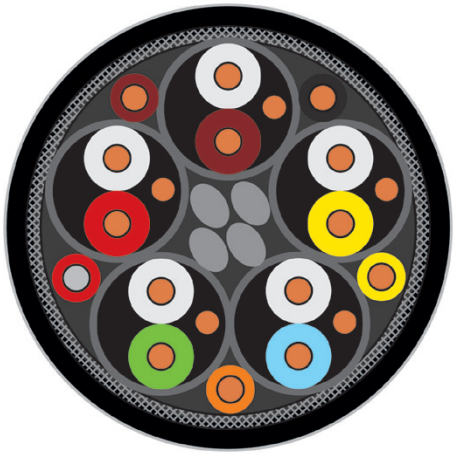


HDMI Demystified

April 2011

What is HDMI?

High-Definition Multimedia Interface, or HDMI, is a digital audio, video and control signal format defined by seven of the largest consumer electronics manufacturers. HDMI specifications and compliance are enforced by an organization called HDMI LLC, which is controlled by representatives from the seven founding companies. Released on 12/9/2002, it is supported by more than 300 companies. HDMI has several advantages over previous connection solutions:

- 1080p and higher resolution capability
- Multichannel high-resolution audio
- One cable for video, audio and control
- Two-way communication for easy system control
- Automatic display and source matching for resolution, format and aspect ratio
- Computer compatibility
- Ethernet/Internet Connectivity

The Evolution of HDMI

Since HDMI's inception, the capabilities have changed as updates have been made to the specification. Version numbers, such as 1.2, 1.3, and most recently 1.4 and 1.4a, have marked these updates. The majority of the changes involve an increased number of options for manufacturers to choose from. All new versions are compatible with electronics designed to meet previous standards, but will not add features that the existing products in your system do not have. For example, a Blu-ray player with 1080p, built to version 1.3 spec will work with a 1080i television built to version 1.2 spec, but will not give you 1080p.

The current version of HDMI, version 1.4a, includes many new feature options, including audio return channel, 4k x 2k resolution, support for 3D video and 3D broadcast video formats, as well as support for Ethernet.

Features and Data

Electronics manufacturers must carefully choose from these features. This is because the current HDMI specification limits the amount of data any piece of electronics can send and receive to 10.2 Gbps (Gigabits per second) or less. This limit is not arbitrary, but is based on current technological realities. A good way to think of this is as if HDMI LLC has created a buffet of options and has given you a 10.2 Gbps plate. It is all you can eat, but it must fit on this 10.2 Gbps plate. Some features take up more room on this plate than others, so the electronics manufacturers must determine what features will be most desirable for their customers.

Video Options

- **Resolution:** Refers to the number of pixels in both the horizontal and vertical direction per frame. Although measured in both dimensions, it is usually referred to by only one of the dimensions.

  For example, 1080p is 1920x1080 pixels per frame, which is in wide use on Blu-ray Disc and a variety of other consumer high-definition sources. The current highest resolution video format supported by HDMI 1.4 and 1.4a is 4k, which can be defined as either 3840x2160 or 4096x2160 pixels per frame. While 4k is often mentioned prominently in discussions of HDMI 1.4's capabilities, no current or planned consumer video formats employ 4k resolution. Such an increase in resolution would dramatically affect the amount of data transmitted.

- **Interlaced/Progressive Scan:** Progressive scan displays the video as a series of complete images or frames, while interlaced divides these frames into two fields, one made of the even horizontal rows of pixels and the other of the odd rows. The most common interlaced format is 1080i, which uses half as much data as 1080p/60.

- **Color Depth:** This is the amount of color information per channel/per pixel (red, green, and blue), usually described as the number of bits per color channel, such as 8-bits, for a total of 24-bits per pixel. While color depths up to 16-bits per color channel are currently supported by HDMI 1.3 and HDMI 1.4, when engaged, Deep Color transmission is typically 10-bits or 12-bits per color channel, increasing the color bit depth to 30-bits or 36-bits total

per pixel. Increases in color bit depth, such as those typical when the Deep Color feature in HDMI 1.3 and HDMI 1.4 components is engaged, dramatically increases the amount of data sent over HDMI cables.

