# OPTIMIZING CABLING FOR HDBASET 3.0

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## INTRODUCTION

The old saying "a chain is only as strong as its weakest link" is very applicable to the interconnects in an AV system. HDBaseT is remarkably adaptable to existing communications cabling infrastructure, but when new cable can be pulled, the choice of specification and quality of termination contributes significantly to achieving the best possible performance, reliability, and safety of HDBaseT installations. Ideally it should also provision a future upgrade path for evolving capabilities.

This paper discusses the standards-based specifications, termination, and verification of cabling for HDBaseT, and is intended to provide deeper learning as a supplement to the online self-paced HDBaseT Master Program. This ultimately leads to the HDBaseT Alliance's recommendation for the use of Cat 6A U/FTP cable (or Cat 7 if preferred by your company) to maximise the performance of HDBaseT versions 1.0 and 2.0, and for achieving the unprecedented bandwidth capabilities of HDBaseT version 3.0 for uncompressed 4K/60 4:4:4 video for distances of 100m.

# CABLE AND INFRASTRUCTURE STANDARDS

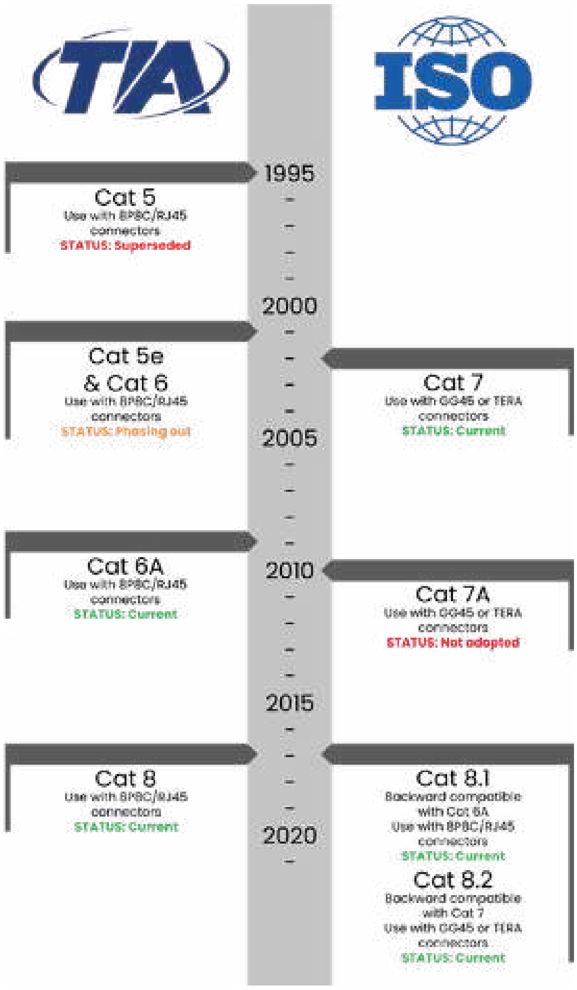
There are two separate standards verticals defining twisted pair category cables:

1. **ANSI/TIA** standards that define Cat 5e, Cat 6, Cat 6A, and Cat 8
2. **ISO/IEC** standards that define Cat 7, and Cat 8.1 and 8.2

Let's take a closer look at both.

## TIA Standards

The Telecommunications Industry Association (TIA) is the predominant organization for global commercial and residential infrastructure cabling standards. Their history goes back to the collaboration with the Electronics Industry Alliance (EIA) to develop Category 3 twisted-pair cable in 1991 with the original TIA/EIA-568 standard.




Fast forward to 2001 and the release of the ANSI accredited TIA/EIA 568-B standard. This shaped the industry for many years to come, specifying Category 5 enhanced (**Cat 5e**) cable at 100MHz and **Cat 6** at 250MHz for gigabit Ethernet to 100m (328ft). These were designed for use with eight-position, eight-contact (8P8C) modular connectors, better known colloquially as RJ45.

By 2009 there was increasing need for 10 Gigabit Ethernet (10GbE) to 100m, giving rise to an augmented version of Cat 6. This resulted in the release of ANSI/TIA-568-C.2 with 500MHz **Cat 6A** cable (note the uppercase A for Augmented, though "enhanced" in Cat 5e is lowercase). The since-renamed Electronics Industry Association was broken up in 2007, and fully dissolved by 2011, leaving the TIA to go it alone from 568-C onwards.

