PXLDRIVE™

Corralling the 18G Beast

Written by Jack MacDougall

Introduction

In professional AV installations, how did we get to the point where HDMI connections everywhere - once standing proud, carrying glorious 1080p signals, start to fail with the insurgence of 4K? Perhaps a more topical question, why did the recently installed 4K interconnect solutions start failing when the latest and greatest HDMI 2.0b enabled equipment was connected around them? The same symptoms are always there - Sparkles, mysterious and random (and sometimes periodic) video drop outs and the dreaded "No Image Found" OSD error. Yes, it's ruined all of our days at one point or another. The answers to these questions are complex, highly technical and snooze-worthy.

To avoid all explanation, ideally, we the hardware manufacturers, could engineer efficient and reliable future-proofed HDMI connectivity products. Permanent HDMI extension technology to help in long haul HDMI applications - sadly, standards evolve and connectivity solutions become obsolete, unable to support the latest and greatest. Predictably installers band together (and understandably so) and it's suddenly a "Grab your spear and pitchforks!" situation towards the manufacturers. I get it - it's frustrating. However, I will do my very best to untangle where things may have gone wrong, but more importantly, I will say right from the get-go to take a deep breath. Everything is going to be ok. There are some amazing products out there that will allow you to run 18G with ease up to some extraordinary reaches. Is now a bad time to mention that all of the solutions I will speak of will be obsolete with the looming HDMI 2.1 standard? I digress.

Background

If you've chosen to read on, first off, I know most are quick to blame HDCP. I am here to say that while the improper implementation of HDCP extension can cause issues, the fact of the matter is, the high-speed signals that supports max 4K HDMI standards (18Gbps) is what is causing the most headaches now regarding HDMI 2.0 equipment compatibility issues, specifically in long reach applications.

In the beginning, the only answer to achieving robust HDMI long reach signal recovery (say above 5m) was just to make the cable as thick as possible to accommodate the eight large 22AWG (or 24 AWG) wires necessary to connect to HDMI displays as far away as possible. The side effect, of course, is that this caused an industry-wide stigma towards passive HDMI cables in the ProAV industry; large basketball sized bend radiuses to/from HDMI equipment therein breaking HDMI ports altogether. That and a tidal wave of random budget HDMI boosters relied upon to fix the problems (either in-cable or detachable form).

" PXLDRIVE™ is the industry's first active long reach THX® Certified 4K Interconnect. Capable of reviving uncompressed signals up to the maximum 18Gbps UHD bitrate over new or pre-existing HDMI cable, PXLDRIVE™ fills one of the biggest 'missing links' in the custom installation market – a reliable and economical full-bandwidth solution."

These active devices made a lot of promises and often fell short regarding interoperability and longevity. These HDMI extenders did lots of "interesting" things to say the least. I've seen great high-speed signal recovery techniques (but no CEC function at all), built-in HDCP extenders that did more harm than good and ones that worked only at 1080p but not 480p. There are also HDMI extenders with manually tunable gain pots and my favourite, dongles that played tricks with the HDCP specification in attempts to eliminate HDCP related issues by permanently removing the keys altogether. Awful.

Somewhere along the way came a revolt. There was an apparent demand for robust long reach HDMI connectivity and the applications were popping up everywhere. Moreover, TV's got bigger, and the walls that supported them got bigger (which meant the rooms were getting bigger) and most importantly customers didn't want their AV gear directly under their TV's anymore. Several companies started creating more practical means of extension methods.

The simple and obvious strategy was to repurpose Category cabling (CAT5e, CAT6 etc.) to adequately fill this void not only to remove the negative bullets of long reach HDMI connectivity but also add a useful solution for non-HDMI signals such as IR, USB & RS232. Fantastic!, right? Yes, and no. There are limitations to everything, more on this later.

I want to be clear about this, I am a tech nerd first, and I admire all the HDMI extension strategies/solutions out there to this point. The reason I say this is that there is always someone (or a team of someone's) behind the origins of each solution, each more passionate than the next. We all have one thing in common, we all want to solve this problem and stay ahead for the end user. I love hearing the debates from 'Team Fiber' to 'Team CATx' to 'Team IP', or 'Team Copper' (fist to chest, Represent!). There is a fit for everyone, let's just make sure we know the pros and cons. Manufacturers should educate and not mislead.

What makes some long reach HDMI cables more lossy than others?

