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HDMI Demystified

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The release of the new HDMI 1.3 specification in June 2006 created both excitement and confusion in the consumer electronics industry. The discussion below is provided to help clarify this new technology and provide you with a better understanding of what you need to know when buying or selling HDMI products.

What Is HDMI?

High Definition Multimedia Interface, or HDMI, is a digital audio, video, and control signal format. The advantages HDMI has over other signal formats are:

- Uncompressed digital signals for the highest picture and sound quality.
- One cable for video, audio, and control signals.
- Two-way communication for easy system control.
- Automatic display and source matching for resolution, format, and aspect ratio.
- PC compatibility.

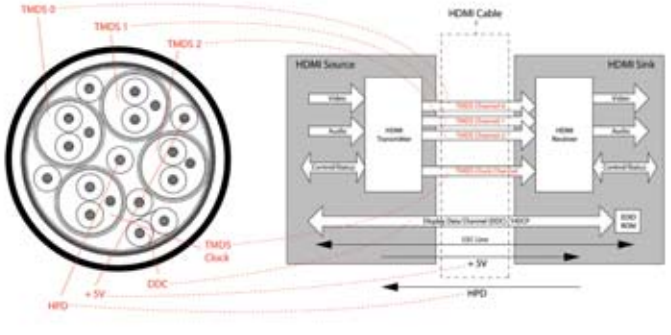

Figure 1. Components inside an HDMI cable. All the signals travel inside one HDMI cable.

What's New In HDMI 1.3?

- Higher speed: The maximum data rate doubles from 5 to 10 Gbps.
- Deeper color: The color depth is increased from 24 bit to 30, 36, or 48 bit.
- Wider color space.
- Supports lossless audio formats: Dolby® TrueHD, DTS®-HD Master Audio, and more.
- Lip sync: Sync audio and video, compensates for signal processing delays.
- New mini plug: Type C for portable devices like camcorders, in addition to the current Type A and B.
- Four TMDS (Transition Minimized Differential Signaling) signals over four twisted pair wires, including three digital video signals (RGB or YCrCb) and one clock signal; the digital audio signals are also multiplexed into the digital video signals.
- DDC (Display Data Channel) data and clock lines carry the two-way communication signals; the HDCP (High-bandwidth Digital Content Protection) signal also floats here.
- CEC (Consumer Electronics Control) data line distributes remote control signals for one-touch system controls.
- HPD (Hot Plug Detection) allows the source to detect a display plugged in real time.
- +5 volt power line supports remote circuits for communication even when power is off.

Video Signal Resolution And Data Rate

- Resolution: Refers to how many pixels in horizontal and vertical directions per frame. 720p has a resolution of 1280 x 720, while both the 1080i and 1080p are 1920 x 1080.
- Refresh rate: Refers to how many frames or fields of pictures per second. The common rates are 30 and 60 Hz in the U.S., or 25 and 50 Hz in Europe.
- Color depth: Refers to how many bits of data are needed to encode each pixel. Common ones are 24, 30, 36, and 48 bits.
- Data rate: Refers to total number of digital bits in a second for a given signal. It's roughly the multiplication of resolution, refresh rate, and color depth together. The higher the three parameters are, the higher the data rate.

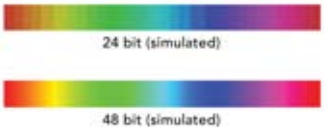

Figure 2. Deep Color.

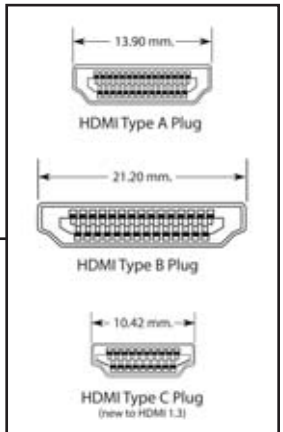

Figure 3. HDMI Plug Types.

