# THE CHALLENGES OF INTERFACING HDMI IN THE WORLD OF PROFESSIONAL AV

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Kramer C-HM/HM

**Figure 1.**
A typical HDMI interconnecting cable

The High Definition Multimedia Interface (HDMI), ubiquitous on everything from consumer televisions and Blu-ray and DVD players to set-top boxes, game consoles, and digital cameras and camcorders, has become just as commonplace in the world of professional video production and display equipment.

You'll find this display interface on digital cameras, camcorders, and media players; videoconferencing equipment, projectors, and display monitors. HDMI distribution amplifiers and matrix switchers are widely available to support all of these connections, as are HDMI presentation switchers and signal format conversion products.

At first glance, using HDMI as a professional AV display interface would appear to be ill-advised, as its copy protection overlay was never designed with multi-point video and audio signal distribution in mind. Yet, these are different times: the world of consumer electronics drives most of the new product innovation and demand for the pro AV channel, so customers routinely expect to use HDMI-equipped products in commercial installations and applications.

HDMI can create major problems when switched among multiple displays, particularly if the displays have different native pixel resolutions. Several approaches have been engineered to overcome these issues while preserving the essential characteristics of HDMI – secure copy protection and automatic display clock detection and optimization – and allow it to be ported reliably to more than one monitor, TV or projector.

## HOW DID WE GET HERE?

Kramer AD-DM/HF

**Figure 2.**
A DVI-HDMI adapter

HDMI evolved from an earlier attempt at an intelligent, 100%-digital display connection known as DVI, or Digital Visual (Video) Interface. DVI was first developed by the Digital Display Working Group (DDWG) and released as a standard in 1999 to replace the 15-pin Video Graphics Array (VGA) analog display connector, commonly found on desktop and notebook computers and still in widespread use today.

DVI allowed video sources to communicate with connected displays by using Extended Display Interface Data (EDID), first seen on VGA connectors in 1994. The intent was to deliver uncompressed digital video to the display at optimal resolution and refresh rates by using transition-minimized differential signaling (TMDS) to support a maximum resolution of 1920x1080 pixels, refreshed @ 60Hz, in a single-link implementation (165 MHz pixel clock), or 2048x1536 pixels, refreshed @ 60Hz, in a dual-link implementation (330 MHz pixel clock).

The first implementation of DVI supported both 'pure' digital connections to computer monitors (DVI-D) and hybrid analog/digital connections (DVI-I). However, the DVI-I connector soon spread beyond computer monitors to consumer electronics devices, such as terrestrial, cable, and satellite set-top receivers, DVD players, and HDTVs.

As a result, concerns were expressed that digital content transmitted through DVI-D connections could be copied and distributed illegally, leading to the formation of the HDMI Consortium (Hitachi, Matsushita Electric Industrial [Panasonic], Philips, Silicon Image, Sony, Thomson [RCA] and Toshiba).

This group developed the HDMI interface in 2002 as a more robust version of DVI; one that could also carry embedded digital audio and metadata, and at faster data rates.

As originally conceived, HDMI would be a "plug-and-play" video/audio interface between media players and HDTVs; one that resembles an ad-hoc "peer-to-peer" network connection. In addition to supporting EDID, HDMI would also feature High-bandwidth Digital Copy protection (HDCP), developed by Intel. The HDMI connector would be smaller than its DVI counterpart, and would also be compatible with both RGB and weighted component video (YCbCr) color.

## HDMI TODAY

Most of the development work and extensions to the HDMI standard have been the responsibility of Silicon Image of Sunnyvale, CA. In the years since the HDMI standard was first announced in 2002, it has undergone numerous revisions and updates, with the latest implementation being version 2.0 (September 2013). V2.0 increases the maximum interface data rate to 18 gigabits per second (Gb/s) and includes support for 32 discrete channels of audio with a maximum sampling rate of 1536 kHz.

