User guide

HDBaseT installation authentication

Product: 4K-9000 HDBaseT tester

Flexible and comprehensive professional tester for HDBaseT installations

Smart-e

DESIGN ♦ INNOVATE ♦ ORIGINATE

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SYMBOLS

To ensure the safe and correct use of equipment, we use a range of symbols on the equipment and in the manuals. These symbols demonstrate the risk of physical harm or possible damage to property for the user or others and provide guidance on standards and disposal. Symbol indications and their meanings are as follows. Please ensure that you correctly understand these instructions before reading the manual and operating the equipment.

	WARNING. This symbol is used to indicate where important instructions are provided to ensure the correct operation of the equipment and user safety.
	To prevent fire or shock hazards, do not expose this equipment to rain or moisture. Also, do not use this equipment's polarized plug with an extension cord receptacle or other outlets unless the prongs can be fully inserted. Refrain from opening the cabinet as there are high voltage components inside. Please refer all servicing to qualified service personnel.
CAUTION DO NOT OPEN RISK OF ELECTRIC SHOCK	This symbol warns user that uninsulated voltage within the unit may have sufficient magnitude to cause an electric shock. Therefore, it is dangerous to make any kind of contact with any part inside this unit.
WiFi	This is a WiFi product, which may cause or be susceptible to radio interference. Users may need to take additional measures to mitigate the interference.
	This is a Bluetooth product, which may cause or be susceptible to radio interference. Users may need to take additional measures to mitigate the interference.
	This is an RF Radio product, which may cause or be susceptible to radio interference. Users may need to take additional measures to mitigate the interference.
IR	This is an Infrared product, which may cause or be susceptible to frequency interference. Users may need to take additional measures to mitigate the interference.
HDBT™	This is a product which conforms to HDbaseT specification.
HD 1080p	This product supports full High Definition 1080p resolution.
4K UHD	This product supports 4K Ultra High Definition resolution.
3D	This product supports 3D definition display.
CE	CE certification means that the product has reached the directive safety requirements defined by the European Union.
SGS	SGS certification means that the product has reached the quality inspection standards proposed by the world's largest quality standards body - SGS.
TÜV CERT ISO9001:2000	This product has passed the ISO9001:2000 international quality certification
	EU-wide legislation, as implemented in each Member State, requires that waste electrical and electronic products carrying the mark (left) must be disposed of separately from normal household waste. This includes monitors and electrical accessories, such as signal cables or power cords. When you need to dispose of your equipment, please follow the guidance of your local authority, or ask the agent where you purchased the product. If you wish to dispose of used electrical and electronic products outside the European Union, please contact your local authority so as to comply with the correct disposal method.

WARNING

In order to ensure the reliable performance of the equipment and the safety of the user, please observe the following matters during the process of installation, use and maintenance:

INSTALLATION

- Please do not use this product in the following places: places with high levels of dust or soot; places with high electric conductivity; places with corrosive or combustible gas; places exposed to high temperature, condensation, wind or rain; places subject to the occasion of vibration or impact.
- When installing screw or wiring, make sure that metal scraps and wire heads will not fall into the screw shaft of the equipment, as it could cause a fire, fault, or incorrect operation.
- When the installation work is completed, ensure there is nothing left on the ventilated vents of the equipment, including packaging items. Blocked vents may cause a fire, fault, incorrect operation.
- Avoid wiring and inserting cable plugs in a charged state, otherwise it is easy to cause shock, or electrical damage.
- The installation wiring should be strong reliable and earthed.
- For installations in areas of high interference, the installer should choose shielded cable as the high frequency signal input or output cable, so as to improve the anti-interference ability of the system.
- Switch off and disconnect the equipment from all power sources prior to handling, installation or wiring, otherwise it may cause electric shock or equipment damage.
- This product grounds to earth by the grounding wires. To avoid electric shocks, grounding wires and the earth must be linked together. Before the connection of input or output terminals, please make sure this product is correctly grounded.
- All terminals and wiring should be fully sheathed or otherwise covered before connecting the equipment to a power supply so as to avoid cause electric shock.

OPERATION AND MAINTENANCE

- Be sure to read this manual, and fully comply with the safety recommendations, before undertaking maintenance or operation.
- Do not touch terminals whilst the equipment is in a powered state, or it may cause a shock, incorrect operation.
- Switch off and disconnect the equipment from all power sources prior to cleaning or tightening terminals or connections. These operations can lead to electric shock in a live current state.
- Switch off and disconnect the equipment from all power sources prior to the connection or disconnection of communication signal cables, expansion modules, or other adapters, or it may cause damage to the equipment, incorrect operation, or lead to electric shock in a live current state.
- Do not dismantle the equipment, and avoid damaging the internal electrical components. Please refer all servicing to qualified service personnel.

DISPOSAL

- Be sure to dispose of the equipment in accordance with local regulations.

CONTENTS

1 FUNCTION

The 4K-9000 is a fully comprehensive test tool for HDBaseT installs, compatible with all HDBaseT certified products. The 4K-9000 has two variants, a transmitter, 4K-TX9000 and a receiver, 4K-RX9000. They can be used in conjunction with one another or individually with any other manufacturers HDBaseT compliant hardware.

Supplied in a convenient, compact, hand-held form factor the 4K-9000 is an ideal and easy to carry tool for installers diagnosing HDBaseT faults with existing installs or for approval of pre-existing cabling which a client wishes to utilise for a new install requiring the transmission of HDBaseT signalling.

Use of the HDBaseT Full chipset within the 4K-9000 enables the throughput of 10.2Gbps of HDMI 1.4 data including HDCP (HDCP 2.2 compliant). This bandwidth enables the transmission of 1080p @60Hz 48bpp (deep colour) HDMI content and support for 4K @30Hz 24bpp. EDID and CEC pass-through is supported by the 4K-9000 range. RS232 pass-through ability is available for control of screens and/or sources.

A 2-line LCD panel presents data relating to the quality of the HDBaseT connection simply and clearly to the installer, including an estimate of the CATx cable distance. Readings can be easily navigated with use of the push buttons on the side of the 4K-9000, access to error rates, firmware information and many more readings can be reached navigating through these menus. 4-LEDs are also present on the front of the 4K-9000 enabling easy at-a-glance access to HDBaseT link status, HDMI video status, HDCP status and Hot-Plug-Detect/5V status.

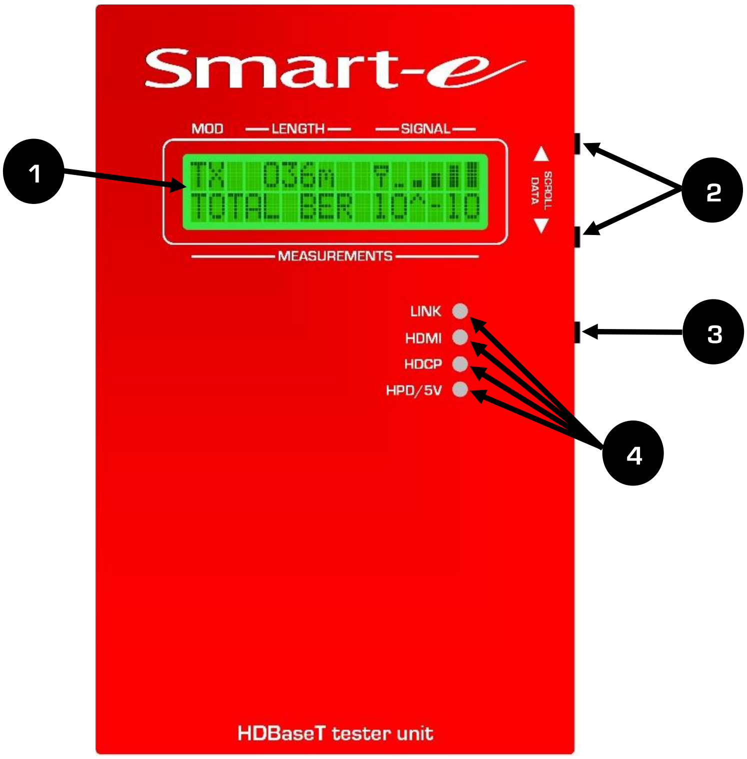
A unique pass/fail verification system is provided, press and hold the test button on the side of the 4K-RX9000 and an installer can instantly see if a CATx cable is suitable for the transmission of HDBaseT signalling.

2 FEATURES

- **Compact Hand-held form factor**
- **Convenient 2-line LCD display**
- **Simple 3 push button controls**
- **Single button HDBaseT pass/fail test function**
- **Compatible with HDBaseT Lite, Full and Extended modes**
- **Estimating of CATx cable length**
- **HDCP 2.2 Compliant**
- **HDMI 1.4 Compliant**
- **CEC pass through**
- **Bi-directional RS232 communication**
- **Deep Colour 3D, 4K & 2K @30Hz & 60Hz**
- **Signals up to 100m of CAT5e-8 cable**
- **Bit-error rate (BER) measurement**
- **Max error measurement**
- **Mean square error measurement**
- **High ground loop immunity**
- **Transmitter and Receiver variants available**

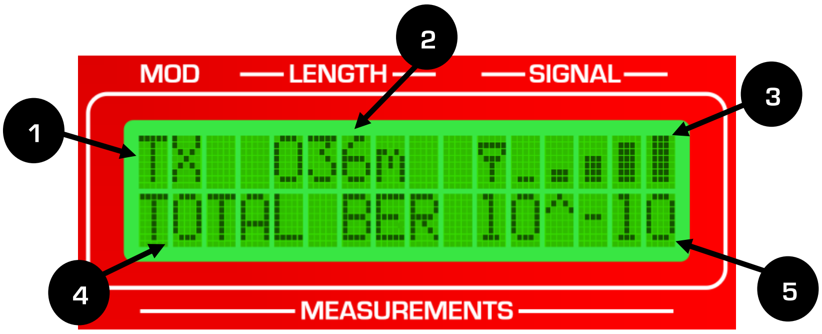
3 CHASSIS PANEL DESCRIPTION

Front Panel



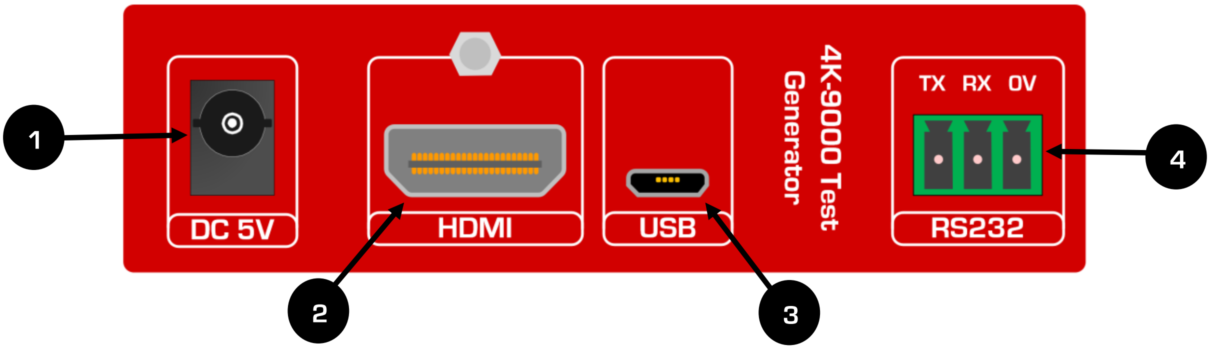
1. LCD display
2. Measurement navigation buttons
3. HDBaseT function test
4. System status

LCD Display



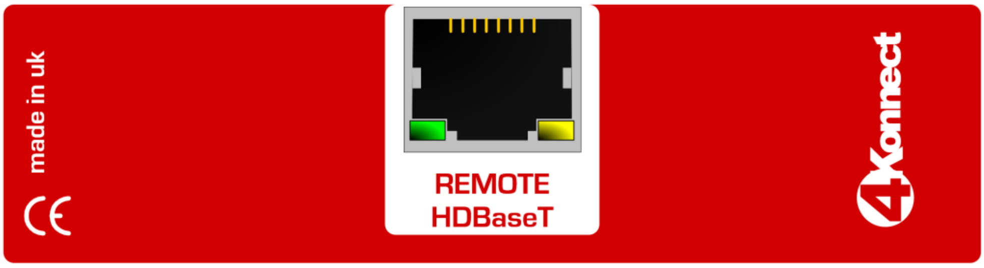
1. TX/RX model indicator
2. Cable length estimation
3. Signal strength indicator
4. Selected measurement
5. Measurement value

Connector Panel

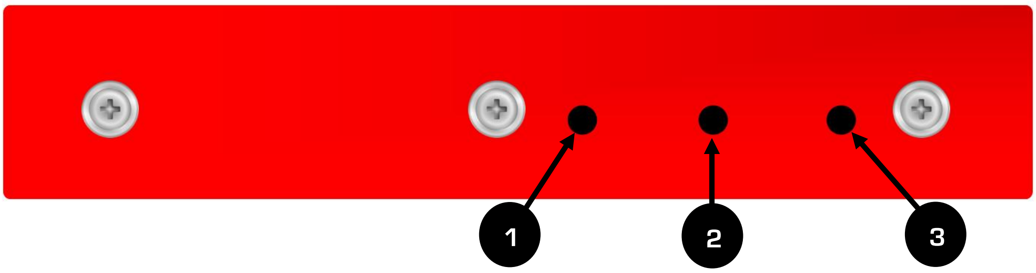


1. DC power input 2.1mm centre positive
2. HDMI I/O connector
3. Micro-USB connector for firmware updates
4. RS-232 passthrough connector

HDBaseT RJ45 Port

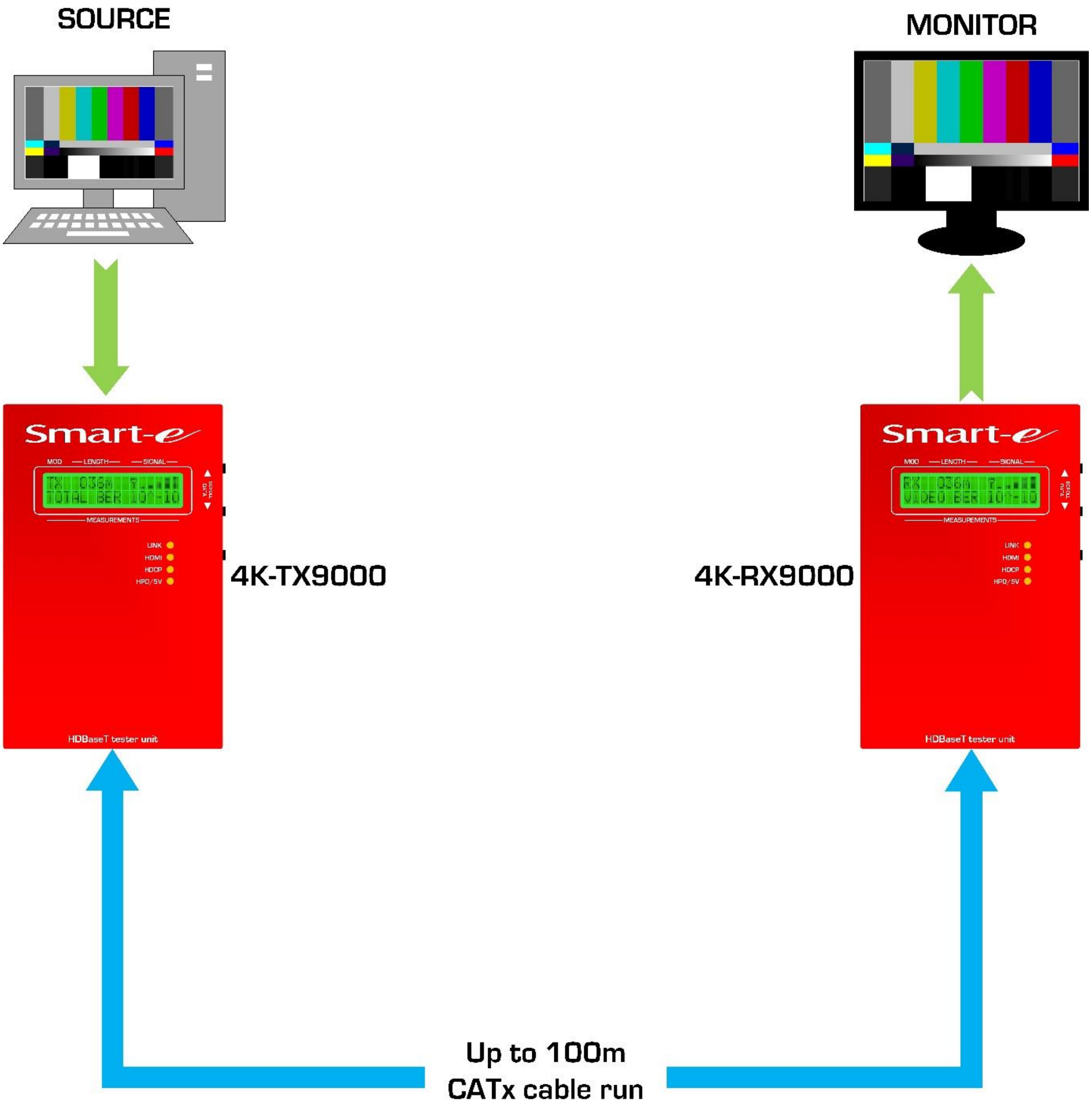


Button Controls



1. HDBaseT function test (applicable only to 4K-RX9000)
2. Measurement navigation down button
3. Measurement navigation up button

4 APPLICATION DIAGRAM



5 WHAT IS INCLUDED

Voyager - 4K-9000

- 1x 4K-TX9000
- 1x 4K-RX9000
- 2x 5V Power Supplies
- 2x UK Type G Plug Adapters
- 2x EU Type F Plug Adapters
- 2x US Type B Plug Adapters
- 2x 3-pin RS232 Adapters

4K-TX9000

- 1x 4K-TX9000
- 1x 5V Power Supply
- 1x UK Type G Plug Adapter
- 1x EU Type F Plug Adapter
- 1x US Type B Plug Adapter
- 1x 3-pin RS232 Adapter

4K-RX9000

- 1x 4K-RX9000
- 1x 5V Power Supply
- 1x UK Type G Plug Adapter
- 1x EU Type F Plug Adapter
- 1x US Type B Plug Adapter
- 1x 3-pin RS232 Adapter

6 BIT ERROR RATES

6.1 DEFINITION AND CALCULATION

A bit in digital communications can have two possible binary values, a '1' or a '0'. A bit error is defined as when a bit is received of an incorrect value due to timing synchronisation errors, interference or data distortion.

Example

Bit Number :	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
Data to be transmitted:	0	1	1	1	0	0	1	0	1
Data received :	0	0	1	1	0	1	0	0	1

In the above example 3-bits received are in error, bits 3, 4 and 8. A Bit Error Rate, abbreviated to BER, is defined as the number of bits received in error per unit of time.

$$BER = \frac{Number\ of\ errors\ received}{Number\ of\ bits\ transmitted}\ per\ second$$

If we assume that the nine bits from the example above are sent in 1 second, then the BER becomes

$$BER = \frac{3}{9} = 0.333$$

This is an extreme example to illustrate the theory of errors, a digital medium in which these many errors were seen would result in no output, especially for high bandwidth transmissions such as HD video.

It is more normal for a digital transmission to consist of many millions or even hundreds of millions of bits per second. If we change the example so we still receive 3 errors but within this second 300 million bits are transmitted the equation becomes

$$BER = \frac{3}{300{,}000{,}000} = 0.00000001$$

This is a more realistic representation of the kinds of bit error rates seen in digital transmission systems, however this is not the value usually presented. For simplicity the figure is presented in standard form

$$0.00000001 = \ 1x10^{-8} = \ 10^{-8} = 10^{\wedge} - 8$$

This is the form BER is presented and the form in which it is seen on the LCD display of the 4K-9000. If the value does not contain a single 1 then the value is rounded up or down to the nearest single 1 value. For example, 6.2x10^-7 becomes 1x10^-6 = 10^-6, 3.8x10^-7 becomes 1x10^-7 = 10^-7. A higher value is therefore desired, the 4K-9000 can read from 10^-0 to 10^-10. 10^-10 is a 'perfect' system with very little error a 10^-0 reading means no video as there are too many errors.

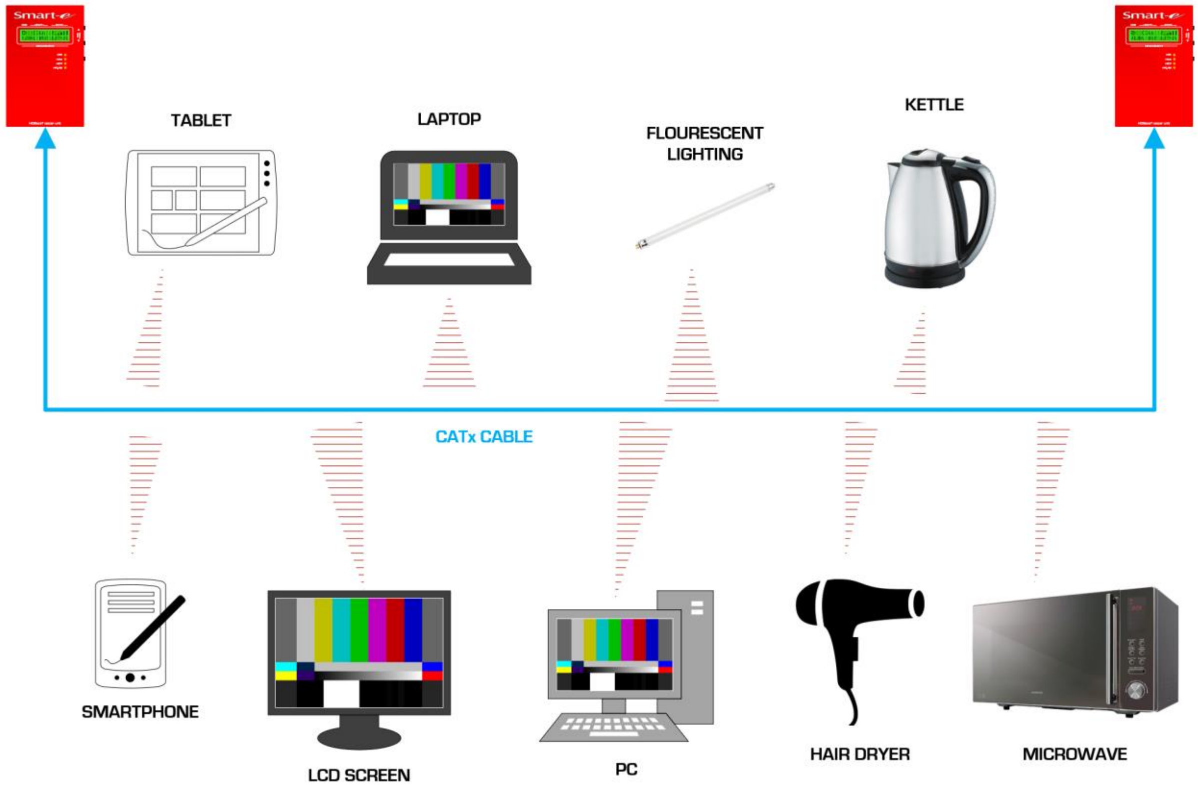
6.2 HOW BIT ERRORS OCCUR

Bit errors can be very destructive events, completely changing an intended instruction or piece of data rendering a data packet useless and possibly leading to a system critical state. Systems mitigate against these kinds of situations by employing methods such as checksums on data packets to ensure any data which has propagated with a bit error is disposed of and a new packet either requested or waited for. More advanced to this are forward error correction systems, commonplace in most modern digital data storage devices, whereby when an error is detected the system can identify the bit or bits which have been affected and correct their values, this is only possible for a limited number of bit errors. If too many errors have been induced it becomes impossible to know which bits have been affected and the data packet must be rejected.