- **Color Space:** Different types of source material use different ranges of colors. Color spaces act as a map to translate these different color ranges between sources. For example, standard definition video from DVD, cable and satellite sources all conform to a different color space than HDTV and HD video sources like Blu-ray. Having multiple color spaces available allows color to be more accurately reproduced from source to source. Additional color space options do not affect the amount of data transmitted.

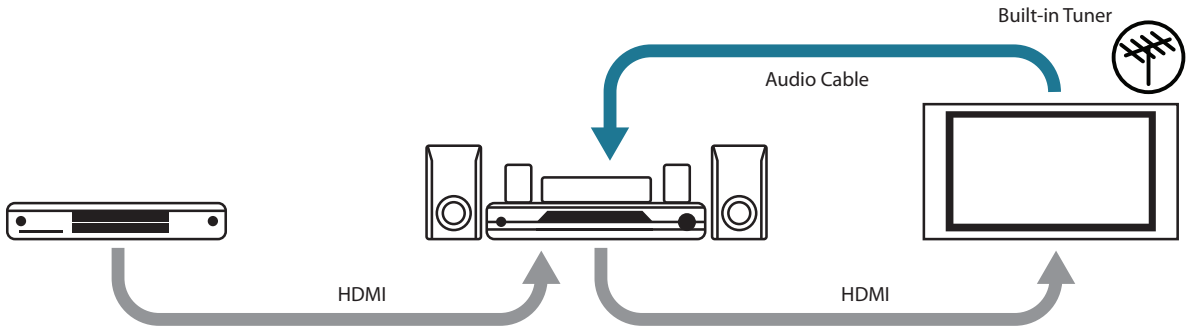
- **3D:** A 3-dimensional effect is created by rapidly displaying separate images for each eye, and keeping the images intended for each eye as entirely separate as possible. This new feature offers resolutions up to 1080p in a variety of configurations for a 3D effect. The data rate for 3D varies depending on the system being used. The frame compatible 3D systems used for cable and satellite broadcast signals are most commonly 1080i using so-called “top/bottom” or “side by side” formats that reduce either horizontal or vertical resolution to conform to the data rates required for typical 1080i HD broadcast signals. Broadcast 3D doesn’t require a higher data rate than a typical 2D 1080p signal. The frame sequential, or frame packing system currently used for Blu-ray 3D offers full 1080p resolution for each eye, which doubles the data rate of the signals transmitted via HDMI.

- **Refresh rate:** Refresh rate refers to the number of times the image on the television is updated per second. It is described in Hz (hertz), and should not be confused with fps (frames per second). One of the most common refresh rates used in HDTVs in the United States is 60 Hz. Currently1080p at 60Hz is the maximum signal resolution and refresh rate that will be transmitted between HDMI-connected components. The 120 Hz and 240 Hz refresh rates that are increasingly common in today’s HDTVs are created in the display and not encoded in the source or created by the source component, so they have no impact on the data rates of HDMI-connected devices.