HDMI 2.0 can also transport two 1920x1080p/60 signals simultaneously through one connector. With this boost in speed, the interface can now transport an Ultra HD (3840x2160) display signal encoded as 8-bit RGB color with a maximum refresh rate of 60 Hz. Ultra HD images with deeper color can be accommodated at slower refresh rates or encoded in the YCbCr format (4:2:2, 4:2:0).

There are five different versions of the HDMI connector, with Type A being the most widely implemented (19 pins, slide-on) across televisions and Blu-ray players. Type C is used on some mobile devices as a stand-alone interface, although it isn't as popular as the Mobile High-definition Link (MHL) iteration that carries HDMI and USB through the same 5-pin connector.

With HDMI now widely adopted, support for the DVI standard has been discontinued, even though the connector remains popular. Manufacturers of motherboards and video cards are largely moving to HDMI to replace VGA, although some have also adopted DisplayPort as a digital display connection, primarily for computer monitors.

## WHERE THE TROUBLE STARTS


VM-4HC

**Figure 3.**
A four output HDMI Distribution Amplifier with "Intelligent" EDID Handling.

In HDMI language, there are two parts to a connection – the 'source' (DVD/BD player, set-top box, game console, and computer) and the 'sink' (TV, monitor, projector). Allowances were made in the HDMI standard for additional AV equipment that might need to be connected between sources and sinks, such as audio receivers.

These devices are equipped with "repeaters" to retransmit the HDCP Keys. The HDCP connection requires a complex exchange of keys between sources and sinks. Each HDCP-capable device has a pool of forty different 56-bit keys, which are exchanged randomly and asymmetrically between each source and sink when an HDMI connection is made. Compromised keys will disable the connection, i.e. Blu-ray and DVD discs will not play if the players are presented with a compromised key or keys.

In a peer-to-peer HDMI connection, only one display would be connected as a sink, but multiple sources could be connected to that sink either directly or through repeater-equipped devices. This architecture worked very well, as the exchange of EDID information and HDCP "keys" was straightforward. The connected display would send its EDID information to the source, which in turn would configure the pixel clock accordingly. The HDCP overlay would then establish that a secure connection existed and begin streaming content.

This approach ensures that copy-protected content remains encrypted from the source to the sink. While this system may work well for the multi-source, single-sink world of consumers, it is not at all manageable in professional and industrial AV channels where the reverse condition is usually found – a single source driving multiple sinks, or displays.

Designing a professional video display distribution system around a secure, all-digital connection like HDMI is generally not ideal, particularly when SDI and HD SDI interfaces can already do the job. Yet it is being done by numerous companies not only to support formats such as Blu-ray players and HDTV set-top receivers, but also to take advantage of the high-density connector and eliminate discrete connections for video, audio, and data.

For AV systems integrators, the challenge is to connect two or more displays with different resolutions to a single HDMI source and maintain reliable connection. Which EDID is to be supported? Are all displays HDCP-enabled? What if multiple sources are being connected to one or more displays? How can any computers connected through a HDMI matrix switcher stay active when no active sink is detected?

All of these are real problems faced by anyone designing a multipoint HDMI distribution system. Let's take a closer look at each of the HDMI interfacing issues.

### HDMI ISSUES: EDID

It can easily be seen that simply connecting and disconnecting different displays to an HDMI matrix switcher or distribution amplifier could possibly result in (a) dropped connections, (b) long intervals waiting for EDID to be exchanged and updated, and (c) in some cases, no images at all. The typical peer-to-peer HDMI connection found in the home does not work for two or more connected displays, particularly if they have different native resolutions.

A more sensible, 'smart' approach for the pro AV market that still takes full advantage of EDID is to store the chosen display settings in memory. These settings can remain active in non-volatile memory, emulating a virtual display to ensure a connected PC or media player does not go into "sleep" mode when it is not the selected source.

A distribution amplifier with "intelligent" EDID can also analyze all of the EDID information for each connected display and automatically choose the highest common display resolution. An example of the use of this "auto-mix" mode operation would be if a 1x4 distribution amplifier were to have two 1080p displays, one 720p display, and one 480p display connected, as seen in figure (4a.)

