



Lighting Control.



Don't miss out!
Get a FREE
subscription to
our newsletter

Certified v1.3 HDMI Cable →
24K Gold Plated Ships Same Day
100% Life Warranty from \$4.64
MyCableMart.com

HDMI Cables, 6ft \$6.99
1.5FT - 200ft Cables, Certified
Quality Cables & Lifetime Warranty
www.FireFold.com

Hdmi Video Cable
HDMI Cable Lengths From 3ft -
50ft. Lifetime Warranty on All
Cables
www.CableWholesale.com

HDMI 1.3b Cables - 1440p
Deep Color Support - Ships today
Tested right before we ship to you!
www.HdtvSupply.com



Ads by Google

- ▶ Home
- ▶ Find a product
- ▶ Find a service
- ▶ News
- ▶ Articles
- ▶ Case studies
- ▶ Training
- ▶ Events
- ▶ Recruitment
- ▶ Glossary
- ▶ Books
- ▶ Newsletter
- ▶ Archive
- ▶ Subscribe
- ▶ About us
- ▶ Advertise
- ▶ Link to us
- ▶ Newsfeeds
- ▶ Contact us
- ▶ Disclaimer

Articles and whitepapers



Whitepaper: HDMI demystified (1/5/2008)



By Xiaozheng Lu, Luxi Electronics

High-Definition Multimedia Interface, or HDMI, is a digital audio, video and control signal format defined by seven of the largest consumer electronics manufacturers, and is supported by more than 300 companies. The release of the 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.



HDMI cable and connector.

The advantages HDMI has over other signal formats are that it supports non-compressed digital signals for the highest picture and sound quality; it requires just one cable for video, audio and control signals; it allows two-way communication for easy system control; it supports automatic display and source matching for resolution, format and aspect ratio; and it offers PC compatibility.

What's new in HDMI 1.3?

HDMI 1.3 offers the following advantages:

- Higher speed - the maximum data rate doubles from 5 to 10Gbps.
- Deeper colour - the colour depth is increased from 24-bit to 30, 36 or 48-bit.
- Wider colour space - the range of colours is widened to the entire visible spectrum of colours.
- Supports lossless audio formats such as Dolby TrueHD, DTS-HD Master and more.
- Lip sync - sync audio and video, compensates for signal processing delays.
- New mini plug - Type C for portable devices such as camcorders, in addition to the current Type A and B.

All signals travel inside one cable

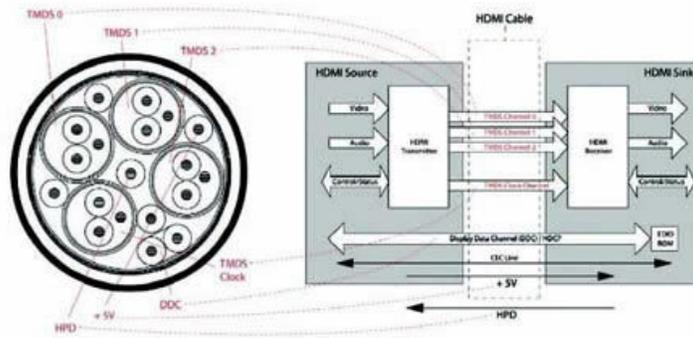
There are four TMDS (Transition Minimised Differential Signalling) signals over four twisted pair wires, including three digital video signals (RGB or YCrCb) and 1 clock signal. The digital audio signals are also multiplexed into the digital video signals. The Dual-Link HDMI has three more twisted pair wires for digital video signals to achieve higher data rate.

Search

HiddenWires Web

Google search





Components inside a HDMI cable.

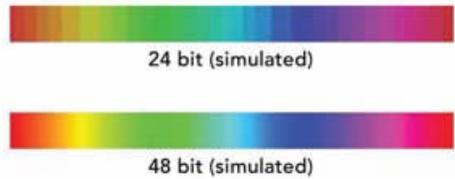
The DDC (Display Data Channel) data and clock lines carry the two-way communication signals; the HDCP (High-bandwidth Digital Content Protection) signal also floats here. The CEC (Consumer Electronics Control) data line distributes remote control signals for one-touch system controls, and HPD (Hot Plug Detection) allows the source to detect a display plugged in, in real time. The +5V power line supports remote circuits for communication even when the power is not turned on.