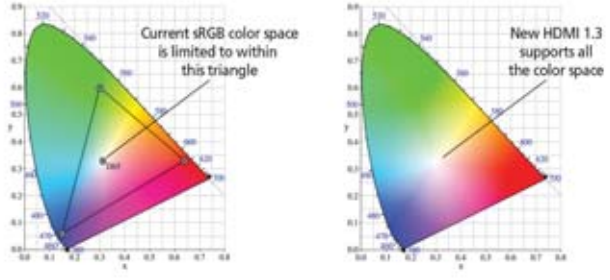

Figure 4. Wider Color Space.

Type Of HDMI Cables

Category 1, supporting TMDS clock frequencies up to 74.25 MHz and Category 2, supporting TMDS clock frequencies up to 340 MHz.

DDC, HDCP, And Compatibility Issues

The DDC lines in the HDMI cable are very busy. Not only do they carry the handshake communications at the initialization (plugged in or powered up), but they also constantly transmit the HDCP (copyright) encryption keys for copy-protected content.

This critical communication is running on a protocol called I2C. The communication lines have an "open" stage in addition to the high and low stage; this "open" stage is not stable, it is highly dependent on the impedance and capacitance of the cable and device. Longer cables and unknown devices introduce the potential for communication error. The symptoms of communication error include no picture, jumping picture, snowy picture, wrong resolution, and/or no audio.

+5V Power Line Overload

The HDMI signal source supplies a +5V power line to power up the DDC communication circuit in the sink (display), even when the display is turned off. According to the HDMI standard, the sink should not draw more than 50 mA current from the +5V line. Some products in the market take advantage of this power source to eliminate the need for an extra power supply, but draw as high as 150 mA current.

1080p

TV manufacturers began promoting 1080p at about the same time the HDMI 1.3 standard was released. This resulted in some confusion as to whether HDMI 1.3 is necessary for 1080p transmission. In fact, it is not. All versions of HDMI are capable of delivering 1080p (60 Hz, 24 bit encoding); but you do need an HDMI connection for delivering 1080p with most products.

The Role Of Cables In The HDMI World

Better products provide better, longer-lasting results. This holds true where HDMI cables are concerned, as expected. However, some of the challenges change, while others stay the same. HDMI cables are highly complex. This complexity is obscured by their simple external appearance. (Figures 5 and 6 show distance and picture quality for analog and digital video signals.)

"Cliff Effect" And The Case For Better Cables

Let's use an analogy. Schools typically use 60 out of 100 points as the pass/fail threshold for students. Student A gets 95 points and Student B gets 65 points on their final exam. They both "pass" this final test. However, is their performance the same? Which one would you hire to work for you? The answer is quite obvious.

Similarly, good and poor HDMI cables pass the test right up to the point where they fall off the "cliff." However, there are measurable differences between the two.

Seeing Is Deceiving

Even when the cable length is within the "cliff," there are already data errors occurring in transmission. See Figure 7.

Why don't we see these defects when we are near or on the "cliff"? The answer is the built-in error correction technology used in digital transmission. The display can tolerate a certain amount of error bits per second; the picture would still be perfect as long as the error rate is below that threshold.

HDMI cables are not created equal. How do we know that there are meaningful differences?

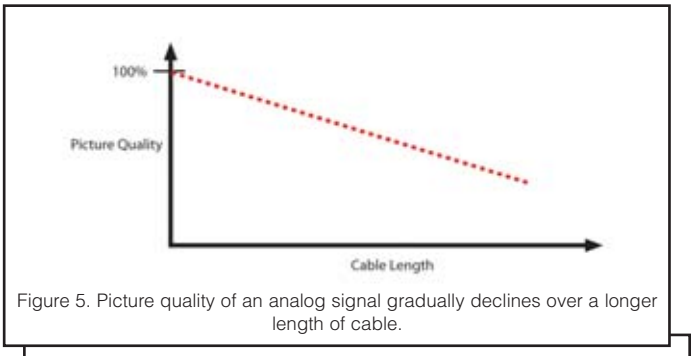

Figure 5. Picture quality of an analog signal gradually declines over a longer length of cable.