The HDMI Distribution Amplifier analyzes all the EDID information and provides the source with a new EDID which is the highest common resolution of all the connected displays.  In this case, the highest common resolution between all four displays is 480P, so that is what the HDMi source will output.

This ensures all displays will have a picture.


**Figure 4a.** By using an "Intelligent" EDID polling and storage system, the installation can be optimized to the highest common resolution.

When all four displays are active, the source is prompted to output 480p as that is the maximum resolution common to all four displays. A picture is seen on all displays. Should the 480p display be disconnected from the distribution amplifier, the EDID analyzer within the distribution amplifier automatically reports back 720p as the highest common display resolution to the connected source, as shown in figure (4b.)

Now, the 480p monitor hasp been unplugged.  In this case, the highest common resolution between all three displays is 720p. So that is what the source will output.

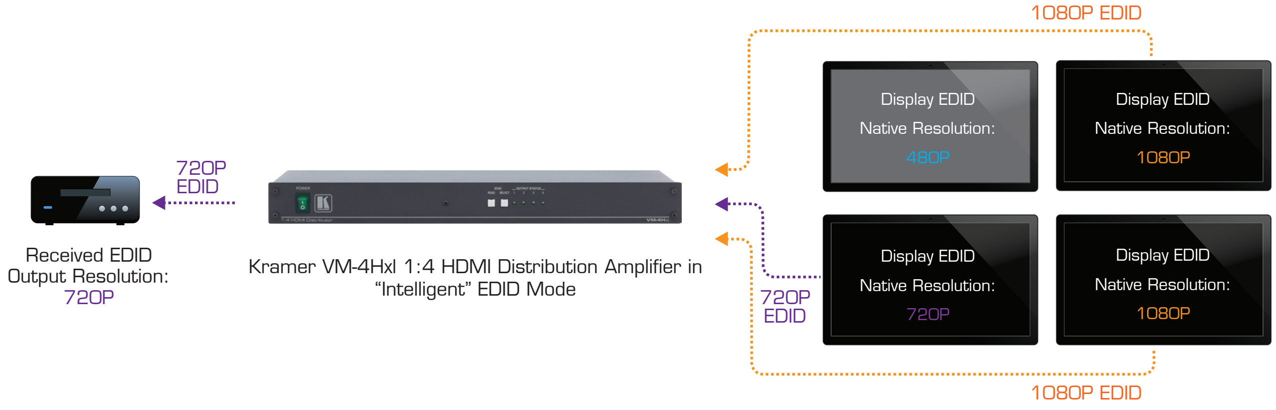


**Figure 4b.** When the display with the lowest native resolution is disconnected, the distribution amplifier automatically defaults to the next highest resolution supported by all the remaining displays.

This design ensures that all connected displays will always have a picture, and it will be the highest resolution image supported by all connected displays.

For matrix switchers, the system designer should design the system with EDID in mind.  The best system uses all the same monitors so that the resolutions and EDID are all the same.  If that is not possible, then the switcher should be set to the highest common resolution possible.

Storing EDID in memory also speeds up the HDMI connection "handshake," which can take several seconds to execute. This approach to handling EDID ensures that all connected sources remain active at all times and that every connected display will show an image, although the resolution may change to accommodate all displays. The adoption of Silicon Image's InstaPort technology has sped up the process of reading EDID considerably, allowing much faster connection times after hot plug detection.

## HDMI ISSUES: HDCP

The next step is to verify and establish an HDCP connection to all sinks. Using the conventional approach, a repeater within a distribution amplifier or matrix switcher would pass all HDCP keys back to the source. This means the source needs to decipher a different set of keys for each connected display, and if any key is corrupted, no signal will pass to any connected display, even if the remaining displays are transmitting valid keys.

(1) Repeaters pass HDCP keys back to the source for handshake

(2) Source needs to decipher 4 HDCP keys instead of 1 to output an image

(3) If one display is not HDCP-compliant, or if one HDCP key is corrupted, then source will not output content to any display

Problem: Many AV sources do not support repeater devices!