Within a typical HDBaseT install there are three key areas where faults can be introduced to data, the HDBaseT transmitter, the transmission medium (CATx cable) and finally the HDBaseT receiver. The transmitter and receiver can be looked at in similar terms as they are a typical PCB assembly with surface mount components all housed within a sealed metal casing.

The most common source of errors within a digital system are caused by electromagnetic interference (EMI) also commonly referred to as radio-frequency interference (RFI). The most effective way to mitigate against the effects of EMI is to house all components within an external shield, this is provided at the transmitter and receiver ends of a HDBaseT system by the metal casing. Whilst not 100% effective products undergo electromagnetic compatibility (EMC) testing to ensure that they (a) are resilient to the effects of external sources of EMI and (b) do not generate a significant EMI effect themselves which could cause issues for other surrounding devices.

With the cased transmitter and receiver protected from any major impact of interference this leaves the transmission medium, in the case of HDBaseT the CATx cable, as the vulnerable point of the system to the effects of EMI.



Nearly all electronic devices are a potential source of EMI, as demonstrated above with some typical consumer electronic products. Internet connected devices using wireless are a low risk source, such as smartphones and tablets, however they also often incorporate Bluetooth technology which is a slightly greater risk. Devices with large switching currents such as hair dryers, fluorescent lighting and microwave ovens are a common source of interference within domestic HDBaseT installations. Large induction effects can occur on CATx cables running in proximity to these devices and the greater the switching current of the device the larger and more destructive this effect is likely to be. This of course is only looking at devices within the home but if we consider large commercial installations with large air conditioning systems and large amounts of server equipment, the chance of interference being encountered is increased and when encountered is likely to be very destructive to system performance. Progressing in to large industrial applications where sites may include the use of robotic machinery, conveyor belts and their associated motors, EMI is going to be unavoidable.

EMI when induced in to a cable is referred to as noise, the data required is referred to as the signal, the aim is to have the greatest signal level possible with the lowest level of noise giving you the best possible signal to noise ratio (SNR). The longer the run of cable whether that be HDMI or CATx cable the more noise is going to be introduced and the lower the received signal is going to be. Frequency of signal being transmitted is a major factor, UHD or HD video is very high frequency content, the greater the frequency of transmitted signal the higher the risk of the transmission to EMI. When noise is seen on a HDMI signal it is common to observe a 'snowflake' effect (see image below), the image is still visible but some information for specific pixels has been lost due to EMI, if the amount of data lost due to EMI is too great no signal will be displayed.

The HDBaseT protocol is designed to be as robust as possible to deal with instances where EMI leads to a low SNR, but it cannot compensate completely. A Long-range mode is available for HDBaseT, whereby the possible transmission bandwidth is lowered which will mean possibly reducing the resolution you transmit to your screen, but the system is a lot more resilient to noise and to this end can extend the range of HDBaseT transmission up to 150m under certain circumstances. The 4K-9000 aims to provide a tool to measure what effects EMI is having on your HDBaseT installation, you can then use the tool to configure the type of content you are sending to bring the transmission to a stable point to ensure resilience for your install.

However, there is another step to consider, the grade of cabling used in your installation. CATx cabling comes in many varieties, the next section of this manual discusses how cabling can protect your system from errors and how it must be at the forefront of your thinking when at the specification stage of a HDBaseT project or considering problems being encountered within an existing installation. As discussed previously, if the errors encountered are so overwhelming to the transmission, no signal is going to be displayed on the output screen. This would generally lead to the conclusion of faulty hardware, this is going to encounter large costs of procuring new equipment or at the very least having to wait for new equipment to be sent from a manufacturer and then having to reattend site to install only to find the problem is still there. The 4K-9000 aims to remove this step by offering a convenient tool to see instantly if the problem lay with the hardware or the often-overlooked problem of EMI.

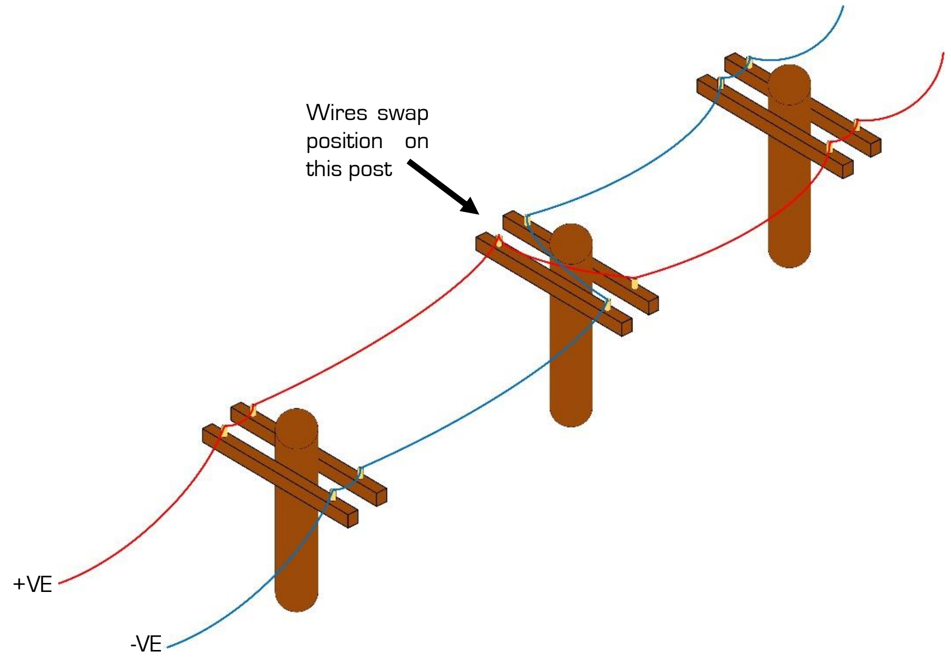
6.3 HOW TO AVOID BIT ERRORS

6.3.1 CATX CABLING

Category cabling is commonplace within digital communication and relies on a number of twisted-pair cables to transmit data between points within a system. Category cables vary in type and are designated a number to show the cables ability ranging from CAT1 – CAT8 (CAT8 is still a work in progress with standards still to be agreed). CAT1 – CAT4 are obsolete in the modern era of technology and were used for low speed communications or for token ring networks, these were networks where data would pass through all points in a network to find the node to which the data it carries is addressed as opposed to our modern centralised network architectures where all data is controlled and transported through a single point. The below table gives a comparison of category cables.

Category	Max Transmission Speed @100m	Max Bandwidth
5e	1 Gbps	125MHz
6	10Gbps	250MHz
6a	10Gbps	500MHz
7	10Gbps	600MHz
8	25-40Gbps	Around 2GHz

All these categories of cables share the architecture of twisted-pairs which was a solution invented by Alexander Graham Bell in 1881 as a solution to the problems of EMI. From the very early days of communications engineers have battled the effects of EMI. Early telephone cables experienced large amounts of interference due to the advent of electricity transport architectures. EMI from these high voltage power cables would cause so much noise on telephone communications they would become useless. The novel solution to this was to implement a method called wire transportation. Wire transportation involved the running of two cables in parallel suspended from telegraph poles, the wires would then swap positions periodically on the poles to give them a twist rate of approximately 4 per kilometre, this meant both wires would receive similar amount of EMI from the problematic electricity cables and the interference would be cancelled out or at least it's effect lessened. The signal is sent in a balanced form meaning the noise level can be calculated from a summation of the two signals and by this periodic swapping of positions the noise level will be similar on both cables and the original signal can be derived. This system is still employed in many countries around the world.



The modern varieties of this method CAT5e-8 use the same principal but with much higher twist ratios of around 100 twists per meter. This increases the likelihood that the individual conductors within each pair are to receive the same levels of EMI. As categories of cable increase the size of the conductor increases, this allows for greater bandwidth but comes with a compromise of having a heavier and less flexible cable. This is where the trade-off lay in the decision between performance and cost/ease of installation.

Category cabling consists of four colour coded twisted pairs (eight conductors). The four colours are orange, green, blue and brown with one of each pair solidly coloured and the other with a white stripe. Cables come with varying levels of shielding to protect against the effects of EMI. The level of shielding varies depending on the category of cabling and the transmission requirements. An abbreviated code system is used to see at a glance the specification of a category cable.

U = unshielded

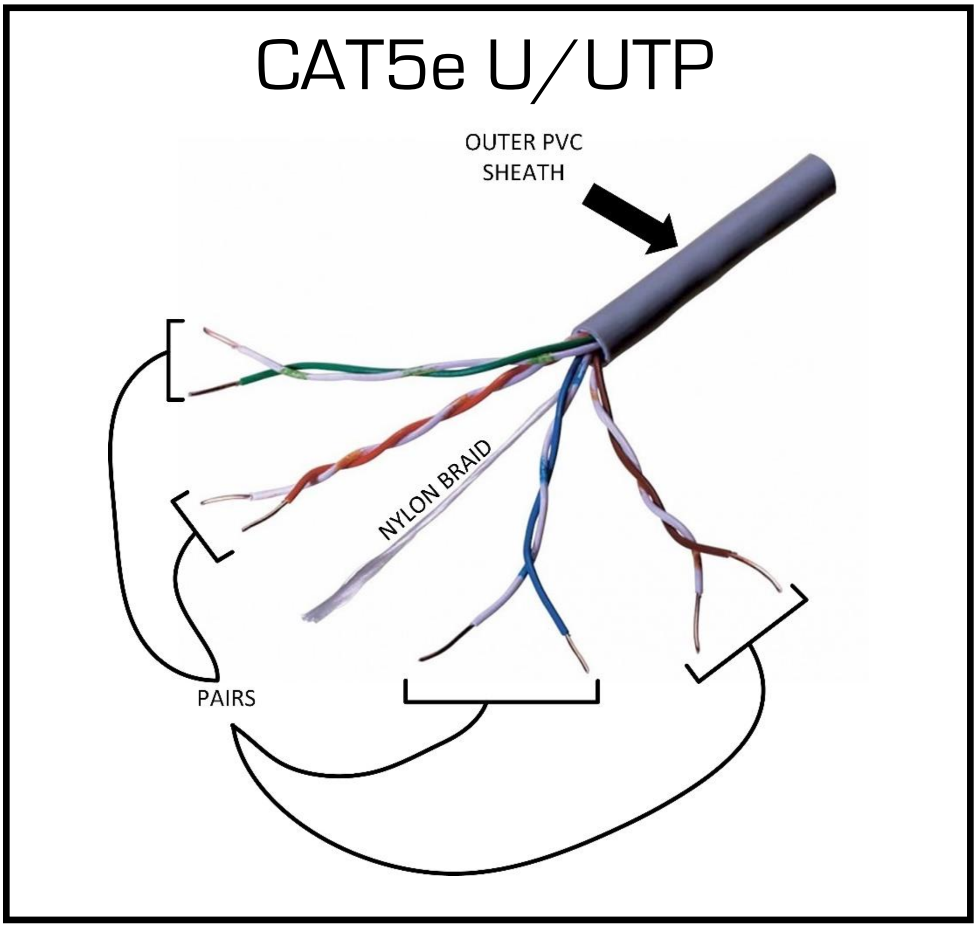
F = foil shielding

S = braided shielding

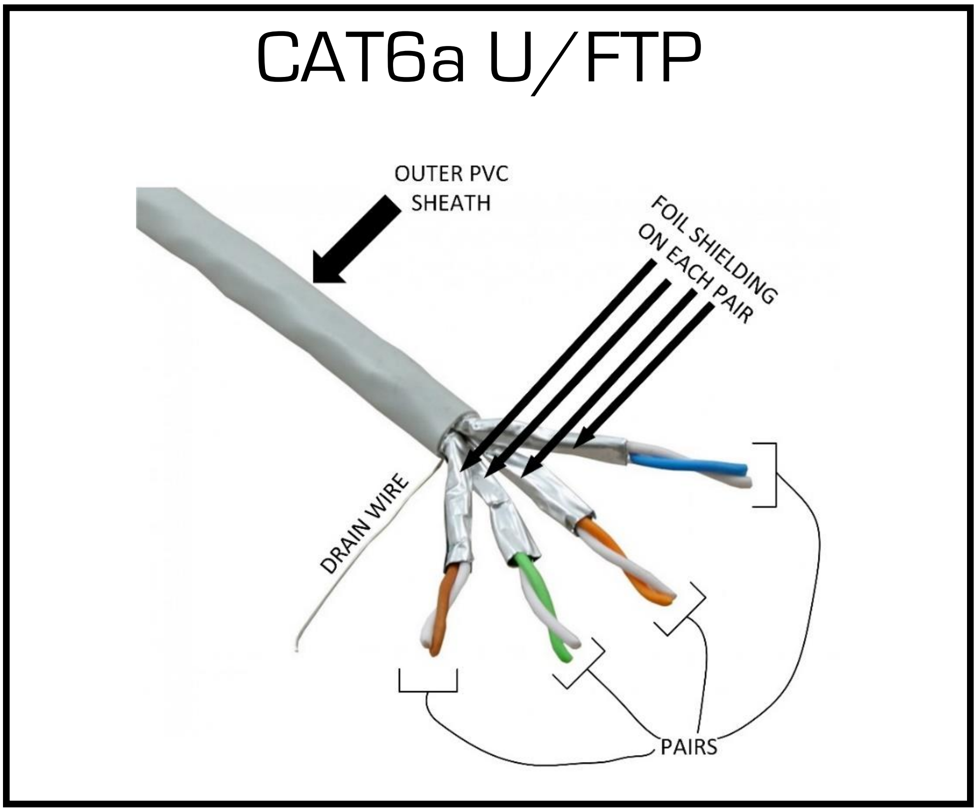
TP = twisted pair

The letter before the / indicates the type of outer shielding the letter immediately after the slash indicates the shielding used for each individual pair.

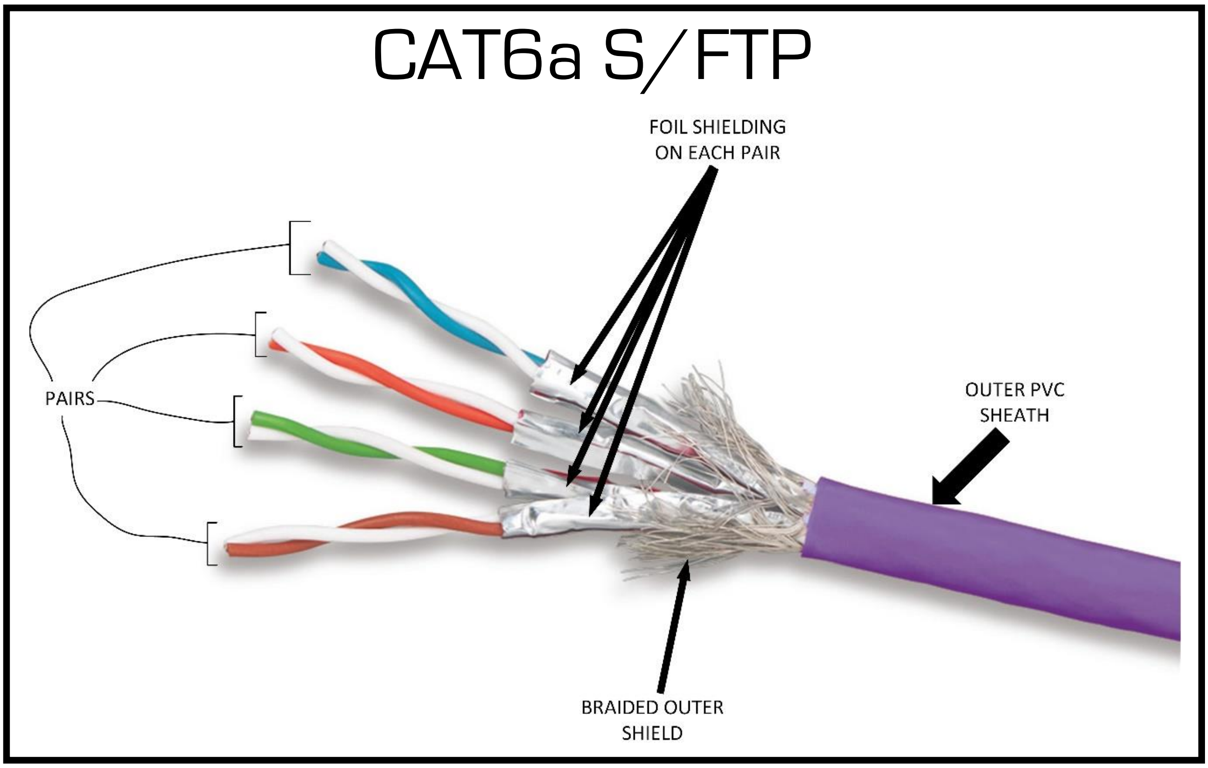
U/FTP = no outer shield, foil shielding of each individual twisted pair



The image above is of a CAT5e U/UTP cable. The nylon braid is non-conductive and is provided as an aid to strip back the outer PVC sheath without damaging the coloured insulation on the conductor cables.

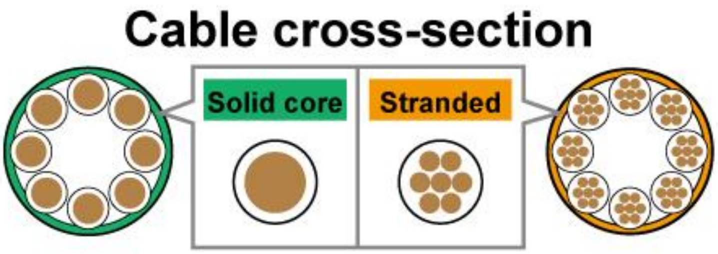


The image above shows a CAT6a U/FTP cable. Each pair has a foil sheath to protect them from the effects of EMI and from crosstalk which may be induced by the signals carried on other pairs. Also present is a drain wire, this is a conductive strip which runs along the entirety of the cable run. The drain should be connected to the shield of the termination points at each end of a cable run providing a ground path for any unwanted signals.



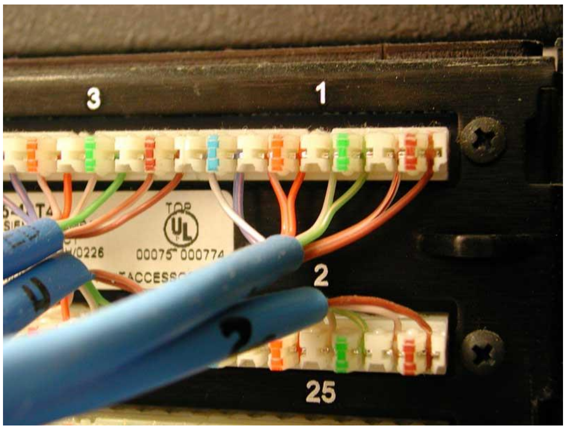
The final example above is of a CAT6a S/FTP cable. The only difference from the previous example is the addition of a braided shield within the outer PVC shield surrounding all four pairs. This provides a further barrier to any EMI. This braided shield should be connected to the shield at the termination points.

With any of the above examples, when it comes to category cable there are two choices, solid core and multi-core (in some cases referred to as stranded core).



	Solid Core Cable	Stranded Cable
Characteristics	Excellent for long distance transmission	Flexible and easy to handle
Suited for	Installations	Touring and short patch links

The above images give a visual representation of the make up of the cable and their benefits and restrictions. For any HDBaseT install it is advised, and this is true of any infrastructure cable, the use of solid core cabling for most of the run from patch panel in comms cupboard to network point and then as short as possible stranded core 'patch' cables to complete the run at both ends. First reason for this is that termination points within infrastructure tend to be designed for push-down termination.



On the left, above is an image of a push down termination patch panel and on the right the associated tool required. The solid core cable is pushed in to the correct position and then small blades within the termination point cut through the conductor's insulation and grip on to the conductor. Secondly solid core cables are far more capable at long distances, stranded cables over long distance can cause degradation in signal quality.

6.3.2 SMART-E RECOMMENDED CABLE CHOICE

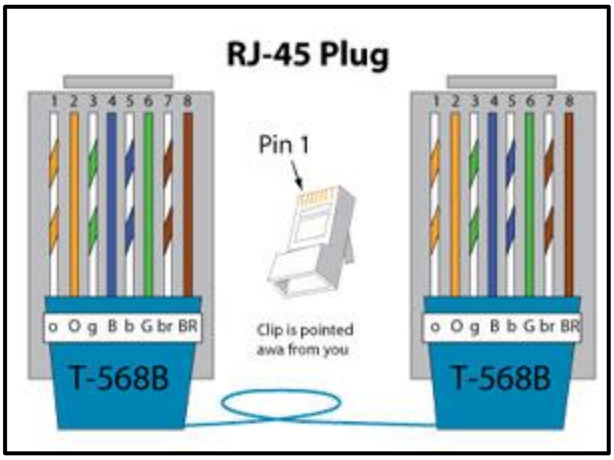
The cable specification below has been rigorously tested by Smart-e engineers and verified to transmit a 3840x2160, HDCP2.2, 4:2:0 specification image over a distance of 100m.

Connectix CAT6a U/FTP Solid core cable (up to 90m)

Connectix CAT6a Keystone modules x2

Connectix CAT6a S/FTP 5m Stranded core patch cables x2

T-568B Termination at both ends



T568B

Pin	Color
1	white /orange
2	orange
3	white /green
4	blue
5	white /blue
6	green
7	white /brown
8	brown

The cable choices listed above have proved to provide near perfect operating conditions for the transmission of HDBaseT signals over long distances. At 100m HDBaseT is at the very limit of performance with the image specification given above, one way to mitigate against this is with the use of a HDBaseT 2.0 specification receiver unit such as the 4K-RX975-USB. HDBaseT 2.0 specification is yet more robust to noise than standard HDBaseT products, at 100m with the specifications set above the same performance levels were observed as were seen at 70m with HDBaseT specification products.

6.3.3 ADHERING TO CABLE INSTALLATION BEST PRACTICES

There are 10 key steps it is advised to follow when installing category cabling for use with a HDBaseT install.