Let's start with the HDMI cables themselves. What makes some HDMI cables more "lossy" than others? Well, to answer this question, first we must define what's under the hood from a high-speed perspective. Inside an HDMI cable, there are three twisted pairs dedicated to transmitting video data (TMDS 2:0) and one additional pair for the clock (running at a much slower rate). There are, of course, several other wires for handling low-speed communication (DDC, CEC, ARC) and DC (+5V, HPD) signals. Each pair of data (by current HDMI 2.0b specification) can run up to 5.94Gbps (this is where "18G" comes from as it is the sum of the three 5.94Gbps signals; 3 TMDS pairs X 5.94G = 17.82Gbps). The aggregate bitrate is what allows for what we at Pixelgen call "Max 4K" signalling. For the record, my personal favourite nickname to date has been "Fat 4K".

Many mechanical attributes make HDMI cables more lossy than others such as; wire gauge, skew, impedance matching, twist ratios to name a few. All of them put in a blender can affect the overall loss of the HDMI cable. If we look at one of the most significant factors, wire gauge, thicker conductors equate to lower loss (longer lengths achievable even at 18G but much bigger) and naturally thinner conductors equate to higher loss (only shorter lengths possible, but easier to run). It's impossible to give precise failure points to the 18G signal over passive HDMI cables, but in my experience, with a quality constructed HDMI cable, you are looking at the following reach expectations with a standard 18G enabled HDMI 2.0b input port (refer to Fig. 1).

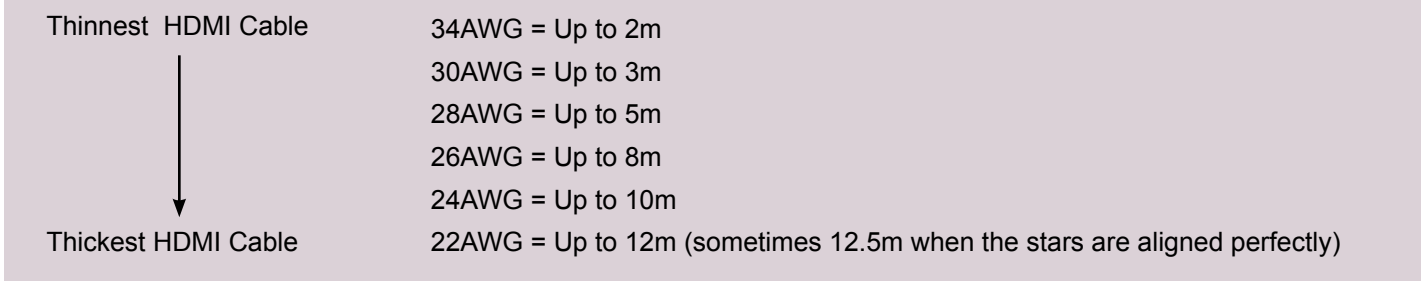

Fig. 1 Passive HDMI length estimates

Now, when I mention "quality constructed HDMI cable", the twisting of the individual pairs becomes paramount in all of this. For example, if cable manufacturer does not account for the wire twist geometries (such as intra-pair, meaning conductor-to-conductor in twist itself or inter-pair skew meaning pair to pair) then in some cases it won't matter what the gauge is, problems may arise at 18G regardless. For example, when a cable bends around a turn in an installation, the twisted pairs have a natural tendency to create gaps in these loosely coupled areas of the twist – and this problem is only exasperated with thicker conductors (I've asked, apparently, they cannot be glued together to maintain the twist). The twist should be preserved to ensure that the signal is always coupled to itself and doesn't fall victim to crosstalk, EMI or other high-speed predators. The point I'm trying to emphasize is that while thicker wires can theoretically reach further, this is not the only electro-mechanical metric that is important. The higher quality cable manufacturers understand things like this and can monitor twists on the fly over their cable building process. So yes - At 18Gbps, cables DO matter.

Why can't HDMI displays themselves recover 4K with long cables?

One of the most challenging aspects of trying to restore a high-bandwidth 4K signal is that typical HDMI receiver chips found within displays also need to recover lower resolutions like 480p (270Mbps), 720p and 1080p. That is, all the while over a vast array of short to mid range HDMI cable lengths and all of this as reliably and robustly as possible. This highly volatile situation (all speeds, all distances) makes it very tricky for the HDMI receiver chips found in 4K displays and projectors (for example) to recover all signal speeds over anything past the length estimates previously outlined (refer to Fig. 1), all the while guaranteeing a good name to the CE brand they represent. Therefore, you often see the bold emphasised "Thou shall use HDMI cable included in the box" statements in user manuals.