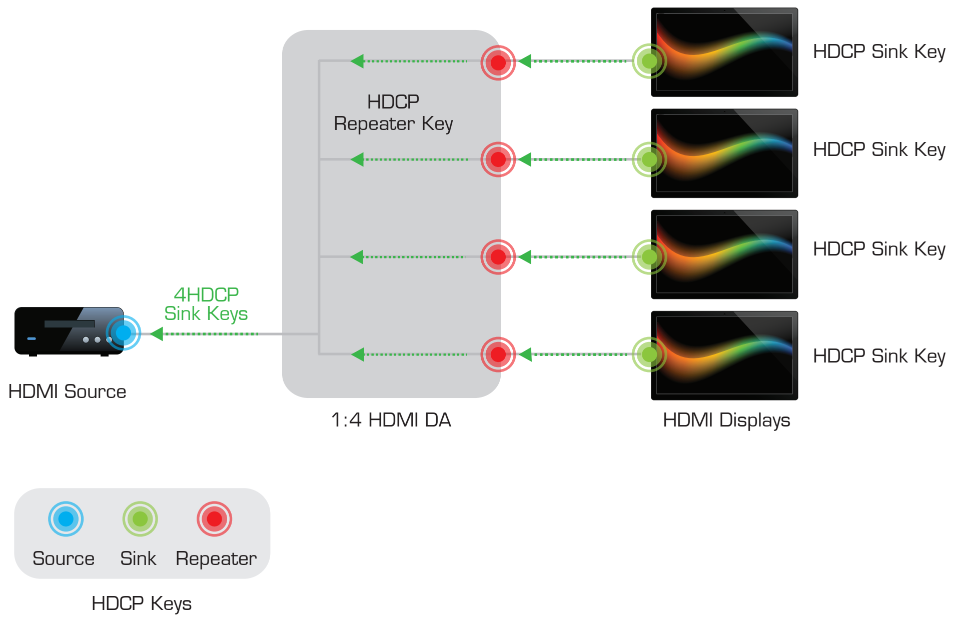


**Figure 5.** An HDMI distribution amplifier that depends on repeater keys is not reliable.

It's clear that the distribution amplifier cannot simply repeat the connection to each display, as it would with a single, peer-to-peer HDMI connection. What happens when a non-compliant display is connected? What if a non-compliant source is switched in place of a compliant source? For a conventional distribution amplifier or matrix switcher using a repeater design, this approach became a nightmare.

Once again, a more practical approach was needed; one that maintains and respects the HDCP overlaywhile also ensuring the reliable HDMI connection of a matrix of displays. The solution? Make the matrix switcher or distribution amplifier a sink unto itself, thereby ensuring a constant and secure connection to every connected source.

No repeater keys needed as each display now has its own 'sink-source' handshake with DA

Source now has its own 'sink-source' handshake with input of DA

If one display is not HDCP-compatible or if one HDCP key is corrupted, then only that display will be affected!

A reliable and secure solution!