1. The cabling used for HDBaseT (CAT5e and above) is the same as that used in LAN applications. For this, many standards have been developed within the industry. In Britain the BS 6701:2016 is the latest version of document available entitled Telecommunications equipment and telecommunications cabling – specification for installation, operation and maintenance. Similar standards exist in other regions around the world. Adhering to the specifications set out in these documents is a key start point for the installation of any category cable project.
2. Make sure a distance is kept between power cables and category cabling. A general rule of thumb is these types of cables should be 12 inches apart. It can be tempting, especially in commercial installations, to run power and catx cables in shared trays and trunkings but this can lead to large amounts of EMI induced in to category cabling and ultimately performance issues.
3. All category cables should be handled with great care. A common cable tidy solution is the use of cable ties or other similar items, these can crush and break the conductor cores within category cables leading to decreased performance. When pulling cables please use minimal force necessary, if a too larger force is being required return to the beginning of the cable run and try again.
4. Use of patch cables should be kept to an absolute minimum. Every join within a system introduces small losses, as outset previously, the majority of a cable run should be a solid core infrastructure category cable and a maximum of 5m stranded patch cable should be used at each end of the run.
5. Be careful of bends within cable runs. The inside bend radius of a cable when installed should be at least 4 times the diameter of the cable. This is a rule of thumb and there is tolerance either way but if a cable is bent significantly within this this rule it can lead to the cable properties being changed and affecting system performance.
6. Keep termination points as small and as neat as possible. Untwisting category cabling reduces the performance of the cable and stripping back the insulation and shielding leaves the conductors vulnerable to EMI, for this reason you should strip back the minimum amount of shielding and sheaving as is possible.
7. Take great care with termination process. Use of approved wire stripping and termination tools is vital to ensure the quality and longevity of the connection. Be sure of the termination scheme used at both ends of a cable run and adhere to this termination across all installed cabling, T568B is the widely used termination standard by HDBaseT manufacturers but please check for your specific installation.
8. Always monitor cable distances. Most category cabling will have meter markings on the outer sheath, so you can monitor the distance of cabling being installed. It is important to have a note of all cable distances as this can affect the choice of HDBaseT hardware or the operation mode the hardware must be used with.
9. Test every cable after termination. Use of a fluke meter or similar test equipment to check all category cabling during install is vital, wrongly wired, damaged or too longer cable can lead to performance issues or damage to hardware.
10. Be sure to label all cabling ends and produce a system drawing with all wiring points clearly marked to match the fitted labels. Although a long and what might seem at the time thankless task, when it comes to fault diagnosis labelled cables and a system diagram can save time and money and easily lead to the resolution of a fault that otherwise would be difficult to find.

6.3.4 WORKING WITH EXISTING CABLING SOLUTIONS

The price difference between CAT5e and CAT6a cabling is approximately a factor of 3, within a small installation this cost may be overwhelming and as the customer expects CAT5e to be suitable for HDBaseT transmission it can be difficult to justify this cost. It may be the case that a site has already been flood wired with CAT5e or CAT6 cable and re-running CAT6a cabling is not a possibility, here the 4K-9000 can be used to find a workaround solution that will keep your customer happy and provide a stable and reliable HDBaseT transmission solution.

As discussed previously, a system is more vulnerable to errors with a higher data rate. The data rate of a HDBaseT system can be measured with the 4K-9000 with reference to the TMDS Clock, the higher the clock rate the higher the data rate is a basic rule. If when transmitting your desired resolution, you are getting no image or the 4K-9000 indicates a very large amount of noise one way to overcome this may be to reduce the resolution. Dropping the resolution from 1080p to 720p could be an ideal solution dependant on the type of content being transmitted. Although this may not be ideal, and the screen is no longer operating at it's native resolution which could show some degradation in image quality it may be a compromise whereby cost is not an issue as new cabling does not need to be installed. The 4K-9000 can be used as a tool to show that the reduction in data rate has led to a much more stable solution giving confidence to the installer and customer alike. The decision can then be left to the customer to decide of the compromised resolution is worth the trade off in image quality or if they wish to install new cabling.

Another issue that comes from working with pre-installed cabling is lack of information as to length of cable runs. Customers are therefore not sure as to which variety of HDBaseT product they require, an inexpensive HDBaseT Lite solution a more expensive HDBaseT Full solution or a project specific Long Reach Mode HDBaseT solution. The 4K-9000 can offer estimations of the cable length at the same time as giving information on the quality of the connection via the automated test function and access to the specific BER readings. Cabling can therefore be pre-approved prior to any work taking place. This can save a lot of time come installation where guesses and estimates have been used uncertainty is present, problems experienced at this stage could lead to increased costs for the customer and a lot of time wasted for the installer.

7 WHAT IS HDBASET

The shift to digital content began in earnest in 2002 when development commenced on the HDMI 1.0 standard, up to this point content had been delivered through a variety of analogue methods and connectors. The aim was to create a new standard suitable for all foreseeable high-resolution and high-bandwidth video needs. Since this time HDMI has grown to become the standard video connector interface. In very recent times competition to HDMI has been seen due to data rates exceeding that designed for HDMI standards, the advent of display port and thunderbolt 3 has enabled higher resolutions for niche applications, however HDMI is still the most common interface for domestic and commercial installs alike.

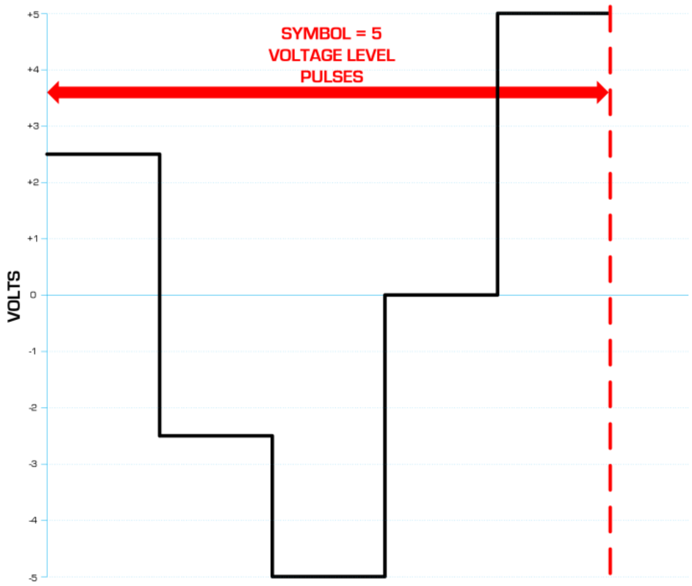
The advent of HDMI did present a challenge to AV distribution. Since the late 80s and early 90s, AV distribution had been perfected to send any analogue content possible over long distances and over a variety of transmission mediums. Initially AV distribution manufacturers saw the only answer was to convert HDMI in to an analogue format and then send the information as they always did. This led to a variety of issues, HDMI was designed to digitally protect content which was near impossible to comply with when sending an analogue signal, HDMI sources relied on EDID reading of the attached screen which was very difficult to incorporate existing analogue designs and it removed a number of the conveniences of HDMI such as CEC control and the Hot Plug Detect mechanisms.

In 2010 Valens developed what has gone on to become the leading standard for extending HD video with their HDBaseT standard and chipsets. HDBaseT enables the transmission of 10.2 Gbps of uncompressed UHD video data over 100m of Cat5e/6 cable. As well as video the transmission can also be used for audio, control, data and power, this provided the AV distribution industry with the perfect tool to replicate the functionality they enjoyed in the analogue world but also to remove some of the headaches with variable image quality and EDID which can now be passed from the screen to the distribution point.

HDBaseT has been adopted by nearly all AV manufacturers, HDBaseT is commonly found as an input directly accessible on high-end screens and projectors removing the need for any additional hardware at the screen location. This convenience does come with some draw backs, previously in the analogue world it was commonplace to be able to extend a HD VGA signal at up to 300m, with HDBaseT the maximum range in long reach mode is 150m, retrospectively replacing these analogue installs would therefore require daisy-chaining back-to-back HDBaseT systems. Another drawback is the large amounts of data flowing through the transmission medium leaves the system more vulnerable to EMI, in the analogue world this would have displayed itself as a distorted signal and an installer could then work through various fixes to see the changes this has on the image, with HDBaseT high levels of EMI on a sub-standard transmission medium will often result in no signal being displayed leaving the installer with not much guidance as to where the problem may lie.

The only viable alternative for extending HDMI over large distances is the use of HDMI over network extenders, commonly referred to as streaming products. These devices use Ethernet protocol to extend HDMI. One benefit of streaming products is no direct physical connection need exist between a transmit and receive device, if both are on the same network any receive device can be pointed at any transmit device. Another benefit is their low cost, compared with HDBaseT extenders a streaming solution can be up to a quarter of the price. A major drawback with a streaming solution is with video quality. HDBaseT is an uncompressed method of transmission, streamers will typically use H.264 encoding, this is a compression method and will hence cause a in quality for the resulting image seen by the client. H.264 encoding is only effective on images up to 1080p in resolution, this compares with HDBaseT ability to send UHD signals. Another downside is the overhead on network resources. Streaming devices require access to a centralised network to communicate between the various transmit and receive devices. Each 1080p stream to a receive device in best case scenario would need a bandwidth allocation of 5Mbps, the solution employed would either need to allow for this overhead on an existing network or employ a whole new network dedicated to the streaming solution.

As discussed in section 6 of this manual the problems of EMI in digital transmission can be overcome or at least mitigated against with the use of high quality cabling, in the case of HDBaseT, CAT6a U/FTP cable. To enable the transmission of such large amounts of data HDBaseT uses a modulation scheme, broadly known as Pulse Amplitude Modulation (PAM). PAM works by dividing a plane in to a 2^x number of voltage levels. PAM therefore has several encoding methods PAM-3 (x=1), PAM-5 (x=2), PAM-8 (x=3) and PAM-16 (x=4). PAM-3 and PAM-5 use the 0V level as an additional encoding level. PAM-16 is the modulation scheme used for HDBaseT, the higher the PAM technique used the greater the bandwidth. Firstly, to understand how PAM works let us look at PAM-5, the modulation technique used for 1Gb Ethernet.



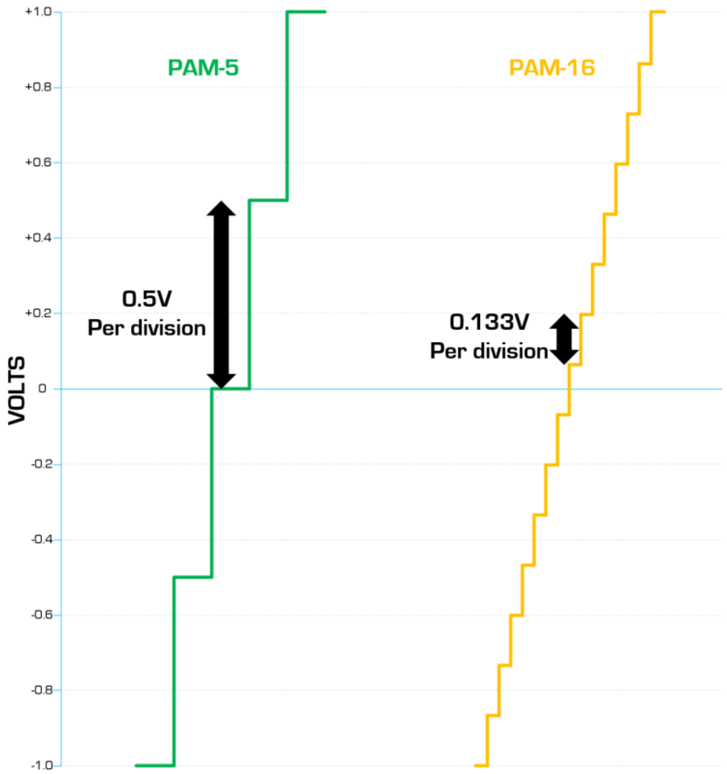
In the example above, we have a 10V envelope signal, -5V to +5V, 10V peak-to-peak (p-p). Five discrete voltage levels exist in the PAM-5 modulation, -5V, -2.5V, 0V, +2.5V and +5V. These voltage levels are purely for example but displays the principal in a clear way. When used for 1Gb Ethernet, 4 of the voltage levels are used to transmit 2 bits of data and the fifth voltage level is utilised for forward error correction (FEC). The maths from this can then be shown to prove the bandwidth is satisfied:

$$Cat5e\ raw\ bandwidth = 125MHz\ or\ 125{,}000\ symbols\ per\ second$$

$$2\ bits\ per\ symbol: 125{,}000\ x\ 2 = 250{,}000\ bits\ per\ second\ or\ 250Mbps$$

$$4\ twisted\ pairs: 250Mbps\ x\ 4 = 1000Mbps\ or\ \mathbf{1Gbps}$$

A more typical voltage envelope for transmission would be 2Vp-p, -1V to +1V. A comparison of PAM-5 and PAM-16 can be used to explain how more discrete voltage levels has an adverse effect on a systems resilience to noise.



The volts per division within a PAM-16 encoding format are approximately 4 times less than that of a PAM-5 encoding format. This means noise introduced which would cause a discrete voltage level to be misinterpreted is 4 times more likely to occur in a PAM-16 encoding mechanism than in one employing PAM-5.

Using the following formulae, can be used to measure a PAM systems noise susceptibility using the example from above.

$$20\log\left(\frac{Vd}{Vp-p}\right)$$

Vd = volts between discrete levels

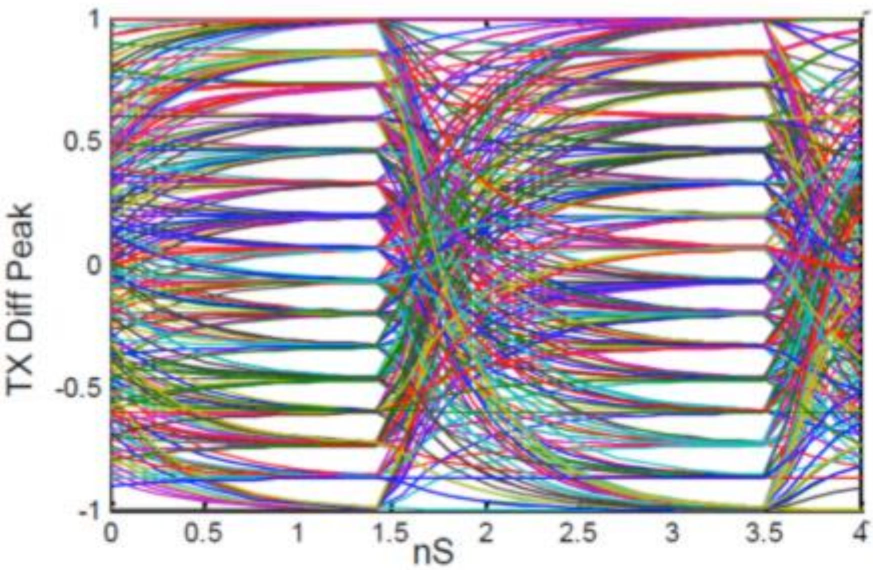
Vp-p = peak-to-peak voltage envelope

$$\boldsymbol{PAM-5 = 20\log\left(\frac{0.5}{2}\right) = -12.04dB}$$

$$\boldsymbol{PAM-16 = 20\log\left(\frac{0.133}{2}\right) = -23.54dB}$$

These figures represent each systems signal-to-noise degradation, the degradation of a signal increases the higher the order of PAM scheme implemented.

The most effective way in dealing with these noise issues is to use high quality category cable as discussed in section 6 of this manual. The use of PAM-16 encoding is essential to enable the transmission of the large amounts of data for UHD video and with proper care during specification and installation can provide an excellent transmission medium. Below is an eye-diagram when implementing PAM-16 coding as in the transmission of HDBaseT, it gives an idea as to the large amount of data it is possible to transmit but also visually shows how easily errors could be induced when good installation practices are not followed.



8 FIRST STEPS

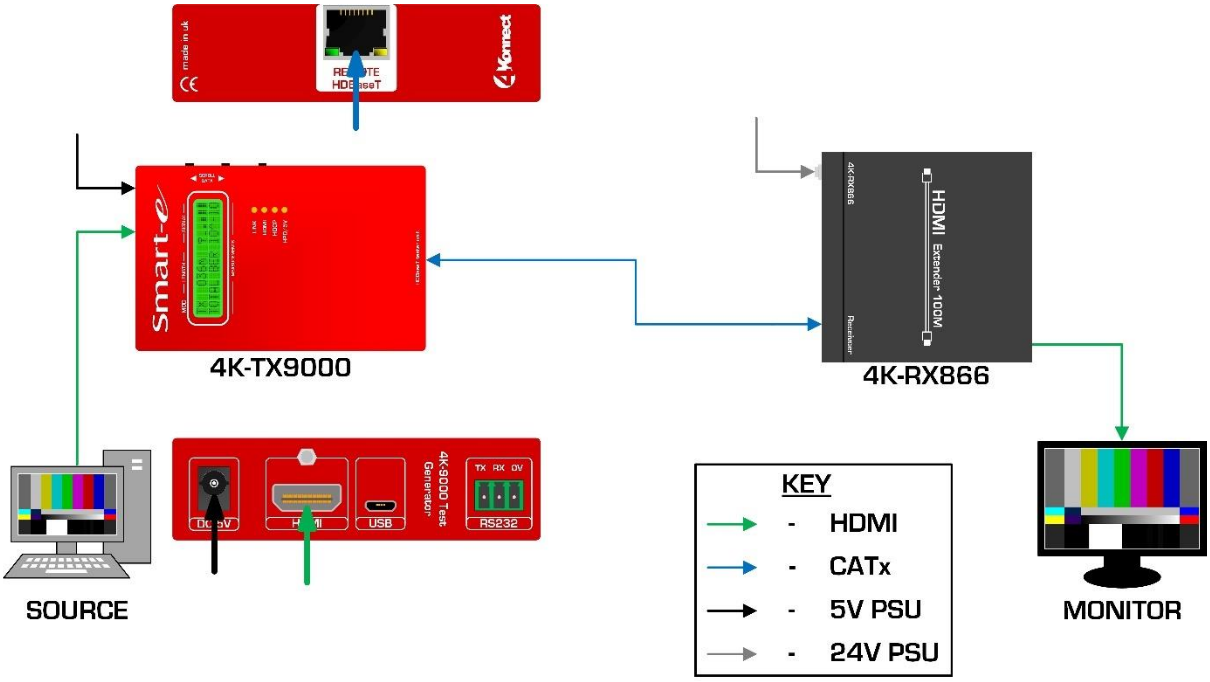
The first step in any HDBaseT installation whether evaluating a fault or checking a cables viability for HDBaseT transmission is to use a network cable tester to verify continuity in all the category cable conductors. If a cable has been damaged or is incorrectly terminated then the 4K-9000 is of no use, the 4K-9000 relies on a HDBaseT link being present to operate. Verifying the cabling at first point will save a lot of time and incorrectly wired cabling could lead to damage of any unit which is attached to it.

The second step is to check the working nature of the source and screen being utilised, if an incompatibility exists between the source and screen it will be difficult to identify with the 4K-9000. As described later in this manual the 4K-9000 can indicate the status of the hot plug detect (HPD) and 5V lines for the HDMI throughput, this would indicate a problem in the HDMI cabling or the source and screen. It is not always easy to remove a source and take it to a screen location but for the instance of verifying cables prior to installation checking the source and screen compatibility prior to use of the 4K-9000 will be beneficial.

9 BASIC SETUP

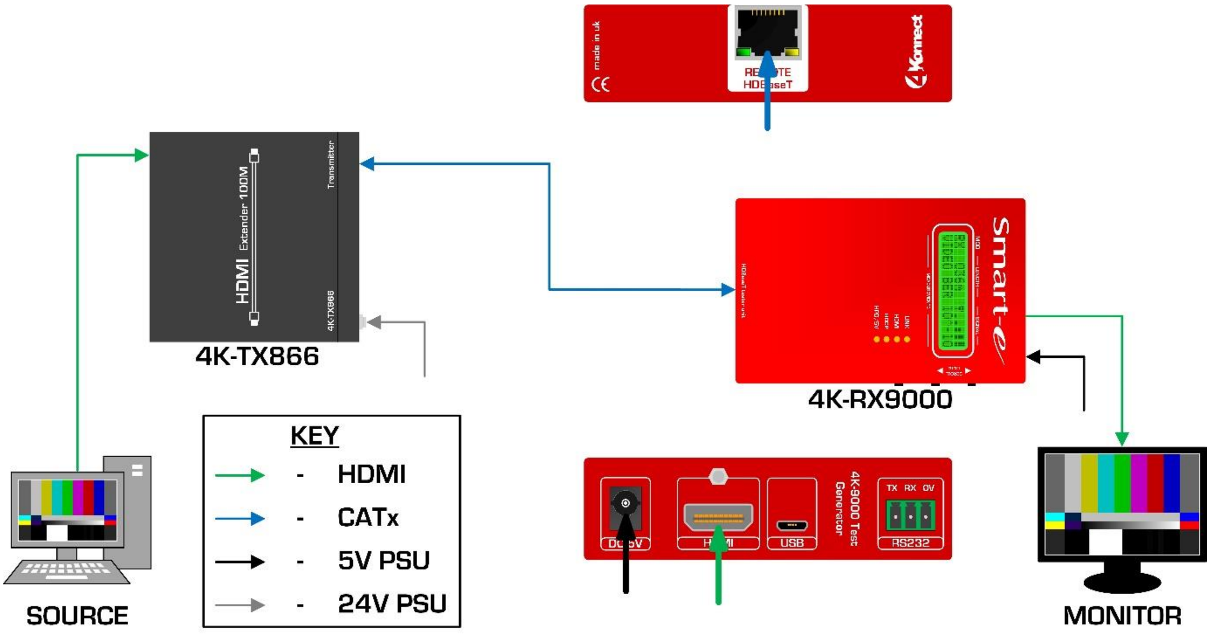
There are three possible setups which can be implemented using the 4K-9000s, firstly a 4K-TX9000 in use with a HDBaseT receiver, for example the 4K-RX866. Secondly, a 4K-RX9000 in use with a HDBaseT transmitter, for example the 4K-TX866. Finally, the use of a 4K-TX9000 and 4K-RX9000 as a point-to-point pair.