Integration of more sophisticated Equalization (EQ) IC's may be perceived as overkill to major CE brands as most cable ranges used by the mass consumer base fall under these short-to-mid ranges anyways. Almost exclusively, CE brands leave the long-reach HDMI aspect to the professional installers. More importantly, I can completely empathize with why no CE equipment provider wants to bear the responsibility of the historical problems that have plagued the industry regarding long reach HDMI. Now I will say this, there hasn't been a solution to this point that can efficiently recover a 4K signal at long ranges in a genuinely cable length adaptive fashion until now (including these short to mid range lengths), so this may change in the future.

Enter 18G (The Beast)

18G (or 18Gbps) represents the HDMI bitrate required to deliver the highest 4K bandwidths currently supported by the HDMI 2.0b specification (we'll leave HDMI 2.1 for another day, 48Gbps, gulp). You're welcome. The HDMI bitrate is an amalgamation of the four key variables described in Fig. 2. These four factors, all put through a simple formula (refer to Fig. 3) will equate to different HDMI bitrates required to deliver the entire spectrum of supported HDMI video formats. To date, the two most troublesome 18G supported formats include the infamous 4K60 8bit 4:4:4 signal and the 4K60 12bit 4:2:2 standard (soon to be deployed Dolby Vision HDR format). FYI, the "4:4:4" you keep hearing about is representative of an image that broadcasts a higher volume of unique colours per independent pixel than 4:2:0, for example.

- **Resolution** (Total pixels per frame including blanking pixels; 1080p, 4K, etc.)
- **Frame Rate** (Frames/s; 24fps, 60fps etc.)
- **Bit Depth** (Total bits per pixel component; 8bit, 10bit, 12bit, etc.)
- **Sub-Chroma sampling** (i.e., 4:2:0, 4:4:4, etc.)

Fig. 2 HDMI bitrate factors

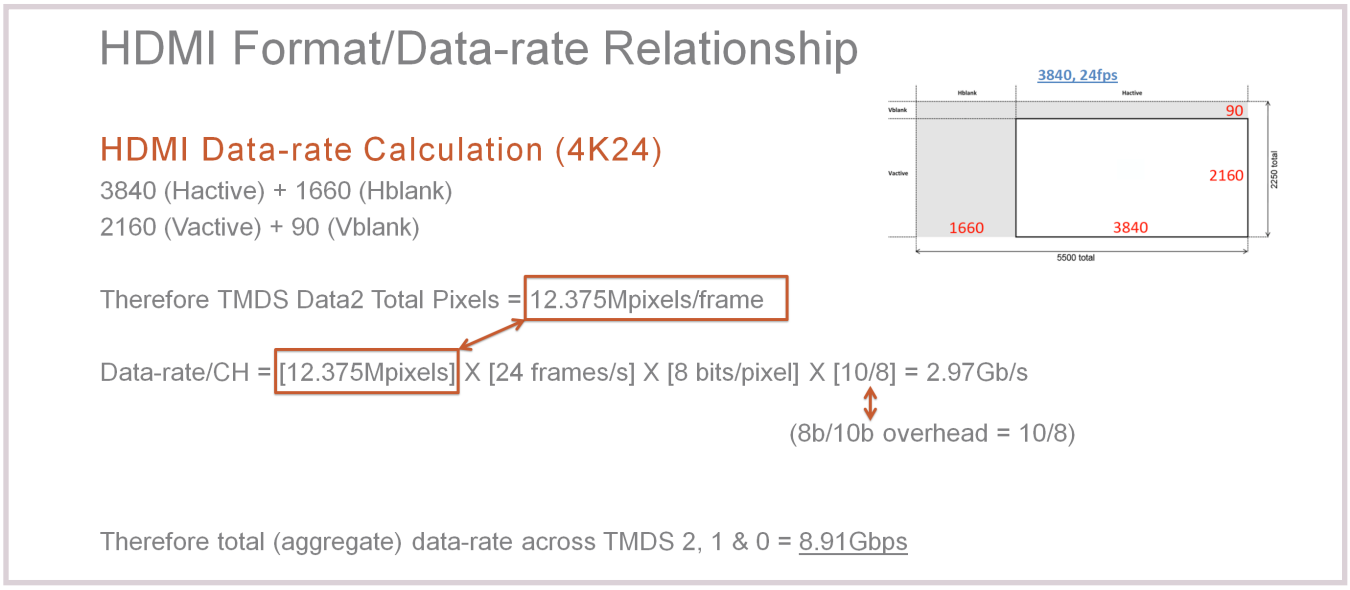

Fig. 3 HDMI aggregate bitrate formula

Compressed vs. Uncompressed. Calling it like it is.