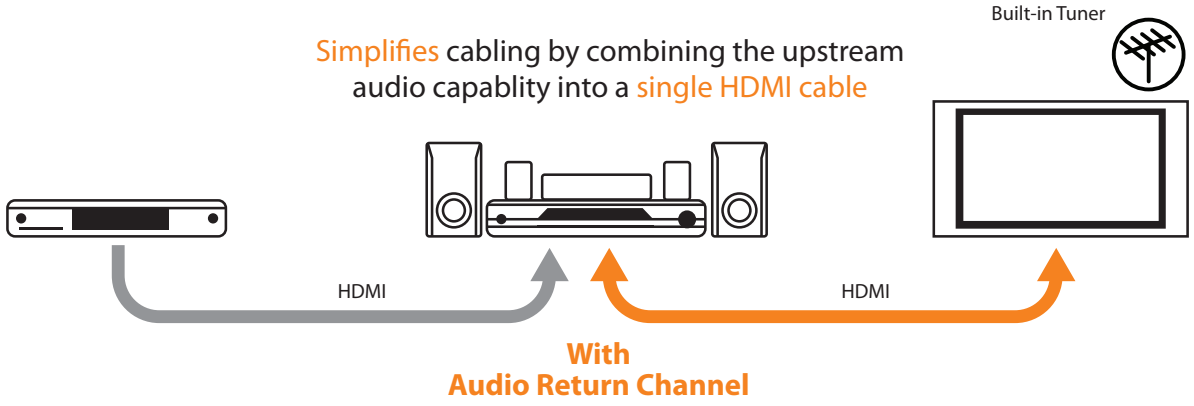
Audio Options

- **Audio formats:** Options range from Dolby Digital and DTS, which are standard lossy compression formats, to uncompressed multichannel PCM and newer formats such as Dolby TrueHD and DTS-HD Master Audio that offer lossless, high resolution digital surround sound. Uncompressed or lossless audio formats have a minor impact on the data transmitted over HDMI.
- **Lip sync:** Synchronizes audio and video compensating for signal processing delays. There is no impact on the data used.
- **Audio Return Channel:** Abbreviated as A.R.C. This is a new feature that allows a single HDMI cable, connected to an AV receiver or surround sound processor, to not only send video from the AV receiver to the HDTV, but to also send audio from

Audio Return Channel : Current



Audio Return Channel : Future

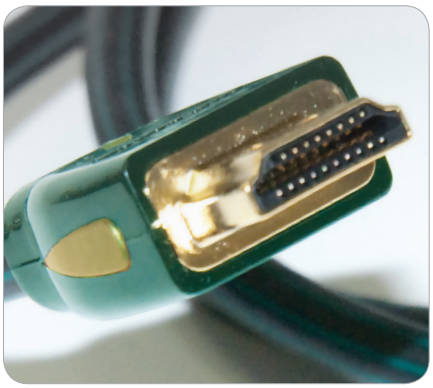


the HDTV back to the AV receiver. Although it is a new feature for HDMI 1.4, it does not require a special cable. There is no impact on data transmission rate. The HDMI components in the system must support this feature, and this feature is not backward compatible with HDMI components that do not support A.R.C.. In short, if the components do not have the A.R.C. marking near the HDMI jack, that indicates that A.R.C. is not supported, and the A.R.C. feature will not work.

Additional Features

- **Ethernet:** A feature included in HDMI 1.4 and 1.4a that allows enabled equipment to share a bi-directional 100 Mbps Ethernet connection through the HDMI cable, as long as one of the HDMI-connected components in the system is connected to the Internet. This feature requires an HDMI cable specified as "with Ethernet." The optional Ethernet feature does not effect the amount of data transmitted over the four audio+video signal-carrying pairs. All connected components must support this feature in order for it to work.
- **Control:** Consumer Electronic Control (CEC) allows electronics to control one another without additional hardware or add-on control systems. Controls are somewhat limited, but often enable the customer to reduce the number of remotes needed. CEC does not impact the data used.

HDMI Cables:



All HDMI cables are made up of 19 individual conductors. Many of these wires perform multiple tasks and transmit large amounts of data, so the quality of the conductors, precision of the geometry, and the quality of the termination all affect the ability of the cable to properly implement its tasks.

For the most part, unlike HDMI enabled components, HDMI cables do not have features, they have capacity (often described as "speed"

and measured in Gbps). The one exception to this is the new Ethernet feature, which requires a Ethernet-compatible cable. Other than this exception, the cable does not care what the resolution, color depth, or refresh rate of the signal is, as long as the data that makes up the signal is not too large for the cable to pass. HDMI LLC has approved two different categories of cable based on their respective speed ratings.

