
  Scan Orientation....................: Left to Right, Top to Bottom
  Luminance Information...............: Exposed as Minimum Guaranteed
  Color Information...................: CIE 1931
  Audio Integrated Into Display.......: No
  Color 1 Chromaticity................: X: 0.680 Y: 0.320
  Color 2 Chromaticity................: X: 0.265 Y: 0.690
  Color 3 Chromaticity................: X: 0.150 Y: 0.060
  White Point Chromaticity............: X: 0.312 Y: 0.329
  Full Max Luminance..................: 320.00 CD/M^2
  10 Percent Rect Max Luminance.......: 400.00
  Min Luminance.......................: 0.40 CD/M^2
  Native Color Depth..................: 8 BPC
  Device Technology...................: ACTIVE MATRIX LCD
```

```
Gamma..............................: 2.20

[Datablock 2: Display Interface Features]
            | 6-bpc | 8-bpc | 10-bpc | 12-bpc | 14-bpc | 16-bpc |
            +-------+-------+--------+--------+--------+--------+
        RGB |   N       Y       Y        N        N        N
YCbCr 4:4:4 |   N       N       N        N        N        N
YCbCr 4:2:2 |  n/a      N       N        N        N        N
YCbCr 4:2:0 |  n/a      N       N        N        N        N

Minimum Pixel Rate at Which YCbCr 4:2:0 Is Supported.........: 0 MP/s

Audio at 48-kHz Supported....................................: No
Audio at 44.1-kHz Supported..................................: No
Audio at 32-kHz Supported....................................: No

sRGB Color Space and EOTF Supported..........................: Yes
ITU-R BT.2020 Color Space and EOTF Supported.................: Yes
ITU-R BT.2020 Color Space and SMPTE ST 2084 EOTF Supported...: Yes

[Datablock 3: Type VII Timing - Detailed]
Detailed Timing 1
 2560 x 1440 Progressive, 234.59MHz
```

C.3 Sample DisplayID for a Scaler That Supports DisplayHDR-600 with HDR10 Support in the Scaler

```
[DISPLAYID RAW DATA]
    |00|01|02|03|04|05|06|07|08|09|0A|0B|0C|0D|0E|0F|
----+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
00 |20 87 04 00 20 00 19 12 34 56 34 12 78 56 34 12
 10 |2a 11 0d 50 43 20 48 44 52 20 53 61 6d 70 6c 65
 20 |21 00 1d 50 14 b8 0b 00 0f 70 08 80 e1 ea 51 3d
 30 |a4 b0 66 52 0f fd 34 54 78 5d b0 60 66 2e 12 78
 40 |26 00 09 06 06 03 04 00 e0 61 00 00 22 00 3c 5b
 50 |af 03 08 ff 09 4f 00 07 80 1f 00 9f 05 28 00 02
 60 |00 04 00 01 23 08 88 ff 0e 9f 00 2f 80 1f 00 6f
 70 |08 3d 00 02 00 04 00 03 1d 02 08 7f 07 9f 00 2f
 80 |80 1f 00 37 04 1e 00 04 00 16 00 26


[DISPLAYID]
  [General Info]
  Version...................: 2
  Revision..................: 0
  Section Size..............: 135
  Product type identifier...: Desktop Productivity
  Extension Count...........: 0
  Checksum..................: 0x26

  [Datablock 0: Product Identification]
  Vendor ID.................: 12-34-56
  Product Code..............: 0x1234
  Serial Number.............: 0x12345678
  Week of Manufacture.......: 42
  Year of Manufacture.......: 2017
  Product ID String Size....: 13
  Product ID String ........: PC HDR Sample

  [Datablock 1: Display Parameters]
  Horizontal Image Size...............: 520.0 mm
  Vertical Image Size.................: 300.0 mm
  Horizontal Pixel Count..............: 3840
  Vertical Pixel Count................: 2160
  Scan Orientation....................: Left to Right, Top to Bottom
  Luminance Information...............: Exposed as Minimum Guaranteed
  Color Information...................: CIE 1931
  Audio Integrated Into Display.......: No
  Color 1 Chromaticity................: X: 0.680 Y: 0.320
  Color 2 Chromaticity................: X: 0.265 Y: 0.690
  Color 3 Chromaticity................: X: 0.150 Y: 0.060
  White Point Chromaticity............: X: 0.312 Y: 0.329
  Full Max Luminance..................: 350.00 CD/M^2
  10 Percent Rect Max Luminance.......: 600.00
  Min Luminance.......................: 0.10 CD/M^2
```

```
Native Color Depth..................: 8 BPC
Device Technology...................: ACTIVE MATRIX LCD
Gamma...............................: 2.20

[Datablock 2: Display Interface Features]
            | 6-bpc | 8-bpc | 10-bpc | 12-bpc | 14-bpc | 16-bpc |
            +-------+-------+--------+--------+--------+--------+
        RGB |   N       Y       Y        N        N        N
YCbCr 4:4:4 |   N       Y       Y        N        N        N
YCbCr 4:2:2 |  n/a      Y       Y        N        N        N
YCbCr 4:2:0 |  n/a      N       N        Y        N        N

Minimum Pixel Rate at Which YCbCr 4:2:0 Is Supported.........: 0 MP/s

Audio at 48-kHz Supported....................................: Yes
Audio at 44.1-kHz Supported..................................: Yes
Audio at 32-kHz Supported....................................: Yes

sRGB Color Space and EOTF Supported..........................: Yes
ITU-R BT.2020 Color Space and EOTF Supported.................: Yes
ITU-R BT.2020 Color Space and SMPTE ST 2084 EOTF Supported...: Yes

[Datablock 3: Type VII Timing - Detailed]
Detailed Timing 1
 2560 x 1440 Progressive, 241.50MHz

Detailed Timing 2
 3840 x 2160 Progressive, Preferred, 533.25MHz

Detailed Timing 3
 1920 x 1080 Progressive, 138.50MHz
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