9.1 4K-TX9000 WITH HDBASET RECEIVER

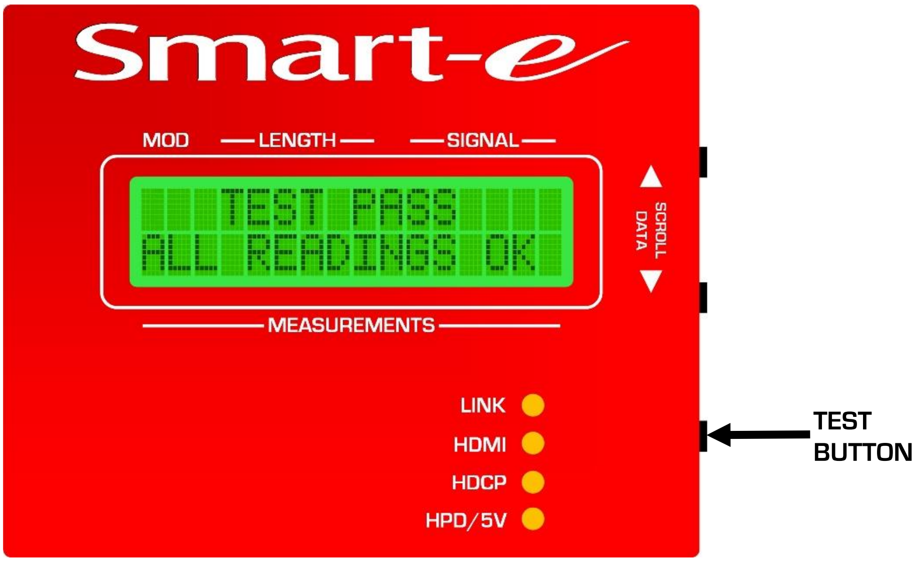


1. Test CATx cable for continuity using a network cable tester
2. Connect HDMI cable between receiver and monitor
3. Connect power supply to HDBaseT receiver, then attach power supply to mains feed
4. Connect CATx cable to RJ45 HDBaseT input on HDBaseT receiver
5. Connect HDMI cable between 4K-TX9000 and source
6. Connect CATx cable to RJ45 HDBaseT output on 4K-TX9000
7. Connect 5V power supply to 4K-TX9000, then attach power supply to mains outlet

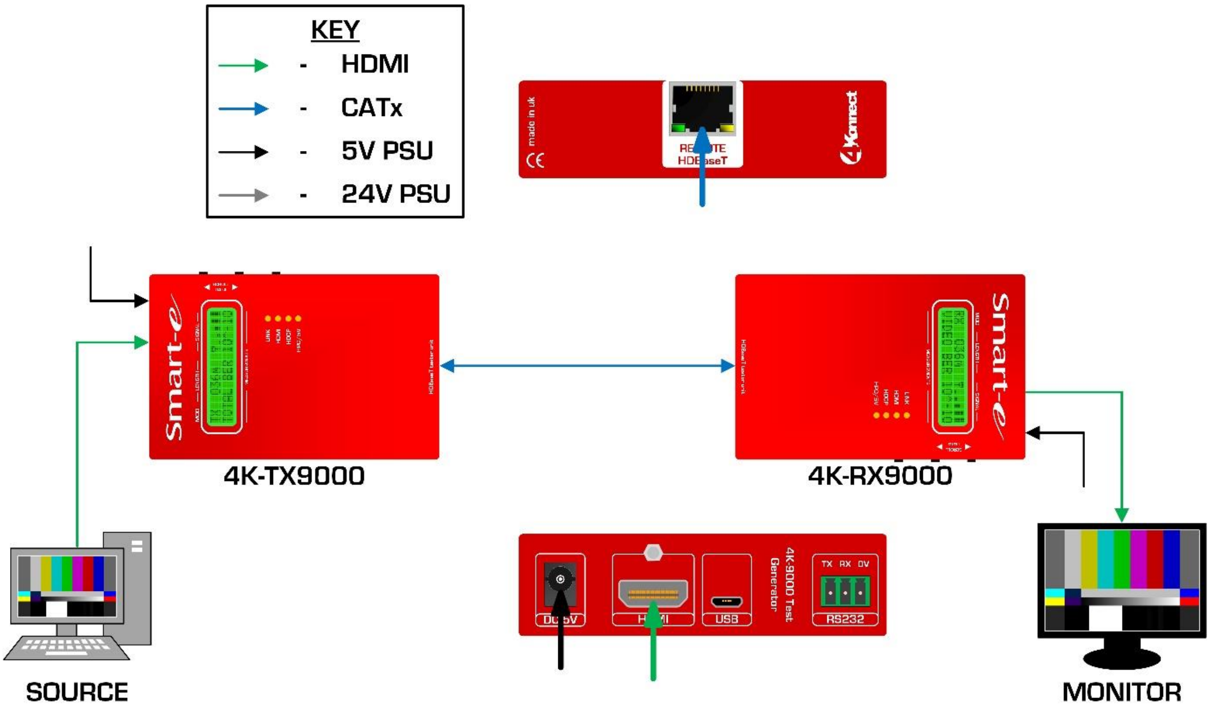
9.2 4K-RX9000 WITH HDBASET TRANSMITTER



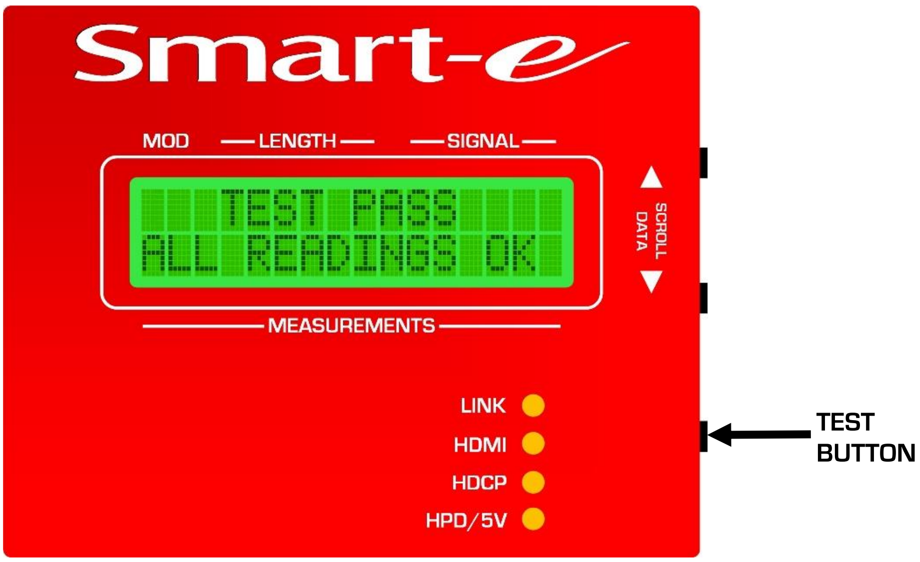
1. Test CATx cable for continuity using a network cable tester
2. Connect HDMI cable between transmitter and source
3. Connect power supply to HDBaseT transmitter, then attach power supply to mains feed
4. Connect CATx cable to RJ45 HDBaseT output on HDBaseT transmitter
5. Connect HDMI cable between 4K-RX9000 and monitor
6. Connect CATx cable to RJ45 HDBaseT input on 4K-RX9000
7. Connect 5V power supply to 4K-RX9000, then attach power supply to mains outlet
8. If link LED is illuminated press and hold the test button on 4K-RX9000 to perform quick test



9.3 4K-TX9000 AND 4K-RX9000

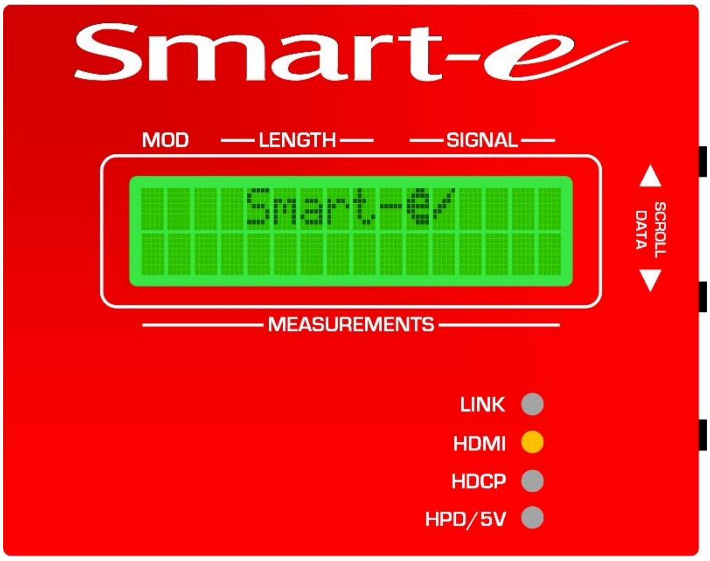


1. Test CATx cable for continuity using a network cable tester
2. Connect HDMI cable between 4K-TX9000 and source
3. Connect 5V power supply to 4K-TX9000, then attach power supply to mains outlet
4. Connect CATx cable to RJ45 HDBaseT output on 4K-TX9000
5. Connect HDMI cable between 4K-RX9000 and monitor
6. Connect CATx cable to RJ45 HDBaseT input on 4K-RX9000
7. Connect 5V power supply to 4K-RX9000, then attach power supply to mains outlet
8. If link LED is illuminated press and hold the test button on 4K-RX9000 to perform quick test

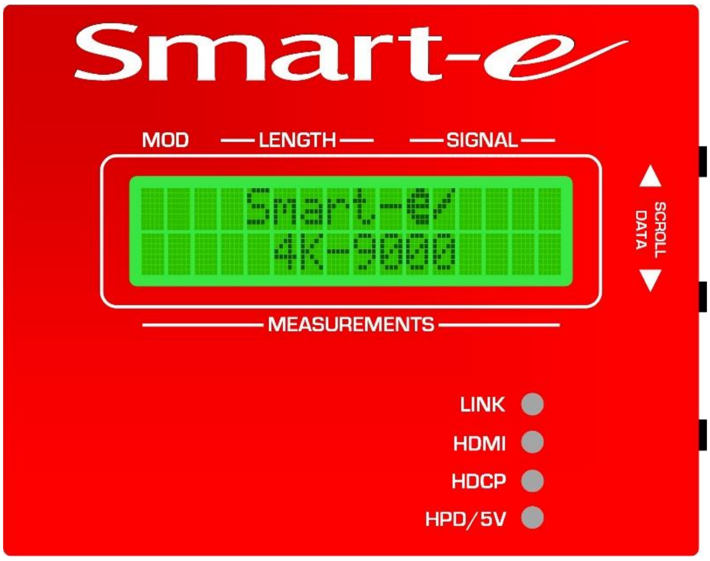


10 STARTUP SEQUENCE

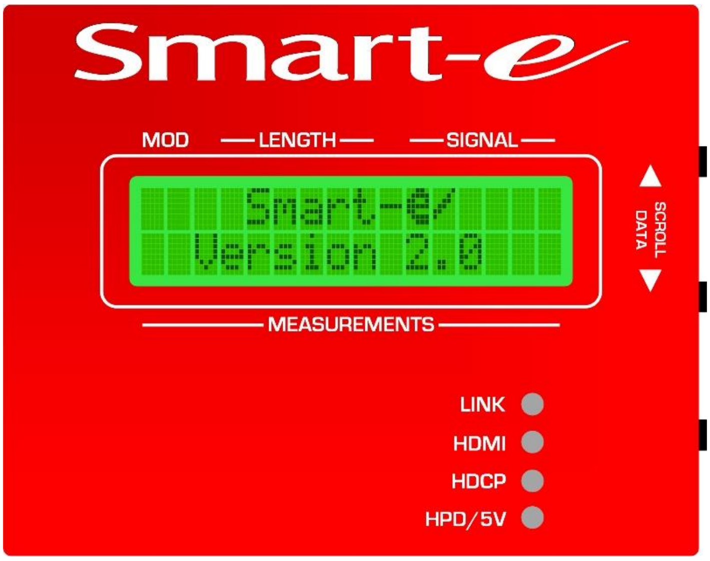
1. When power is applied to a 4K-9000 the HDMI LED will blink briefly, and the Smart-e logo will appear on the LCD screen



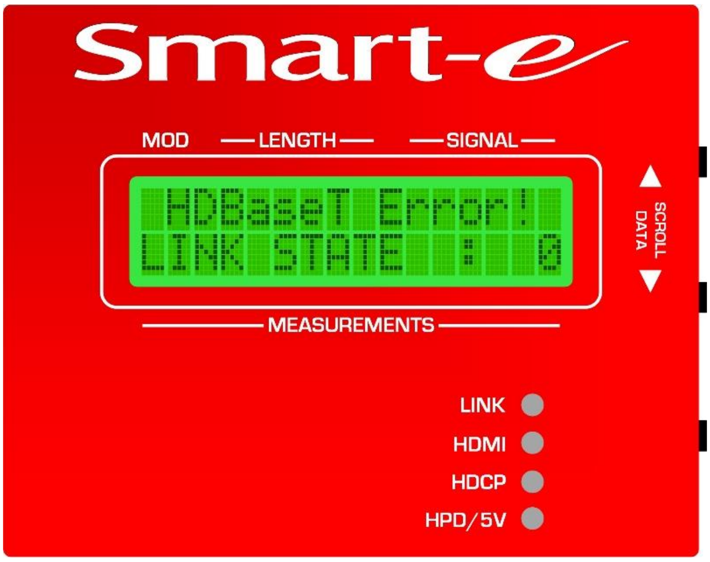
2. The LCD will then update to show 4K-9000 product range logo also on LCD screen



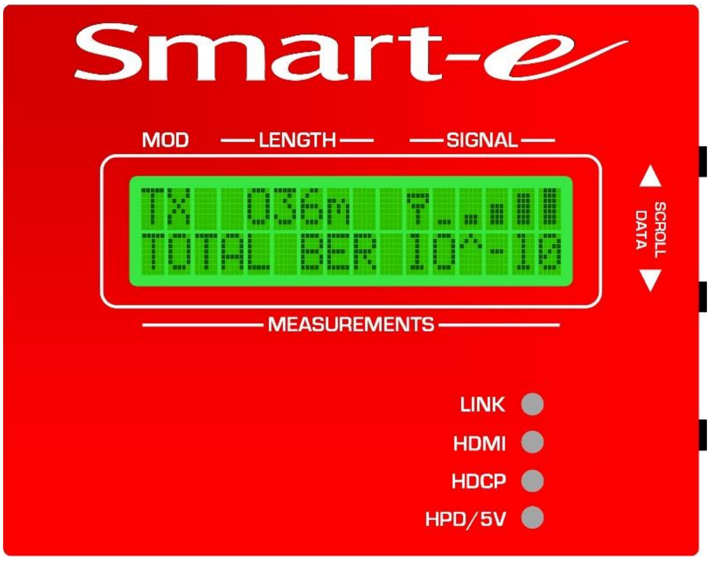
3. LCD screen will then update to show the firmware version of the 4K-9000 unit



4. After a short period, LCD will update again to show the HDBaseT error screen, this is the screen shown by the 4K-9000 when no HDBaseT link is present. It shows by default very briefly whilst background actions are performed by the processor



5. The 4K-9000 will then update to show the current state of the HDBaseT system to which it is connected. If the screen remains as it was in step 4 above it indicates an error in the system with either the HDBaseT hardware or the CATx cable



The first indication as to the model variant of 4K-9000 is only shown on the LCD at this point, to aid in the identification of the unit a serial number is attached on the underside

11 INFO PAGES GUIDE

Once a 4K-9000 has booted the measured values are shown on the lower line of the LCD, the up and down scroll buttons on the side of a 4K-9000 unit can be used to navigate between these measurements. The table below shows the relevant pages and what information is displayed on the TX and RX versions of the 9000.

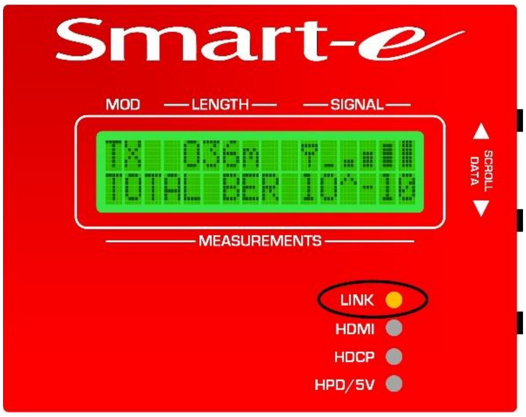
Page Number	Model			
	TX	**Description**	**RX**	**Description**
1	Total BER	Indicates the initial signal strength Range: 10^-10 - 10^-0 Best: 10^-10, Worst: 10^-0	Video BER	Measure of the video bit error rate after transmission through the CATx cable Range: 10^-10 - 10^-0 Best: 10^-10, Worst: 10^-0
2	Remote unit firmware version date	Gives the date of the remote HDBaseT receivers Valens firmware in form dd/mm/yyyy	Audio BER	Measure of the audio bit error rate after transmission through the CATx cable Range: 10^-10 - 10^-0 Best: 10^-10, Worst: 10^-0
3	Local unit firmware version date	Gives the date of the local 4K-TX9000 Valens firmware in form dd/mm/yyyy	Blank BER	Measure of the blank bit error rate after transmission through the CATx cable Range: 10^-10 - 10^-0 Best: 10^-10, Worst: 10^-0
4	HPD/5V status	Shows the status of the hot-plug detect and 5V lines at each end of the HDBaseT transmission. A tick indicates it is present a cross indicates it is missing	Control BER	Measure of the control bit error rate after transmission through the CATx cable Range: 10^-10 - 10^-0 Best: 10^-10, Worst: 10^-0
5	Local unit operation mode	Gives the operation mode of the local 4K-TX9000 unit FULL: HDBaseT mode LONG: Long reach mode	Remote unit firmware version date	Gives the date of the remote HDBaseT transmitters Valens firmware in form dd/mm/yyyy
6	Remote unit operation mode	Gives the operation mode of the remote HDBaseT receiver FULL: HDBaseT mode LONG: Long reach mode	Local unit firmware version date	Gives the date of the local 4K-RX9000 Valens firmware in form dd/mm/yyyy
7	Mean average error channel A	Secondary Qaulity indicator, a fractional value expressed as a negative dB value for pair 1 of CATx cable. More negative is better, e.g. -18dB is better than -17dB	HPD/5V status	Shows the status of the hot-plug detect and 5V lines at each end of the HDBaseT transmission. A tick indicates it is present a cross indicates it is missing
8	Mean average error channel B	Secondary Qaulity indicator, a fractional value expressed as a negative dB value for pair 2 of CATx cable. More negative is better, e.g. -18dB is better than -17dB	Local unit operation mode	Gives the operation mode of the local 4K-RX9000 unit FULL: HDBaseT mode LONG: Long reach mode
9	Mean average error channel C	Secondary Qaulity indicator, a fractional value expressed as a negative dB value for pair 3 of CATx cable. More negative is better, e.g. -18dB is better than -17dB	Remote unit operation mode	Gives the operation mode of the remote HDBaseT transmitter FULL: HDBaseT mode LONG: Long reach mode
10	Mean average error channel D	Secondary Qaulity indicator, a fractional value expressed as a negative dB value for pair 4 of CATx cable. More negative is better, e.g. -18dB is better than -17dB	Mean squared error channel A	Secondary Qaulity indicator, a fractional value expressed as a negative dB value for pair 1 of CATx cable. More negative is better, e.g. -18dB is better than -17dB
11	TMDS clock speed	Measurement in MHz of the TMDS clock for HDMI data throughput	Mean squared error channel B	Secondary Qaulity indicator, a fractional value expressed as a negative dB value for pair 2 of CATx cable. More negative is better, e.g. -18dB is better than -17dB
12	N/A		Mean squared error channel C	Secondary Qaulity indicator, a fractional value expressed as a negative dB value for pair 3 of CATx cable. More negative is better, e.g. -18dB is better than -17dB
13	N/A		Mean squared error channel D	Secondary Qaulity indicator, a fractional value expressed as a negative dB value for pair 4 of CATx cable. More negative is better, e.g. -18dB is better than -17dB
14	N/A		Max error channel A	A relative measure as to the size of error induced in pair 1 of CATx cable Range: 0-255 Best: 0, Worst: 255
15	N/A		Max error channel B	A relative measure as to the size of error induced in pair 2 of CATx cable Range: 0-255 Best: 0, Worst: 255
16	N/A		Max error channel C	A relative measure as to the size of error induced in pair 3 of CATx cable Range: 0-255 Best: 0, Worst: 255
17	N/A		Max error channel D	A relative measure as to the size of error induced in pair 4 of CATx cable Range: 0-255 Best: 0, Worst: 255
18	N/A		TMDS clock speed	Measurement in MHz of the TMDS clock for HDMI data throughput

12 INTERPRETTING LED STATUS

Four LEDs are presented on the front of the 4K-9000 on both TX and RX variants. This section of the manual describes how to interpret them and how they aid in showing status of the HDBaseT transmission.

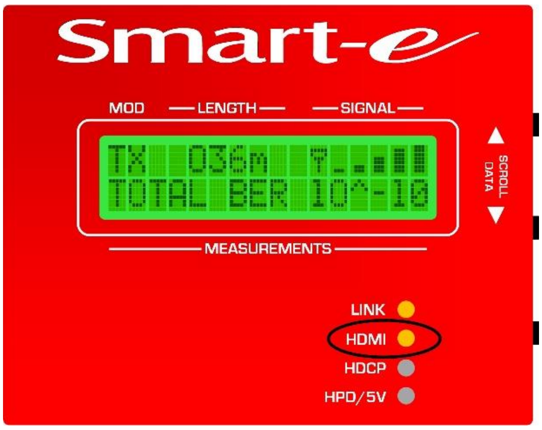
12.1 LINK LED

The HDBaseT link is a status communicated between the TX and RX Valens chips. Embedded within the HDBaseT protocol, it says that one chip is talking to another. When the link is present the 4K-9000 will illuminate the LINK LED on the front of the unit. It does not indicate that the link is of good quality just that the chips are able to communicate. The LINK does not depend on operation mode, it will display if the units are in HDBaseT mode or Long Reach mode. If the LINK LED is not lit it suggests a problem with the CATx cable, either in length or build quality, or the problem may lie with either the transmit or receive HDBaseT hardware.



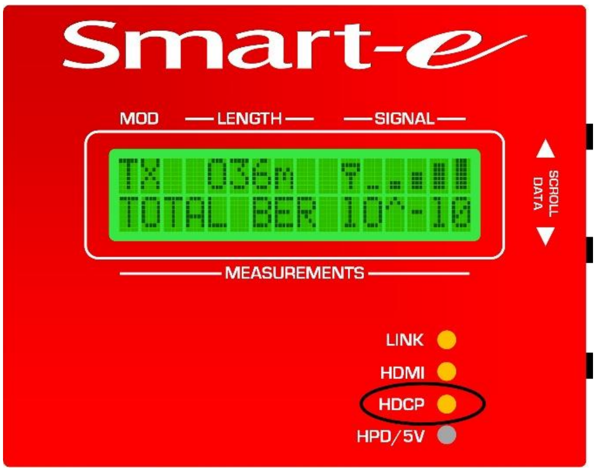
12.2 HDMI LED

The HDMI LED indicates the status of HDMI signal throughput. For the LED to be illuminated HDMI data must be transmitting completely from source to screen. If the LINK LED is illuminated but the HDMI LED is not it suggests that there is a problem with the HDMI cabling at either end of the system. It could also be that the screen is not operational or on the wrong video input, on the other hand the source may not be generating an output. The final reason, although unlikely as the LINK is lit, could be due to the quality of the CATx cable link.