**Cat 8** followed in 2017 with TIA-568-2.D. Its unprecedented 2GHz frequency is designed for 25GbE and 40GbE, albeit to much shorter lengths of 30-36m, but still terminated with the ubiquitous 8P8C/RJ45 connectors.

## ISO/IEC Standards

International Standards Organization (ISO) and International Electrotechnical Commission (IEC) collaborated to develop their own twisted-pair cable standards for enterprise and data center performance needs. This started with ISO/IEC 11801 in 2002, defining Cat 7 cable.

The significant difference with Cat 7, compared with TIA-defined cables, is that Cat 7 was designed to be used with Gigagate 45 (GG45) or TERA connectors. These both provide tighter control and separation of wire pairs compared to 8P8C/RJ45, and when combined with the fully shielded geometry of the cable it results is a higher operating frequency. That is, higher bandwidth and tighter performance margins. However, when used with RJ45 connectors, Cat 7 performance is generally comparable to the TIA's Cat 6A cable that came several years later.

In 2010, an update to ISO/IEC 11801 defined **Cat 7A** in anticipation of 40G Ethernet, supporting frequencies up to 1GHz when used with GG45 or TERA connectors. However, in 2017 when the TIA released Cat 8 and the IEEE nominated its use for up to 40GbE, Cat 7A had still not seen industry adoption in equipment and was effectively made redundant.

Also in 2017, the two standards verticals finally converged. Several months after the release of ANSI/TIA Cat 8, the ISO/IEC ratified the standard, albeit with their own distinctions, effectively unifying the industry. These distinctions are:

- **Cat 8.1** for backward compatibility with Cat 6A and use with 8P8C/RJ45 connectors, and
- **Cat 8.2** for backward compatibility with Cat 7/7A with GG45 or TERA connectors.

Importantly, Cat 7 and Cat 7A were never recognized by the TIA. Note that any reference to Cat 8 is TIA nomenclature, whereas Cat 8.1 and Cat 8.2 are ISO/IEC iterations.

## Suitability for HDBaseT

The choice of cable is an important consideration in determining the performance potential of HDBaseT. With HDBaseT v1.0 and v2.0 each twisted pair carries 4-bit modulated "symbols" at a rate of 500M symbols per second. This results in a Nyquist frequency— the carrier frequency at half the sampling rate— of 250MHz. This aligns with the bandwidth of Cat 6 cable. HDBaseT version 3.0 doubles the signal rate to 1G-symbols per second for a frequency of 500MHz, which neatly aligns with the TIA specification for Cat 6A cable.

HDBaseT was designed from the release of version 1.0 in 2010 to be compatible with Cat 5e, even though Cat 5e is nominally only 100MHz, well below the 250MHz of the HDBaseT signal. This was made possible for two key reasons:

1. The primary signal in HDBaseT v1.0 and 2.0 is asymmetrical with 8Gbps downstream and only 150Mbps upstream. TIA specs are based on a symmetrical signals, namely for Ethernet, but weighting the signal to mostly downstream increases the effective capability.
2. HDBaseT's unique, powerful, purpose-built digital signal processing (DSP) enables excellent signal recovery, bolstering the performance of cables below 250MHz.

Furthermore, HDBaseT v2.0 has a further improved DSP and retransmission capability to minimise the bit error rate, providing even better performance than HDBaseT v1.0. The result is that Cat 5e can support up to 100m (328ft) at HD resolutions, and around 70m (230ft) at 4K UHD. Stepping up to Cat 6 cable pushes this up to 90m (295ft) with HDBaseT v1.0 and the full 100m with v2.0 at 4K UHD. All distances as indicated include up to 5m (16ft) patch cable at each end.

The unprecedented capability of HDBaseT v3.0 to double the transmission bandwidth requires much tighter operating margins, so the use of cable qualified to at least 500MHz is essential.