High Speed: meets or exceeds the maximum current data rate for HDMI of 10.2 Gbps, capable of transmitting 100% of the data required for al of HDMI's current audio/video features, including Blu-ray 3D. Nearly all short length cables meet or exceed this category. Very high quality cables will meet this specification for lengths up to about 10m. For the most part, longer length HDMI cables can only meet the High Speed specification with the use of active-circuit equalization or amplification.

Standard Speed: meets or exceeds the minimum HD data rate of 2.25 Gbps, the amount needed to transmit 1080i or 720p. Many Standard Speed cables are capable of higher data rates that allow for features such as 1080p or broadcast 3D (which requires about 4 Gbps), but do not have the capacity to achieve the High Speed rating. A well-made moderate length (such as 12m) cable may even be able to pass Blu-ray 3D, but still be rated as Standard Speed. Even the best long length HDMI cables are currently limited to a Standard Speed rating.

Since the ability for an HDMI cable to pass Ethernet requires an additional twisted-pair of conductors inside the cable, HDMI has added two additional cable types. These are High Speed with Ethernet and Standard Speed with Ethernet.

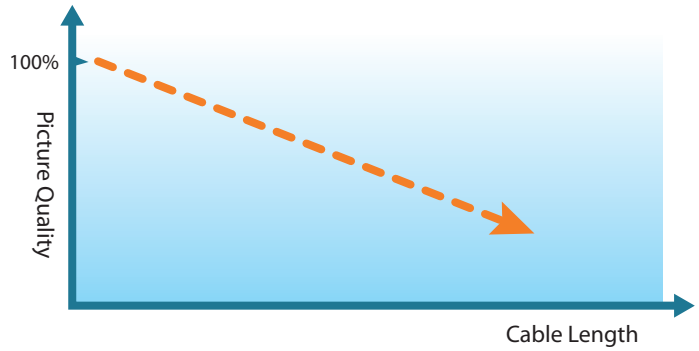
To recap, there are four cable types approved for home use by HDMI LLC:

1. Standard Speed
2. High Speed
3. Standard Speed with Ethernet
4. High Speed with Ethernet

Other speed rating systems are on the market, but are not approved by HDMI LLC and are primarily for marketing purposes. Only the four cable types listed above are certified by HDMI LLC. Also be wary of cable manufacturers that tout incredibly high data rates or speed ratings on very long length cables. These manufacturers are usually labeling long length cables based on results obtained from testing shorter versions of the cable.

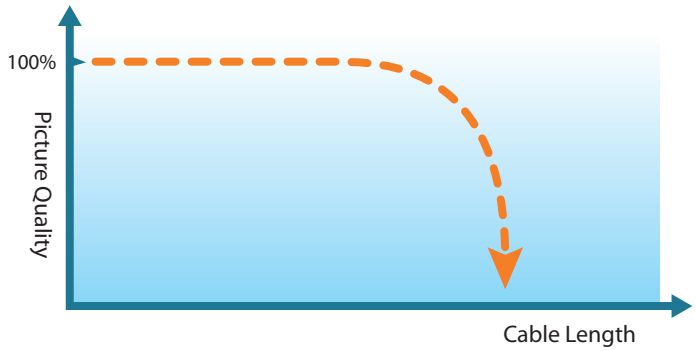
Cable Length, Data Rate, and the Cliff Effect:

In earlier sections, length is often mentioned as a concern for HDMI cables. The reason for this is that HDMI cables function differently than analog cables, like component video. When a component video cable is run longer, it will pick up noise and lose signal along the way in a very linear fashion. It is unrelated to the amount of signal being sent, and will result in visible noise and loss of detail and brightness. A better component video cable will lessen this effect and give you better performance by reducing the amount of distortion in the cable and shielding the signal from outside noise.



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

HDMI cables transmit packets of digital data along twisted pairs of wire. While there is still noise and loss, as long as enough of the signal gets to the television, error correction inside the TV will fill in the missing pieces and give you a good clean picture that is difficult to distinguish from a picture with fewer errors. If loss is too great, the image will appear to “sparkle” or you will lose picture completely. This is called the “cliff effect,” which will be explained further below.



