STE February
HDMI Overview and Picture testing

Presented by Steve Holmes
Agenda

- Overview, HDMI 1.3, 1.4, 1.4A & 3D
- Deconstructing HDMI - how is it related to SDI
- Where did my Anc data go
- Challenges in Monitoring Video over HDMI, HDCP, STB, OTT, CALM act, Tablet, Phone, ??
HDMI Overview
HDMI what is it

- **HDMI (High-Definition Multimedia Interface)**
  - is a compact audio/video interface for transferring uncompressed digital audio/video data from an HDMI-compliant device ("the source device") to a compatible digital audio device, computer monitor, video projector, or digital television. HDMI is a digital replacement for existing analog video standards.
  - can be used for any uncompressed video format, including standard, enhanced, high definition, and 3D video signals; with up to 8 channels of compressed or uncompressed digital audio
  - HDMI can use **HDCP** (High-bandwidth Digital Content Protection) to encrypt the signal if required by the source device. CSS, CPRM and AACS require the use of HDCP on HDMI when playing back encrypted DVD Video, DVD Audio, HD DVD and Blu-ray Disc
HDCP what is it?

- HDCP (High-bandwidth Digital Content Protection)
  - HDMI can use HDCP to encrypt the signal, if it is required by the source device.

- Content Scramble System, (CSS), is a Digital Rights Management, (DRM), and encryption system employed on commercially produced DVD-Video discs. Utilizes a proprietary 40-bit stream cipher. Introduced around 1996.

- Content Protection for Recordable Media and Pre-Recorded Media, (CPRM/CPPM), mechanism for controlling the copying, moving and deletion of digital media on a personal computer or other digital player. A form of Digital Restrictions Management, (DRM), developed by the 4C Entity, LLC (consisting of IBM, Intel, Matsushita and Toshiba).

- The Advanced Access Content System, (AACS), intended to restrict access to and copying of the post DVD generation of optical discs. Released April 2005 and adopted as the access restriction scheme for HD DVD and Blu-ray Disc. Developed by a consortium that includes Disney, Intel, Microsoft, Panasonic, Warner Bros., IBM, Toshiba and Sony.
HDMI Connectors

- There are 5 types of HDMI Connectors.
- Type A, B, C, D, E
- Type A Standard HDMI Connector
- Type B has a 2 TMDS links. (Dual Link HDMI) for Super High Resolutions >4K
- Type C is a smaller Version of Type A
- Type D is a Micro Version of Type A
- Type E is for Automotive applications
HDMI Video Channels and Signals

- **TMDS** - Transition Minimized Differential Signaling
  - During the Video Data Period, the pixels of an active video line are transmitted during the horizontal and vertical blanking intervals, audio and auxiliary data are transmitted within a series of packets. The Control Period occurs between Video and Data Island periods.

- **DDC** - The Display Data Channel
  - A communication channel used by the HDMI source device to read the E-EDID data from the HDMI sync device to learn what audio/video formats it supports. The standard mode speed (100 kbit/s) and allows optional support for fast mode speed (400 kbit/s) used for HD Content Protection.

- **Utility Line**
  - Is used for Ethernet and return Audio

- **HPD** - Hot Plug Detect

- **CEC** - Consumer Electronics Control
  - Command and control up-to ten CEC-enabled devices
HDMI Channels

**HDMI Block Diagram**

- **Video**
- **Audio**
- **Control/Status**

**HDMI Transmitter**
- TMDS Channel 0
- TMDS Channel 1
- TMDS Channel 2
- TMDS Clock Channel
- Display Data Channel (DDC)

**HDMI Receiver**
- EDID ROM
- Video
- Audio
- Control/Status

- **CEC**
- **HEAC**
- **detect**
- **Utility Line**
- **HPD Line**

High-Definition Multimedia Interface

Specification Version 1.4

HDMI Licensing, LLC
HDMI Versions 1.0 – 1.2a

- HDMI 1.0 was released on December 9, 2002
  - A single cable digital Audio/Video interface with a TMDS bandwidth of 4.95 Gbit/S allowing 3.96 Gbit/S of video bandwidth, (1080p/60 UXGA) and 8 channels of LPCM/192 kHz/24 bit Audio.

- HDMI 1.1 was released on May 20, 2004
  - Added support for DVD Audio.

- HDMI 1.2 was released on August 8, 2005
  - Added up to 8 channels of one bit audio and the Type A connector for computer sources.

- HDMI 1.2a was released on December 14, 2005
  - Fully specifies Consumer Electronics Control.
HDMI Versions 1.3 – 1.3C

- HDMI 1.3 was released June 22, 2006
  - Increased the single-link bandwidth to 340 MHz, (10.2 Gbit/S), increased deep color from 24 bit to 30 bit, 36 bit, 48 bit. Added Dolby TrueHD & DTS-HD audio and Audio/Video Sync. Defined category 1 & 2 cables and test procedures. Added type C connector.

