Deep Color Support of Intel® Graphics

Technical White Paper

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Contents

Figures

Revision History

Document Number	Revision Number	Description	Revision Date
333611-001	0.8	Initial release	December 2015

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1 Overview of Deep Color

1.1 Purpose and Scope of this Document

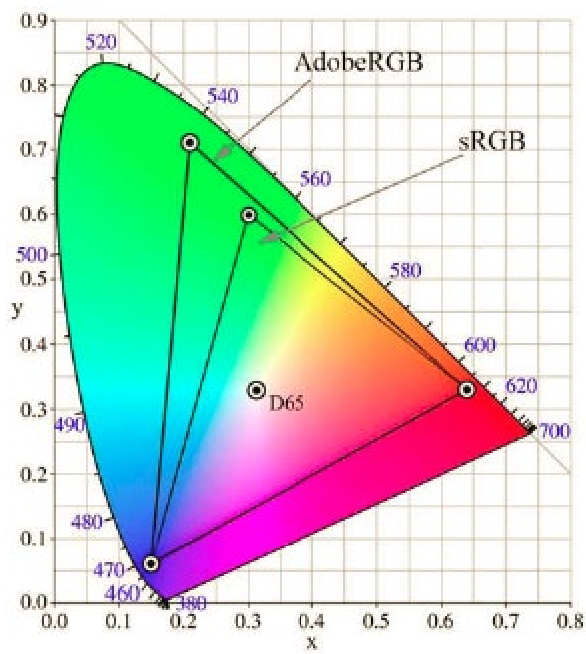
This white paper provides an overview of Intel® graphics deep color (higher bits per color) support over HDMI and DisplayPort, software support and what options applications have to show deep color data. Some of the images used are from internet and the document has it purely for ease of explanation.

1.2 Introduction

"Deep color" in HDMI world refers to support of 12 bits per color (bpc). This translates to 12*3=36 bits per pixel instead of the usual 8 bpc*3=24 bits per pixel (bpp). It's casually used to refer more than 8 bpc as well. In this document we use this term to indication both 10- and 12-bit display support. A color space defines the various colors a display can show or even a camera can capture. This is also referred to as color gamut, i.e. the "gamut of colors".

Figure below shows standard RGB (sRGB) along with another common space (Adobe RGB) with regard to what the human eye can see (the complete colored section). Note that this is a two dimensional mathematical representation whereas the actual color space is a 3-dimensional space.

Figure 1-1. Color Space



sRGB traditionally use 24 bpp (8bpc) and for most common scenarios this is considered enough, but for higher color spaces 10-12 bits are must have to avoid banding like side effects. Banding happens when multiple nearby colors cannot be represented accurately enough and hence they all translate into the same visual pixel color value. This will result in an image which has bands of color instead of a smooth gradation of colors. Same is true during image capture as well and scenes which require higher gamut and precision when saved as a 24-bpp image can inherently create banding. Content creators need to do special post processing to remove such banding.

Figure below shows an example of banding with 8 bpc whereas with 16 bpc it's much smoother. Note that this is a simulated image to showcase the difference on a normal laptop panel (8 or even less than 8 bpc). For reference, 16 bpc can represent a total of 65536^3 = 281 trillion colors instead of 8 bpc which is limited to 256^3 = 16.7 million.

Figure 1-2. Sky with Banding (8 bpc)