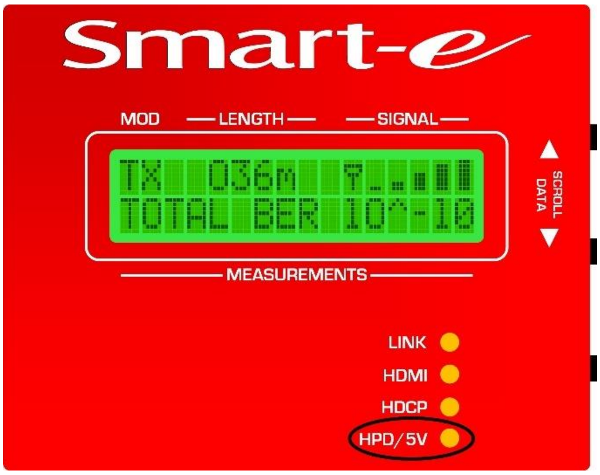
12.3 HDCP LED

The HDCP LED indicates the HDCP status of video being transmitted. This LED is only relevant when the HDMI LED is illuminated, if no HDMI video is present there can be no HDCP. When illuminated the HDCP LED indicates the content being transmitted has High-bandwidth Digital Copy Protection (HDCP), if not lit then the content is non-HDCP. The system can give no indication as to the version of HDCP either 1.4 or 2.2 this would need to be determined from the source and screen. Later in this manual HDCP is discussed in more detail.



12.4 HOT-PLUG DETECT (HPD) / 5V LED

The HPD/5V LED shows the status of the 5V line from the source to the transmitter unit and the status of the HPD line from the screen to the receiver unit. These variables are discussed in more detail later in this manual. The LED will only be illuminated if both the 5V and HPD are present, if not lit it means either one of them is missing or both are missing. This would point to an error with the HDMI cables being used, a problem with the source or an issue with the screen.



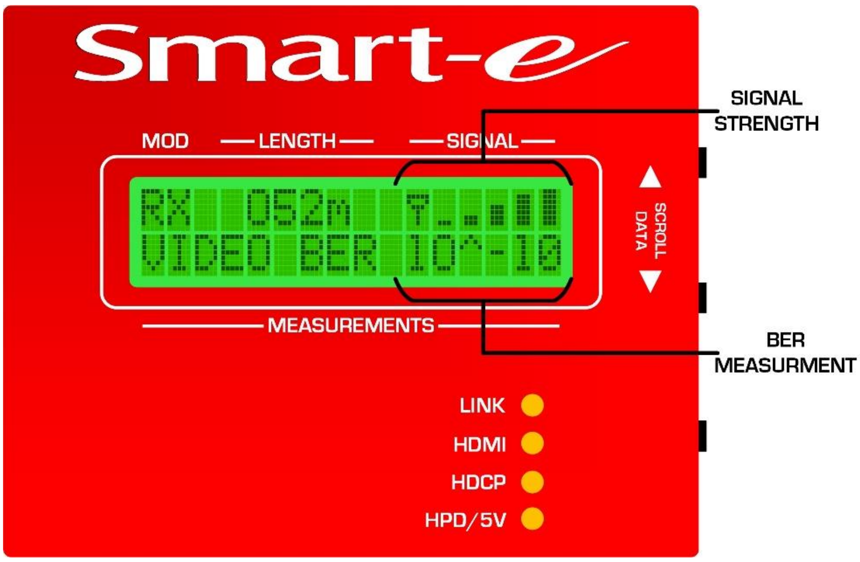
13 INTERPRETTING BIT ERROR RATES

Bit error rate readings are available on both the TX and RX variants of the 4K-9000, one on the 4K-TX9000 the total BER and four on the 4K-RX9000, video BER, audio BER, blank BER and control BER.

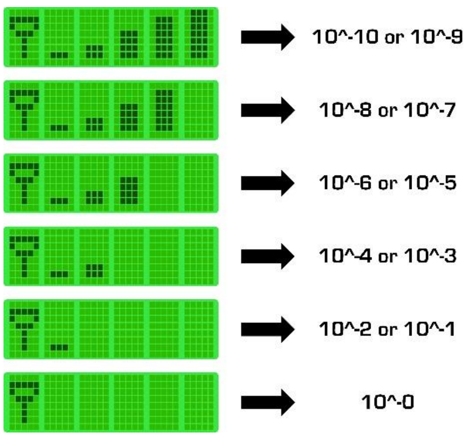
The bit error rate of digital communications is calculated using cyclic redundancy checks (CRC). HDBaseT uses a variant of CRC32 commonly employed in Ethernet communications. It works by adding bits to a section of data at the source and checking this data at the receiving end. Using these bits, the data can be checked for errors and where minor errors are encountered the code is used to correct the bits received incorrectly.

In the case of HDBaseT transmission the CRC code is added to section of data at the transmitter end of the system, these CRC codes are then checked at the receiver end, errors incurred are then output as the video, audio, blank and control BERs at the receiver end. These four different readings are obtained by reading the individual streams within the originally encoded TMDS signal.

The video BER is the most important reading, the vast majority of the data being transmitted is video data. If errors are present in the video data errors are likely to be seen as interference on the screen. The perfect reading shown by the 4K-9000 is 10^-10, any value more than this (10^-10 is a smaller number than 10^-9) and errors are being encountered and are of a measurable level. The video BER is the reading on the 4K-RX9000 used to give the relative signal quality seen in the top right of the LCD display.

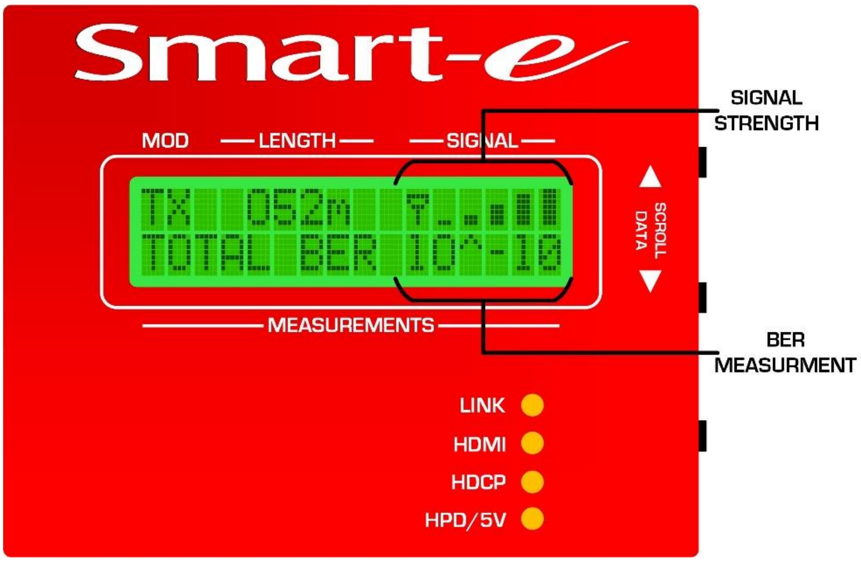


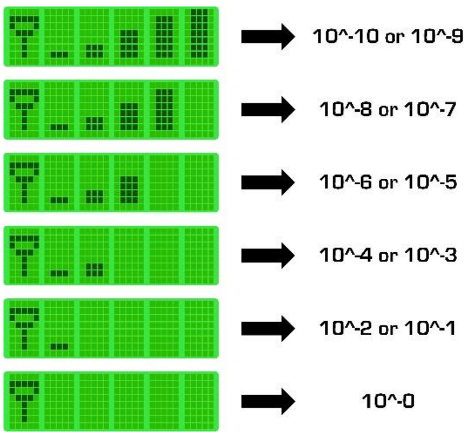
This quick signal strength reference is placed here so whilst observing any other reading the user has the quick ability to see the video BER state at a glance, this reading is updated in real time, approximately every 3 seconds. Below is a guide to the signal strength bars and the video BERs they indicate.



The audio, control and blank BERs can be read on the 4K-RX9000 by navigating to them via the scroll buttons, the page numbers for this info is given in section 11 of this manual. These 3 readings are not as important to overall system performance and would not be noticeable as interference on the display. If any one of these values differs significantly from the value as shown by the signal strength indication in the top right of the LCD, it is likely to be due to a HDBaseT related hardware issue which can be verified with use of each TX and RX 4K-9000 individually and then in tandem to isolate the faulty piece of hardware.

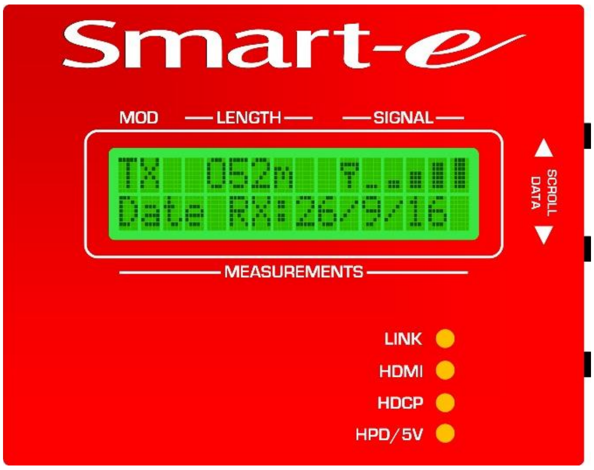
As mentioned the only BER reading for the 4K-TX9000 is the total BER. This reading should always read 10^-10 or very close to, if it is not it would suggest an issue with the CATx cable. The signal strength indicator on the 4K-TX9000 is linked to the total BER reading, this means whilst viewing any other reading on the 4K-TX9000 the user can quickly check the total BER at a glance.





14 FIRMWARE VERSION DATES

The firmware version dates are a very useful measure when using the TX or RX variant of the 4K-9000 in conjunction with another TX or RX HDBaseT unit. The date relates to the Valens firmware, Valens manufacture the chipset which encodes and decodes the HDBaseT signal across the CATx cable. Valens periodically update this firmware when issues are identified by manufacturers or installers. Units with older firmware could have these already identified issues. If a firmware from Q1 of 2016 or earlier is observed and issues with the HDMI transmission is seen but no obvious reason is visible from the measures on the 4K-9000s, this would suggest a firmware issue. The TX or RX variants of the 4K-9000 can read the remote units firmware version or their own local firmware version. The units firmware being displayed is denoted by the presence of an RX or TX in the measurement section of the LCD display. **NOTE: This firmware is not that which runs the processor of the 4K-9000 unit, the version of firmware for the 4K-9000 unit is shown during the start-up sequence, refer to section 10 of this manual for more info.**



15 HDBASET OPERATION MODES

The 4K-9000 in both TX and RX variants can act in two different operation modes, HDBaseT and Long Reach Mode. Each variant of the 4K-9000 can show the operation modes of both the local and remote HDBaseT units. When the correct page is navigated to (see section 11 of this manual), the measurement section of the LCD will show OP MODE and then either (L) for the local unit or (R) for the remote unit. After the colon, there will then be the word either FULL for HDBaseT mode or LONG for Long Reach Mode.

The 4K-9000 utilises the Valens VS100 chipset, this chip can operate in either LONG or FULL modes. There is another commonly seen chipset, the VS010, HDBaseT products incorporating these devices are often referred to as HDBaseT Lite products, they **cannot** operate in LONG mode. When a HDBaseT Lite product is connected to a unit in Long Reach Mode, it will be impossible for the units to establish a HDBaseT link, if any link LED is present on either of the products it will be seen to flash constantly.

HDBaseT mode when implemented with the VS100 chipset enables the 5-play feature set as outlined by the HDBaseT standard. This incorporates the transmission of video, audio, control, power and ethernet. This is the most commonly utilised operation mode, the majority of products purchased from a manufacturer will default to this operation mode. The hardware design within is often left in an automatic mode selection state, if a transmitter and receiver both implementing automatic mode selection are connected they will both default to HDBaseT operation mode. HDBaseT mode enables transmission up to 100m of 1080p@60Hz 48bpp video content.

Long reach mode reduces the available bandwidth enabling the transmission of 1080p @60Hz 24bpp video content at up to 150m. If either a transmitter or receiver is set to long reach mode and the other unit is set to automatic operation mode both units will operate in long reach mode. Due to the reduced bandwidth, long reach mode is often an ideal solution for use in noisy environments where interference is causing large errors on the transmission. As mentioned above long reach mode is only compatible with the VS100 chipset and will not operate with the VS010 chipset.

There are three other operation modes possible, LPPF1, LPPF2 and Ethernet Fall-back. These modes are not compatible with the 4K-9000 and will show as no HDBaseT link on the LCD display but they are worth mentioning in this section. LPPF1 and 2 are low power modes, a manufacturer may wish to use these states as a kind of standby function but should wake when attached to another HDBaseT unit. Ethernet fall-back mode allows only the transmission of ethernet across the CATx cable.

The table below shows the features each operation mode is capable of.

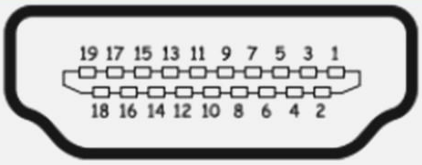
Mode	Max Video	RS232	Baud-rate	Infra-red	Audio	10BaseT Ethernet	100BaseT Ethernet	Distance
HDBaseT	1080p@60Hz 48bpp	✓	115200	✓	✓	✓	✓	100m
Long Reach	1080p@60Hz 24bpp	✓	115200	✓	✓	✓	✓	150m
LPPF1	None	✓	9600	✓	✓	×	×	150m
LPPF2	None	✓	9600	✓	✓	✓	✓	150m
Ethernet Fall-back	None	×	N/A	×	×	✓	✓	150m

This table shows the operation mode that is selected dependant on the operation mode of transmitter and receiver units.

		RX Operation mode				
		HDBaseT	**Long Reach**	**LPPF1**	**LPPF2**	**Auto**
TX Operation Mode	**HDBaseT**	HDBaseT	Long Reach	LPPF1	LPPF2	HDBaseT
	Long Reach	Long Reach	Long Reach	LPPF1	LPPF2	Long Reach
	LPPF1	LPPF1	LPPF1	LPPF1	LPPF1	LPPF1
	LPPF2	LPPF2	LPPF2	LPPF1	LPPF2	LPPF2
	Auto	HDBaseT	Long Reach	LPPF1	LPPF2	HDBaseT

16 HOT PLUG DETECT

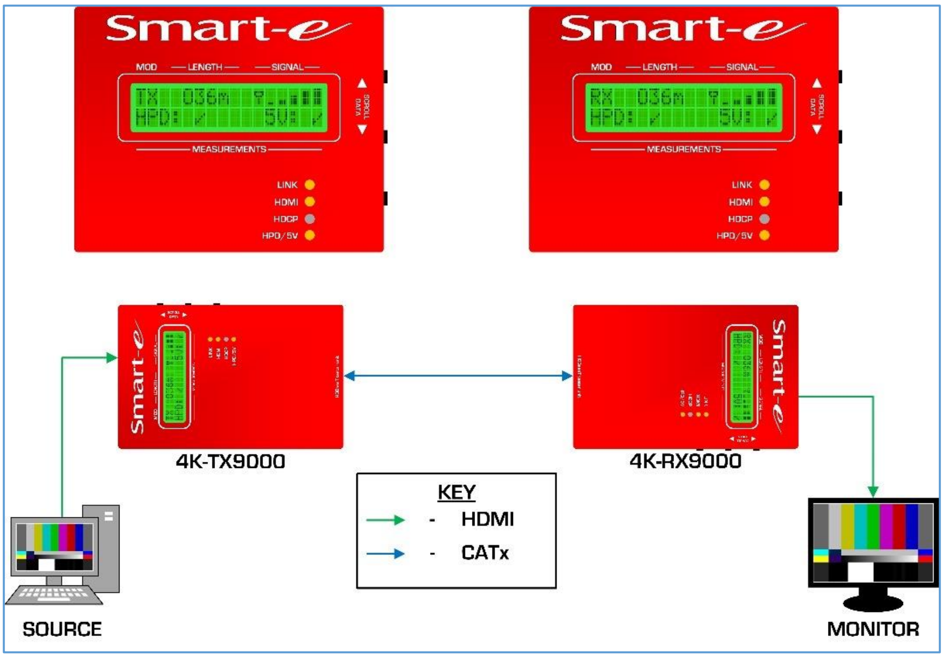
Within the HDMI specification is the hot plug detect mechanism. This is the way by which a screen can tell when it has been connected to a source. Two pins, 18 and 19, on any HDMI connecter are concerned with this function.

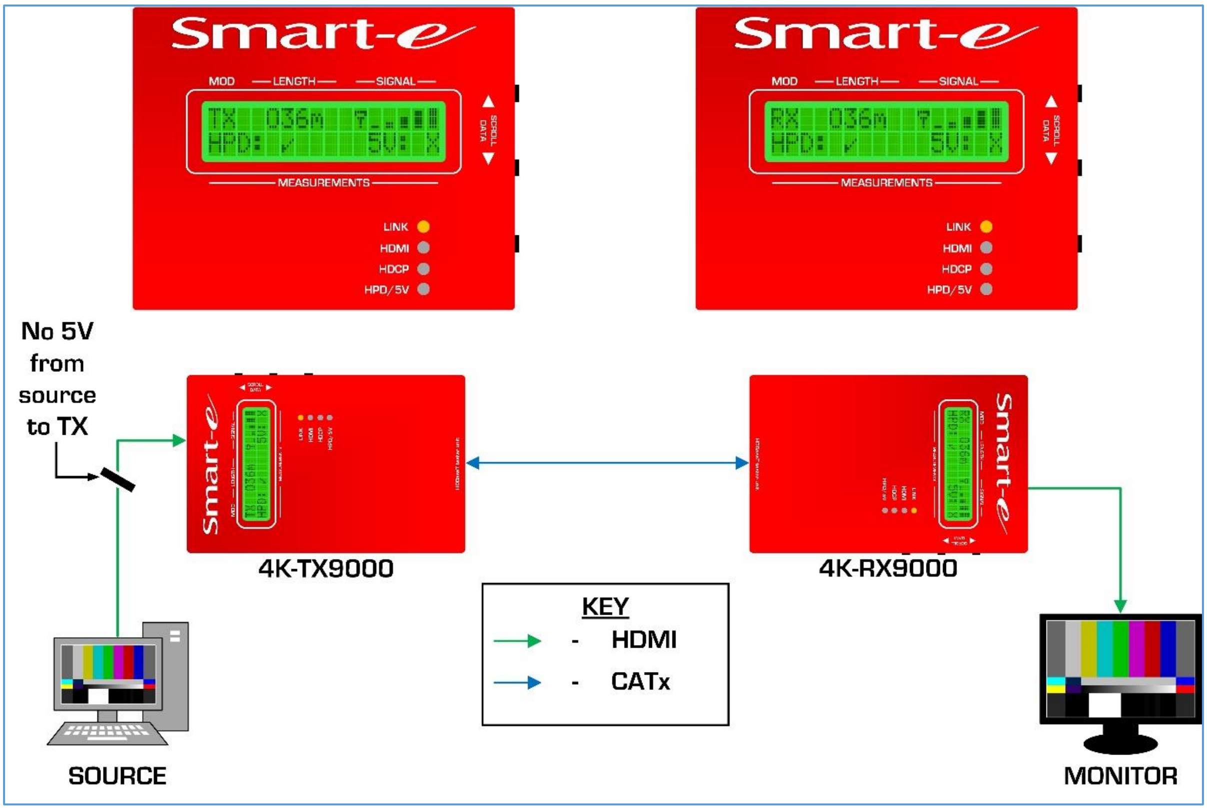


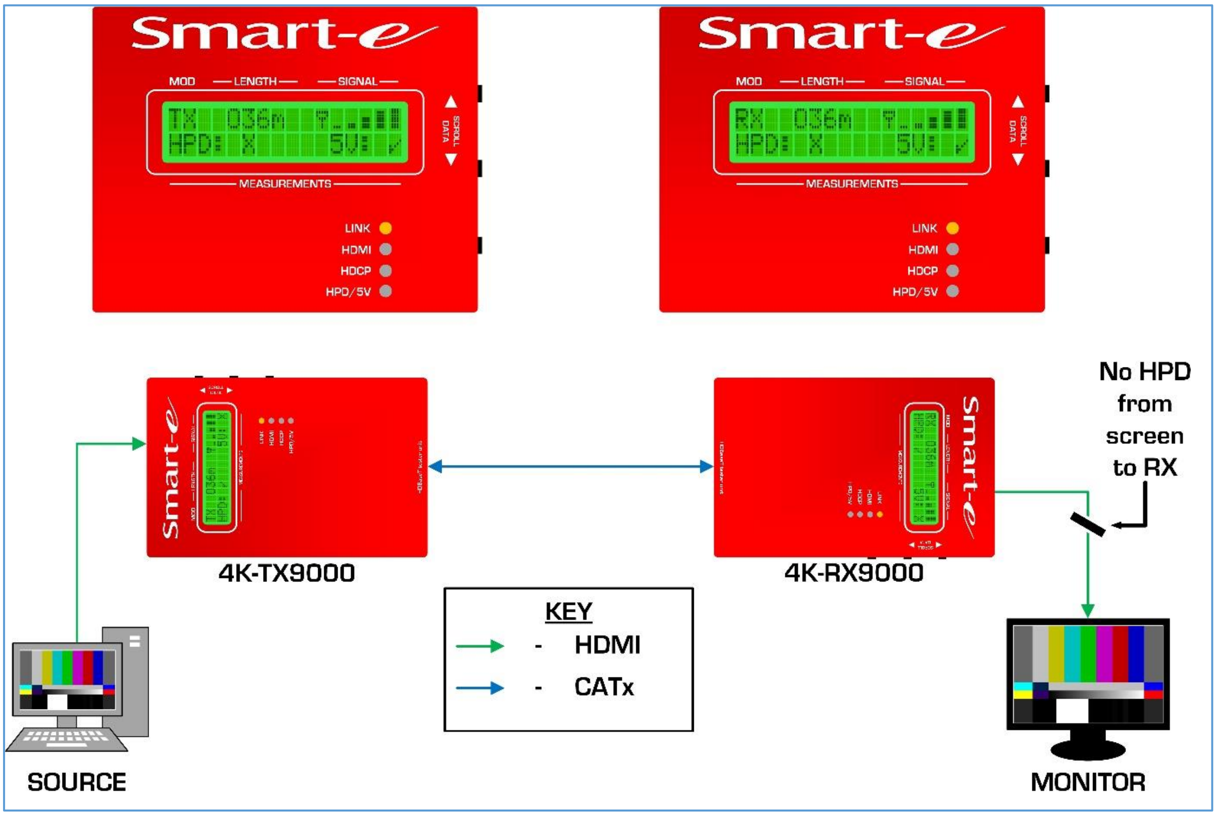
Pin#	Signal	Pin#	Signal
1	TMDS data 2+	11	TMDS clock shield
2	TMDS data 2 shield	12	TMDS clock-
3	TMDS data 2-	13	CEC
4	TMDS data 1+	14	No connected
5	TMDS data 1 shield	15	DDC clock
6	TMDS data 1-	16	DDC data
7	TMDS data 0+	17	Ground
8	TMDS data 0 shield	18	+5V power
9	TMDS data 0-	19	Hot plug detect
10	TMDS clock+		

Pin 18 is the +5V line, this carries a +5V signal generated by a HDMI source. This signal is used to power a memory chip (EEPROM) within the screen it is connected to holding the EDID information (see EDID section of this manual for further information). When the +5V signal is received by the screen it will output a +5V signal on the hot plug detect line, this is picked up by the source and it then knows a screen is attached. A source does not have to be outputting content for a +5V signal to be generated it simply has to be powered, even when in standby a +5V will be generated but this does vary by device. In the same respect a screen does not have to be turned on or set to the correct input to generate the hot plug detect signal, it is also convention to be able to generate a hot plug detect when in standby as the received signal will usually be required to wake the screen.