Definitions - video signal resolution and data rate

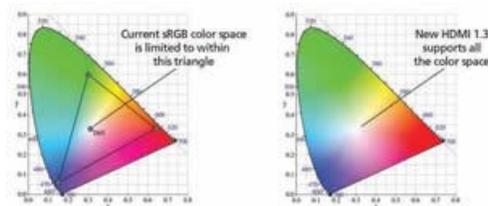
Resolution: refers to how many pixels in horizontal and vertical direction per frame. 720p has a resolution of 1280x720, while both the 1080i and 1080p are 1920x1080.

Refresh rate: refers to how many frames or fields of pictures per second. The common rates are 30 and 60Hz in the U.S., or 25 and 50Hz in Europe.

Colour depth: refers to how many bits of data are needed to encode each pixel. Common ones are 24, 30, 36 and 48 bits.

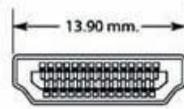


Comparison of 24-bit and 48-bit deep colour

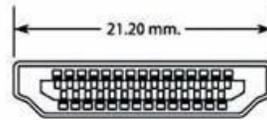


Wider colour space with HDMI 1.3.

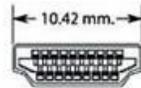
Data rate: refers to total number of digital bits in a second for a given signal. It's roughly the multiplication of all the three numbers above. So, the higher the resolution, refresh rate, colour depth, the higher the data rate. The maximum data rate for HDMI 1.0 thru 1.2 is 5Gbps, while the new HDMI 1.3 maximum is 10Gbps.



HDMI Type A Plug



HDMI Type B Plug



HDMI Type C Plug
(new to HDMI 1.3)

HDMI plug types.

Definitions - HDMI plug types and cables

Type A plug: the most common HDMI plug, 13.9mm wide, 19 pins, designed with one set digital video TMDS lines (Single-Link).

Type B plug: the seldom-used HDMI plug, 21.2mm wide, 29 pins, designed with two sets of digital video TMDS lines (Dual-Link) for higher data rates.

Type C plug: the new mini HDMI plug, 10.4mm wide, 19 pins, designed with one set of digital video lines (Single-Link) for small portable devices.

SingleLink HDMI uses one set of digital video TMDS lines to carry lower data rate signals using cable with at least 15 conductors.

DualLink HDMI uses two sets of digital video TMDS lines to carry higher data rate signals using cable with at least 22 conductors.

Before HDMI 1.3, the Single-Link was good for 5Gbps; the Dual-Link could handle 10Gbps. HDMI 1.3 changed that, now the Single can carry 10Gbps, the Dual even more.

Types of HDMI cable

For the first time, HDMI 1.3 specification divide the HDMI cables into two categories:

Category 1 or Cat 1 cable: can carry signal with a maximum pixel clock of 74.25MHz (roughly equivalent to data rate of 2.2Gbps).

Category 2 or Cat 2 cable: can carry signal with a pixel clock greater than 74.25MHz (roughly equivalent to data rate of 2.2Gbps).

All of the HDMI cables made before the publication of the HDMI 1.3 specifications are at least HDMI Cat 1 compliant.

DDC, HDCP and compatibility issues

The DDC (Display Data Channel) lines in the HDMI cable are very busy. Not only do they carry the handshake communications at the initialisation (plugged in or powered up), they also constantly transmit the HDCP (copyright) encryption keys for copy-protected content. The source needs to verify if the display is HDCP compliant; the display needs the keys constantly to decode the encrypted digital signal.

This critical communication is running on a protocol called I2C (read 'I squared C', or Inter-Integrated-Circuit) developed by Philips originally for the communications between IC chips in the same device. It's not the most reliable protocol for long distance transmission like HDMI cables. 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.

The HDMI standard is derived from DVI. DVI was originally designed for the tightly-specified computer industry. Additionally, distance was not at issue as the monitor is generally in close proximity to the CPU. Longer cables and unknown devices introduce the potential for communication error. The symptoms of communication error can range from no picture, jumping picture, snowy picture, and wrong resolution to no audio.

There are IC chips available to reduce or eliminate this problem, but the circuit may cause power overload.

+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 not turned on. The purpose of this design is to enable the source component to 'know' information about the targeted display at all times. This is a very convenient feature, however some products in the market take advantage of this power source to eliminate the need for an extra power supply. According to the HDMI standard, the sink should not draw more than 50mA current from the +5V line when the sink is turned off and no more than 10mA when the sink is turned on. Some HDMI cables use a built-in electronics driver that draws more than 150mA constantly. This could result in poor picture performance or even damage to the source electronics.