Ok, now 18G is here to stay, and this may come as a shock to many, but here it is. Nothing running over CATx cabling is 100% uncompressed at the highest bandwidths available in the latest HDMI 2.0b specification. Even the Category cabling connectivity solution of choice essentially shoe-horns the additive bandwidth on anything over the 9Gbps aggregate bitrate (refer to Fig.4) under its maximum ceiling of internal bandwidth capabilities, meaning the only real uncompressed signal goes up to 4K30 10bit 4:2:0 (HDR10) with this solution. So all of those new UltraHD 4K 60fps HDR movies will indeed compress the image. Note: other IP-based HDMI connectivity variants may compress all video formats, not just bitrates over 9Gbps.

It doesn't matter if it says "light compression" or "visually lossless" or "virtually lossless" or "*No" compression (aka, follow the asterisk to find that "No" apparently means "Some"). It's compressed. When I was a kid, standing in front of a lamp with a crack in it - tennis ball in hand, I tried getting away with saying "it's KINDA broken", sadly this didn't pass my mother's standards and nor should it with all of you on the front lines in the field.

Now, let's look on the bright side, for all involved in creating these Category cabling HDMI solutions, good work! There was a problem, and you solved it! Most of the truly uncompressed 18G solutions (including our very own

Standard	Resolution	Frame Rate	Bit Depth	Sub-Chroma Sampling	Applications	HDMI TMDS Bitrate (Gbps)		Long Reach HDMI Extension Method		
						Single TMDS Channel	Aggregate TMDS (x3)	Native HDMI Copper (PXLDRIVE)	Optical & AOC	CATx
1.4b	1080p	30	8	4:4:4	Standard 1080p/HD	0.74	2.23	✓	✓	✓
1.4b	1080p	60	8	4:4:4	Standard 1080p/HD	1.48	4.46	✓	✓	✓
1.4b	1080p	60	12	4:4:4	1080p Deep Color (PS4)	2.23	6.68	✓	✓	✓
1.4b	4K	30	8	4:4:4	Up-converting 4K Blu-ray	2.97	8.91	✓	✓	✓
2.0	4K	60	8	4:2:0	SDR UHD BR Player	2.97	8.91	✓	✓	✓
2.0	4K	30	10	4:2:0	HDR10 UHD BR Player **(30fps)**	2.97	8.91	✓	✓	✓
2.0	4K	60	10	4:2:0	HDR10 UHD BR Player **(60fps)**	3.71	11.14	✓	✓	✓ *
2.0	4K	60	12	4:2:2	Dolby Vision UHD BR Player	5.94	17.82	✓	✓	✓ *
2.0	4K	60	8	4:4:4	PC Gaming + UHD BR Player	5.94	17.82	✓	✓	✓ *

* Compression

Fig. 4 HDMI format to bitrate correlation

PXLDRIVE™) are great at delivering every pixel 1:1 as it was meant to be viewed but cannot come close to competing with the incredible advantages that come with Category cabling extenders. 100m range, convenient onsite termination and all those peripheral connectivity benefits – incredible!

Furthermore, anybody running 'out-of-zone' should feel happy about running CATx cabling, not a horrible trade-off to accept compression at the higher 4K bandwidths considering all the advantages mentioned above with the solution as a whole. Once again, for in-zone – say up to 20m, uncompressed solutions will always be there.

" There is absolutely no reason for a truly uncompressed HDMI link not to exist in every home cinema or 'in zone' installation with the options available today."

On the side of actual uncompressed HDMI, as mentioned, I firmly believe that there is an excellent fit for all different HDMI connectivity solutions as long as it is evident where the dividing lines are as to which applications they are most suitable. So, here is my firm stance on the matter. There is absolutely no reason for a truly uncompressed HDMI link not to exist in every home cinema or 'in zone' installation with the options available today.