In summary:

- **Cat 5e** is the minimum requirement for HDBaseT v1.0 and v2.0, albeit with reduced distances compared to Cat 6 or higher.
- **Cat 6** is recommended for HDBaseT versions 1.0 and 2.0 to maximize the distances for all resolutions up to 4K UHD at 60Hz 4:2:0 or 30Hz 4:4:4.
- **Cat 6A** U/FTP is required for HDBaseT v3.0 to enable 4K UHD at 60Hz 4:4:4 to 100m (328ft). Cat 7 is approximately equivalent when used with RJ45 connectors, and an optional alternative.

Many installers and vendors still pragmatically advocate the ongoing use of Cat 6 in some infrastructure cabling settings, such as for gigabit Ethernet or NBASE-T 2.5/5GbE. However, for the sake of provisioning an upgrade path for both Ethernet and HDBaseT, the use of Cat 6A is most recommended when pulling new cables. In this, the HDBaseT Alliance is aligned with the latest TIA infrastructure standards for both commercial and residential, both of which nominate Cat 6A as the minimum Category cable to use. These standards are:

- **ANSI/TIA-570-D** Residential Telecommunications Infrastructure Standard (July 2018)
- **ANSI/TIA-568.1-E** Commercial Building Telecommunications Cabling (March 2020)

In any case, the wire gauge in infrastructure twisted pair cable should be at least 24AWG, with 23AWG optional.

## CABLE SHIELDING

Shielding in a cable is used to protect the signal from surrounding electromagnetic interference (EMI), including radio frequency interference (RFI). The source of EMI is commonly from the surrounding environment in the form of electrical noise, but each twisted pair also emits an electromagnetic field (EMF) of its own when transmitting a signal. This can cause the unwanted transfer of signals to adjacent wire pairs in the same cable, known as **crosstalk (XT).** This same phenomenon can also happen between adjacent signal-carrying cables, such as when two or more Category cables are bundled together. This is called **alien crosstalk (AXT)**.

To counter crosstalk within a cable, manufacturers implement relatively simple design principles, either with or without shielding. But to mitigate alien crosstalk, some form of screening is required. As cable bundling is very common in distributed AV systems and general cabling infrastructure, this is an increasingly important consideration in cable selection.

Each twisted pair in a Category cable is described as either an unshielded twisted pair (UTP) or foil-screened twisted pair (FTP), as follows:

**UTP** None of the four pairs are independently screened. Instead, each uses a different twist rate—the length of each 360° rotation— to mitigate crosstalk. This works by basing the twist rate of each pair on a different prime number so that no two twists ever align, and therefore the EMF and resulting crosstalk from each pair also never aligns, effectively nullifying its effect. Also keep in mind that this results in a slightly different wire length in each pair, causing a "delay skew" across the four pairs. But that's deliberately engineered, and HDBaseT automatically adjusts for a typical amount of skew in UTP cables.

As the four unshielded twisted pairs are grouped into one cable, the overall geometry can either remain unshielded **(U/UTP)** overall, or feature an outer aluminum foil wrap (F/UTP) to screen it from external EMI and alien crosstalk. Cables marketed simply as UTP can generally be assumed as being U/UTP. Common examples include Cat 5e UTP, Cat 6 UTP, and Cat 6A UTP or F/UTP.


*Figure 1 Example of F/UTP cable geometry featuring an overall foil wrap around 4x unshielded twisted pairs.*

**FTP** This type employs a separate foil screen wrap encasing each twisted pair to block crosstalk. As such, each pair can employ the same twist rate, so FTP cables may be described as "skewless."

Similar to UTP, there are also two common geometries for the resulting 4-pair cable: no outer screen is **U/FTP**, or the fully shielded version commonly features an even more robust metal wire (e.g, tinned copper) braid or spiral around the 4-pair group, designated as **S/FTP**, or more commonly simply as STP. Cat 7 cables are typically **STP**.


*Figure 2 Example of U/FTP cable geometry with each pair separately foil screened, but with no overall shield/screen*

## Which Type is Right for HDBaseT?

The choice of cable specification depends partly on the HDBaseT version in use:

- **HDBaseT v1.0 and v2.0** do not generally require the use of shielded cable where single runs in relatively noise-free environments are concerned, and generally work equally well with UTP or FTP (skewless) cables of comparable quality. As such, UTP is popular as it the most accessible, versatile, and economical cable type. However, in runs of two or more adjacent cables, especially during the first 20m (65ft) where the signals are strongest, using **F/UTP** Category cable is the simplest way to mitigate alien crosstalk and other typical sources of low-mid level EMI.

