VESA Display Standards Updates

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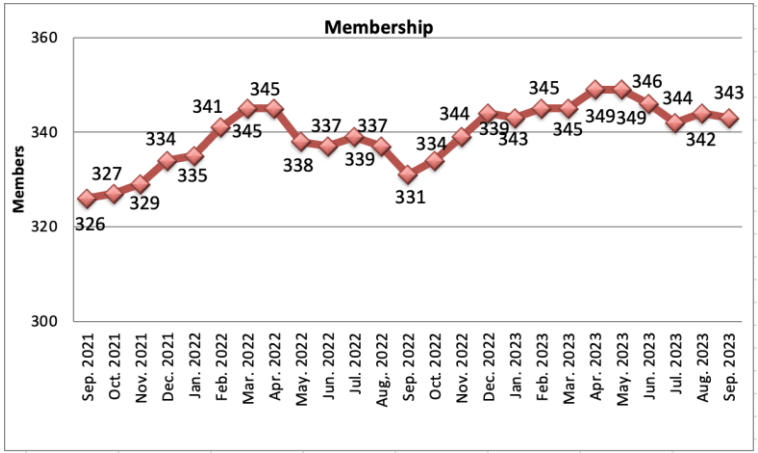
VESA Compliance Program Manager
October 10, 2023

Agenda

- VESA Overview and Standards Updates: Jim Choate
- DP Alt Mode v 2.1 Overview and Updates: Tim Wei, Ellisys
- VESA AdaptiveSync Specification Overview and Test: Do Kyun Kim, Seung Hyun Yoo, LGE
- ClearMR Specifications and Compliance Testing Overview: Dr. Yongwoo Yi, Samsung Display
- VESA Compliance Program Updates: Jim Choate
- DP v2.1 Link Layer CTS updates: Sergey Grushin, Unigraf
- Summary, Questions & Answers

About VESA

- A growing global industry alliance with more than 340 members. Strong growth in membership.

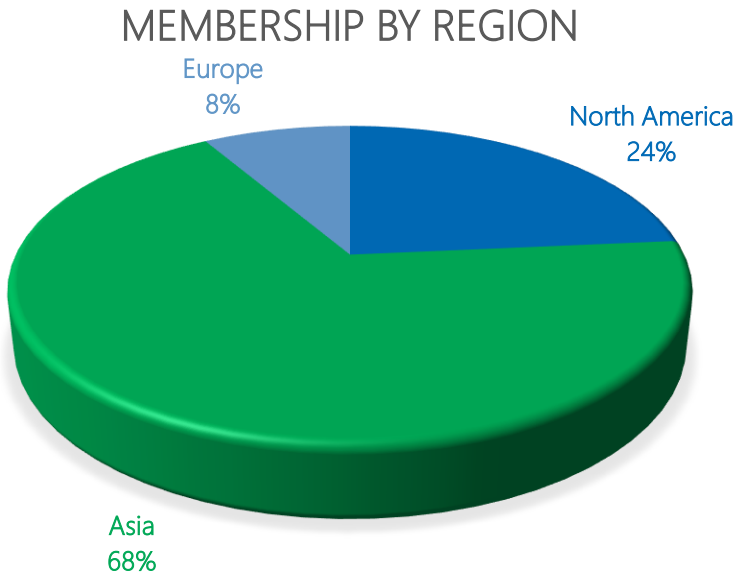


Mission to develop, promote and support ecosystem of vendors and certified interoperable products for the electronics industry.

Develops OPEN standards, contribution is open to all companies at all stages of development

VESA 2023 Membership

- Leading PC/computer, display, hardware, software, and component manufacturers worldwide
- VESA membership continues to grow the most in Asia



VESA Local Asian Support Capability

- VESA has long had a dedicated Japan Task Group with charter to promote the development of design tools and reference guides, PlugTests, educational seminars, and other activities for the benefit of VESA member companies, particularly those in Japan.
- **NEW:** VESA has added to its local support to Asia to address growing regional membership needs
- China (Mainland) and Taiwan are the fastest growing areas for VESA's membership.
- **Kellen** is VESA's Representative for all Chinese speaking areas of Asia
- This partnership will provide members with a communication option in their native language. Kellen will handle membership related activities including, new membership requests, renewals, PlugTest and event support and translation of VESA member messaging, etc.

VESA Standards Enable Many Market Segments…

Monitors, PCs and laptops

Gaming consoles and headsets

Digital signage / kiosks

Smartphones and tablets

Automotive

Digital projectors

...As Well as Many Aspects of Display Technology

Display Interfaces

- DisplayPort
- Embedded DisplayPort (eDP)
- DisplayPort Alt Mode
- DisplayPort Tunneling (USB4 and Thunderbolt)
- DP Automotive Extensions (DP AE)

Display Data Compression

- Display Stream Compression (DSC)
- VESA Display Codec for Mobile (VDC-M)

Display Metrology

- Standardized Display Performance Measurement
- VESA DisplayHDR Certification (High Dynamic Range)
- VESA ClearMR
- VESA AdaptiveSync

Display Capability Parameters

- DisplayID
- Extended Display Identification Data (EDID)
- Multi-Display Interface
- Bulk Display Protocol

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VESA

DISPLAYPORT™ 2.1

DisplayPort 2.1 Summary

- DisplayPort v2.1 was released in October 2022
- DisplayPort 2.1 brings DisplayPort into convergence with USB4 PHY specifications to ensure the highest video performance across a broad range of consumer products
- Added DP40 (up to UHBR10) and DP80 (up to UHBR20) cable specifications and certification
- Enhanced DP connectors provide highest performance with full sized DP and mDP connectors

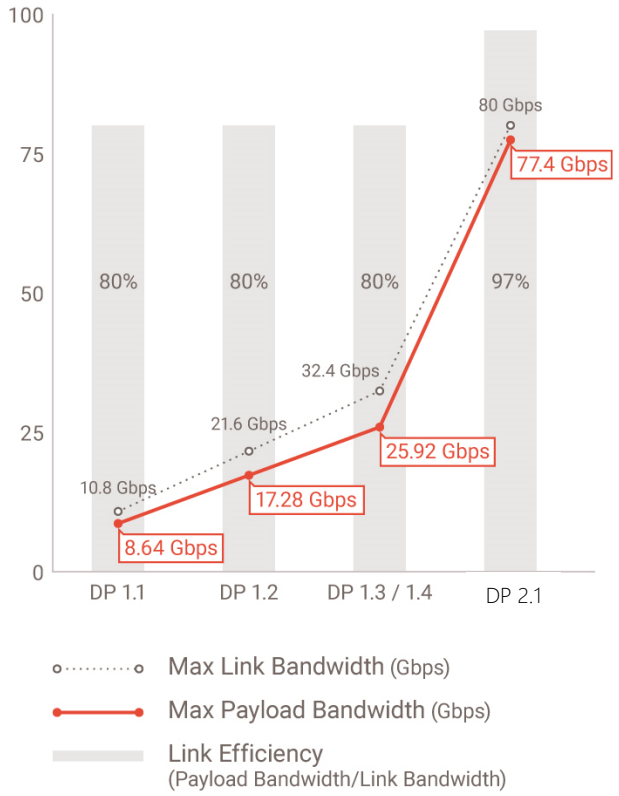
https://vesa.org/featured-articles/vesa-releases-displayport-2-1-specification/

VESA

- DisplayPort 2.1 enables up to 3X increase in video bandwidth performance
- First standard to support 8K resolution (7680 x 4320) at 60 Hz refresh rate with full-color 4:4:4 resolution, including with 30 bits per pixel (bpp) for HDR-10 support
- Beyond 8K resolutions achieved with maximum link rate to up to 20 Gbps/lane and more efficient 128b/132b channel coding

DisplayPort™

EVOLUTION OF DISPLAYPORT DATA BANDWIDTH



DisplayPort 2.1 Resolution Capability
(Single Display Examples)

Port Configuration	DisplayPort 1.4a	DisplayPort 2.1
No Compression		
4 Lanes, max link rate	5K (5120x2800)@60fps 24bpp	10K (10240x4320)@60fps 24bpp
2 Lanes, max link rate	4K (3840x2160)@60fps 24bpp	8K (7680x4320)@30fps 30bpp
With Compression (DSC)		
4 Lanes, max link rate	8K (7680x4320)@60fps 30bpp	16K (15360x8460)@60fps 30bpp
2 Lanes, max link rate	5K (5120x2800)@60fps 24bpp	10K (10240x4320)@72fps 30bpp

Notes:

- 2 Lane configuration is common for USB-C DP Alt Mode
- All above modes assume full 4:4:4 color encoding
- 30bpp is required for DisplayHDR operation

Key:

- DSC = Display Stream Compression
- fps = frames per second
- bpp = bits per pixel

Optimization for Shared Interface Use

- Numerous specification enhancements to simplify the use of DisplayPort as an ingredient in the following interface examples:
  - The USB-C connector, using the DisplayPort Alt Mode (DP Alt Mode)
  - VESA Embedded DisplayPort Standard (eDP)
  - ThunderBolt
  - USB4
  - Wireless interfaces

DP 40/DP 80 Cable Specification and Certification

- Developed as part of DP 2.1 specification update
- DP40 and DP80 Certified cables provide added assurance of smooth operation and full compliance at the UHBR data rates
- Dozens of DP40 and DP80 cables have been certified since launch of program

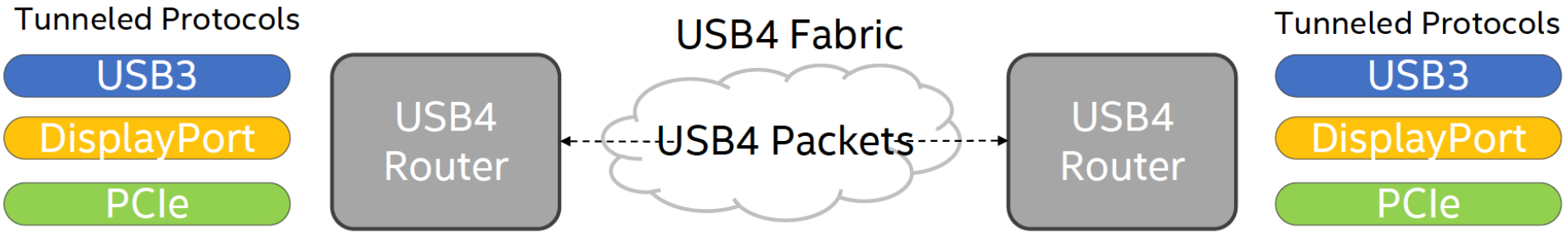
VESA Technology Development Areas

VESA technology development

- VESA members are collaborating on several key technology areas
- AR/VR Task Group
  - Specification is released. Work started on CTS
  - Focused on creating solutions roadmap to meet performance, power and implementation requirements for future AR/VR needs
- DP Automotive Extension Task Group
  - Working with automotive industry to address needs for high-resolution performance in this market segment
  - Working on DP AE specification and CTS
- Bulk Display Protocol
  - BDP specification and CTS nearing release
- Display Performance Metrics Task Group
  - DisplayHDR, ClearMR, AdaptiveSync

USB4 Overview

- Runs over USB Type-C® interconnect
- Tunnels USB3, PCIe and DP protocols
- Signaling rates of 10 or 20 Gbps (10 to 40Gbps aggregated b/w)
- Helps converge USB Type-C connector ecosystem to minimize end-user confusion



DP Alt Mode v 2.1 Overview and Updates

Presented by Tim Wei, Senior Application Engineer, Ellisys

DP Alt Mode v 2.1 Overview and Updates

Tim Wei *– Senior Application Engineer, Ellisys*

VESA Seoul Workshop

October 10, 2023

USB Enabling Connections™

USB Test and Analysis Solutions

USB Explorer™ 350

Multi-function USB Type-C®, USB 3.2, and Power Delivery Protocol Test Platform

VESA-Approved Tester for DisplayPort ALT Mode

Type-C Tracker™

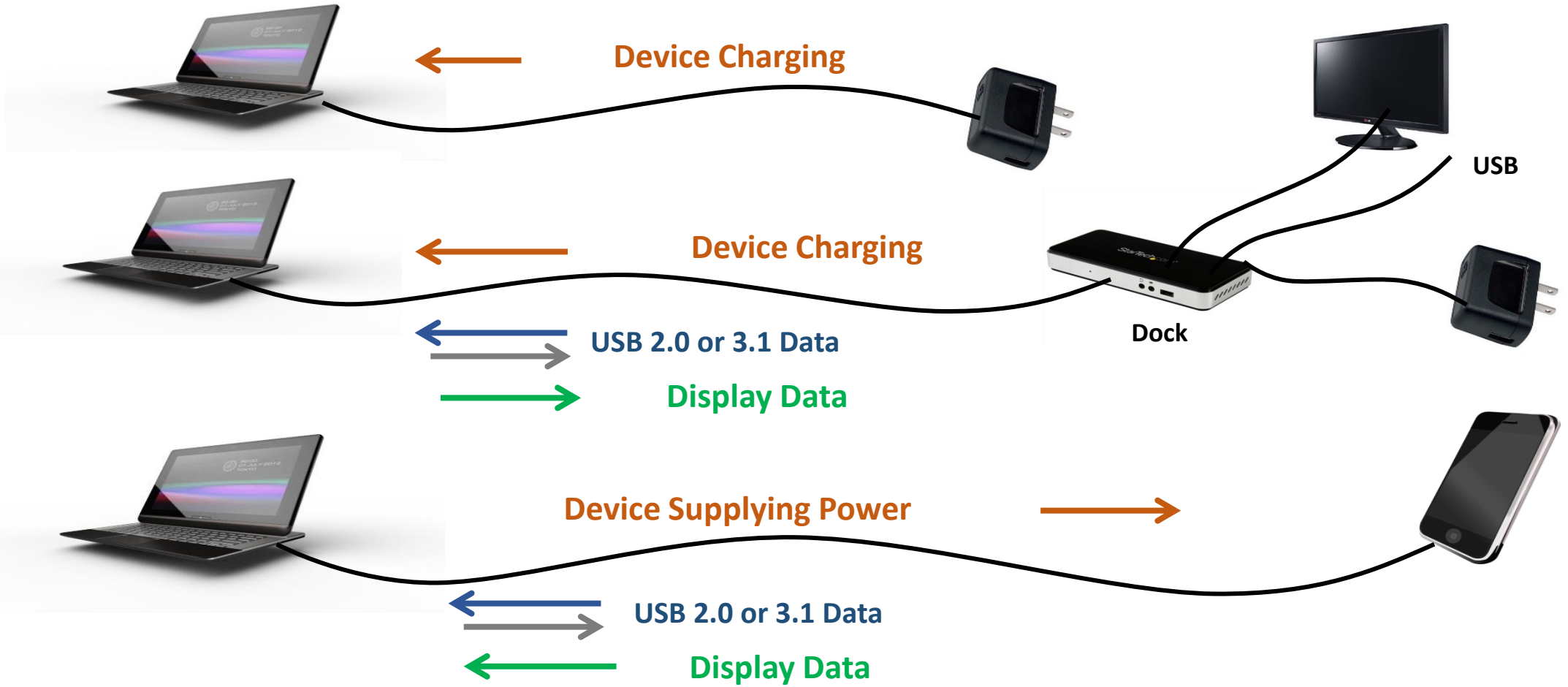
Protocol and Electrical Analysis Tool for USB Type-C® Standards

Includes DP AUX and DP ALT Support

ellisys
Better Analysis

Example USB Type-C Configurations

Either end can serve as USB Host, USB-PD Power Consumer, and DisplayPort Video Source (these services are independent of each other



DP Alt Mode over USB-C Ecosystem is Mainstream

USB-C Tablets

USB-C Laptops

USB-C Displays

Multi Function Adapters

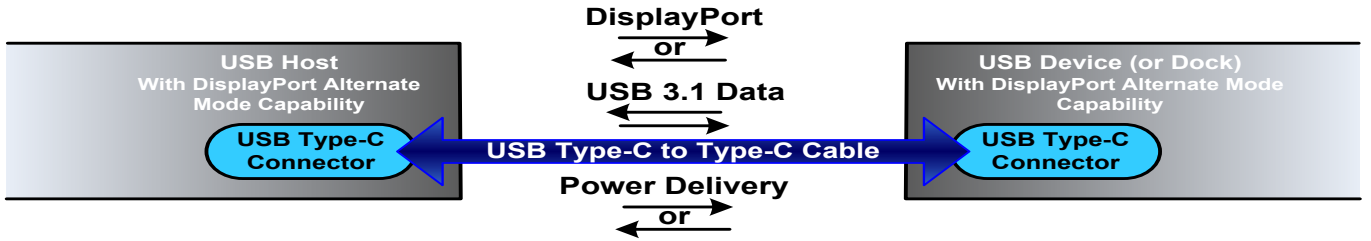
All types of certified adapters available

- C to DP adapters, Multifunction docks
- Type C protocol converters (HDMI, VGA, DVI) using DP Alt Mode

More are certified every week

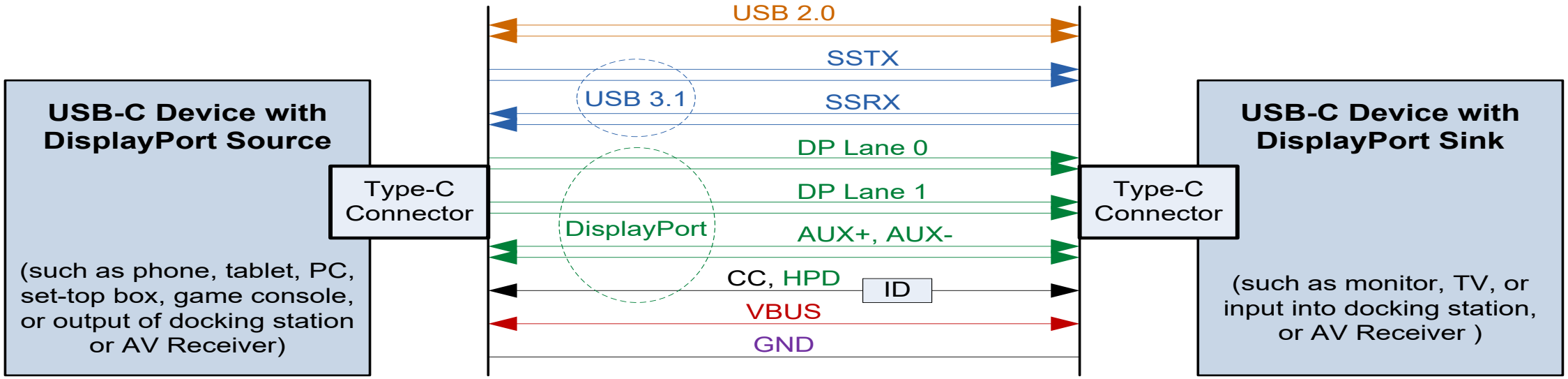
- Major PC OEMs continue to launch new products with DP Alt Mode over USB-C
- Major Display OEMs continue to add USB-C inputs to their products

USB-C Connector Functional Extension
DP Alt Mode



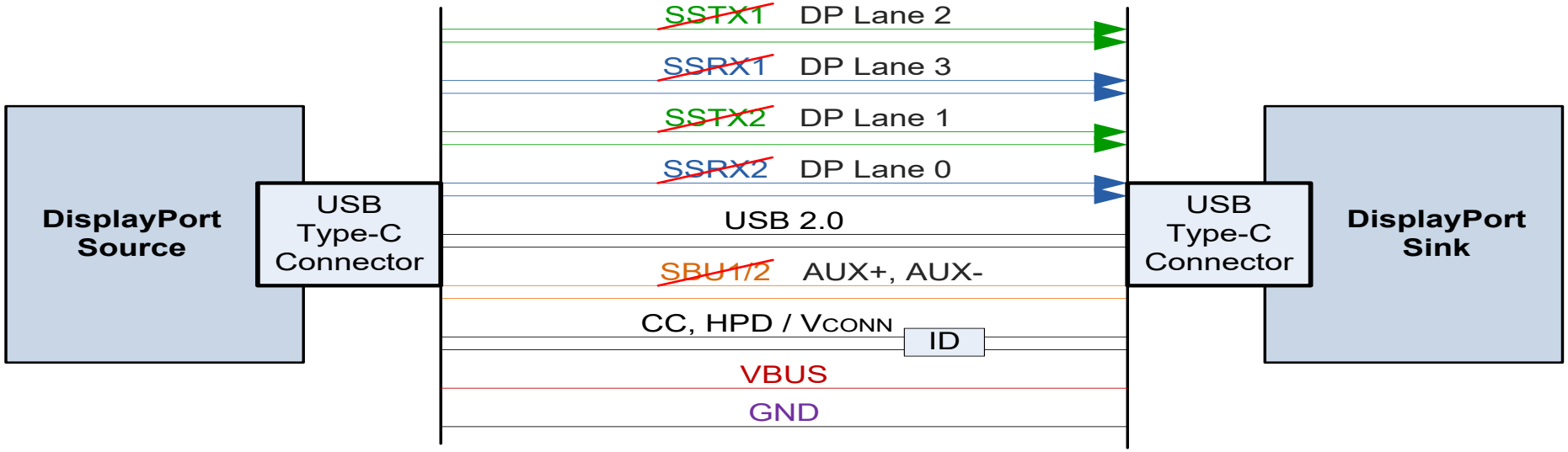
- A passive Full Feature USB Type-C to Type-C cable can carry up to four DisplayPort lanes
  - Same performance and features as a standard DisplayPort connection
  - Allows DisplayPort data rates to increase in the future, since the USB Type-C connector has very high data rate capability
- DisplayPort can be combined with USB 3.2 operation over the same USB Type-C cable
- USB 2.0 and USB Power Delivery is available in all configurations

2xDisplayPort and USB 3.2 over a Standard USB-C Cable



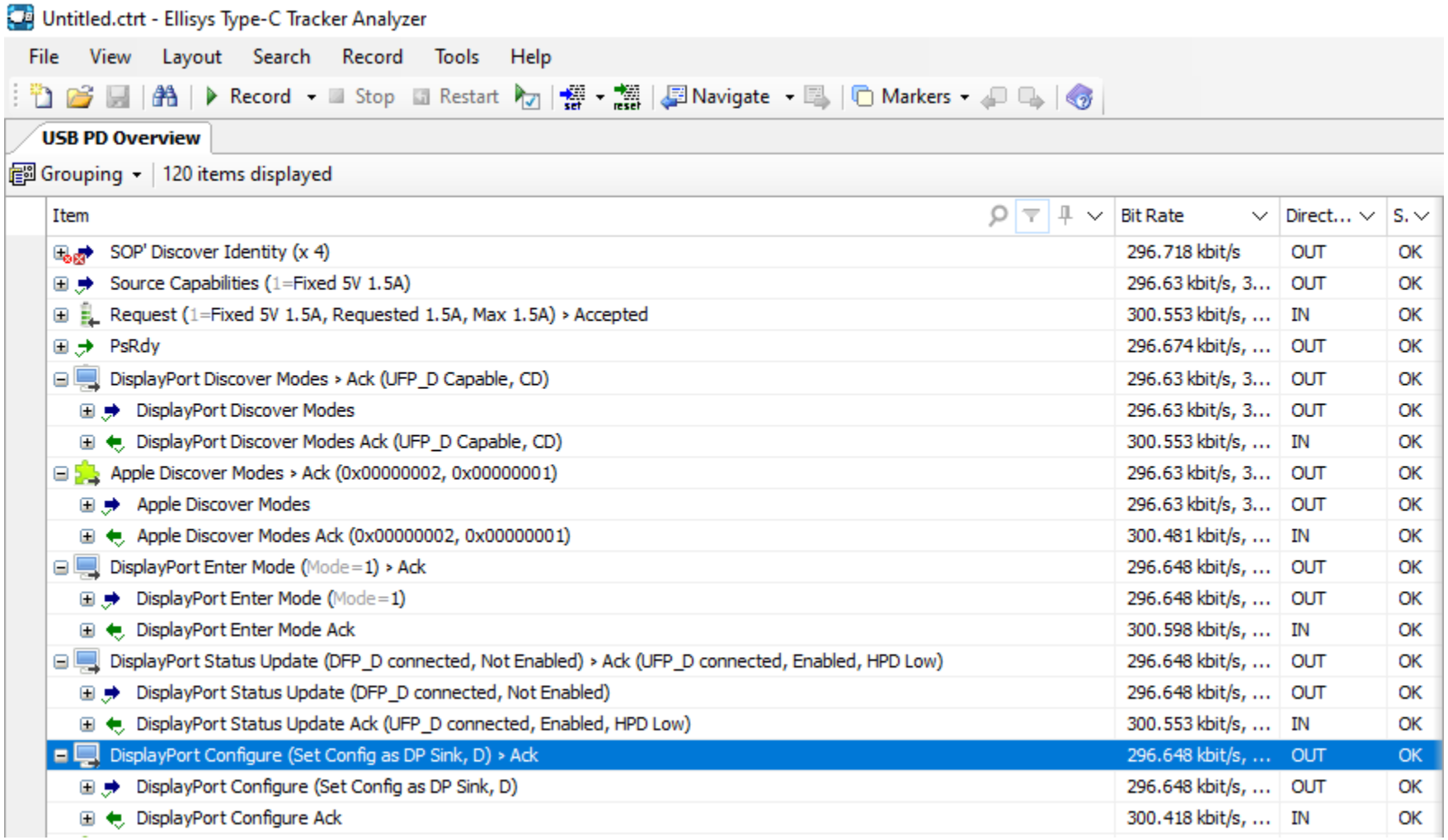
- Uses a standard “Full Feature” USB-C to USB-C cable which is designed to include DisplayPort
- The above configuration uses two high-speed lanes each for DisplayPort and USB 3.2
  - Ideal for docking stations, or for displays or TVs that include USB 3.2 functions

4xDP Over a USB Type-C to USB Type-C Full Feature Passive Cable



- Utilizes optional DP Alt Mode capability of USB Type-C connector
- DisplayPort can use all four high speed lanes to deliver full DisplayPort performance
- The DisplayPort AUX Channel uses the SBU pins
- The DisplayPort HPD / IRQ is transmitted over the CC pin using the USB-PD protocol
- USB 2.0 and USB Power Delivery always available

Typical DisplayPort Alternate Mode Flow



DisplayPort Alternate Mode 2.1 Update

- SVDM Header Update (by USB PD Spec)
- Cable DP Capabilities VDO update to support UHBR20 and UHBR13.5
  - Both passive and active cables
- SOP' Active Cable DisplayPort Configurations VDO update
- DP Capabilities VDO Update (DPAM Version field)
- SOP DisplayPort Configurations VDO Update
  - Cable information
  - DPAM Version
- DisplayPort Status Update VDO Update

SVDM Header Update

12:11	**Structured VDM Version (Minor)[a]**	Version number (Minor) of the SVDM (not the *USB PD* version number). 00b = Version 2.0 or earlier 01b = Version 2.1 All other values are RESERVED.
14:13	**Structured VDM Version (Major)[a]**	Version number (Major) of the SVDM (not the *USB PD* version number). 00b = Version 2.0 or earlier. 01b = Version 2.x. (x indicates SVDM minor version) All other values are RESERVED.

12:11 was reserved

Cable DP Capabilities VDO update

Table 4-5: SOP' Cable DP Capabilities (VDO in the Responder USB PD *Discover Modes* VDM)[a]

Bit(s)	Description	Values
1:0	**RESERVED**	RESERVED (always 00b).
5:2	**Signaling for Transport of DisplayPort Protocol[b]**	XXX1b = Supports all defined *DP* bit rates up to HBR3. XX1Xb = Supports *DP* bit rate UHBR10. X1XXb = Supports *DP* bit rate of UHBR20 (e.g., 0111b supports all *DP* bit rates, including UHBR10 and UHBR20). All other values are RESERVED for higher bit rates.[c]
7:6	**RESERVED**	RESERVED (always 00b).
15:8	**DP Source Device Pin Assignments Supported**	0Ch = Pin Assignments C and D are supported. 10h = *USB-C* and *DP* connector Pin Assignment E is supported. All other values are RESERVED.
23:16	**DP Sink Device Pin Assignments Supported**	0Ch = Pin Assignments C and D are supported (USB-C-to-USB-C cable). 10h = *USB-C* and *DP* connector Pin Assignment E is supported. All other values are RESERVED.
25:24	**RESERVED**	RESERVED (always 00b).
26[d]	**UHBR13.5**	0 = UHBR13.5 is not supported. 1 = UHBR13.5 is supported.[e]
27	**RESERVED**	RESERVED (always 0).
29:28[d]	**Active Component**	00b = Passive. 01b = Active re-timer. 10b = Active re-driver. 11b = Optical.
31:30	**DPAM Version**	00b = Version 2.0 or earlier. 01b = Version 2.1 or higher.

