EFFECTS OF COLOR DEPTH

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The first few years of HDMI in ProAV have been, for lack of a better word, unpredictable. What works with one display doesn't work with another. Why does HDMI go 50ft out of this source, but not that source? The list is endless and comments like this have almost become commonplace for HDMI, but why? Furthermore, excuses have been made in order to allow ambiguity to remain such as, "All Blu-ray players are not made equally, because their outputs must have different signal strength." However, is this the real reason? While the real answers may not truly be known, understanding how color depth quietly changes our HDMI signals will help make HDMI less unpredictable.

What is Color Depth?

Every HDMI signal has a color depth associated with it. Color depth defines how many different colors can be represented by each pixel of a HDMI signal. A normal HDMI signal has a color depth of 8 bits per color. This may also be referred to as 24-bit color (8-bits per color x 3 colors RGB). The number of bits refers to the amount of binary digits used to determine the maximum number of colors that can be rendered. For example, the maximum number of colors for 24-bit color would be:

111111111111111111111111(binary) = 16,777,215 = 16.7 million different colors.

Color depth is very important in HDMI signals, because the more colors you send the higher the bandwidth of your HDMI signal.

Deep Color

HDMI 1.3 introduced something called Deep Color, which adds color depths of 30-bit, 36-bit, and 48-bit into the HDMI standard. These higher color depths were added so HDMI sources could send more colors than the human eye can discern. This would eliminate any potential color banding artifacts that could be seen when there are not enough colors to properly display certain images.

Maximum Colors

30-bit: 1.073 Billion Colors

36-bit: 68.71 Billion Colors

48-bit: 281.5 Trillion Colors

Calculating HDMI Bandwidth

Since all HDMI products are hardware limited to a maximum bandwidth, it is important to know how to calculate the bandwidth of source signals to make sure all downstream devices are compatible. There are many factors that determine bandwidth like Resolution, Refresh Rate, and Color Depth.

The first thing to determine is the pixel clock of the desired resolution. Pixel Clock is the number of pixels being sent every second by the source:

Pixel Clock = Total_Horizontal_Pixels * Total_Vertical_Pixels * Refresh_Rate

Common Pixel Clocks

1080p@60Hz: approximately 154MHz

1080p@24Hz: approximately 74.275MHz

1080i@60Hz: approximately 74.275MHz

720p@60Hz: approximately 74.275MHz

Once the Pixel Clock is determined the bandwidth can be calculated with the following formula:

Bandwidth = Pixel_Clock * (bit_depth_per_color + 2)

Common Bandwidth Calculations

720p/1080i@60Hz Pixel Clock = 74.275MHz

@24bit Color Depth: Data Rate = 74.275 * (8 + 2) = 742.75Mbps

@36bit Color Depth: Data Rate = 74.275 * (12 + 2) = 1.039Gbps

@48bit Color Depth: Data Rate = 74.275 * (16 + 2) = 1.336Gbps

1080p@24 Pixel Clock = 74.275MHz

@24bit Color Depth: Data Rate = 74.275 * (8 + 2) = 742.75Mbps

@36bit Color Depth: Data Rate = 74.275 * (12 + 2) = 1.039Gbps

@48bit Color Depth: Data Rate = 74.275 * (16 + 2) = 1.336Gbps

1080p@60Hz Pixel Clock = 154MHz

@24bit Color Depth: Data Rate = 154 * (8 + 2) = 1.540Gbps

@36bit Color Depth: Data Rate = 154 * (12 + 2) = 2.156Gbps

@48bit Color Depth: Data Rate = 154 * (16 + 2) = 2.772Gbps

Blu-ray Players and Deep Color

If not all, the majority of new HDMI 1.3 Displays and Blu-ray players support Deep Color on their HDMI input/outputs. Blu-ray players use the EDID of their connected display to determine if deep color should be outputted or not. In a simple Home Theater application this would generally not be a problem, but in the ProAV world this can be dangerous. All ProAV HDMI products have a specific bandwidth limitation and also handle EDID a certain way. This information will be very important when choosing sources.

Example

You want to send an HDMI signal at 1080p@60Hz over twisted pair to an HDMI display. You hook everything up, and even after buying the manufacturer's recommended twisted pair cable you still have no picture. What could the problem be? The twisted pair products being used have a bandwidth limitation of 1.65Gbps per channel, which is very common for HDMI over twisted pair. Also common of HDMI over twisted pair is that the EDID from the display is passed directly back from the connected display device. Since both your display and Blu-ray player support deep color, the Blu-ray reads the EDID of the display and sees it can handle deep color, so the Blu-ray outputs 1080p@60Hz with 36-bit color depth. Now without your knowledge, the source is now attempting to send a 2.156Gbps signal through an HDMI over twisted pair product that is limited to 1.65Gbps. This will result in no picture.

The Solutions

There are a few ways around this problem and some are cheaper and more convenient than others.

1. For the most part, Blu-ray movies themselves are mastered in 8-bit color depth from the beginning, so any type of deep color is being artificially created by the Blu-ray player. Some Blu-ray players have a menu setting that will allow you to change the deep color setting from Auto to Off. Changing this setting to off will change the color depth back to 8-bit; therefore, lowering the bandwidth of 1080p@60Hz down to 1.54Gbps. Keep in mind that not all Blu-ray players have a setting like this and rely completely on EDID to make the deep color decision.

2. If your Blu-ray cannot turn off Deep Color, change the EDID the Blu-ray player reads. Use an EDID emulator to emulate the EDID of a display that does not support Deep Color. This will force the Blu-ray to output 8-Bit color at 1.54Gbps

3. The other option is to lower the refresh rate of your Blu-ray player. The best resolution for your Blu-ray player is 1080p@24Hz, a little known fact. While the native resolution on most Blu-ray discs is 1080p@24Hz (Frames per Second), this is the original film rate, not a display rate. By setting the Blu-ray player to 1080p@60Hz, you are asking it to scale the 1080p@24Hz that is on the disc to 1080p@60Hz. Since the quality of scalers in Blu-ray players vary, it would be wise to send 1080p@24Hz out of the Blu-ray player, and let a downstream scaler or display device scale the disc up to 1080p@60Hz. There will be no loss in quality and since the bandwidth of 1080p@24Hz is half as much as 1080p@60Hz, you can send deep color and remain within 1.65Gbps.

Summary

Before blaming Blu-ray players for having quality differences in their output strength, consider that you may not be comparing apples to apples. Since different Blu-ray players handle Deep Color in different ways, it may seem that one player is better than the other; however, one player is outputting a much higher bandwidth signal than the other because of deep color. Although unpredictable problems could still arise based on a Blu-ray manufacturer's choice of chipset and electronic components, Blu-ray players will more or less act the same when outputting an identical signal bandwidth wise.

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