HDMI™ Over Category Cable
The Solution? Or Part of the Problem?

Installer’s Guide to HDMI™ Over Category Cable

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Overview

The utilization of Category 5/6 cables as an HDMI™ connectivity solution has grown astronomically over the past 2 years – primarily because it provides a means for installers to field-terminate exact length cables. This capability is generally not available with dedicated HDMI™ cables.

Our technical support team at DPL Labs receives countless letters, emails, and phone calls every day about HDMI™ over Category 5/6 solutions. Although this type of installation is often successful, it is the unsuccessful ones that we mostly hear about.

Our support staff’s research into the issues surrounding HDMI™ over Category cables has enabled us to address and resolve many emerging problems from this relatively new phenomenon. To fully understand these issues requires not only a good understanding of HDMI™ technology, but also that of cable, of termination, and of proper installation methodologies.

In this white paper, we will not only review important details about how HDMI™ over Category cable systems work – we will also help you understand proper installation techniques that will assure reliable performance - or in their absence, place future dependability at risk. We will also cover single- and double-cable versions of HDMI™ over Category cable systems in order to illuminate the various issues surrounding these configurations.

The HDMI™ Interface - Four Key Areas of Focus

Compared to the days of analog television, today’s high definition digital video entertainment systems are like analog television on steroids. An HDMI™ solution requires: greater bandwidth (there's a lot of data), a bidirectional intelligence system (for automatic configuration capability), new installation techniques (to ensure reliable performance), and installer education in the new skills required for effective deployment and trouble-free service. These factors alone can be enough to cause trouble, but add the proverbial Murphy’s Law and it can become a nightmare.

Focus #1 - HDMI™ Video: Digital and Demanding

Now completely digital, the HDMI™ video channels consist of super wide bandwidth data that spans from a low of 74MHz to a high (under Rev 1.3) of 340 MHz. These frequencies are so high that they become extremely difficult to manage. They don’t take bends around corners too well; they require a
reliable transport mechanism, and they require accurate timing. If you don’t get all of these factors right, you could be sitting there scratching your head looking at a completely blue or dark screen with nowhere to turn.

As bad as all that sounds, it gets even worse when you start sending this information down a Category 5/6 cable for which the HDMI™ system was never really designed. We will cover this area in some depth later, so you have a solid foundation on how to install and troubleshoot it.

Focus #2 - HDMI™ Intelligence: Is Category Cable Smart Enough?
HDMI™ requires some smarts in order to operate correctly. Besides getting these high bandwidth video signals down the transmission line, a certain amount of knowledge also needs to be shared between the source and its associated display (sometimes referred to as the “sink” as in “heat sink”).

Information called Extended Display Identification Data (EDID) arbitrates functions like resolution, type of sound, and various service issues - ensuring that the system will be properly configured. And in addition to EDID, High-Bandwidth Digital Copy Protection (HDCP), which protects the intellectual property of the content providers, makes up the rest of the informational data requirements of the system.

The transmission line that does the job of conveying this data is relatively low in frequency and high in impedance. It all operates around a serial based system created by Philips many years ago. Originally designed primarily for communication protocols on printed circuit boards, the Philips I2C system has been very reliable and dynamic. Now, with HDMI™ over Category cable, we are asking the HDMI™ intelligence data to travel down a transmission line for which it was never intended or designed.

Focus #3 - HDMI™ Voltage: LOW in Power...HIGH in Importance
HDMI™ cables, unlike many other types of connectivity solutions, require a low-current voltage – and this voltage can be the source of many issues. In order for the interface to properly boot, it requires the +5-volt power to appear at the display. This voltage can not deviate more than -.3 volts from the cable's beginning to end. Yep, that means it cannot go any lower than 4.7 volts. So you can see that the longer the cable, the more critical this voltage drop becomes with cable resistance rising at longer lengths. Watch this issue, it can sting you.