Lip sync

Modern AV devices have many signal processing features. Most signal processing causes signal delay. Usually, video processing has a longer delay than audio processing, causing the picture and sound to be out of sync. HDMI 1.3 added communications via the DDC line to allow the source to adjust the audio delay based on video-audio mismatches reported by the downstream devices. This solved the lip sync problem. All HDMI cables made before the HDMI 1.3 specification was published can support lip sync features because the inserted data is part of the DDC line.

1080p

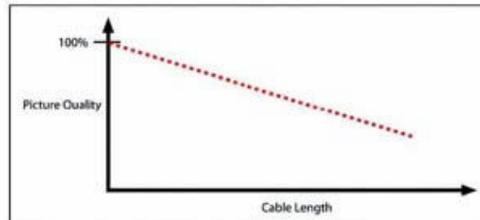
TV manufacturers started promoting 1080p at about the same time the HDMI 1.3 standard was released. This resulted in some confusion as to whether they are one and the same. In fact, they are not. 1080p has been part of the HDMI standard since the very first revision 1.0; HDMI 1.3 added signal rates higher than 1080p. You don't need HDMI 1.3-compliant products to enjoy 1080p (60Hz, 24-bit encoding); but you do need an HDMI connection, as most devices will not output 1080p through the component video outputs due to copyright concerns.

Backwards compatibility

In most cases, you don't need to worry about the evolution from HDMI 1.2 to HDMI 1.3. Like most new technologies, HDMI 1.3 is backwards compatible. Also, most of the HDMI devices have DDC communication capability. If any device in the chain is not HDMI 1.3 compliant, the whole system will fall back to HDMI 1.2 or lower to ensure compatibility through the DDC communication. The only time you may have compatibility issues with HDMI 1.3 is when one of the devices, such as many extenders and distribution amplifiers, is not HDMI 1.3 compliant, and it does not 'speak up', that is, it has no DDC communication capability, or if the cable length is too long AND you are running a signal higher than 1080p 30Hz.

Analogue video signal related to cable length

When the analogue video cable length increases, the video signal quality gradually declines.



Picture quality of an analogue single gradually declines over longer length of cable.

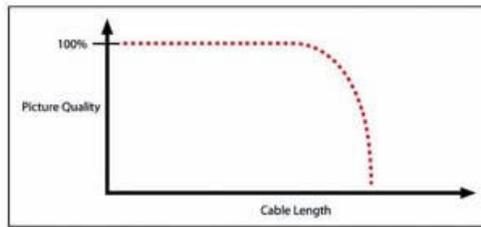
The main types of analogue video signal loss are:

- 1) Amplitude loss - the result is a dimmer image.
- 2) High-frequency signal loss - the result is a softer image.
- 3) Low-frequency signal loss - the result is horizontal smearing on the image.

There are marked differences in image quality between poor-quality and superior-quality analogue video cables. Regardless of how bad the signal loss is however, the display will still generally show a picture. Many viewers would not know how much image quality was lost without comparing pictures to a perfectly-functioning display. In addition, there is no two-way communication between the source and display in an analogue-video-based system.

The Cliff Effect

Digital video signals behave quite differently from analogue video. When the cable length increases, the image quality is perceived to be perfect by human eyes until a certain length. After that length, the image is either not viewable or disappears altogether.

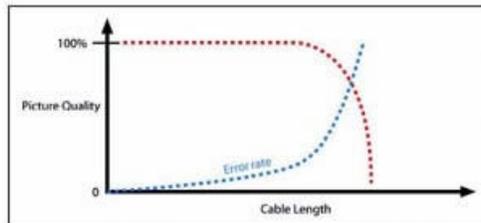


Picture quality of digital signal (e.g. HDMI) drops suddenly after certain length of cable. i.e. the Cliff Effect.

Why should consumers pay for better cables if they are below the Cliff Effect? This is a hot topic among consumers and manufactures. One side insists that you do not need to pay more for higher-performance cables, because as long as the signal has not exceeded the cliff, even cheap HDMI cables will provide a quality image. The other side argues that there are always differences between higher- and lower-quality products and this is a difference worth paying for. Good and bad HDMI cables pass the test right up to the point where they fall off the cliff. But, there are measurable differences between the two.

