Compliance Testing, Functional Testing and Debugging of HDMI Interfaces
Application Note

Products:

▪ R&S®VTC

▪ R&S®VTE

▪ R&S®VTS

The high-definition multimedia interface (HDMI™) is used to transmit audio and video data. HDMI has become the standard for a variety of consumer electronic products, such as Blu-ray™ players, A/V receivers, set-top box, TV monitors and digital video/still cameras.

The HDMI interface measurements needed for these products require specialized T&M equipment. This equipment is not only needed for certification, but is also used for a variety of tests during development, for quality assurance and for end-of-line production testing. The R&S®VTC, R&S®VTE and R&S®VTS video testers from Rohde & Schwarz make it possible to test A/V interfaces such as HDMI easily, reliably and cost efficiently.

This application note focuses on functional testing and debugging of HDMI interfaces using the R&S®VTC/VTE/VTS. It explains how these instruments can be used to assess the HDCP implementation, the ARC or the CEC functionality.

ROHDE & SCHWARZ

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1 Overview

1.1 Introduction

High-definition multimedia interface (HDMI™) is established worldwide as the fully digital, backwards-compatible replacement for the digital visual interface (DVI) and is used to transmit audio and video (A/V) data. The HDMI cable transmits status and control data alongside the A/V data. Through the cooperation of several companies, the standard was published by HDMI Licensing, LLC in 2002. Development of the standard has continued in the intervening years. The latest version, HDMI 2.0, was published in September 2013.

HDMI has conquered the consumer electronics sector, bringing benefits for manufacturers, media groups and consumers. Manufacturers benefit from the flexibility of the standard, along with the relatively low costs and the standardization. For media groups, the option of using high-bandwidth digital copy protection (HDCP) and the requirement for Digital Content Protection, LCC certification of every HDCP-capable device are important arguments in favor of HDMI. Consumers find it easier to connect and operate devices. The consumer dream of turning the living room into a theater experience with high-definition (HD) videos and surround sound can be fulfilled with HDMI. Even the sharp rise in consumer expectations with respect to picture resolution can be met with HDMI.

HDMI has become established for various consumer electronics products, such as Blu-ray™ players, A/V receivers, TV receivers, TV monitors, tablet PCs, digital video/still cameras, video game consoles, PCs and smartphones. The HDMI interface measurements needed for these products require specialized T&M equipment. This equipment is not only needed for certification, but is also used for a variety of tests during development, for quality assurance and for end-of-line production testing.

1.2 T&M Solution

Rohde & Schwarz developed the Rohde & Schwarz video test family as a way to perform the many different HDMI interface measurements easily, reliably and cost efficiently. The available base instrument types – the R&S®VTC, the R&S®VTE and the R&S®VTS – are adapted to the differing requirements for manufacturing, quality assurance and development (see Fig. 1-1).
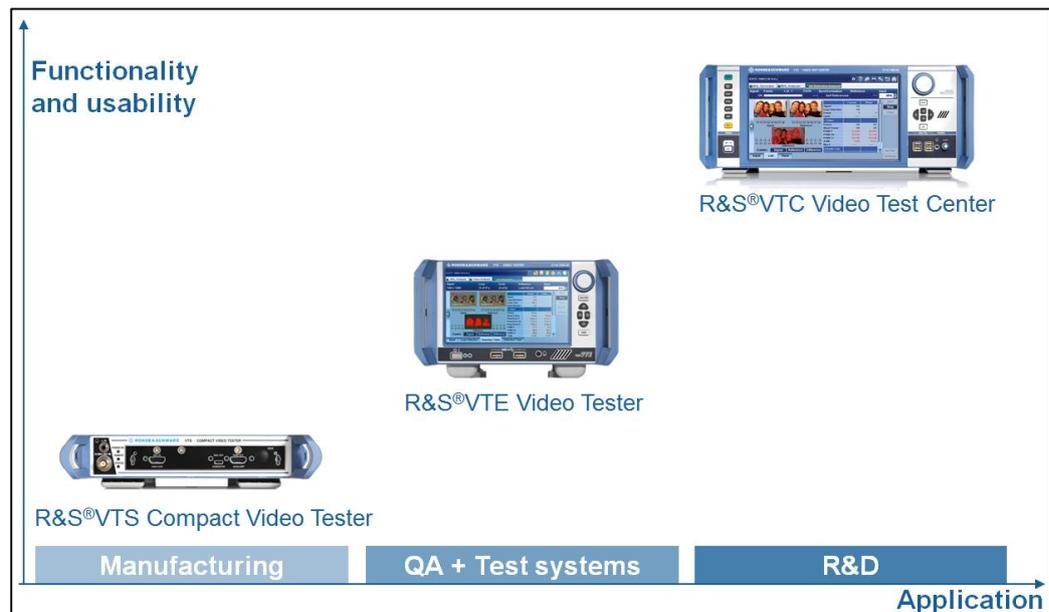

Fig. 1-1: Distinguishing features of R&S®VTS, R&S®VTE and R&S®VTC.

	R&S®VTS	R&S®VTE	R&S®VTC
Dimensions (width x height)	1 HU (229 mm x 44 mm)	3 HU (232 mm x 132 mm)	4 HU (445 mm x 176 mm)
Display size	External I/O or remote	7" touchscreen	11.6" touchscreen
Module slots	1	3	8

The modular design of the instruments mean that they are ready for the future and can be configured to meet customer requirements. The Rohde & Schwarz video testers can be equipped with an HDMI generator module for testing HDMI sinks and or with an HDMI analyzer module for testing HDMI sources. The HDMI analyzer module is available with two different TMDS clock rates, 225 MHz and 300 MHz. A DUT often has other A/V interfaces in addition to the HDMI interfaces. Adding the analog A/V RX module makes it possible to test, among others, the component video output (analog), which is frequently present for compatibility. Combined HDMI/MHL ports make it possible for the end user to transmit A/V content directly from mobile phones to TVs. The required MHL interface measurements can also be performed easily using the R&S®VTC/VTE/VTS and the MHL RX/TX module (see Application Note 7BM83).

In addition, the functional scope of the R&S®VTC/VTE/VTS can be customized for specific applications by adding software options. Besides detailed video or audio analysis and compliance testing (see Chapter 3), this also includes the objective A/V quali-

ty assessment (see 4.7). The A/V quality assessment makes it possible to evaluate the performance of transmission paths or user equipment with respect to the end-user experience.

1.3 About this Application Note

Chapter 2 provides an overview of the HDMI basics and the terms and abbreviations associated with HDMI. Chapter 3 explains the HDMI compliance tests and how Rohde & Schwarz video testers can be used to perform a variety of automated tests. In the final chapters, the focus is on functional tests and debugging of HDMI interfaces. This is divided into HDMI source tests (Chapter 4) and HDMI sink tests (Chapter 5).

2 HDMI Basics

The HDMI standard distinguishes between HDMI sources and HDMI sinks. An HDMI device can have one or more HDMI inputs and/or one or more HDMI outputs. Each input must follow all of the rules of the HDMI sink and each output all of the rules of the HDMI source.

2.1 Lines, Functions and Protocols

A standard HDMI cable consists of 19 separate lines (wires) that fulfill a variety of functions:

▪ Three transition-minimized differential signaling (TMDS) channels: Used for transmitting A/V data, signaling and InfoFrames (see also 2.1.1). Each TMDS channel is composed of TMDS data+, TMDS data– and TMDS data shield. The three TMDS data channels must be synchronized to one another because all reference the same TMDS clock.

▪ TMDS clock: Used to transmit the TMDS clock pulse. The TMDS clock consists of TMDS clock+, TMDS clock– and TMDS clock shield.

▪ Display data channel (DDC) bus: This bidirectional bus is based on the Inter-Integrated Circuit (I^2C) bus and consists physically of a clock line (serial clock – SCL), a data line (serial data – SDA) and a ground connection. It is used to read the enhanced extended display identification data (E-EDID) and for HDCP (see also 2.1.2).

▪ Power for 5 Volt supply voltage: Used to supply power to the DDC, making it possible to read the EDID-ROM data even when the HDMI sink is powered off.

▪ Consumer electronics control (CEC) bus: Used for bidirectional exchange of information between CEC-capable devices (see also 2.1.3). CEC is based on the AV.link. The CEC bus consists physically of a single wire and shares the ground connection with the DDC.

▪ HEAC bus / HPD bus (hot plug detection): The HEAC and HPD physically share the same lines. HPD is used to detect newly connected or removed HDMI devices during operation. HEAC includes two functions, the HDMI Ethernet channel (HEC) and the audio return channel (ARC) (see also 2.1.4). Three physical lines are used to transmit HDMI Ethernet data (supported from Version HDMI 1.4), i.e. HEAC data+, HEAC data– and a ground connection. HEAC data+ uses the same physical line as HPD. The ground connection shares a physical line with the DDC ground connection.
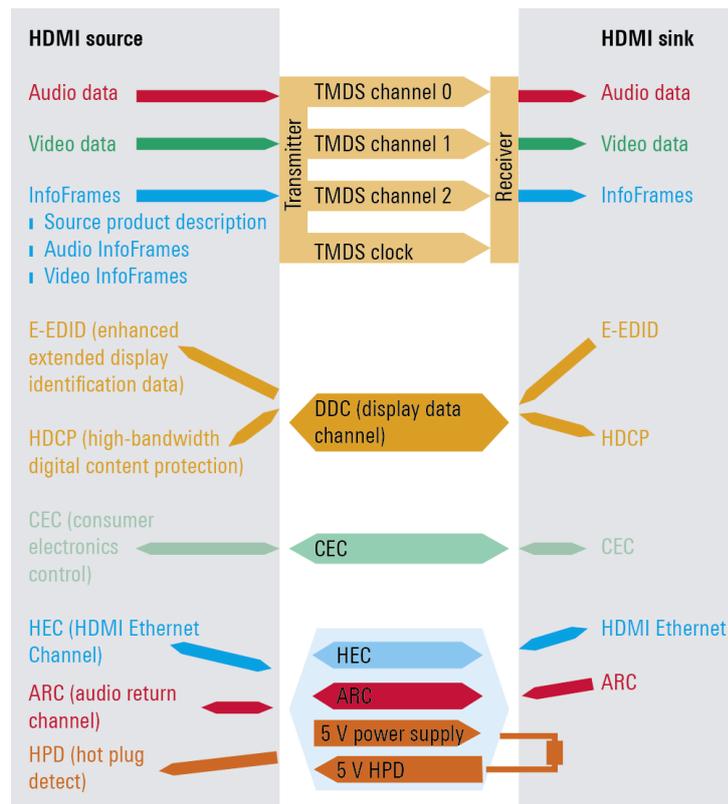
Fig. 2-1: Schematic illustration of the data transfer between the HDMI source and the HDMI sink.

The HDMI standard specifies the cable and its pin assignment. Different connectors are defined to meet the various requirements. The most widely used is Type A, or Standard, and is typically used for TVs and set-top boxes. Type E, Automotive, locks in to provide a vibration-proof connection. Type E is most commonly used for internal connections. Type C (mini) and Type D (micro) are smaller than the standard HDMI plug and are therefore suited for small devices such as cameras and mobile phones.

Standard (type A) Mini (type C) Micro (type D) Automotive connection system (type E)

Fig. 2-2: HDMI connectors.

2.1.1 The TMDS Line

TMDS was developed for uncompressed digital A/V data transmission and is used for signal coding, including as a basis for the HDMI protocol.

The video composition on the TMDS line is based on the video composition for analog video transmission. A brief look back to analog video transmission makes this easier to understand: In analog video transmission, a blanking interval exists in addition to an active picture area. This is necessary because during the video refresh on CRT displays, when the electron beam reaches the end of a line, it requires a certain amount of time until it is again at the start of a line or start of a picture. Within this blanking interval, no video information is transmitted, with the exception of synchronization pulses (HSYNC and VSYNC) and auxiliary information. The durations of these intervals differ depending on the format (including resolution, refresh rate).