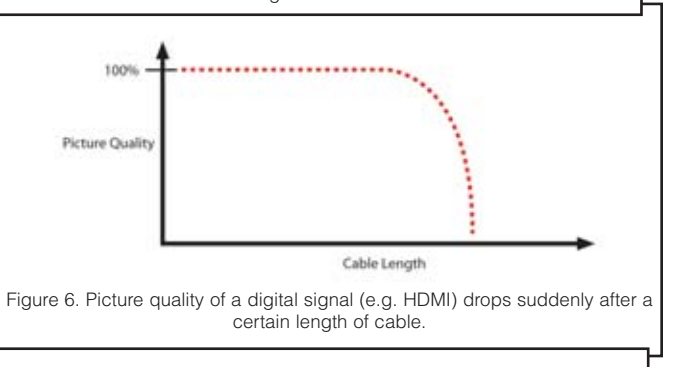

Figure 6. Picture quality of a digital signal (e.g. HDMI) drops suddenly after a certain length of cable.

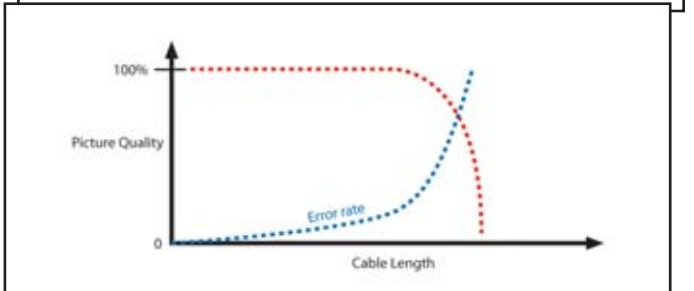

Figure 7. Long before reaching the "cliff," the signal error rate starts to increase with the length of the cable.

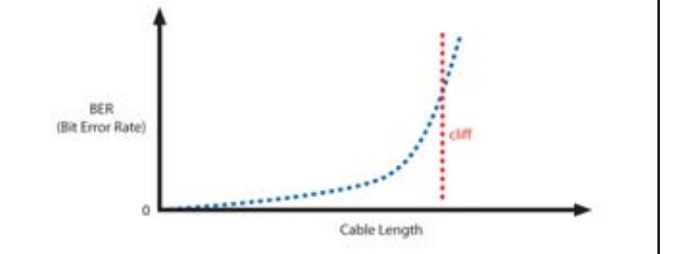

Figure 8. BER (Bit Error Rate) test counts the number of error data at the far end of the cable. The "cliff" effect is visible.

BER Test:

BER stands for Bit Error Rate. In this test, the signal generator sends billions of data bits through a cable. A comparison is made bit by bit with the sent data. The BER display then shows the results as the total numbers of error bits in a given period of time (usually less than a second).

Eye Pattern Test:

"Eye pattern" is what the digital signal looks like on an oscilloscope. The traces of many 1s and 0s overlap together on the oscilloscope to form a pattern that resembles an eye shape. See Figure 9.

The Eye Pattern test shows many aspects of the digital signal, more specifically the following two:

1) Signal amplitude: The height of the "eye" represents the signal amplitude.

2) Timing jitter: On an oscilloscope, the "eye" appears fuzzy in the horizontal direction.

If the "eye" collapses in either horizontal or vertical direction, the signal is lost.

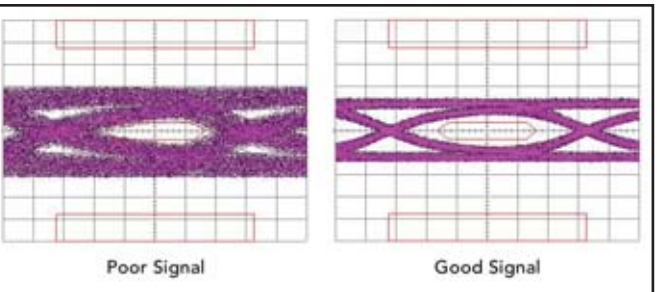

Figure 9. HDMI "Eye" Patterns.