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

The primary factors that affect any given quality level of HDMI cable's ability to provide a picture, are the amount of data being sent, and the length of the cable. Higher data rates bump up against the capacity of the cable, a capability which very simply diminishes with length. A cable that may be capable of passing 1080i at 30m may not be able to pass 1080p until it is as short as 15m, and will not be able to pass 1080p 3D signals or Deep Color signals.

The Premium Cable Argument:

More than any other cable category, premium HDMI cables are maligned for being "not worth it." This is mostly due to a fundamental misunderstanding of how digital works as well as oversight of all the functions an HDMI cable is tasked with. That said, there is an element of truth to what is often said about HDMI cables. Two short length (let's say 2m) cables of different qualities connected to identical systems will often be difficult to distinguish from one another in picture quality. This is because the error rate is very low on a short length cables and the HDMI signal contains extra bits for error correction. Sharp eyes may see differences in brightness, or errors when a lot of motion is present. These video differences can be more pronounced as lengths increase, but are not always as clear as night and day. Premium cables are capable of reliably going longer distances at higher data rates. Because of this, most of the grumbling and pushback from naysayers is in regards to shorter cables.

It should be said though, that errors do still exist on shorter cables and error correction is never ideal. A premium cable, even in short

lengths, will result in less error correction and a measurably better signal, even though the human eye might be easily fooled.

While the human eye is easily fooled, the human ear is in many ways much more perceptive. Think of this … if you are trying to really hear something, what is the first thing you do? Close your eyes! This is because vision can be so deceptive. Don't forget that HDMI is not just a video cable, but is also an audio cable. It is THE audio cable for our most sophisticated consumer level surround formats, but audio is rarely mentioned, leaving all of the focus on video. For many reasons, audio is far more complicated to reproduce, and error correction is rarely proven effective. This is partly due to the more freeform nature of audio verses video, as well as the ear's sensitivity to timing errors (also known as jitter in the digital world). The audio differences in HDMI cables can be heard just as dramatically on even the shortest lengths, and improvements in the cable materials make a marked difference in the sound quality from all HDMI enabled devices.

The AudioQuest Difference:

If you've read AudioQuest 101 or the Four Elements, you understand the fundamental design principles in all AudioQuest cables. Given the complexity of HDMI, one can imagine that the Four Elements are integral to the design. Here is a refresher on these design elements and how they relate to AudioQuest HDMI cables.

Solid Core: Unlike most HDMI cables on the market, all AudioQuest HDMI cables use only solid core conductors. This allows for reduced distortion (jitter in the digital world), which means lower error rates. In our listening, solid core conductors greatly improve the audio performance of an HDMI cable, even when simply transmitting signal from a cable box to a TV!

Metals: Great attention is paid to the quality of metals used in AudioQuest HDMI cables. The same quality LGC (Long-Grain Copper) used in our analog cables is used as our HDMI cables' base metal, with increased amounts of silver plating added as the models improve. AudioQuest has even introduced a PSS (Perfect-Surface Silver) HDMI cable, called Diamond. Quality metals make large improvements in digital audio performance.

Geometry: Consistent, reliable performance from an HDMI cable, particularly a long one, requires very precise geometry with tight tolerances. This is why AudioQuest HDMI cables are constructed using the best precision twist machines available.

Dielectric: In HDMI cables, the proper dielectric (insulation) material can not only reduce jitter and crosstalk, its mechanical qualities and its resistance to deformation significantly affect its ability to maintain the necessary precise geometry. AudioQuest chooses the best dielectric materials for all its HDMI cables in order to ensure that the geometry maintains its integrity. Coffee and Diamond also have the additional enhancement of AudioQuest's patented Dielectric-Bias System (DBS), which drastically reduces any distortion and timing errors caused by the dielectric. For more information on DBS, see our separate DBS educational module.