Technically, this structure taken from analog video transmission is no longer required today, but was retained for the TMDS line to ensure better backward compatibility. TMDS also divides every frame into lines for video transmission. Within a line, TMDS successively transmits the pixels in the video data periods (see 2.1.1.1). The blanking intervals are also transmitted. They are available for the control periods (see 2.1.1.2) and the data islands periods (see 2.1.1.3).
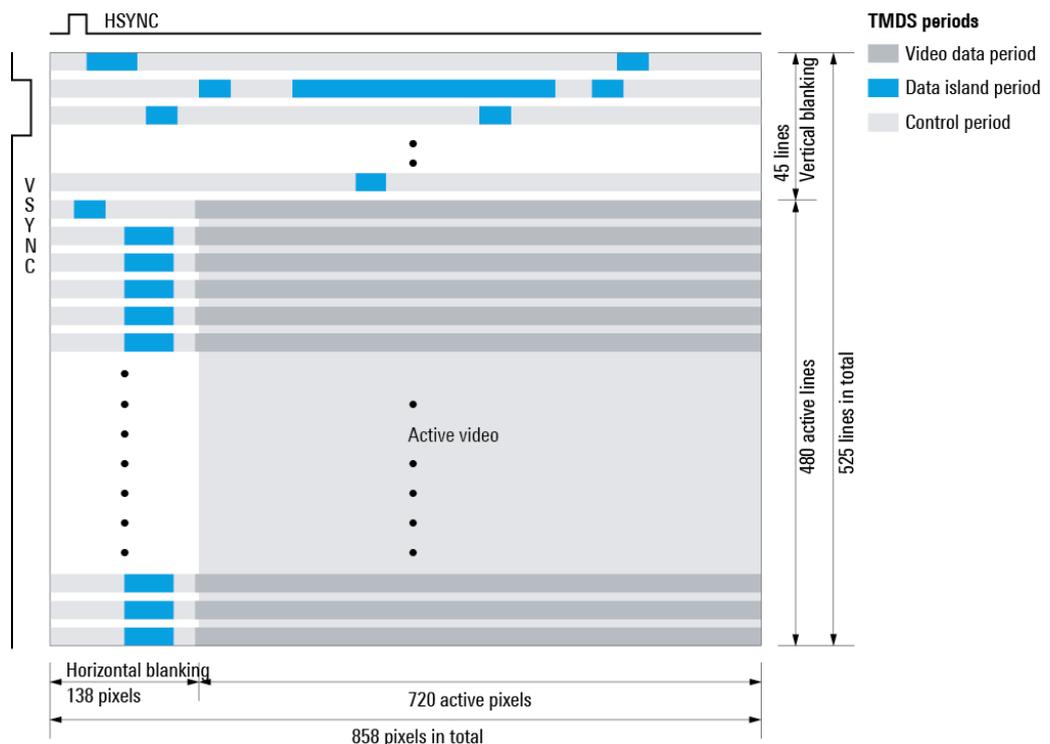

Fig. 2-3: Example of a TMDS frame structure in 720x480 format.

The signals are transmitted over three TMDS line pairs, using a differential (= symmetrical) data transmission. The three data channels (TMDS channels) and one clock channel (TMDS clock) together are called a TMDS link.

2.1.1.1 Video Data

TMDS coding is used for the video data. Each 8-bit data word is coded into a 10-bit data word. The coding ensures that the number of level transitions from zero to one and back to zero is reduced (= transition minimized - TM). As a result, the transmission is less susceptible to faults caused by electromagnetic interference (EMI).

The visible pixels are transmitted uncompressed in the video data portion of the TMDS structure. Different color codings (pixel encoding) determine how the color information for a pixel is transmitted. A distinction is made between coding directly as red/green/blue components (RGB 4:4:4) and coding as used in analog TV signals as luminance Y and blue and red color difference signal (Cb and Cr). YCbCr 4:4:4, YCbCr 4:2:2 and YCbCr 4:2:0 are typical. The various color coding transmissions are mostly used for data decimation. Unlike 4:4:4 mode, in 4:2:2 mode only every second color information is transmitted in the horizontal direction, with the result that the bit depth (= color depth) of every component is increased from the normal 8 bits to 12 bits. The 4:2:0 color coding is used to transmit 4K resolution and was included in the HDMI 2.0 specification.

HDMI supports color depths 24, 30, 36 and 48 bits per pixel. This is equivalent to 2^{24} ($\approx$ 16 billion) to 2^{48} ($\approx$ 281 trillion) different color gradations. A color depth of 24 bits is called True Color, and color depths of 30 bits, 36 bits and 48 bits are called Deep Color.

The color space definition can be taken from the standard ITU-R Rec. BT.601 (= YCbCr 4:2:2) for SD content and ITU-R Rec. BT 709-5 (= sRGB) for HD content. Also possible are color space definitions xvYCC, sYCC601, AdobeYCC601, AdobeRGB and, since HDMI 2.0, ITU-R BT.2020.

HDMI development of video data							
HDMI version	**1.0**	**1.1**	**1.2 1.2a**	**1.3**	**1.3a 1.3b 1.3c**	**1.4 1.4a 1.4b**	**2.0**
Color space							
SD: ITU-R Rec. BT.601 (YCbCr)	Green	Green	Green	Green	Green	Green	Green
HD: ITU-R Rec. 709-5 (sRGB)	Green	Green	Green	Green	Green	Green	Green
xvYCC	Red	Red	Red	Green	Green	Green	Green
sYCC601	Red	Red	Red	Red	Red	Green	Green
Adobe YCC601	Red	Red	Red	Red	Red	Green	Green
Adobe RGB	Red	Red	Red	Red	Red	Green	Green
ITU-R BT.2020	Red	Red	Red	Red	Red	Red	Green
Color codings							
RGB 4:4:4	Green	Green	Green	Green	Green	Green	Green
YCbCr 4:4:4	Green	Green	Green	Green	Green	Green	Green
YCbCr 4:2:2	Green	Green	Green	Green	Green	Green	Green
YCbCr 4:2:0 (4K signals only)	Red	Red	Red	Red	Red	Red	Green

2.1.1.2 Control Period

The preamble is transmitted within the control period. This is necessary in order to identify the subsequent data as video data or data island. At least one control period must always be present between the video data and the data island. The horizontal (HSYNC) and vertical (VSYNC) synchronization signals are transmitted in the control period. As with analog video transmission, these serve to mark the start of the line and start of the picture. Transmission-maximized encoding is used to code the control period. In this case, 2 information-bearing bits are coded into 10 bits.

2.1.1.3 Data Islands

Data islands can contain a variety of content and are therefore split into various packet types. These handle several tasks. Many of these different packet types are defined for audio transmission. The packets consist of a header and the information data. The packet type is announced in each packet's header. Transmission error reduced coding 4 bits (TERC4) is used for coding the data islands. In this case, 4 information-bearing bits are coded into 10 bits.

Audio sample packet

The samples from the individual sound tracks are transmitted sequentially in the audio sample packets. Optimal surround sound is possible with up to 32 individual one-bit audio sound tracks. The audio data can be transmitted either compressed or uncompressed. The HDMI standard requires the audio format linear pulse-code modulation (L-PCM) with a sampling rate of 32 kHz, 44.1 kHz or 48 kHz. The following compressed audio formats are optional in the HDMI standard: Dolby Digital, DTS (Digital Theater Sound), MPEG surround, DVD-Audio, Super Audio CD (SACD), Dolby TrueHD, MPEG-4 (high efficiency advanced audio coding - HE-AAC), DRC (dynamic range compression).

The sample frequency is recovered in the receiver with the aid of the TMDS clock and the information from the separately transmitted audio clock regeneration packet, the cycle time stamp (CTS) and N (fixed value representing the specific video/audio rate).

The audio content protection (ACP) packet protects the material against copyright infringements. The one-bit audio sample packet, the direct stream transfer of audio (DST audio) packet, the high bit rate (HBR) audio packet and the international standard recording code 1/2 (ISRC 1/2) packet all transmit additional information for the audio data.

Additional data island packet types

Other very important data island packet types are the "EIA/CEA-861E InfoFrames". There are a number of different types of these InfoFrames. Several examples are the auxiliary video InfoFrame (AVI), the audio InfoFrame, the source product description (SPD) InfoFrame, the MPEG InfoFrame and the HDMI vendor-specific InfoFrame.

An AVI InfoFrame packet might transmit the video identification code (VIC), the video aspect ratio and the color space, for example. Information about the manufacturer and the device type of the A/V source are found in the SPD InfoFrame. This information

makes it possible to display the device in the input selection list of the sink to the user. The number of audio channels and the channel assignment can be defined in the audio InfoFrame.

If no defined content is to be transmitted in the blanking intervals, data islands of the type "stuffing" are sent.

2.1.2 DDC Bus

Information exchanged over the DDC bus allows problem-free connection of different HDMI devices. The E-EDID stored in the sink's ROM is used for this purpose. This data includes information about supported resolutions and available picture refresh rates for the HDMI sink. As a result, the HDMI source can provide the A/V data in a preferred/supported format for the sink.

To prevent unauthorized copying of digital A/V material by means of a tap between the HDMI source and HDMI sink (between a Blu-Ray® player and a TV, for example), HDCP licensed data encryption is used with HDMI. The initial handshake and subsequent encryption are both performed via the DDC bus.

2.1.3 CEC Bus

CEC permits the exchange of control information among several devices. For example, this could be used to remotely control all connected HDMI devices. Or after a user inserts a Blu-ray® disk into the Blu-ray® player, the TV could be switched on and the appropriate video input enabled automatically.

2.1.4 HEAC Bus

As described above, the HEAC bus has two functions, the HDMI Ethernet channel (HEC) and the audio return channel (ARC). The HEAC bus is sometimes called the utility line.

HEC makes it possible to split an Internet connection among HDMI devices. As a result, for example, the Internet connection for a TV monitor can be shared by all devices connected via HDMI. A connected set-top box, which does not have its own Internet connection, could then perform a firmware update.

ARC permits the transmission of audio information independently of video in the opposite direction, i.e. out of the HDMI sink. This means that if a TV has an integrated tuner, ARC will allow the sound to be transmitted from the TV to the A/V receiver. The A/V receiver outputs the received sound over the connected loudspeakers. Before HDMI, additional cables were needed, which typically used the Sony/Philips Digital Interface (S/PDIF) digital audio interface.

2.2 Data Rate and Pixel Clock Speed

HDMI interfaces are available for a variety of data rates and therefore also bandwidths. The new hardware specified in HDMI 2.0 permits a bandwidth of 600 MHz, which equates to 6 Gbit/s per data channel and a total data rate of 18 Gbit/s.

The primary factor affecting the data rate in the TMDS channel is the selected resolution, along with the refresh rate for video data. For videos, the necessary data rate per second is easily calculated as the product of the refresh rate, the color depth and the horizontal and vertical resolution of the picture. Other factors must be considered, however, when calculating the HDMI data rate. One consideration is that the data rate is increased by the blanking intervals, during which control periods and data islands periods (see 2.1.1) are transmitted. The size of the blanking intervals is dependent on the resolution and sampling rate of the video, and can be taken from CEA-861. Another consideration is that HDMI encodes an 8 bit data word into a 10 bit data word in order to reduce the number of level transitions. Of course, the color coding (RGB or YCbCr) will also influence the data rate.

As a result, the data rate of a TMDS link for an RGB-coded video with a resolution of 1920x1080p, a refresh rate of 30 Hz and a color depth of 12 bits per color component is calculated as follows:

$$(1920 + 280) \cdot (1080 + 45) \cdot 30\ Hz \cdot 36\ Bit\ \cdot \frac{10\ Bit}{8\ Bit} \approx 3.34\ \text{Gbit/s}$$

This equals an approximate data rate of 1.11 Gbit/s per data line for this TMDS link.

The pixel clock speed can be calculated from the data rate. To do this, the data rate per data line is divided by the number of bits that are transmitted per pixel. At a color depth of 12 bits, there are 15 bits ($= 12 \cdot \frac{10}{8}$) transmitted per pixel. The above example results in a pixel clock speed of 74.25 MHz.

2.3 Video Identification Code (VIC)

The number of possible different combinations is enormous when considering resolutions, refresh rates and whether progressive mode or interlaced mode is used. The HDMI standard supports nearly all conventional video formats defined by the Consumer Electronics Association (CEA) and by the Video Electronics Standards Association (VESA), which was used for DVI. In addition, several new formats called HDMI codes were defined for ultra high definition. To simplify identification and handling, unique video identification codes (VIC) were defined for CEA formats.

The HDMI specification distinguishes between primary formats and secondary formats. Primary formats include VIC 1 through 7 and VIC 17 through 22.

VIC	Resolution and field rate	Pixel clock
Snapshot of commonly used CEA formats		
Standard television SDTV CEA-861 video code		
1	640×480p (VGA), 59.94/60 Hz	25.175 MHz
2,3	720×480p, 59.94/60 Hz	27.000 MHz
17,18	720×576p, 50 Hz	27.000 MHz
6,7	720 (1440)×480i, 59.94/60 Hz	27.000 MHz
21,22	720 (1440)×576i, 50 Hz	27.000 MHz
High-definition television HDTV CEA-861 video code		
4	1280×720p, 59.94/60 Hz	74.250 MHz
19	1280×720p, 50 Hz	74.250 MHz
5	1920×1080i, 59.94/60 Hz	74.250 MHz
20	1920×1080i, 50 Hz	74.250 MHz
16	1920×1080p, 59.94/60 Hz	148.500 MHz
31	1920×1080p, 50 Hz	148.500 MHz
34	1920×1080p, 29.97/30 Hz	74.250 MHz
4K formats in line with HDMI 2.0		
101	4096×2160p, 50 Hz	594.000 MHz
102	4096x2160p, 59.94Hz	594.000 MHz

2.4 3D Videos

3D videos have long been a part of cinema offerings. To simplify the move to the private arena, the HDMI 1.4b standard added primary 3D formats.