Focus #4 - HDMI™ Timing: It’s Important to Be On Time
Due to the fact that the HDMI™ data is serial based, it requires an accurate clock to time the red, blue, and green video data channels so that they are precisely coordinated. Timing is very important. And as we increase frequency, the timing of these data channels becomes even more critical. Each individual signal wire within the cable must be at the exact same length as the others so that the timing...
of any one signal will not be shifted relative to the others. The terms used to describe this phenomenon is inter-pair skew and intra-pair skew.

**Inter-pair skew** relates to the precise timing between two pairs of wires. **Intra-pair skew** relates to the precise timing between each individual pair of wires. These numbers can be crucial for proper HDMI™ operation. When operating at a resolution of 1080P, for instance, the lengths of these wires should not differ by more than 100 thousandths of an inch or .1 inches. Greater variation than that can skew the timing enough to cause sparkles to appear on the screen – or, if really bad – cause total darkness or a solid blue screen.

When working with Category cable, the utmost care should be taken when pulling these cables through homes to refrain from stretching them to a point where the twisted pair inside has a chance to move or stretch…thereby causing timing errors due to these kinds of mechanical influences.

**Using Category Cable as an HDMI™ Transport System**

**The History of Category Cable**

In 1985 AT&T was researching techniques for newer and faster computer network systems in an effort to design a system that could run over an existing telecommunications infrastructure. It was based on the Universal Service Order Codes (USOC) for termination and would provide a backwards compatible wire scheme that would support both single line phones and Category (Unshielded Twisted Pair) network systems. The AT&T specification for this was named 258A. This standard became widely used and helped to increase the popularity of Category network systems.

In 1995 the International Organization for Standardization (ISO) conformed to the Telecommunications Industry Association/ Electronics Industry Association (TIA/EIA) standards for Category 5 terminations, known as 568A. They also conformed with AT&T’s 258A, also known as the TIA/EIA 568B. You would think they would keep the A’s and the B’s matched, but that is the way it was decided…go figure.

The bottom line is that the majority of HDMI™ Category 5/6 extension systems tend to support the 568A&B specification because it has already been standardized for local area network (LAN) systems.

**It Takes Two - Typically**

Generally you will find most HDMI™ Category 5/6 extension systems require two Category 5/6 cables. So let’s do the numbers, the entire connector has a total of 19 pins. All but one of them is used (Figure 1). You would think that if the HDMI™ connector has 18 active pins, then it must need 18 wires…right? Actually no, it really only needs 14 pins! How is this possible? The reason is
because out of the 18 wires, five of them are ground connections. You actually can get by with just one ground. That eliminates four wires and pins, dropping the total to within the 16 wires available with two Category cables. This is the reason why most systems require two Cat5/6 cables since there are 8 wires in each Category cable.

All of these wires are divided up according to their function. We need 4 twisted pair just for the video. In most cases, you will find the 2 cable systems segregating the video data on one Category cable and the power, intelligence, Hot Plug, Consumer Electronics Control (CEC), and ground on the second Category cable. Clearly, it is best to focus most of your attention on the video routing as this is the signal that is most susceptible to integrity issues.

**A Balanced Approach to Noise**

One of the major design goals with Category 5/6 cable was to incorporate a twisted pair topography to add noise immunity to the line - eliminating the need for any additional shielding. The HDMI™ interface specifies basically the same noise immunity, balanced line and twisted pair topography as used in Category 5/6 cable. Let’s analyze balanced line systems in a little more detail so you can get a better understanding of the similarities between Category 5/6 cable and HDMI™ cable.

Balanced line signaling has been utilized for decades. It simply moves information, whether analog or digital, over a two wire system by transmitting a signal on one wire inverted from the same signal on the second wire. (Figure 2).