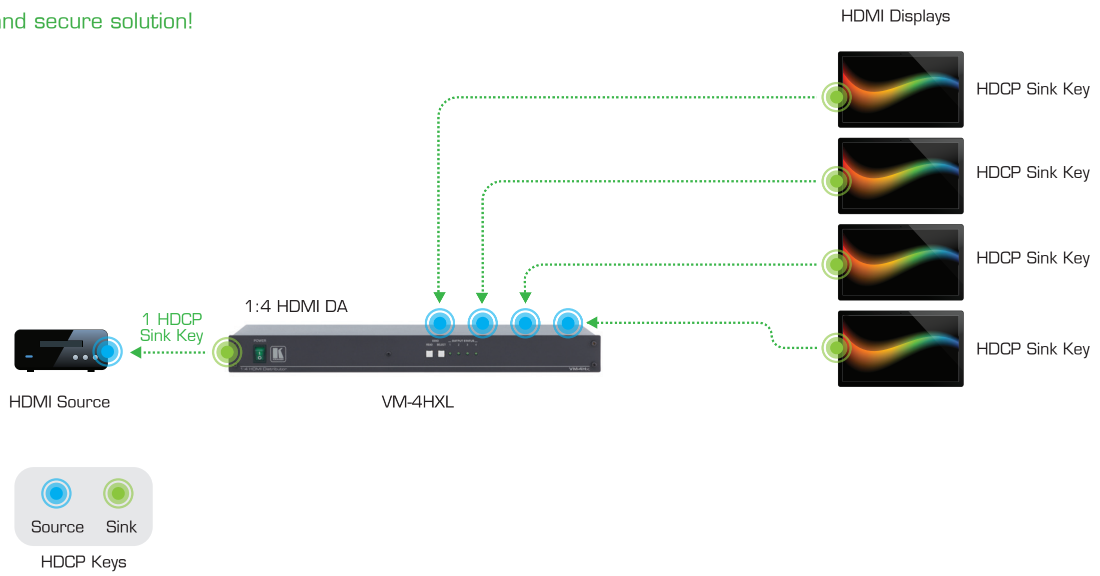


**Figure 6.** By using separate source keys on each output of the HDMI distribution amplifier, HDCP connections are maintained reliably while outputs to non-compliant displays are disabled.

Now, each HDMI output of the distribution amplifier becomes a second source, looking for its own HDCP handshake with a connected display in a peer-to-peer arrangement. Once the secure connection is verified and keys exchanged, video from the actual source is passed through to the display.

If any connected display is non-compliant with HDCP, the matrix switcher or DA will not pass video to that display only – all other connected, compliant displays will continue to see video normally without interruption. As new displays are connected to each port on the matrix switcher or DA, the secure connection is simply re-established during the HDCP key exchange. The copy protection is maintained at all times, on all ports. The issue with repeaters is eliminated, and multiple sources can now be connected as easily as multiple displays.

## HDMI ISSUES: APPLE PRODUCTS

Most Apple products, including MacBook notebook computers, Apple TV set-top boxes, and iPads enable or disable copy protection automatically. This setting is determined by (a) the presence of protected video content and (b) the detection of either an HDCP-compliant or non-compliant destination, or "sink." If any of these Apple products first sense a non-compliant switching or signal distribution product in the signal path, copy protection will be disabled. This allows non-compliant video and audio to pass, but blocks HDCP-compliant content from being viewed.

However, if an HDCP-compliant device is first detected in the video path, the Apple product will encrypt all video and audio content through the display connection continuously, even if the original content was never protected. The idea was to allow for easy switching from non-protected to protected video on an Apple product, but this operating mode can create major problems for AV professionals.

An example would be if a MacBook is connected to the input of an HDCP-compliant scaler/switcher and a non-compliant video monitor or video conferencing codec is connected to the output. Since the scaler/switcher is HDCP-compliant, the MacBook detects that and accordingly encrypts all content that it plays back. The result is that the scaler/switcher's analog outputs (component video, VGA, etc.) are disabled, even when they do not need to be.

When configuring an AV system with Apple products and connecting one or more displays that are not HDCP-compliant, this unique problem can be solved with the addition of an EDID emulator (such as Kramer's PT-1C) right after the Apple product in the signal path. The Apple product will detect the emulator, turn off its encryption mode, and pass non-protected video and audio content through the system.


DVI - Non HDCP Compiant

- HDMI cable is inserted
- The EDID exchange begins
- HDCP key is verified with scaler/switcher
- Compliant handshake is made
- If non HDCP material is output, it will still be encrypted
- The result is no picture is displayed

**Figure 7.** Issues with HDCP using Apple products, compliant switchers, and non-compliant displays.

### HDMI ISSUES: DEEP COLOR

Version 1.3 of the HDMI standard added support for three so-called "extended color" operating modes, in addition to the basic 24-bit (8 bits per color) mode used by DVDs, Blu-ray discs, and set-top boxes. These added modes are 30-bit color (10 bits per pixel), 36-bit color (12 bits per pixel), and 48-bit (16 bits per pixel).

