The Rainbow Treasure Map
Advanced Color Management on Linux with AMD/SteamDeck

Melissa Wen
XDC 2023 - A Coruña - Spain
Technical Talk

1. XDC 2022 | "I'm not an AMD expert, but..." | Melissa Wen
2. XDC 2022 | Is HDR Harder? | Harry Wentland
3. XDC 2022 Lightning | HDR Workshop Summary | Harry Wentland
4. Color management and HDR documentation for FOSS graphics | Pekka Paalanen et al.
5. Cinematic Color - 2012 SIGGRAPH course notes | Jeremy Selan
6. AMD Driver-specific Properties for Color Management on Linux (Part 1) | Melissa Wen
Advanced Color Management on Linux

- Wide variety of source content colorimetry (SDR/HDR/different color gamuts, profiles, etc.)
- Wide variety of output display devices
- Internal processing (window composition, etc)
- Users expect consistent color reproduction
- Linux kernel lacks an interface to manage the diversity of color profiles
### AMD Driver-Specific Color Properties

- [PATCH v4 00/32] drm/amd/display: add AMD driver-specific properties for color mgmt
- Endless KMS generic color API
- Many uncertainties regarding the diversity of color capabilities among hardware vendors
- Gamescope is the userspace case (SteamOS 3.5)
- Advanced color management: gamut mapping, HDR rendering, SDR on HDR, HDR on SDR
AMD Steam Deck Kernel Driver

➔ **Accelerated Processing Unit (APU)**

➔ Product Name: STEAMDECK

➔ Code Reference: VANGOGH

➔ Display Driver: DCN3.01 (DCN3 family)
AMD Display Driver in the Linux/DRM

- DRM/KMS
- AMD Display Manager (DM)
- AMD Display Core (DC)
Connecting DC and DRM

kernel space

DRM/KMS

AMD Display Manager (DM)

AMD Display Core (DC)
Examining AMD DC

kernel space

- DRM/KMS
- AMD Display Manager (DM)
- AMD Display Core (DC)
AMD Display Core Next (DCN)

https://dri.freedesktop.org/docs/drm/qpu/amdqpu/display/dcn-overview.html
AMD Display Core Next (DCN) - Color Caps

**Pre-blending**
DPP: Display Pipe and Plane

**Post-blending**
MPC: Multiple Pipe/Plane Combined
Pre-blending: DRM plane
Pre-blending: DRM plane
Pre-blending: DRM plane + AMD DC DPP
Pre-blending: DRM plane + AMD DC DPP

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Pre-blending: DRM plane + AMD DC DPP

DRM/AMD plane

- Degamma TF
- Degamma LUT
- CTM
- HDR Mult
- Shaper TF
- Shaper LUT
- 3D LUT
- Blend TF
- Blend LUT

AMD DC

- input func
- gamut remap
- hdr mult
- shaper func
- 3dlut func
- blend func
- Degam ROM
- Gamma Corr
- Gamut Remap
- HDR Mult
- Shaper RAM

Blending

- 3D LUT
- Blend Gamma

DRM CRTC

- Degam LUT
- CTM
- Gamma LUT

- gamut remap
- out func
- Gamut Remap
- Gamma RAM

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AMD Plane Degamma TF and LUT

Transition from encoded values to linear values for precise arithmetic operations

Pre-defined TFs are hardcoded curves to **DPP Degamma ROM block**
- sRGB EOTF;
- BT.709 inverse OETF;
- PQ EOTF;
- Gamma 2.2, Gamma 2.4 and Gamma 2.6 EOTF

1D LUT supports 4096 entries to **DPP Gamma Correction block**

The data is interpreted as an array of `struct drm_color_lut` elements
Pre-blending: DRM plane + AMD DC DPP

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AMD Plane CTM

For color space conversion

3x4-dimensions matrix of fixed-points s31.32 set to DPP Gamut Remap block

Remapping **CRTC CTM** to **MPC Gamut Remap block**
Pre-blending: DRM plane + AMD DC DPP

DRM/AMD plane

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- Blend TF
- Blend LUT

input func

gamut remap
hdr mult
shaper func
3dlut func
blend func

Degamma ROM
Gamma Corr
Gamut Remap
HDR Mult
Shaper RAM
3D LUT
Blend Gamma

DRM CRTC

- Degam LUT
- CTM
- Gamma LUT

gamut remap
out func
Gamut Remap
Gamma RAM

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AMD Plane HDR Multiplier

Applied to the color values of an image to increase their overall brightness

Useful for converting images from SDR to HDR

PQ TF is needed for any subsequent transforms
Pre-blending: DRM plane + AMD DC DPP

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- Degamma LUT
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- Degamma ROM
- Gamma Corr
- Gamut Remap
- HDR Mult
- CTM
- HDR Mult
- Shaper TF
- Shaper LUT
- 3D LUT
- Blend TF
- Blend LUT

**Blending**

- Degamma LUT
- CTM
- Gamma LUT
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AMD Plane Shaper TF and LUT

**Delinearize/normalize** the color space before applying a 3D LUT

**NO** hardcoded curves

Pre-defined TFs are *calculated* by **AMD color module**
- sRGB inverse EOTF;
- BT.709 OETF;
- PQ inverse EOTF;
- Gamma 2.2, Gamma 2.4 and Gamma 2.6 inverse EOTF.

The color module *combines* TF and user LUT into the LUT to **DPP Shaper LUT RAM block**
Pre-blending: DRM plane + AMD DC DPP

**DRM/AMD plane**
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- Shaper LUT
- 3D LUT
- Blend TF
- Blend LUT
- input func
- gamut remap
- shaper func

**Degamma LUT**
- Degamma LUT
- CTM
- Gamma LUT

**DRM CRTC**
- Gamut Remap
- Gamma RAM
- out func

**Blending**
AMD Plane 3D LUT

Suitable for complex color transformations and **adjustments between color channels**

Supported size: **17x17x17** (4913 entries) and **9x9x9** (729)

**Tetrahedral** interpolation

Blue is the outermost dimension, red the innermost.
Pre-blending: DRM plane + AMD DC DPP

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AMD Plane Blend TF and LUT

**Linearize** the color space again, after 3D LUT and before blending

**NO** hardcoded curves

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Pre-blending: DRM plane + AMD DC DPP

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Post-blending: DRM CRTC + AMD DC MPC
AMD CRTC Gamma TF

Delinearize/convert to **wire encoding**

**NO** hardcoded curves

Pre-defined TFs are calculated by **AMD color module**
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- PQ inverse EOTF;
- Gamma 2.2, Gamma 2.4 and Gamma 2.6 inverse EOTF.

The color module combines TF and user LUT into the LUT to **MPC Gamma RAM block**.
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Steam Deck Color Pipeline

AMD Driver-Specific Color Properties
The search for the Rainbow treasure is not over!
Thank You!

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