For a person to perceive a scene in 3D, different pictures must be sent to the left and the right eye. Several 3D formats are used to transmit these two pictures. In the case of both the side-by-side and the top-and-bottom 3D formats, the horizontal or vertical resolution of the frame is reduced in order to reduce the necessary data rate. For a resolution of 1920x1080 pixels, the side-by-side format transmits the pictures for the left and the right eye at a resolution of 960x1080 pixels. In the case of the top-and-bottom format, a resolution of 1920x1080 is converted to a resolution of 1920x520 pixels for both the left and the right eye. In the case of the frame packing 3D format, both perspectives are packed into a frame without reducing the resolution. The frames for the left and the right eye are separated only by a few blank lines. At a resolution of e.g. 1920x1080, the result is a resolution of 1920 x 2205 pixels (with 45 pixels separating the two perspectives), which can then be transmitted via HDMI cable. In this example, the pictures for the left and the right eye each have a resolution of 1920x1080 pixels.

Fig. 2-4: The various 3D formats: Side-by-side (left), top-and-bottom (middle) and frame packing (right).

Since HDMI 2.0, the use of 3D transmission makes it possible to display different 2D picture contents on a single screen. This is called dual-view mode and is an alternative to split screen mode. By each wearing different 3D glasses, several viewers can view their own separate content simultaneously. Separate audio channels can be provided via headsets. Game consoles use this feature to display different images to users playing against one another. This is also known as dual-view video gaming.

2.5 HDMI 2.0 Extensions

The most significant extension of HDMI 2.0 is the ultra high definition (UHD) option, which permits transmission of 4K resolution at a refresh rate of 50 Hz or 60 Hz. 4K is also known as UHD-1 and represents a resolution of 3840x2160 pixels (typical cinema format) or 4096x2160 pixels (typical standard format for consumer electronics). The UHD-2 or 8K resolution of 7680x4320 pixels or 8192x4320 pixels is not part of the HDMI 2.0 specification.

UHD-1 has four times the number of pixels as compared to the widely used full HD (1920x1080 pixels). UHD also takes the transition to higher refresh rates into consideration, and films are recorded at two times the frame rate, i.e. 48 Hz in place of 24 Hz. The playback can then take place at 100/120 Hz.

Fig. 2-5: Various resolutions ranging from SD to UHD.

To implement the higher resolution and refresh rates, the maximum bandwidth of the three data channels (i.e., a TMDS link) is increased from 10.2 Gbit/s to 18 Gbit/s (6 Gbit/s per data channel). HDMI 2.0 permits TMDS with character error detection and data scrambling. The latter reduces the sensitivity with respect to electromagnetic interference and radio interference (EMI/RF). An additional color coding YCbCr 4:2:0 was implemented specifically for 4K/60Hz. This permits the transmission of 4K/60Hz content over existing 3 Gbit/s hardware. The color space ITU-R BT.2020 and cinema format 64:27 (21:9) were also added to the specification.

For better audio quality, the audio sampling rate of the LPCM audio data of maximum 192 kHz was increased to 1536 kHz. For HDMI 1.4b, a maximum of 8 uncompressed audio sound tracks are possible. With HDMI 2.0, up to 32 sound tracks can be transmitted. In addition, HDMI 2.0 permits up to 4 independent audio signals, e.g. for multilanguage or dual-view video gaming. Compressed audio formats HE-AAC and DRC were added and the dynamic auto lip sync feature permits the HDMI sink to dynamically adapt and specify the latency information.

To increase the ease of operation, the CEC commands were expanded in an extension named CEC 2.0.

3 HDMI Compliance Tests for Sink and Source

3.1 Background

In order to guarantee functionality and interoperability, the standards for HDMI have been set high. Every manufacturer claiming HDMI compliance must submit least one of its HDMI-capable devices from each product type to an authorized test center (ATC) for testing. The audit is conducted in line with the compliance test specification (CTS). HDMI Licensing recognizes four product types (source, sink, repeater and cable). The CTS defines the minimum requirements to be met for product certification. The CTS additionally describes the general sequence of each individual test, including the required configuration.

The manufacturer first registers with the HDMI Consortium as an "adopter". This gives the manufacturer access to the contents of the standards and to the CTS. Manufacturers that list products as being HDMI compliant must adhere to the HDMI standard and have at least one HDMI-capable device per product type certified at an ATC. Manufacturers that do not adhere to these requirements can have their adopter status terminated. To obtain certification, a manufacturer schedules an appointment at one of the 10 ATCs currently operating worldwide, at the same time submitting the capability document form (CDF) and other forms. The required CTS tests and their configuration depend on the scope of functions offered by an HDMI device. This information is provided by the manufacturer in the CDF.

Once the ATC confirms compliance, the manufacturer sends the ATC confirmation, the HDMI test results and a copy of the CDF to HDMI Licensing. The certification can then be issued.

The adopter is also responsible for regularly testing devices produced after certification by the ATC for HDMI compliance. This can be done either at an ATC or by means of self-testing. Self-testing must comply with the CTS criteria. Testing must be performed on the test equipment listed in the CTS or equivalent test equipment. For each HDMI test instrument listed in the CTS, the manufacturer of the test instrument must publish the method of implementation (MOI). The MOI details the step-by-step procedure for performing each CTS using that test instrument. Adopters can access the MOI for each listed test instrument free of charge.

The HDMI Consortium recommends that self-testing be supplemented with occasional retesting at an ATC. Screening at an ATC is likewise recommended for significant new functionality.

Before the testing at the ATC, manufacturers are advised to perform their own precompliance testing of as much of the CTS as possible while still in the development lab. Manufacturers can eliminate uncovered problems quickly before certification, making it less likely that they will have to pay to repeat the ATC certification. The equipment setup obtained for this effort can later be used for self-testing.

3.2   CTS Implementation using Rohde & Schwarz Equipment

The user interface on the R&S®VTC/VTE/VTS is optimized for launching the individual CTS tests. This ensures that tests are performed correctly and permits rapid and easy configuration.

After the CTS test is selected on the R&S®VTC/VTE/VTS, the required configurations are selected based on the DUT's scope of functions. For example, in the "HDMI source test Video Format Timing (7-25)", the various video formats must be selected sequentially.

The ability to select and run individual tests directly via the user interface makes the R&S®VTC/VTE/VTS an ideal choice for implementation and testing in the development lab (see Fig. 3-1).
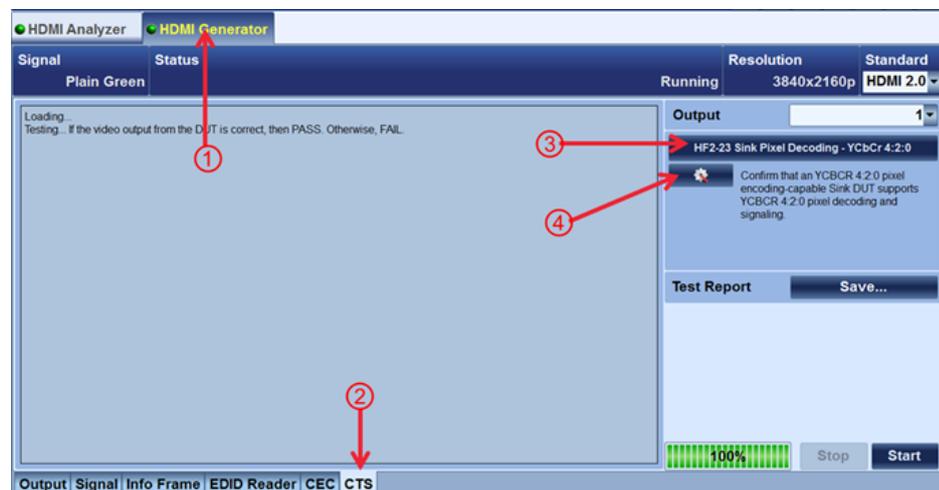
① Select HDMI Generator
② Select CTS tab
③ Push Test ID button for CTS Test selection
④ Configure CTS Test

Fig. 3-1: R&S®VTC/VTE/VTS: Configuring and starting a CTS HDMI sink test in a few easy steps.

The Rohde & Schwarz video testers are listed in the CTS for HDMI 2.0. The Rohde & Schwarz MOI – available free of charge to every adopter for download from the HDMI website – details the steps required to perform the individual tests.

3.2.1 Automating the CTS for HDMI

Rohde & Schwarz offers the R&S®AVBrun software together with the HDMI CTS Source Test Suite or the HDMI CTS Sink Test Suite[1] for performing a number of different configurations and tests, or for complete assessments. This software controls the R&S®VTC/VTE/VTS and launches all relevant CTS tests sequentially. The software prompts the user to make the necessary visual checks and to report the results to the software with the press of a button.

The specific CTS tests that must be performed depend on the DUT's functional range. This functional range must be specified in the CDF for the HDMI certification. The configuration of the R&S®AVBrun software matches that of the CDF (see Fig. 3-2). The R&S®AVBrun software can be run either on an external PC or directly on the Rohde & Schwarz video testers.
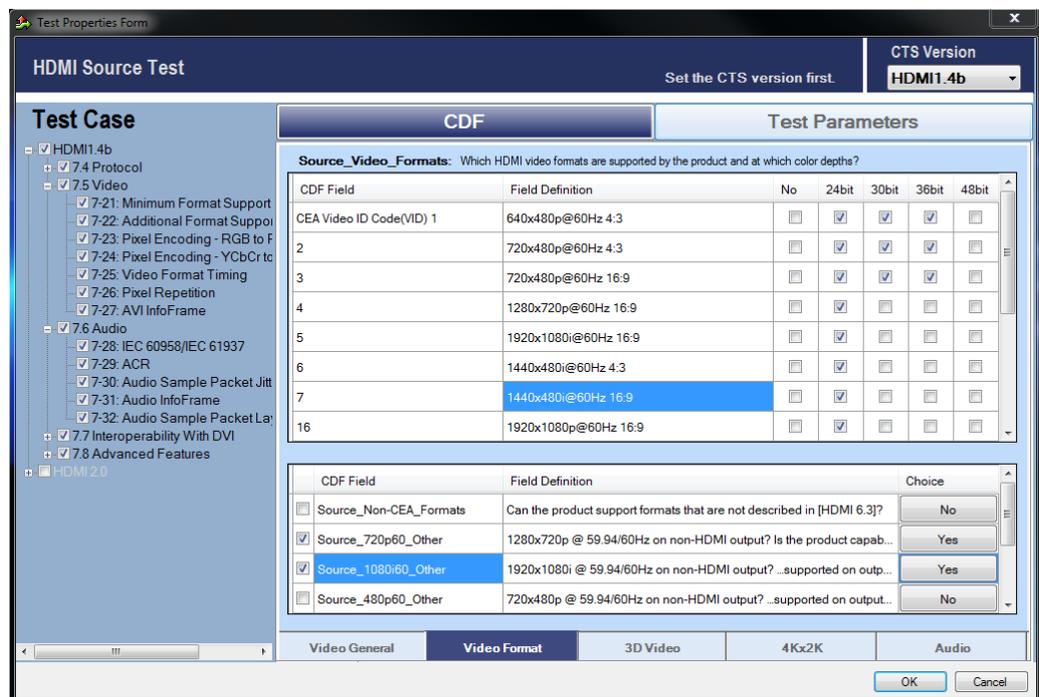
Fig. 3-2: R&S®AVBrun HDMI Test Suite: DUT functional range defined in the CDF.

Each time a test is run, a test report is generated with the detailed test configurations, individual test results and overall test results. The report can be exported in various formats, such as PDF or XML, for documentation and archiving purposes.

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[1] Under development.

3.2.2 CTS Sink Tests Currently Supported by Rohde & Schwarz Video Testers (as of April 2014)

Depending on the test case, tests can be fully automated or semi-automated. In the case of semi-automated tests for sinks, the user is prompted to assess the displayed picture. The test result is determined by the user in this situation.