Table 4-2: Active Cable DP Capabilities (VDO in the Responder USB PD *Discover Modes* VDM)

Bit(s)	Description	Values
1:0	RESERVED	RESERVED (always 00b).
5:2	Signaling for Transport of DisplayPort Protocol[a]	XXX1b = Supports *DP* bit rates and electrical settings (shall always be set apart from diagnostic purposes). XX1Xb = RESERVED. X1XXb = RESERVED. 1XXXb = RESERVED.
7:6	RESERVED	RESERVED (always 00b).
15:8	DP Source Device Pin Assignments Supported	0Ch = Pin Assignments C and D are supported. All other values are RESERVED.
23:16	DP Sink Device Pin Assignments Supported	0Ch = Pin Assignments C and D are supported (USB-C-to-USB-C cable). All other values are RESERVED.
31:24	RESERVED	RESERVED (always 00h).

a. "X" value indicates "Don't Care."

Active Cable DisplayPort Configurations VDO update

Table 4-7: SOP' Active Cable DisplayPort Configurations

Bit(s)	Description	Values
1:0	**Select Configuration**	00b = Set configuration for *USB*.[a] 01b = Set configuration for active cable as a *DP* Source device (UFP_U is a *DP* Source device).[b] 10b = Set configuration for active cable as a *DP* Sink device (UFP_U is a *DP* Sink device).[b] 11b = RESERVED.
5:2	**Signaling for Transport of DisplayPort Protocol**	0h = Bit rate is unspecified (used only when the Select Configuration field is programmed for USB Configuration). 1h = Select *DP* bit rates and electrical settings. All other values are RESERVED.
7:6	**RESERVED**	RESERVED (always 00b).
15:8	**Configure Active Cable Pin Assignment**	00h = Deselect pin assignment. 04h = Select Pin Assignment C.[c] 08h = Select Pin Assignment D.[d] 10h = Select Pin Assignment E.[e] All other values are RESERVED.
31:16	**RESERVED**	RESERVED (always 0000h).

Table 4-3: Active Cable *DisplayPort Status Update*

Bit(s)	Description	Values
2:0	RESERVED	RESERVED (always 00b).
3	Enabled	0 = Active cable *DP* functionality is disabled. 1 = Active cable *DP* functionality is enabled and operational.
31:4	RESERVED	RESERVED (always 0000000h).

DP Capabilities VDO Update

Table 5-6: DP Capabilities (VDO in the Responder USB PD *Discover Modes* VDM)

Bit(s)	Description	Values[a]
1:0	**Port Capability**	00b = RESERVED. 01b = *DP* Sink Device Capable (including *DP* Branch device). 10b = *DP* Source Device Capable (including *DP* Branch device). 11b = Both *DP* Source and Sink Device Capable.
5:2	**Signaling for Transport of DisplayPort Protocol**	XXX1b = Supports *DP* bit rates and electrical settings (shall always be set apart from diagnostic purposes). XX1Xb = RESERVED. X1XXb = RESERVED. 1XXXb = RESERVED.
6	**Receptacle Indication**	0 = *DP* interface is presented on a *USB-C* plug. 1 = *DP* interface is presented on a *USB-C* receptacle.
7	**USB 2.0 Signaling Not Used**	0 = *USB 2.0* may be needed on A6 – A7 –or– B6 – B7 while in DisplayPort Configuration. 1 = *USB 2.0* is not needed on A6 – A7 –or– B6 – B7 while in DisplayPort Configuration.
15:8	**DP Source Device Pin Assignments Supported (reported by a DP Source device receptacle or DP Sink device (direct-attach) plug)**	00000000b = *DP* Source device pin assignments are not supported. XXXXXXX1b = RESERVED. XXXXXX1Xb = RESERVED. XXXXX1XXb = Pin Assignment C is supported.[b] XXXX1XXXb = Pin Assignment D is supported.[c d] XXX1XXXXb = Pin Assignment E is supported.[e] XX1XXXXXb = RESERVED. X1XXXXXXb = RESERVED. 1XXXXXXXb = RESERVED.
23:16	**DP Sink Device Pin Assignments Supported (reported by a DP Sink device receptacle or DP Source device (direct-attach) plug)**	00000000b = *DP* Sink device pin assignments are not supported. XXXXXXX1b = RESERVED. XXXXXX1Xb = RESERVED. XXXXX1XXb = Pin Assignment C is supported.[f] XXXX1XXXb = Pin Assignment D is supported.[c g] XXX1XXXXb = Pin Assignment E is supported.[h] XX1XXXXXb = RESERVED. X1XXXXXXb = RESERVED. 1XXXXXXXb = RESERVED.
29:24	**RESERVED**	RESERVED (always 00h).
31:30	**DPAM Version[j]**	00b = Version 2.0 or earlier. 01b = Version 2.1 or higher.

Table 5-5: DP Capabilities (VDO in the Responder USB PD *Discover Modes* VDM)

Bit(s)	Description	Values[a]
1:0	Port Capability	00b = RESERVED. 01b = *DP* Sink device-capable (including *DP* Branch device). 10b = *DP* Source device-capable (including *DP* Branch device). 11b = Both *DP* Source and Sink device-capable.
5:2	Signaling for Transport of DisplayPort Protocol	XXX1b = Supports *DP* bit rates and electrical settings (shall always be set apart from diagnostic purposes). XX1Xb = RESERVED. X1XXb = RESERVED. 1XXXb = RESERVED.
6	Receptacle Indication	0 = *DP* interface is presented on a *USB-C* plug. 1 = *DP* interface is presented on a *USB-C* receptacle.
7	USB 2.0 Signaling Not Used	0 = *USB 2.0* may be needed on A6 – A7 –or– B6 – B7 while in DisplayPort Configuration. 1 = *USB 2.0* is not needed on A6 – A7 –or– B6 – B7 while in DisplayPort Configuration.
15:8	DP Source Device Pin Assignments Supported (reported by a *DP* Source device receptacle or *DP* Sink device (direct-attach) plug)	00000000b = *DP* Source device pin assignments are not supported. XXXXXXX1b = RESERVED. XXXXXX1Xb = RESERVED. XXXXX1XXb = Pin Assignment C is supported.[b] XXXX1XXXb = Pin Assignment D is supported.[c d] XXX1XXXXb = Pin Assignment E is supported.[e] XX1XXXXXb = RESERVED. X1XXXXXXb = RESERVED. 1XXXXXXXb = RESERVED.
23:16	DP Sink Device Pin Assignments Supported (reported by a *DP* Sink device receptacle or *DP* Source device (direct-attach) plug)	00000000b = *DP* Sink device pin assignments are not supported. XXXXXXX1b = RESERVED. XXXXXX1Xb = RESERVED. XXXXX1XXb = Pin Assignment C is supported.[f] XXXX1XXXb = Pin Assignment D is supported.[c g] XXX1XXXXb = Pin Assignment E is supported.[h] XX1XXXXXb = RESERVED. X1XXXXXXb = RESERVED. 1XXXXXXXb = RESERVED.
31:24	RESERVED	RESERVED (always 00h).

If SVDM Version is 2.1 or higher, DPAM Version field is applicable else this field shall be set to 00b.

A Bit More Background

From DisplayPort Alt Mode 2.0 Spec

Future versions of this Standard may describe other modes associated with the DP_SID. Such modes shall be identified by having a non-zero value in bits 31:24 of the VDO. The DFP_U shall examine the list of modes returned until it finds 0s in bits 31:24 of the VDO and a non-zero value in bits 23:0 of the VDO (i.e., DP Capabilities). The DFP_U and UFP_U shall use the corresponding offset (indexed from 1) as the Object Position in the following commands:

SOP DisplayPort Configurations VDO Update

Table 5-13: SOP DisplayPort Configurations

Bit(s)	Description	Values
1:0	**Select Configuration**	00b = Set configuration for *USB*.[a] 01b = Set configuration for UFP_U as a *DP* Source device.[b] 10b = Set configuration for UFP_U as a *DP* Sink device.[b] 11b = RESERVED.
5:2[c]	**Signaling for Cable Information Transport of DisplayPort Protocol**	XXX1b = Supports all defined *DP* bit rates up to HBR3 -or- capability is unknown XX1Xb = Supports *DP* bit rate UHBR10. X1XXb = Supports *DP* bit rate of UHBR20 (e.g., 0111b supports all *DP* bit rates, including UHBR10 and UHBR20). All other values are RESERVED for higher bit rates.[d]
7:6	**RESERVED**	RESERVED (always 00b).
15:8	**Configure UFP_U Pin Assignment**	00h = Deselect pin assignment. 04h = Select Pin Assignment C.[e] 08h = Select Pin Assignment D.[f] 10h = Select Pin Assignment E.[g] All other values are RESERVED.
25:16	**RESERVED**	RESERVED (always 0000000000b).
26[h]	**Cable UHBR13.5 Support**	0 = Not supported.[i] ~~-or- capability is unknown~~ 1 = Supported.
27	**RESERVED**	RESERVED (always 0).
29:28[h]	**Cable Active Component**	00b = Passive -or- cable type is unknown 01b = Active re-timer. 10b = Active re-driver. 11b = Optical.
31:30[j]	**DPAM Version**	00b = Version 2.0 or earlier. 01b = Version 2.1 or higher.

Table 5-8: DisplayPort Configurations

Bit(s)	Description	Values
1:0	Select Configuration	00b = Set configuration for *USB*.[a] 01b = Set configuration for UFP_U as a *DP* Source device.[b] 10b = Set configuration for UFP_U as a *DP* Sink device.[b] 11b = RESERVED.
5:2	Signaling for Transport of DisplayPort Protocol	0h = Bit rate is unspecified (used only when the Select Configuration field is programmed for USB Configuration). 1h = Select *DP* bit rates and electrical settings. All other values are RESERVED.
7:6	RESERVED	RESERVED (always 00b).
15:8	Configure UFP_U Pin Assignment	00h = De-select pin assignment. 04h = Select Pin Assignment C.[c] 08h = Select Pin Assignment D.[d] 10h = Select Pin Assignment E.[e] All other values are RESERVED.
31:16	RESERVED	RESERVED (always 0000h).

- This is the most challenging part for DPAM 2.1 DFP_U

DisplayPort Status Update VDO Update

Table 5-7: DisplayPort Status Update

Bit(s)	Description	Values
1:0	**DP Source/Sink Device Connected**	00b = Neither a *DP* Source device nor *DP* Sink device is connected, –or– the adapter is disabled. 01b = *DP* Source device is connected. 10b = *DP* Sink device is connected.[a] 11b = Both a *DP* Source and Sink device are connected.
2[b]	**Power Low**	0 = Adapter is not in low power state ~~is functioning normally or is disabled~~. 1 = Adapter has detected low power ~~and disabled *DP* support~~.
3[b]	**Enabled**	0 = Adapter *DP* functionality is disabled. 1 = Adapter *DP* functionality is enabled and operational.
4[d]	**Multifunction Preferred**	0 = No preference for multifunction. 1 = Multifunction is preferred.
5[c]	**DisplayPort/ USB Configuration Request**	0 = Request change to DisplayPort Configuration (if currently in USB Configuration). 1 = Request change to USB Configuration (if currently in DisplayPort Configuration).
6[c]	**Exit DisplayPort Alt Mode Request**	0 = Maintain the current mode. 1 = Request exit from DisplayPort Alt Mode (if currently in DisplayPort Alt Mode).
7[d]	**HPD State**	0 = HPD_Low. 1 = HPD_High.[e]
8[d]	**IRQ_HPD**	0 = IRQ_HPD has not been issued since the last status Message. 1 = IRQ_HPD.[f]
9[g]	**NO_DPAM_SUSPEND**	0 = UFP_U/ DP Sink device has no preference for entry into low power state. 1 = UFP_U/ DP Sink device prefers not to enter low power state.
31:10	**RESERVED**	RESERVED (always 0000000h).

Table 5-6: *DisplayPort Status Update*

Bit(s)	Description	Values
1:0	DP Source/Sink Device Connected	00b = Neither a *DP* Source device nor *DP* Sink device is connected, –or– the adapter is disabled. 01b = *DP* Source device is connected. 10b = *DP* Sink device is connected.[a] 11b = Both a *DP* Source and Sink device are connected.
2[b]	Power Low	0 = Adapter is functioning normally or is disabled. 1 = Adapter has detected low power and disabled *DP* support.
3[b]	Enabled	0 = Adapter *DP* functionality is disabled. 1 = Adapter *DP* functionality is enabled and operational.
4[b]	Multi-function Preferred	0 = No preference for multi-function. 1 = Multi-function is preferred.
5[b]	DisplayPort/ USB Configuration Request	0 = Request change to DisplayPort Configuration (if currently in USB Configuration). 1 = Request change to USB Configuration (if currently in DisplayPort Configuration).
6[b]	Exit DisplayPort Alt Mode Request	0 = Maintain the current mode. 1 = Request exit from DisplayPort Alt Mode (if currently in DisplayPort Alt Mode).
7[c]	HPD State	0 = HPD_Low. 1 = HPD_High.[d]
8[c]	IRQ_HPD	0 = IRQ_HPD has not been issued since the last status Message. 1 = IRQ_HPD.[e]
31:9	RESERVED	RESERVED (always 0000000h).

Two New timers:

- tAttentionSpacing min 10ms
- tHpdConvertPd max 5ms

DPAM Version Resolution

Table 5-5: DPAM Version Resolution

DFP_U, Cable and UFP_U with DP SID	DFP_U	Cable	UFP_U	DPAM Version Resolution
DPAM Version	2.0 or earlier	2.0 or earlier	2.0 or earlier	2.0 or earlier[ab]
	2.1 or higher	2.0 or earlier	2.0 or earlier	2.0 or earlier[ab]
	2.0 or earlier	2.1 or higher	2.0 or earlier	2.0 or earlier[ab]
	2.0 or earlier	2.0 or earlier	2.1 or higher	2.0 or earlier[ab]
	2.1 or higher	2.1 or higher	2.0 or earlier	2.0 or earlier[ab]
	2.0 or earlier	2.1 or higher	2.1 or higher	2.0 or earlier[ab]
	2.1 or higher	2.0 or earlier	2.1 or higher	DPAM 2.1 or higher[c]
	2.1 or higher	2.1 or higher	2.1 or higher	2.1 or higher[d] (Shall support DPAM 2.1 or higher)

a. *If Initiator and Responder support SVDM Version 2.0 or earlier and if DisplayPort Alternate Mode is supported all DP Capabilities exchange shall follow DisplayPort Alt Mode on USB Type-C specification 2.0 or earlier.*

b. *If Initiator and Responder both support SVDM Version 2.1 or higher and if either Initiator or Responder supports DPAM Version 2.0 or earlier, then all DP Capabilities exchange shall follow DisplayPort Alt Mode on USB Type-C specification 2.0 or earlier.*

c. *When DPAM 2.1 or higher DFP_U and DPAM 2.1 or higher UFP_U are connected with a legacy active DPAM 2.0 cable, then the system shall exchange all DP Capabilities as per DisplayPort Alt Mode on USB Type-C specification 2.1 or higher but support HBR3 rates.*

d. *If Initiator and Responder both support SVDM Version 2.1 or higher and DPAM Version 2.1 all DP Capabilities exchange shall follow DisplayPort Alt Mode on USB Type-C specification 2.1 or higher.*

DPAM 2.1 CTS Update (1)

- 10.3.2 DPAM2.1 Entry with USB-C to USB-C non-emarked cable
- 10.3.3 DPAM2.1 Entry with USB-C to USB-C Passive TBT3 cable
- 10.3.4 DPAM2.1 Entry with Passive E-Marked USB-C to USB-C
- 10.3.5 DPAM2.1 Entry with USB-C to USB-C DP2.0 LRD Cable
- 10.3.6 DPAM2.1 Entry with USB-C to USB-C DP2.0 Active Retimer cable
- 10.3.7 DPAM2.1 Entry with USB-C to USB-C DP2.1 LRD cable
- 10.3.8 DPAM2.1 Entry with USB-C to USB-C Active Non-DP cable
- 10.3.9 DPAM2.1 Entry with USB-C to USB-C USB2.0 cable
- 10.3.10 DPAM2.1 Entry with USB-C to DP2.1 cable

- All these tests were added to make sure the DFP_U set correct cable information in DisplayPort Configurations VDO

DPAM 2.1 CTS Update (2)

- **DPAM Version Resolution Tests**
  - **10.3.23 DPAM Version 2.1 DFP_U Connected to DPAM Version 2.0 or 2.1 UFP_U**
  - **10.4.3 DPAM Version 2.1 Cable Connected to DPAM Version 2.0 or 2.1 DFP_U**
  - **10.2.8 DPAM Version 2.1 UFP_U Connected to DPAM Version 2.0 or 2.1 DFP_U**

Questions?

VESA®

DisplayPort

VESA AdaptiveSync Specification Overview and Test

Presented by Do Kyun Kim, Professional Engineer, and Seung Hyun Yoo, Senior Research Engineer, LGE

VESA AdaptiveSync Specification Overview and Test

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LG Electronics, Inc.

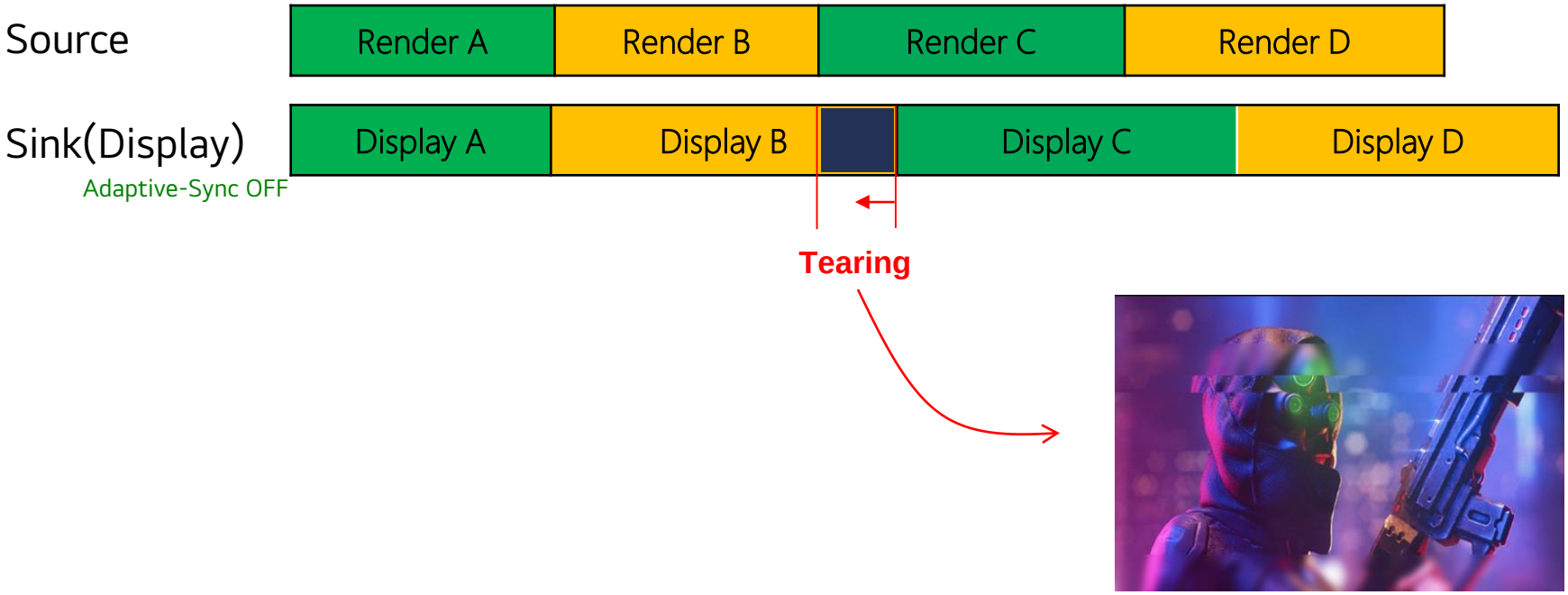
10. Oct. 2023

Adaptive-Sync Function

- 목적 : Tearing(찢어짐)/Stuttering(Frame 빠짐) 방지
- 원인 : GPU가 보내는 V-Sync와 모니터가 처리하는 V-Sync간 차이 발생
- 해결 : GPU가 고정 Frame Rate로 전송, 모니터에서 Variable Frame Rate 처리 **AdaptiveSync**
- AdaptiveSync 동작 (AdaptiveSync 이전)
  - GPU(Source)는 그래픽 연산에 따라 Vsync길이 조절하여 변경된 주사율(Frame Rate) 전송
  - Monitor(Sink)에서는 수신된 비디오 Frame Rate에 맞게 처리하여 Display

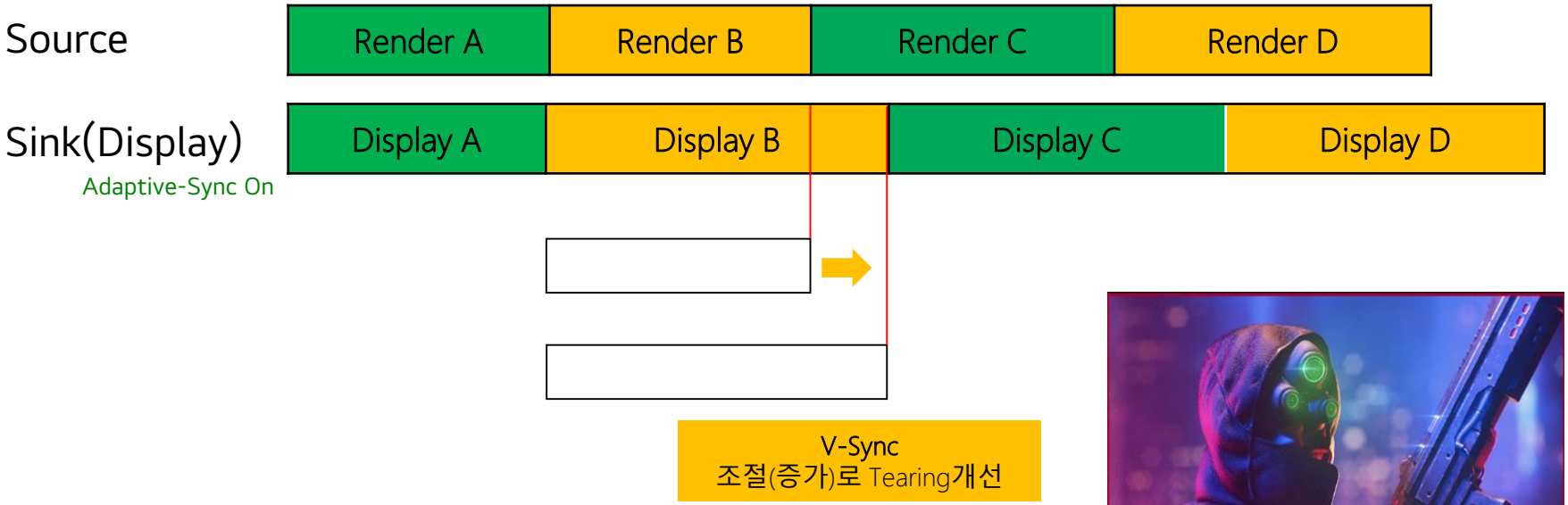
Adaptive-Sync Operation

- Adaptive-Sync OFF



Adaptive-Sync Operation

- Adaptive-Sync On : V-Sync 조절로 Tearing개선



History

2009년

Adaptive-Sync

기능 발표

Target : eDP(embedded DP)

2014년

Adaptive-Sync

Interface 확장

Target : DP 1.2~1.4a

2022년

VESA AdaptiveSync CTS

발표

신규 기능, 요구사항 추가

Target : DP 2.0~2.1

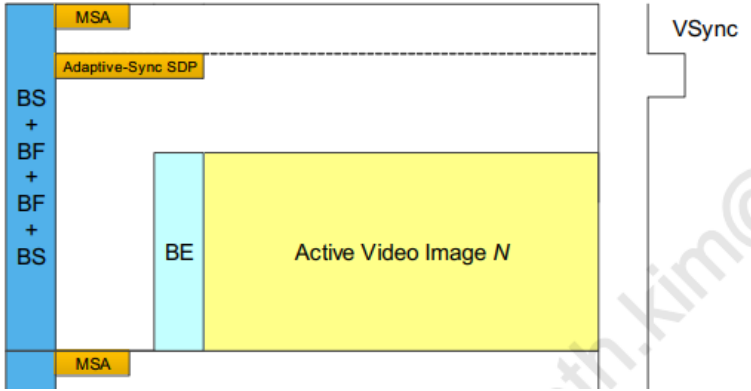
Adaptive-Sync Mode

- Adaptive V-Total(AVT)
  - Gaming Mode
  - CVT2.0[1]표준에서의 Reduced Blanking Timing version 3(RB3) 사용
  - Source는 Sink에 정의된 Frame Rate 범위 내에서 Adaptive Sync SDP 생성하여 주파수 가변
- Fixed Average V-Total(FAVT)
  - Media에서의 Media playback을 지원하기 위해 사용
  - CVT2.0표준에서의 Reduced Blanking Timing version 3(RB3) 사용
  - Source에서는 고정된 V-Total로 Video Data를 송부

1) CVT(Coordinated Video Timings)

DP2.1 VESA AdaptiveSync 추가 된 요구사항

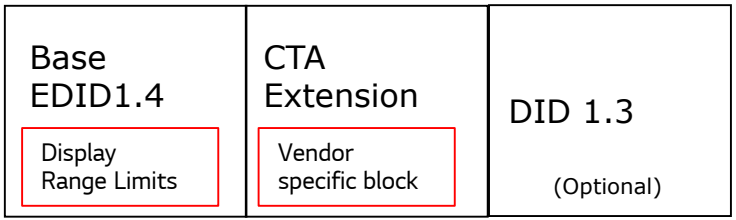
- Adaptive-Sync Data Block DisplayID2.1
  - CVT[1]2.0의 Reduce Blanking Version3 Timing CVT2.0
- Adaptive-Sync SDP[2] data structure Version1 DisplayPort2.1



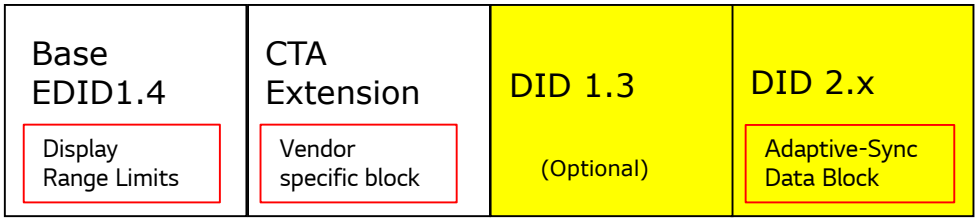
1) CVT(Coordinated Video Timings)
2) SDP(Secondary Data Packet)

EDID/DisplayID 요구사항

- 기존(Base EDID 1.4 + CTA Extension)



- 변경(Base EDID 1.4 + CTA Extension + Display ID 2.1)



Multi DisplayID Block(1.3 / 2.0 사용 가능)

Adaptive-Sync Data Block

DisplayID2.1

Byte#	Bit	Description/Format/Priority
00h	7:0	Adaptive-Sync Data Block Format Value 2Bh
01h	2:0	Block Revision 000b = Revision 0.
	3	RESERVED
	6:4	Number of Payload Bytes (M) 000b = 5+0 bytes per descriptor
	7	RESERVED
02h	7:0	Number of Payload Bytes in Block(N)
03h – 03h+M-1	(M*8-1):0	First Adaptive-Sync Operation Mode
03h ~ 03h+2M-1	(M*8-1):0	Second Adaptive-Sync Operation Mode
.....	.....	...
03h+(N-1)*M ~ 03h+(N*M)-1	(M*8-1):0	Nth Adaptive-Sync Operation Mode

Byte#	Bit	Description/Format/Priority
0	0	Adaptive-Sync Range 0b = Non-Native Panel Range. 1b = Native Panel Range.
	1	Successive Frame Duration Increase Tolerance(SFDIT) 0b = 미지원 1b = 지원
	3:2	00b = Fixed Average V-Total Mode 지원 01b = Fixed Average V-Total Mode 와 Adaptive V-Total Mode 지원
	4	0b =Adaptive-Sync Mode 변경 시 Seamless Transition 지원 1b =Adaptive-Sync Mode 변경 시 Seamless Transition 미 지원
	5	Successive Frame Duration Decrease Tolerance(SFDDT) 0b = 미지원 1b = 지원
	7:6	RESERVED
1	7:0	Max Single Frame Duration Increase (Max 63.75ms)
2	7:0	Minimum Refresh Rate
3	7:0	Maximum Refresh Rate Low Bits 7:0
4	1:0	Maximum Refresh Rate High Bits 9:8
	7:2	RESERVED
5	7:0	Max Single Frame Duration Decrease (Max 63.75ms)