  HDBaseT 2.0 is also compatible with optical fiber cable in supporting products, for extra-long runs of 400-800m with multi-mode or many kilometers with single-mode. To learn more, see the HDBaseT Master Program.

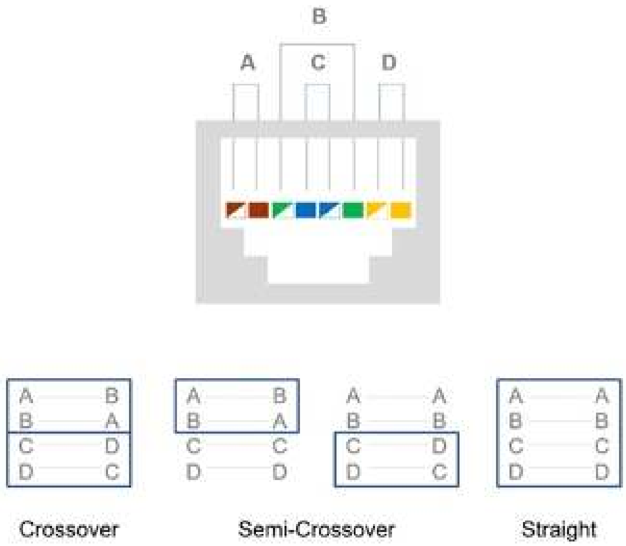
- **HDBaseT v3.0** – **Cat 6A U/FTP** is the recommended setting. The skewless nature and inter-pair shielding of FTP provides the better near-end crosstalk (NEXT, source end) and far-end crosstalk (FEXT, receiver end) parameters required to achieve the maximum performance and distance.

In summary, any project will benefit from the installation of Cat 6A U/FTP or better, simplifying any upgrade to HDBaseT v3.0 for uncompressed 4K at 60Hz 4:4:4, or potentially even 8K video with the addition of Display Stream Compression (DSC). Whichever cable construction you prefer, the termination of the cable and its shield to suitable RJ45 connectors is important in maintaining the integrity and reliability of the HDBaseT link.

## TERMINATION

HDBaseT supports straight, crossover, or semi-crossover termination of RJ45 connectors, similar to those defined by TIA-568B. Irrespective of which topology is used, special care should always be taken to ensure a high-quality termination. In particular, this means maintaining the twists right up to the contacts in the connector, otherwise all the careful engineering that goes in the manufacturing of a cable to minimize crosstalk can be undone by substandard terminations.

As a general rule, performance margins become narrower as bandwidth increases. For this reason, the integrity of the termination is most important with HDBaseT v3.0, where achieving the maximum performance and distance is reliant not only upon using the best cables, but on expert terminations. As was stated in the introduction, "a chain is only as strong as its weakest link."




### Terminating the Cable Shield

It may seem logical to think that if a shielded cable is used, it should be properly grounded to a shielded connector at both ends. However, there are some system topologies where different rules apply. Predicting performance is usually straight-forward where grounded/chassis devices are concerned, but extra consideration must be given if one or both ends use floating power supply units (PSUs).

A floating voltage is one that is ungrounded. These are extremely common, namely DC power adapters, usually without a ground pin. In systems where one or both ends use floating voltage, connecting the shield at both ends could produce a potential difference in the circuit's ground reference voltage. This is known as a ground loop, the inadvertent creation of which can manifest in a number of unpredictable and problematic ways, and can be troublesome to diagnose. The exception is when using Power-over-HDBaseT (PoH), which inherently maintains the reference ground between power sourcing equipment (PSE) and powered device (PD) ends.

The best way to mitigate ground loops is to terminate the cable shield according to two simple rules, irrespective of HDBaseT version:

1. For any connector mating to a device with a grounded chassis or one utilizing PoH, terminate the cable shield to a shielded connector.
2. the cable only. Where one end is a chassis device, terminate the shield there and leave the floating end with shield not connected. If both ends are separately powered by floating PSUs, terminate the cable shield at one end only — it doesn't matter which end.