HDMI 1.4b CTS Sink Tests		
Protocol		
8-15	Character synchronization	Verify that the Sink establishes synchronization with the data when it receives only minimum-length control periods.
8-16	Acceptance of all valid Packet Types	Verify that Sink supports reception of all valid packet types
Video		
8-17	Basic Format Support Req.	Verify that no CEA video format is declared only in a DTD
8-18	HDMI Format Support Req.	Verify that Sink DUT indicates support for all required Video Formats in its EDID
8-19	Pixel Encoding Requirements	Verify that Sink supports YCbCr pixel encoding when required
8-20	Video Format Timing	Verify that Sink supports required variations of mandatory video formats and CEA video formats indicated in EDID
Audio		
8-21	Audio Clock Regeneration	Verify proper Sink operation with respect to Audio Clock Regeneration
8-22	Audio Sample Packet Jitter	Verify that Sink supports Audio Sample Packets with maximum jitter
8-23	Audio Formats	Verify that Sink supports every audio format specified in EDID
Interop DVI		
8-24	Interoperability with DVI	Verify that Sink DUT can handle required transition from DVI to HDMI mode
Advanced		
8-25	Deep Color	Verify that a Deep Color-capable Sink DUT supports Deep Color packing and signaling
8-29	3D Video Format Timing	Verify that a 3D-capable Sink DUT supports required variations on mandatory 3D video formats and other primary 3D video formats listed in the EDID
8-30	4K x 2K Video Format Timing	Verify that a 4K x 2K-capable Sink DUT supports 4K x 2K video formats indicated in EDID

HDMI 2.0 CTS Sink Tests		
Sink TMDS Prot.		
HF-2-9	Scrambling <= 340 Mcsc	Confirm that the Sink property supports scrambling for TMDS Character Rates at or below 340 Mcsc.
Sink Pixel Dec.		
HF-2-23	Sink Pixel Decoding - YCbCr 4:2:0	Confirm that an YCbCr 4:2:0 pixel encoding-capable Sink DUT supports YCbCr 4:2:0 pixel decoding and signaling
Sink Video Timing		
HF2-25	21:9 (64:27)	Confirm that a "21:9" (64:27)-capable Sink DUT, whenever it receives any supported "21:9" (64:27) Video Format, correctly decodes and displays it
Sink EDID		
HF2-31	Sink EDID - YCbCr 4:2:0 - Data Blocks	Confirm that an YCbCr 4:2:0 capable Sink DUT E-EDID contains a valid Video Data Block and/or YCbCr 4:2:0 Capability Map Data Block.
HF2-32	YCbCr 4:2:0 BT.2020 – Data Block	Confirm that a YCbCr 4:2:0 BT.2020 capable Sink DUT EDID contains a valid Colorimetry Data Block
HF2-35	YCbCr 4:2:0 Deep Color HF-VSDB	Confirm that a YCbCr 4:2:0 Deep Color Pixel encoding-capable Sink DUT EDID contains a valid HF-VSDB
HF2-39	3D and Multi-stream Audio Data Blocks	Confirm that the structure of the HDMI Audio Data Block in the EDID is valid
HF2-41	HDMI-VSDBs – Independent-View	Confirm that the Sink DUT has the correct content in the HF-VSDB for the "independent view" feature
HF2-26	Video Format Declaration	Confirm that an HDMI 2.0-capable Sink DUT correctly declares support for Video Formats in its EDID
HF2-53	HF-VSDB	Confirm that a Sink DUT EDID contains a valid HF-VSDB when required by any feature.

3.2.3 CTS Source Tests Supported by Rohde & Schwarz Video Testers

In the case of semi-automated tests for sources, the user is prompted to activate the required test signal at the source.

HDMI 1.4b CTS Source Tests		
Protocol		
7-16	Legal Codes	Verify that Source only outputs legal 10-bit codes.
7-17	Basic Protocol	Verify that Source only outputs code sequences for Control Periods, Data Island Periods and Video Data Periods corresponding to basic HDMI protocol rules.
7-18	Extended Control Period	Verify that Source outputs an Extended Control Period within the required period.
7-19	Packet Types	Verify that Source only transmits permitted Packet Types and that reserved fields are zero.
Video		
7-23	Pixel Enc. RGB to RGB-only Sink	Verify that the Source DUT always outputs required pixel encoding (RGB), which also correlates with Y0 and Y1 fields in AVI InfoFrame when connected to an RGB-only Sink. Also verify that the Source DUT outputs AVI InfoFrame with default range value in Q and YQ field when a Sink device does not support selectable RGB Quantization Range.
7-24	Pixel Enc. YCbCr to YCbCR Sink	Verify that the Source DUT always outputs pixel encoding that correlates with Y0 and Y1 fields in AVI InfoFrame when presented with a YCbCr-capable Sink and that DUT is capable of supporting YCbCr pixel encoding when required. Also verify that the Source DUT outputs AVI InfoFrame with default range in Q and YQ when a Sink device does not support selectable YCC Quantization Range.

7-25	Video Format Timing	Verify that Source DUT, whenever transmitting any CEA video format, complies with all required pixel and line counts and pixel clock frequency range.
7-26	Pixel Repetition	Verify that Source DUT indicates Pixel Repetition values in AVI InfoFrame as required and that the pixels are actually repeated the indicated number of times.
7-27	AVI InfoFrame	Verify that at least one AVI InfoFrame is transmitted for every two fields when required and that any AVI InfoFrame transmitted is accurate.
Audio		
7-28	IEC 60958 / IEC 61937	Verify that the behavior of all fields within the Audio Sample or High-Bitrate Audio Stream Subpackets follow the corresponding rules specified in the IEC 60958 or IEC 61937 specifications.
7-29	ACR	Verify that the relationship between the parameters (N, CTS, audio sample rate) is correct with respect to the Audio Clock Regeneration mechanism.
7-30	Audio Sample Packet Jitter	Verify that the source audio packet jitter is within the limits specified.
7-31	Audio InfoFrame	Verify that Source transmits an Audio InfoFrame whenever required and that contents are valid.
7-32	Audio Sample Packet Layout	Verify that Source only transmits audio using permitted Layout type.
Interop DVI		
7-33	Interoperability with DVI	Verify that Source never outputs a Video Guard Band or Data Island to a device without an HDMI VSDB.
Advanced		
7-34	Deep Color	Verify that a Deep Color-capable Source DUT outputs correct Deep Color packing and signaling.
7-35	Gamut Metadata Transmission	Verify that an xvYCC-capable Source outputs valid Gamut Metadata Packets.
7-36	High-Bitrate Audio	Verify that a High-Bitrate Audio-capable source is able to transmit High-Bitrate Audio Stream Packets with packet jitter limited to compliant values.
7-37	One Bit Audio	Verify that a One Bit Audio-capable source is able to transmit One Bit Audio Packets in a compliant manner.
7-38	3D Video Format Timing	Verify that Source DUT, whenever transmitting any supported mandatory 3D video format or other primary 3D format complies with all required pixel and line counts and pixel clock frequency range.
7-39	4K x 2K Video Format Timing:	Verify that Source DUT, whenever transmitting any 4K x 2K video format, complies with all required pixel and line counts and pixel clock frequency range.
7-40	Extended Colorimetry Transmission:	Verify that a Source does not transmit sYCC601 or AdobeYCC601 or AdobeRGB to a Sink which does not support these Extended Colorimetries.

HDMI 2.0 CTS Source Tests		
HF1-31	Src Pix Enc – YCbCr 4:2:0 – TMDS Pix Enc	Confirm that a YCbCr 4:2:0 Pixel encoding-capable Source DUT outputs correct YCbCr 4:2:0 Pixel encoding and signaling.
HF1-33	Src Video Timing – YCbCr 4:2:0	Confirm that the Source outputs the correct timing for YCbCr 4:2:0 timings.
HF1-35	Src Video Timing – 21:9 (64:27)	Confirm that a "21:9" (64:27) capable Source DUT complies with all of the required Pixel and line counts and Pixel clock frequency range whenever transmitting any supported "21:9" (64:27) Video Format.
HF1-51	Src AVI InfoFrame – YCbCr 4:2:0	Confirm that the YCbCr 4:2:0 signaling information in the AVI InfoFrame is correct.

4 Debugging Tests for HDMI Sources

The R&S®VTC/VTE/VTS with the HDMI analyzer module (R&S®VT-B2360 or R&S®VT-B2361) is used for the applications described here. Unless specified otherwise for the tests described here, only an HDMI connection between the DUT and the HDMI input on the analyzer module is required to perform these tests (see Fig. 4-1).
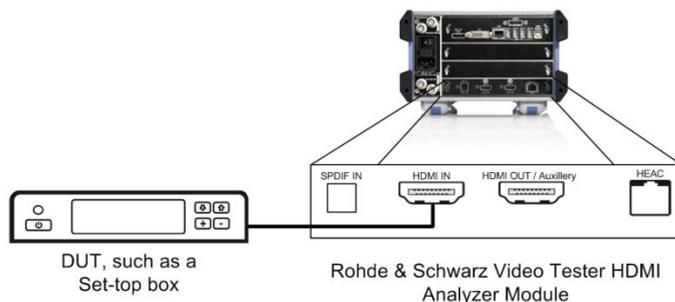
Fig. 4-1: Typical test setup for testing an HDMI source.

4.1 Video

4.1.1 Correct Video Signaling in AVI InfoFrame

The TMDS structure defines the horizontal video parameters and the vertical video parameters. These parameters are signaled via the VIC in an AVI InfoFrame. If the video signaling and the transmitted TMDS structure do not match, the R&S®VTC/VTE/VTS automatically signals the discrepancy:

► HDMI Analyzer → Video → Parameters that do not match the AVI InfoFrame are indicated in red (see Fig. 4-2).

HDMI Analyzer	HDMI Generator			
Video Code	**HDCP**		**Pixel Clock**	**HPD Signal**
1920 x 1080p @ 59.94/60Hz (16)		Active	74.250MHz	On
Video Code (derived from AVI InfoFrame)			1920 x 1080p @ 59.94/60Hz (16)	
Pixel Clock	74.250000MHz	**Vertical Frequency**	50.000Hz	
Video Format	Interlaced	**Horizontal Frequency**	28.125kHz	
Horizontal Video Parameters		**Vertical Video Parameters**		
H Total Pixels	2640	**V Total Lines**	1125	
H Active Pixels	1920	**V Active Lines**	1080	
H Front Porch Pixels	528	**V Front Porch Lines**	2	
H Sync Pixels	44	**V Sync Lines**	5	
H Back Porch Pixels	148	**V Back Porch Lines**	15	
H Sync Polarity	Positive	**V Sync Polarity**	Positive	

| Input | Video | Audio | HDCP | InfoFrame | CTS | CEC |

Fig. 4-2: R&S®VTC/VTE/VTS: Any deviation between the signaled video format and the transmitted video format is indicated in red.

4.1.2   InfoFrames

If the HDMI source incorrectly signals the color coding in the AVI InfoFrame, the colors will be displayed incorrectly on the HDMI sink (see Fig. 4-3).
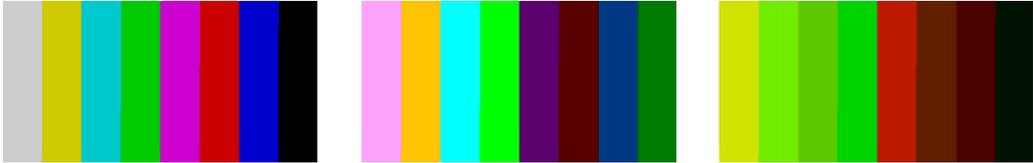
Fig. 4-3: Color bar for correct color signaling (left) and incorrect color signaling (center, right).

The color coding is signaled in the AVI InfoFrame. This and all other InfoFrames can be displayed by the R&S®VTC/VTE/VTS (see Fig. 4-4).

► HDMI Analyzer → InfoFrame → Packet Type: AVI InfoFrame: RGB or YCbCr

Fig. 4-4: R&S®VTC/VTE/VTS: Review of signaling for color coding in the AVI InfoFrame.

4.2 Review of the HDCP Implementation

HDMI uses the licensed data encryption HDCP to protect the digital A/V signal. The source must ensure that copyrighted material is encrypted during transmission. Problems associated with HDCP are frequently the cause when an HDMI transmission fails.

4.2.1 Confirming Encrypted Transmission of Protected A/V Material

Protected A/V material may not be transmitted from the source to the sink without encryption. To check this, HDCP can be disabled on the R&S®VTC/VTE/VTS HDMI analyzer (simulating a sink without HDCP). If the source transmits the A/V material with encryption, no picture should be displayed or sound heard (see Fig. 4-5).

