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The Art (and Science) of HDMI Cables

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Are HDMI cables now commodities?

HDMI is one of the most success electronics technologies in history; in just 8 years since its introduction, well over 1 billion HDMI devices have been sold, plus even more HDMI cables.

Because HDMI cables have been around for 8 years and you can pick up one for as little as $2, people start see them as commodities. Several consumer advocates also publish their test results to show no visible differences between cheap and expensive HDMI cables and advice people to shop strictly by price.

There are always differences between products, no matter how mature they are. Look at the automobiles; they have been around for over 100 years, we can still see big differences between cars. The keys questions are how much difference, how significant is the difference and how to tell the difference; for the people with curious mind, what makes the differences.

First let's don't be fooled by the simple appearance of an HDMI cable. How fast is the fastest computer microprocessor chip nowadays? The Intel's Sandy Bridge's top speed in turbo mode is only 3.9 GHz. An HDMI cable can carry up to 10 Gbps (Gigabits per second) data rate and also need to send such a high data rate signal to over 100' away.

How big can the differences be?

We did a comparison test of the top of line HDMI cables from top manufacturers; each cable is 75' long, made of 24 AWG cable, cost about $1000. We use a BER (Bit Error Rate) tester to test how many error bits occurred after a 1080p signal is sent thru each cable. Here are the test results:

The tester sends out about 8.3 million bits each color in a split second. The total numbers of errors per color for the 4 top cables are:

Cable 1: 0 (except 3 errors in Blue)
Cable 2: 0.5 million errors in each of the Red and Blue
Cable 3: 3 million errors in each of the 3 colors
Cable 4: 1.5 million errors in each of the 3 colors

See the screen shots in the next page:

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Now you can see there are not only differences among HDMI cables, there could be huge differences.

Why I (or the consumer advocates) cannot see the difference?

I'm sure many of you did the comparison test between HDMI cables and you did not see any differences on TV. That's what several consumer advocates claimed too.

HDMI is a digital technology. Digital behaves quite different from analog. See the charts below:

Fig. 1 - Picture quality of an analog signal gradually declines over longer length of cable.

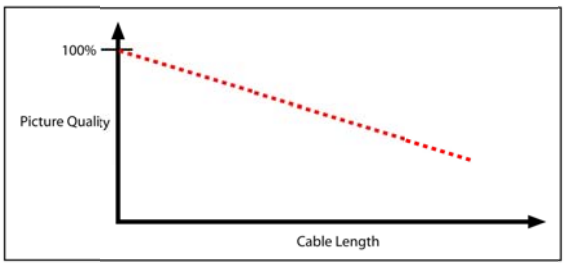
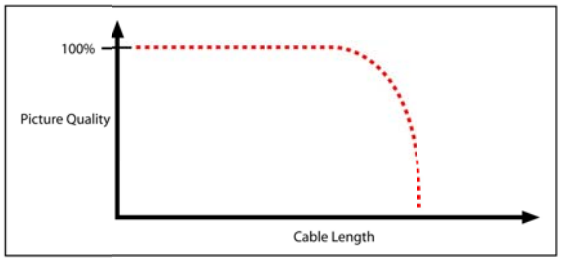


Fig. 2 - Picture quality of a digital signal (e.g. HDMI) drops suddenly after certain length of cable.



You can see from the left chart, the picture quality of an analog signal gradually declines over longer length of cable.

While the right chart shows that the picture quality of a digital signal drops suddenly after certain length of cable. This is called "Cliff Effects". The Cliff Effects is a result of the receiver (TV)'s ability to distinguish a digital "1" from a digital "0". When the signal is distorted, as long as the receiver's front end can recover 1s and 0s, and the error correction circuit can correct the wrong data, the recovered picture would be perfect. But when the error rate exceeds the receiver's error correction capability, the whole signal cannot be recovered at all. This is what we call either you have it perfectly or not at all.

Because of the cliff effects, if two HDMI cables are vastly different in quality, but they are both "on cliff" in certain test condition (e.g., signal resolution), then they would both be perceived as perfect. This is what many people including some consumer advocates see.

Do better HDMI cables matter?

Many people would argue, if they cannot see a difference between an expensive and cheap cable, they would just go with the cheap one. This is common sense.

This time the common sense does not give you a full picture. Please take a look at the chart in the next page. At first, it looks overwhelming. We'll help you to read it.