CVT2.0 Generator

- Reduce Blanking Version3 Timing 생성 가능

1) Enter Desired Horizontal Pixels Here (I_H_PIXELS) =>		3840
2) Enter Desired Vertical Lines Here (I_V_LINES) =>		2160
3) Enter Vertical Scan Frame Rate Here (I_IP_FREQ_RDQ) =>	NOTE: Actual frame rate will be within 0 Hz due to pixel clock rounding to 0.001MHz. Actual frame rate is off target by 0 ppm.	60
4) Enter (Y or N) If You Want Reduced Blanking Here =>		y
5) Use Reduced Blank (RB) Timing version (2, 3) rules (I_RED_BLANK_VER) =>		3
6) Apply (1000/1001) factor to Frame Rate for video optimized variant (I_VIDEO_OPT) (Y or N) =>		n
7a) Additional Horizontal Blank Pixels (I_ADDITIONAL_HBLANK) (default blank is 80 pixels, additional horizontal blank pixels between 0 and 120 may be added) =>		0
7b) Apply Early Vertical Sync Location Required (I_EARLY_VSYNC_RQD) (Y or N) =>		n
7c) Additional Vertical Blank Time (I_VBLANK - 460us) =>	Note: additional vertical blank time in the range 0 to 245 us plus duration of one horizontal line may be added. DisplayID Type X descriptor additionally requires	0.00

DownLoad URL : https://vesa.app.box.com/s/o5m4tqtyt1b1qx0138ridi6lb4gq5ch6

Adaptive-Sync SDP

Adaptive-Sync SDP SCR Header Block

Byte#	Bit #	Description/Format/Priority
HB0	7:0	Secondary Data Packet ID 00h
HB1	7:0	Secondary Data Packet Type 22h=Adaptive-Sync
HB2	4:0	Revision Number 00h=Initial revision 01h=VESA AdaptiveSync, Version 1 is required
	7:5	Reserved
HB3	4:0	Number of Valid Data Bytes 00h=No Payload Data 01h=9개의 Payload Data
	7:5	Reserved

Adaptive-Sync SDP SCR Payload Bytes(1/2)

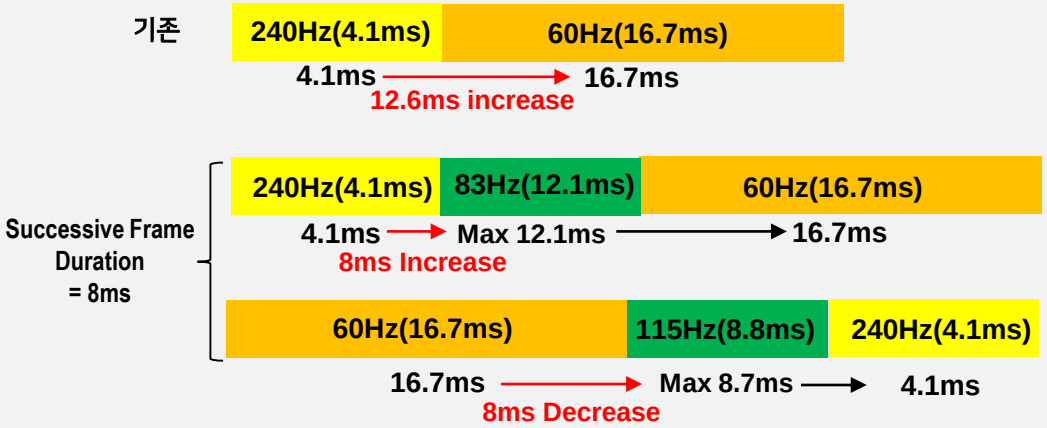
Byte#	Bit #	Description/Format/Priority
DB0	0:1	VARIABLE_FRAME_RATE_DISABLE 00 = AVT Mode_ Frame Duration 변경 01 = AVT Mode_ Frame Duration 고정 10 = FAVT Mode_ Target refresh rate 정보 없음 = FAVT Mode_ Target refresh rate 정보 받음
	2	Adaptive Sync SDP Transmission Disable in PR_Active State(Panel Replay 기능 지원시) 0 = Adaptive-Sync SDP와 타이밍 동기화 Enable 1 = Adaptive-Sync SDP와 타이밍 동기화 Disable

Adaptive-Sync SDP SCR Payload Bytes(2/2)

Byte#	Bit #	Description/Format/Priority
DB0	3	Remote Frame Buffer (RFB) Update in PR_Active State 0 = No RFB update 1 = Update the RFB
	7:4	Reserved
DB1	7:0	Minimum Vertical Total [7:0]
DB2	7:0	Minimum Vertical Total [15:8]
DB3	7:0	Target Refresh Rate[7:0]
DB4	1:0	Target Refresh Rate[9:8] - AVT mode : DB4[1:0] = 00b and DB3 = 00h. - FAVT mode : Match the Target Refresh rate
	4:2	Reserved
	5	Target Refresh Rate Divider(FAVT only) 0=1.000 1=1.001
	6	Successive Frame Duration Increase Configuration 0= 미사용 1= DB5지정 값 사용
	7	Successive Frame Duration Increase Configuration 0= 미사용 1= DB6지정 값 사용
DB5	7:0	Successive Frame Duration Increase Value(0 to 63.75ms)
DB6	7:0	Successive Frame Duration Decrease Value(0 to 63.75ms)
DB7	7:0	PR_Active State - Adaptive-Sync 작동이 비활성화되었을 때 재생률을 유지하는 VTotal LSB(Least Significant Byte) 값
DB8	7:0	

Successive Frame Duration Increase/Decrease Tolerance

- 배경 : 급격하게 Frame Duration 증가 시 Flicker나 Judder 발생 할 수 있음
- 기능 : 표기된 Max Successive Frame Duration Tolerance 맞춰 Video Rendering
  - e.g. Max Successive Frame Duration Increase/Decrease Tolerance = 8ms



DisplayID2.1 추가

VESA

Adaptive-Sync Display CTS ver 1.1

Program Objectives & Requirements

Adaptive-Sync Display Logo

- 목적 : Flicker, G2G, Jitter, Frame Drop에 대한 Display 성능 평가

VESA CERTIFIED AdaptiveSync

For Gaming

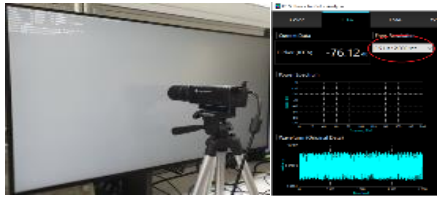
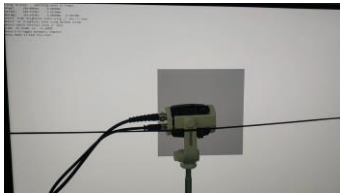
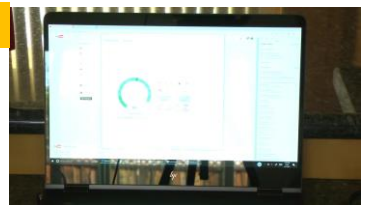
VESA CERTIFIED MediaSync

For Film

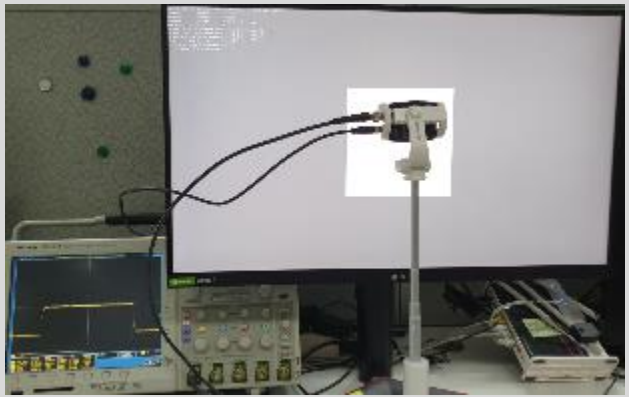
VESA CERTIFIED AdaptiveSync DISPLAY 144

Max Frame Rate 표기 가능
Ex: 165Hz, 240Hz 등

항목별 현상 / 측정

Test 항목	현상	측정
Flicker	동영상 	
Grey to Grey (G2G)		
Frame Drop	동영상 	동영상 
Jitter	동영상 	

측정 항목 및 장비

Flicker	G2G : Response Time, Over/Undershoot	Frame Drop, Jitter
		
Device : Color Meter (CA:410)	Device : Photo Sensor DAQ(AD converter) PC(Generation Tool)	Device : DSLR 카메라 Photo Shop

Adaptive-Sync Display CTS1.1 Requirements(1/2)

		Tier	
		AdaptiveSync	MediaSync
Maximum Refresh Rate		≥144Hz	≥60Hz
Minimum Refresh Rate		≤60Hz	≤48Hz
G2G (Max Frame Rate)	Response Time(Avg)	≤5ms	-
	Overshoot(Max)	≤ Delta-PQ Tolerance of each section (다음페이지 참조)	≤ Delta-PQ Tolerance of each section (다음페이지 참조)
	Undershoot(Max)		
Flicker	Low variability refresh	≤-50dB	≤-50dB
	High variability refresh	≤-50dB	N/A
Frame-to-frame jitter duration for 23.976- to 60-Hz video		±0.5ms	±0.5ms
Frame Drop		0	
The 10 Static frequency video frame rates 지원		23.976, 24, 25, 29.9 30, 47.952, 48, 50, 59.94, 60Hz	
If Successive Frame Duration Increase Tolerance is present, minimum duration for variable		8.5 ms 240Hz(4.1ms) → 79Hz(12.6ms) → 60Hz(16.7ms)	1 ms
If Successive Frame Duration Decrease Tolerance is present ,minimum duration for variable		9.75 ms	1 ms

Adaptive-Sync Display CTS1.1 Requirements(2/2)

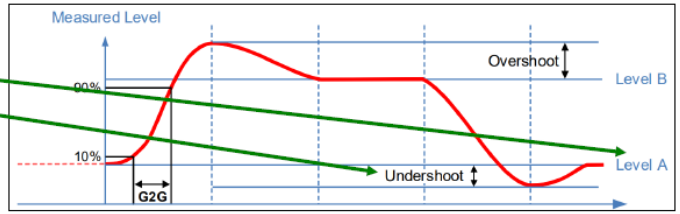
- Delta-PQ Tolerance Table

From/Start \ To/End	0	31	63	95	127	159	191	223	255
0			18	18	18	18	18	18	15
31			15	15	18	18	18	18	10
63				13	15	15	15	18	10
95			20		10	15	15	15	10
127			20	20		10	10	10	10
159			20	20	15		8	10	10
191			30	20	20	13		8	10
223			30	20	20	20	12		5
255			30	30	20	20	10	10	

  - Luminance를 PQ값으로 치환하여 Over/undershoot과 Saturation 된 부분의 차이를 계산

PQ

- Luminance : 8.56cd/m2→ PQ 294
- Undershoot Delta : 5.56cd/m2 → PQ 261
- Undershoot= PQ294 – PQ261 = 33



Testing Procedure

Test Sequence Ambient temperature 72.5F(22.5℃) ~76F(24.4℃)

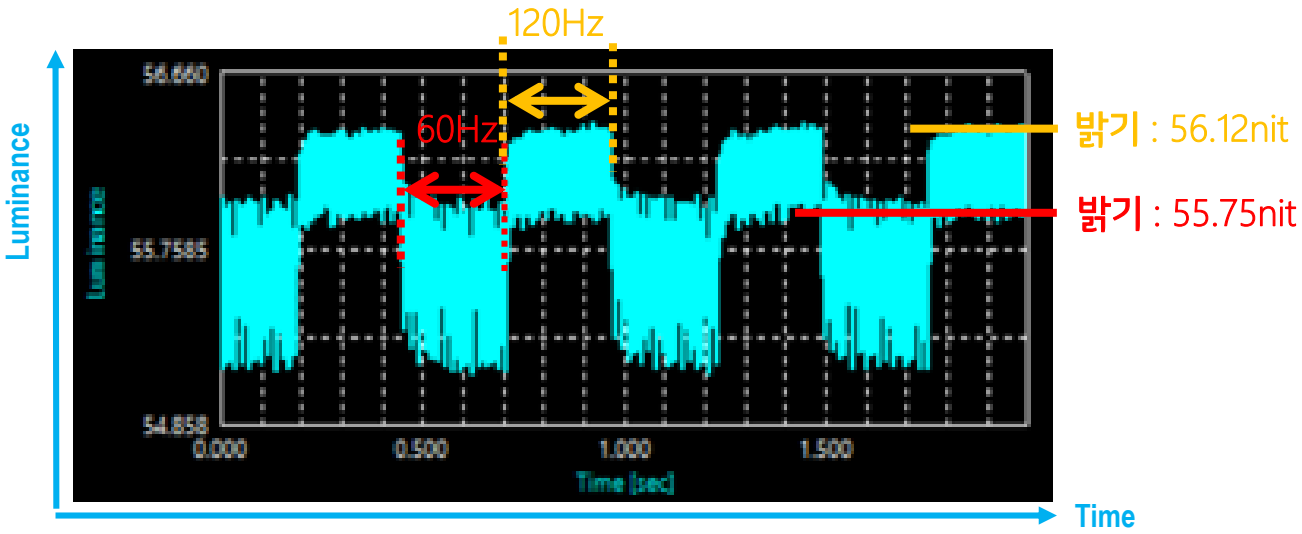
- <1000nit 제품
  1. Warm-up phase(40nit) -1hour
  2. Static Flicker tests
  3. Variable Flicker tests
  4. G2G tests
  5. Frame Drop tests
  6. Jitter tests
  7. If the display supports HDR, then also the HDR tests

- >1000nit 제품
  1. Warm-up phase(40nit) -1hour
  2. Static Flicker tests
  3. Variable Flicker tests
  4. Frame Drop tests
  5. Jitter tests
  6. Warm-up phase(185nit)- 20 minutes
  7. High-luminance G2G Tests
  8. If the display supports HDR, then also the HDR tests

DC Offset 방지를 위해 반드시 순서대로 Test 진행

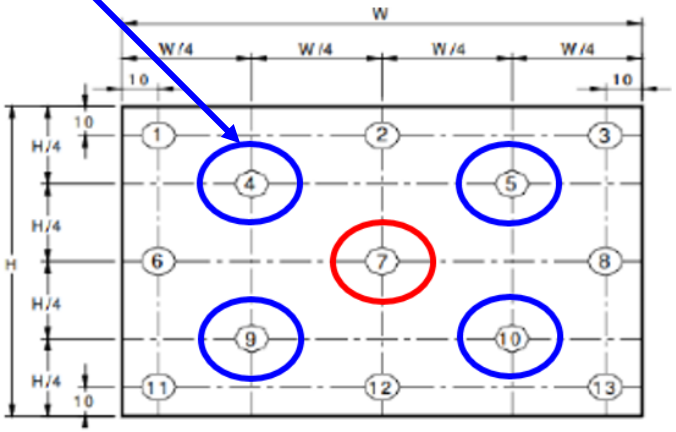
Flicker tests(1/2)

- 목적 : Frame Rate 변화에 따른 깜빡임 확인
  - 각 Frame Rate 마다 Pixel 소자의 충/방전 시간이 다름으로 밝기(Luminance) 차이 존재



Flicker tests(2/2)

- Test 환경 : SDR mode 40cd/m2 by ±5%Center
  - Center >-60dB 측정되는 경우 → Corner에서(4 Point) Test 추가 측정
- Test Refresh Rates
  - Static : 23.976, 24, 25, 29.9, 30, 47.952, 48, 50, 59.94, 60Hz
  - Variable
    - Low variability refresh : Zigzag Sweep, Sine Wave Sweep
    - High variability refresh : Square Wave, Random Frame rate



G2G tests(1/2)

- 목적 : Code value 별 응답 속도
- Test 환경 : SDR 8-bit Gamma 2.2 Code Values
  - 9 x 9 Matrix 사용

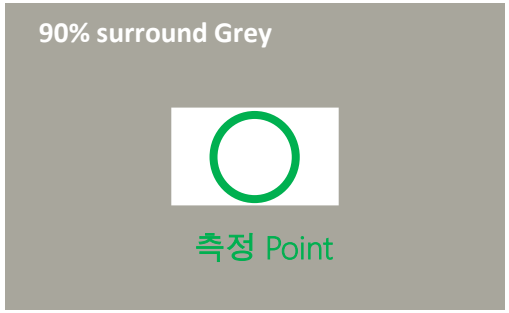


Table 7-1: SDR G2G Test Levels – 8-bit Gamma 2.2 Code Values, Displays with MaxLuminance < 1,000 cd/m^2

9 × 9 Matrix Test Patch Values	SDR 10% Test Patch	SDR 90% Gray Surround
Test 1 (Black)	0	127
Test 2 (Very Dark Gray)	31	127
Test 3 (Dark Gray)	63	127
Test 4 (Dark-Mid Gray)	91	127
Test 5 (Mid Gray)	127	127
Test 6 (Light Mid Gray)	159	127
Test 7 (Light Gray)	191	127
Test 8 (Bright Gray)	223	127
Test 9 (White)	255	127

Table 7-2: SDR High-Luminance G2G Test Levels – 8-bit Gamma 2.2 Code Values, Displays with MaxLuminance ≥ 1,000 cd/m^2

9 × 9 Matrix Test Patch Values	SDR 10% Test Patch	SDR 90% White Surround
Test 1 (Black)	0	255
Test 2 (Very Dark Gray)	31	255
Test 3 (Dark Gray)	63	255
Test 4 (Dark-Mid Gray)	91	255
Test 5 (Mid Gray)	127	255
Test 6 (Light Mid Gray)	159	255
Test 7 (Light Gray)	191	255
Test 8 (Bright Gray)	223	255
Test 9 (White)	255	255

G2G tests(2/4)

- Test Pattern : CTS1.0 5x5 테이블 → CTS1.1 9x9 테이블

AS1.0
5x5 테이블

8bit Gamma2.2 Code Value	0	63	127	191	255
0	X				
63		X			
127			X		
191				X	
255					X

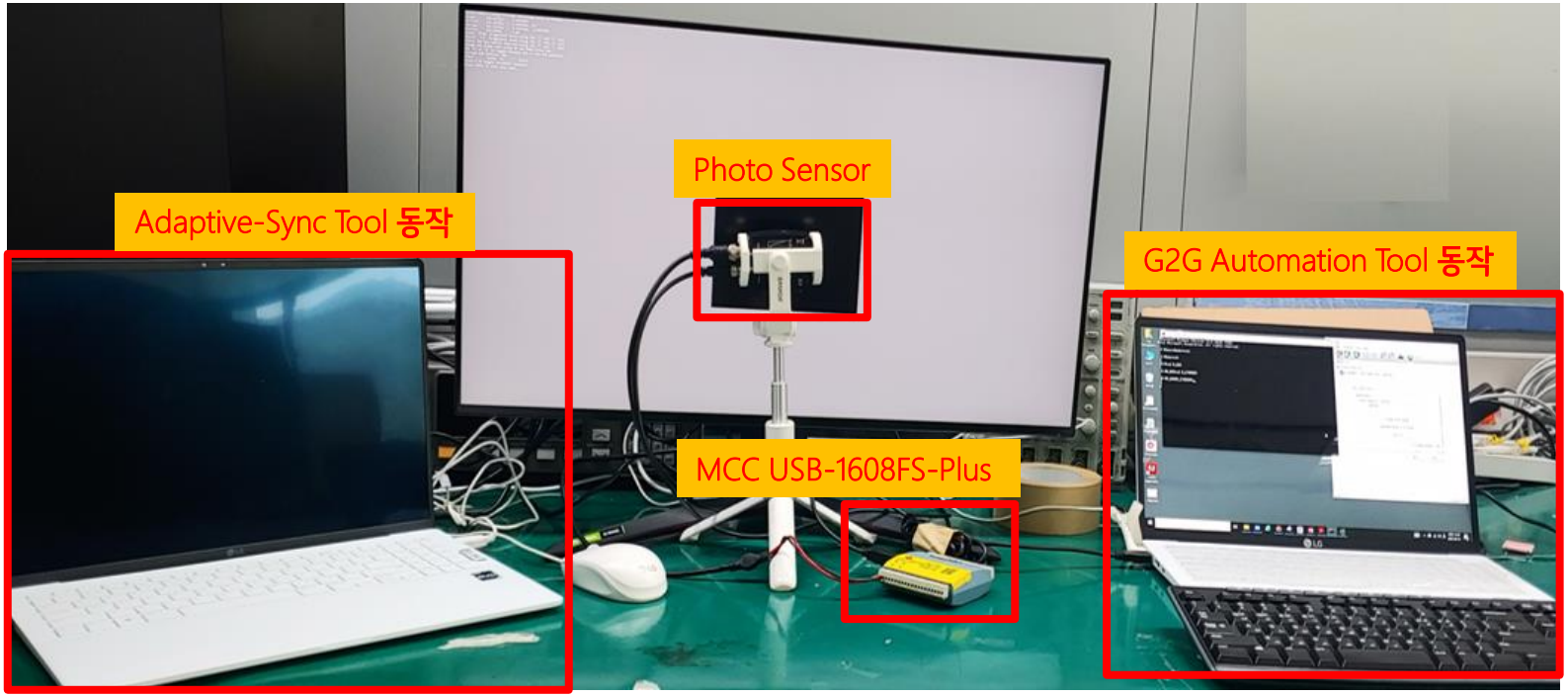
AS1.1
9x9 테이블

8bit Gamma2.2 Code Value	0	31	63	95	127	159	191	223	255
0	X	X							
31		X							
63		X	X						
95		X		X					
127		X			X				
159		X				X			
191		X					X		
223		X						X	
255		X							X

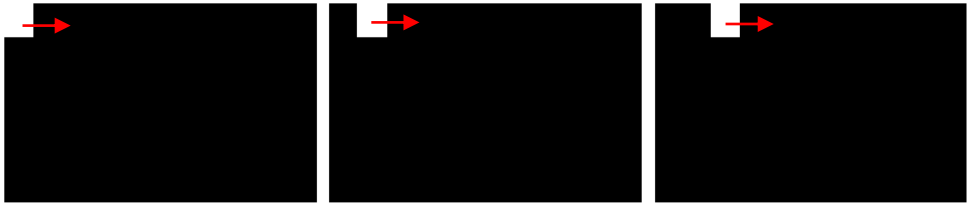
*Tests that end at code value 31 are excluded because at the 1.79 cd/m$_2$ luminance level, testing tools are typically **not** both sufficiently fast and sufficiently accurate to obtain reliable results.*

G2G tests(2/2)

- Tool Setting : MCC USB-1608FS-Plus(DAQ) + Photo Sensor + 노트북 2대

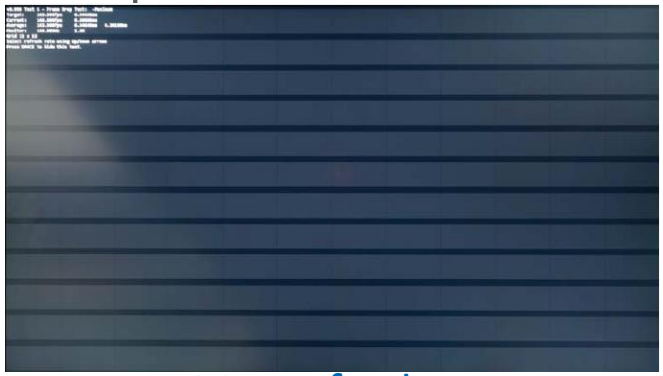


Frame drop tests

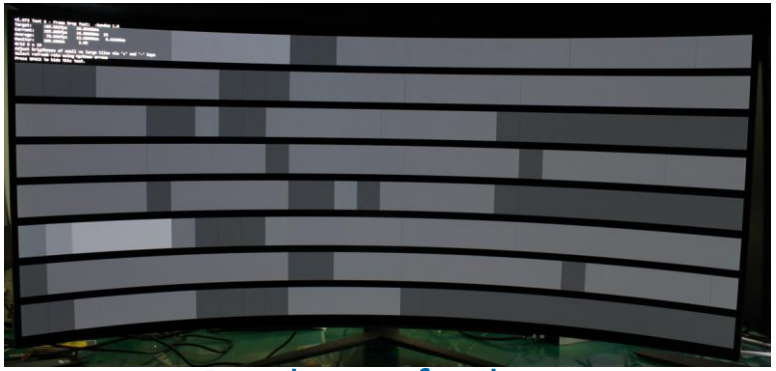


- 목적 : Frame Drop 확인
- Test 환경 : 1개의 White블럭이 Frame당 오른쪽으로 이동
  - Testing frequency : Max refresh rate/ Random refresh rate

- 측정 방법 : 카메라 Shutter Speed를 1초로 설정하고 촬영 후 Drop된 Box가 있는지 확인



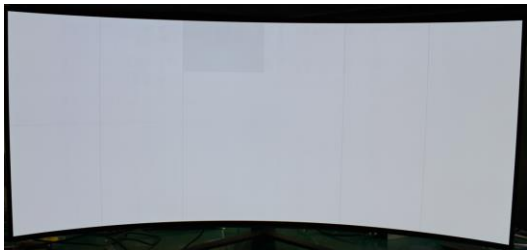
Max refresh rate



Random refresh rate

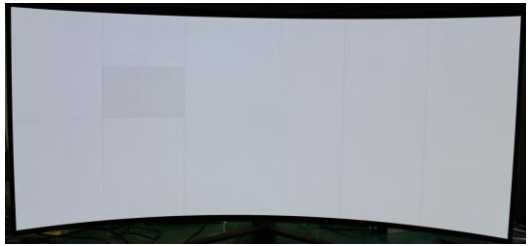
Jitter tests

- 목적 : Video 신호 출력 error확인
- Test 환경 : Frame Drop Testing 패턴과 동일
  - Testing frequency : 23.976, 24, 25, 29.97, 30, 47.952, 48, 50, 59.94, 60Hz
- 측정 방법 : 움직이는 Block을 1초 동안 2번 촬영하여 각 Block의 Luminance 변화가 있는지
  - 포토샵 프로그램에서 Code Value Delta값 확인 가능(자세한 요구사항은 CTS 참조)



촬영1

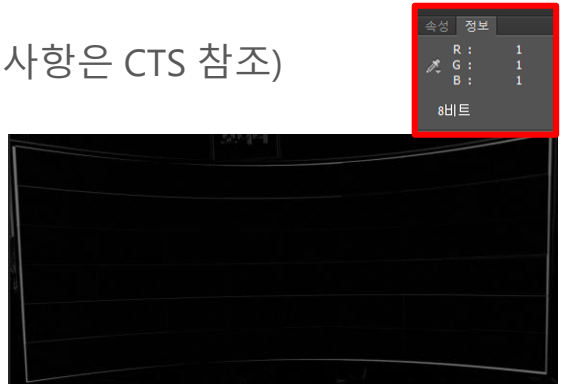
+



촬영2

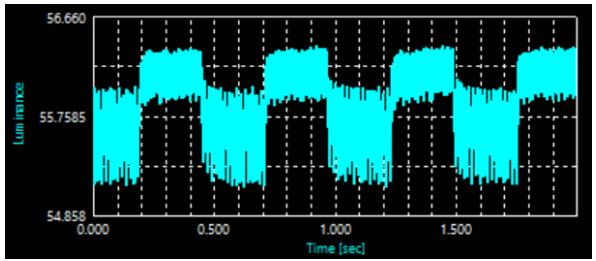
=

포토샵
합성

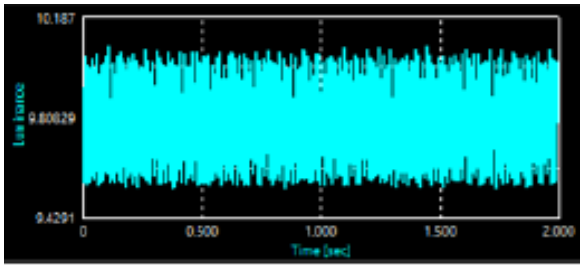


HDR tests

- 목적 : HDR On에서 Frame Rate 변화 여부 확인 SDR만 지원 시 Test 하지 않아도 됨
- Test 환경 : Flicker testing에서의 Square Wave 사용
- 측정 방법 : Frame Rate에 따른 Luminance 변화 Pattern이 일정 한지 확인



Pass



Fail

VESA

Q&A

ClearMR Specifications and Compliance Testing Overview

Presented by Dr. Yongwoo Yi, Principal Engineer, Samsung Display

VESA Seoul Workshop 2023

ClearMR

: Specifications and Compliance Testing Overview

October 10, 2023

Yongwoo Yi
Samsung Display Co. Ltd.