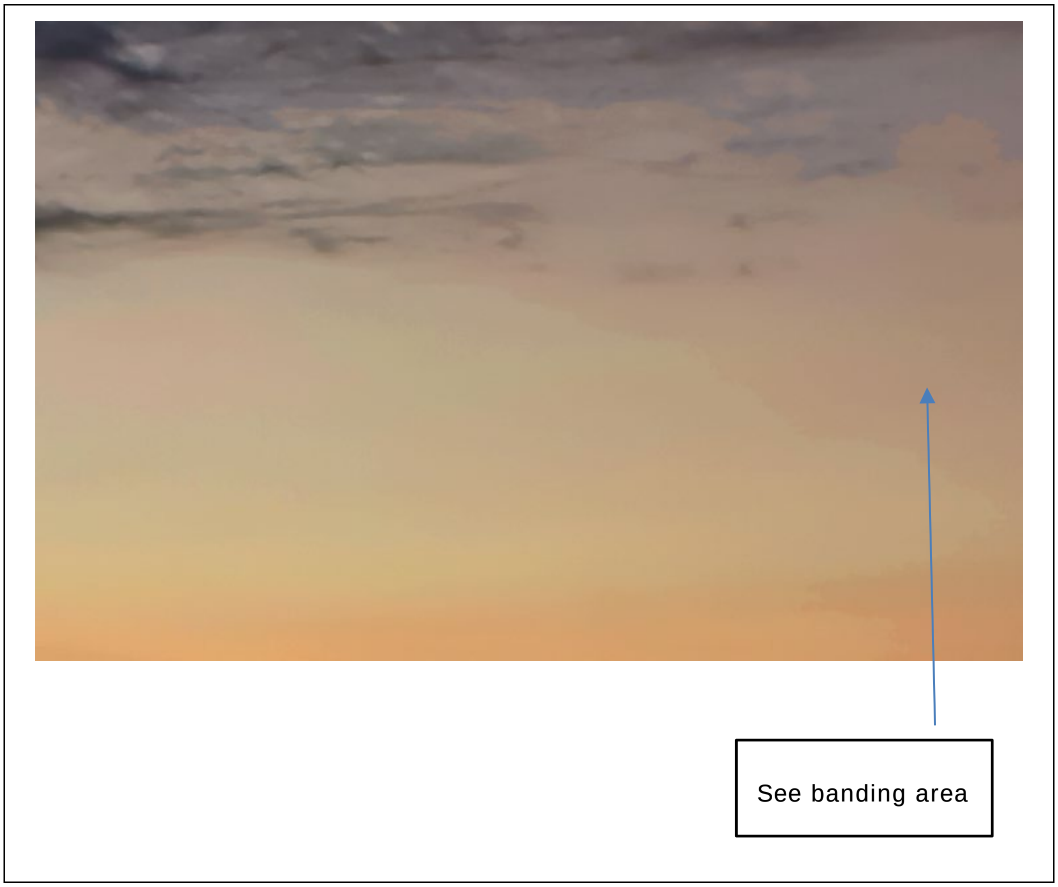


Figure 1-3. Sky without Banding (16 bpc)

An uncalibrated display as well can show banding like artifacts especially in darker regions of the image. In such scenarios one can try monitor calibration tools or Intel® Graphics control panel applet.

1.3 Benefits of Deep Color

Once displays start showing more than sRGB colors one need deep color support to avoid banding kind of artifacts. A higher bpc is also preferred during content editing process (using tools like Photoshop) as image processing with lower precision often results in side effects like loss of contrast, sharpness, etc.

Figure 1-4. 16 bpc vs. 8 bpc Processing on 8 bpc Display

Left: Explosions calculated at 16-bpc and then brought down to 8-bpc on the display;
Right: 8-bit calculation from start to finish.

In addition to having higher precision with higher color space, more number of bits will help with future High Dynamic Range (HDR) imaging and display systems as well. In this case a higher luminance range (e.g. 0-10000 instead of 0-100) needs to be captured/presented.

1.4 Past, Present and Future

Given the display backlight and OLED improvements, higher color space than sRGB is bound to become mainstream in the near future. Media content also is coming up as part of UHD (Ultra High Definition) standard which has resolution of 4k and color depth of 10 or 12 bits. Here the color gamut is bigger as well – represented by BT.2020 spec. This document is not going to describe these as such but will highlight the hardware/software end-to-end flow for deep color on Intel graphics.

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2 Hardware Support

Basic deep color for HDMI (=12 bpc) is supported from Intel® microarchitecture code name Sandy Bridge platform onwards itself. Ten and 12 bpc are supported on Intel's DisplayPort as well. This support is independent of the content's bpc but unless content bpc is more than 8, there is no visual benefit in enabling it. Since Microsoft Windows* desktop is limited to 8 bpc there won't be a clear advantage that one gets by enabling an 8→12 bpc conversion. Due to this Intel doesn't provide a UI option to enable/disable this option instead Intel's strategy has been to enable the E2E path when such content is presented.