For HDBaseT to operate it must handle the hot plug detect, which it does by being able to sense the +5V line and hot plug detect line and communicate their states between a transmit and receive device. The 4K-9000 can show at either the TX or RX end, which of the two are present or not. The below diagrams show how this is displayed and where the problem may lay dependant on which, if any, variable is missing.



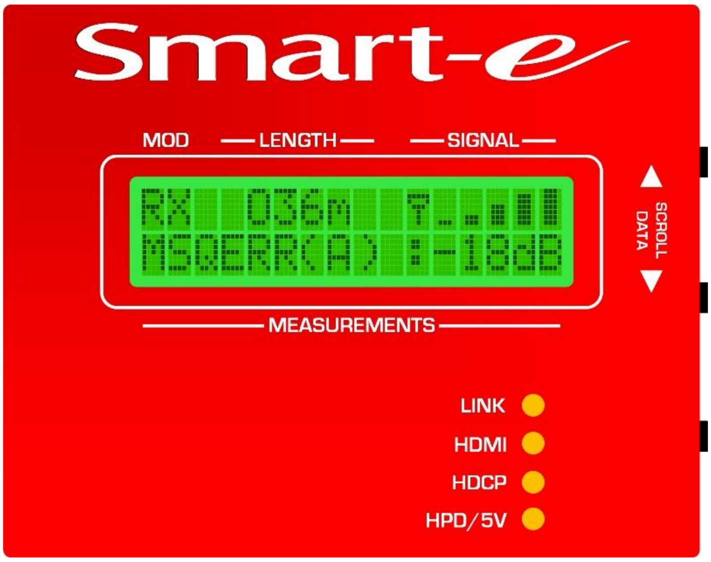

Smart-e
MOD
LENGTH
SIGNAL
TX 036m
HPD: ✓ 5V: X
MEASUREMENTS
SCROLL DATA
LINK
HDMI
HDCP
HPD/5V
Smart-e
RX 036m
HPD: ✓ 5V: X
No 5V from source to TX
4K-TX9000
4K-RX9000
KEY
- HDMI
- CATx
SOURCE
MONITOR


Smart-e
MOD
LENGTH
SIGNAL
TX 036m
HPD: X 5V: ✓
MEASUREMENTS
SCROLL DATA
LINK
HDMI
HDCP
HPD/5V
Smart-e
RX 036m
HPD: X 5V: ✓
No HPD from screen to RX
4K-TX9000
4K-RX9000
KEY
- HDMI
- CATx
SOURCE
MONITOR

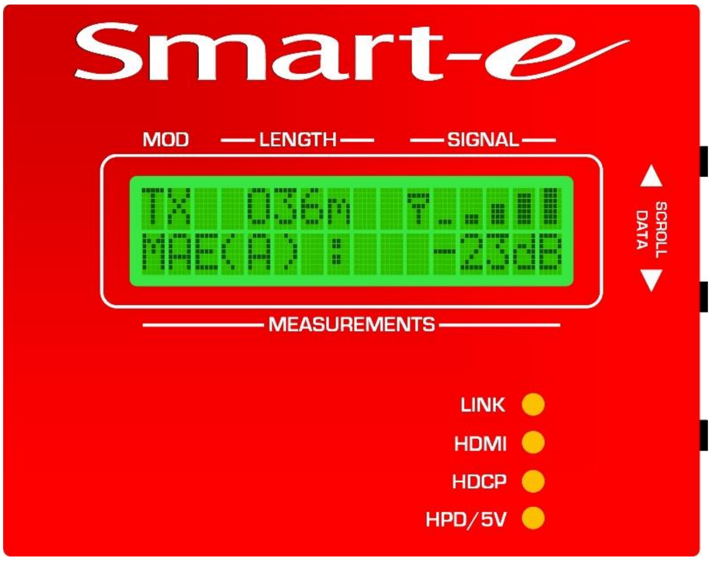
17 SECONDARY QUALITY INDICATORS

Both the RX and TX variants of the 4K-9000 have readings looking at signal errors within each pair of the CATx cable. This can help an installer to identify if problems being encountered are due to a specific cabling/termination error.

The 4K-RX9000, the secondary quality indicator is referred to as the mean squared error or as it is displayed on the LCD screen MSQERR. There is then a letter between A and D for the four communication channels. The readings seen on all four channels should be around -17db ± 2dB for a good quality signal.



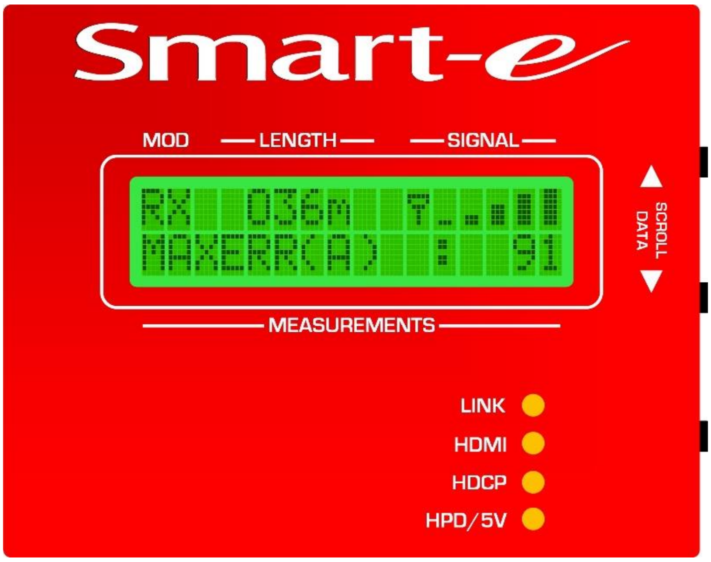
The 4K-TX9000, the secondary quality indicator is referred to as the mean average error or as it is displayed on the LCD screen MAE. There is then a letter between A and D for the four communication channels. The readings seen on all four channels should be around -22db ± 2dB for a good quality signal.



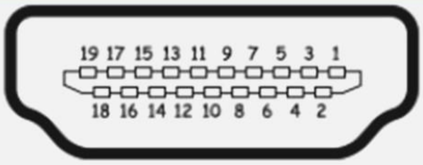
18 MAX ERROR READINGS

Another statistical reading are the maximum error readings, these are applicable only to the 4K-RX9000. These readings are displayed on the LCD in the form MAXERR, then follows a letter between A and D representing the four cable pairs. The maximum error is a decimal number between 0 and 255. It is a count of the maximum number of bit errors out of all the packets sampled since the 4K-RX9000 has been running. As explained in section 6.1 of this manual, it is possible to count and calculate the exact number of errors within a packet of data. Therefore, the lower the values of the max error readings the better. All max error readings should be below 100, the maximum value of 255 is the maximum number of errors it is possible to read, the value could actually be more than 255 but if this value is read and is present on and of the four channels of the 4K-RX9000 it suggests a major source of interference and most likely a video drop out has been encountered at some point. If one or more channels but not all four have a raised number of errors, it points towards a possible issue in the CATx cable. If all four readings are raised, it suggests excessive noise is being encountered and the measures outlined in section 6 of this manual should be referred to, ensure all cabling advice and installation best practices are being followed to reduce noise ingress in to the CATx cabling.

NOTE: It has been seen during testing that when a HDMI cable is removed from either a transmit or receive HDBaseT device, it can cause the max error readings to climb until eventually all channels read 255. This is likely to be a timing bug within the CRC structure of the Valens device. If this issue is encountered it is advised to remove the power supply from the receiver unit and repower. Allow the system to settle again with all video and CATx cables attached and this will then produce a reliable reading for the max errors on all channels.



19 TMDS DATA, CLOCK & COLOUR DEPTH



Pin#	Signal	Pin#	Signal
1	TMDS data 2+	11	TMDS clock shield
2	TMDS data 2 shield	12	TMDS clock-
3	TMDS data 2-	13	CEC
4	TMDS data 1+	14	No connected
5	TMDS data 1 shield	15	DDC clock
6	TMDS data 1-	16	DDC data
7	TMDS data 0+	17	Ground
8	TMDS data 0 shield	18	+5V power
9	TMDS data 0-	19	Hot plug detect
10	TMDS clock+		

To understand the significance of the TMDS clock and how it can tell you a lot about the signal being transmitted, first we must refer to the HDMI connector pin out as above. Pins 1-9 carry the three TMDS data pairs, these cables are concerned with the transmission of video and audio information from source to screen. Pins 10-12 are the TMDS clock pins, these pins provide the clock by which the data transmitted on pins 1-9 is timed. In the case of HDMI 10 bits of data are transmitted per TMDS clock cycle. HDMI specification 1.4b to which the 4K-9000 is compliant, supports a maximum clock rate of 340MHz or 340 million clock ticks per second. We can from this show the maximum bandwidth throughput possible.

$$\boldsymbol{10\ bits\ x\ 340MHz = 3{,}400{,}000{,}000\ bits\ per\ second\ or\ 3.4Gbps\ per\ TMDS\ pair}$$

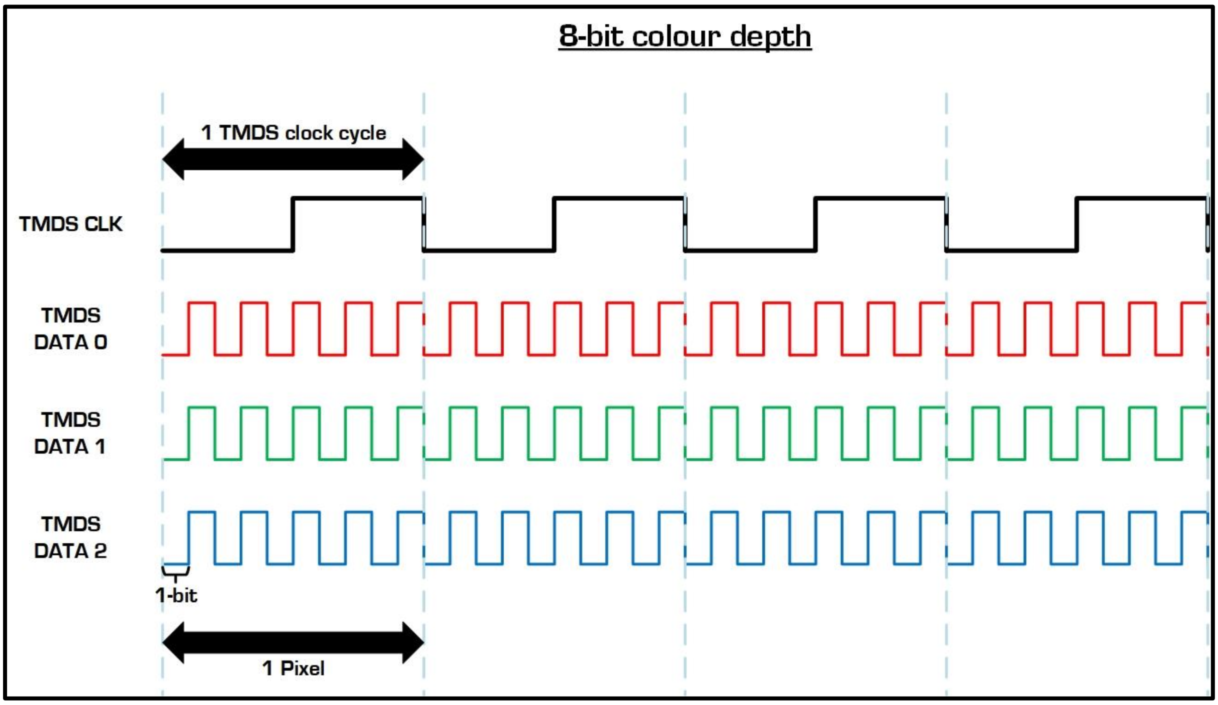
$$\boldsymbol{3.4Gbps\ x\ 3\ TMDS\ Data\ pairs = 10.2GBps\ total\ throughput}$$

The clock is generated by the HDMI compliant source dependant on the amount of data being output, the higher the resolution and colour depth, otherwise referred to as bits per pixel (bpp), the more bits need to be transmitted and hence the TMDS clock speed must increase.

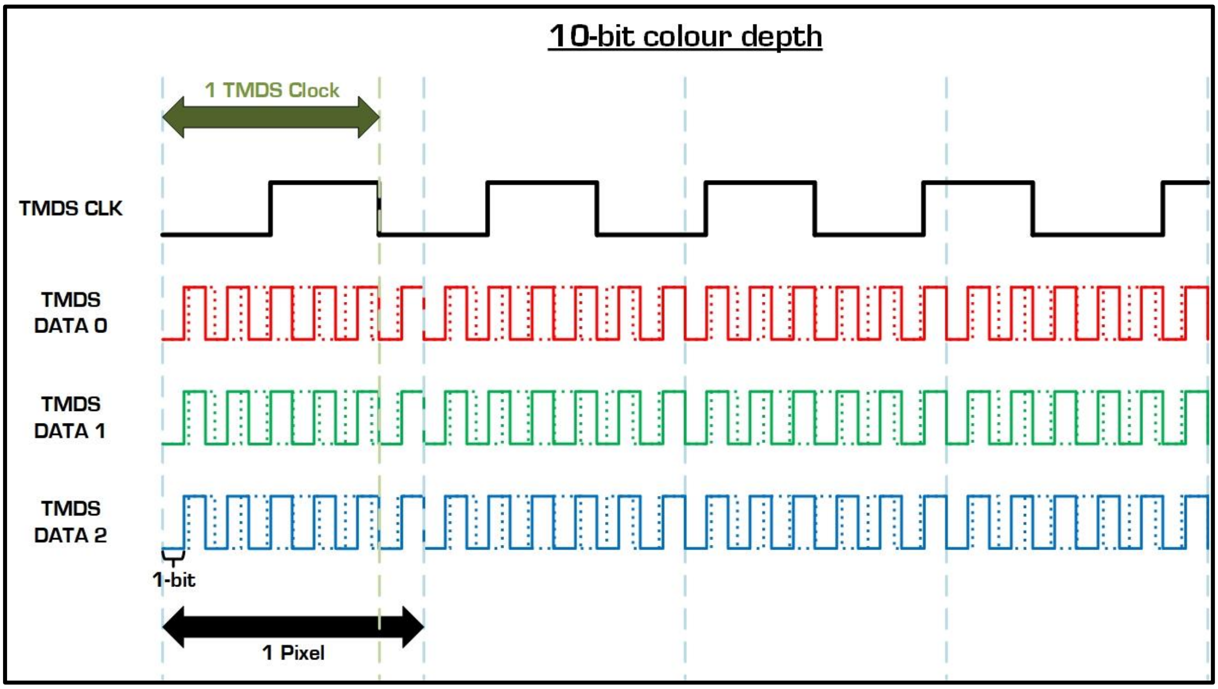
Colour depth or bits per pixel (bpp), define the number of colour information bits are transmitted per pixel of video data. To be compliant with HDMI standards, all HDMI sources and screens must support 8-bit colour depth, these 8-bits are per TMDS data channel, when a source is outputting in RGB mode these channels represent the red, green and blue video data, so in total there are 8x3 = 24-bits per pixel of colour information. Each 8-bit block of data is encoded to a 10-biy YMDS word. It is possible to send more colour information per pixel, 10, 12 and 16-bit colour modes are available for sources and monitors supporting, what is referred to as deep colour content. These modes give 30, 36 and 48-bpp respectively. Below shows the number of colours possible dependant on the colour depth.

8-bit:	**2^(8 x 3 TMDS channels)**	**=**	**2^24**	**=**	**16.8 Million**
10-bit:	**2^(10 x 3 TMDS channels)**	**=**	**2^30**	**=**	**1.07 Billion**
12-bit:	**2^(12 x 3 TMDS channels)**	**=**	**2^36**	**=**	**68.7 Billion**
16-bit:	**2^(16 x 3 TMDS channels)**	**=**	**2^48**	**=**	**281 Trillion**

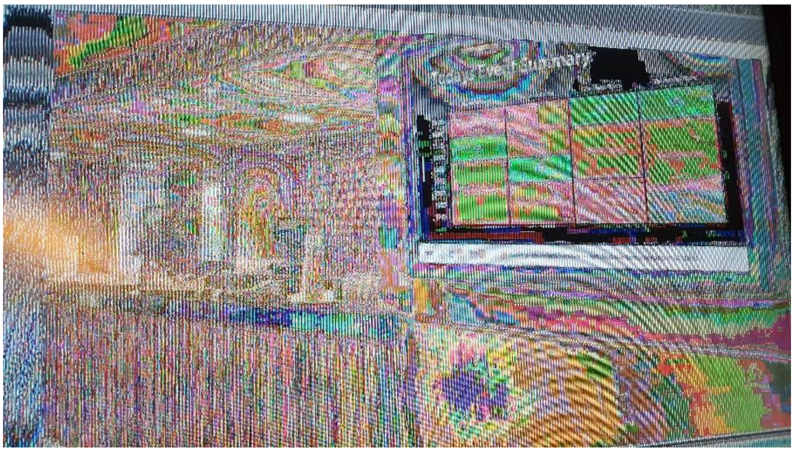
The general overview of a HDMI, TMDS signal is shown in the below example. This example is based on a HDMI output where the pixels are in RGB format, HDMI may also output pixels in YCbCr format, which is the common output for video sources such as Blu-ray players.



It can be seen above that there are 10-bits per TMDS clock cycle, the 8-bit colour data has been encoded in to a 10-bit TMDS word. Each TMDS clock cycle is equal to 1-pixel worth of information. In the below example the resolution is the same as above, but the colour depth has increased to 10-bit.



The dotted lines show the data as it was for the 8-bit example. It can be seen there are now 12-bits per pixel, but the TMDS clock has had to increase in frequency to complete one cycle every 10 TMDS data bits. A source capable of deep colour output will be able to manipulate the TMDS clock to this increased frequency, however it must be attached to a screen which is also deep colour capable. A deep colour capable screen will recognise that the TMDS clock has been increased and then be able to interpret the colour information being received correctly, mapping it to the correct pixels. If a deep colour input is applied to a non-deep colour screen you will either see no image at all or something like that shown in the example below with colours scattered randomly over the viewable area and very little eligible content. This information is conveyed from source to screen using the blanking areas of a frame, see section 21.1 of this manual for more information.



As colour depth is increased the TMDS clock must increase by a factor of the base pixel clock or the number of bits per pixel. In the 8-bit example there were 10 bits of data per pixel, in the 10-bit example there are 12 bits per pixel. The TMDS clock is therefore increased by a factor of 1.2 compared from the 8-bit to 10-bit example. The table below gives a convenient guide to the increase in TMDS clock as colour depth is increased.

Colour depth	TMDS clock factor
8-bit	1.0
10-bit	1.2
12-bit	1.4
16-bit	1.8

The 4K-9000 provides an on-screen read out approximation of the TMDS clock speed from the data sampled. This measurement is available on both the TX and RX variants.

A number of in house tests have been carried out using the 4K-9000 here at Smart-e, they involved varying resolutions, refresh rates and colour depths to ascertain the TMDS clock speed as read by the 4K-9000. These results are as shown in the table below. With reference to this table it is possible for an installer to ascertain more about the signal output from a source than would otherwise be known, a source may be defaulting to a higher colour depth than can be shown by the display and the TMDS clock will be able to show this even if the variable cannot be viewed on the source. This is a common issue with Blu-ray and signage players. **Note: The maximum TMDS clock speed read by the 4K-9000 is 255MHz, this is due to the restriction of the 8-bit registry value reported from the Valens device. For any TMDS clock speed over 255MHz an erroneous reading may be returned. Using the table below it should be possible to discern when this has occurred, if in doubt please contact Smart-e support for advice.**

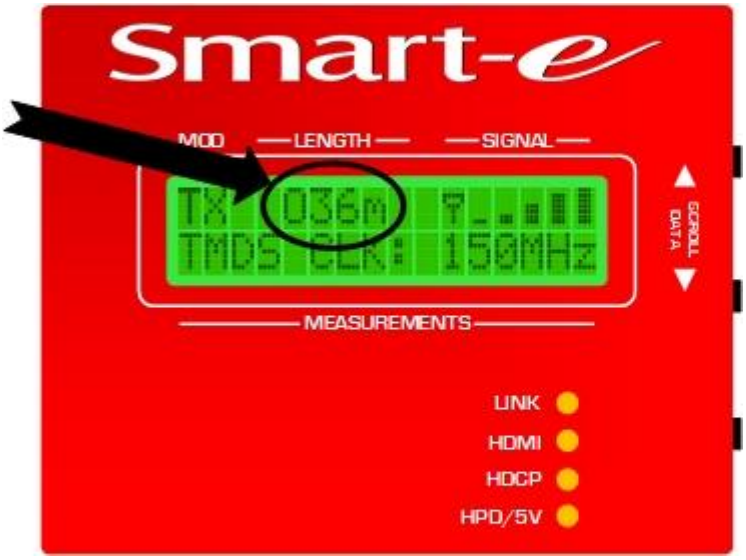
TMDS Clock Testing

All tests performed using 4K-9000s on a 90m CAT6A U/FTP cable run

Resolution	Refresh Rate (Hz)	Colour Depth	Colour Depth (BPP)	TMDS Clock (MHz)
640x480	60	8-bit	24	25
640x480	60	10-bit	30	31
640x480	60	12-bit	36	38
640x480	60	16-bit	48	51
720x480	60	8-bit	24	27
720x480	60	12-bit	36	41
720x576	50	8-bit	24	27
720x576	50	12-bit	36	41
800x600	60	8-bit	24	40
800x600	60	10-bit	30	50
800x600	60	12-bit	36	60
800x600	60	16-bit	48	81
1024x768	60	8-bit	24	66
1024x768	60	10-bit	30	82
1024x768	60	12-bit	36	99
1024x768	60	16-bit	48	132
1280x720	60	8-bit	24	75
1280x720	60	12-bit	36	113
1280x720	60	16-bit	48	150
1280x720	60	10-bit	30	94
1280x960	60	8-bit	24	109
1280x960	60	10-bit	30	137
1280x960	60	12-bit	36	164
1280x960	60	16-bit	48	219
1360x768	60	8-bit	24	86
1360x768	60	10-bit	30	108
1360x768	60	12-bit	36	130
1360x768	60	16-bit	48	173
1600x1200	60	8-bit	24	164
1600x1200	60	10-bit	30	205
1600x1200	60	12-bit	36	246
1920x1080	30	8-bit	24	75
1920x1080	30	10-bit	30	94
1920x1080	30	12-bit	36	113
1920x1080	30	16-bit	48	150
1920x1080	50	8-bit	24	150
1920x1080	50	12-bit	36	226
1920x1080	60	8-bit	24	150
1920x1080	60	10-bit	30	188
1920x1080	60	12-bit	36	226
1920x1200	60	8-bit	24	156
1920x1200	60	10-bit	30	195
1920x1200	60	12-bit	36	234

20 CABLE DISTANCE ESTIMATION

The 4K-9000, in both RX and TX variants, can give an estimation of the CATx cable which is displayed on the LCD screen. This feature can provide useful information to an installer, for instance if assessing a cable prior to installation, if the cable run is below 70 meters a more cost effective HDBaseT Lite product could be specified. On the other hand, if assessing a problem with an install, if the cable distance is found to be greater than 70m but a HDBaseT Lite product has been installed the problem is easily identified. The reading has a degree of error of approximately ±5m, for high accuracy readings of length it is advised to use a dedicated tool. For short cable runs of about 20 or 30 meters the cable reading will return a value of zero, for long cable runs values up to 110m can be read, longer cables (100m plus would only provide HDBaseT link when in Long Reach Mode) will return an error reading.