The 1st column shows 4 brands of cables; A is the cutting edge "super HDMI" cable; B is the highest quality HDMI cable currently in the market; C is good quality cable; D is the low cost cable. The 1st row is the cable length in meters. You can time the numbers there by 3.3 to convert into feet. All the numbers in the middle colorful cells are the max data rate (bandwidth) that particular cable at particular length can carry, in Gbps. For your reference, the 1080p signal is about 4 Gbps, with silver color coding in the chart. The cable's bandwidth number must be higher than the signal data rate to pass the signal.

You can see two trends:

1) For a given cable design, shorter the cable, higher the bandwidth
2) For a given cable length, better the cable design, higher the bandwidth

For example, if you need a 45' (15 m) cable for 1080p signal (4 Gbps), then only cable A and B would work. If you need to send a 3D or deep color signal (8 Gbps), then only cable A would work.

Next example is more related to the average consumers who use the short 6' (2 m) cables most. You can see the cheap cable D works just fine for the 1080p signal (4

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Gbps). But if you upgrade your Blu-ray and HDTV to deep color or 3D (8 Gbps), all of a sudden you won't get any pictures. You have to buy the cable C for this increased bandwidth requirement. This increased bandwidth is a common electronics industry trend described as Moore's Law.

	HDMI cable max data rate												
Length (m) / Brand	1.0	2.0	3.0	4.5	6.0	7.5	9.0	12.0	15.0	20.0	25.0	30.0	35.0
A	93	47	32	32	23	19	16	12	9	7	6	5	4
B	32	26	18	18	13	11	9	7	5	4			
C	21	15	10	10	8	6	5	4					
D	12	6	4	5	4								
Color coding:	2	1080i, Satellite/cable STBs, DVD players				12	Not in use yet						
	4	1080p, Blu-ray players, PS3, Xbox 360				16	Not in use yet						
	6	1080p 36-bit deep color				32	Not in use yet						
	8	4k x 2k, 3D, 1080p 48-bit deep color											
						Note:	All numbers are nominal transfer data rate in Gbps						
	Here are more signal formats:												
HDMI 1.2	**720p/1080i**	24 Hz	60 Hz	120 Hz									
	24-bit	0.8	**2**	4									
HDMI 1.3	**1080p**	24 Hz	60 Hz	120 Hz									
	24-bit	1.6	**4**	8									
	36-bit	2.4	6	12									
	48-bit	3.2	8	16									
HDMI 1.4	**4k x 2k**	30 Hz	60 Hz	120 Hz									
	24-bit	**8**	16	32									
	3D 1080p	24 Hz	60 Hz	120 Hz									
	24-bit	3.2	**8**	16									

Moore's Law and future proof:

Moore's law describes a long-term trend in the history of computing hardware. The number of transistors that can be placed inexpensively on an integrated circuit doubles approximately every two years; and the cost is cut in half every two years.

We have witnessed similar trend in video industry. We have seen the 720p, then 1080p, then deep color, then 3D in a 2 year interval; each change doubles the data rate.

One thing for sure, the signal bandwidth will continue to rise rapidly. A cheap cable D would only work for a short period of time and has to be changed to better cables (say, C) soon. This would cost consumer to pay for cable D and C, and the big hassle finding the problem, and changing the cable, especially when the cable is sealed in the wall. It's cheaper just to buy at least cable C (or B and A for longer length) to begin with. This is called future proof.

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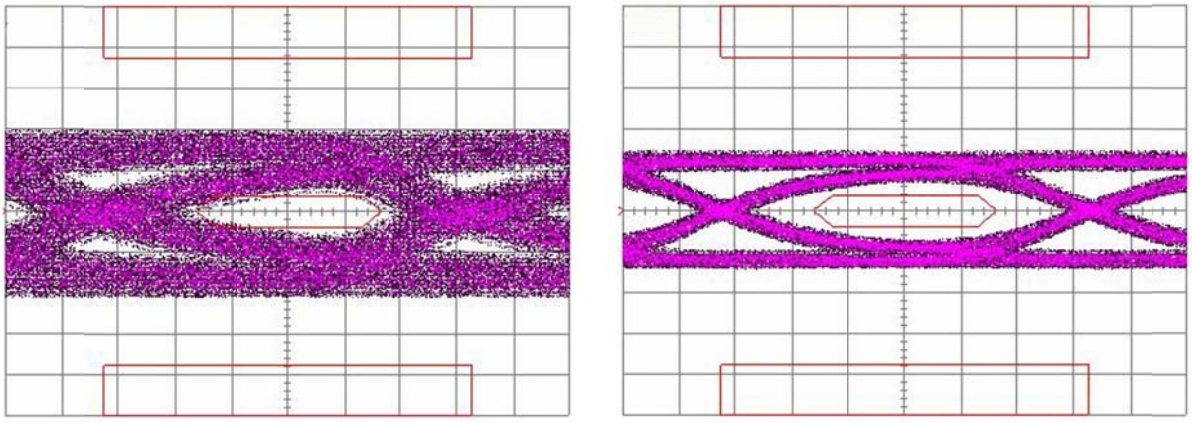
The design aspects of raw HDMI wires