The signal enters IC1 which converts the original unbalanced incoming signal to a balanced signal. Any noise that is created on the wire itself is always in phase and amplitude on each wire however the incoming signal gets inverted on the bottom signal. When both sides of the balanced signal enter the input of IC2 (Figure 3) the bottom signal is inverted again keeping the fundamental signal in phase – but at the same time inverting the noise out of phase which causes the common noise on each wire to cancel.
Beware - Danger Lurks
The HDMI™ interface was not designed around Category 5/6 cable, however it turns out that the impedance of Cat 5/6 cable happens to be 100 ohms, the same as HDMI™ cable. Add to that the fact that the HDMI™ cable specification also calls for balanced twisted pair cables, just as Cat5/6 cable offers. With that kind of invitation, who wouldn't want to take advantage of that situation!

However - BEWARE - danger lurks if you are not completely familiar with the technical details of this opportunity to swap Category cable for HDMI cable.

Category Cable Considerations: Video
The first important consideration when using Category cable to build an HDMI™ transport system is in handling the high frequency video data. As mentioned earlier, data rates at bandwidths of 340MHz do not take corners very well. Wiring these types of signals takes a highly experienced and extremely competent person that understands the ramifications of a poorly routed system.

The Category 5/6 cable should not be bent, knotted, kinked or distorted in any way that would prevent these high frequency signals from traveling throughout the intended length.

Our lab has studied a wide variety of Category 5/6 cables and RJ45 connectors used for this application and found many provide excellent integrity...while others performed with horrible results. Looking deeper into this situation, our engineers discovered that even if we used the same spool of cable and built 4 identical Cat 5/6 cables at the same length with RJ45's – we ended up with 4 totally different response curves! This tells us that either the cable we used had bad integrity and consistency, or there was poor connector performance, or both.

Figure 4 illustrates a sample Category 5 orange/white wire. You can see quite clearly the consistent symmetry and spacing of this twisted pair. However, Figure 5's sample demonstrates a poor twist construction where the white wire twists around the blue, as opposed to twisting with the blue. In other words, the individual wires are not properly twisted together. What's really amazing is that both of these wire bundles came from the same Category 5 bundle!

Either way you look at it, it pays big dividends to spend the extra time and effort (and money) to use high quality Category 5/6 cable. Don't get sloppy, one mistake could cost you untold additional hours of troubleshooting that would not be necessary if installed correctly the first time. Never splice a Category cable. A splice or a punch down block will never come close to the integrity of a non-cut cable.

Category Cable Considerations: Which Cable Standard?
The second important consideration when using Category cable to build an HDMI transport system is to be sure you fully understand what type of cable standard the manufacturer suggests. We have found that cable standards
mistakes can be a major headache, with some products being supplied without an instruction and wiring diagram showing precisely how the Category 5/6 cable is to be configured to the RJ45 connector. This is where things can get kind of sticky. While we always recommend that you follow manufacturer's recommended wiring diagrams – we have discovered, on occasion, that units sometimes perform better by using different configurations rather than the ones suggested. The reason for this is pretty simple to understand.

The integrated circuit that is used for cable correction utilizes a pin configuration that mirror images the IC's input to its output (see Figure 6). The + and - symbols on each pin designates the polarity of each balanced line channel. You can see that the input channels match the output channels like a mirror.

However, when routed on a printed circuit board – for best signal integrity we must strive to route these traces directly to each pin from the output of the IC to each pin on the RJ45. Notice that under 568A rules the orange and the orange-and-white pins are separated by the blue and blue-and-white pins. This configuration forces the + blue channel to be connected to the orange pin 6 on the RJ45 and the – blue channel to the blue-and-white pin 5 on the RJ45 connector. This positions each wire on non-twisted pair pins 3,4 and 4,6 respectively, losing the entire balanced line system and decreases integrity.

The same thing happens in Figure 7 to the green channel when using a 568B standard. The only way this situation can be prevented is by modifying the board traces using a Crossover Technique as we did in Figure 8 and Figure 9 which, unfortunately, adds losses to the blue and green video channels due to additional printed circuit board routing necessary to reach their associated pin assignments.