SAMSUNG

SAMSUNG DISPLAY

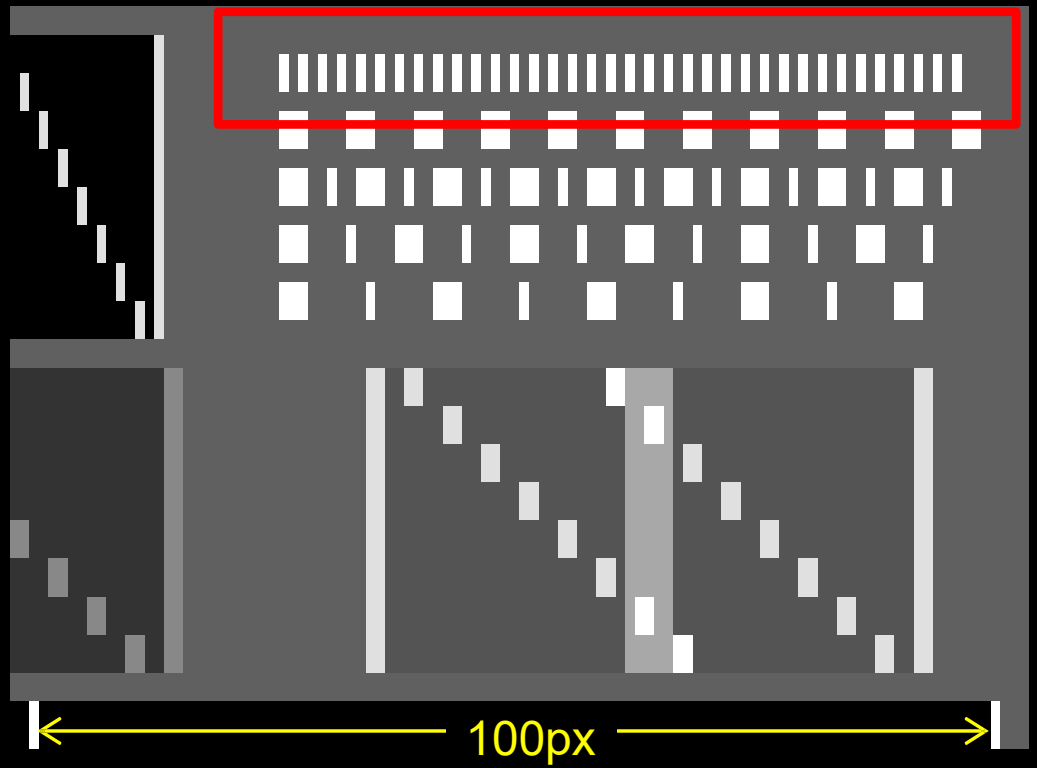
ClearMR™

Table of Contents

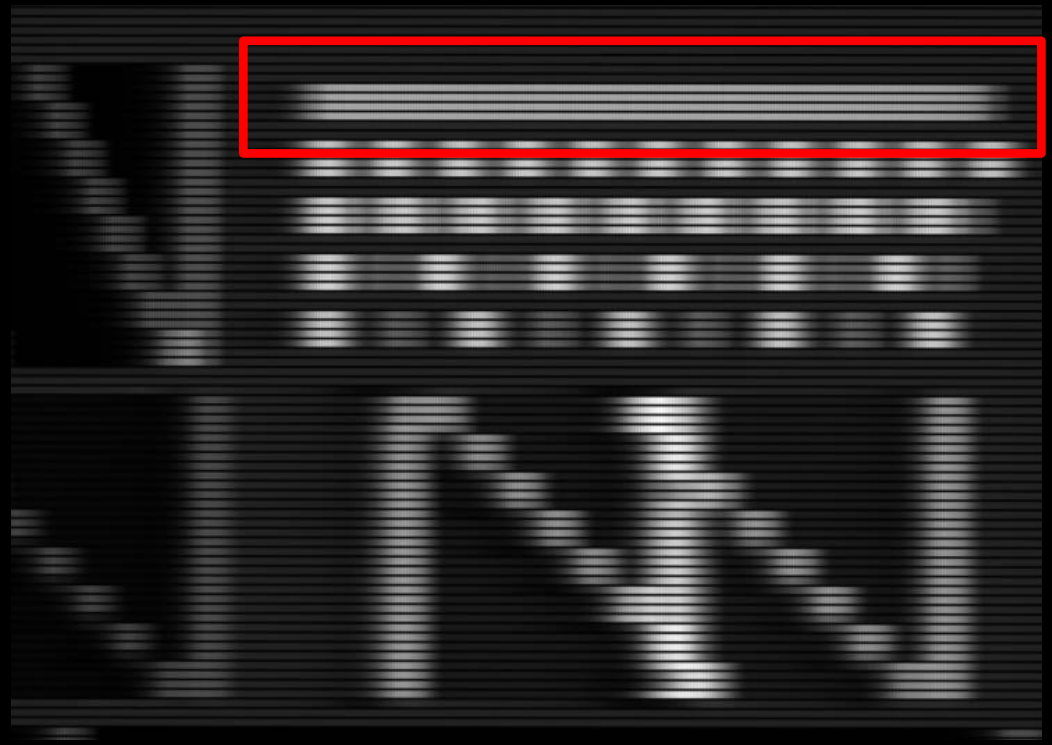
ClearMR™

Introduction

Blur beyond recognition

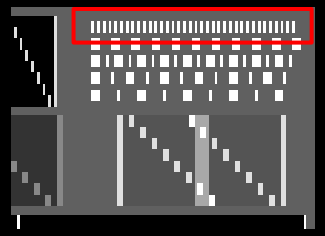


still frame of the actual pattern

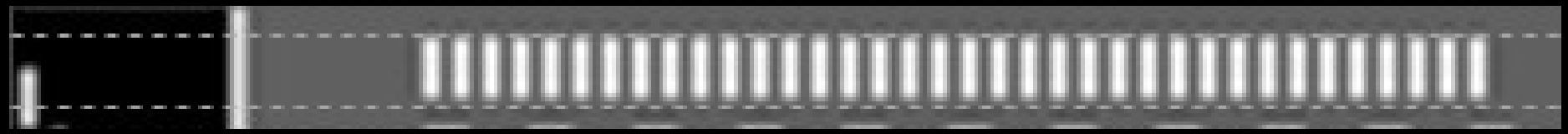


motion composite showing blur similar to what humans might see

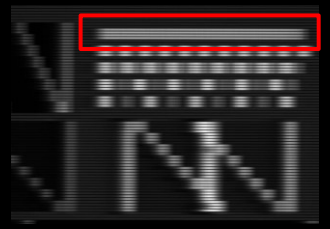
Blur beyond recognition

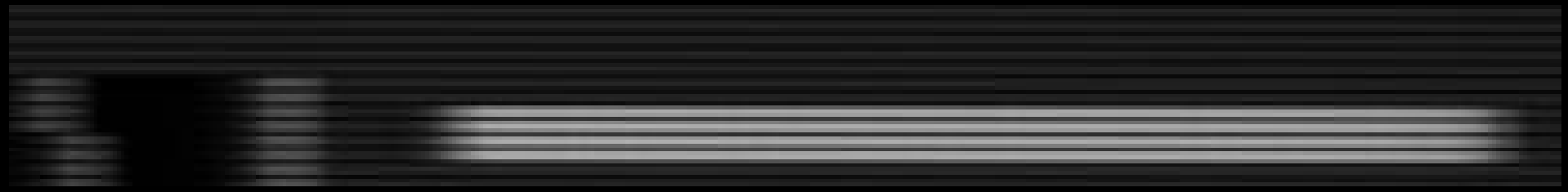


Actually, vertical lines 2 pixels wide, 2 pixels apart



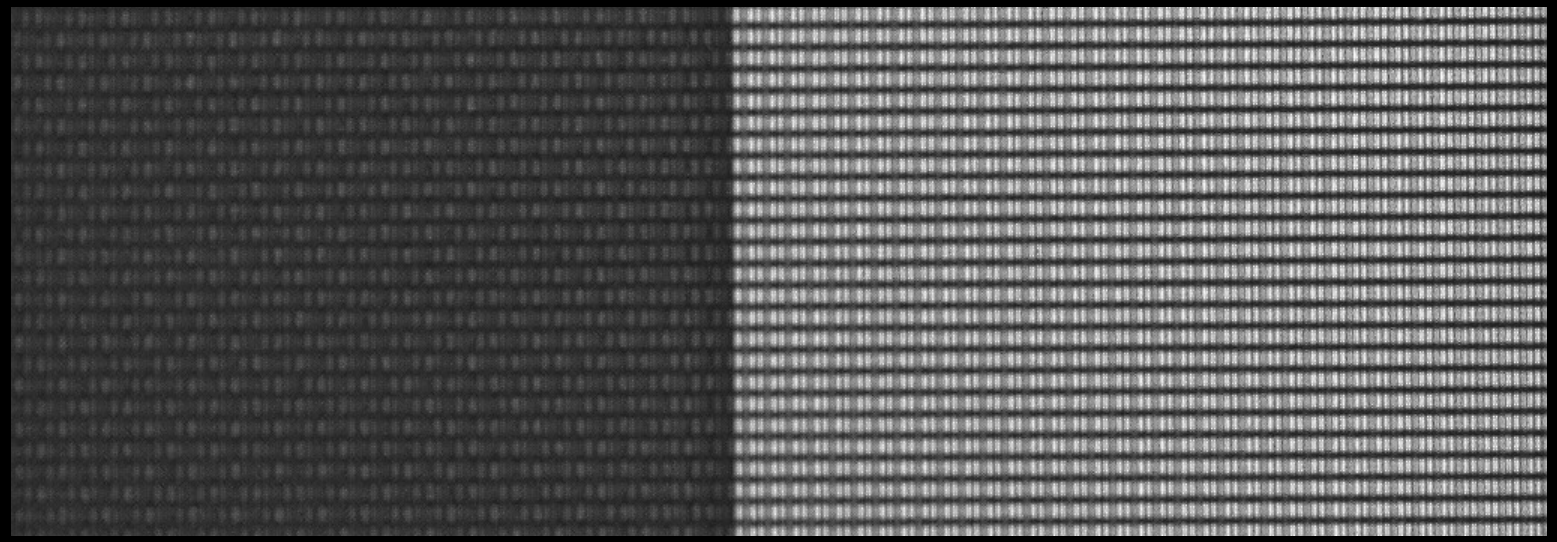
Horizontal lines?





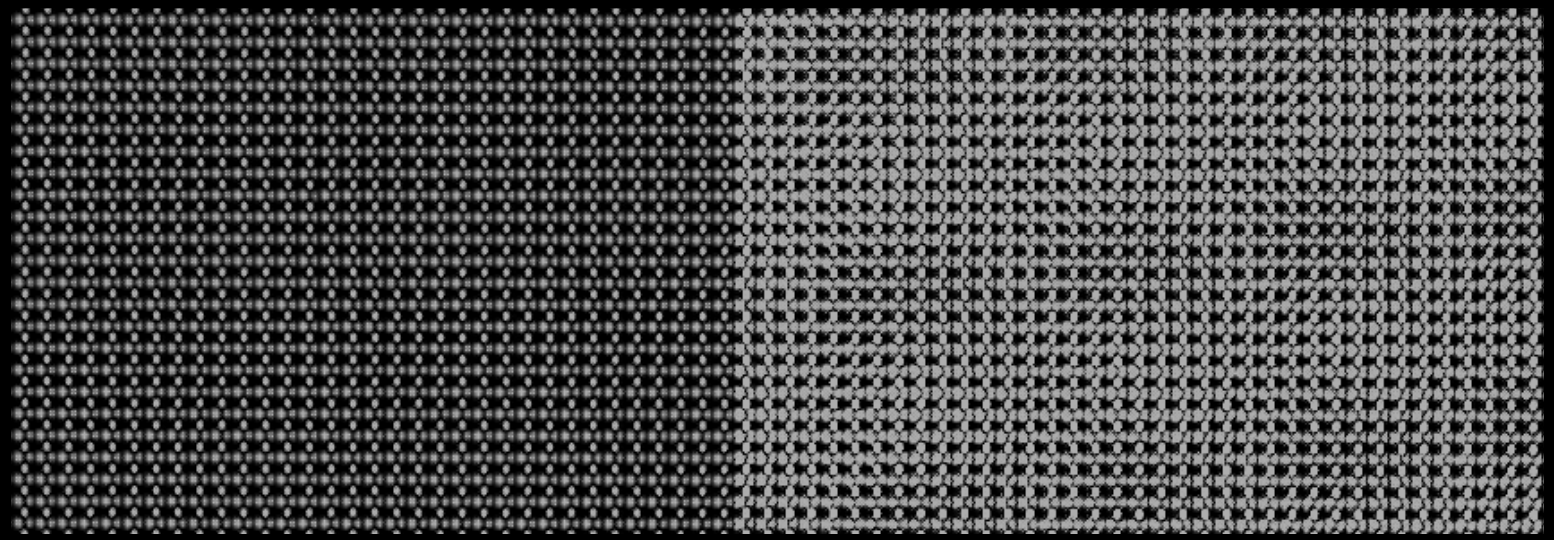
Product A
240Hz

10000 / 240 = 41.67



Product B
175Hz

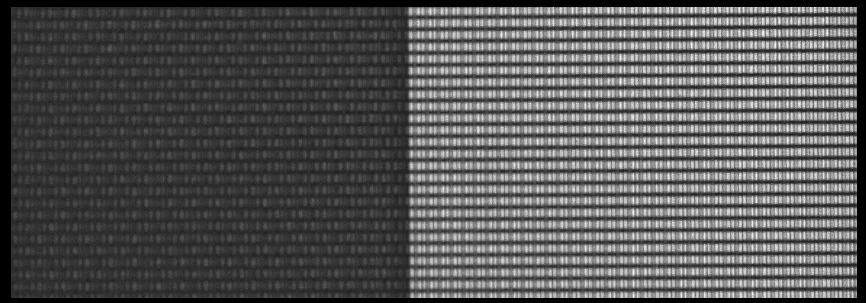
10000 / 175 = 57.14



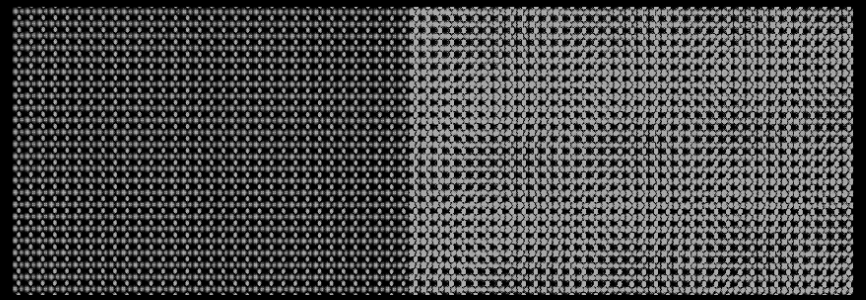
* 1 frame Captured by High-Speed Camera(10,000 fps)

The problem statement

- **How blurry is the picture**
- Is blur by Product A the same as blur by Product B?
- What metric/method is best for quantifying blur?
  - Hertz (Hz)
  - milliseconds (ms)
  - G2G? MPRT?



Product A [240Hz]

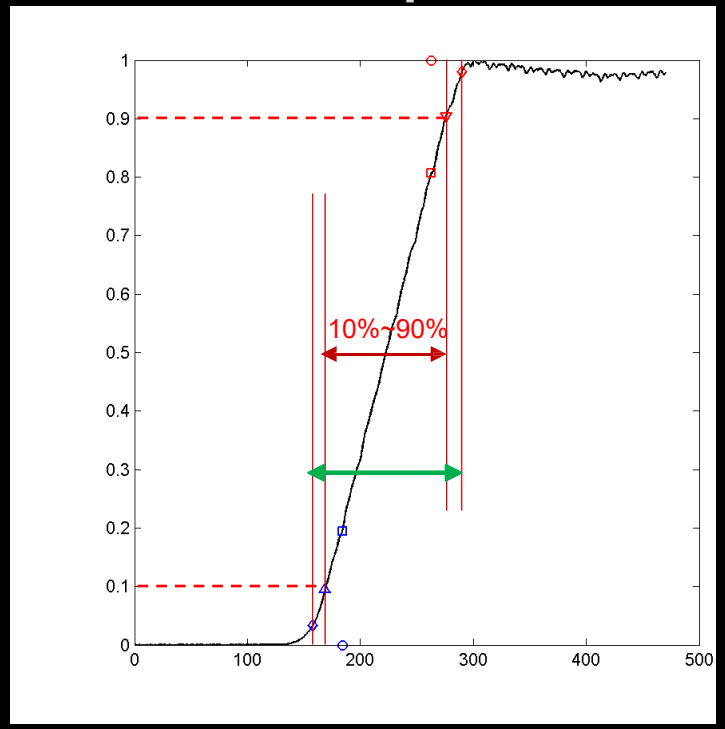


Product B [175Hz]

Blur vs. MPRT(Moving Picture Response Time)

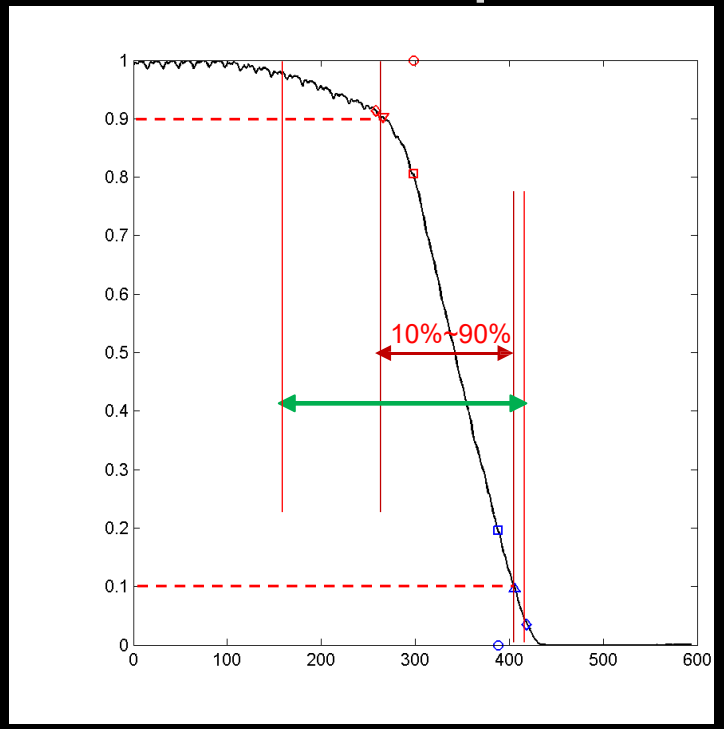
- **MPRT [ms]**
  - only analyzes 80% of light
  - Incorrectly assumes linearity outside of 10% and 90%

Linear blur profile



$$blur\ profile \sim k_{scale} \times MPRT$$

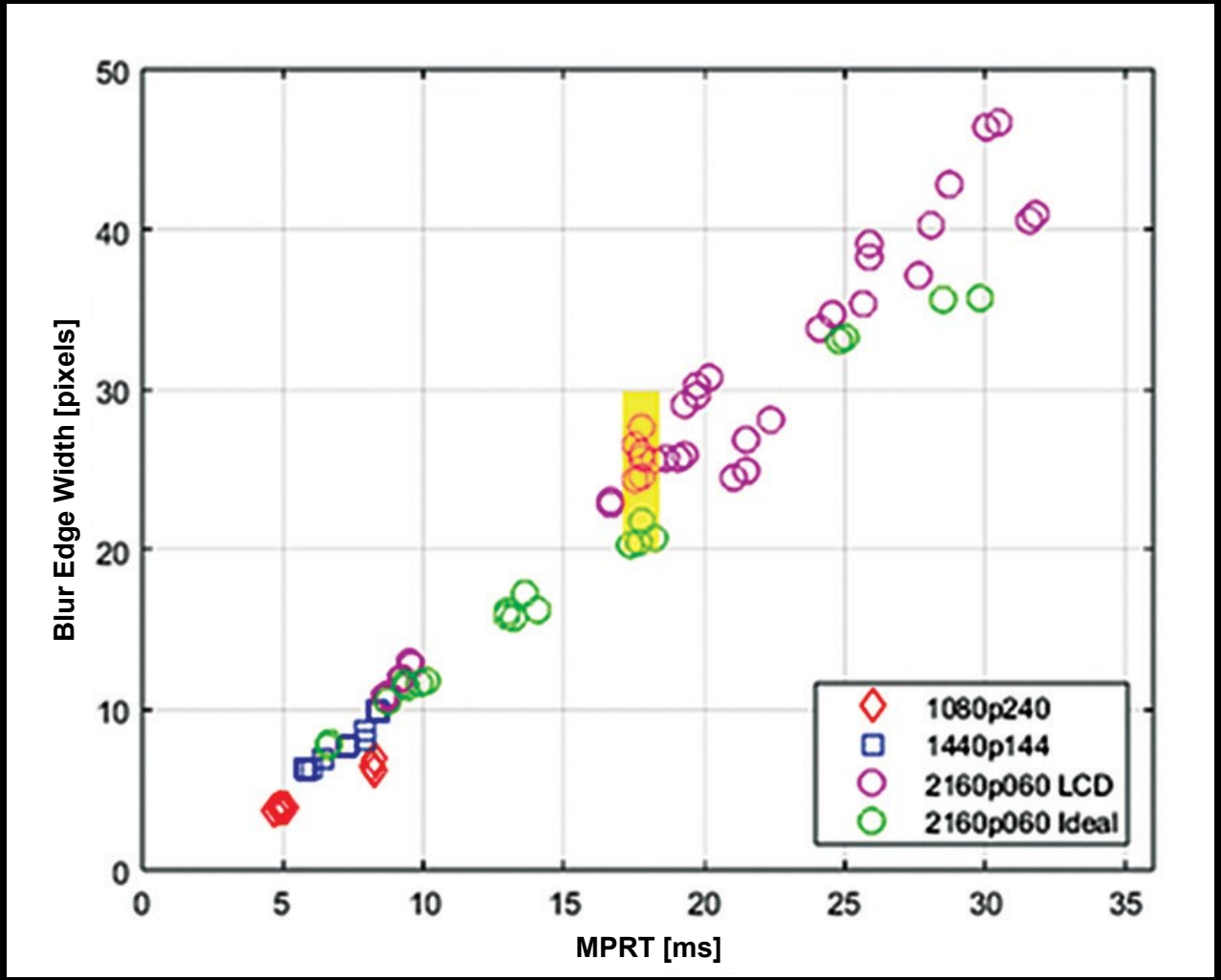
Non-linear blur profile



$$blur\ profile \neq k_{scale} \times MPRT$$

Blur vs. MPRT(Moving Picture Response Time)

Blur Edge Width vs. MPRT



A new metric : Clear Motion Ratio (CMR)

- **No objective blur description**
  - Gray-to-gray is a step response, do not explain the full picture
  - MPRT only analyzes 80% of light
- **A new metric must:**
  - Capture all the display light output
  - Be suitable for high density displays > 300 ppi
  - Be repeatable
  - Make fair points of comparison (eg. Limit overdrive to eliminate ghosts)

√ ClearMR uses the new Clear Motion Ratio (CMR) for a *better* and *fairer* measure of display blur.

ClearMR™

Methods

01 Problem statement

02 Clear Motion Ratio design

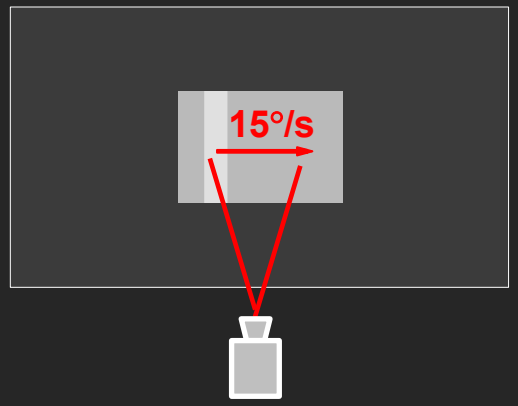
03 Setup for testing: Hardware and Software