Some practical examples of this include:

- An HDBaseT matrix switch used with non-PoH receiver units — terminate the shield at the matrix switch end and do NOT terminate the shield at the Rx ends.
- An HDBaseT matrix switch that interoperates with PoH-enabled receiver units — terminate the shield at BOTH ends of the cable.
- A source device or AV receiver with HDBaseT output connected to a projector with HDBaseT input — connect the shield at BOTH ends. This assumes that the devices have proper grounding (i.e. not a floating power supply).
- An HDBaseT extender pair that is not equipped with PoH and uses a floating power supply at each end, terminate the shield at one end only.

For let's turn to some tips on terminating the shield, at those ends that do require it. In addition to maintaining each pair's twist right up to the terminals, as mentioned earlier, the foil screen fold-back should also be kept short to maintain inter-pair screening as close to the terminals as practically possible. These important details combine to minimize NEXT and FEXT for best performance.

Following these simple rules for terminating the cable shield will optimize system performance and avoid troubleshooting time. Follow the manufacturer's advice for mating appropriate connectors to a given cable, and any further methods or advice for termination. For any cable end where the shield is not terminated, the use of an unshielded connector is advisable for ease of installation and to ensure easy identification.

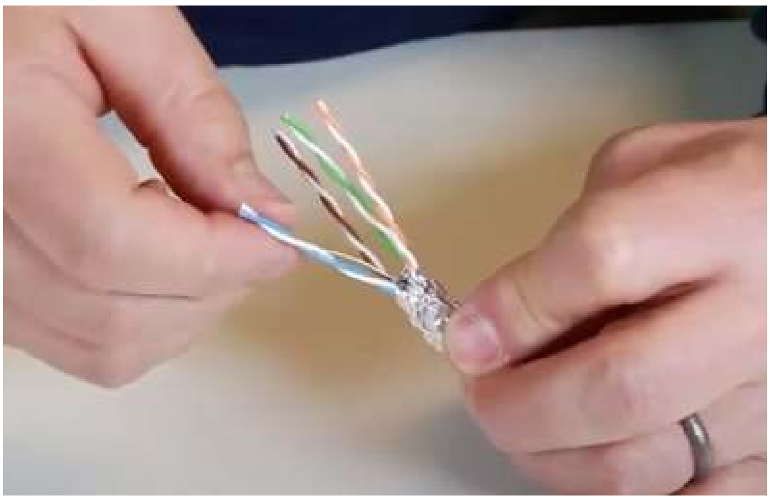


*Figure 3 Follow industry practices and manufacturers' advice for the proper termination of cable shield to connectors*

## CABLE TESTING AND CERTIFICATION

As mentioned earlier, HDBaseT is highly adaptable to most types of Category cables. However, the manufactured quality and compliance of cables in the market can and does vary, even within a given Category specification. For instance, not all Cat 6A cables are created equal!

Compliance to TIA performance parameters is typically subject to self-testing by manufacturers, or may not even be publicly reported. However, this is a very important consideration as the performance of a cable will directly influence the performance of HDBaseT transmissions, and also its safety for use with PoH.

PoH can deliver up to 100W of DC power through the HDBaseT link (Category cable only, not fiber). Doing so generates a small amount of heat. When cables are bundled, as is common practice in infrastructure cabling, the heat profile can build exponentially especially in the center of the bunch. This can inhibit data transmission capabilities, but even worse it can compromise the structural integrity of substandard cables if the wire insulation melts or distorts. At worst it could even present a fire hazard with particularly bad cables!

For these reasons, the HDBaseT Alliance has two separate programs for testing cables, designed to promote installer confidence in delivering optimal performance and safety in installations. These are the HDBaseT Recommended Cable Program, and the PoH Certified Cables Program.

### HDBaseT Recommended Cables Program

The Recommended Cables Program tests Category cables submitted by participating vendors in an HDBaseT Alliance recognized testing facility. A quality cable manufacturer will typically design cables to meet or exceed the current TIA standards, but the HDBaseT program goes a step further: it is based on the **HDBaseT Compliance Test Specification (CTS)**, designed to ensure a candidate cable also meets HDBaseT performance requirements, including its ability to meet or exceed the transmission frequency (bandwidth) needed for the uniquely asymmetric nature of HDBaseT data transmission.