HDMI represents Deep color support using CEA blocks. DisplayPort indicates support in base EDID block itself (EDID is a blob describing display's capabilities). For both kinds of displays higher bits mean higher BW on the transmission link. This puts some restrictions on where all more than 8 bpc is possible.

2.1 Connector/Port Bandwidth (BW) Restriction

More than 8 bpc means more BW required to transmit the extra bits. Say 1080p60 at 8 bpc (standard full HD) required 148.5MHz then 1080p60 at 12 bpc requires 148.5 * (12/8) = 222.75MHz. This applies to 10 bpc as well (148.5*10/8 = 185.625MHz). This means is a SKU's HDMI port is limited to say 148.5MHz, then it won't be able to support Deep color with 1080p60.

Port BW restriction is applicable to DisplayPort as well. Following table shows an example of what's possible with Intel GPU over HDMI (for 12 bpc) and DisplayPort (for 10 and 12 bpc).

	Broadwell H/ULT/ULX (10/12bpc)			Skylake/Kaby Lake (all SKU's) (10/12bpc)		
CEA Video Modes**	**HDMI**	**DP**		**HDMI**	**HDMI2.0 (via LSPCON*)**	**DP**
1080p24/30	Y	Y		Y	Y	Y
1080p60	Y	Y		Y	Y	Y
2160p24/30	N	Y		N	Y	Y
2160p60 (RGB/YUV444)	No spec	N		No spec	No spec	N
2160p60 (YUV420)	N	N		N	Y***	N

NOTES:
- * LSPCON: This is a convertor device which helps with providing HDMI2.0 output from a DisplayPort output and is soldered on board.
- ** CEA: Consumer Electronics Association
- *** With limited LSPCON vendors alone, special support required from LSPCON side

There is no 10 bpc support on HDMI. This is due to the fact that all HDMI TV's are expected to support 12 bpc to claim "Deep color" support. Given this if a source supports 12 bpc over HDMI then source will be interoperable with such "Deep color" HDMI TV's.

Table below shows 8 bpc support which as one can expect will be able to support higher resolutions due to reduced bandwidth requirements.

	Broadwell H/ULT/ULX (8bpc)			Skylake/Kaby Lake (all SKU's) (8bpc)		
CEA Video Modes**	**HDMI**	**DP**		**HDMI**	**HDMI2.0 (via LSPCON*)**	**DP**
1080p24/30	Y	Y		Y	Y	Y
1080p60	Y	Y		Y	Y	Y
2160p24/30	Y	Y		Y	Y	Y
2160p60 (RGB/YUV444)	N	Y		N	Y	Y

2.2 Laptop Panels (local display)

Most of the traditional laptop panels were internally of 6bpc (=18bpp panels). This naturally means even a normal 24bpp image can show dithering when viewed on an 18bpp panel. To avoid this, a process called "dithering" is applied which is almost like introducing a small noise to adjoining pixel. This will create variations in 18bit representation and results in hiding color banding on such panels. Either the GPU's display HW or panel itself might do this. When a panel does this, source (GPU display HW) is not aware of the same and panel will advertise itself as a normal 8bpc (24bit) panel.