BER Versus Eye Pattern Test

Both tests are essential in the HDMI industry. They are similar in that they both show elements of digital signal integrity. Figures 10 and 11 show these two different tests revealing the same cliff effects.

These two tests are considerably different. The BER Test is best for QC (quality control) and real-world field support applications, while the Eye Pattern test is best for engineering design and fault analysis.

AudioQuest employs both types of testing. Their extensive use begins at the initial design phase and ends with a 100 percent QC process to ensure the highest quality for each cable.

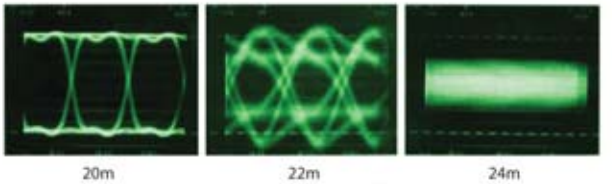

Figure 10. "Eye Pattern" test shows the wave forms of the digital signal (bits) visually. It also shows the "cliff" effects.

Cable Length Versus Maximum Data Rate

This is a complex question. The maximum length for an HDMI cable to transmit a usable HDMI signal depends on the entire system: the source device performance, the display performance, the signal data rate, and the cable performance and length.

The higher the data rate, the shorter the maximum length for a given HDMI cable design (Table 1). Higher data rate signals present a bigger challenge to long HDMI cables.

The maximum distance will be reduced when you run the higher data rate signals now made possible by HDMI 1.3.

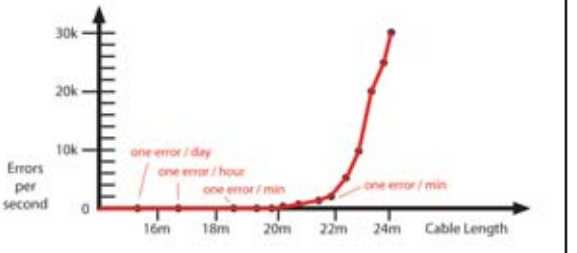

Figure 11. BER test also shows the "cliff" effects.

Future Proof Your System

Taking a look at the cable length and data rate from the cliff effect chart, it is clear that the higher the data rate, the closer the cliff (Figure 13).

We can expect the cliff to "move in," with the advancement of technology that enables higher data rates, over time.

A low-quality cable that may work fine for the 1080i signal you are using today may not work for the 1080p signal you may use tomorrow. A good quality HDMI cable does not cost much more than a mediocre one, especially compared to the investment in the HDTV in your system.

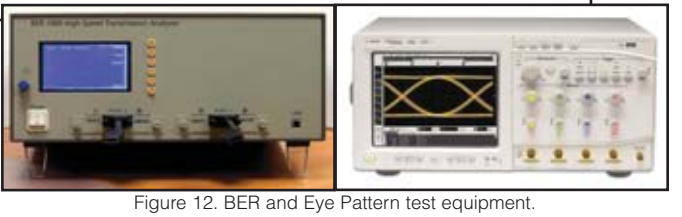

Figure 12. BER and Eye Pattern test equipment.

What Makes A Better HDMI Cable?

Better Design

Don't let the simple appearance of an HDMI cable fool you. HDMI cables can carry signals up to 10 Gbps! Here are some of the elements for a good HDMI cable:

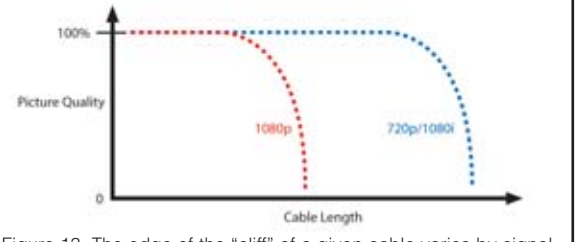

Figure 13. The edge of the "cliff" of a given cable varies by signal rate. The max distance of 1080p is only 1/2 of 1080i.