Enter PXLDRIVE™: The in-zone uncompressed 18G solution

So today, staring directly at the mandate of all HDMI interconnect being able to support a complete 18G HDMI ecosystem, these "garden hose" HDMI cables are either sitting in walls (mostly useless on their own) or are once again being deployed in new installs, usually the most economical solution.

Enter PXLDRIVE™, a signal recovery method that I have personally put over two years of my working life engineering, refining and perfecting. PXLDRIVE™ is a detachable dongle placed at the display end of an HDMI link with the ability to revive uncompressed HDMI signals up to the maximum 18Gbps bitrate over new or pre-existing passive long reach HDMI cables.

If we look simply at the retrofitting application (cables already residing in the wall), it is clear the industry requires a highly effective detachable active implementation to resurrect these cables. PXLDRIVE™ is the perfect answer. PXLDRIVE™ is highly robust, interoperable and as a bonus supports long reach HDMI cables that can be thin and convenient to pull in new install scenarios due to its industry leading 18G gain curve implementation. PXLDRIVE™ is an interconnect solution that acts in every way like it is a 1m cable regardless of its actual length, say up to 20m (all low-speed features, all high-speed formats, including 18G). Yes, 100% uncompressed. PXLDRIVE™ is attempting to enable a long range tip-to-tip solution that is essentially a long 'short cable'. See Fig.5. Truly one of a kind.

Fig. 5 PXLDRIVE™ Max 4K Interconnect System

PXLDRIVE™ uses an adaptive equalizer and retimer block to maximize its effectiveness as a robust HDMI retrofitting product. See Fig.6. Each block is critical to ensure the maximum throughput of an 18Gbps signal can be correctly restored to achieve 4K60 8bit 4:4:4 and 4K60 12bit 4:2:2 signal delivery through to the HDMI display over long distances. It has been validated to be the most highly interoperable recovery module in the market and has achieved the first long reach THX Certified 4K Interconnect distinction. It uses what I call a "bit-in, bit-out" methodology (get a bit, regenerate a bit,

clean the bit, send the bit) – no digital processing or native bit manipulation in any way and certainly no need for firmware updates. Future proofed to HDMI 2.0b standards out of the box and completely plug and play. Did I mention that PXLDRIVE™ can also power itself with any available USB port on the HDMI display itself? Shameless, yet very necessary sales bullet there.

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How does PXLDRIVE™ work?

PXLDRIVE™ Adaptive Equalization

PXLDRIVE™ utilizes an adaptive equalizer device that adjusts frequency dependent gain automatically depending on the amount of loss detected in the channel. Simply put, the adaptive equalizer block operates by applying the appropriate gain for any given loss (also known as attenuation). The benefit of a truly adaptive EQ is that it can detect cable length based on a simulated model of what a physical cable looks like regarding attenuation (or loss) and can smartly apply the inverse gain.

Conversely, the clear majority of native HDMI 18Gbps recovery methods (Active cables/dongles), utilize fixed equalization. This strategy sets a typically high gain state permanently for the frequencies required to be regenerated. In the case of Active cables (chips inside the cable head itself) the length is known, therefore a pre-determined gain setting may be applied. Unfortunately, this is STILL not enough to guarantee reliability as there is no retiming function post-EQ (as there is limited PCB real estate inside the cable head itself). Some detachable signal recovery boosters apply a permanent high gain state (fixed EQ) for the frequencies required to be regenerated and may fall short if an HDMI cable is not long enough for example. In this case, this can lead to over equalization in conflict with the HDMI input EQ stage of the display itself (which may be adaptive or fixed, really no control over which). In my opinion, fixed EQ boosters are not an acceptable solution for retrofitting applications for this reason. Furthermore, with external (detachable) HDMI boosters, there is a misconception in the industry that the equalizer needs to be perfectly tuned to cooperate with HDMI inputs to which they are connecting to directly (TV/ Projector end), both to function efficiently and maximize a robust interconnect. This, however, is not the case. This previous statement is only true if a retimer device is not placed between the front end EQ recovery block of the extender unit itself and the internal HDMI display EQ. If the retimer block exists on the external extender, then an adaptive EQ with very high gain (and low gain) capabilities can be applied without issue. (refer to Fig. 6 Detachable 18Gbps HDMI Equalizer Strategies)