Cables that have passed testing in the program are listed by vendor on the HDBaseT website at **https://hdbaset.org/hdbaset-recommended-cables/**

## PoH Certified Cables Program

The PoH Certified Cable Program was co-developed by the HDBaseT Alliance and Underwriters Laboratories (UL), the US-based safety consulting and certification organization. It is a dedicated program to test and certify cables for the stable and safe use of PoH. The tests are based on the requirements of PoH as outlined in the HDBaseT Compliance Test Specification (CTS), along with safety and performance tests under heating conditions developed by UL.

The tests include bundling the cable in specified bundle sizes, and sending 100 watts of DC power along with the HDBaseT signal parameters. The temperature of the bundle is monitored and measured during operation, and HDBaseT signals are transmitted and captured. To achieve certification a cable must be able to maintain its structural integrity at high temperatures, meaning the insulation on each wire can't melt or soften, and importantly, it must still be able to support the full signal transmission while at temperature.

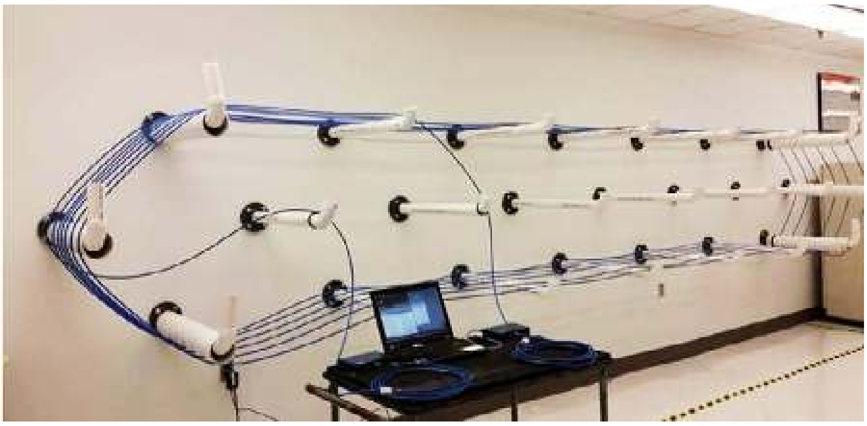


*Figure 4 This picture shows an actual test underway at UL's test facilities*

Cables that have passed performance and safety testing in the program are listed by vendor on the HDBaseT website: **https://hdbaset.org/hdbaset-recommended-cables/**

To make it easy for installers to identify UL certified cables in the marketplace, they are distinguished with an industry recognized UL Certification Mark and anti-counterfeit holographic sticker, an example of which is pictured below. Then to ensure ongoing compliance by manufacturers, UL conduct a Follow-up Program to cover factory inspections and market surveillance. UL are also a Recognized Test Facility (RTF) for the HDBaseT Recommended Cables program.

## Field Testing

While the use of HDBaseT Recommended cables can provide assurances of best suitability, what about installations utilizing existing cabling infrastructure? And what about the integrity of terminations? For this, field testing is required.

Being able to verify at least some key link parameters can bolster performance and help to expedite installations; information that could even be provided to the client for added confidence and installer credibility. There are a number of different testers available for this — a professional grade network cable analyzer such as one designed to certify cables to IEEE 802.3an (10GBASE-T), possibly using guidelines defined by TIA TSB-155, can approximate its suitability for HDBaseT. Parameters may include electrical properties such as insertion loss and near-end/far-end crosstalk (NEXT and FEXT).

However, more HDBaseT specific testing is available, such as with the test equipment from MSolutions. It is extremely helpful for an installer to be able to verify the cable length and separately measures each pair to show a pass or fail suitability for HDBaseT. A separate module for DC resistance can also measure a cable's suitability for PoH.

