How to perform HDMI measurements

Klaus Schiffner - September 09, 2013

Klaus Schiffner from Rohde & Schwarz explains what HDMI is, and how it needs to be evaluated. By way of example, he describes how to perform HDMI tests using the R&S UPP audio analyzer.

The high-definition multimedia interface (HDMI) has become a firmly established standard in consumer electronics. The interface allows audio and video signals as well as InfoFrames to be carried on a single cable. For audio measurements over this interface, the test instrument must be able to generate and evaluate complete test signals in HDMI format, including video signals.

HDMI is a further development of the digital visual interface (DVI) from the consumer electronics sector and came on the market in 2003. Unlike DVI, it also transmits audio signals. The interface simplifies the cabling and operation of multimedia equipment. As required by the movie industry, it largely prevents illegal copying of digital video films. As screen resolutions increased and color rendition improved, HDMI transmission bandwidths increased. Also, today it is possible for users to operate all devices connected per HDMI with a single remote control. This capability, too, was incorporated into the HDMI standard.

Figure 1: Video and audio data must be generated and analyzed for HDMI audio analysis. This figure shows the Rohde & Schwarz UPP audio analyzer, which can conduct HDMI testing simultaneously for up to eight surround sound channels using the R&S UPP audio analyzer.

The current HDMI version 1.4b supports bidirectional data transmission (on the audio return channel), new lossless compressed audio coding methods, and Ethernet connection. With the definition of the micro HDMI connector, the interface is gradually finding its way into mobile phones and portable audio devices, and a new locking connector means it can now be used in vehicles too. All these features make HDMI the most successful and versatile connector system ever in the field of audio and video. All advanced TVs, DVD and Blu-rayTM players, A/V receivers and game consoles connect with one another via HDMI cables. Digital multichannel audio and high-definition TV signals with surround sound are carried over the same cable.

Numerous interfaces
Consumer electronics manufacturers conduct comprehensive audio measurements during the development, testing, and production of their devices and audio chips. If the products have HDMI interfaces, they need an audio analyzer capable of testing audio signals as well as the transmitted InfoFrames and video signals. Additionally, the audio analyzer must provide all conventional audio interfaces:

- several XLR inputs for analog channels to test loudspeaker, headphone and preamplifier output signals
• digital audio interfaces in S/P DIF format (Sony/Philips digital interface) for BNC and TOSLINK connectors
• a digital I²S interface (inter-IC sound interface) for multichannel audio IC testing in the transmit and receive directions.

The test requirements vary greatly. Test instruments must be configurable for any interface combination. An audio analyzer must be able to feed I²S signals to a chip and then analyze the results at its HDMI output. It applies HDMI test signals to the input of an A/V receiver and tests the audio quality on the receiver's analog loudspeaker output or the headphone output. Digital outputs can be tested via an S/P DIF cable or the HDMI audio return channel. The audio analysis of surround sound transmissions includes the correct transmission of the audio signal in addition to verifying correct channel assignment, for example.

**Comprehensive audio measurements**
HDMI differentiates between a two-channel and an eight-channel data structure. With the eight-channel data structure, up to eight digital audio signals (surround sound channels) are transmitted as linear PCM data with up to 24 bit word length and up to 192 kHz sampling rate. HDMI can also transmit compressed data streams, including streams compressed using Dolby methods.

Testing eight-channel transmissions quickly and efficiently requires a test instrument with eight parallel channels. An audio analyzer can generate up to eight separate test signals in HDMI or I²S format at the same time, or it can measure up to eight input signals in parallel – HDMI, I²S or analog. Unlike pure HDMI testers, an audio analyzer offers comprehensive testing of audio signals, including parameters such as level, frequency response, crosstalk, SNR, THD+N and phase. Plus, it generates sine and multi-tone signals for intermodulation measurements as well as burst and noise signals, and plays back voice and music signals. A state-of-the-art audio analyzer is capable of:

• playing back Dolby Digital® and Dolby Digital Plus® encoded data streams and decoding them to conduct realtime measurements
• performing modulation factor analyses
• measuring difference frequency distortion (DFD), DC voltage and group delay
• carrying out fast Fourier transform (FFT) analyses on eight channels simultaneously with a resolution down to the millihertz range
• displaying the trace in the time domain

FFT analysis offers a detailed spectral representation of the signal, which is useful for detecting individual noise components during a total harmonic distortion and noise (THD+N) measurement.

**Figure 2:** The R&S UPP-B4 option, for example, features four HDMI ports and is available for HDMI tests with the R&S UPP audio analyzer. How to make video measurements

**How to make video measurements with the R&S UPP audio analyzer**
HDMI transmits audio and video data in a common frame structure. The interface is suitable for all common video formats, up to the highest resolutions. To be able to test a DUT with a full HDMI data stream, an HDMI test instrument also needs to be able to generate and analyze video data. Depending on requirements, audio analyzers used for HDMI measurements must be able to generate monochrome or multicolored, static or moving test patterns in configurable colors and color depths.

The R&S UPP audio analyzer, for example, generates test patterns conform to the CEA-861-E video standard and has a maximum resolution of 1920 x 1080 pixels. Some manufacturers require more
complex video test signals for their measurements. In this case, users can feed their own video test sequences via an HDMI interface. The R&S UPP analyzer then combines the picture data with audio test signals and transfers them to the DUT as a single HDMI data stream.