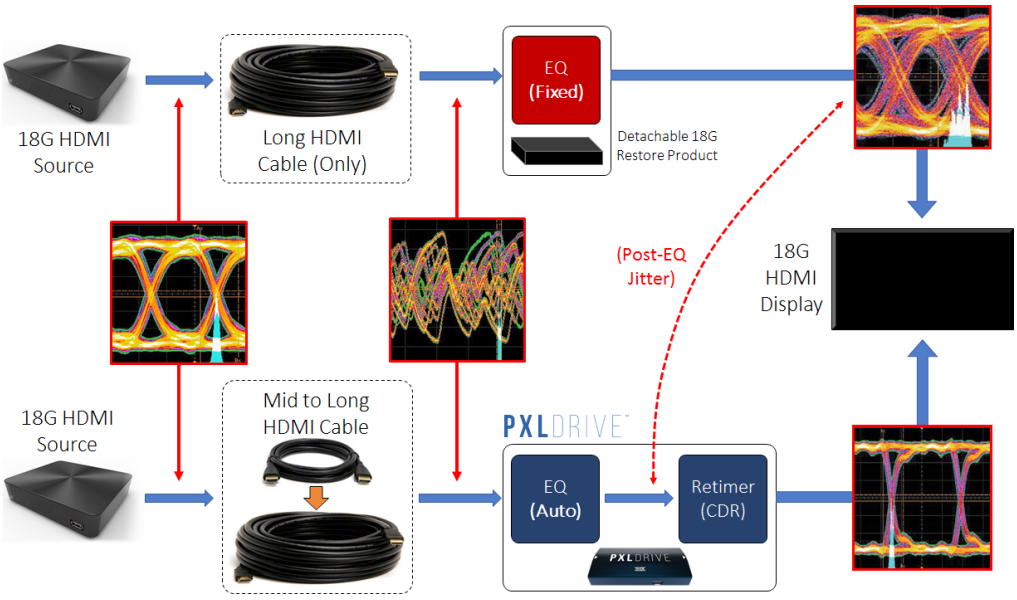

Fig. 6 Detachable 18Gbps HDMI equalizer strategies

Other solutions in the market that solely utilize 'EQ-only' techniques (without a retiming block post-EQ) can be susceptible to conflicting EQ states. For example, the EQ setting within the dongle or active cable will conflict with

another internal EQ within the HDMI display which may be inches away from one another in application (in the example of an active cable) and will get confused. This double-EQ effect can create havoc on the system; same old sparkles, streaks and blinking. In fact, other HDMI extender solutions in the market purposely lower the EQ gain level to ensure that there is as little conflict as possible between EQ's. In this scenario, you may now be sacrificing longer HDMI cables from having the ability to be successfully resurrected when upgrading to 18G capabilities.

IMPORTANT: When I say "length", it is far more accurate to look at cables in terms of "loss" as even if you put ten 5m cables side by side, they can all have dramatically different attenuation/loss results. Therefore providing windows of HDMI cable length adaptability is completely misleading. It's an estimate nevertheless, but rest assured adaptive equalization takes all the guess work out of it.

PXLDRIVE™ Retiming

PXLDRIVE™ uses a retiming device directly after the adaptive equalizer stage to ensure that the high-speed data is completely restored to HDMI source worthy specification (refer to Fig. 6). The Retiming block operates by regenerating a signal by phase aligning a reference clock to the incoming signal and clocking out the signal using the phase aligned reference clock so that the output signal has less jitter than the input signal. Essentially this like bringing your 18G capable UHD Blu-ray player directly to the HDMI display.

A retiming block (also referred to as a CDR) ensures that the first equalization stage (connected to the unknown long HDMI cable) is always completely isolated from the HDMI display itself. This is what makes PXLDRIVE™ completely one of a kind in terms of effectiveness and overall reliability. No window of acceptable cable length and no conflicts between the extender (PXLDRIVE™) and the display it is being connected to. Another highly beneficial PXLDRIVE™ feature that is built into the retiming block is 'de-skew'. Essentially de-skew realigns all of the three TMDS pairs to compensate for long twisted pairs over long HDMI cable runs (Equalizer-only solutions obviously have no way of accommodating for this). Moreover, by resetting all signal pairs to mimic what an HDMI source looks like (both in jitter eye quality and signal to signal skew alignment), PXLDRIVE™ allows for multihopping applications as an added convenience to the end user. This means that you can apply multiple PXLDRIVE™ "hops" one after the other if you need to go further than 15m, even at 18Gbps. Even if you're not multihopping, by resetting the output signal to look like the HDMI source, you can also run up to 5m from the PXLDRIVE™ unit to the display (20m in total).