Other technologies beyond the four elements:

Directionality: All audio cables are directional, including HDMI. The correct direction is determined through listening to every batch of metal used in every AudioQuest audio cable. Care is even taken to run the conductors used in the Audio Return Channel in the opposite direction to ensure the best performance for that application. Arrows are clearly marked on the plugs to insure you get the best sound quality.

Terminations: All AudioQuest HDMI cables are terminated using a wave solder machine, an automated process that allows for the greatest control of conductor placement, solder flow and temperature. This not only insures a reliable connection, but also further reduces signal loss and distortion.

AudioQuest High Speed with Ethernet:

All HDMI cables up through 10m currently made by AudioQuest, meet or exceed the 10.2 Gbps maximum current data rate for HDMI. These cables are rated and labeled as High Speed with Ethernet, regardless of price level. From 12m to 20m, AudioQuest HDMI cables are rated and labeled Standard Speed with Ethernet. AudioQuest

HDMI cables will transmit 100% of the data required for Blu-ray 3D up to and including 12M lengths, and they will transmit 100% of the data required for broadcast 3D from cable and satellite sources up to 20M. Every cable is tested to ensure that it passes 1080p on a Bit Error Rate (BER) machine. 100% QC is unheard of in the cable industry, but AudioQuest feels that HDMI is complicated enough without having to worry about defective cables.

Troubleshooting HDMI Cables:

Despite rigorous QC, issues can arise in HDMI systems. It is rarely a defective cable, but it can sometimes seem that way. There is a lot going on in a system configured with HDMI and that means troubleshooting an issue may not be as simple as it is with analog cables. Not only does the video and audio need to be transmitted, but also data and copy protection (HDCP) and various “handshaking” metadata. These issues can be broken down into a couple of categories as they relate to cables.

Cliff Effect: Cliff effect typically affects only long length cables. If all the gear in the system is set up properly and capable of the desired resolution, but you are not getting a picture or the image appears to “sparkle,” it is most likely cliff effect. You can test this by lowering the resolution on the source and seeing if the picture appears. You can have this problem even if a cable is rated to be capable of a certain resolution. Physical damage to the cable, low or noisy signal output from the source, or TV sensitivities can affect the ability for the signal work properly. The best solution is to go with the highest quality cable at the shortest length possible for the system. If incredibly long lengths are required, there are solutions on the market commonly called electronic extenders or “baluns” that send the signal over CAT5 or CAT6, or fiber. These solutions have a varying degree of success and cost.

Data and HDCP: While both Data and HDCP signals are weakened over distance, Data and HDCP issues can be a problem even in systems using short cables. A single wire inside the HDMI cable is used for two-way communications, such as HDCP, format and resolution synchronization. Much like two-way traffic on a single lane road, the timing of the data transmissions is very important. Small variations

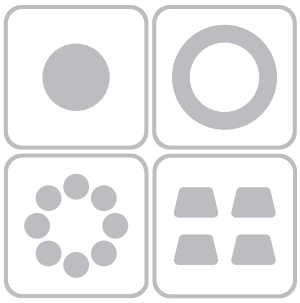
in transmission voltages in the electronics, combined with variations in wire properties like capacitance, can result in poor timing and data crashes. While no particular product in the system is defective (for example you can put the HDMI cable on a different system and it works fine), the system as a whole fails. The solution is often to change the system slightly by using a different model HDMI cable, a different source or TV, or even adding a device into the system like an HDMI splitter.

In Conclusion:

HDMI is the most advanced connection method available today, but its complexity can often be intimidating. Hopefully, this educational module answered some questions. AudioQuest believes the best marketing is an informed and inspired consumer, and that begins with you!

Summary:

1. With the exception of Ethernet, HDMI cables are described as High Speed or Standard Speed, which indicates whether a given HDMI cable at a given length is compatible all of HDMI's current features.
2. All AudioQuest HDMI cables up to and including 10 meters are rated High-Speed with Ethernet, the highest rating possible, and can therefore transmit 100% of the data required for all of HDMI's current features, including Blu-ray 3D.
3. AudioQuest HDMI cables are designed to maximize the audio and video experience through the best materials, design, and testing



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