21 FURTHER CONSIDERATIONS

21.1 BANDWIDTH CALCULATION

The bandwidth required for a HDMI signal can be calculated in the following method.

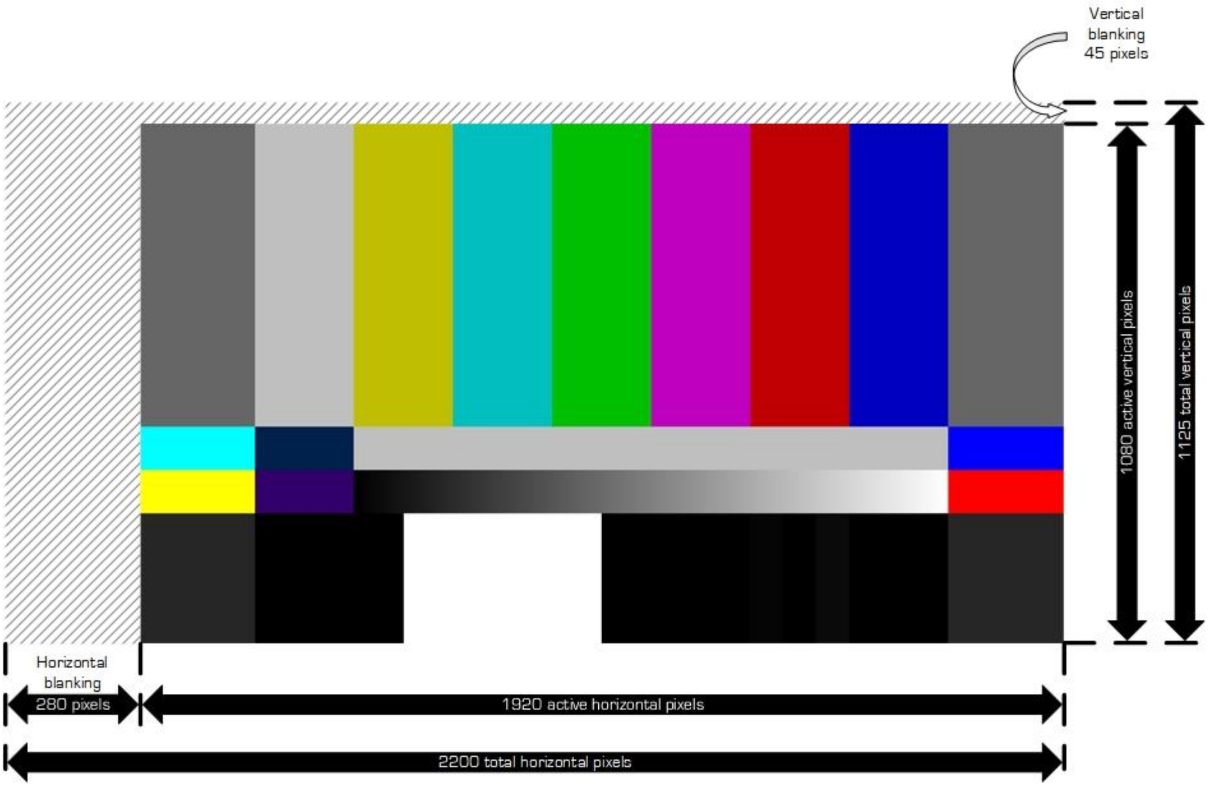
Total Horizontal Pixels X Total Vertical Pixels = Pixels per Frame

Pixels Per Frame X Refresh Rate = Pixels per Second

Pixels per Second X Colour Depth Factor X 10 bits per TMDS clock

= Bandwidth per Channel x 3 TMDS data channels = Total Bandwidth

The total number of horizontal and vertical pixels is not simply the resolution, for example 1920x1080, it also must include the blanking areas which are to the left and above of the active pixel area. For a 1080p image the total number of pixels are 2200x1125. These blank areas are referred to as the horizontal blanking and vertical blanking areas. They are used to separate the active areas of frames, a process vital in old analogue broadcast systems. HDMI formats use these areas to send control and data signals, such as the colour depth information for the frame allowing the screen to correctly map the incoming colour data to the active area of the screen. The below example shows an example of a 1080p @60Hz image including blanking.



The sizes of these blanking areas are defined in standards developed by the Society of Motion Picture and Television Engineers (SMPTE), the standard for 1080p @60Hz is SMPTE 424M. A standard exists for every standard resolution. From this example we can now calculate the bandwidth required for a 1080p @60Hz transmission at any colour depth, below is an example assuming 12-bit colour depth.

$$\mathbf{2200\ x\ 1125 = 2,475,000}\ \boldsymbol{pixels\ per\ frame}$$

$$\mathbf{2,475,000\ x\ 60 = 148,500,000}\ \boldsymbol{pixels\ per\ second}$$

$$\mathbf{148,500,000\ x\ 1.4\ x\ 10 = 2,079,000,000}\ \boldsymbol{bps\ or}\ \mathbf{2.079}\boldsymbol{Gbps\ per\ channel}$$

$$\mathbf{2,079,000,000\ x\ 3 = 6,237,000,000}\ \boldsymbol{bps\ or}\ \mathbf{6.237}\boldsymbol{Gbps\ total\ bandwidth}$$

The maximum bandwidth allowed by the HDMI 1.4b specification is 10.2Gbps, this is also the bandwidth limit for HDBaseT. With this knowledge it is always a good idea to calculate the required bandwidth before deciding on the transmission medium required. For quick reference a table is included below showing the total bandwidth required for some of the most common resolutions, refresh rates and colour depths. The higher the total bandwidth of your signal the more susceptible it is to noise, please see section 6 of this manual where noise and mitigating factors are discussed in detail.

Resolution	Refresh Rate (Hz)	Colour Depth	Total Bandwidth (Gbps)
VGA(640x480)	24	8-bit	0.3
VGA(640x480)	24	10-bit	0.36
VGA(640x480)	24	12-bit	0.42
VGA(640x480)	24	16-bit	0.54
VGA(640x480)	30	8-bit	0.38
VGA(640x480)	30	10-bit	0.45
VGA(640x480)	30	12-bit	0.53
VGA(640x480)	30	16-bit	0.68
VGA(640x480)	50	8-bit	0.63
VGA(640x480)	50	10-bit	0.76
VGA(640x480)	50	12-bit	0.88
VGA(640x480)	50	16-bit	1.13
VGA(640x480)	60	8-bit	0.76
VGA(640x480)	60	10-bit	0.91
VGA(640x480)	60	12-bit	1.06
VGA(640x480)	60	16-bit	1.36
SVGA(800x600)	24	8-bit	0.46
SVGA(800x600)	24	10-bit	0.55
SVGA(800x600)	24	12-bit	0.65
SVGA(800x600)	24	16-bit	0.83
SVGA(800x600)	30	8-bit	0.58
SVGA(800x600)	30	10-bit	0.69
SVGA(800x600)	30	12-bit	0.81
SVGA(800x600)	30	16-bit	1.04
SVGA(800x600)	50	8-bit	0.96
SVGA(800x600)	50	10-bit	1.15
SVGA(800x600)	50	12-bit	1.34
SVGA(800x600)	50	16-bit	1.73
SVGA(800x600)	60	8-bit	1.19
SVGA(800x600)	60	10-bit	1.43
SVGA(800x600)	60	12-bit	1.67
SVGA(800x600)	60	16-bit	2.15
XGA(1024x768)	24	8-bit	0.78
XGA(1024x768)	24	10-bit	0.94
XGA(1024x768)	24	12-bit	1.09
XGA(1024x768)	24	16-bit	1.40
XGA(1024x768)	30	8-bit	0.97
XGA(1024x768)	30	10-bit	1.17
XGA(1024x768)	30	12-bit	1.36
XGA(1024x768)	30	16-bit	1.75
XGA(1024x768)	50	8-bit	1.62
XGA(1024x768)	50	10-bit	1.95
XGA(1024x768)	50	12-bit	2.27
XGA(1024x768)	50	16-bit	2.92

XGA(1024x768)	60	8-bit	1.95
XGA(1024x768)	60	10-bit	2.34
XGA(1024x768)	60	12-bit	2.73
XGA(1024x768)	60	16-bit	3.51
720p	24	8-bit	1.07
720p	24	10-bit	1.28
720p	24	12-bit	1.50
720p	24	16-bit	1.92
720p	30	8-bit	1.34
720p	30	10-bit	1.60
720p	30	12-bit	1.87
720p	30	16-bit	2.41
720p	60	8-bit	2.67
720p	60	10-bit	3.21
720p	60	12-bit	3.74
720p	60	16-bit	4.81
1280x960	24	8-bit	1.23
1280x960	24	10-bit	1.47
1280x960	24	12-bit	1.72
1280x960	24	16-bit	2.21
1280x960	30	8-bit	1.53
1280x960	30	10-bit	1.84
1280x960	30	12-bit	2.14
1280x960	30	16-bit	2.76
1280x960	50	8-bit	2.55
1280x960	50	10-bit	3.06
1280x960	50	12-bit	3.57
1280x960	50	16-bit	4.59
1280x960	60	8-bit	3.06
1280x960	60	10-bit	3.68
1280x960	60	12-bit	4.29
1280x960	60	16-bit	5.51
SXGA(1280x1024)	24	8-bit	1.30
SXGA(1280x1024)	24	10-bit	1.55
SXGA(1280x1024)	24	12-bit	1.81
SXGA(1280x1024)	24	16-bit	2.33
SXGA(1280x1024)	30	8-bit	1.62
SXGA(1280x1024)	30	10-bit	1.94
SXGA(1280x1024)	30	12-bit	2.27
SXGA(1280x1024)	30	16-bit	2.92
SXGA(1280x1024)	50	8-bit	2.70
SXGA(1280x1024)	50	10-bit	3.24
SXGA(1280x1024)	50	12-bit	3.78
SXGA(1280x1024)	50	16-bit	4.86
SXGA(1280x1024)	60	8-bit	3.24
SXGA(1280x1024)	60	10-bit	3.89
SXGA(1280x1024)	60	12-bit	4.53
SXGA(1280x1024)	60	16-bit	5.83
1366x768	24	8-bit	1.03
1366x768	24	10-bit	1.24
1366x768	24	12-bit	1.44
1366x768	24	16-bit	1.85
1366x768	30	8-bit	1.29
1366x768	30	10-bit	1.55
1366x768	30	12-bit	1.80
1366x768	30	16-bit	2.32
1366x768	50	8-bit	2.15
1366x768	50	10-bit	2.58
1366x768	50	12-bit	3.01
1366x768	50	16-bit	3.86
1366x768	60	8-bit	2.58

1366x768	60	10-bit	3.09
1366x768	60	12-bit	3.61
1366x768	60	16-bit	4.64
UXGA(1600x1200)	24	8-bit	1.94
UXGA(1600x1200)	24	10-bit	2.33
UXGA(1600x1200)	24	12-bit	2.72
UXGA(1600x1200)	24	16-bit	3.50
UXGA(1600x1200)	30	8-bit	2.43
UXGA(1600x1200)	30	10-bit	2.92
UXGA(1600x1200)	30	12-bit	3.40
UXGA(1600x1200)	30	16-bit	4.37
UXGA(1600x1200)	50	8-bit	4.05
UXGA(1600x1200)	50	10-bit	4.86
UXGA(1600x1200)	50	12-bit	5.67
UXGA(1600x1200)	50	16-bit	7.29
UXGA(1600x1200)	60	8-bit	4.86
UXGA(1600x1200)	60	10-bit	5.83
UXGA(1600x1200)	60	12-bit	6.80
UXGA(1600x1200)	60	16-bit	8.75
1080i	24	8-bit	2.14
1080i	24	10-bit	2.57
1080i	24	12-bit	2.99
1080i	24	16-bit	3.85
1080i	30	8-bit	2.67
1080i	30	10-bit	3.21
1080i	30	12-bit	3.74
1080i	30	16-bit	4.81
1080i	60	8-bit	5.35
1080i	60	10-bit	6.42
1080i	60	12-bit	7.48
1080i	60	16-bit	9.62
1080p24	24	8-bit	2.23
1080p24	24	10-bit	2.67
1080p24	24	12-bit	3.12
1080p24	24	16-bit	4.01
1080p50	50	8-bit	4.46
1080p50	50	10-bit	5.35
1080p50	50	12-bit	6.24
1080p50	50	16-bit	8.02
1080p60	60	8-bit	4.46
1080p60	60	10-bit	5.35
1080p60	60	12-bit	6.24
1080p60	60	16-bit	8.02
1920x1200(narrow blanking)	24	8-bit	1.85
1920x1200(narrow blanking)	24	10-bit	2.22
1920x1200(narrow blanking)	24	12-bit	2.59
1920x1200(narrow blanking)	24	16-bit	3.33
1920x1200(narrow blanking)	30	8-bit	2.31
1920x1200(narrow blanking)	30	10-bit	2.77
1920x1200(narrow blanking)	30	12-bit	3.24
1920x1200(narrow blanking)	30	16-bit	4.16
1920x1200(narrow blanking)	50	8-bit	3.85

1920x1200(narrow blanking)	50	10-bit	4.62
1920x1200(narrow blanking)	50	12-bit	5.39
1920x1200(narrow blanking)	50	16-bit	6.94
1920x1200(narrow blanking)	60	8-bit	4.62
1920x1200(narrow blanking)	60	10-bit	5.55
1920x1200(narrow blanking)	60	12-bit	6.47
1920x1200(narrow blanking)	60	16-bit	8.32
1920x1200	24	8-bit	2.32
1920x1200	24	10-bit	2.79
1920x1200	24	12-bit	3.25
1920x1200	24	16-bit	4.18
1920x1200	30	8-bit	2.90
1920x1200	30	10-bit	3.49
1920x1200	30	12-bit	4.07
1920x1200	30	16-bit	5.23
1920x1200	50	8-bit	4.84
1920x1200	50	10-bit	5.81
1920x1200	50	12-bit	6.78
1920x1200	50	16-bit	8.71
1920x1200	60	8-bit	5.81
1920x1200	60	10-bit	6.97
1920x1200	60	12-bit	8.13
1920x1200	60	16-bit	10.46
Ultra HD (24)	24	8-bit	8.91
Ultra HD (24)	24	10-bit	10.69
Ultra HD (24)	24	12-bit	12.47
Ultra HD (24)	24	16-bit	16.04
Ultra HD (30)	30	8-bit	8.91
Ultra HD (30)	30	10-bit	10.69
Ultra HD (30)	30	12-bit	12.47
Ultra HD (30)	30	16-bit	16.04
Ultra HD (50)	50	8-bit	17.82
Ultra HD (50)	50	10-bit	21.38
Ultra HD (50)	50	12-bit	24.95
Ultra HD (50)	50	16-bit	32.08
Ultra HD (60)	50	8-bit	17.82
Ultra HD (60)	50	10-bit	21.38
Ultra HD (60)	50	12-bit	24.95
Ultra HD (60)	50	16-bit	32.08
DCI 4K (24)	24	8-bit	8.91
DCI 4K (24)	24	10-bit	10.69
DCI 4K (24)	24	12-bit	12.47
DCI 4K (24)	24	16-bit	16.04
DCI 4K (50)	50	8-bit	17.82
DCI 4K (50)	50	10-bit	21.38
DCI 4K (50)	50	12-bit	24.95
DCI 4K (50)	50	16-bit	32.08
DCI 4K (60)	60	8-bit	17.82
DCI 4K (60)	60	10-bit	21.38
DCI 4K (60)	60	12-bit	24.95
DCI 4K (60)	60	16-bit	32.08

21.2 HDCP COMPLIANCE

High-bandwidth Digital Content Protection or HDCP as it is more commonly known was developed by Intel to act as copy protection for digital media. The basic aim is to stop the transmission and copying of digital content to unauthorized devices. Manufacturers must apply and pay an annual licence fee to gain HDCP accreditation, then they can purchase HDCP keys, whether in 3rd party chipsets or for use in their own memory devices. These keys can then be used within designs which must meet the requirements of HDCP, they must not record content and must actively try to prevent the circumnavigation of copy protection.

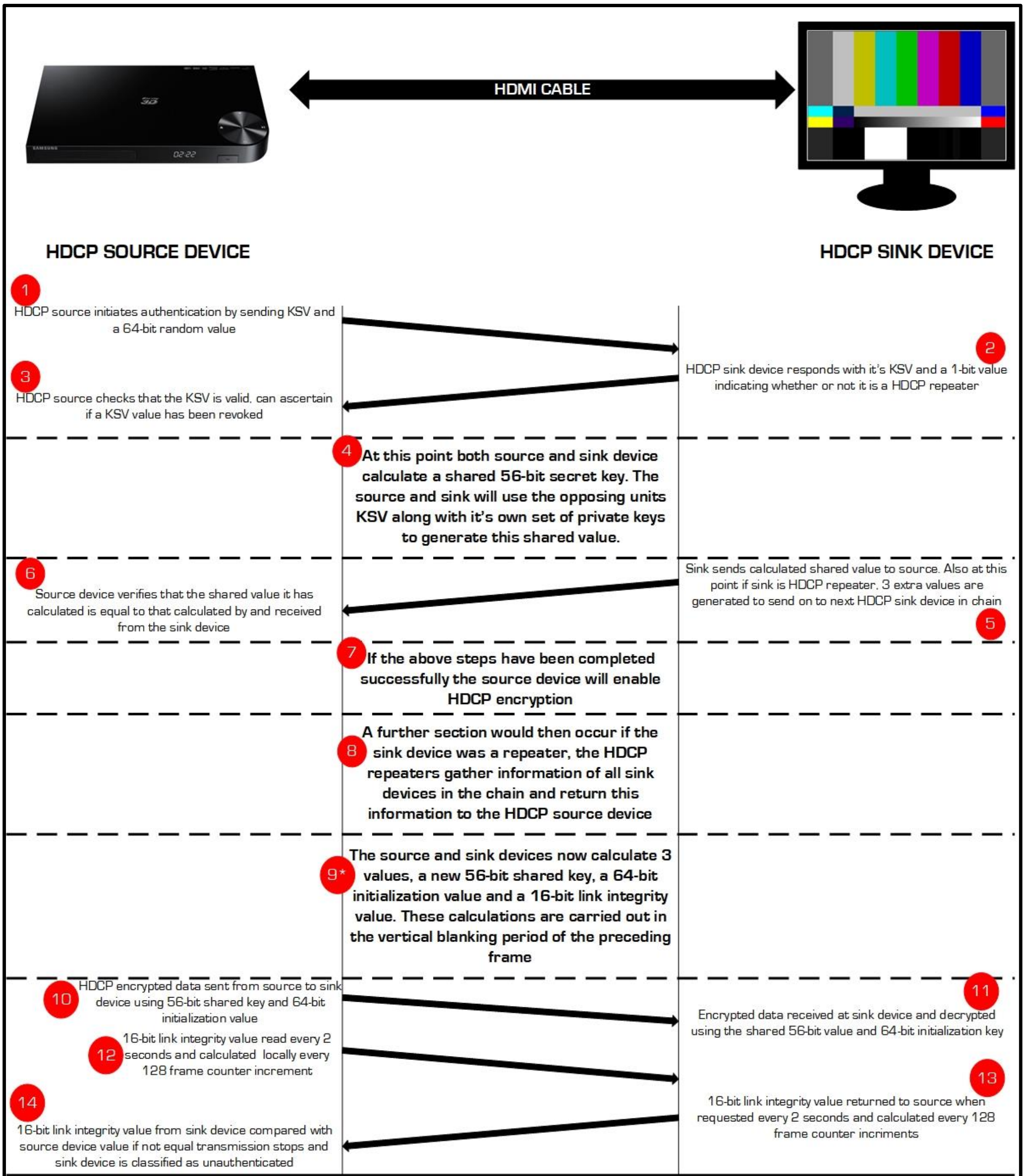
All installers will have at some time or another come across HDCP issues during installation. When HDCP issues occur, a screen will do one of three things. Firstly, the screen may be able to recognise there is a HDCP issue and output a warning message on the screen, this is of great help to an installer as they get an indication straight away as to where the problem lies. Secondly, a screen may show an active area of white noise, this is a clear sign of a HDCP issue but as it is not conveyed it could be misinterpreted as a different issue. Thirdly, the screen may simply return a no signal message, this provides no help to the installer as to what the issue might be, unfortunately this is the most common way in which a HDCP issue manifests itself.

When a HDCP compliant source talks to a HDCP compliant sink device, they go through what is known as a handshaking process. During this period source and sink devices exchange information relating to their HDCP version if they are compatible the devices will then exchange HDCP keys, a hash code is calculated at the source and sink devices and if everything computes correctly then the transmission of HDCP content can proceed.

Each HDCP source and sink device will have an area of memory on which an array of 40, 56-bit keys are stored. These are what are referred to as the Device Private Keys. Also, within this memory is a 40-bit binary value known as the Key Selection Vector (KSV). The KSV consists of 20 ones and 20 zeroes through the 40-bit binary value. The flow diagram at the end of this section gives a guide as to how these values are used in the HDCP handshaking process.

There have been many versions of HDCP since it was first introduced for DVI in 2000. The latest of which is HDCP 2.3. One of the major problems is these various versions are not always compatible with one another and can lead to errors with very little guidance as to HDCP being the culprit. This has led to installers and even home consumers using various methods to circumnavigate HDCP with the use of stripping devices or HDCP version converter in line tools.

HDBaseT point-to-point solutions are unlikely to encounter many of these problems as they pass the HDCP information straight from source to sink device, on HDBaseT applications involving point-to-multipoint or multipoint-to-multipoint distribution HDCP management is crucial. It is always worth assessing the HDCP chain on paper prior to an install and checking all products to be utilized HDCP version compliance. The 4K-9000 can give indication to the presence of HDCP content but cannot discern the version.