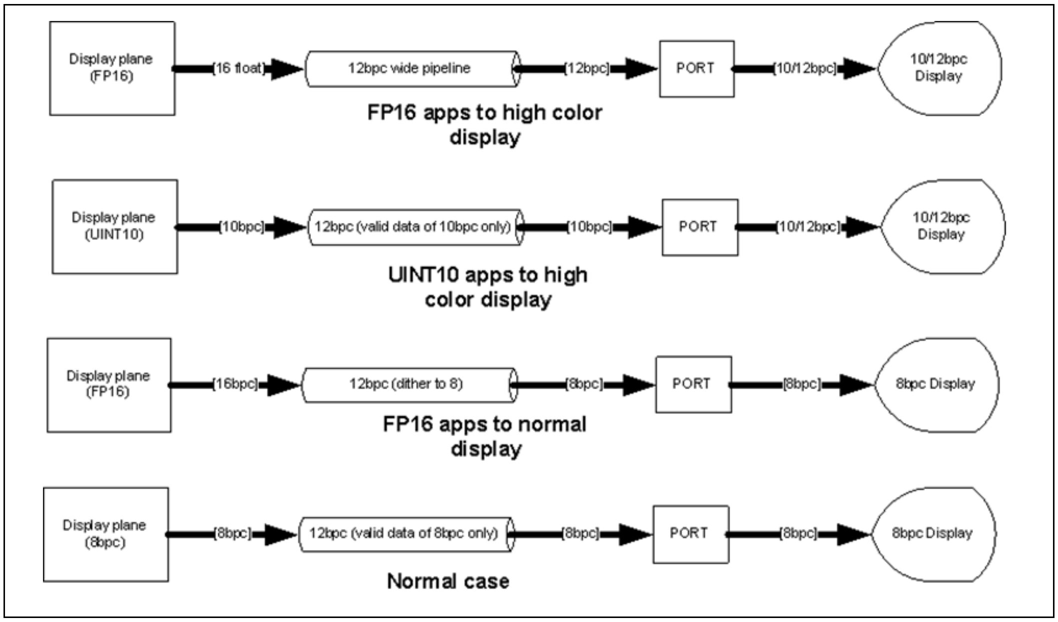
2.3 Higher than 8 bpc Frame Buffer Support

If a content of more than 8 bpc is presented to display HW (source transmitter - TX), then it should be able to fetch it and manipulate it irrespective of the end display support. This is required as applications don't need to bother about end display's ability and render/present content as per DirectX* specifications. In addition to this the same frame buffer might get displayed on a different bpc display. So driver/HW shall ensure appropriate mapping happens and relive application of this trouble.

2.4 End-to-End Flow

Figure below shows various possibilities of having more than 8 bpc between source and receiver. Purpose of this figure is to show the various elements involved in the pixel path with respect to bits per color. In general HW pipeline keeps improving its precision to support various industry usage models which are dependent on color precision.

Figure 2-1. HW E2E Flow



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3 Graphics Driver Support

Intel graphics driver on Windows* Microsoft support higher than 8 bpc using the mechanisms exposed by OS alone. At the time of writing this document this is limited to exclusive full screen DirectX* applications. Most games fall under this category. Given that most displays support 8 bpc as minimum and application

3.1 Determining Deep/High Color Support

Display driver determines display's 10/12 bpc support from its EDID. There are various tools available in market which parses EDID and shows deep color support if present. For most of the external displays 8 bpc support is a must have for compatibility reasons.

3.1.1 HDMI/CEA Displays

Displays having CEA block in EDID can be considered as consumer TV like displays. They indicate higher than 8 bpc in the vendor specific data block as highlighted below. Here display/sink supports 10 and 12 bpc. This is indicated by byte 46 of the vendor specific data block (VSDB).

[42-64]Vendor Specific Data Block

IEEE Registration Number:HDMI display

[45] Components of source physical address('A' and 'B' 4 bits each)

[46] Components of source physical address('C' and 'D' 4 bits each)

The Sink shall Accept and Process any ACP,ISRC1 or ISRC2 packet

Sink supports 30 bits/pixel (10 bits/color).

Sink supports 36 bits/pixel (12 bits/color).

3.1.2 DisplayPort Displays

VESA EDID 1.4 indicates display bpc in its base block itself as highlighted below. Here display indicates just 8 bpc but it can potentially indicate higher bpc as well.

****

Block No.: 0 Base Block

****

[0-7],Header OK!

[8-9],Manufacturer ID: CMN

[10-11],Product ID: 1343

[12-15],Serial ID: 0 0 0 0

[16],Week Of Manufacture: 52

[17],Year of Manufacture: 2011

[18],EDID Version: 1

[19],EDID Revision: 4

[20-24],Display Parameters

Digital

8 Bits per Primary Color

Display Port Is Supported

Note: Tool used to get/parse EDID here is from Intel and is used internally for debug purpose.