Seeing is deceiving

Even when the cable length is within the cliff, there are data errors already occurring in transmission. 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. Once the error rate exceeds the capability of the display, signal recovery may fail altogether.

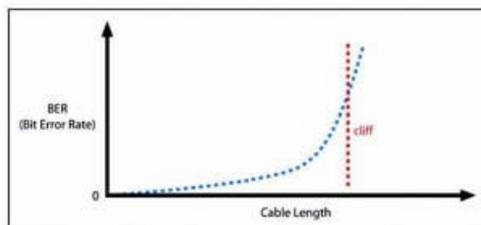


Long before reaching the cliff, the signal error rate starts to increase with length of cable.

HDMI cables are not created equal. But how would we know that there are meaningful differences? There are two industry standard tests for HDMI cable, namely the BER test and the Eye Pattern test.

The BER test

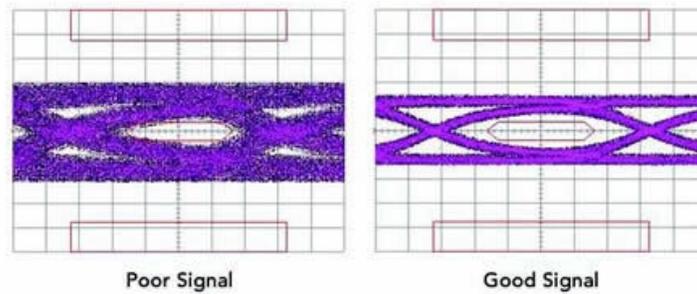
BER stands for Bit Error Rate. In a BER test, the signal generator would output billions of data bits (per the HDMI standard), send them to the cable (or the input of other devices), and receive them from the other end of the cable (or the output of other devices). Then, a comparison is made bit by bit with the sent data. The BER display shows the results as the total numbers of error bits in a given period of time, usually less than a second. The BER test accurately shows the real number of bad data bits a display could receive under a given condition. The higher the number, the worse the signal. The BER test is the most accurate real-world test for HDMI cable performance and quality control.



BER (Bit Error Rate) test counts the number of error data at the far end of the cable. The Cliff Effect is visible.

The 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.

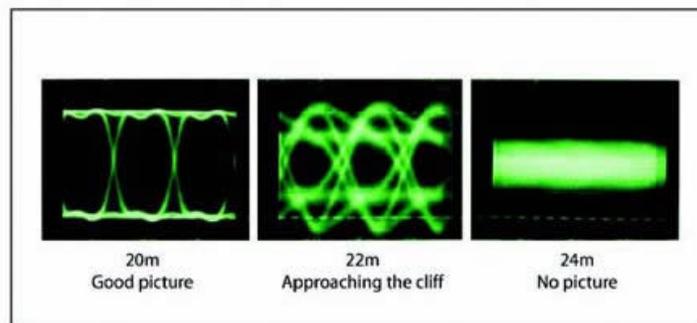


HDMI Eye patterns.

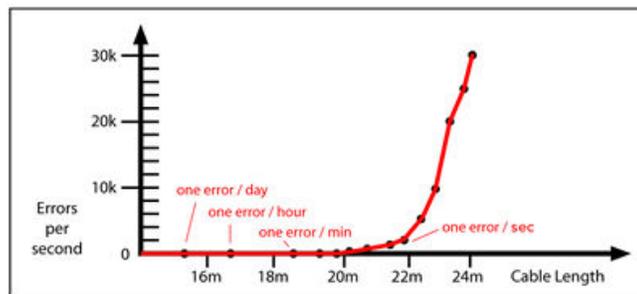
The eye pattern test shows many aspects of the digital signal. The height of the eye represents the signal amplitude. It must not fall into or become smaller than the marked diamond shaped area in the middle, otherwise the signal will be too small for the display to recover. The eye will appear to be closed in the vertical direction. The eye pattern also shows timing jitter where the rising and falling edges of digital bits do not always arrive at the precise time they should. On an oscilloscope, it appears that the eye gets fuzzy in the horizontal direction as a result of some bits shifting left, some shifting right and overlapping together. The internal width of the eye can't fall into or become narrower than the marked diamond area in the middle, otherwise the display won't recover the data. In short, if the eye collapses in either horizontal or vertical direction, the signal is lost.

BER vs. 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.