**Other HDMI™ Over Category Cable Issues**

**Voltage and Intelligence**

If you do receive proper documentation, including detailed wiring instructions, be sure you follow it carefully! As discussed previously, be sure you treat the video Category cable with the utmost care. The second Category cable is used to transfer the necessary EDID, HDCP and HDMI™ cable voltage which supports the power used by EDID and HDCP data.

Category 5/6 has the same attenuation problems with direct current (DC) and serial data as any other wire. It is always a good idea to carry a small voltmeter with you to these installations in case some troubleshooting is required.

Figure 10 illustrates how the HDMI™ +5-volt DC supply responds to cable in general. As the illustration demonstrates, a voltage drop will develop over this cable. The question is how much? If the voltage drops below 4.7-Volts
DC at the display end of the interface, the system may not come on at all or intermittently come on and off. Should this situation occur, use your voltmeter to measure the +5-volt DC supply at the end of the Cat5/6 cable. If it is below 4.7-volts you could be seeing an immediate problem, or risk trouble down the road. HDMI™ specifies a relatively low current for this application which can leave you hanging if the cable is not sufficient in providing the necessary voltage at the display.

**Hot Plug Detect**

What if you have verified that the full 5-volts is present…but there still seems to be a problem? Then the next suspect would be the Hot Plug detect voltage. Based once again on HDMI™ specifications, the Hot Plug detect voltage can be no lower than 2.5 volts DC. By using the same meter you used earlier, you can verify if the Hot Plug detect is in fact working. (See Figure 11) One very important thing to remember here: the Hot Plug detect voltage will only be measurable when the unit is connected to both source and display. Also the display must be set to match the input to which the Cat 5/6 system is connected.

We have found other issues with the intelligence channel used within the HDMI™ interface that communicates the EDID and HDCP copy protection data. Again, over Category 5/6 cable, issues may surface that can cause this data to become corrupt. Try to use Category extension products that adds electrical correction to the EDID and HDCP data. There are products on the market built specifically to cure this problem.

**Single Cable Cat. 5/6 Systems**

We are now seeing some single-cable Category 5/6 configurations enter the marketplace. There are a few different techniques used to accomplish transmitting HDMI™ over a single Category cable. We’ll share a couple of the initial versions we’ve reviewed here.

So with what you’ve learned in this paper up until now, you must be asking yourself, “How is it possible to get the entire HDMI™ interface down just one Category5/6 cable?” Good question! Although single cable solutions have not been the best systems in the world, some do work and more are on the way.

The original HDMI™ interface layout is illustrated in Figure 12. Here you can see all 14 connections required for the interface to function. This is exactly what a double-cable Cat, 5/6
Figure 13: HDMI™ to Component Video System

Figure 14: Compressed HDMI™ System

These clever solutions are all still susceptible to poor installation techniques and low quality cable products.

system transports. However, with some clever thinking, this can be condensed to only 8 wires rather than 14.

Figure 13 illustrates one clever way of accomplishing this. It is a system that receives HDMI™ uncompressed serial data and converts all the video to an analog component video signal. Yep, just like the component video signal you’ve been using for years. The only difference is that the Y, Pr, Pb channels are transported in a balanced line arrangement for the best noise immunity. That takes up 6 out of the 8 wires in a Cat5/6 cable. The remaining wires can be used for Consumer Electronics Control (CEC) and Hot Plug detect. So what's missing?

This is where it gets pretty clever. To begin with, the +5-volts normally sent from source to display is not even used. Instead, the maker “fakes out” the system and supplies the +5-volts on the receiver (display) side from its own internal supply. The EDID and HDCP data are also generated within the receiver side to accommodate the display's need for this data. The downside to this configuration is that the source never receives any EDID (display) information which would allow the system to configure itself to the best overall native resolution of the display device. That pretty much eliminates any HDMI™ 1.3 capability.