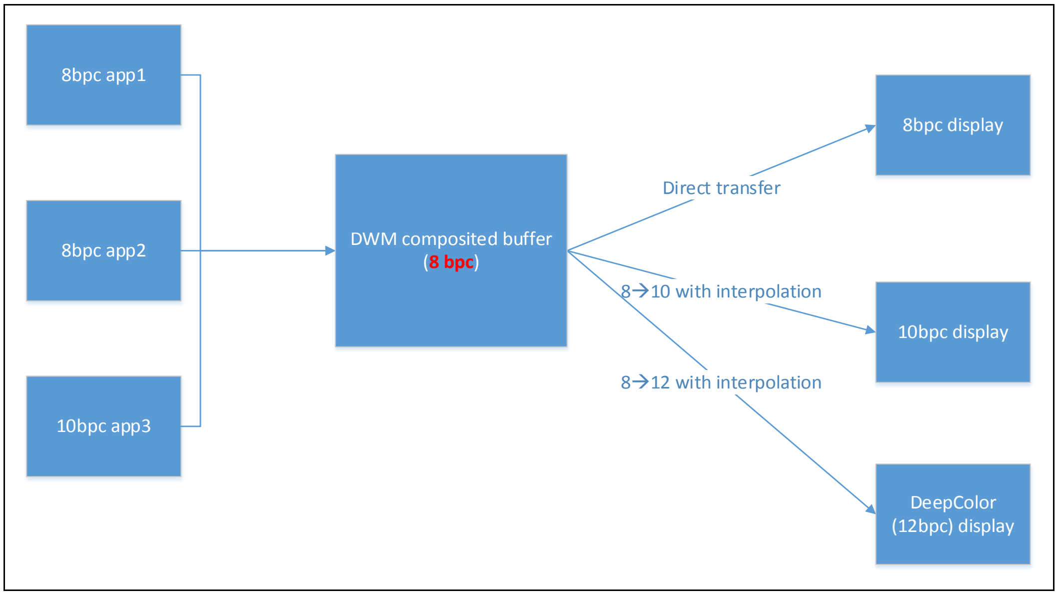
3.2 Enable/Disable of Deep Color

Since the visual advantage of showing an 8 bpc content on a 10/12 bpc display is less, Intel graphics driver doesn't enable 10/12 bpc by default. It will internally enable this mode of transmission if content is also of higher bpc. This happens with exclusive mode DirectX* applications alone. As mentioned above.

3.3 Microsoft DirectX* Support

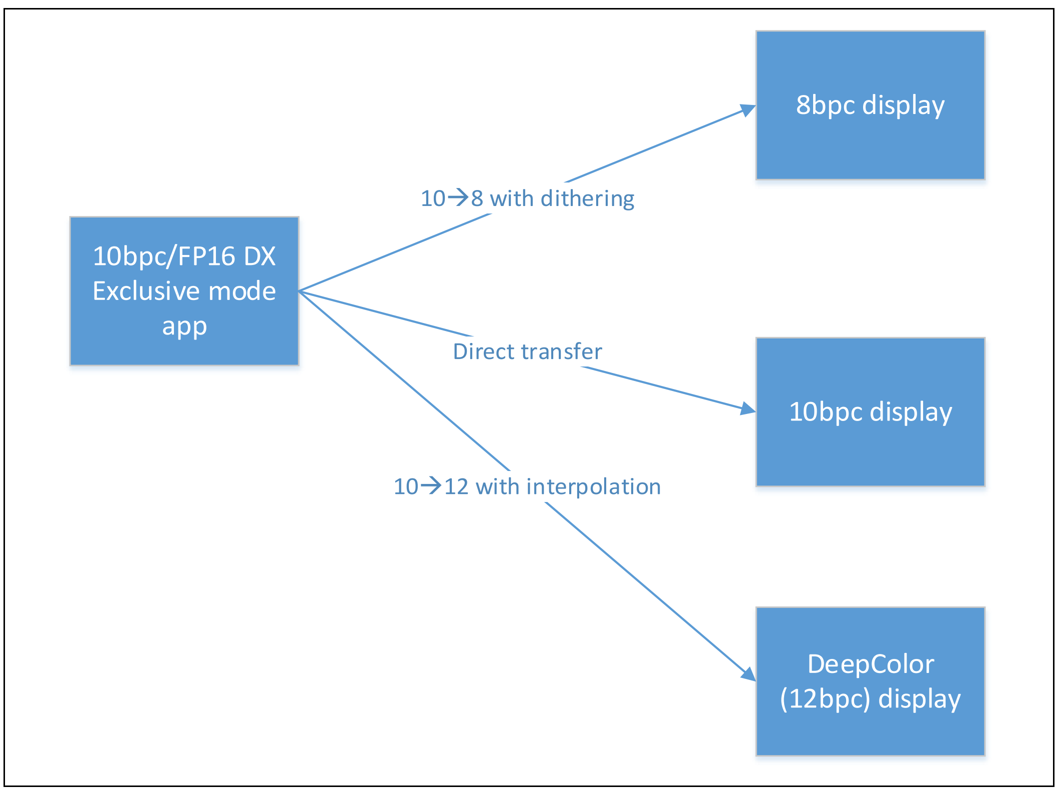
Windows* OS doesn't support more than 8 bpc for desktop. This means even if an application has a more than 8 bpc content, it will all be compressed to 8 bpc during desktop window composition process as shown in figure below.