► HDMI Analyzer → Input → HDCP: Off
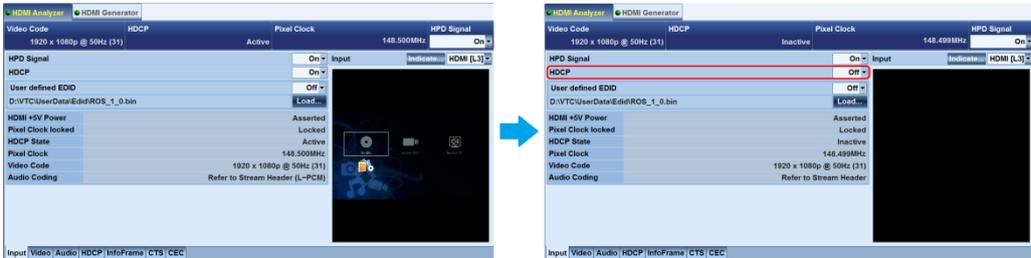
Fig. 4-5: R&S®VTC/VTE/VTS: After HDCP is disabled (right), the picture and sound for protected A/V material must not be visible or audible.

4.2.2 Initialization and Maintenance of Encryption

The initial handshake and subsequent encryption are both performed via the DDC bus. Authentication is initialized by the HDMI source. During the handshake, a 56 bit value "An" is exchanged for the decoder built into the device. During the playback, the Ri' value is continually calculated by the sink and transmitted back to the source for monitoring purposes. Both values are displayed on the R&S®VTC/VTE/VTS during active HDCP (see Fig. 4-6):

► HDMI Analyzer → HDCP → Ri'

► HDMI Analyzer → HDCP → An

If problems arise during the transmission, it might be necessary to perform another HDCP handshake, in which case the value of An will change. This can be simulated with the R&S®VTC/VTE/VTS (see Fig. 4-6):

► HDMI Analyzer → HDCP → Re-Authentication
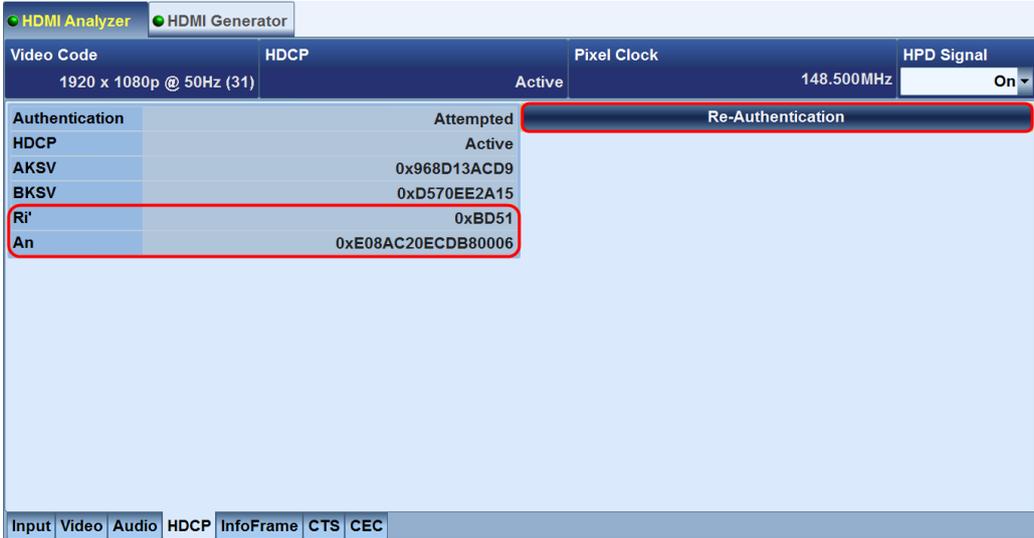
Fig. 4-6: R&S®VTC/VTE/VTS: Display of the Ri' and An values needed for HDCP.

4.3 Audio

The sound transmitted via HDMI is audible over the loudspeakers on the R&S®VTC/VTE/VTS.

4.3.1 Audio Dropouts

Audio dropouts can be caused by an incorrectly recovered audio clock. The audio clock is calculated from the TMDS clock, parameter N and the cycle time stamp (CTS) value of the audio clock regeneration packet. The TMDS clock that is used in the autio clock calculation is dependent on the format of the transmitted video. With some video formats, it might be necessary to change the CTS parameter periodically during the transmission. The R&S®VTC/VTE/VTS displays the transmitted parameters N and CTS, making it possible to check them.

► HDMI Analyzer → Audio → N

► HDMI Analyzer → Audio → CTS
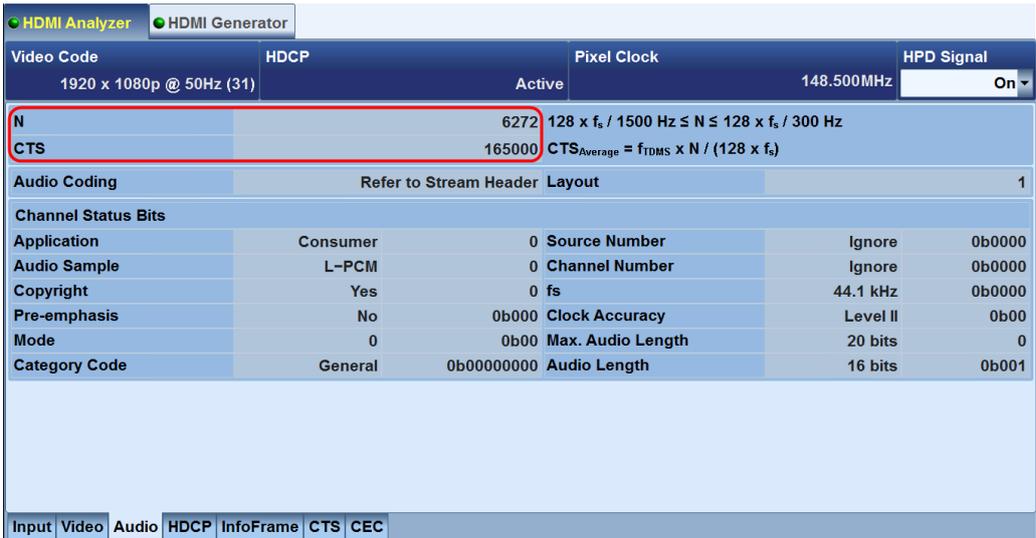
Fig. 4-7: R&S®VTC/VTE/VTS: Checking the audio parameters.

4.3.2 Audio Channels

The layout parameter indicates the type of audio transmission. The transmission of only one stereo signal (front left & front right) is indicated by layout = 0. On the other hand, when more than these two audio channels are transmitted, the layout parameter = 1 (see Fig. 4-7).

► HDMI Analyzer → Audio → Layout

The HDMI 1.4b standard defines that with Layout = 1 (i.e. more than two audio channels), the audio sample packets for eight audio channels must be transmitted in the TMDS stream. If fewer than eight audio channels are used, the corresponding packets are identified as invalid. The number of channels with audio data is indicated by the channel count parameter in the audio InfoFrame. The channel allocation parameter,

which is also transmitted in the audio InfoFrame, indicates which of the eight audio channels contain audio data.

The R&S®VTC/VTE/VTS can display the various InfoFrames, making it possible to check the audio InfoFrame, including the Channel Count and Channel Allocation (see Fig. 4-8):

► HDMI Analyzer→ InfoFrame → Packet Type: Audio InfoFrame: Channel Count

► HDMI Analyzer → InfoFrame → Packet Type: Audio InfoFrame: Channel Allocation
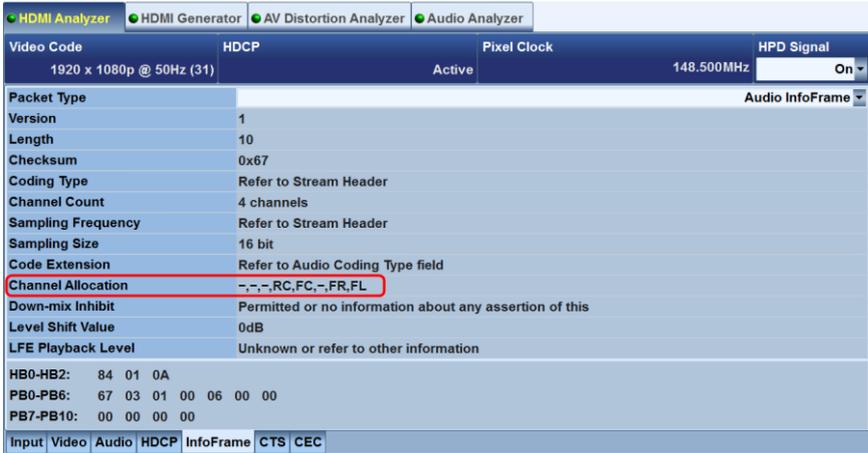
Fig. 4-8: R&S®VTC/VTE/VTS: Audio InfoFrame and the Channel Allocation parameter.

The transmitted sound can be analyzed using the audio analyzer (software option R&S®VT-K2150). It is possible not only to check whether the audio data is transmitted in the expected channels (see Fig. 4-9), but also to measure the level, THD and frequency response.

► Audio Analyzer → Input: HDMI

Fig. 4-9: R&S®VTC/VTE/VTS: Checking which channels are transmitting audio data.

4.3.3 Output of the Audio Data Received via the ARC

The ARC is primarily used to transmit the sound for a TV (HDMI sink) with an integrated tuner to an A/V receiver (HDMI source). ARC permits the transmission of audio information independently of video in the opposite direction, i.e. toward the HDMI source. The HDMI source must correctly process and reproduce the received audio data. To check the ARC functionality of an HDMI source, an audio signal must be transmitted from the HDMI sink over the HEAC bus on the HDMI cable. If the transmitted sound from the HDMI source is reproduced correctly, the ARC is functioning.

The R&S®VTC/VTE/VTS uses the ARC to transmit the audio signal received by the Rohde & Schwarz video tester via the optical S/PDIV port. The audio signal can be fed to the R&S®VTC/VTE/VTS via any audio source with an optical S/PDIV port. For example, the R&S®UPP or R&S®UPV can be used for high-quality, configurable audio signals. By using different frequencies for the two different audio channels, the test technician can immediately hear whether all channels are being processed correctly.
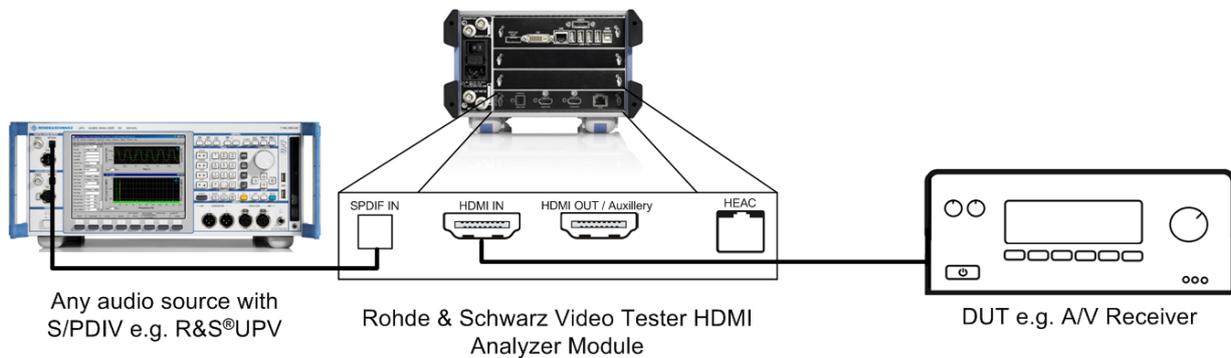
Fig. 4-10: Testing the ARC using the R&S®VTC/VTE/VTS.

The audio signal fed to the R&S®VTC/VTE/VTS via the optical S/PDIV port can be made audible by using the integrated audio analyzer (software option R&S®VT-K2150).

► Audio Analyzer → Input: S/PDIF

4.4 5 Volt Supply Voltage is Present and Stable

The HDMI connection to a sink requires a stable 5 volts from the source. To check this, the R&S®VTC/VTE/VTS indicates whether the required supply voltage is present and stable.

► HDMI Analyzer → Input → HDMI +5V Power

Fig. 4-11: R&S®VTC/VTE/VTS: Display of the present and stable supply voltage.

4.5 Emulation of a Defined Sink with EDID Data

It is important that manufacturers of HDMI sources, such as a set-top box, ensure that their devices function with a wide variety of sinks. According to the HDMI standard, the source is responsible for transmitting the A/V data in a format that is supported by the sink. It might be necessary for the source to scale down video or to convert a sound format.

The source distinguishes among sinks by the video formats that they support. The source reads this information from the sink's EDID. The Rohde & Schwarz video testers (R&S®VTC/VTE/VTS) can emulate a specific sink with a user-defined EDID.