Presently, no broadcast, disc, or streaming content is available that has been authored in these Deep Color modes. However, since newer televisions and monitors do support Deep Color, then a newer, connected Blu-ray player will detect that support and switch into a simulated Deep Color output mode. Again, this operating mode can create a serious problem in a commercial AV installation.

Here's why: Many HDMI twisted-pair distribution products were designed to handle a maximum data rate of 1.65 gigabits per second (Gb/s) per color channel (1920x1080 pixels, 60Hz refresh rate, with 24-bit color). But increasing bit depth pushes the data rates up to 2.08 Gb/s for 36-bit color, and 2.67Gb/s for 48-bit color, well beyond the extender's bandwidth.

One work-around is to set the Blu-ray player's output frame rate to 24Hz (if available) when playing back movies. This is the native resolution of most Blu-ray discs and it is an original film rate, not a display resolution. By dropping the frame rate to 24Hz from 60Hz, the bit rate and bandwidth are also reduced to a range supported by professional AV switching and distribution devices, regardless of the color depth. (It's important to check all Blu-ray players to verify that, if Deep Color modes are supported during playback, they can be easily disabled or reset from the menu.)

It should also be noted that notebook computers that support deep color modes are also widely available. If support for deep color is detected in EDID, that mode will be turned on in the computer's video card and it may not be possible to disable this mode without a lot of work. An EDID emulator, such as the PT-1C, may be required in the signal chain to force 8-bit color output.

To resolve this problem, change the refresh rate of the output 36-bit Color Signal from the Blu-ray player to 24 Hz.

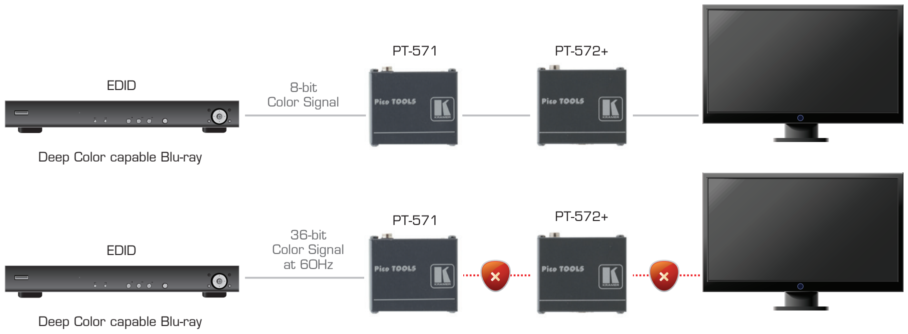


**Figure 8.** The switcher and source are compatible with 36-bit color, but the UTP/STP transmitter and receiver are not.

## CONCLUSION

High-bitrate, multifunction digital consumer display interfaces based on a peer-to-peer architecture (HDMI, DisplayPort) are here to stay. In order to distribute video from these connections to two or more displays in a commercial or education AV installation, the exchange and storage of EDID must be managed in a sensible, repeatable, and reliable way.

Similarly, exchanging and verification of HDCP keys when viewing protected content must also work within the requirements of commercial and educational AV installations and their need to support multiple displays from one HDMI source, even if there is only one HDCP-compliant device in the entire system.

An ounce of prevention is definitely worth a pound of cure when it comes to installing HDMI switchers, distribution amplifiers, and STP transmitters and receivers in a commercial or educational AV system. The smart approach is to start in the design phase and identify every HDMI source/sink connection in a distributed video/audio system.

Third-party software programs like Entech's Monitor Asset Manager (www.entechtaiwan.com) are invaluable aids when reading and configuring EDID and ensuring that EDID is exchanged correctly and maintained even when connected sources or displays are "sleeping."

HDCP issues are best resolved during the build and testing phases. HDCP exchanges should be verified at every source-sink connection to ensure video and audio are presented without interruption, that all HDMI switching and transmission components are compatible with the latest version of HDMI, and that any connected sources can be configured manually if there are compatibility issues.

The Kramer white paper library covers many important topics. Several of the topics covered in this white paper are also covered in greater depth in other papers. Please be sure to check out our full white paper library.

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