04 Seeing is believing

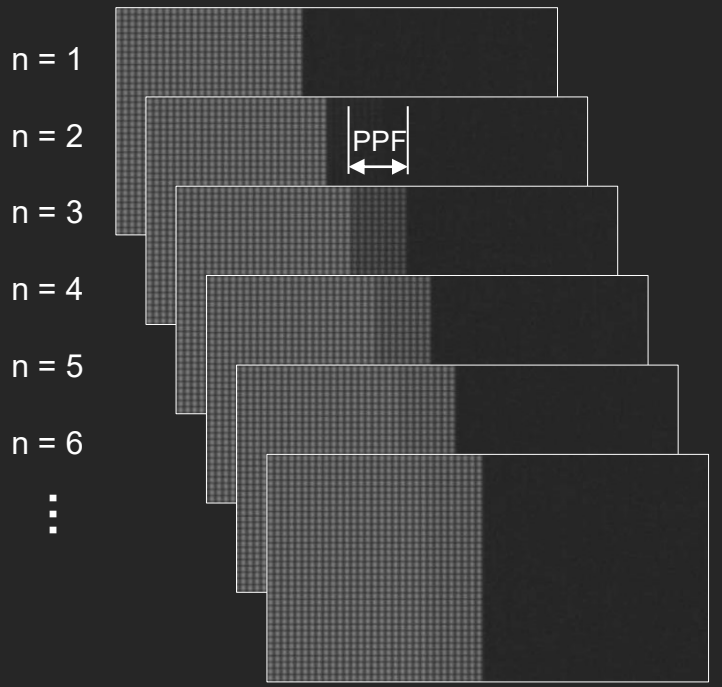
ClearMR : Theory of Operation

Concept

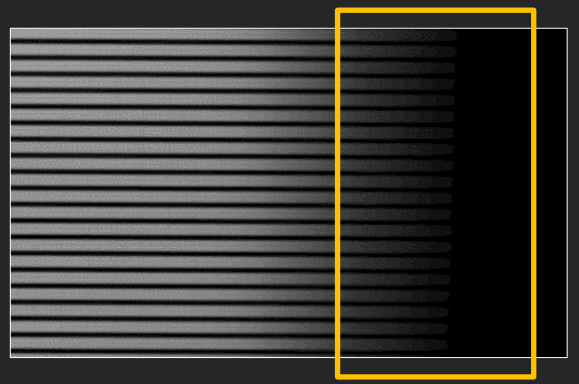
Test pattern and capture



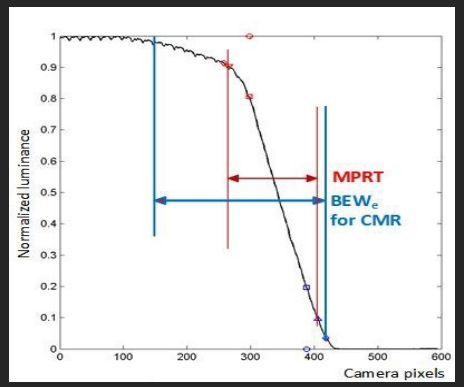
Frame stack



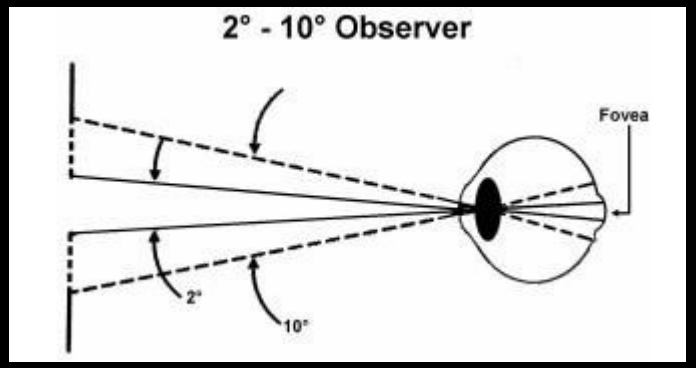
Blur image composition

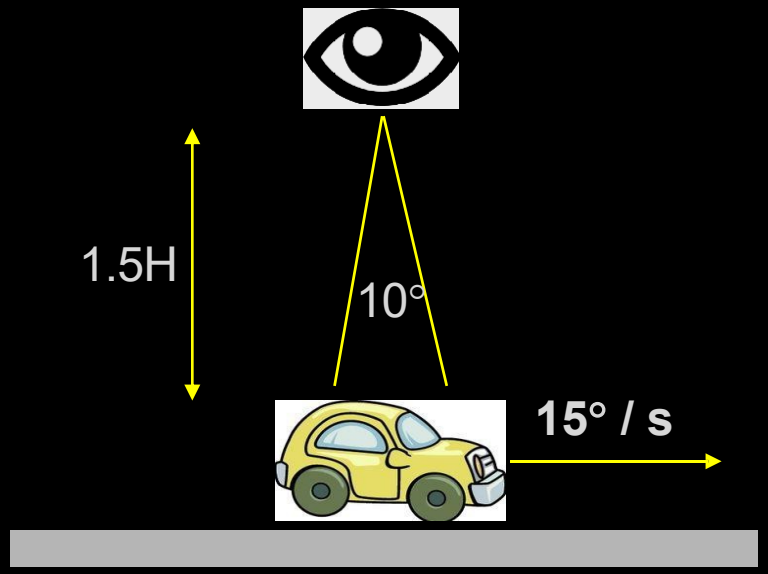


Blur profile



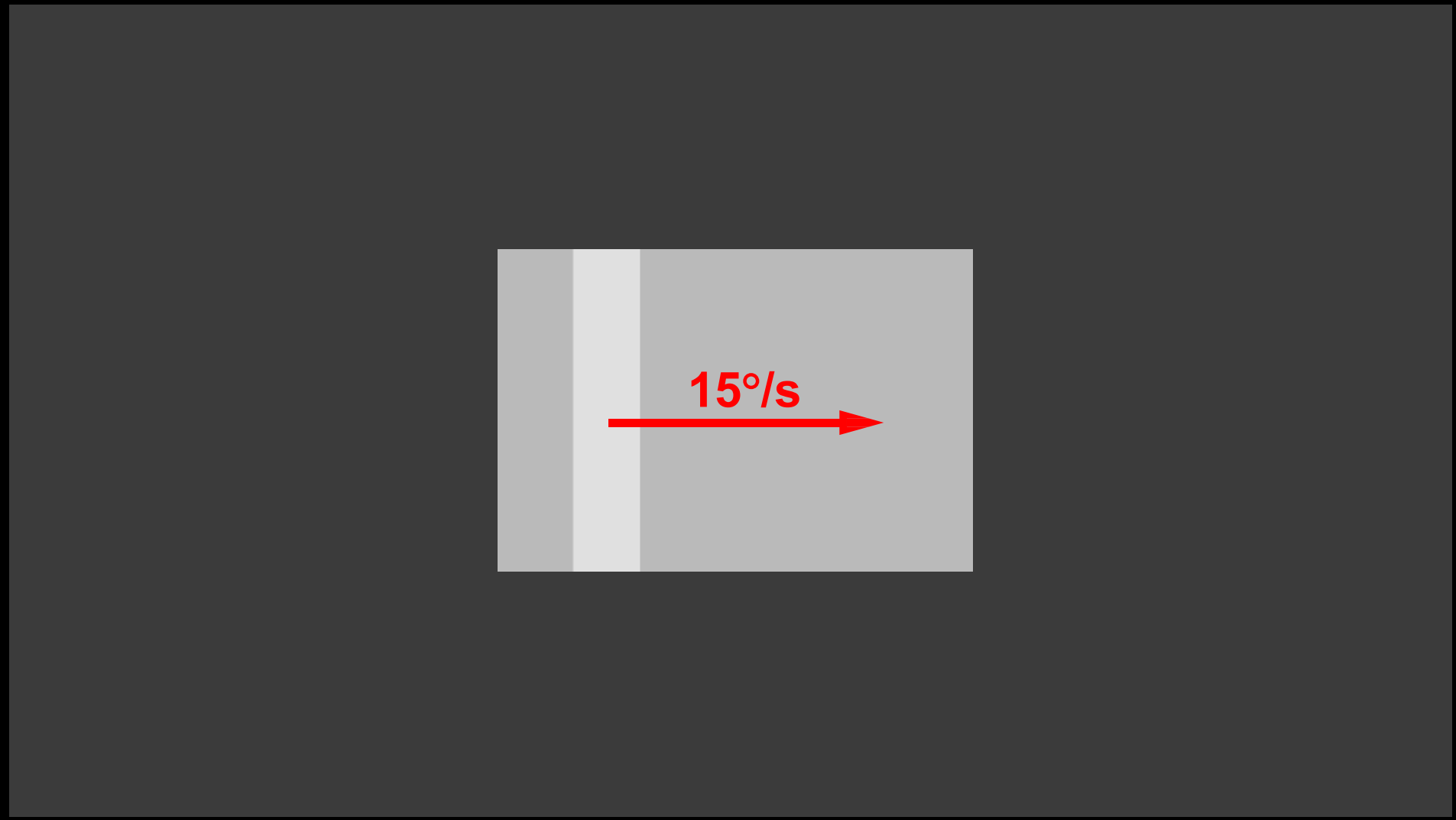
Concept



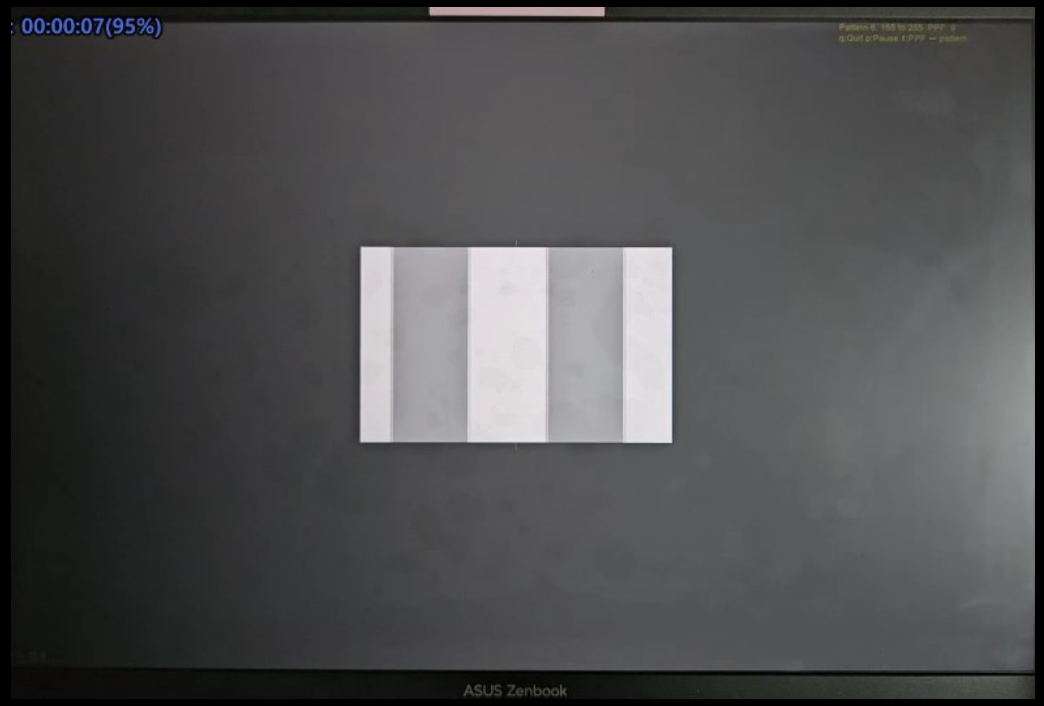


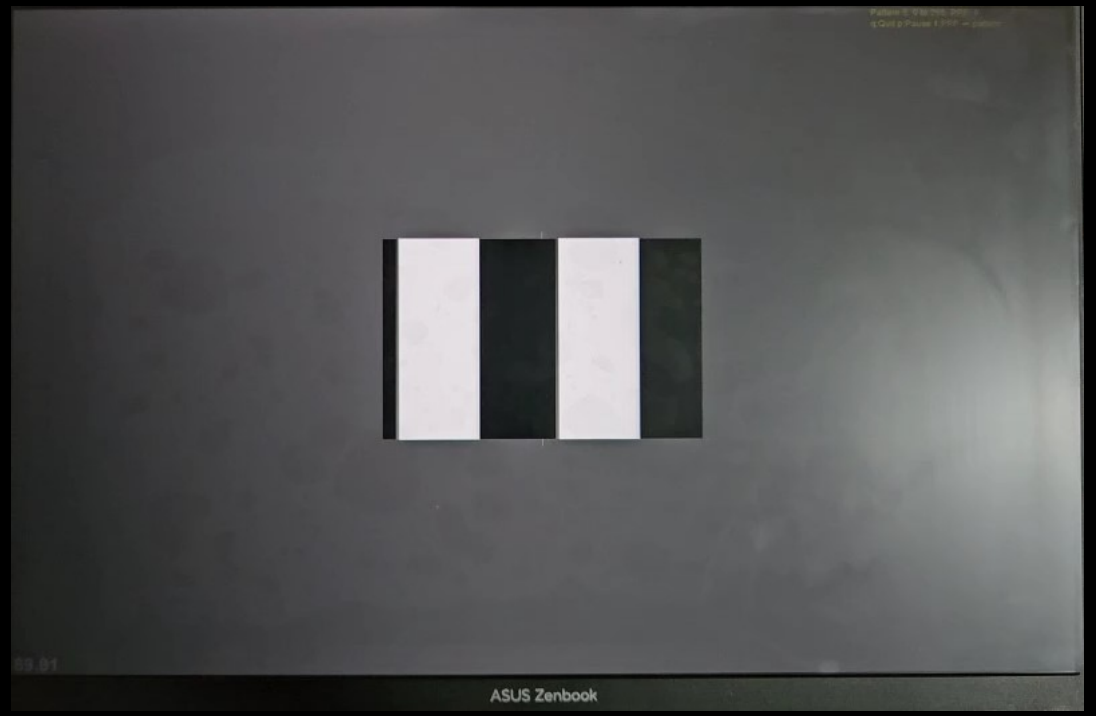
- **Determine pixels viewed when eye tracking**
  - Use a focus area similar to the CIE Standard Observer
    - **10** ° field of view good for motion
    - 2 ° model would apply to fixed objects
  - Viewing distance at **1.5H**(height)
  - Fast motion but does not exceed human tracking capability
    - **15°/s** angular velocity (v_θ)
    - ~4s to cross a 16:9 screen (61.3 °)

Test pattern



Test pattern





Patten speed : PPF

Calculator and table to determine an applicable PPF. The DUT may only use integral PPF values

v1.2.01 2023-04-02 *Please edit only green values*

vϑ [deg/s]	*FPS* [Hz]	*hres* [pixels]	*vres* [pixels]	*dv* [H]	*AR* [ratio]	*PPF(REAL)* [pixels/frame]	*floor(PPF)* [pixels/frame]	*ceil(PPF)* [pixels/frame]
15	60	1920	1080	1.5	1.78	7.830	7	8
15	60	3840	2160	1.5	1.78	15.660	15	16
15	120	1920	1080	1.5	1.78	3.915	3	4
15	120	3840	2160	1.5	1.78	7.830	7	8

- 15° / s → PPF (pixel per frame)
- Calculated PPF is Real number → flooring & ceiling
- **Logarithmic Interpolation**

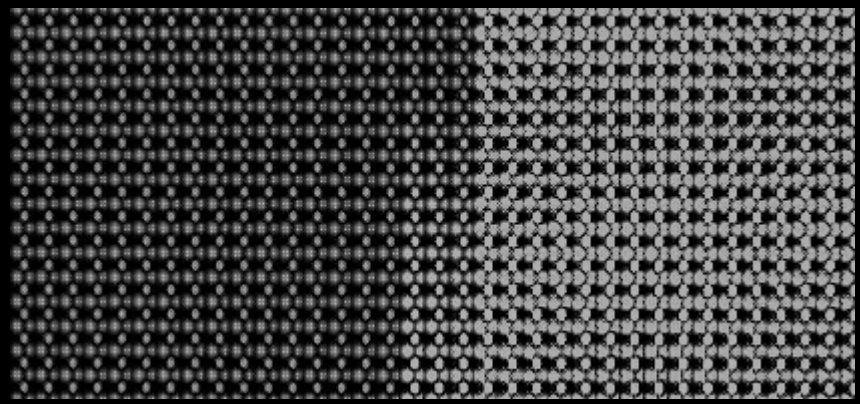
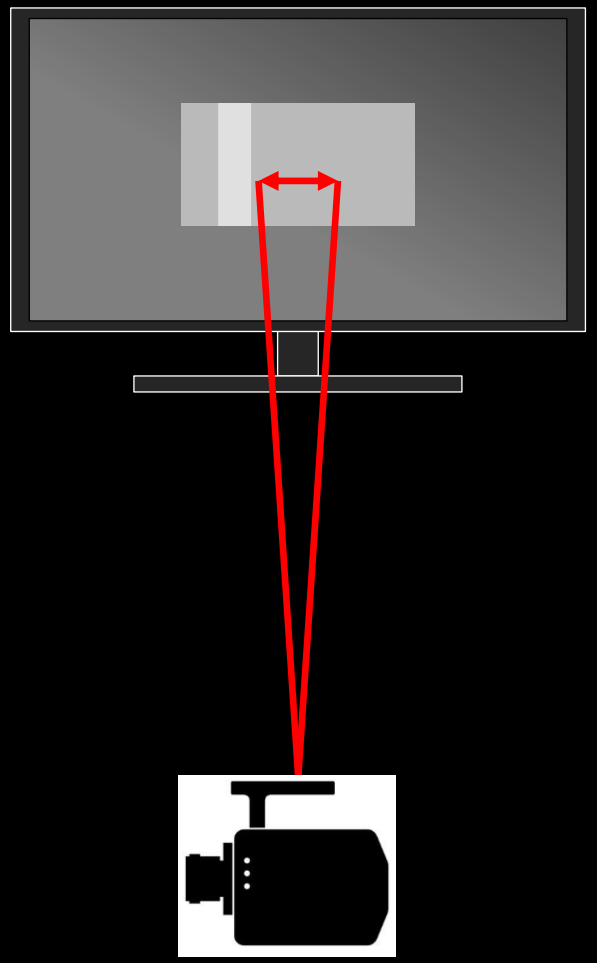
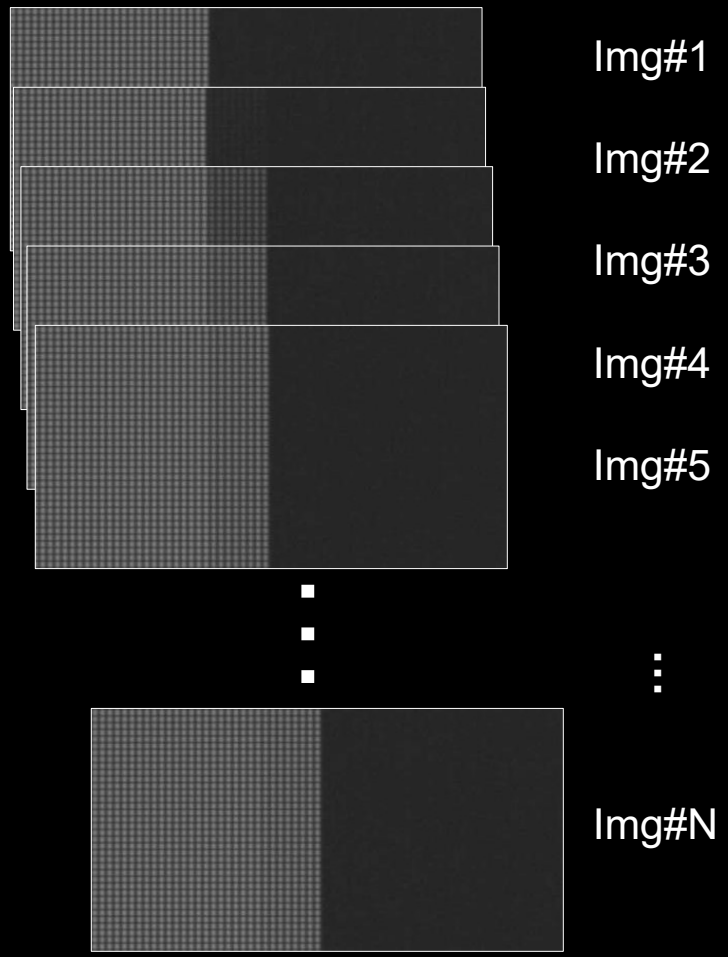


Image captured by high-speed camera



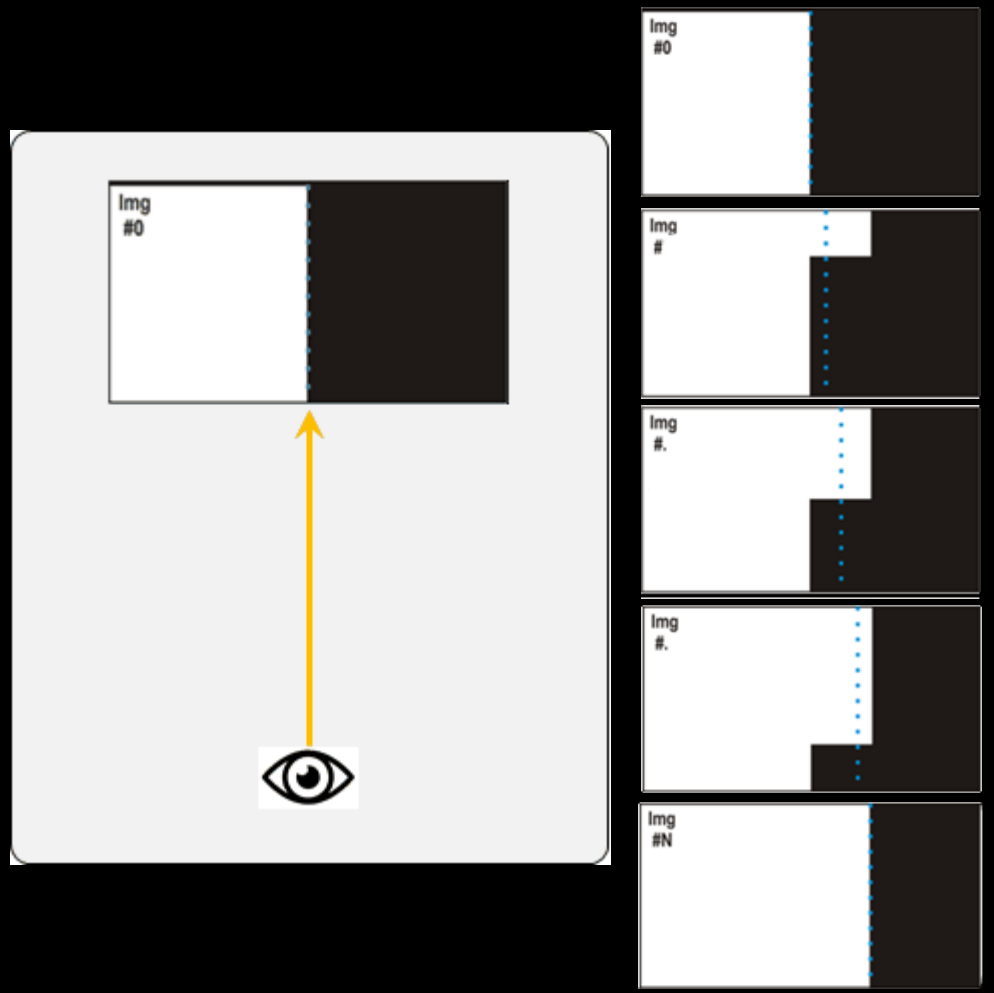
High-speed Camera

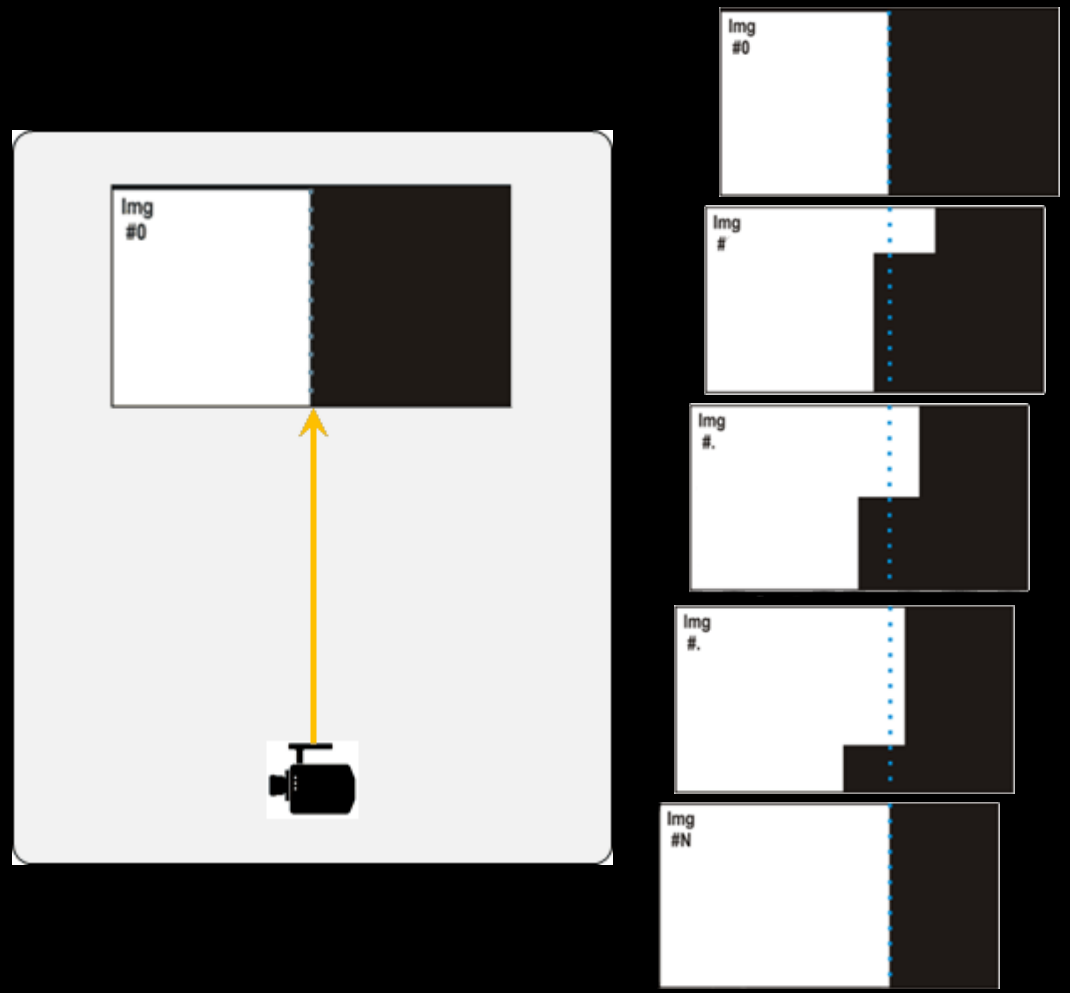


1 frame captured by high-speed camera

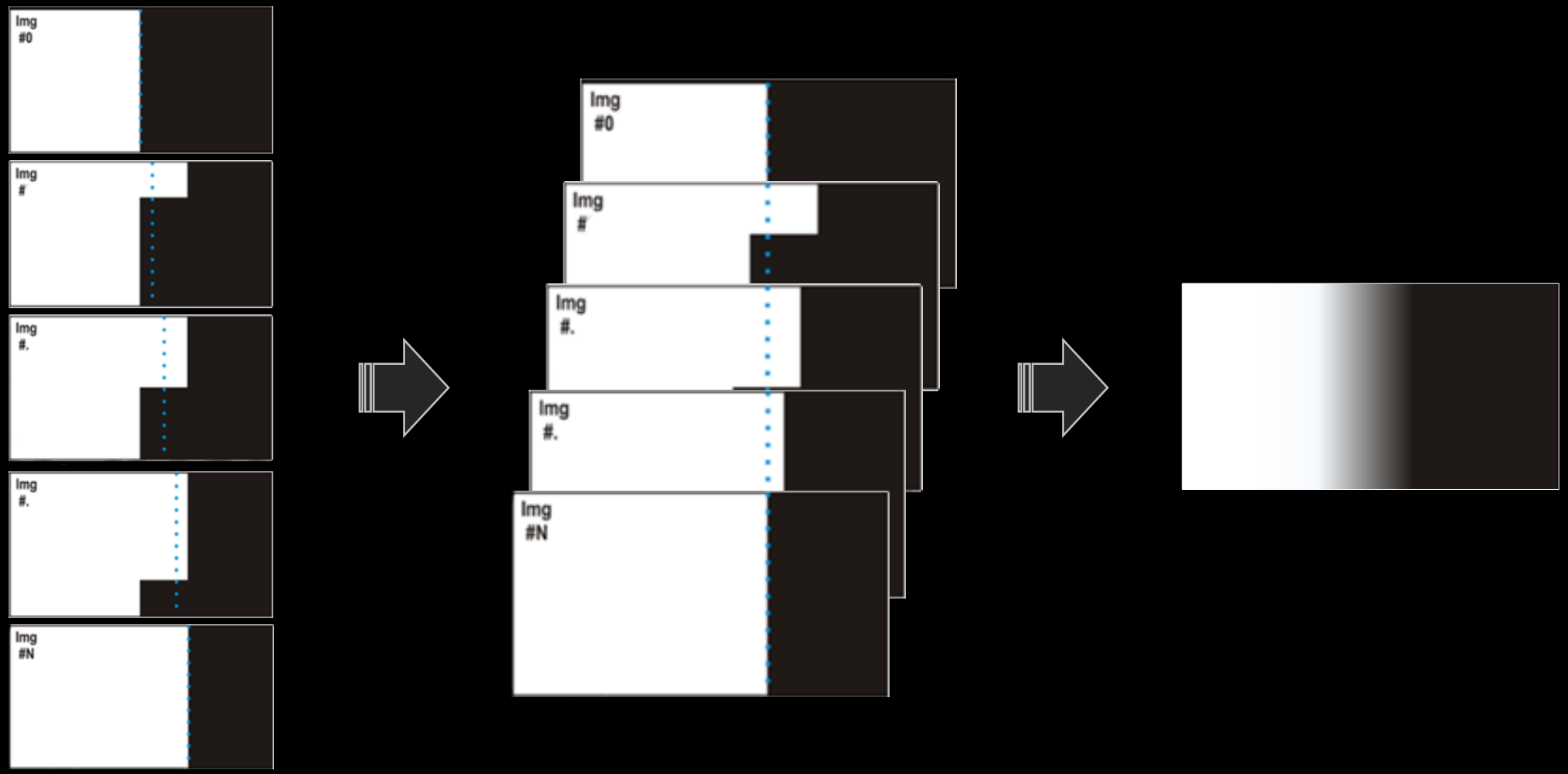
ex) 240Hz monitor with 10,000fps camera → N = 10000/240 = 41.67