4.5.1 Readout / Storage of EDID Data from a Sink

Rohde & Schwarz video testers can read the EDID data from any sink and save the data as needed. The sink to be emulated is connected to the auxiliary port via an HDMI cable. This permits the R&S®VTC/VTE/VTS to read out the EDID. For the DUT, the R&S®VTC/VTE/VTS has the same EDID as the device connected to the auxiliary port (see Fig. 4-12).
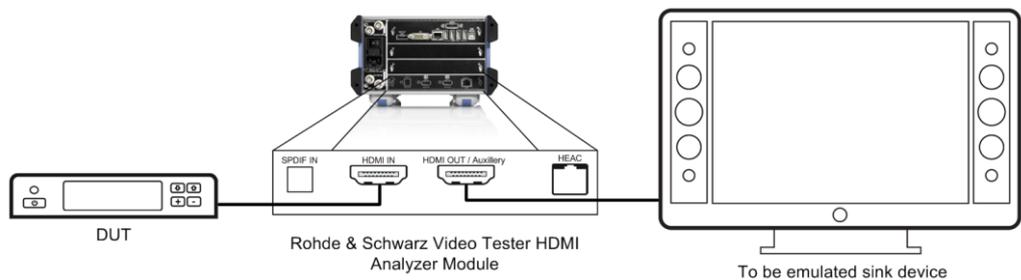
Fig. 4-12: Test setup for emulating a connected sink.

Settings on the R&S®VTC/VTE/VTS (see Fig. 4-13):

► HDMI Analyzer → Input → User defined EDID: AUX

The EDID data can be stored so that the connected sink can be simulated at a later time without restoring the cabling (see 4.5.2):

► HDMI Analyzer → Input → AUX connected / AUX EDID active: Save: The default directory for EDID files is UserData, e.g. for the R&S VTE it is "D:\VTE\UserData\EDID".
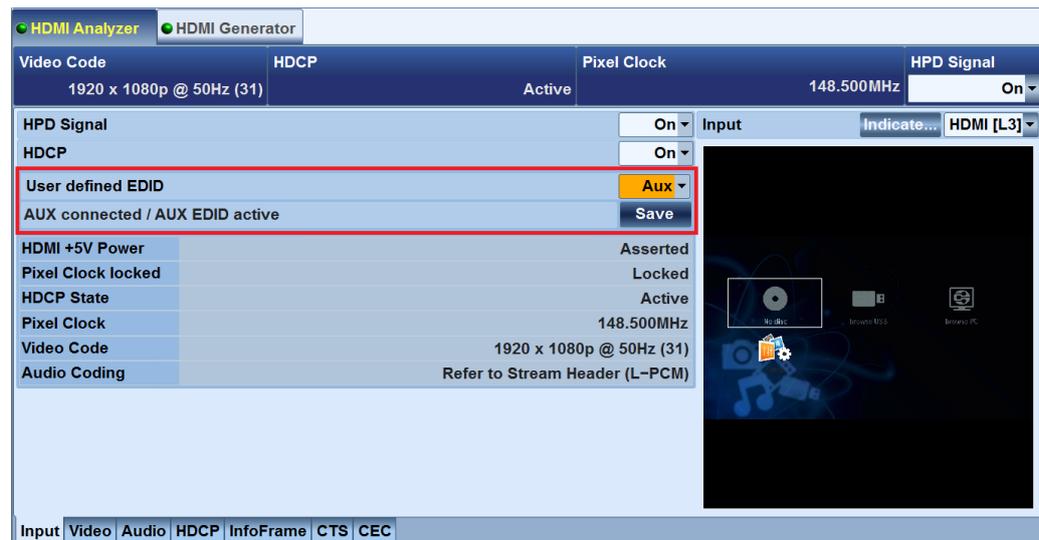
Fig. 4-13: R&S®VTC/VTE/VTS: Configuration for emulating a connected sink.

4.5.2 Using an Existing EDID

Saved EDID data (see also 4.5.1 and 5.6.2) can be enabled directly:

► HDMI Analyzer → Input → User defined EDID → LOAD: Select an existing bin file

► HDMI Analyzer → Input → User defined EDID → ON

4.5.3 Forcing a Format Using EDID Data

To check whether a DUT correctly outputs a specific format, such as 1080p, the DUT must be forced to use this format. To do this, an EDID that contains only this one format can be selected on the R&S®VTC/VTE/VTS. For the DUT, the R&S®VTC/VTE/VTS acts as an HDMI sink that supports only this one format. The R&S®VTC/VTE/VTS contains several EDID configurations, and other EDID configurations can be generated using any of several Freeware tools.

4.6 CEC

The CEC protocol permits commands to be exchanged among the various HDMI devices. A number of these commands are available to permit communication between the devices. These commands contain opcodes, among other information. Each device connected via CEC is assigned a physical and a logical address. The logical address "TV (0)" is the sink and must always be present. If there is no device with the logical address "TV (0)", then the configuration is considered to be invalid. This means that it is not possible to test the CEC communication between only two HDMI sources.

The HDMI analyzer on the R&S®VTC/VTE/VTS represents the logical address "TV (0)". When the Start button is pressed, the R&S®VTC/VTE/VTS performs a device discovery. All connected devices are detected. The device that should receive a CEC command is defined in the Destination field. The button next to the opcode field is used to select the command to be sent.

► HDMI Analyzer → CEC → Start: Click this button to have the R&S®VTC/VTE/VTS perform a device discovery. The devices detected on the CEC bus are displayed on the left side of the screen (see Fig. 4-14).

► HDMI Analyzer → CEC → Opcode: Select a command (see Fig. 4-15) e.g. "0x36 Standby"

► HDMI Analyzer → CEC → Send: The selected command is sent; the response is displayed on the left side of the screen; this can be monitored for the appropriate DUT response based on the command, e.g. standby mode
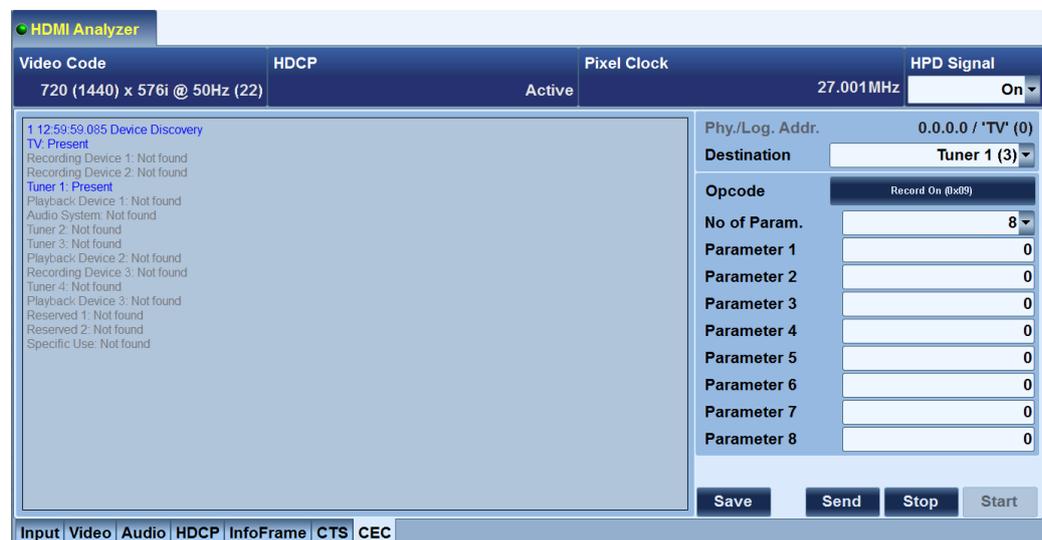
Fig. 4-14: R&S®VTC/VTE/VTS: Display on the instrument after a device discovery.

Fig. 4-15: R&S®VTC/VTE/VTS: Selecting the CEC command.

4.7   Pixel Error Test and A/V Quality Analysis

The assessment of the A/V quality (R&S®VT-K2111 A/V distortion analysis) is based on an analysis of the difference between the A/V signal to be tested and a previously acquired reference signal (double-ended audio/video analysis). The difference analysis does not assess the absolute A/V quality, but rather the deviation from a reference value. The reference can be the last frame (self-referenced), a previously acquired still picture or a previously acquired, time-limited A/V sequence (e.g. 20 seconds).

The A/V distortion analysis reliably detects pixel errors, making it possible to find errors occurring on the TMDS line.

The A/V distortion analysis records pixel errors, reliably assesses video quality based on quality parameters (peak signal-to-noise ratio (PSNR), structural similarity (SSIM) and mean opinion score (MOS)) and detects any deviation from a reference signal.

More information as well as configuration instructions for the A/V distortion analyzer are available in Application Note 7BM87 (R&S®A/V Distortion Analysis – Inspecting Output Quality of Audio and Video Devices).
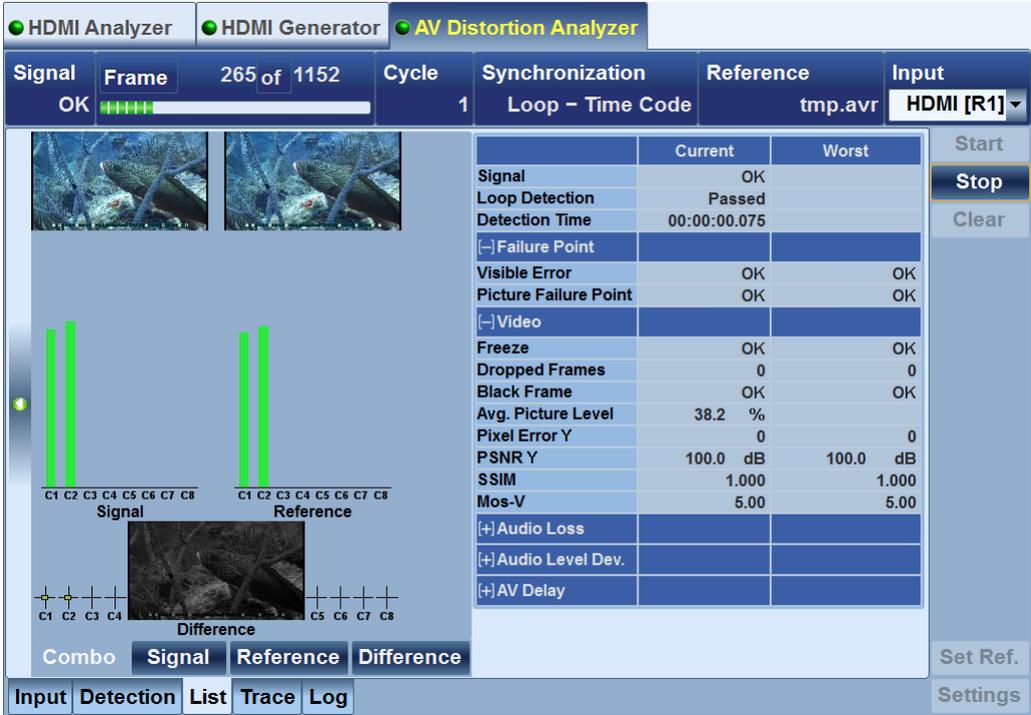
Fig. 4-16: R&S®VTC/VTE/VTS: A/V distortion analysis for assessment of the A/V quality.

5 Debugging Tests for HDMI Sinks

The applications described here use the R&S®VTC/VTE/VTS equipped with the HDMI generator module (R&S®VT-B360). This module offers four HDMI outputs, all of which are available at the same time (see Fig. 5-1). This permits parallel testing of up to four DUTs.
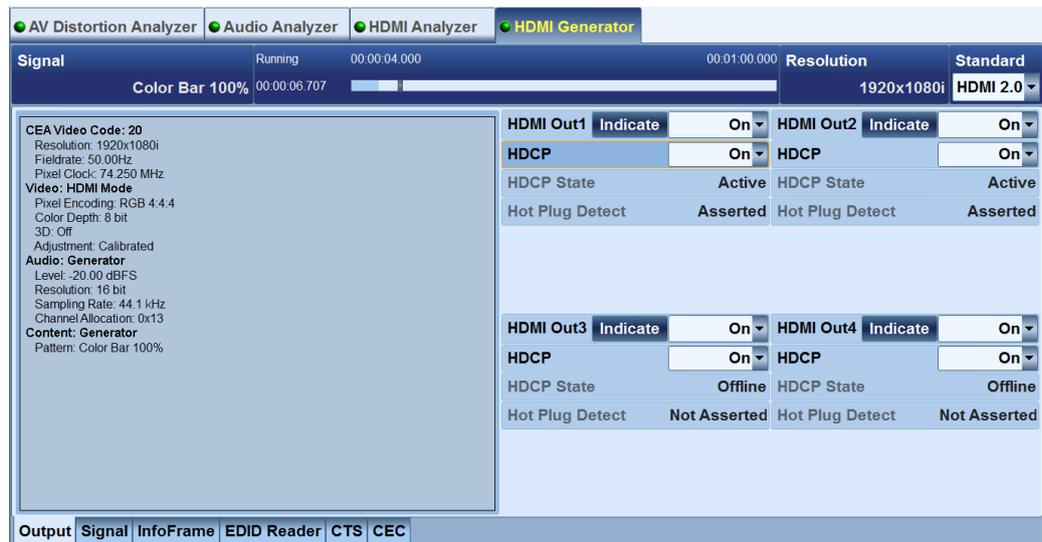
Fig. 5-1: R&S®VTC/VTE/VTS: The HDMI generator module permits up to four DUTs to be supplied with the HDMI signal simultaneously.