It is critical that a retiming block is implemented in any external HDMI recovery circuit (i.e. between the external "booster" EQ and the display EQ). As already mentioned, most HDMI extension solutions in the market today do not utilize this critical Retiming function. This will be evident if the specs say anything about a window of allowable HDMI lengths that need to be applied for proper operation ("Between 5m and 15m, for example"). Truth be told, giving a window of acceptable cable lengths is tough to quantify to the end user. Installers likely have no idea how long the cable is. Furthermore, even if the length is known, all cables have different physical loss characteristics based on the aforementioned mechanical characteristics anyways. So how does this applicable length window make any sense to the installer?

Real world cable retrofitting shootout testing

We decided to evaluate approximately 20 random passive long reach HDMI cables (some purchased, most donated) connected to PXLDRIVE™ in comparison to a common 18G extender in the market today. See Fig. 7. Truly apples to apples. We used four readily available HDMI 18G capable UHD sources and a single 18G 4K60 4:4:4 capable HDMI display. Here is what we learned - PXLDRIVE™'s auto-adaptive solution could; A) recover more short cables regardless of gauge (cable that still didn't operate at 18G on their own), B) recover more mid-range

cables with more 18G source types and C) Still resurrect the longer HDMI cables. See Fig. 8.

As we performed this exhaustive sweep over several days in our lab, the real value of PXLDRIVE™ and specifically the adaptive EQ implementation became abundantly clear. These "long" thick cables in many cases looked like shorter cables to PXLDRIVE™ – which is no problem at all. However, the fixed equalization implementation of the competing HDMI booster created failures consistently as there was too much gain for too short a cable length.

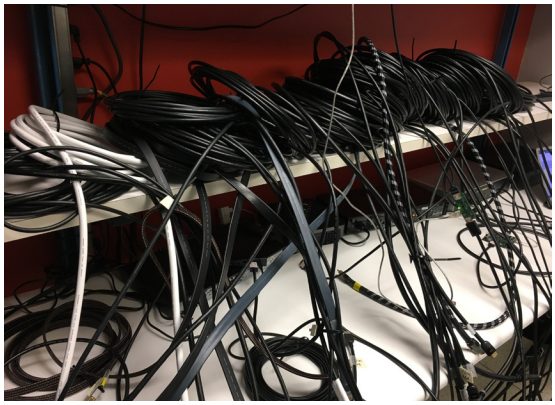

Fig. 7 Long reach HDMI cables used in retrofitting test

An interesting revelation occurred during this testing that inadvertently made me respect the product even more. In my mind, I was always in the mindset that all random HDMI cables buried away in walls out there had high loss, but this simply isn't the case – remember most were just going thicker to reach in the 1080p days! For example, one (very thick) 12.2m/22AWG HDMI cable we tested technically lumped itself into the "shorter" cable category as an EQ stage only looks at the HDMI cable in terms of loss and thus this cable "looked" like a shorter HDMI cable through the EQ's eyes. It's easy to see that this underlines the importance of Adaptive Equalization. Shorter, mid-range and long HDMI cables regardless of gauge will have a shot at 18G. PXLDRIVE™ does the heavy lifting for you.

"For example, one (very thick) 12.2m/22AWG HDMI cable we tested technically lumped itself into the "shorter" cable category as an EQ stage only looks at the HDMI cable in terms of loss and thus this cable "looked" like a shorter HDMI cable through the EQ's eyes. "

HDMI 18Gbps Retrofitting Evaluation/Shootout

Test Setup:
HDMI Source (17.81Gbps/4K60 8bit 4:4:4) --> Long Reach Passive HDMI Cable (DUT) --> "18G Repeater #1" / "PXLDRIVE" -->
1m HDMI out (34AWG) --> Panasonic TC-50CX600U

Power:
0.3m USB Cable directly to dongle via USB 2.0 Port (Panasonic TC-50CX600U)

Failure Mechanism:
Upon 5 minute playback observation; sparkles, streaks, flashing or 'no image found', If > 0, THEN Fail