Blur image composition

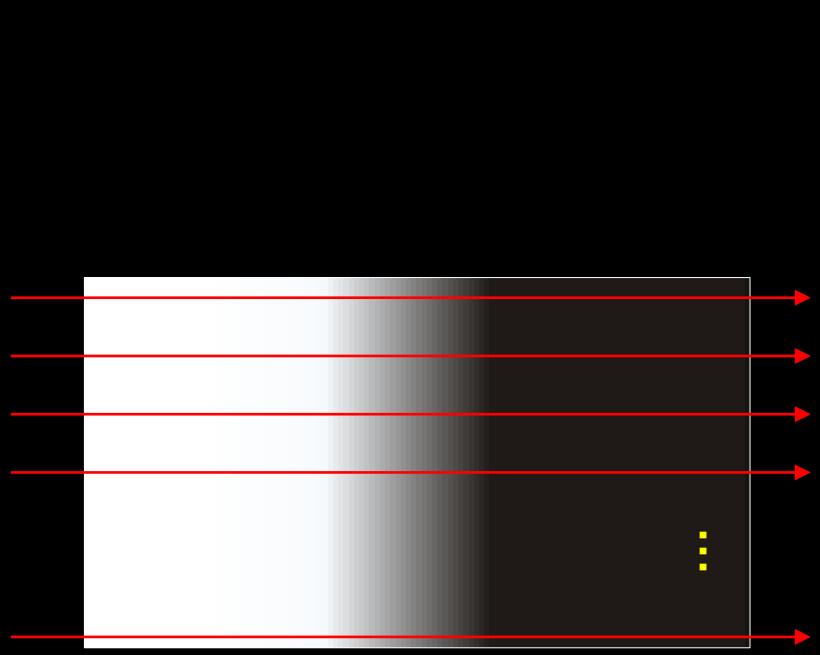


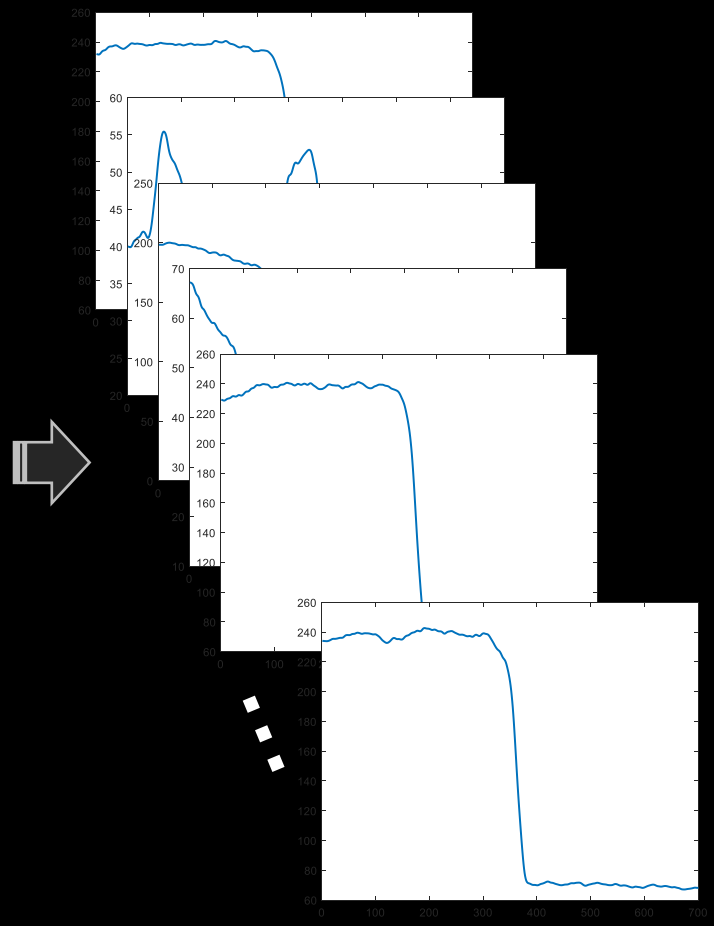


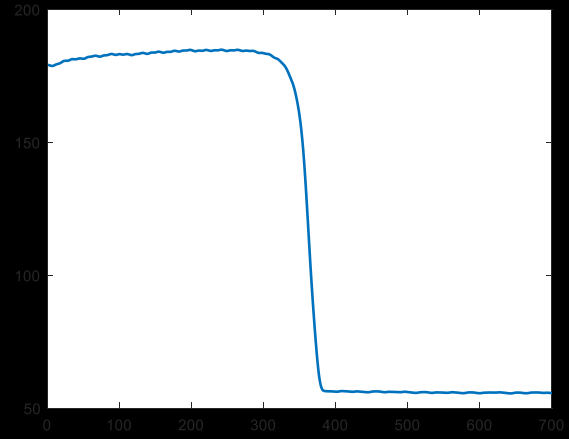
Blur image composition



Blur profile

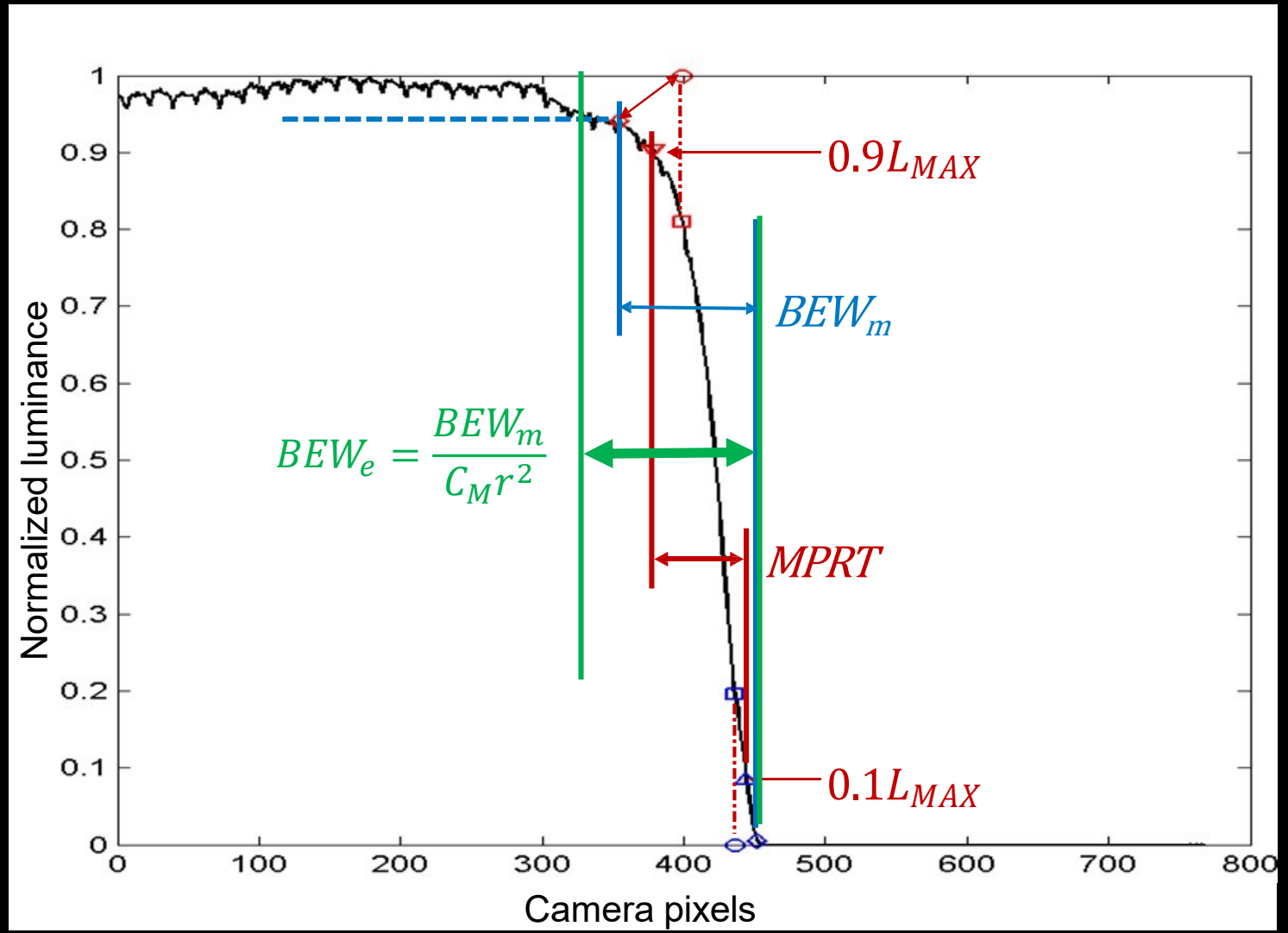






blur profile
= Vertically averaged blur image

Profile identifies the Blur Edge Width (BEW)

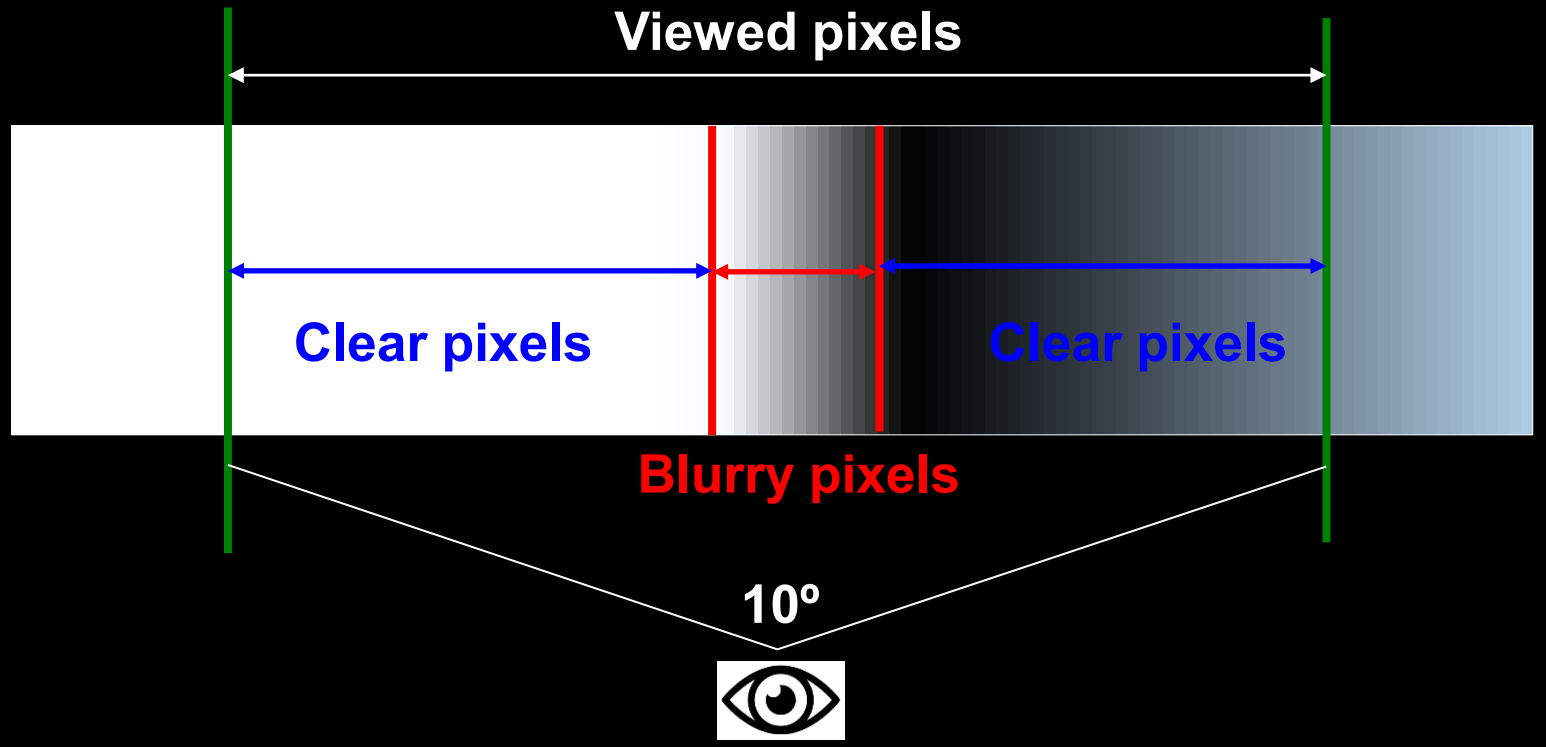


- Accounts for non-linearity
- Accounts for light outside of BEW_m
- Challenge: calculation should include all luminance change
- BEW_m is between the knees (◊) of the profile
- BEW_e corrects for non-linearity of the profile locus outside of BEW_m

  * BEW_m : measured BEW
  * BEW_e : effective BEW
  * C_m : contrast modulation
  * r^2 : coefficient of determination

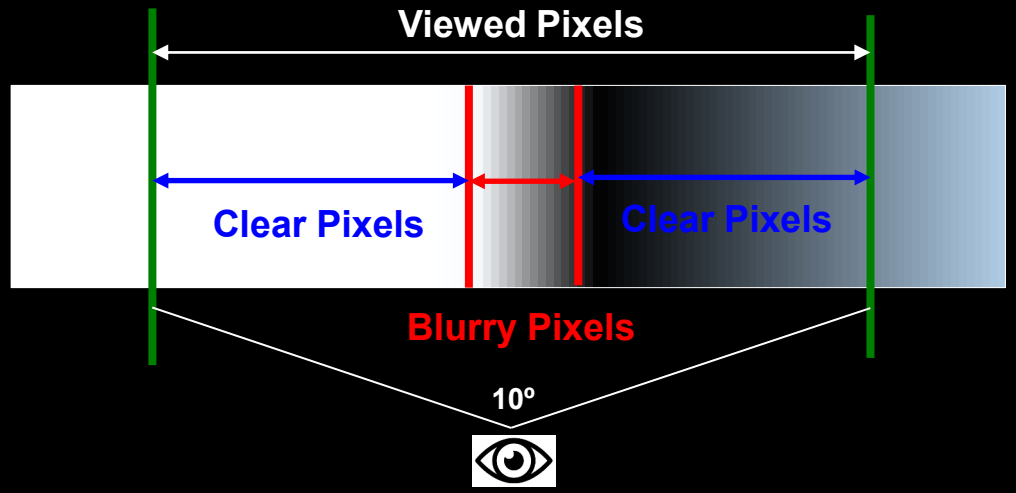
CMR(Clear Motion Ratio)

Clear Motion Ratio : Ratio of *Blurry pixels* and *Clear pixels* in a *10°* FOV with Viewing distance at *1.5H*

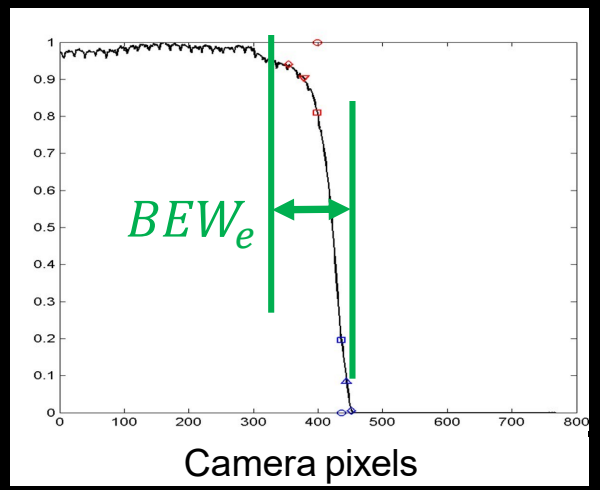


$$\mathrm{CMR} = \frac{Clear\ pixels}{Blurry\ pixels}$$

CMR(Clear Motion Ratio)



$$\text{CMR} = \frac{\textit{Clear pixels}}{\textit{Blurry pixels}}$$



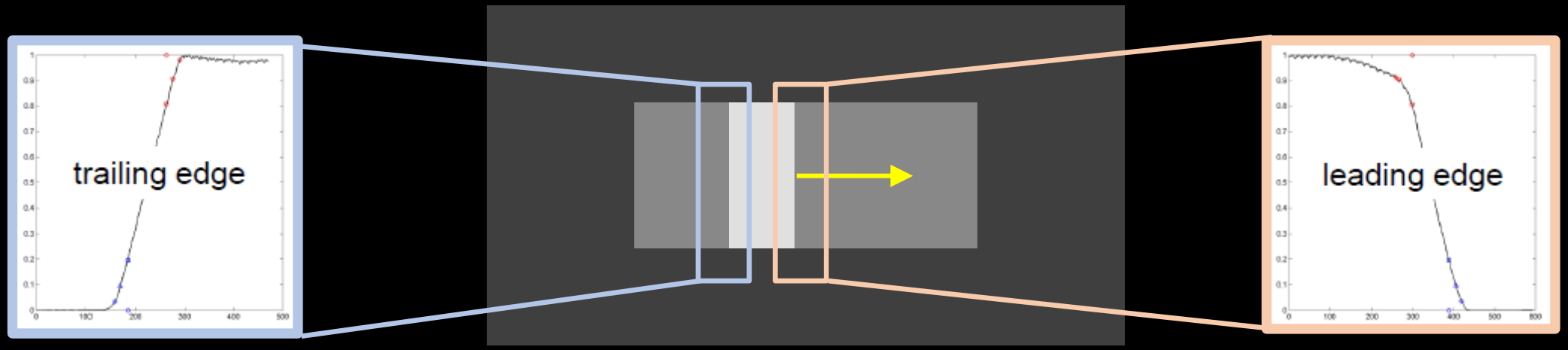
$$\textit{Viewed pixels} = 2d_v v_{res} \tan\left(\frac{arc}{2}\right)$$

$$d_v = 1.5H$$
$$v_{res} = \textit{Display Vertical Resolution}$$
$$arc = 10°$$

$$\textit{Blurry Pixels} = BEW_e$$

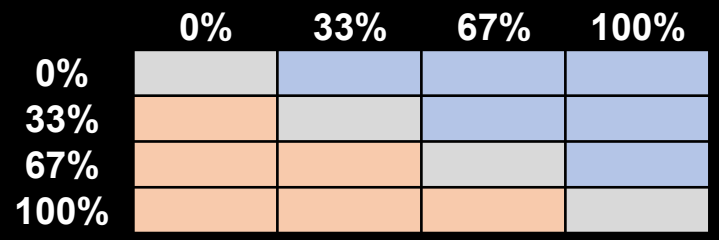
$$\textit{display pixels} = \textit{camera pixels} \times \frac{\textit{display pixel density}}{\textit{camera pixel density}}$$

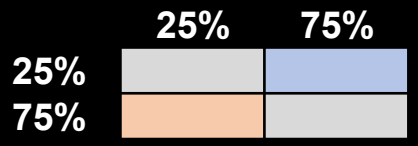
Rising and Falling (Leading and Trailing)

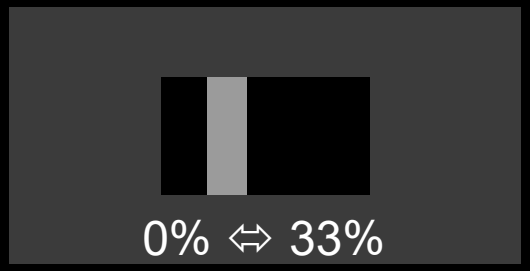


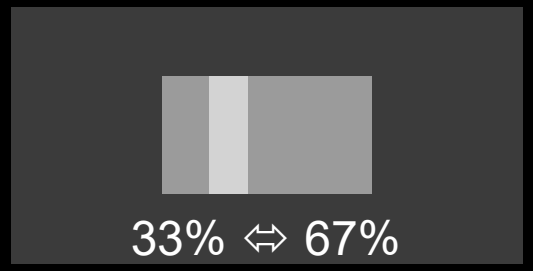
	Leading			Trailing	
	0%	33%	25%	67%	75%	100%
0						
25%						
33%						
67%						
75%						
100%						

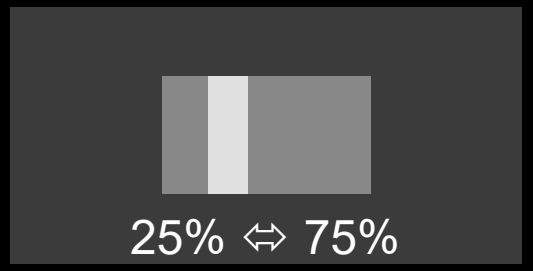
Rising and Falling (Leading and Trailing)

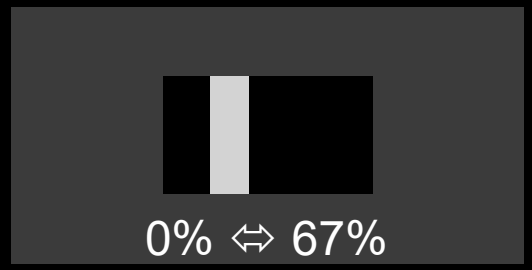


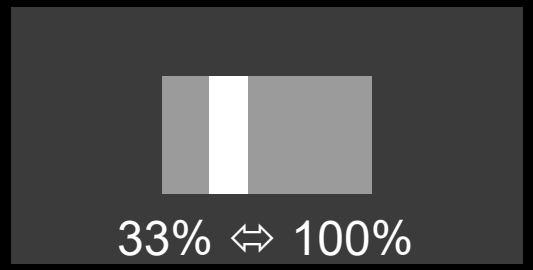


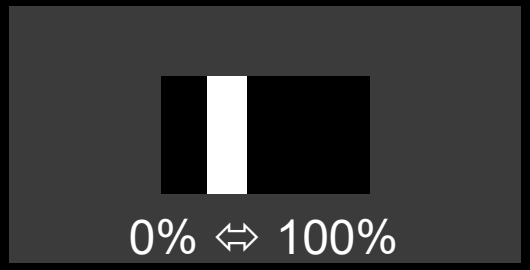


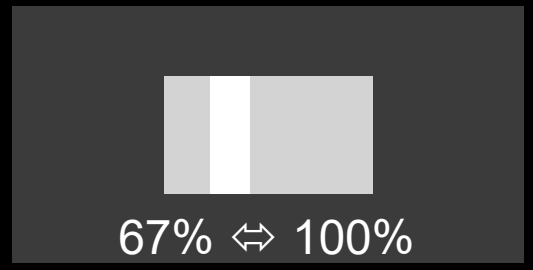


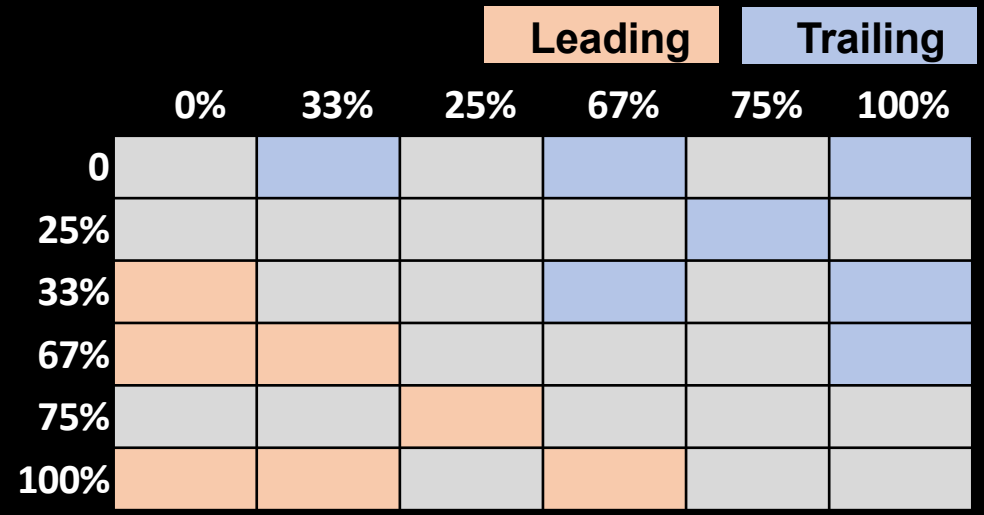






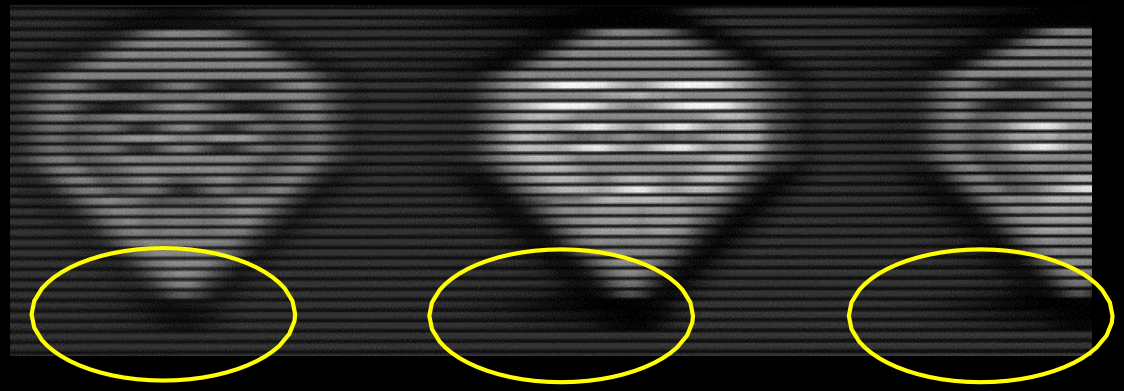


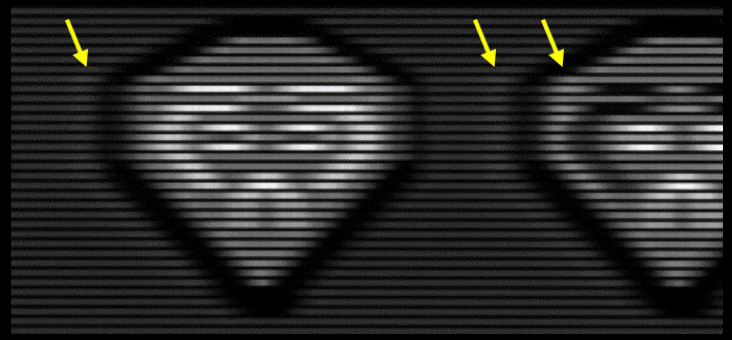




Ghosts and coronas

- **Ghosts**
  - Uneven transitions
  - Trailing artifact
  - Usually, a dark trail
- **Coronas**
  - Inverse of ghosts
  - Over-shooting the final pixel value
  - A trailing glow