Many people even the cable manufacturers still think the keys for better raw HDMI wires are to reduce the signal attenuation by using better conductors. This is carryover thinking from analog days. The front end equalization circuit of a digital receiver (TV) has 100 times (40 dB) gains; which mean it can recover a signal with 100 times amplitude lost. So the attenuation is not the biggest design aspect of a HDMI cable.

The biggest design aspect for any digital products is the jitter. Take a look at the "eye pattern" test results of 2 cables below:

Fig. 5 HDMI "Eye" patterns



Poor Signal Good Signal

You can see the "eye" on the left is fuzzy comparing to the one in the right. Even the left one is bigger in amplitude; it's a much poorer signal. The fuzziness is called jitter. The jitter reduces the receiver's capability to distinguish a "1" from a "0", and a bit in the previous clock cycle or in the next one.

In HDMI cables, the jitter is caused by the cable capacitance (which slows the rising and falling time) and by the manufacturing imprecision in the wire pair twisting. There are a few cutting edge designs to improve both and I won't talk about them in details due to the competitive reasons.

The design aspects of HDMI connectors and terminations:

The connector design and termination is equally important to the raw wire design.

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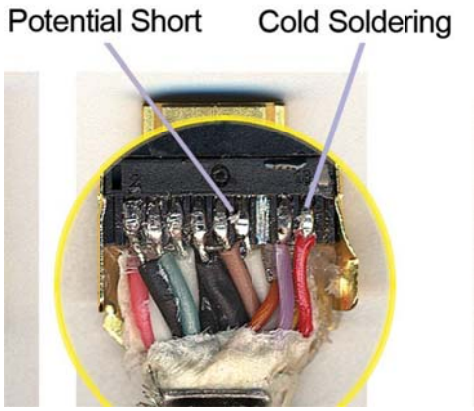
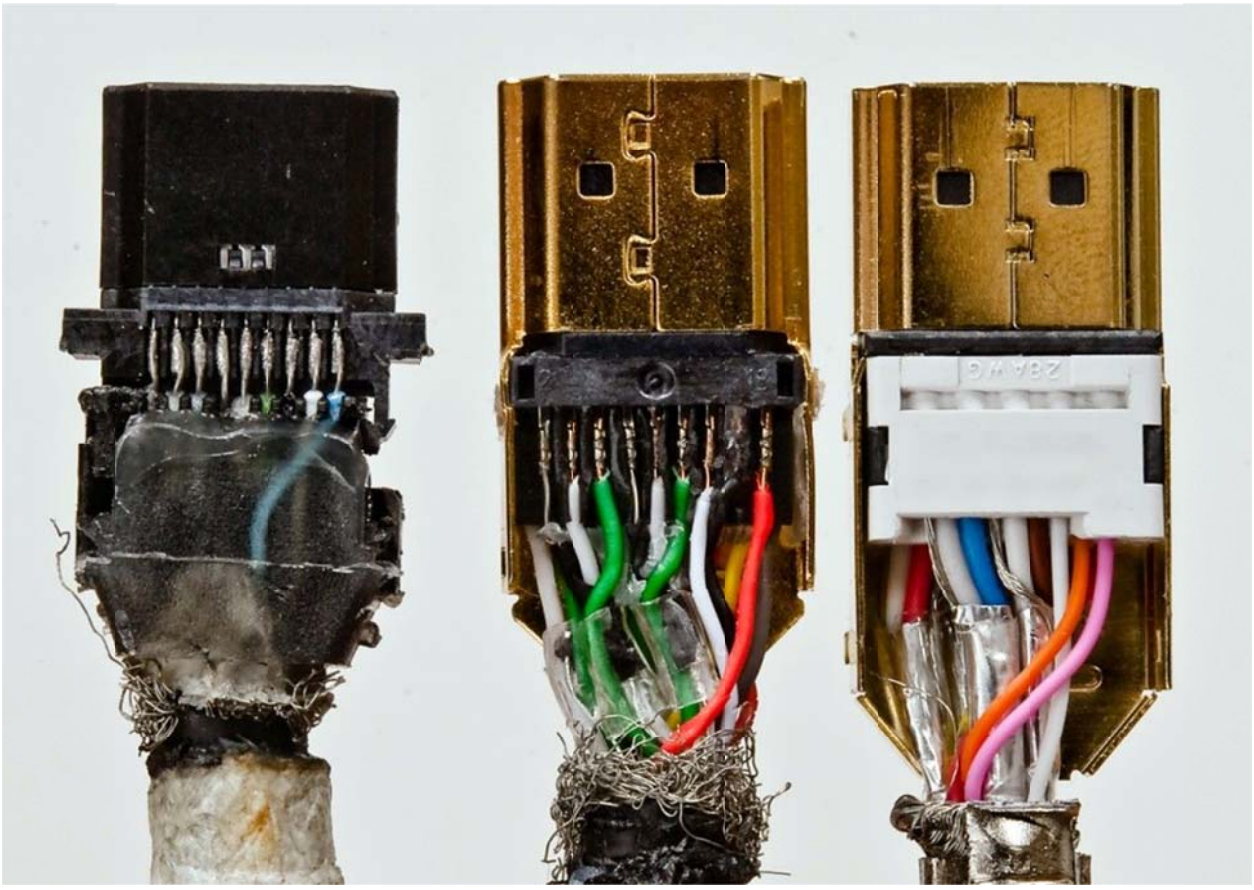