Long Reach HDMI Cables		"18G Repeater #1"				Pixelgen Design - PXLDRIVE			
(DUT) Length Random Cable Brands	TMDS '8C' Wire Gauge (AWG)	NVIDIA Shield	Samsung K8500	Philips BDP-7501	Panasonic U900X	NVIDIA Shield	Samsung K8500	Philips BDP-7501	Panasonic U900X
5m	24	P	F	F	F	P	P	P	P
7m	24	P	P	P	P	P	P	P	P
7.5m	28	P	P	P	P	P	P	P	P
7.6m	24	P	F	P	P	P	P	P	P
9.2m	24	P	F	P	P	P	P	P	P
10m	24	P	F	P	P	P	P	P	P
10m	26	P	P	P	P	P	P	P	P
10m	28	P	P	P	P	P	P	P	P
10m	30	P	P	P	P	P	P	P	P
11m	26	P	P	P	P	P	P	P	P
12m	24	P	P	P	P	P	P	P	P
12m	24	P	P	P	P	P	P	P	P
12.2m	22	P	F	P	F	P	P	P	P
12.5m	30	F	F	F	F	P	P	P	P
15m	24	P	P	P	P	P	P	P	P
15m	26	P	P	P	P	P	P	P	P
15m	26	P	P	P	P	P	P	P	P
15m	28	F	F	F	F	P	P	P	P
15.24m	30	F	F	P	F	P	P	P	P
20m	24	F	F	P	P	P	P	P	P

Fig. 8 Detachable 18G extender shootout results

The THX® Certified 4K Interconnect Advantage

As you may have noticed, there are many 3rd party (HDMI post grad) test options popping up these days. In my opinion, any active HDMI interconnect (anything that is not 100% a passive HDMI cable) can fall victim to active-centric issues and these issues can arise in many ways outside of the product simply having a beautiful eye diagram and sharp DDC signal edges. Active implementations can fall victim to power cycles, hotplugs, random dropouts or all out interoperability issues in-line with the HDMI equipment itself. For this reason, we selected the THX® Certified 4K Interconnect program as it set itself apart in these key areas outlined in Fig. 9. It is the only program that focuses on an appropriate balance of electrical parametric testing and real-life interoperability required for active interconnect such as PXLDRIVE™. In our case, PXLDRIVE™ (active extender) was put through it's paces in a way that helped us achieve as much of a real-world guarantee of reliability and robustness as possible and all the while at the highest bandwidths. As mentioned earlier, we spent a ton of time making sure PXLDRIVE™ would be engineered as the most robust long range 4K interconnect in the market and the good name of THX helps reflect this quality through it's vigorous test procedure and attention to detail.

THX® Certified 4K Interconnect Test	Test Details
18G TMDS Pixel Error Analysis	Ensuring that each bit is deemed 100% uncompressed and for an extended period of time
Fitness to Application Testing	Interoperability, power sequencing, hot-plugging & equipment down/up power recovery
Full HDMI Protocol Functional Testing	Application based ARC, HEC & CEC validation
HDCP Burn-in Verification	In system burn-in of HDCP handshaking
TMDS Jitter/Eye Analysis	Increased pass/fail margin applied
Low-speed DDC (HDCP) Communication Analysis	Confirming proper setup and hold timing

Fig. 9 Key differentiators for THX® Certified 4K Interconnect testing

Conclusion

For now and the foreseeable future, I believe the HDMI 2.0b specification provides us all with an incredible end user experience. With PXLDRIVE™, our goal was to deliver this same experience over long reaches in a smart, clean and economical fashion. We set out to create a versatile 18G restorer tool to revitalize an otherwise useless HDMI cable on it's own for that one zone to which there should be no compromise, thus no compression. So for that moment where you realize that the cable is in there for good, PXLDRIVE™ provides the ultimate 'Get-out-of-jail-free' card. In a way, 18G enabled HDMI 2.0b connectivity solutions have matured to the point where there are a ton of great options out there to support both uncompressed and compressed long range links. However, in a more accurate way, we the "long reach enablers" are already venturing into the very new HDMI 2.1 8K landscape which will demand the monstrous 48Gbps - and for this it's a whole new ball game. If you listen closely you will hear the sound of hundreds of hardware engineers flipping through their IC vendor phone books searching for answers.

Teaser: Pixelgen is ready. Game on!