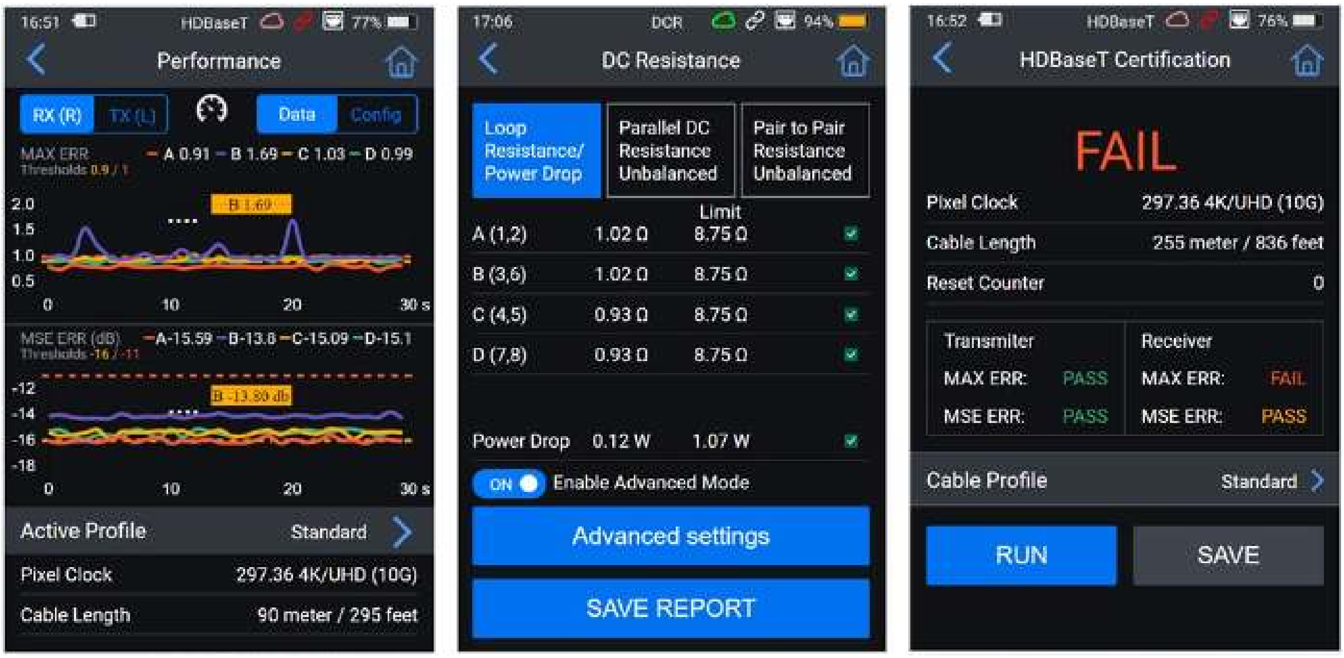



*Figure 5 Screen shots showing some of the test capabilities of the MSolutions tester*

## CONCLUSION

HDBaseT is highly adaptable to existing cabling infrastructure in a building, simplifying the installation of HD and UHD video extension and distribution systems. But where new cables are being installed, using the most appropriate specification and quality of cable, and ensuring it is terminated according to best practices will certainly optimize the performance, capabilities, and even the length potential of HDBaseT. Guidelines can be summarized as follows:

- Cat 5e is the minimum requirement for HDBaseT v1.0 and v2.0, albeit with reduced distances compared to Cat 6 or higher. While Cat 5e will work with HDBaseT v3.0, it is not recommended, and will result in non-optimized performance with respect to both maximum distance and resolution.
- Cat 6 is recommended for HDBaseT versions 1.0 and 2.0 to maximize the distances for all resolutions up to 4K UHD at 60Hz 4:2:0 or 30Hz 4:4:4.  While Cat 6 will work with HDBaseT v3.0, it is not recommended, and will result in non-optimized performance with respect to both maximum distance and resolution.
- Cat 6A U/FTP is the recommended cable for HDBaseT v3.0, in order to enable long distance 4K UHD at 60Hz 4:4:4 (328ft). Cat 7 is approximately equivalent when used with RJ45 connectors, and thus, an optional alternative.

The HDBaseT Alliance recommends always reviewing equipment documentation for a better understanding of functionality and limitations. Furthermore, even if not installing HDBaseT 3.0 right away, any new installations should factor future upgrade paths. As such, the use of Cat 6A U/FTP is most recommended to enable the uncompressed 4K/60 4:4:4 (equivalent to 18Gbps in HDMI) to the full 100m distance.

## HDBASET MASTER PROGRAM

The HDBaseT Master Program provides a comprehensive overview of HDBaseT technology in a self-paced online course.  It contains a section dedicated to cabling, including installation best practices and troubleshooting tips to complement the information included in this white paper.

**https://experts.hdbaset.org/**

HDBaseT

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