Yet another technique is a system similar to Figure 14. Notice that all data lines are now comprised of just one compressed data line. Over this one Compressed Digital Data line is all the video, audio, intelligence, and control data. Its downside is picture quality. Due to the fact that it is highly compressed, there can be a high degree of motion artifacts.

With either solution, I would suggest using the same care and attention when pre-wiring. These clever solutions are all still susceptible to poor installation techniques and low quality cable products. Although HDMI™ over Category cable is not the greatest solution to long distance cable runs, it is at least a start and can get you out of trouble pretty quickly.
It should be noted that not every available Cat 5/6 system has been tested in our labs, however those we have tested and discovered in our lab show that these systems do work – but may not offer the amount of performance headroom you need for your installation. It would be best to take a careful, cautious, and conservative approach when choosing to install any kind of HDMI™ over Category cable system.

**Summary**

HDMI™ over Category 5/6 cable solutions do work and can provide a straightforward and reliable HDMI™ installation. Again, caution should be exercised when installing these types of HDMI™ configurations as discussed elsewhere in this white paper. Be careful not to configure an installation that takes you right to the limit, it could sting you later on as environmental conditions can change the chemistry of these products over time – literally changing their characteristics and causing problems down the road. You want to have adequate headroom in an installation of this type.

Also, look specifically for HDMI™ over Category cable products that address the issues surrounding the EDID and HDCP signals. As many installers and integrators are relying on this type of system, DPL Labs will continue to monitor developments as new and improved versions are introduced. Watch www.dplrating.org...or sign up for our newsletter for future reports on this category.

**Suggested Installation Do’s and Don’ts**

**DO:**

1. DO maintain the twists of the pairs as close as possible to the point of termination, or no more than 0.5” (one half inch) untwisted.
2. DO make only gradual bends in the cable where necessary to maintain the minimum bend radius of 4 times the cable diameter or approximately 1” radius (about the roundness of a half-dollar).
3. DO use low-to-moderate force when pulling cable. The standard calls for a maximum of 25 lbf (pounds of force).
4. DO use cable pulling lubricant for cable runs that may otherwise require great force to install. (You will be amazed at what a difference the cable lubricant will make)
5. DO keep Category cables as far away from potential sources of EMI (Electro-Magnetic Interference – such as electrical cables, transformers, light fixtures, etc.) as possible. Cables should maintain a 12-inch separation from power cables.
6. DO install proper cable supports, spaced no more than 5 feet apart.

7. DO test every installed segment with a cable tester.

8. DO test every installed segment with a cable tester settling on the contacts. The contacts (pins) of the jack should face up on flush mounted plates, or left, right, or down (never up) on surface mount boxes.

9. DO always use grommets to protect cables passing through metal studs or anything that can possibly cause damage.

10. DO always obey all local and national fire and building codes. Be sure to fire-stop all cables that penetrate a firewall. Use plenum rated cable where it is mandated.

DON’T:

1. DON’T allow the cable to be sharply bent, twisted, or kinked at any time. This can cause permanent damage to the geometry of the cable and cause transmission failures.

2. DON’T over-tighten cable ties or use plastic ties.

3. DON’T EVER splice or bridge Category cable at any point.

4. DON’T use excessive force when pulling cable.

5. DON’T use oil or any other lubricant not specifically designed for Category network cable pulling as they can infiltrate the cable jacket, causing damage to the insulation.

6. DON’T tie cables to electrical conduits, or lay cables on electrical fixtures.

7. DON’T install cables taught. A good installation should have the cables loose, but never sagging.

8. DON’T use staples on Category cable that crimp the cable tightly. The common T-18 and T-25 cable staples are not recommended for Category cable. However, the T-59 insulated staple gun is ideal for fastening both Category and fiber optic cabling, as it does not put any excess pressure on the cable.

9. DON’T use patch cords (cables) or punch down blocks.
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