Eye Pattern test shows the waveforms of the digital signal (bits) visually. It also shows the Cliff Effect.



BER test also showing the Cliff Effect.

These two tests are considerably different. The BER test shows the scale (how many) of data errors, but does not tell the cause of the problem. The BER equipment costs tens of thousands of dollars. The test time is about a second for all four TMDS pairs and all other lines within an HDMI cable. These make the BER test the best for QC (quality control) and real-world field support applications.

The eye pattern test on the other hand, shows the cause of the problem, but not the scale of the data errors. This equipment costs hundreds of thousands of dollars. The test takes about 15 to 20 minutes because the technician needs to test one pair at a time, and needs to analyse the pattern subjectively one by one. This makes the eye pattern test the best for engineering design and fault analysis.

At AudioQuest, we employ both types of testing. Their extensive use begins throughout the design phase and ends with a 100% QC process to ensure the highest quality for each cable.



BER and Eye Pattern test equipment.

HDMI 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.

In the analogue world, we use bandwidth to describe the amount of information of the signal. The higher the picture resolution, the higher the signal bandwidth.

In the digital world, we use data rate to describe the number of bits per second of the signal. The higher the picture resolution, the higher the refresh rate. The deeper the colour, the higher the data rate. 720p and 1080i have about the same data rate of 2Gbps (regular 24-bit encoding). 1080p has about twice the data rate at 4Gbps (regular 24-bit encoding). 48-bit deep colour has about twice the data rate of the 24-bit encoding, or about 8Gbps for 1080p deep colour.

Please study the max data rate table below; you can see two trends:

- 1) The shorter the cable length of a given cable design, the higher the max data rate
- 2) The better the cable design at a given length, the higher the max data rate

Example HDMI cable product family										
Length (m)	1.0	2.0	3.0	4.5	6.0	7.5	9.0	12.0	15.0	20.0
Model										
Premium Level	34	29	20	20	16	13	11	8	6	5
▲	31	26	18	18	13	11	9	7	5	4
▲	25	19	13	13	10	8	7	5	4	
▲	21	15	10	10	8	6	5	4		
Entry Level	21	15	10	10	8	6	5	4		

Note: all data rates are nominal, in Gbps

- "1440p", deep color, 120 Hz, or about 32 Gbps
- "120 Hz", 1080p 48 bit, or about 16 Gbps
- Beyond HDMI 1.3 limit
- "Deep Color" 1080p 48 bit, 60 Hz or about 8 Gbps
- "1080p" 24 bit, 60 Hz or about 4 Gbps
- NA

Table showing HDMI maximum data rate versus cable length.

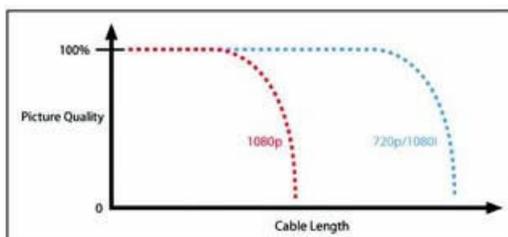
Higher data rate signals presents a bigger challenge to long HDMI cables. All HDMI cables made prior to the enactment of HDMI 1.3 will pass HDMI 1.3 signals. However, when data is sent at the maximum rate, the effective HDMI cable length is reduced by half. Keep in mind that HDMI 1.3 only EXTENDS the maximum allowable signal data rate, it does not INCREASE the data rate of a given signal. Your cable will still run the same distance on the same 1080p signal regardless of whether the devices are HDMI 1.2 or 1.3. The maximum distance will be reduced when you run the higher data rate signals now made possible by HDMI 1.3.

HDMI extender (repeater, amplifier) compatibility with HDMI 1.3

Unlike cables, most of the IC chips used in electronic HDMI extenders have a hard cut-off on their maximum data rate limit. Therefore, the extenders made before the HDMI 1.3 standard was published often won't work with the HDMI 1.3 signals with data rates higher than 5Gbps.

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



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

From the discussion above, we see that there are absolute differences among cables. The worse the cable, the closer the cliff. 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 cost of the HDTV in your system.

What makes a better HDMI cable?