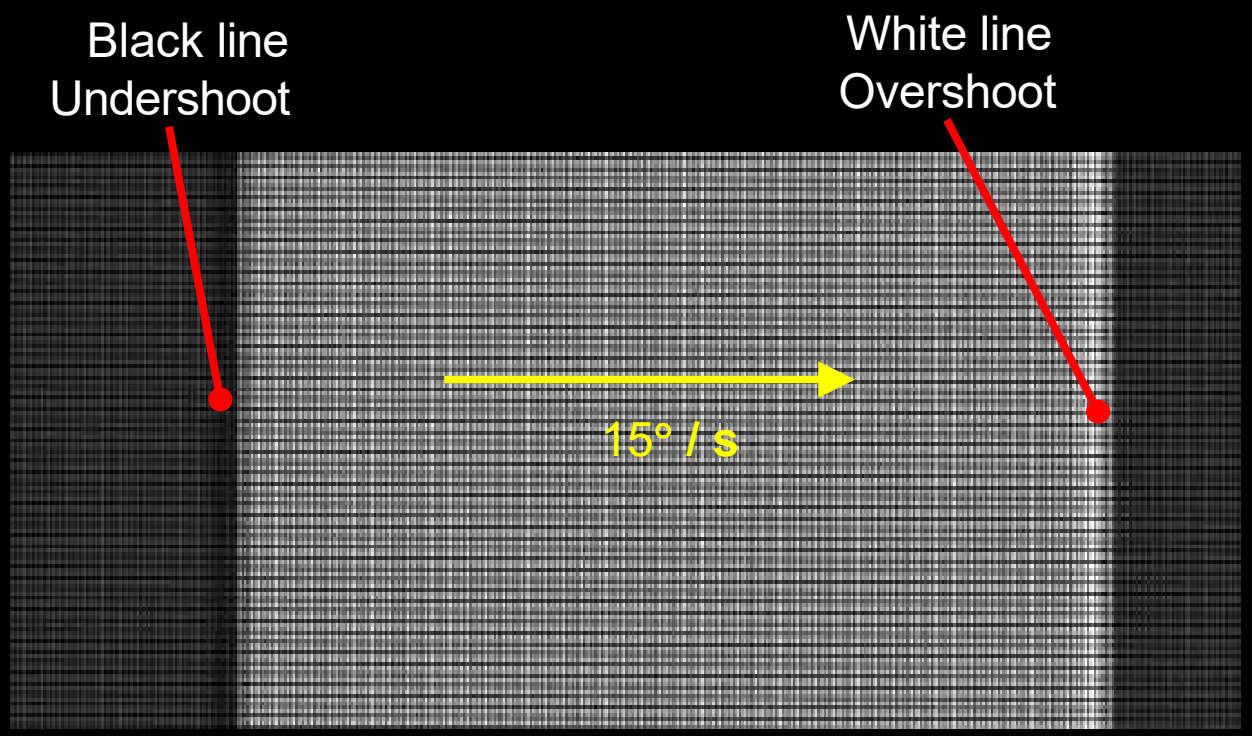


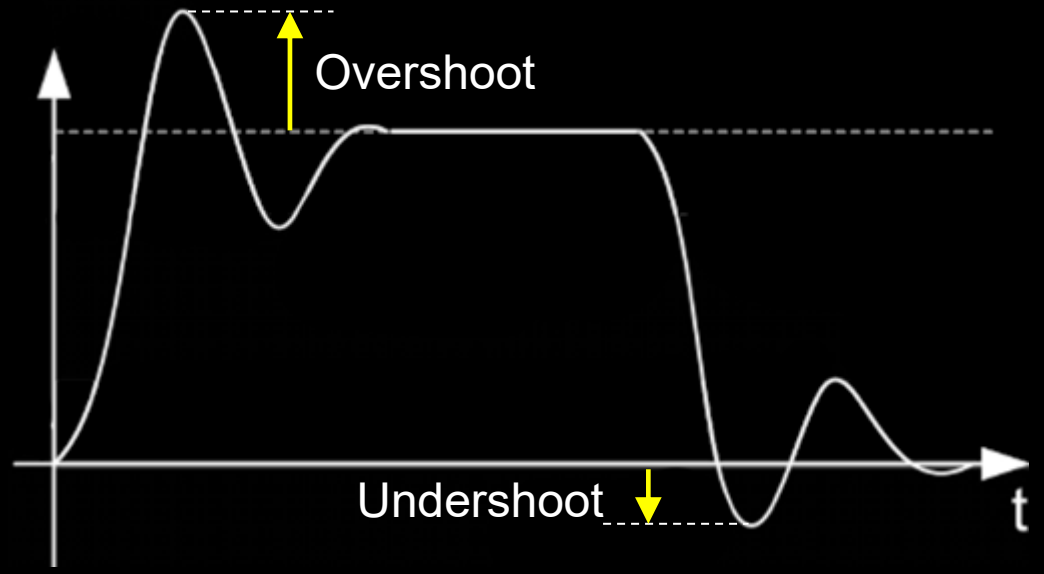


Working definitions by Mark Rejhon (2021)[1]…

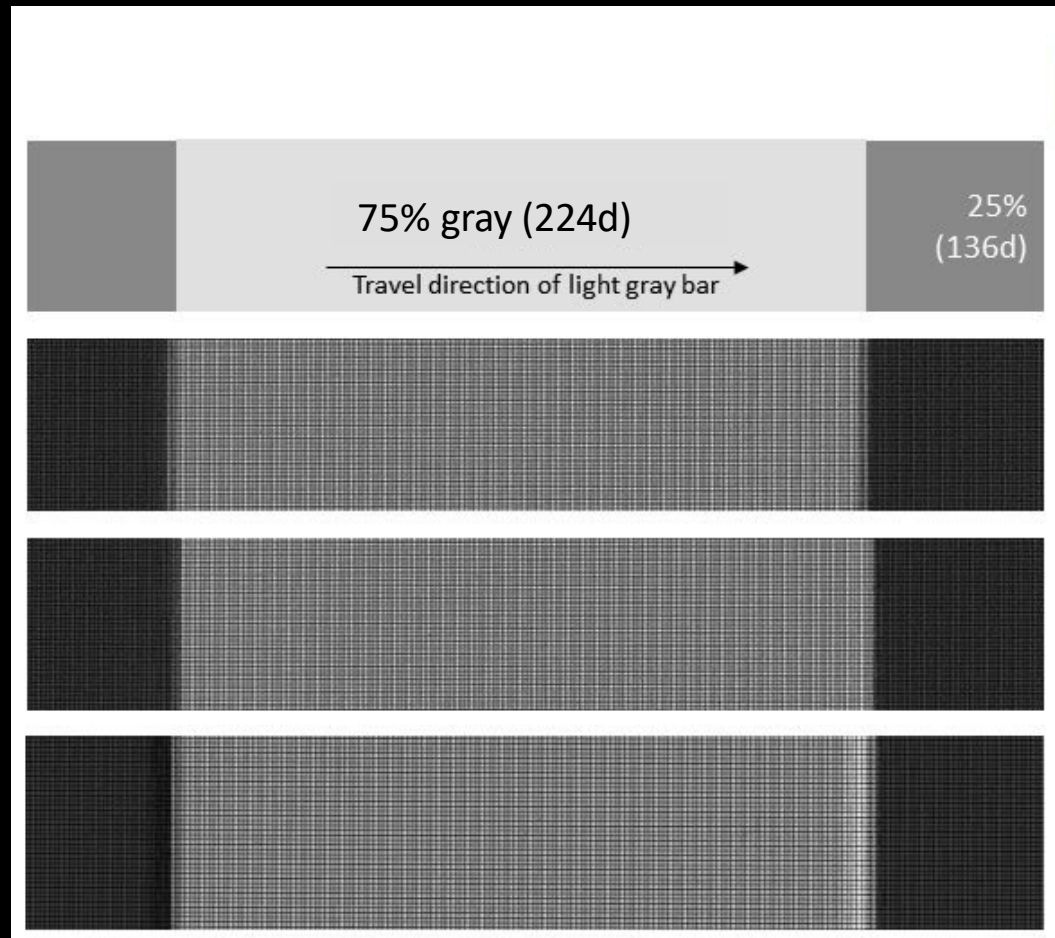
1. Accessed July 26, 2021. https://blurbusters.com/faq/lcd-motion-artifacts
2. Test patterns © 2021, Samsung Display Co., Ltd. right reserved.

Over/undershoot creates ghosts and coronas





Moving bar subjective test



Picture	Views	Leading Edge seen	Trailing edge seen	Fractional response
Test image	40			
Default	8	0	0	0
Increased overdrive	16	7	6	0.41
Excessive overdrive	16	16	16	1.0

$$Overshoot < 20\%, \quad Undershoot < 10\%$$

ClearMR™

Methods

01 Problem statement

02 Clear Motion Ratio design

03 Setup for testing: Hardware and Software

04 Seeing is believing

High Speed Camera & Lens

- High Speed Camera
  - 10,000 fps
  - Monochrome 12-bit+ precision
  - at least 768px wide
  - Example: Photron FASTCAM Mini AX100 or better
    Vision Research Phantom VEO 1010 or better

- Macro Lens
  - Macro with 1:1 magnification (avoid ultra macro with over 1:1 magnification)
  - Prime, f/2.8, fixed focal length, typically 70 to 105 mm
  - Match lens size with camera sensor (ie: full frame lens with full frame camera sensor)
  - Match lens mount type with camera (ie: Nikon F / Canon / C)
  - Check back focus length (Photron appnote)
  - Example: Sigma 105mm f/2.8

Macro Lens Setup

- Focal Distance
  - Get close ~0.3m screen-to-sensor
  - The camera's ideal 1:1 magnification occurs at the minimum focus distance
  - Target between 85% and 100% of the ideal magnification
  - CTS Calculator helps find the ideal magnification.

This table calculates the user's camera magnification in use

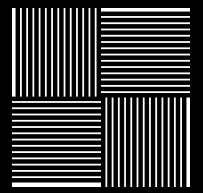
Camera model: FASTCAM Mini AX series — 500.00 ppcm

	Display parameters						
Type	Diagonal	horizontal resolution	vertical resolution	panel pixel density	Camera sensor pixel density	1:1 Sensor pixels / display pixel	Minimum magnification*
	in	pixels	pixels	ppcm	ppcm	ratio	**85.0%**
Monitor #1 example	27	1920	1080	32.122	500	15.566	13.23
Monitor #2 example	34	3840	1440	47.489	500	10.529	8.95
Small laptop	13.3	2560	1600	89.363	500	5.595	4.76
Larger laptop	15.6	3840	2160	111.191	500	4.497	3.82

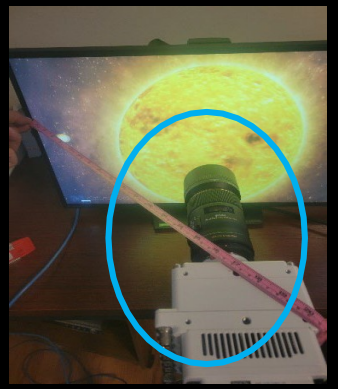
- Note the following attributes for later:
  - Capture Frame Rate
  - Sensor density

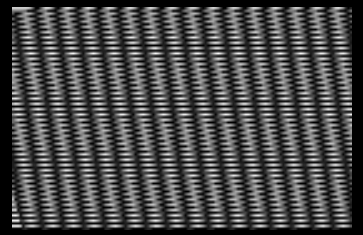
High Speed Camera : Align

Align monitor

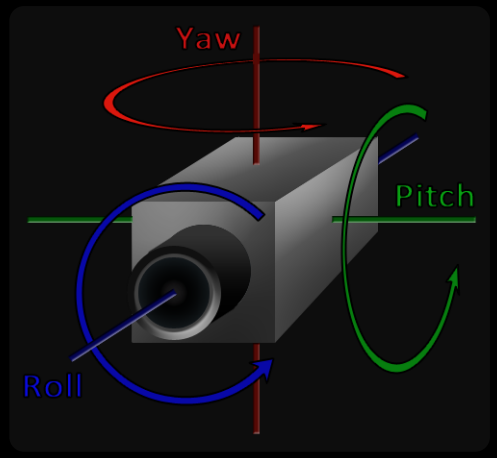


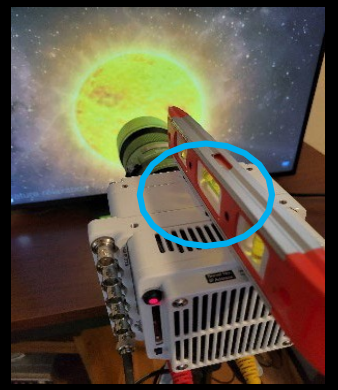
align pattern





unaligned



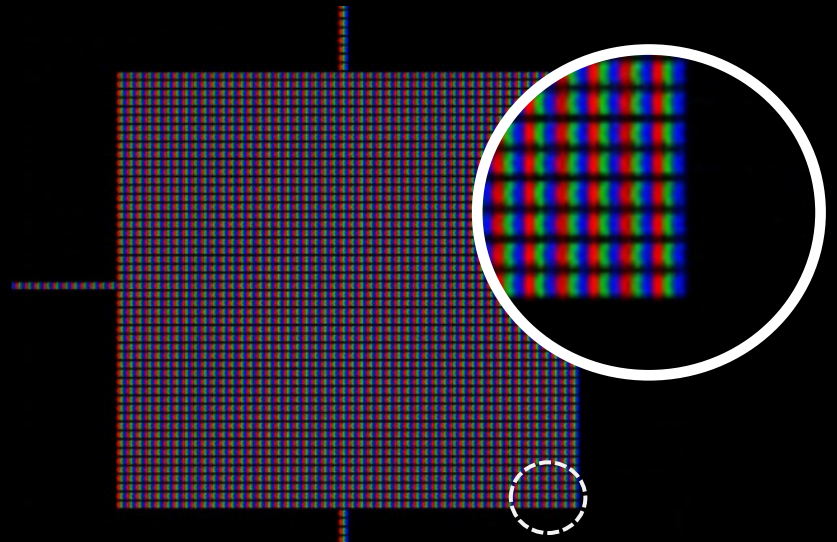


Align camera

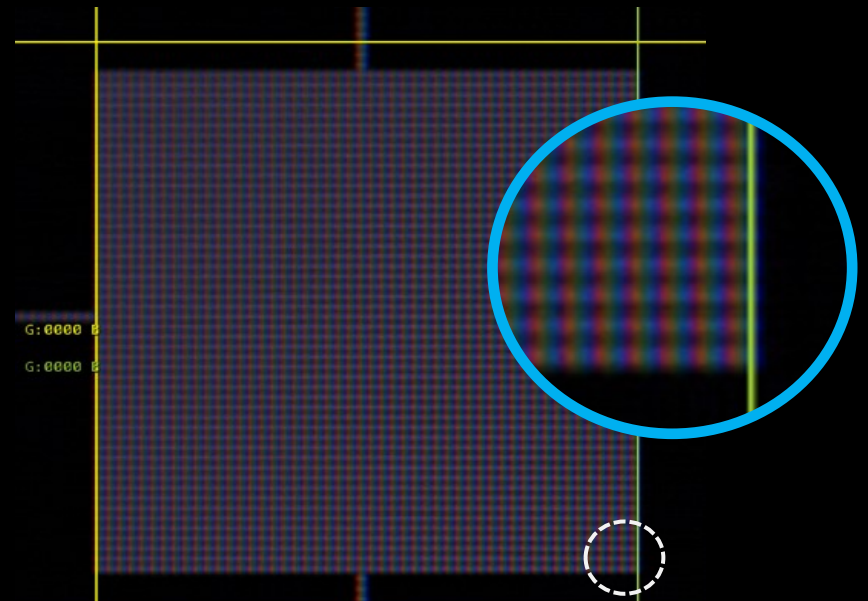
- Fast Ethernet connection to the camera and…
- Use a good tripod with gear controls for easy alignment

High Speed Camera : Focus

Color

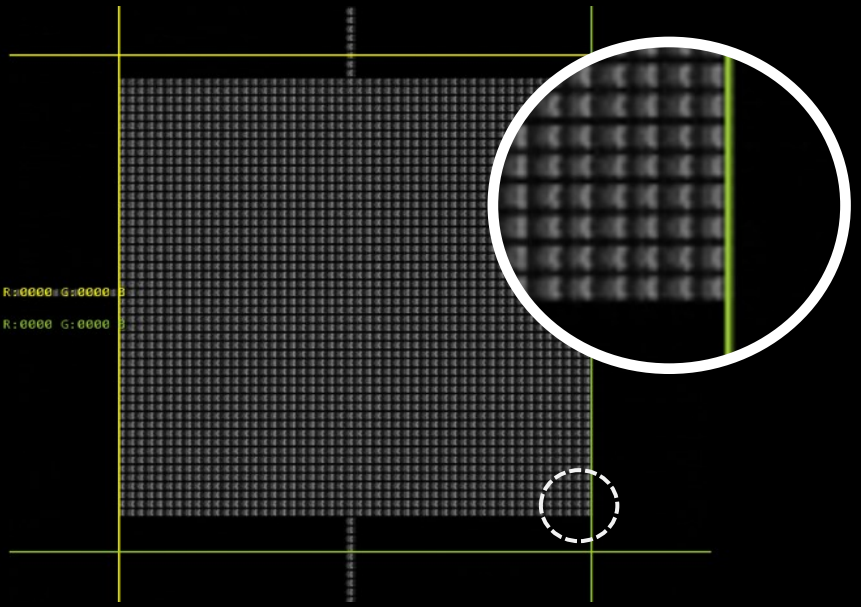


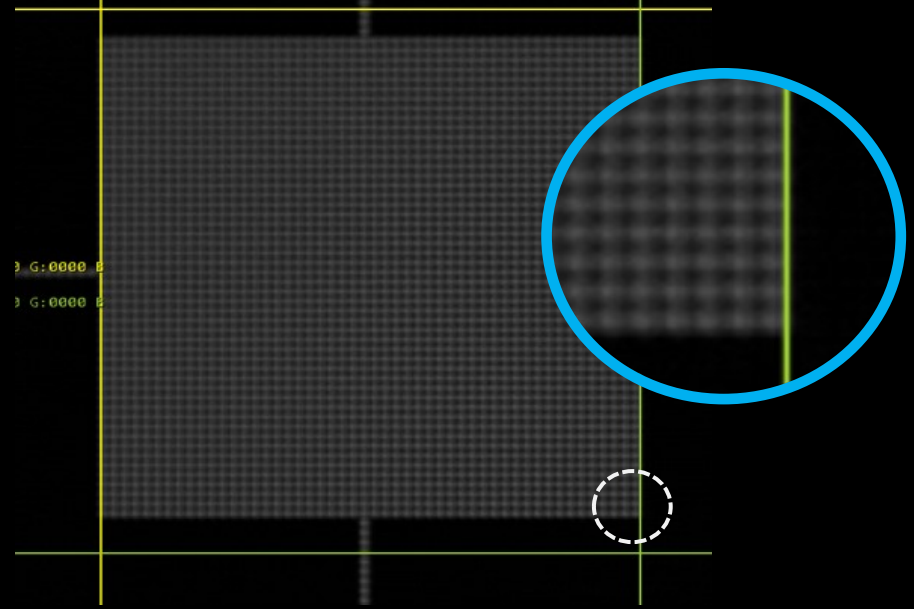
Best Focus



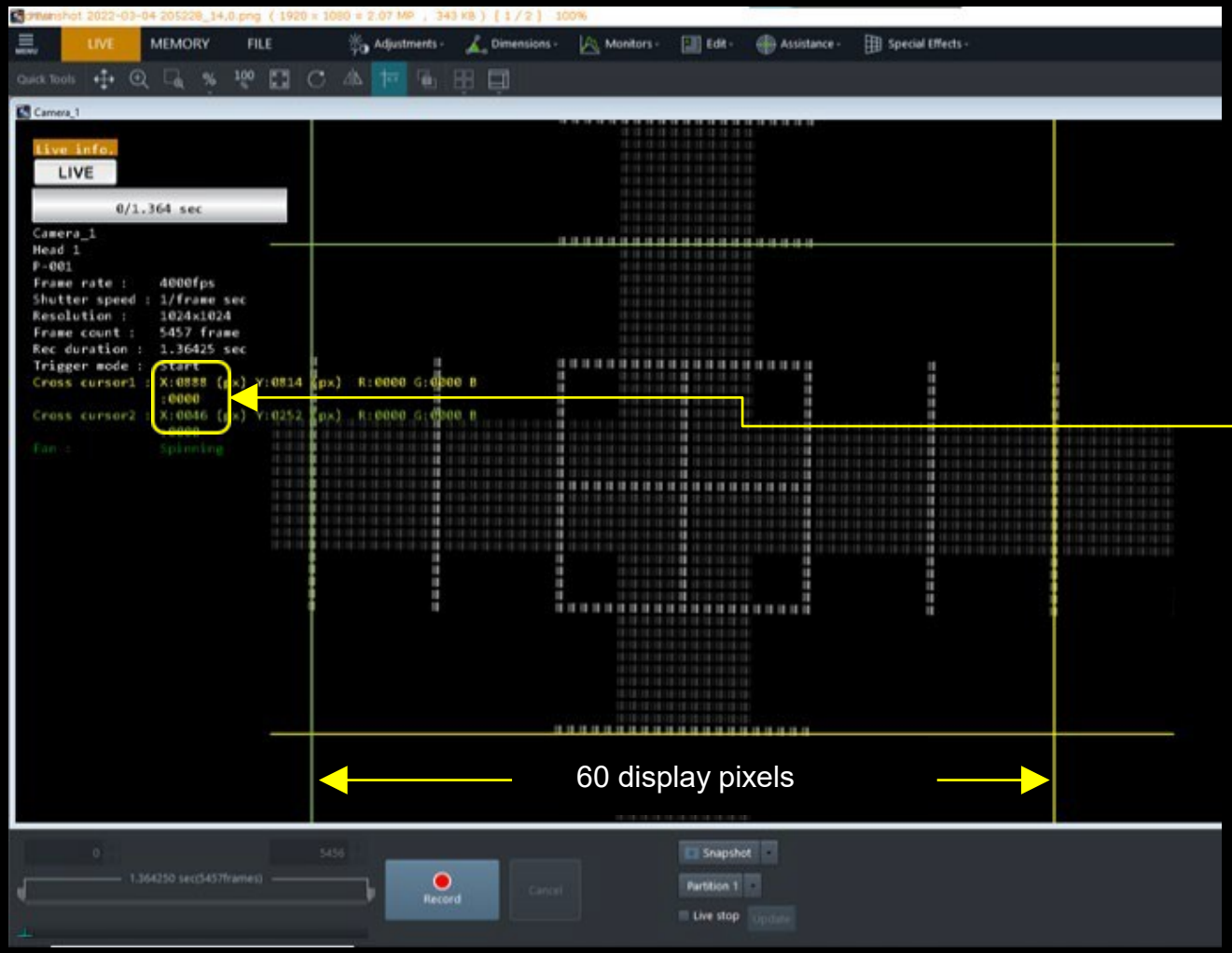
De-focus

Mono





High Speed Camera : Camera Magnification

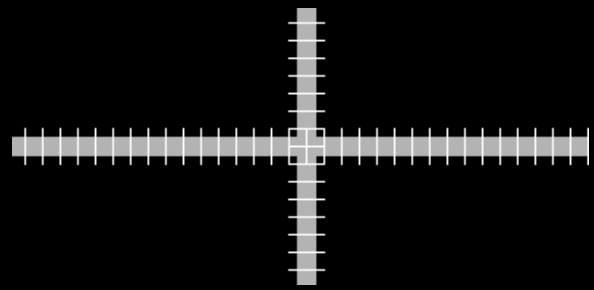


- Measuring the calibrated cross
- Measure a known pattern
- this cross has 10 px/div markers
- Sensor = 1024 x 1024 (informative)

- X cursors = 888, 46

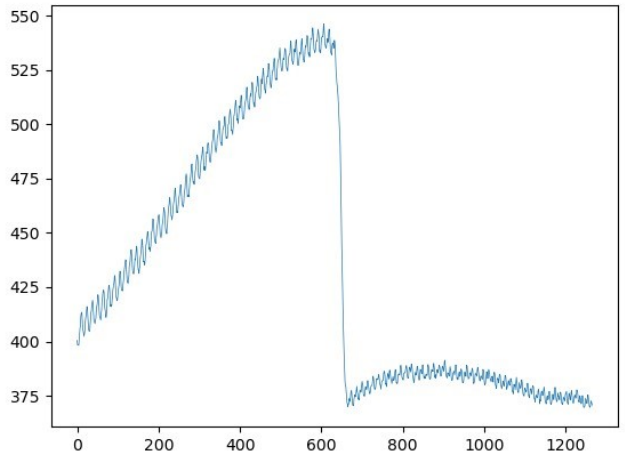
$$mag = \frac{(888 - 46)}{60} = \mathbf{14.0}$$

- Put a screenshot in the test report

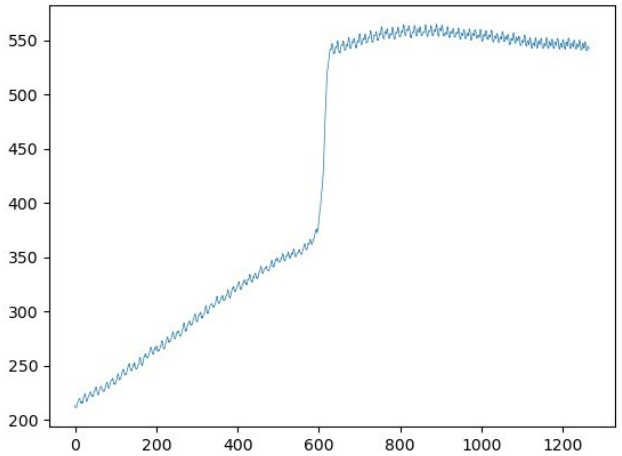


High Speed Camera : Calibration

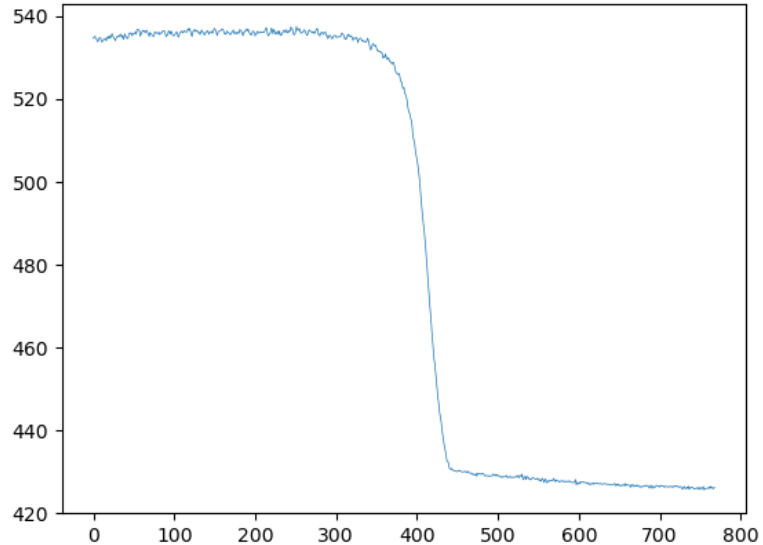
Uncalibrated



Uncalibrated



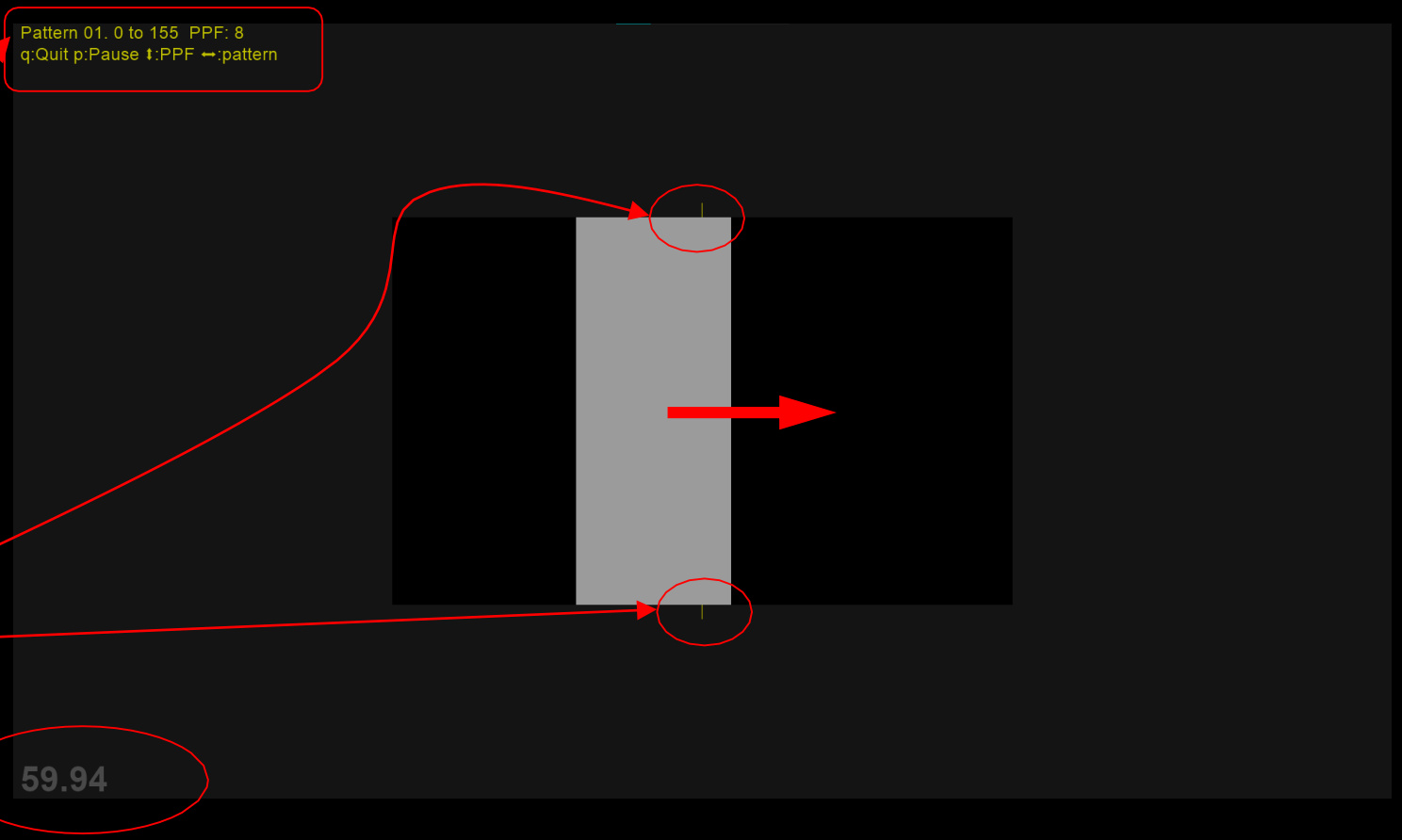
Calibrated



- Calibrate and set the black level of the camera after setup

Pattern Generator

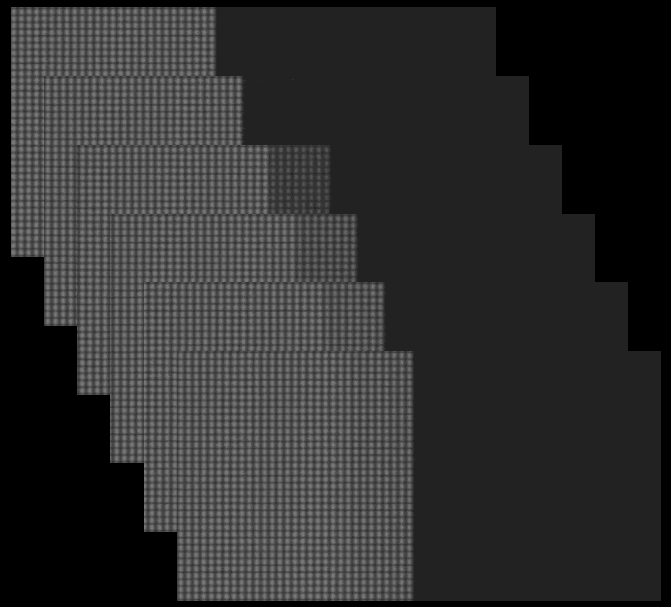
- Generates test pattern at various PPF rates and luminance
- Still images used for camera alignment and magnification calculation
- Download from VESA (CMR Tools)