Unless specified otherwise for the tests described here, only the HDMI connection between the DUT and generator module is required to perform these tests (see Fig. 5-2). The first HDMI output (Output = HDMI Out1) is used as an example here. The described tests can also be performed on each of the other three HDMI outputs.
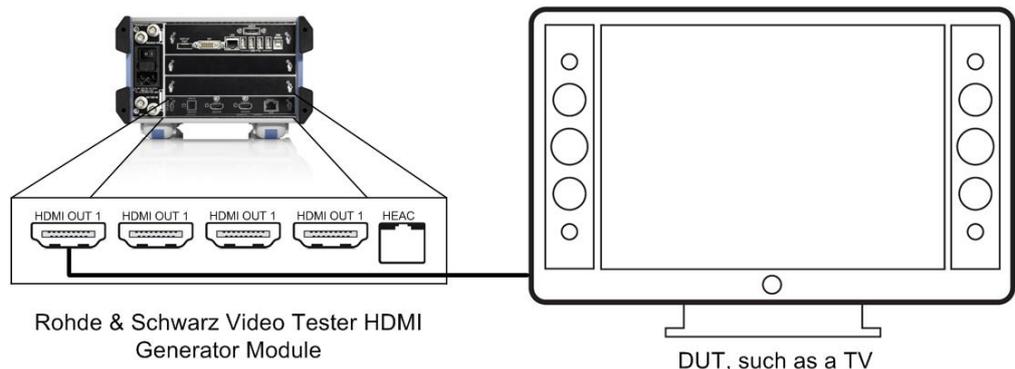
Fig. 5-2: Typical test setup for testing an HDMI sink.

5.1 Sink Response to Unsupported/Free Video Formats

An HDMI sink supports a limited number of video formats that are tested during the compliance test. With the large number of different HDMI sources, however, it is possible that an HDMI sink receives a video format that it does not support. In this case, the HDMI sink cannot display the transmitted video. User-friendly devices will display a notification to the user that there is a problem. Ideally, the HDMI sink will function again normally (without a restart) when a supported video format is received.

In order to test these scenarios, the R&S®VTC/VTE/VTS together with the HDMI generator board (R&S®VT-B360) can be used to generate user-defined video formats (free formats) as well as all video codes defined for CEA, HDMI or VESA.

The first step in the test is to select the video content[2] (see Fig. 5-4):

▶ HDMI Generator → Signal → Content Selection: Select a video or pattern, e.g. Color Bar 100%
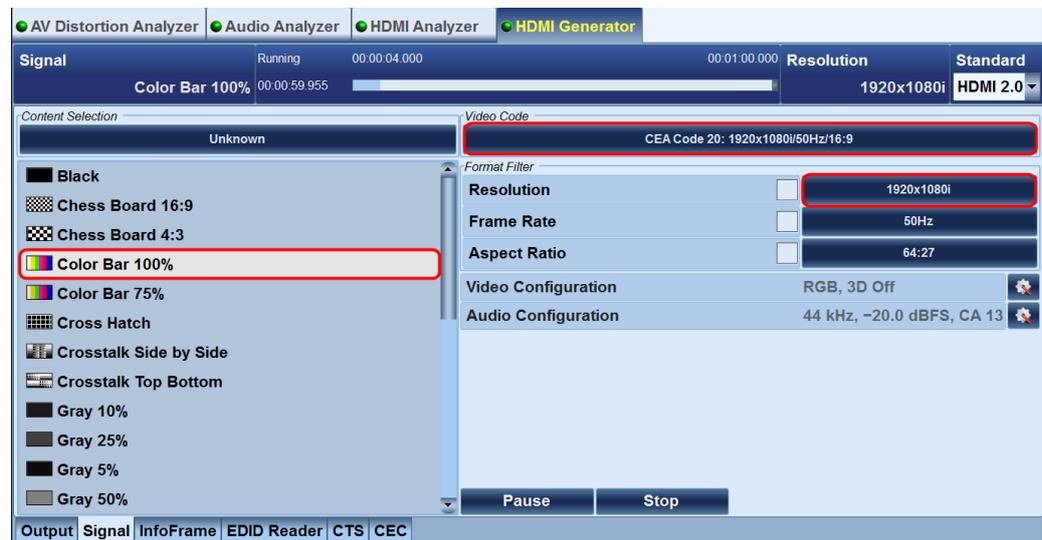
Fig. 5-3: R&S®VTC/VTE/VTS: Selecting the video content and configuring the video format.

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[2] The supplied patterns are flexible and can be assigned any desired setting. If a moving picture will be used, the Pixelshift option (HDMI Generator → Signal → Video Configuration) permits continuous motion for the pattern. The HDMI generator can also use proprietary videos in the avg format. These videos are available only with their original settings (resolution, aspect ratio, etc.). The free-of-charge software R&S®AVG Pattern Import (download available from www.rohde-schwarz.com) permits conversion to other formats.

Depending on whether a defined format is to be used or whether the video format will be defined by the user (see Fig. 5-4), either a CEA, HDMI or VESA video code should be selected:

► HDMI Generator → Signal → Video Code: Select any video code

or a user-defined video format can be set:

► HDMI Generator → Signal → Resolution: Press the button and enter the new configuration under User Defined (see Fig. 5-4)

These settings make it possible to apply first a supported, followed by an unsupported and then another supported video format to the DUT and to analyze the DUT's response.
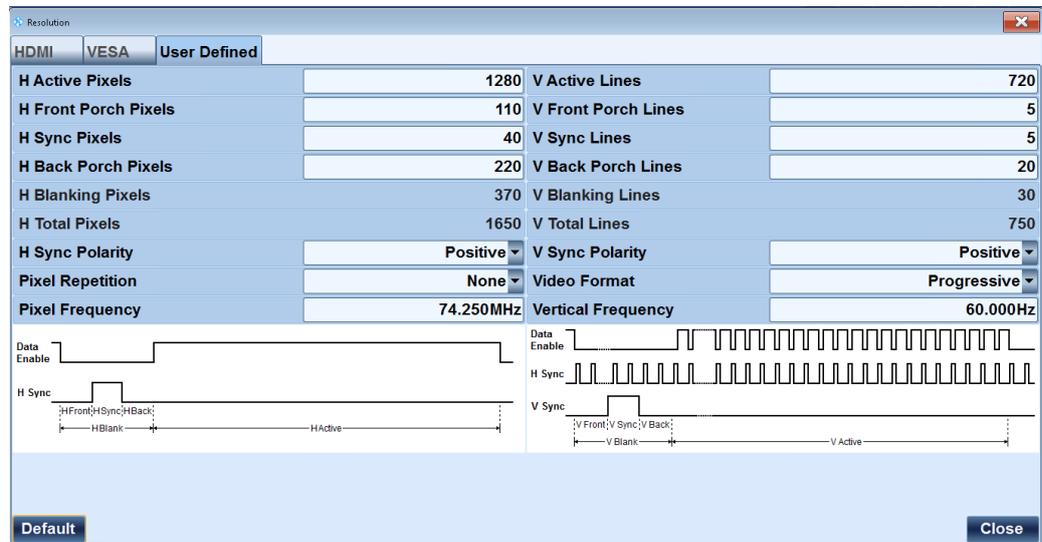
Fig. 5-4: R&S®VTC/VTE/VTS: Configuring a user-defined video format.

5.2 Sink Response to Incorrectly Signaled Data

In practice, it is possible for HDMI sources to signal data in the InfoFrames that does not match the transmitted A/V data. To test these scenarios, the R&S®VTC/VTE/VTS can be used to modify the data in the various InfoFrames (AVI InfoFrame, Audio InfoFrame, SPD InfoFrame, MPEG InfoFrame and Vendor Specific InfoFrames). To generate the faulty signaling, the signal configuration must be performed first. After the signal configuration, all data is signaled correctly in the InfoFrames. Finally, the signaling can be modified in the various InfoFrames and the DUT behavior can be tested. The "Default" button can be used to reset all InfoFrames to the correct signaling at any time.

- ► HDMI Generator → Signal → Content Selection: Select a video or pattern, e.g. Color Bar 100%

- ► HDMI Generator → Signal → Video Code: Select the VIC

- ► HDMI Generator → Signal → Video Configuration: Configure the video data

- ► HDMI Generator → Signal → Audio Configuration: Configure the audio data

- ► HDMI Generator → InfoFrame: Add an incorrect configuration to the InfoFrames (see Fig. 5-5)

In addition to testing how a DUT handles InfoFrames with incorrect signaling, the R&S®VTC/VTE/VTS also tests the DUT response to signaling that is modified during operation or to an incorrect CRC checksum.

By directly modifying the hexadecimal values of the package bytes (PB0-13), it is possible to modify the signaling as well as the CRC checksum (PB0) (see Fig. 5-5).

Fig. 5-5: R&S®VTC/VTE/VTS: Configuring the InfoFrames independently of the transmitted A/V data.

5.3 Checking the Processed Bit Depth

The resolution clipping option can be used to set the uppermost bits of the color components to 0. This reduces the color depth. If Resolution Clipping is set to 7 bpp for a true color signal (8 bpp), it will be detected by a visual check of the displayed picture. To make the difference visible to the human eye, a suitable test signal must be used:

► HDMI Generator → Signal → Content Selection: Select a suitable video or pattern, e.g. Grey Ramp

► HDMI Generator → Signal → Video Configuration → set Resolution Clipping (see Fig. 5-6)
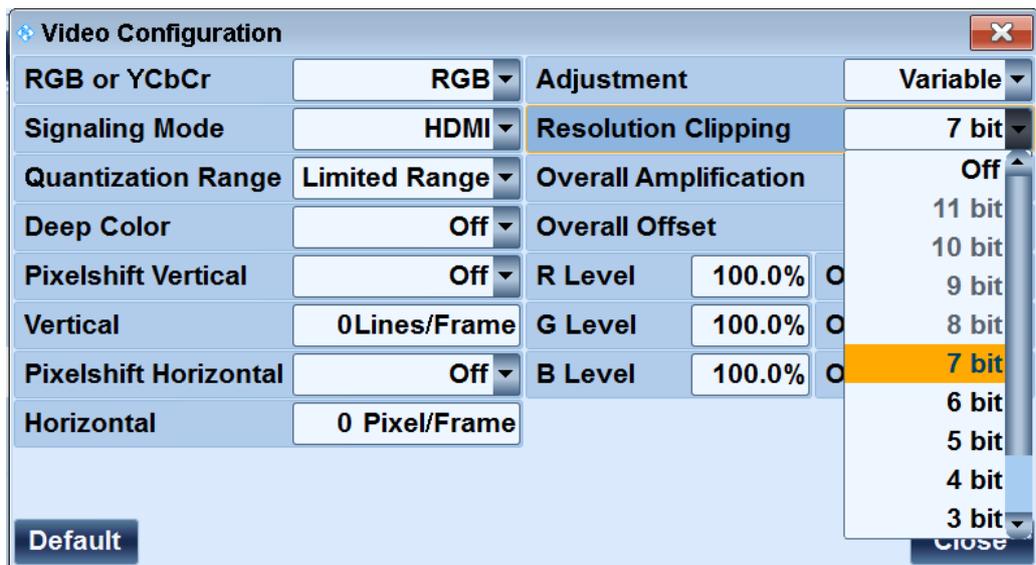
Fig. 5-6: R&S®VTC/VTE/VTS: Video Configuration dialog box.

5.4 Checking the ARC

The ARC is primarily used to transmit the sound for a TV (HDMI sink) with an integrated tuner to an A/V receiver (HDMI source). The ARC permits the transmission of audio information independently of video in the opposite direction, i.e. toward the HDMI source. The HDMI sink must transmit ARC data correctly to the HDMI source so that it can replay the audio data.

To test the ARC functionality of an HDMI sink, the HDMI sink must support the function and transmit a sound. The HDMI source must be capable of analyzing the audio signal that is transmitted via the HEAC bus of the HDMI cable.

To ensure that the DUT will transmit the ARC, the connected HDMI source should simulate an audio system and the ARC should be initialized.

► HDMI Generator → CEC → Output: HDMI Out1

► HDMI Generator → CEC → Logical Addr: Audio System (5)

► HDMI Generator → CEC → Start: Press button to execute a device discovery with the R&S®VTC/VTE/VTS. All detected devices are displayed on the left side of the screen.