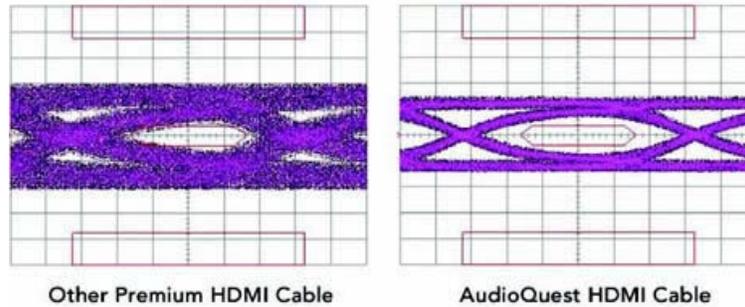
There's a widespread myth about digital video cables such as HDMI. Due to the Cliff Effect, all the cables have the same perfect picture when they work, even those of lowest cost. The discussion in previous sections already shows that there are test methods to clearly show the differences between cables. Now let's examine the differences from a design and manufacturing point of view.

Better Design

Don't let the simple appearance of an HDMI cable fool you. HDMI cable carries signal up to 10Gbps. That's one of the most challenging cables to make due to this super high data rate - just compare it to the data rate of any network or computer, which is only a small fraction of the data rate of HDMI. Here are some of the elements for a good HDMI cable:

- 1) Better conductor - this is the most critical element. OFC (Oxygen Free Copper) is a very pure copper (higher than 99.99% purity), used in better quality cables. Silver-plated OFC is an even better conductor because high-purity silver is plated at the surface where high-frequency signals concentrate due to the skin effect.
- 2) Solid core construction - single solid conductor eliminates interferences around the electromagnetic fields of the signals travelling in different strands in a stranded cable.
- 3) Superior cable geometry design - the core elements of the HDMI cable are the four twisted pairs with ultra-precise twist ratio. Some high-end cables use twisted quad for better performance.
- 4) Insulation - better cables use skin-form-skin (gas injection with hardened skins) insulation to achieve better electrical performance while maintaining mechanical stability.

A cable benefiting from more advanced design has much cleaner eye pattern, see below.



Eye Pattern test results.

Better manufacturing

Manufacturing techniques, equipment, processes and quality controls are critical to make every cable you buy the highest quality possible. This is even more important for HDMI cables. HDMI cables are very complex and require high precision manufacturing controls:

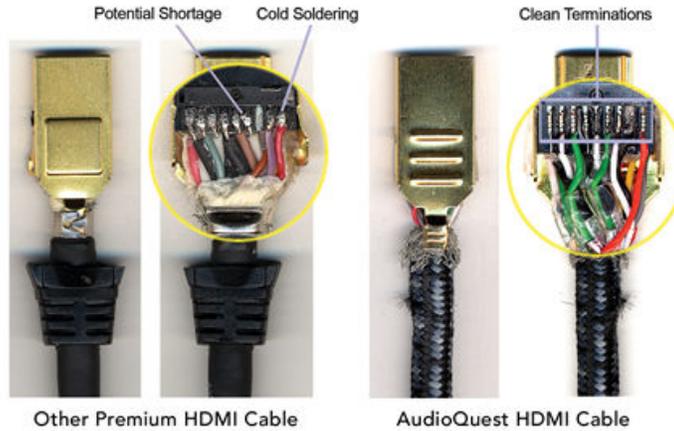
- 1) Precision HDMI twisted pair machine - HDMI cables can handle up to 10Gbps data rate, which is higher than the fastest computer. To achieve such high performance, the twist ratio control on the four twisted pair wires inside a HDMI cable is critical. The picture below is an ultra-precision twist machine for making high-quality HDMI cables.



The precision twisted-pair machine.

- 2) HDMI crimping technology - there are 19 conductors in one HDMI plug and the distance between pins is very small. 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. Each could render the cable defective. 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.



Soldering versus crimping connection.

The speed rating system

It isn't useful, or accurate, to describe a signal by its resolution, refresh rate and bit depth. For example, 720p and 1080i have about the same amount of information; 1080i 60Hz and 1080p 30Hz have about the same amount of information.

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, 4Gbps is roughly the data rate for 1080p, 60Hz and 24-bit bit-depth. The maximum data rate a given cable can carry depends on the cable quality and the cable length. Some manufacturers 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 paper, 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, and to understand that there are marked differences in performance and quality between today's HDMI cable products.

Xiaozheng Lu is the Senior Vice President of Product Development for Luxi Electronics, manufacturer and distributor of premium performance audio and video cable products and accessories.

www.luxielelectronics.com