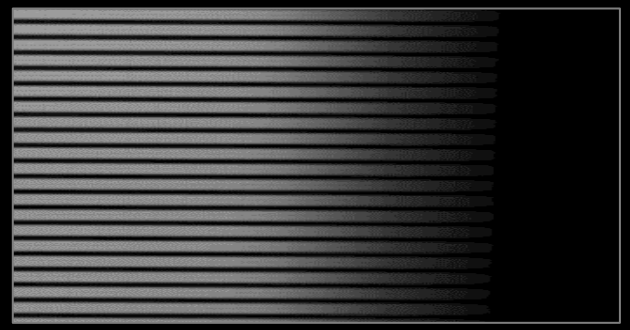
- Pattern displayed with levels, PPF rate, Hot keys
- Center of screen markers
- Actual frame rate,
- must be stable

Frame stacking using “digital pursuit”

Record an image stack sequence



S/W combines into a blur image



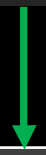
CMR Analysis : overview

- A batch program with several functions
- **[profile]** creates a look-up table of image stack directories with all data required to find the clear motion ratio
- **[blur]** transforms multiple image stacks into blur profiles
- **[cmr]** build an analysis table of all blur profiles and statistics
- Usage is: cmr [OPTIONS] COMMMAND

```
C:\demo>cmr_04.15.2022.exe --help
Usage: cmr_04.15.2022.exe [OPTIONS] COMMAND [ARGS]...

  (c) 2020-2022 Samsung Display Co., Ltd. All Rights Reserved. CMR Analysis

Options:
  --version                   Show the version and exit.
  -v, --verbose
  -p, --ppf INTEGER           ppf override
  --hz FLOAT                  monitor frame rate override
  -s, --scale FLOAT           camera magnifciation scale override
  --vres INTEGER              vertical resolution override
  --hres INTEGER              horiz resolution override
  -c, --camera_fps INTEGER    camera frame rate override
  --sensor_density FLOAT      Sensor density (px/cm)
  --diagonal FLOAT            Diagonal (inches)
  --ignore_mag                ignore check for scale within 85% of ideal
                              magnification
  -r, --root_prefix PATH      [default: (C:\demo)]
  -i, --indir PATH            [default: ($ROOT/profiles/)]
  -o, --outdir PATH           [default: ($ROOT/plots/)]
  -h, --help                  Show this message and exit.

Commands:
  blur     - calculate blur profile from images
  cmr      - calculate cmr from profile
  profile  - generate profiles/blur_params.csv
```

CMR Analysis : read in parameters [profile]

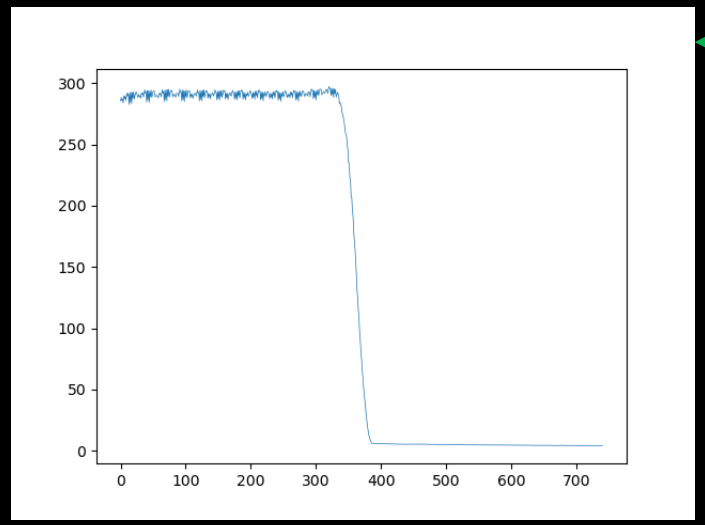
name	ppf	hz	scale	vres	hres	camera_fps	denSen	diagonal
gamemnt_239Hz_2ppf_0_212_C001H001S0001	2	239.76	13.5	1080	1920	10000	500	27
gamemnt_239Hz_2ppf_0_255_C001H001S0004	2	239.76	13.5	1080	1920	10000	500	27
gamemnt_239Hz_2ppf_155_212_C001H001S0001	2	239.76	13.5	1080	1920	10000	500	27
gamemnt_239Hz_2ppf_212_255_C001H001S0002	2	239.76	13.5	1080	1920	10000	500	27

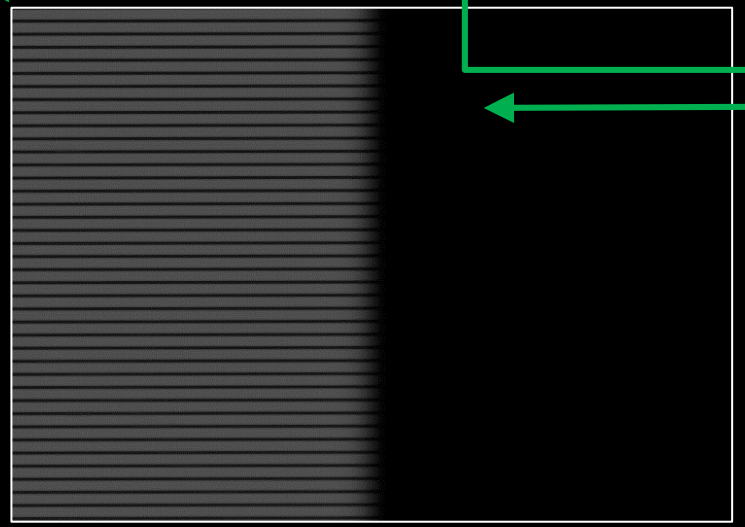


name	Directory name of captured images
ppf	PPF (from pattern generator)
Hz	Display's refresh rate
scale	Camera magnification (from capture and measure)
vres	Display's vertical resolution (pixels)
hres	Display's horizontal resolution (pixels)
camera_fps	Camera's capture frame rate
denSen	Camera's sensor density (ppcm)
diagonal	Display's diagonal (inches)

CMR Analysis : [blur]

```
D:\mb\mb_data\game_monitor_240>cmr -r day_01 blur
trying day_01\profiles\blur_params.csv
                                  name  ppf      hz  scale  vres  ...  denSen  diagonal  lpf  lvl1  lvl2
0    gamemnt_239Hz_2ppf_0_212_C001H001S0001    2  239.76   13.5  1080  ...     500        27    0     0   212
1    gamemnt_239Hz_2ppf_0_255_C001H001S0004    2  239.76   13.5  1080  ...     500        27    0     0   255
2  gamemnt_239Hz_2ppf_155_212_C001H001S0001    2  239.76   13.5  1080  ...     500        27    0   155   212
3  gamemnt_239Hz_2ppf_212_255_C001H001S0002    2  239.76   13.5  1080  ...     500        27    1   212   255

[4 rows x 12 columns]
gamemnt_239Hz_2ppf_0_212_C001H001S0001: using 41 / 50 files
100%|| 41/41 [00:00<00:00, 59.76it/s]
gamemnt_239Hz_2ppf_0_255_C001H001S0004: using 41 / 50 files
100%|| 41/41 [00:00<00:00, 58.22it/s]
gamemnt_239Hz_2ppf_155_212_C001H001S0001: using 41 / 50 files
100%|| 41/41 [00:00<00:00, 62.27it/s]
gamemnt_239Hz_2ppf_212_255_C001H001S0002: using 41 / 50 files
100%|| 41/41 [00:00<00:00, 61.33it/s]
```





game_monitor_240 › day_01 › profiles

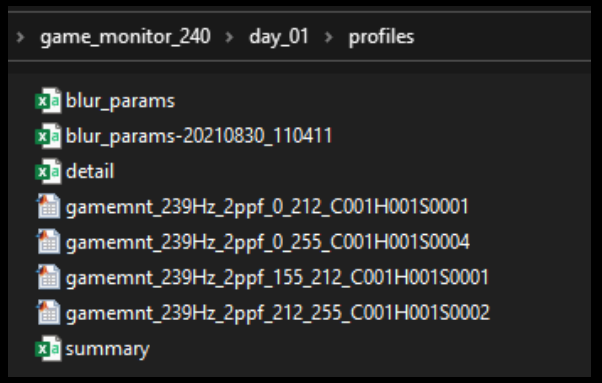
- blur_params
- blur_params-20210830_110411
- gamemnt_239Hz_2ppf_0_212_C001H001S0001
- gamemnt_239Hz_2ppf_0_255_C001H001S0004
- gamemnt_239Hz_2ppf_155_212_C001H001S0001
- gamemnt_239Hz_2ppf_212_255_C001H001S0002

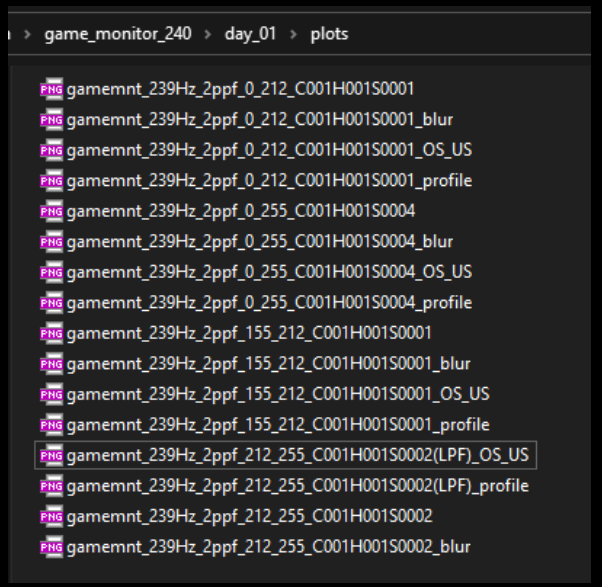
game_monitor_240 › day_01 › plots

- gamemnt_239Hz_2ppf_0_212_C001H001S0001
- gamemnt_239Hz_2ppf_0_212_C001H001S0001_blur
- gamemnt_239Hz_2ppf_0_255_C001H001S0004
- gamemnt_239Hz_2ppf_0_255_C001H001S0004_blur
- gamemnt_239Hz_2ppf_155_212_C001H001S0001
- gamemnt_239Hz_2ppf_155_212_C001H001S0001_blur
- gamemnt_239Hz_2ppf_212_255_C001H001S0002
- gamemnt_239Hz_2ppf_212_255_C001H001S0002_blur

CMR Analysis : [cmr]

```
_monitor_240\day_01>..\..\batch_processing\cmr_11.19.2021_1.23\cmr -r . cmr
trying profiles\blur_params.csv
                                    name  ppf      hz  scale  vres  ...  denSen  diagonal  lpf  lvl1  lvl2
0    gamemnt_239Hz_2ppf_0_212_C001H001S0001    2  239.76   13.5  1080  ...     500        27    0     0   212
1    gamemnt_239Hz_2ppf_0_255_C001H001S0004    2  239.76   13.5  1080  ...     500        27    0     0   255
2  gamemnt_239Hz_2ppf_155_212_C001H001S0001    2  239.76   13.5  1080  ...     500        27    0   155   212
3  gamemnt_239Hz_2ppf_212_255_C001H001S0002    2  239.76   13.5  1080  ...     500        27    1   212   255

[4 rows x 12 columns]
Individual CMR Details
                                    name            label  total_distance  denDis  ...     c_m     OS     US       cmr
0    gamemnt_239Hz_2ppf_0_212_C001H001S0001    Leading_212_0              44 32.1217  ... 0.9915 1.8500 0.0000 9375.6890
1    gamemnt_239Hz_2ppf_0_255_C001H001S0004   Trailing_0_255              48 32.1217  ... 0.9925 0.2700 0.0000 8807.5502
2  gamemnt_239Hz_2ppf_155_212_C001H001S0001  Leading_212_155              66 32.1217  ... 0.9783 0.0000 0.0000 6105.0168
3  gamemnt_239Hz_2ppf_212_255_C001H001S0002  Leading_255_212              81 32.1217  ... 0.9479 0.0000 3.1800 4781.5071

[4 rows x 12 columns]
5.5.2 FAIL: samples test < 2 or > 10
            label  size
0    Leading_212_0     1
1  Leading_212_155     1
2  Leading_255_212     1
3   Trailing_0_255     1
OS/US Summary
                      OS     US
Leading_212_0   1.8500    NaN
Leading_212_155 0.0000 0.0000
Leading_255_212    NaN 3.1800
Trailing_0_255     NaN    NaN
avg             0.9250 1.5900
max             1.8500 3.1800
Cmr Summary
                   edge       cmr
label
Geo-mean CMR       Both 7712.7699
average CMR    Leading 6754.0710
average CMR   Trailing 8807.5502
CMR Score: WARNING: Not enough datapoints 7712.7699
```





ClearMR™

Conclusion

01 Problem statement

02 Clear Motion Ratio design

03 Setup for testing: Hardware and Software

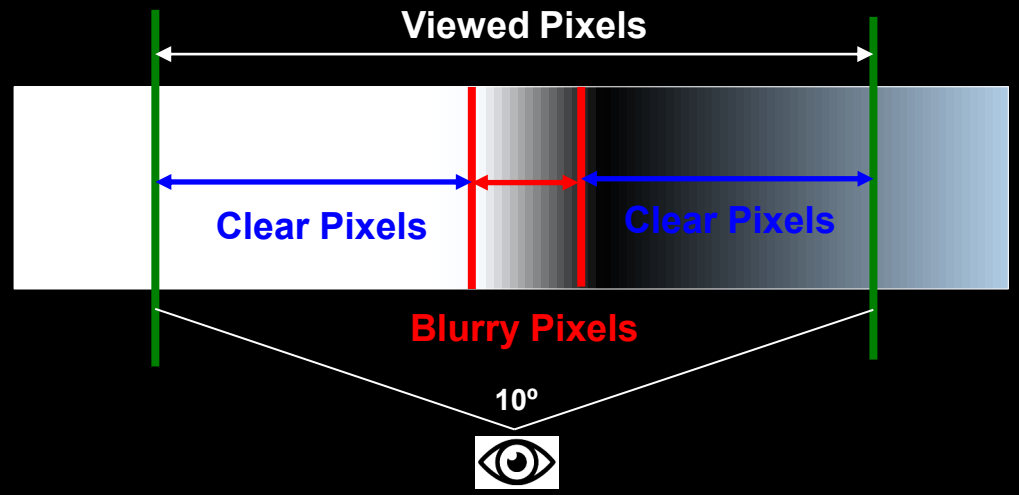
04 Seeing is believing

ClearMR Tiers

VESA CERTIFIED ClearMR

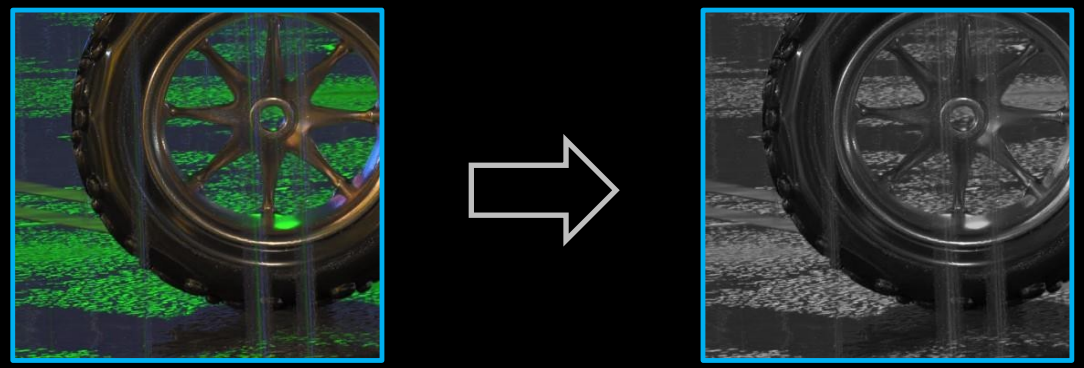
ClearMR™ TIER	CMR RANGE
ClearMR *3000*	2500 ≤ CMR < 3500
ClearMR *4000*	3500 ≤ CMR < 4500
ClearMR *5000*	4500 ≤ CMR < 5500
ClearMR *6000*	5500 ≤ CMR < 6500
ClearMR *7000*	6500 ≤ CMR < 7500
ClearMR *8000*	7500 ≤ CMR < 8500
ClearMR *9000*	8500 ≤ CMR < 9500
ClearMR *10000*	9500 ≤ CMR < 10500
ClearMR *11000*	10500 ≤ CMR < 11500
ClearMR *12000*	11500 ≤ CMR < 12500
ClearMR *13000*	12500 ≤ CMR

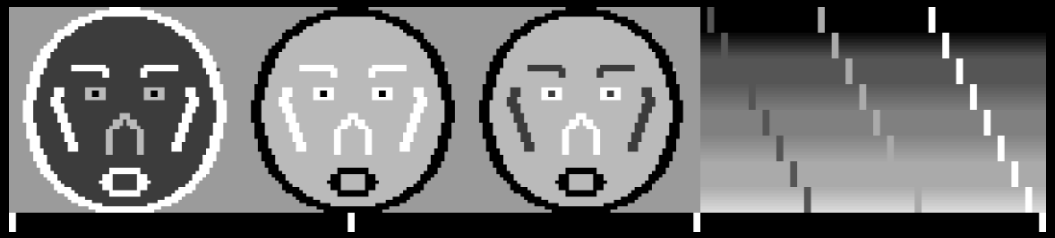
*These tables may be extended in the future to certify faster products



$$\mathrm{CMR} = \frac{Clear\ pixels}{Blurry\ pixels}$$

Simulated results : Seeing is believing



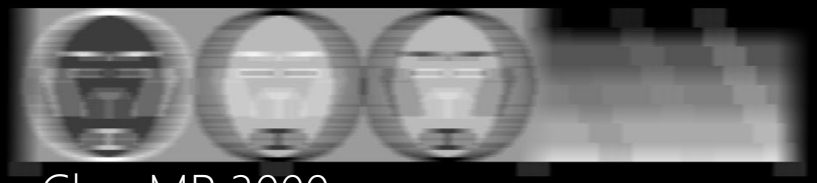


- Ideal edges, $C_M = 1$, $r^2 = 1$
- Show on 2560 x 1440 display

* ambientCG images are 400 x 400 from York University, licensed under a Creative Commons BY 4.0 license)

Animated tire

Grayscale cartoons and diagonal bars



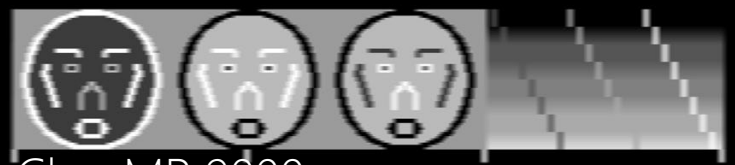
ClearMR 3000

ClearMR 7000

ClearMR 4000

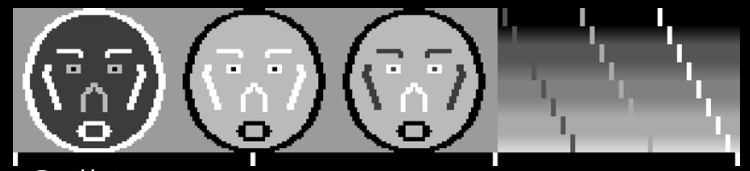
ClearMR 8000

ClearMR 5000



ClearMR 9000

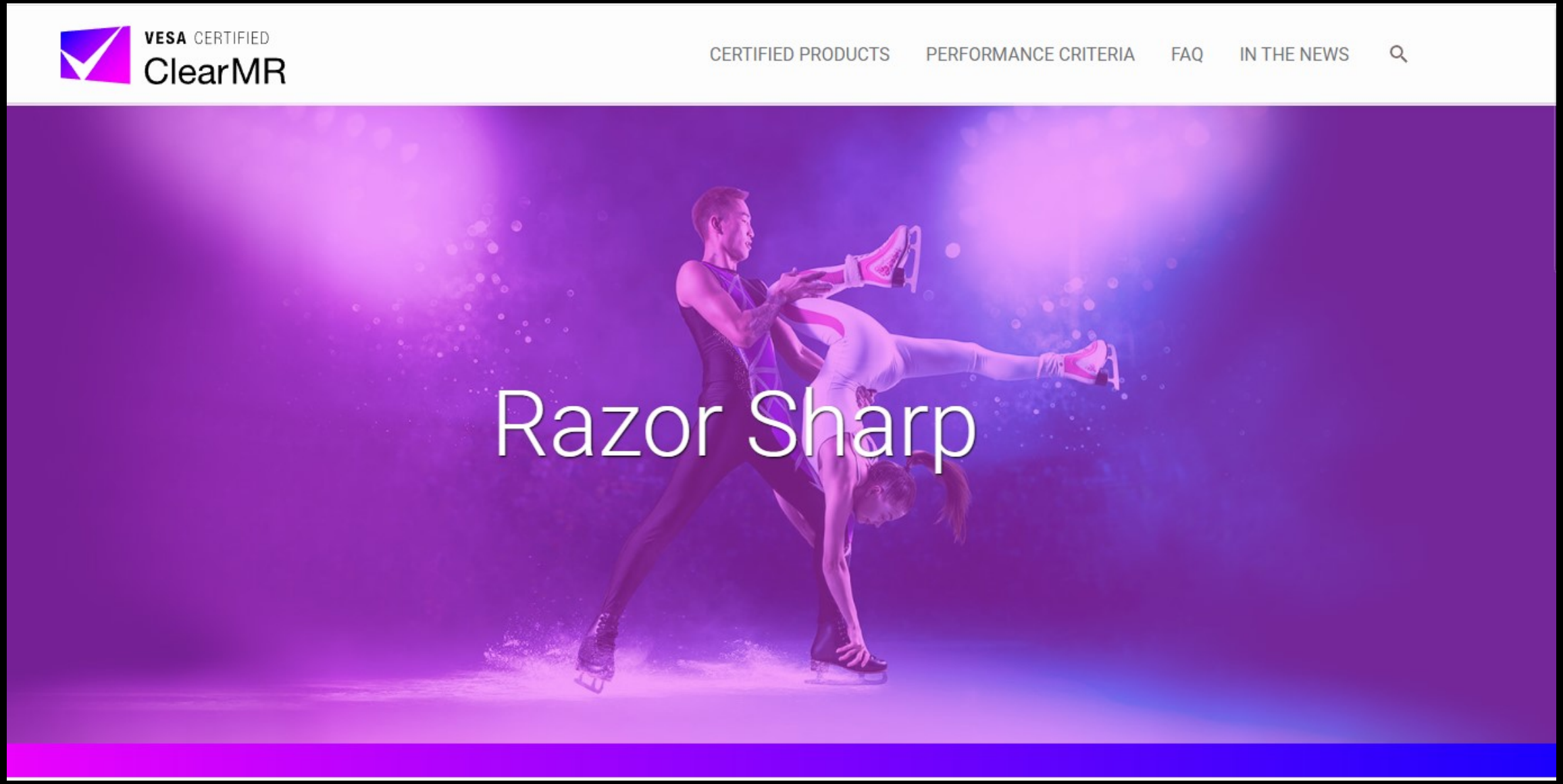
ClearMR 6000



Still image

Summary

- Press release announcing the Clear Motion Ratio certification program and specification, www.vesa.org, Aug 22, 2022.
- Clear Motion Ratio captures all blur not 80% like other metrics
- Visually verified
- Sets a fair basis for comparison
  - Limits overdrive to eliminate ghosts
  - Eliminates strobing unless an intrinsic part of the panel design
- Backed by VESA, the key industry organization for IT Display Panel Quality and major OEMs who are certifying their displays today



Visit www.clearmr.org for the latest certifications and test details.

Thank you

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VESA Compliance Program

Presented by Jim Choate and Sergey Grushin (Unigraf)

VESA PlugTest Events

- Provide significant value to member companies, particularly as new capabilities and products are deployed.
- Demonstrate and improve Traditional Interoperability
- Test Native DP and DP Alt Mode over USB Type-C products
  - UHBR20/13.5/10, DSC, FEC and other new capabilities
  - Verify Test Equipment Correlation (DP 2.1 LL CTS and PHY CTS)
- VESA hosted two successful PlugTests in 2022 (Taiwan and US)
- VESA will host two PlugTests in 2023
  - Taipei, Taiwan: **October 2023 (Next week)**
  - Burlingame, CA: **May 2023 (done)**

Product certifications 2022/2023

Products	2022	2023
DP Sources	141	99
DP Sinks	339	277
DP Cables	42	59
DisplayHDR	388	397
ClearMR	14	45
AdaptiveSync	25	80

DP 2.1 Link Layer CTS

- Link Layer CTS is ready for release. Under final technical editor review.
- Sergey will cover details of new CTS and certification/test tools

DP 2.1 Link Layer CTS Update

Sergey Grushin
Unigraf
9.10.2023

DP 2.1 vs DP 1.4a

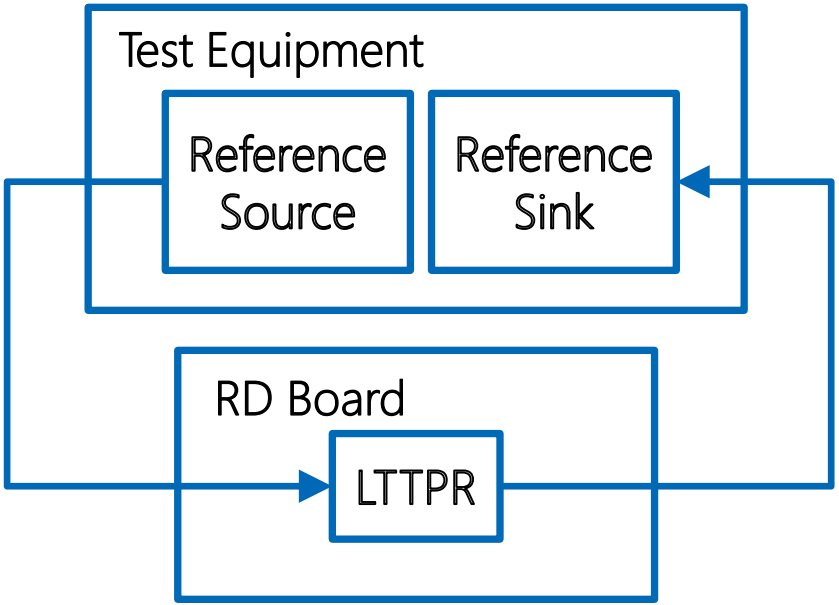
- Sink and Source test procedures updated to comply with DP 2.1 requirements (Sections 4.2-4.4, 5.2-5.5)
  - UHBR link rates
  - AUX read interval
  - Take into account presence of LTTPRs
  - Video timings list revised
  - DSC timings list updated including 10K resolution timings
  - FEC aggregated error counters

DP 2.1 vs DP 1.4a (continued)

- DisplayID/EDID validation is now part of the DP 2.1 LL CTS (Sections 4.7, 5.7)
- Covers Adaptive-Sync validation (Sections 4.8, 5.8)
- Introduced tests to validate how Source device handles presence of LTTPRs on the link (Section 4.9)
- Introduced tests to validate Sink devices with embedded LTTPR (Section 5.9)

DP 2.1 vs DP 1.4a (continued)

- Introduced tests to validate LTTPR devices (Section 7)



DP 2.1 vs DP 1.4a (continued)

- Deprecated number of tests (EDID, AUX, Lane Count Reduction/Increase)
  - EDID tests (Sections 4.2, 5.2). Redundant with addition of DisplayID/EDID test sets (Section 4.7, 5.7)
  - AUX tests (Section 5.2). Implicitly tested by almost every Sink device test.
  - Lane Count Reduction/Increase (5.3.1.6, 5.3.1.7). Lane count change without Link Training is not required by DP 2.1 specification.

Planned Updates to DP 2.1 LL CTS

- Introduce MST test procedures
- Update Audio tests to DP 2.1 requirements including HBR audio testing (Sections 4.4.4, 5.4.4)
- Update Branch device tests to DP 2.1 requirements (Section 6)

Summary

Summary

- Product shipments and certifications on DP 2.1 based products continue to grow
- DisplayPort over USB-C is now the defacto standard for laptops, tablets and handheld devices
- Momentum continues to grow for DisplayHDR, ClearMR and VESA AdaptiveSync product certification
- Development and adoption of new technologies continues to drive increases in VESA membership growth

VESA

THANK YOU

DisplayPort.org

DisplayHDR.org

VESA.org

Questions?