Figure 3-1. 8 bpc Typical Desktop



If a display supports 10/12 bpc alone, then driver will perform the 8→10/12 bpc conversion internally to satisfy the basic need of the panel. Such displays don't exist though. The exclusive mode scenario is as shown below.

Figure 3-2. More than 8 bpc Exclusive Mode DX App



3.4 OpenGL* Support

There is no OpenGL* support for 10/12 bit with Intel graphics driver. Intel will re-evaluate this as the technology matures.

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4 Application Support

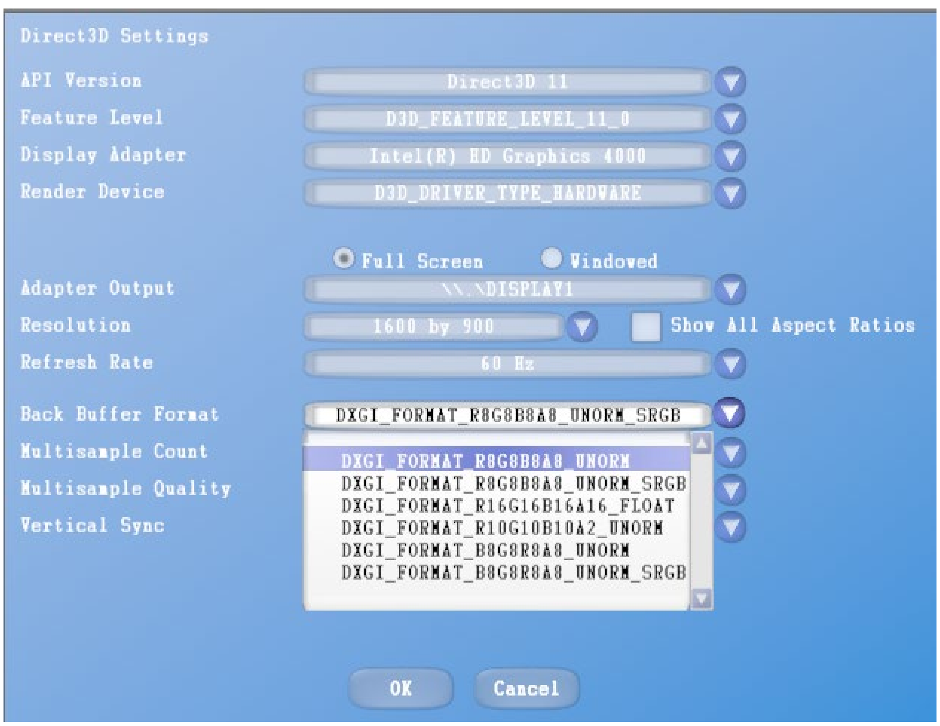
There are no known commercial applications which utilize the exclusive mode higher than 8 bpc DirectX* ability to show 10/12 bpc content. This is expected to change with video content based on UHD (BT2020/HDR) specs. Also improving display capabilities will help with improving application adoption as well.