Cable Length	2 m (6')	4.5 m (15')	10 m (32')	12 m (39')	15 m (49')	20 m (65')	40 m (130')
Max data rate	25 Gbps	18 Gbps	8 Gbps	7 Gbps	5 Gbps	4 Gbps	2 Gbps
Equivalent HDTV format	Future	Future	1080p 48bit Deep Color	1080p 36bit		1080p 24bit	720p/1080i

Table 1: Maximum data rates for various HDMI cable lengths.

1) Better conductor: OFC and silver plating.
2) Solid conductor.
3) Superior cable geometry design.
4) Insulation: Skin-form-skin or Teflon.

As a result, a cable benefiting from more advanced design produces a much cleaner Eye Pattern (Figure 9).

Better Manufacturing

1) Precision HDMI twisted-pair machine (Figure 15).

2) HDMI crimping technology. Most factories rely on the production technicians to solder the many wires onto the tiny pins, one by one. By doing so, there is a high probability of overheating and loosening of the pins, a short circuit between pins, or a cold solder joint. On the other hand, the new Cold-Weld technology can clamp all 19 wires in place and crimp them in one step, significantly increasing the reliability of the contact and eliminating the chance of worker-related error.

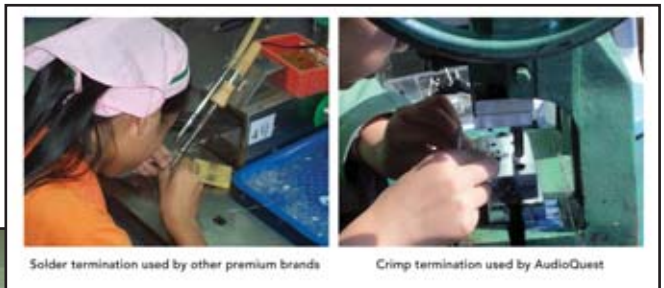

Figure 14. Soldering vs. crimping.


Figure 15. The $800,000 precision twisted-pair machine.

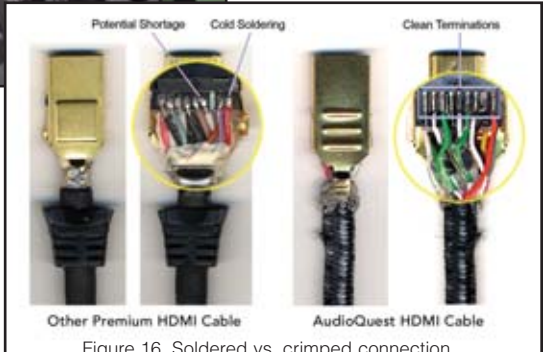

Figure 16. Soldered vs. crimped connection.

The Speed-Rating System

Speed, or more accurately, data rate, which is measured in bits of data per second, is the combination of resolution, refresh rate, and bit depth. It's a single, meaningful number. For example, 4 Gbps is (roughly) the data rate for 1080p, 60 Hz and 24-bit bit-depth.

The maximum data rate a given cable can carry depends on the cable quality and the cable length (Table 1). Some manufactures give a fixed speed rating to a cable series (family) regardless of cable length. This is neither useful, nor accurate. A more accurate speed-rating system should be based on cable quality AND cable length.

Summary

In this article, we have discussed how HDMI works, what's new in HDMI 1.3, the compatibility issues related to devices and cables, the cliff effect for digital transmission, the two ways of measuring the digital transmission performance—the Eye Pattern test and the BER test—and the design and manufacturing requirements for building a good HDMI cable.

Hopefully, this information will help you in selecting the right HDMI cables for your system. More importantly, to help you understand that there are marked differences in performance and quality between today's HDMI cable products.

Note: For a full version of this white paper, please go to http://www.audioquest.com/resource_tools/whitepapers.html. WSR

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