► HDMI Generator→ CEC → Opcode: 0xC0

► HDMI Generator → CEC → Send: Initialize ARC

The R&S®VTC/VTE/VTS uses the audio analyzer (software option R&S®VT-K2150) to analyze the sound transmitted via the ARC. It is possible not only to check whether the audio data is transmitted (see Fig. 5-7), but also to measure the level, THD and frequency response.

► Audio Analyzer → Input: HDMI Tx Arc

The ARC check is possible only when the DUT is connected to HDMI Out 1!
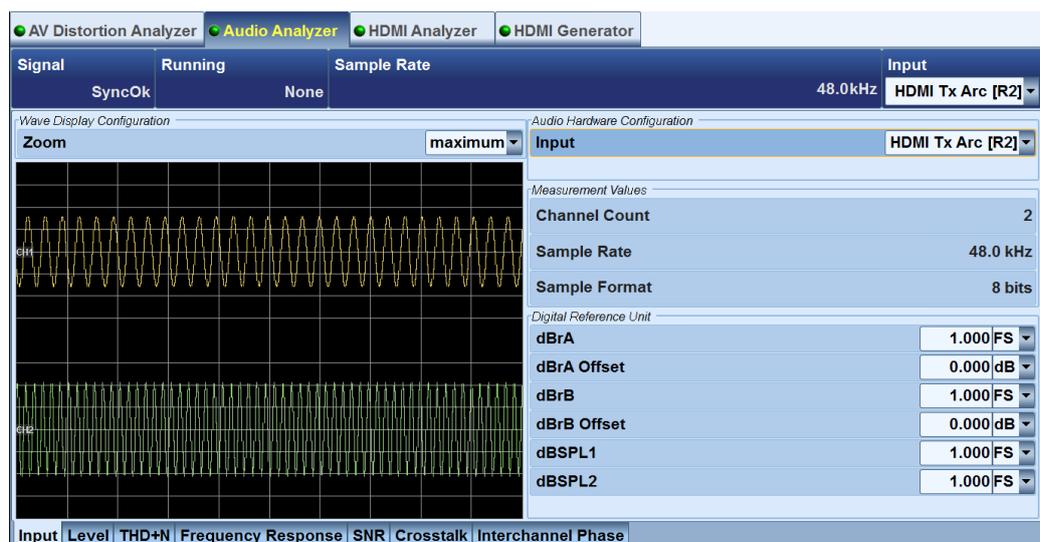
Fig. 5-7: R&S®VTC/VTE/VTS: Checking the audio data transmitted via the ARC.

5.5 HPD Test

The HPD bus permits the connected devices to be detected during operation. The DUT must detect if it is connected to the HDMI generator board (R&S®VT-B360) of the Rohde & Schwarz video analyzer during operation.

5.6 EDID Data

5.6.1 EDID Data with a HDMI Sink that is Powered off

The 5V power supply permits the DDC bus to function even when the HDMI sink is powered off. This makes it possible to read out the EDID-ROM data even when the HDMI sink is powered off. To test this, the EDID data is read from the HDMI sink when the device is powered off.

► HDMI Generator → EDID Reader → Output: HDMI Out1

► HDMI Generator → EDID Reader → Update
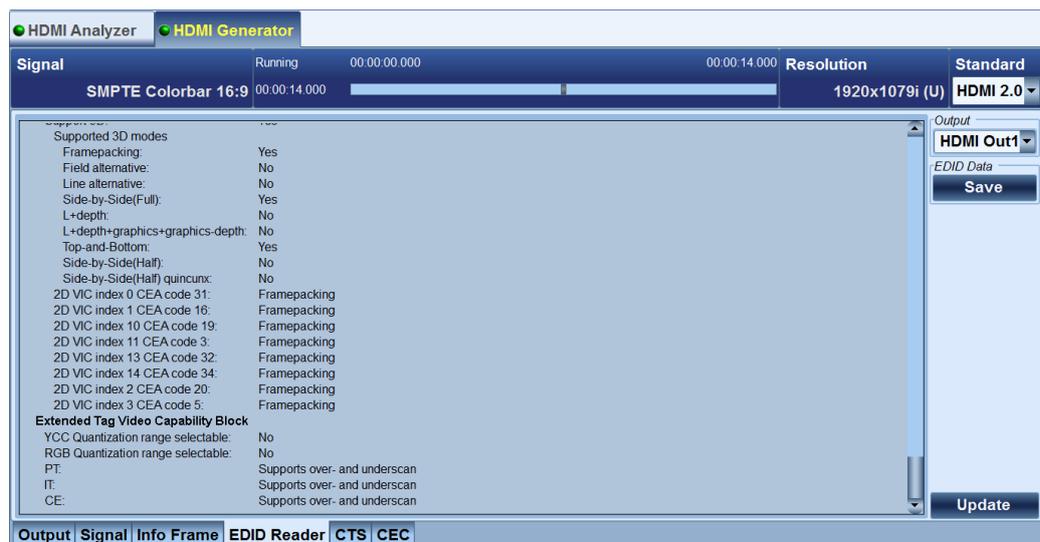
Fig. 5-8: R&S®VTC/VTE/VTS: Reading out the EDID data for a connected sink that is powered off.

5.6.2 Recording EDID Data

The HDMI generator board (R&S®VT-B360) of the Rohde & Schwarz video analyzer can read the EDID data for a connected sink and store it directly on the hard drive of the Rohde & Schwarz video tester (bin format and hex format).

► HDMI Generator → EDID Reader → Output: HDMI Out1

► HDMI Generator → Update

► HDMI Generator → EDID Reader → EDID Data → Save: The default directory for EDID files is UserData, e.g. for the R&S VTE it is "D:\VTE\UserData\EDID". The filename and directory path for the generated EDID data are displayed.

5.7 CEC

The CEC protocol permits commands to be exchanged among the various HDMI devices. A number of these commands are available to permit communication between the devices. These commands contain opcodes, among other information. Each device connected via CEC is assigned a physical and a logical address. The logical address "TV (0)" is the sink and must always be present. If there is no device with the logical address "TV (0)", then the configuration is considered to be invalid. This means that it is not possible to test the CEC communication between only two HDMI sources.

The DUT must represent the logical address "TV (0)". The device that the R&S®VTC/VTE/VTS will represent can be selected in the HDMI generator under "Logical Addr.". This field lists all addresses available, with the exception of the logical address "TV (0)". When the Start button is pressed, the R&S®VTC/VTE/VTS performs a device discovery. All connected devices are detected. The device that should receive a CEC command is defined in the Destination field. The button next to the opcode field is used to select the command to be sent.

► HDMI Generator → CEC → Output: Select the HDMI output

► HDMI Generator → CEC → Logical Addr.: Select which logical address the R&S®VTC/VTE/VTS will use

► HDMI Generator → CEC → Start: Click this button to have the R&S®VTC/VTE/VTS perform a device discovery. The devices detected on the CEC bus are displayed on the left side of the screen.

► HDMI Generator → CEC → Opcode: Select a command

► HDMI Generator → CEC → Send: The selected command is sent; the response is displayed on the left side of the screen.
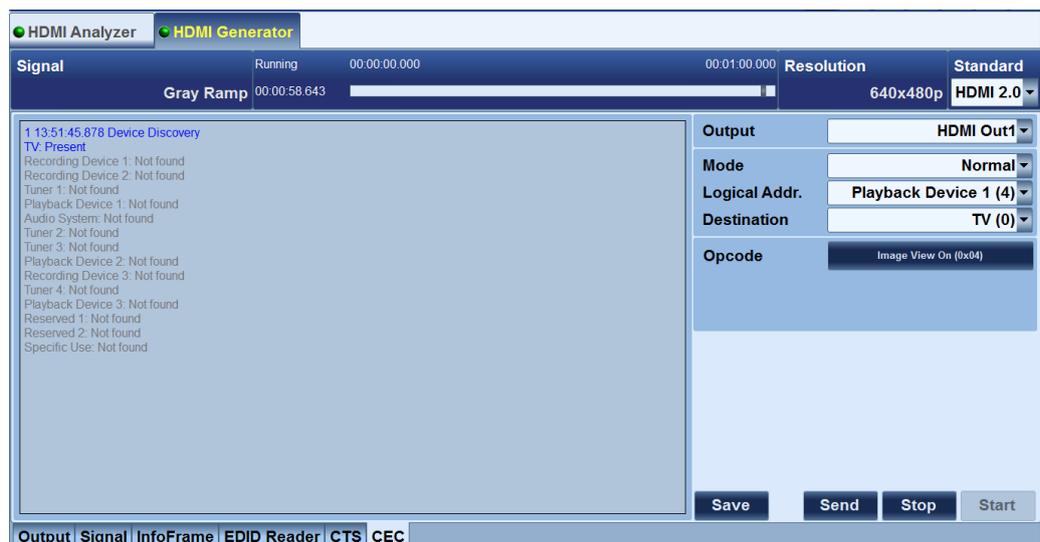
Fig. 5-9: R&S®VTC/VTE/VTS: Checking CEC commands.

6 Abbreviations

A/V	Audio and video
ACP	Audio content protection
ARC	Audio return channel
ATC	Authorized test center
AUX	Auxiliary
AVI InfoFrame	Auxiliary video InfoFrame
CDF	Capability document form
CEC	Consumer Electronics Control
CTS	Compliance test specification Cycle timestamp
DDC	Display data channel
DST Audio	Direct stream transfer of audio
DTD	Detail Time Descriptor
DTS	Digital Theater Sound
DUT	Device under test
DVI	Digital Visual Interface
E-EDID	Enhanced extended display identification data
EMI	Electromagnetic interference
HBR	High bit rate
HD	High-definition
HDCP	High-bandwidth digital copy protection
HDMI™	High-definition multimedia interface
HE-AAC	High efficiency advanced audio coding
HEAC	HDMI Ethernet and audio channel
HEC	HDMI Ethernet channel
HPD	Hot plug detection
ISRC 1/2	International Standard Recording Code 1/2
ITU	International Telecommunications Union
LPCM	Linear pulse-code modulation
MOI	Method of implementation
MPEG	Moving Picture Experts Group
S/PDIF	Sony/Philips Digital Interface
SACD	Super Audio CD
SPD	Source product description
TERC	Transmission error reduced coding
TMDS	Transition-minimized differential signaling
VGA	Video Graphics Array
VIC	Video identification code

7 References

- HDMI.org

- Rohde & Schwarz Application Brochure: HDMI measurements with the R&S®UPP audio analyzer

8 Additional Information

Our application notes are regularly revised and updated. Check for any changes at http://www.rohde-schwarz.com.

More information about R&S®VTC/VTE/VTS measurements can be found in the following Application Notes and Application Cards:

- A/V quality testing of set-top boxes and TVs

- R&S®A/V Distortion Analysis – Inspecting Output Quality of Audio and Video Devices (7BM87)

- R&S®Time Code Inserter: Time Code-Based A/V Distortion Analysis (7BM84)

- MHL2.0 Compliance Testing (7BM83)

Please send any comments or suggestions about this application note to Broadcasting-TM-Applications@rohde-schwarz.com.

9 Ordering Information

Designation	Type	Order No.
Base units		
Video Test Center	R&S®VTC	2115.7400.02
Video Tester	R&S®VTE	2115.7300.02
Compact Video Tester	R&S®VTS	2115.7100.02
HDMI Hardware Modules		
HDMI RX 225 MHz	R&S®VT-B2360	2115.7616.06
HDMI RX 300 MHz	R&S®VT-B2361	2115.7639.06
HDMI TX 300 MHz	R&S®VT-B360	2115.7500.06
Software Options		
Audio Analysis	R&S®VT-K2150	2115.8235.02
A/V Distortion Analysis[3]	R&S®VT-K2110	2115.8035.02
A/V Inspection	R&S®VT-K2111	2115.8041.02
HDMI CTS Source Test	R&S®VT-K2365	2115.8270.02
HDMI CTS Sink Test	R&S®VT-K265	2115.8312.02
R&S AVBrun, HDMI CTS Sink Test	R&S®VT-KT3356	2115.8506.02
R&S AVBrun, HDMI CTS Source Test	R&S®VT-3357	2115.8493.02

[3] A/V Distortion requires the A/V Inspection option

10 Glossary

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About Rohde & Schwarz

Rohde & Schwarz is an independent group of companies specializing in electronics. It is a leading supplier of solutions in the fields of test and measurement, broadcasting, radiomonitoring and radiolocation, as well as secure communications. Established more than 75 years ago, Rohde & Schwarz has a global presence and a dedicated service network in over 70 countries. Company headquarters are in Munich, Germany.

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Environmental commitment

▪ Energy-efficient products

▪ Continuous improvement in environmental sustainability

▪ ISO 14001-certified environmental management system

Certified Quality System
ISO 9001

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