4.1 How Can Applications Utilize Intel Deep Color Support?

Applications need to implement DirectX* based exclusive mode presentation of DXGI_FORMAT_R10G10B10A2_UNORM or DXGI_FORMAT_R16G16B16A16_FLOAT. DXSDK from Microsoft already got samples for this.

DX10/11 samples by default don't show up FP16 or RGB10 formats in "Back Buffer Format" list box (one can get to this from settings of the sample apps – F2 key). For this one need to set the variable *m_bEnumerateAllAdapterFormats* to TRUE in code. This will result in application showing all possible formats supported by display HW of Intel GPU. A sample screen show of the same is shown below.

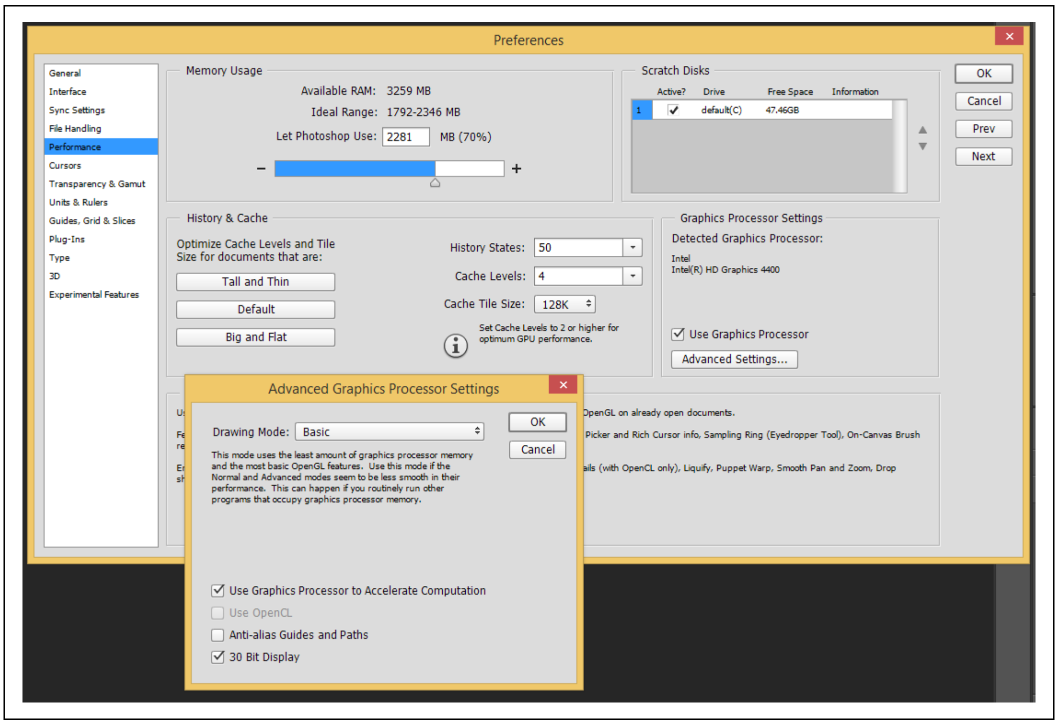
Figure 4-1. DX11 DXSDK Sample Settings UI after Code Change



4.2 Adobe Support

Adobe provides an option to enable/disable a 30-bit display as shown below and there are claims of it working on older operating systems like Windows* XP. Given that there are no OS/driver interfaces to enable this from Microsoft side, at this point this stands as an undocumented feature from the vendor(s) claiming this support. Future OS plans, if any, to support higher bpc within OS's composition framework can solve such issues and will provide a uniform way for applications to present higher bpc content even in windowed mode.

Figure 4-2. Photoshop UI Option for 30-Bit Display



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5 FAQ

Q. What's the future of more than 8 bpc displays and Intel support?

A. Intel is actively working with vendors to enable higher than 8 bpc support. Some require OS level change to provide the best user experience. This is expected to take time and once productized, this white paper will be updated to reflect the end to end flow.

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