*** These values are calculated preceding the transmission of a frame of encrypted content during the vertical blanking period, they are re-calculated again when the frame counter increases. The frame counter can advance on every frame when the ADVANCE_CIPHER mode is enabled or only on encrypted frames when it is not. The 16-bit link integrity value is updated every for every 128 increments of the frame counter and is read every 2 seconds from sink device and compared with value at source device, if values match transmission continues, if not source defines sink as unauthenticated. It is acceptable to read the 16-bit integrity value every 128 frames if not able to perform the necessary operation to read every 2 seconds by the presence of asynchronous polling.**

21.3 EDID MANAGEMENT

EDID (Extended Display Identification Data) is how information is sent from a screen or sink device to a video source, informing the source of various things such as max resolutions and refresh rates supported, colour depth capabilities, manufacturer name and model number and various other parameters. Here at Smart-e we recommend a program developed by EnTech Taiwan called MonInfo, below is an example of the real-time information which may be read from a screen attached to a PC with MonInfo software installed.

```
Monitor #1 [Real-time 0x0100]
  Model name.............. U2879G6
  Manufacturer............ AOC
  Plug and Play ID........ AOC2879
  Serial number........... 2903
  Manufacture date........ 2017, ISO week 21
  Filter driver........... None
  -------------------------
  EDID revision........... 1.4
  Input signal type....... Digital (DisplayPort)
  Color bit depth......... 10 bits per primary color
  Color encoding formats... RGB 4:4:4, YCrCb 4:4:4, YCrCb 4:2:2
  Screen size............. 620 x 340 mm (27.8 in)
  Power management........ Active off/sleep
  Extension blocs......... 1 (CEA-EXT)
  -------------------------
  DDC/CI.................. Supported
  MCCS revision........... 2.2
  Display technology...... TFT
  Controller.............. Mstar 0x1600
  Firmware revision....... 0.9
  Firmware flags.......... 0x0000006F
  Active power on time..... 1324 hours
  Power consumption....... Not supported
  Current frequency....... 133.30kHz, 59.99Hz

Color characteristics
  Default color space...... Non-sRGB
  Display gamma........... 2.20
  Red chromaticity........ Rx 0.633 - Ry 0.340
  Green chromaticity....... Gx 0.311 - Gy 0.633
  Blue chromaticity........ Bx 0.158 - By 0.061
  White point (default).... Wx 0.313 - Wy 0.329
  Additional descriptors... None

Timing characteristics
  Horizontal scan range.... 140-140kHz
  Vertical scan range...... 40-62Hz
  Video bandwidth......... 600MHz
  CVT standard............ Not supported
  GTF standard............ Supported
  Additional descriptors... None
  Preferred timing........ Yes
  Native/preferred timing.. 3840x2160p at 60Hz
    Modeline.............. "3840x2160" 533.250 3840 3888 3920 4000 2160 2163 2168 2222 +hsync -vsync
  Detailed timing #1....... 2560x1440p at 60Hz
    Modeline.............. "2560x1440" 241.500 2560 2608 2640 2720 1440 1443 1448 1481 +hsync +vsync

Standard timings supported
     640 x  480p at  60Hz - IBM VGA
     800 x  600p at  56Hz - VESA
     800 x  600p at  60Hz - VESA
    1024 x  768p at  60Hz - VESA
    1920 x 1080p at  60Hz - VESA STD
    1280 x 1024p at  60Hz - VESA STD
    1280 x  960p at  60Hz - VESA STD
    1440 x  900p at  60Hz - VESA STD
    1680 x 1050p at  60Hz - VESA STD
    1280 x  720p at  60Hz - VESA STD

EIA/CEA-861 Information
  Revision number......... 3
  IT underscan............ Supported
  Basic audio............. Supported
  YCbCr 4:4:4............. Supported
  YCbCr 4:2:2............. Supported
  Native formats.......... 1
  Detailed timing #1....... 1920x2160p at 60Hz
    Modeline.............. "1920x2160" 277.250 1920 1968 2000 2080 2160 2163 2173 2222 +hsync -vsync
  Detailed timing #2....... 1280x720p at 60Hz
    Modeline.............. "1280x720" 74.250 1280 1390 1430 1650 720 725 730 750 +hsync +vsync
  Detailed timing #3....... 1920x1080p at 50Hz
    Modeline.............. "1920x1080" 148.500 1920 2448 2492 2640 1080 1089 1095 1125 -hsync -vsync
  Detailed timing #4....... 720x480p at 60Hz
    Modeline.............. "720x480" 27.000 720 736 798 858 480 489 495 525 -hsync -vsync

CE video identifiers (VICs) - timing/formats supported
    1920 x 1080p at  60Hz - HDTV (16:9, 1:1)
    1920 x 1080p at  50Hz - HDTV (16:9, 1:1)
    1280 x  720p at  60Hz - HDTV (16:9, 1:1)
    1280 x  720p at  50Hz - HDTV (16:9, 1:1)
     720 x  480p at  60Hz - EDTV (16:9, 32:27)
     720 x  576p at  50Hz - EDTV (16:9, 64:45)
     720 x  480p at  60Hz - EDTV (4:3, 8:9)
     720 x  576p at  50Hz - EDTV (4:3, 16:15)
     640 x  480p at  60Hz - Default (4:3, 1:1)
    1920 x 1080i at  60Hz - HDTV (16:9, 1:1)
```

1920 x 1080i at 50Hz - HDTV (16:9, 1:1)
NB: NTSC refresh rate = (Hz*1000)/1001

CE audio data (formats supported)
LPCM 2-channel, 16/20/24 bit depths at 32/44/48 kHz

CE speaker allocation data
Channel configuration.... 2.0
Front left/right......... Yes
Front LFE............... No
Front center............ No
Rear left/right.......... No
Rear center............. No
Front left/right center.. No
Rear left/right center... No
Rear LFE................ No

CE vendor specific data (VSDB)
IEEE registration number. 0x000C03
CEC physical address..... 2.0.0.0
Supports AI (ACP, ISRC).. No
Supports 48bpp.......... No
Supports 36bpp.......... No
Supports 30bpp.......... Yes
Supports YCbCr 4:4:4..... Yes
Supports dual-link DVI... Yes
Maximum TMDS clock....... 600MHz
Audio/video latency (p).. n/a
Audio/video latency (i).. n/a
HDMI video capabilities.. Yes
EDID screen size......... No additional info
3D formats supported..... Not supported
Data payload............ 030C002000197820006001020З

Report information
Date generated.......... 29/03/2018
Software revision........ 2.90.0.1020
Data source............. Real-time 0x0100 - NB: improperly installed
Operating system......... 10.0.16299.2

Raw data
00,FF,FF,FF,FF,FF,FF,00,05,E3,79,28,57,0B,00,00,15,1B,01,04,B5,3E,22,78,3B,08,A5,A2,57,4F,A2,28,
0F,50,54,23,08,00,D1,C0,81,80,81,40,95,00,B3,00,81,C0,01,01,01,01,4D,D0,00,A0,F0,70,3E,80,30,20,
35,00,6D,55,21,00,00,1A,56,5E,00,A0,A0,A0,29,50,30,20,35,00,6D,55,21,00,00,1E,00,00,00,FC,00,55,
32,38,37,39,47,36,0A,20,20,20,20,20,00,00,00,FD,00,28,3E,8C,8C,3C,01,0A,20,20,20,20,20,20,01,DC,
02,03,26,F1,4B,10,1F,04,13,03,12,02,11,01,05,14,23,09,07,07,83,01,00,00,6D,03,0C,00,20,00,19,78,
20,00,60,01,02,03,4D,6C,80,A0,70,70,3E,80,30,20,3A,00,6D,55,21,00,00,1A,01,1D,00,72,51,D0,1E,20,
6E,28,55,00,6D,55,21,00,00,1E,02,3A,80,D0,72,38,2D,40,10,2C,96,80,6D,55,21,00,00,18,8C,0A,D0,8A,
20,E0,2D,10,10,3E,96,00,6D,55,21,00,00,18,00,00,00,00,00,00,00,00,00,00,00,00,00,00,00,00,00,CB

This information is supplied to help a source optimise its output to give the best quality but also a supported format to the output screen. EDID is therefore an incredibly useful tool however, it is also the source of many AV integration issues. For consumer grade products problems are limited as the applications tend to be source directly to screen but with large AV installations the incorporation of matrices, splitters, repeaters, mixed screens and sources, EDID management is very likely, if not handled carefully, to cause problems.

HDBaseT point-to-point installations tend to avoid these problems as EDID is passed through the extenders directly from source to screen as if they were connected by a direct cable. Issues may however arise when using HDBaseT matrices and/or HDBaseT splitter devices.

Within a screen is usually a EEPROM (electronically erasable programmable read-only memory) device, on which is stored the raw data of 128 or 256 bytes, as seen in the example above. The HDMI output on a source has a +5V signal on pin 18, as previously discussed in this manual this is used as part of the hot-plug detect mechanism, this +5V signal is also used as the power supply for the EEPROM device, this is not always the case but is common in most screens. When the +5V powers the EEPROM it can then begin outputting data and this is transmitted to the HDMI source via the DDC clock and data connections, pins 15 and 16 respectively on a HDMI connector. From this point on, even if the screen is not powered on the HDMI source will have access to the EDID data of the screen.

The raw data, at the bottom of the example above, is the information that is sent from the sink to source device. The example above is read from a monitor connected to a PC via a display port connection, display port supports EDID V1.4, which is a 256 Byte raw data exchange. EDID 1.3 is the latest revision supported by HDMI, this is a 128-byte raw data exchange from sink to source. These 128 bytes are mandatory for any device, the extension to 256 bytes enables the transmission of extra information and is optional but possible for manufacturers to include this information in a screens EDID information, this is called E-EDID (enhanced extended display identification data). This extra 128-byte block contains information such as colour depth information. A full break down to the structure of E-EDID can be found here: http://read.pudn.com/downloads110/ebook/456020/E-EDID%20Standard.pdf

The table below gives a breakdown of the 128-byte standard EDID structure. For reference a byte consists of 2 hexadecimal characters with a range of 0 to F (1-16 in decimal). A hexadecimal byte is usually written in the form 0xFF, the preceding 0x denoting that the following characters are hexadecimal. Each hexadecimal character represents 4 binary bits, for example 0xF = '1111' in binary and 16 in decimal. As a byte consists of 2 hexadecimal characters, this represents 8 bits of information.

Bytes	Description	
0-19	**Header Block**	
0-7	Fixed headrer value: 0x00 FF FF FF FF FF FF 00	
8-9	Manufacturer ID	
	Bit 15	Reserved, always 0
	Bits 14-10	First letter of manufacturer ID
	Bits 9-5	Second letter of manufacturer ID
	Bits 4-0	Third letter of manufacturer ID
10-11	Manufacturer assigned model number	
12-15	Manufacturer assigned serial number	
16	Week of manufacture	
17	Year of manufacture	
18	EDID version	
19	EDID revision	
20-23	**Basic Display Capabilities**	
20	Input Specific Capabilities	
	Bit 7	Digital input = 1, Analogue input = 0
	Digital	
	Bits 6-4	bit depth: 000=undefined, 001=6, 010=8, 011=10, 100=12, 101=14, 110=16, 111=reserved
	Bits 3-0	interface: 0000=undefined, 0001=HDMIa, 0010=HDMIb, 0100=MDDI, 0101=DisplayPort
	Analogue	
	Bits 6-5	Video white and sync levels
	Bit 4	Blank to black setup expected
	Bit 3	Separate sync support
	Bit 2	Composite sync support
	Bit 1	Sync on green support
	Bit 0	Vsync pulse control
21	Horizontal viewable screen size in centimeters	
22	Vertical viewable screen size in centimeters	
23	Factory default gamma value	
24	**Feature Support**	
24	Bit 7	VESA display power management signalling support
	Bit 6	VESA display power management signalling suspend support
	Bit 5	VESA display power management signalling active-off support
	Bits 4-3	Digital: 00=RGB 4:4:4, 01=RGB 4:4:4 & YCrCb 4:4:4, 10=RGB 4:4:4 & YCrCb 4:2:2, 11= RGB 4:4:4 & YCrCb 4:4:4 & YCrCb 4:2:2
		Analogue: 00=Grayscale, 01=RGB colour, 10=Non-RGB colour, 11=undefined
	Bit 2	Standard sRGB colour space
	Bit 1	Preferred timing mode location in standard position or in extended block
	Bit 0	Continuous timings GTF or CVT
25-34	**Colour Characteristics**	
25	Bits 7-6	Red x value least significant 2 bits
	Bits 5-4	Red y value least significant 2 bits
	Bits 3-2	Green x value least significant 2 bits
	Bits 1-0	Green y value least significant 2 bits
26	Blue x and y least significant 2 bits	
27	Red x value most significant 8 bits	
28	Red y value most significant 8 bits	
29-30	Green x and y value most significant 8 bits	
31-32	Blue x and y value most significant 8 bits	
33-34	Default white x and y value most significant 8 bits	

35-27	Established Timings (legacy)	
35	Bit 7	720x400 @ 70Hz
	Bit 6	720x400 @ 88Hz
	Bit 5	640x480 @ 60Hz
	Bit 4	640x480 @ 67Hz
	Bit 3	640x480 @ 72Hz
	Bit 2	640x480 @ 75Hz
	Bit 1	800x600 @ 56Hz
	Bit 0	800x600 @ 60Hz
36	Bit 7	800x600 @ 72Hz
	Bit 6	800x600 @ 75Hz
	Bit 5	832x624 @ 75Hz
	Bit 4	1024x768 @ 87Hz (interlaced)
	Bit 3	1024x768 @ 60Hz
	Bit 2	1024x768 @ 72Hz
	Bit 1	1024x768 @ 75Hz
	Bit 0	1280x1024 @ 75Hz
37	Bit 7	1152x870 @ 75Hz
	Bits 6-0	Manufacturer defined display modes
38-53	**Standard Timings**	
Up to 8 2-byte fields, unused fields filled with 0x01 01		
	Bits 15-8	X resolution divided by 8 take away 31, 0x00 reserved
	Bits 7-6	Aspect ratio: 00=16:10, 01=4:3, 10=5:4, 11=16:9
	Bits 5-0	Vertical frequency minus 60
54-125	**Detailed Timings**	
54-71	Descriptor 1	Descriptor Blocks in decreasing preference order: 1. Monitor range limits 2. ASCII text for monitor name and serial number 3. 6 additional standard timing blocks 4. Colour mapping data
72-89	Descriptor 2	
90-107	Descriptor 3	
108-125	Descriptor 4	
126	**Extension Blocks**	
126	Number of extension blocks to follow, 0x00 if no extensions	
127	**Checksum**	
127	Sum of all previous bits should equal 0 (balancing byte)	

Handy tips for ensuring EDID compatibility:

1. Know the lowest denominator of screen for resolution and colour depth
2. Use this monitor(s) at the various stages of your installation such as at location of matrices, splitters and any other sink device
3. Ensure lowest screen resolution and colour depth is read in to EDID management of any devices with the ability to do so
4. Use an EDID reading tool on all screens and sink devices to check EDID version compatibility
5. Sketch out an EDID compatibility map of devices within EDID chain and have to hand in case any issues are seen as this will make locating issues much less complex
6. If a source device has an unknown output refer to the manufacturers manual and in conjunction with the TMDS clock reading of the 4K-9000 it should be possible to discern a detailed idea of the output signal

21.4 THERMAL CONSIDERATIONS

The 4K-9000 has an operating temperature range of -20 – 50 degrees Celsius, this is the ambient temperature of the environment where the unit is located and defines the range of temperatures the unit can operate in. Every electronic device will have an operating and storage temperature range defined in its specification.

The ambient temperature recommendation is defined by the manufacturer to enable the unit to operate safely and consistently. If the ambient environment does not fall within this specified range, there is a danger that the unit could malfunction or in the worst case fail.

Power consumption within electronic devices increases with the more operations a device must perform, the more power consumed by a unit the more heat develops and hence needs to be dissipated. The most common form of heat dissipation users are aware of, are heat sinks on processors within PCs, the heat from these heat sinks is then carried away by fans, in laptops the fan speed can be heard to increase quite rapidly when performing heavy tasks.

HDBaseT application with data rates of up to 10.2Gbps ensures a lot of heat needs to be dissipated. Within a HDBaseT matrix this is done with the use of heatsinks and fans, in small receiver and transmitter devices the incorporation of fans, whilst not impossible, would make units very cumbersome. Most transmitter and receiver HDBaseT devices tend to utilise the metal case in which the units are housed as a heat sink, therefore HDBaseT units can often feel warm to the touch after they have been operating for a period of time. If the environment where the unit is located is already warm this will reduce the effect the case can have as a heat sink.

Electronic chips often utilise a thermal cut off, that is if the chip gets too hot the device will seize operation to protect itself from damage. Passive electronic devices such as resistors or capacitors, will be affected by temperature and change properties, if this occurs to a significant point it may affect system operation.

A thermal issue may show itself by either power or HDBaseT link being lost after a period of time. When a HDBaseT link is lost the most likely problem is going to be noise induced on the CATx cable as discussed in previous sections of this manual but if all advise has been followed and problems still persist, assessing for thermal issues is another area worth consideration.

Handy tips for avoiding thermal issues:

1. **Where possible place units in temperature-controlled environments**
2. **Try to locate devices away from screens as they generate a lot of heat**
3. **Locate units where there is good air flow**
4. **Avoid placing units in wall cavities wherever possible**
5. **Use a digital thermometer to measure temperature of HDBaseT units case if issues encountered**

22 TECHNICAL SPECIFICATION

22.1 4K-TX9000 TECHNICAL SPECIFICATION

Audio and Video Ports	
Input Ports	1x HDMI
Output Ports	None
Serial port	
Serial control interface	RS-232, 3 pin female phoenix connector
Baud rate and protocol	Baud rate: 115200, data bits: 8 bits, stop bits: 1 bit, no parity check bit
Serial control interface structure	3 pin female phoenix interface: 1 = TX, 2 = RX, 3 = GND
Specifications	
Mains Power to external power supply	100VAC-240VAC, 50/60Hz, international adaptive power
Power Adapter Output	5VDC, 3A, 2.1mm centre positive 11mm barrel
Power Input Connector	2.1mmx5.5mm centre positive DC connector
Operating temperature range	-20 - +50 degrees Celsius
Storage temperature range	-30 - +60 degrees Celsius
Relative humidity operational or storage	20 - 90%
Product weight	245g
Power consumption	4.5W (max)/0.8W (standby)
Chassis dimensions	145(l)x92.4(w)x27(d)mm
Mean time between failures	30,000 hours
Quality guarantee	3-year return to base warranty

HDMI port specification	
Protocols	HDMI 1.4b, HDCP 2.2 and DVI 1.0
Interface	1x Independent HDMI (Type-A) Female
Gain	0 dB
Pixel Bandwidth	340MHz full digital
Interface Bandwidth	3.4Gbps, Full digital (a total of 10.2Gbps, each colour is 3.4Gbps)
Maximum Resolution	PC: 1600x1200 @60Hz 48-bit HDPC: 1920x1200p @60Hz 36-bit HDTV: 3840x2160 @30Hz 4:2:0
Clock Jitter	<0.15T bit
Rise Time	<0.3T bit (20-80%)
Fall Time	<0.3T bit (20-80%)
Maximum Transmission Delay	5ns (+/- 1ns)
Signal Strength	T.M.D.S +/- 0.4V p-p

Minimum/Maximum Level	T.M.D.S 2.9V/3.3V
Impedance	50Ω
EDID	Pass-through
Maximum DC Offset error	15mV
Maximum Input cable length	15 meters (always use high quality cable)
Maximum Output cable length	N/A

HDBaseT port specification	
Protocols	HDBaseT
Input Ports	None
Output Ports	1x RJ45 female
Gain	0 dB
Pixel Bandwidth	340MHz Full Digital
Interface Bandwidth	3.40Gbps, Full digital (a total of 10.2Gbps, each colour is 3.40Gbps)
Maximum Resolution	PC: 1600x1200 @ 60Hz 48-bit HDPC: 1920x1200p @ 60Hz 36-bit HDTV: 3840x2160 @ 30Hz 4:2:0
Clock Jitter	<0.15T bit
Rise Time	<0.3T bit (20%~80%)
Fall Time	<0.3T bit (20%~80%)
Signal Type	High speed differential signal defined in HDBaseT protocol
PoE	None
EDID	Pass-through
RS232 Serial Control Signal	Pass-through
Infrared Control Signal	Pass-through
Maximum DC offset error	15mV
Maximum Input Cable	N/A
Maximum Output Cable	≤100-meters (CAT 5e – 7a U/UTP – S/FTP)

22.2 4K-RX9000 TECHNICAL SPECIFICATION

Audio and Video Ports	
Input Ports	None
Output Ports	1x HDMI
Serial port	
Serial control interface	RS-232, 3 pin female phoenix connector
Baud rate and protocol	Baud rate: 115200, data bits: 8 bits, stop bits: 1 bit, no parity check bit
Serial control interface structure	3 pin female phoenix interface: 1 = TX, 2 = RX, 3 = GND
Specifications	
Mains Power to external power supply	100VAC-240VAC, 50/60Hz, international adaptive power
Power Adapter Output	5VDC, 3A, 2.1mm centre positive 11mm barrel
Power Input Connector	2.1mmx5.5mm centre positive DC connector
Operating temperature range	-20 - +50 degrees Celsius
Storage temperature range	-30 - +60 degrees Celsius
Relative humidity operational or storage	20 - 90%
Product weight	250g
Power consumption	6.0W (max)/0.9W (standby)
Chassis dimensions	145(l)x92.4(w)x27(d)mm
Mean time between failures	30,000 hours
Quality guarantee	3-year return to base warranty

HDMI port specification	
Protocols	HDMI 1.4b, HDCP 2.2 and DVI 1.0
Interface	1x Independent HDMI (Type-A) Female
Gain	0 dB
Pixel Bandwidth	340MHz full digital
Interface Bandwidth	3.4Gbps, Full digital (a total of 10.2Gbps, each colour is 3.4Gbps)
Maximum Resolution	PC: 1600x1200 @60Hz 48-bit HDPC: 1920x1200p @60Hz 36-bit HDTV: 3840x2160 @30Hz 4:2:0
Clock Jitter	<0.15T bit
Rise Time	<0.3T bit (20-80%)
Fall Time	<0.3T bit (20-80%)
Maximum Transmission Delay	5ns (+/- 1ns)
Signal Strength	T.M.D.S +/- 0.4V p-p
Minimum/Maximum Level	T.M.D.S 2.9V/3.3V
Impedance	50Ω

EDID	Pass-through
Maximum DC Offset error	15mV
Maximum Input cable length	N/A
Maximum Output cable length	15 meters (always use high quality cable)

HDBaseT port specification	
Protocols	HDBaseT
Input Ports	1x RJ45 female
Output Ports	None
Gain	0 dB
Pixel Bandwidth	340MHz Full Digital
Interface Bandwidth	3.40Gbps, Full digital (a total of 10.2Gbps, each colour is 3.40Gbps)
Maximum Resolution	PC: 1600x1200 @ 60Hz 48-bit HDPC: 1920x1200p @ 60Hz 36-bit HDTV: 3840x2160 @ 30Hz 4:2:0
Clock Jitter	<0.15T bit
Rise Time	<0.3T bit (20%~80%)
Fall Time	<0.3T bit (20%~80%)
Signal Type	High speed differential signal defined in HDBaseT protocol
PoE	None
EDID	Pass-through
RS232 Serial Control Signal	Pass-through
Infrared Control Signal	Pass-through
Maximum DC offset error	15mV
Maximum Input Cable	≤100-meters (CAT 5e – 7a U/UTP – S/FTP)
Maximum Output Cable	N/A