Let's first look at a most common yet very poor termination; the 19 wires are soldered onto the small connector one by one by not always well trained workers (see right). It's easy to tell why it's not good. This is still the most commonly used termination nowadays. With the Chinese labor costs rise each year, some factories start to change to semi machined termination methods below.



The left one is done by wave soldering; the middle is by crimp and the right is done by DIY™ (a patented and trademark pending method of IDC termination). Each is designed to remove the human errors and to increase the productivity and reliability. Among these 3 modern terminations, the DIY has the best performance because the wire insulation is never stripped off as required in the other 2 methods, thus the wire impedance never changes at the termination point. See the test results in the next page.

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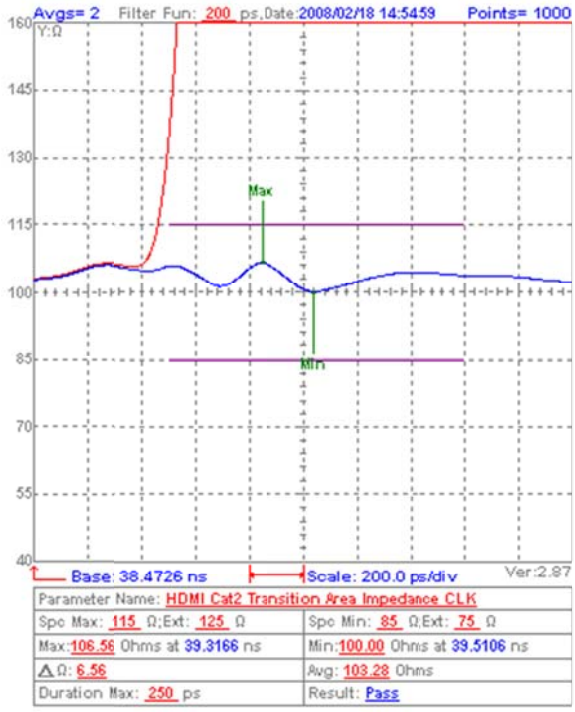