In the opposite direction, the audio analyzer receives all HDMI data and analyzes the audio content. In the simplest scenario, the quality of the transmitted video signal can be visually assessed on a connected screen. The R&S UPP audio analyzer also measures video parameters such as pixel clock, HSync and VSync frequencies, displays the timing parameters, and determines the bit error rate (BER) over an HDMI video transmission path. The time offset between video and audio signals can be measured using the lip sync function.

**Figure 3: Evaluation of HDMI video timing. Source: Rohde & Schwarz**

**Physical HDMI data channels**

In HDMI, data is transmitted between a source and a sink. A Blu-ray™ player, for instance, is a source; a TV monitor is a sink. In an HDMI cable, audio and video data and InfoFrames are transmitted between the source and the sink on four transition-minimized differential signaling (TMDS) lines. On a separate line in the display data channel (DDC), HDMI devices exchange encryption information and information to facilitate interconnection. The consumer electronics control (CEC) data bus carries data in both directions for the remote control of all connected HDMI devices, and the HDMI Ethernet audio control (HEAC) line transmits HDMI Ethernet data and the audio return channel.

**Figure 4: The physical channels in an HDMI connection. Source: Rohde & Schwarz**

**HDMI InfoFrames**

HDMI uses a large number of InfoFrames. The source product description InfoFrame, for example, contains general information on an HDMI source and the auxiliary video InfoFrame provides an HDMI sink with a range of information, including the video format being transmitted, the color depth and color range.

An HDMI tester needs to be able to generate all this data to match the HDMI test signals to be output. It also should be possible for users to edit the InfoFrame data and deliberately send incorrect data to the DUT in order to determine whether the DUT identifies errors properly and makes the corrections required by the HDMI specification.

**HDMI display data channel**

The enhanced extended display identification data (E-EDID) packet and the key information for high-bandwidth digital content protection (HDCP) data encryption are transmitted on the display data channel (DDC). An analyzer must be capable of automatically decrypting the HDMI signal to conduct measurements.

The E-EDID packet provides an HDMI source with information on the video and audio formats supported by a connected HDMI sink. The audio analyzer reads the DUT's E-EDID information and sets the HDMI test signals in the suitable format. Conversely, the analyzer provides the DUT with its E-EDID information. If required, users can alter the audio analyzer's E-EDID information in order to test how the DUT will respond. The analysis functions should be so comprehensive that the test engineer has no need for a specialized HDMI protocol tester.
HDMI Consumer electronics control (CEC)
Multiple HDMI devices can be operated with a single remote control using the bidirectional consumer electronics control (CEC) data line. During audio measurements this data should be transmitted unchanged.

HDMI Ethernet audio control (HEAC)
The HEAC line comprises the audio return channel (ARC) and the HDMI Ethernet channel (HEC). The ARC allows audio signals to be transmitted from a TV to an A/V receiver – to output audio through the loudspeakers in a multimedia system, for example. The R&S UPP audio analyzer, for example, can generate and analyze audio data on the ARC. The HDMI Ethernet channel (HEC) enables HDMI devices to access content on the Internet. The analyzer needs a suitable duplex data connection for testing Ethernet functionality.

Example: TV sink tests
The assessment of a TV via its HDMI interface is a classic example of an HDMI sink test. The audio analyzer generates test signals in HDMI format and sends them to the DUT. For eight-channel HDMI, that means eight parallel audio signals.

A listening test is often sufficient for verifying correct channel assignment. For a more accurate test, the TV audio signals are fed back to and analyzed by the test instrument either in analog format via the loudspeaker or headphone outputs, or in digital format via the S/P DIF cable.

The E-EDID data content can be analyzed to verify the DUT's response to the transmitted data contents of the audio and video InfoFrames. For visual analysis of the video quality, the tester checks if the picture data is displayed without error.

Example: A/V receiver tests
Because A/V receivers have both HDMI inputs and outputs, measurements are performed in both directions on all A/V inputs and outputs. The audio analyzer generates complete HDMI test signals, with audio, video and data content. When the test signals are fed in over HDMI, the audio signals are processed in the A/V receiver and then sent to the various outputs. Then they can be measured in analog format at the speaker, headphone or preamplifier outputs. In order to test the digital outputs, the analyzer must offer the same interfaces as the A/V receiver. Besides the S/P DIF interface, these are the RCA ports for coaxial cables and/or TOSLINK connectors for fiber optic cables. The test instrument compares the input signals with the previously generated HDMI signals.

If the analyzer feeds audio/video test signals in the opposite direction to the DUT, for example via the S/P DIF interface, it can receive and test the related output signals via the analog output or the HDMI interface.

Compressed data, e.g. using the Dolby Digital or Dolby Digital Plus methods, are widely used, especially for consumer electronics. To test if the A/V receiver correctly decompresses the data, the analyzer must be able to generate this kind of data.
To make sure that the A/V receiver acts according to the HDMI specifications, it is also possible to test how it responds if the HDMI InfoFrames are incorrect or do not match up. For that reason, the HDMI test data must be editable.

With the right audio analyzer, users often have no need for additional T&M equipment, such as an HDMI protocol tester. All key tests can be conducted using a single instrument. This reduces both space requirements and costs.

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Klaus Schiffner’s profile.

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