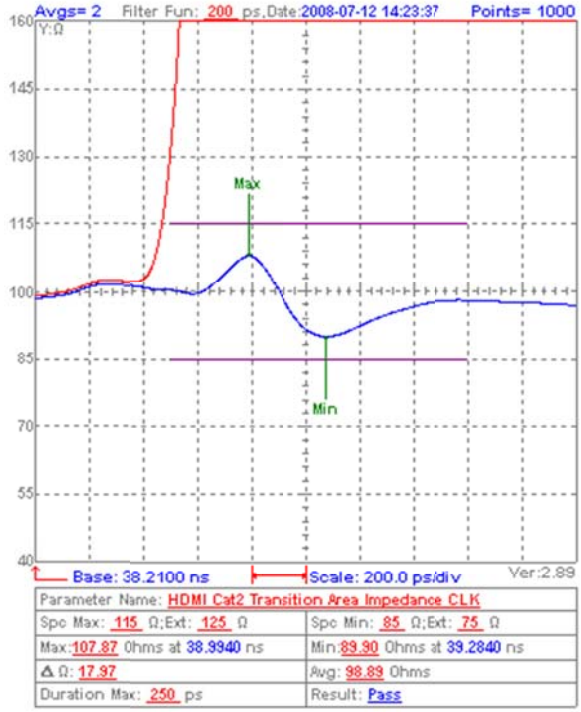

The TDR tests show the wire impedance around the connector termination area. The left one is DIY termination, the right is wave soldering termination. You can see the DIY impedance is tightly in the range of 100 to 105 ohm, while the solder impedance is in the much wider range of 90 to 108 ohm. The tighter impedance makes the cables with DIY termination goes significantly longer distance than the solder termination.

The locking HDMI plugs

HDMI cables are thicker than other A/V cables but the HDMI connector does not have a locking design thus the plugs would get loose or even fall off the receptacles rather easily when the cable or the TV is moved slightly. This is a major headache. Some manufacturers come out different ways to address this issue; one of them is shown on the right. It's easy to use, locking in very tightly (retaining force about 15 lbs), backwards compatible, and won't break the TV if the cable is accidentally kicked (the plug would dis-engage in sudden heavy pull).

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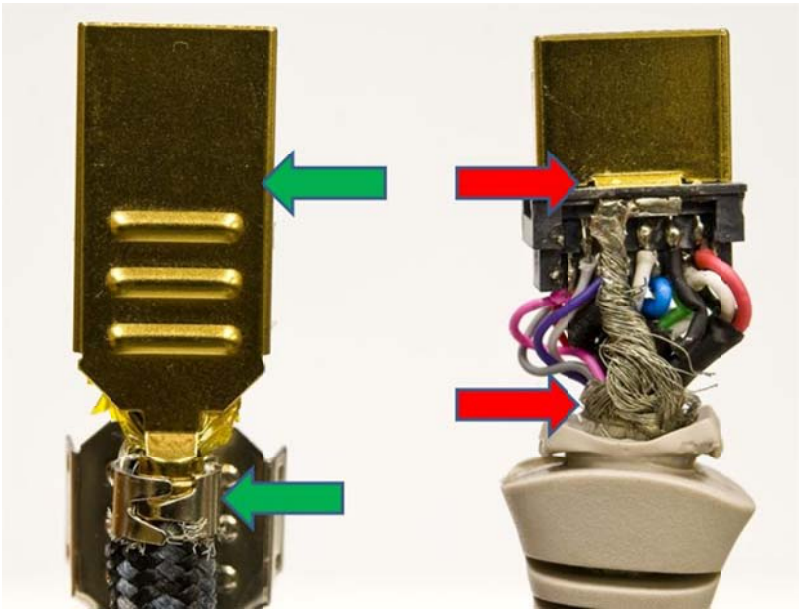
The mechanical strength

How often do you see the plugs like the one shown to the right? Yes, the HDMI cable is heavy and the plug is fragile.

But there are some better designs to prevent this; see the pictures to the right. The one on the right is a common plug design; you can see the front probe of the connector is one separated piece and is only held to the body by a very thin tin tab (top red arrow) thus it can easily break. Also the 19 fragile wires inside the connector would take the beat if the cable is pulled (bottom red arrow). The left design is far superior; the front probe, the middle shell and the rear strain relief in one whole piece of metal and it's virtually indestructible. This design also provides the best EMI shielding and the best ground connections between the device and the cable.



Many other design aspects too

There are still many other design aspects; we choose not to discuss them here due to the complexity and the desired length of this article.

Conclusion

Hopefully we have shown you some differences in HDMI cables and the significance of them. A $20 more spent on a better cable is money well spent. Buying the cheapest HDMI cables often requires buying a better one soon and you end up paying both the cheap one and the good one, plus the hassle of troubleshooting what's wrong with the cheap one and the labor to replace it if it's in the wall. It does not mean more expensive the cable, better it would be. Like everything else, do your homework, use the common sense (of course the educated common sense) to choose the right products.

Technologies are designed to serve human beings. Happy "HDMIing…"