- HDMI 1.3a was released on November 10, 2006
- HDMI 1.3b was released on March 26, 2007
- HDMI 1.3b1 was released on November 9, 2007
- HDMI 1.3c was released on August 25, 2008
- Each adding or changing specific items and some housekeeping.
HDMI 1.4 – 1.4a

- HDMI 1.4
  - HDMI 1.4 cable has a new data channel that 1.3 and earlier did not have, for a Reverse Ethernet Channel and return audio.
  - HDMI 1.4 required that 3D displays support the frame packing 3D format at either 720p50 and 1080p24 or 720p60 and 1080p24.
  - Increase in the maximum resolution to 4K × 2K

- HDMI 1.4a
  - The big change from 1.4 was that 1.4a added side-by-side 3D horizontal at either 1080i50 or 1080i60 and top-and-bottom 3D at either 720p50 and 1080p24 or 720p60 and 1080p24.

- Change in the cable from 1.3 to 1.4, No change in the cable between 1.4 and 1.4a
HDMI 1.4 Ethernet Channel

- Change from 1.3 to 1.4

- Some STB may check to see if Pin 14 is used, to know that the TV supports Side-by-Side 3D
  - Needs 1.4 HDMI cable
  - (HEC –data)
HDMI 1.4 4K x 2K Support

- Resolution on par with state-of-the-art Digital Cinema projectors used in the local multiplexes will be coming to your living rooms. 4K x 2K which represents resolutions of 3840x2160 and 4096x2160 will both be supported by HDMI 1.4
The specification for this channel is not as challenging as for the higher speed 3.4Gbps TMDS pair and performance can be achieved by managing the physical cable design with particular consideration to the attenuation, common mode impedance and differential impedance. For more details on the HEAC channel performance targets, refer to the HEAC1 Supplement to the HDMI Specification.
HDMI vs SDI
HDMI signals

- Transition-minimized differential signaling (TMDS) is a technology for transmitting high-speed serial data and is used by the DVI and HDMI video interfaces, as well as other digital communication interfaces.

- The transmitter incorporates an advanced coding algorithm which reduces electromagnetic interference over copper cables and enables robust clock recovery at the receiver to achieve high skew tolerance for driving longer cables as well as shorter low cost cables.

- HDMI carries video, audio and auxiliary data via one of three modes, called the Video Data Period, the Data Island Period and the Control Period.

- During the Video Data Period, the pixels of an active video line are transmitted. During the Data Island period (which occurs during the horizontal and vertical blanking intervals), audio and auxiliary data are transmitted within a series of packets. The Control Period occurs between Video and Data Island periods.

- This format is very similar to SDI SAV-Video-EAV-Anc data.
Sample Frame of HDMI data
TMDS channels

- The Video carried across the link will be in one of 3 formats.
  - RGB 4:4:4
  - YCbCr 4:4:4
  - YCbCr 4:2:2

- 8 Bit color is mandatory
- 10, 12, or 16 Bit color is optional. (Deep Color) if Deep Color is supported 12 Bit is mandatory. (1.3)
Video Levels Full Range, Limited Range

- SDI normal range 10 bit video is 64 to 940
- SDI extended range 10 bit is 4 to 1019
- HDMI see below

<table>
<thead>
<tr>
<th>Color Component</th>
<th>Component Bit Depth</th>
<th>for Full range</th>
<th>for Limited range</th>
</tr>
</thead>
<tbody>
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<td></td>
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<td>Nominal Peak</td>
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<td>0</td>
<td>255</td>
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<tr>
<td>R / G / B</td>
<td>10</td>
<td>0</td>
<td>1023</td>
</tr>
<tr>
<td>R / G / B</td>
<td>12</td>
<td>0</td>
<td>4095</td>
</tr>
<tr>
<td>R / G / B</td>
<td>16</td>
<td>0</td>
<td>65535</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Color Component</th>
<th>Component Bit Depth</th>
<th>for Full range</th>
<th>for Limited range</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Black level</td>
<td>Nominal Peak</td>
</tr>
<tr>
<td>Y</td>
<td>8</td>
<td>0</td>
<td>255</td>
</tr>
<tr>
<td>Cb / Cr</td>
<td>8</td>
<td>0</td>
<td>0 and 255</td>
</tr>
<tr>
<td>Y</td>
<td>10</td>
<td>0</td>
<td>1023</td>
</tr>
<tr>
<td>Cb / Cr</td>
<td>10</td>
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<td>0 and 1023</td>
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<td>0 and 4095</td>
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<tr>
<td>Y</td>
<td>16</td>
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<td>65535</td>
</tr>
<tr>
<td>Cb / Cr</td>
<td>16</td>
<td>0</td>
<td>0 and 65535</td>
</tr>
</tbody>
</table>

Extended Range Y Cb Cr added in 1.4
Video Data Encoding

- Each 8 bits of video data is coded to 10 bits, using a type of 8b 10b coding.
- Each 10 Bit output is either XOR or XNOR to produce the fewest transitions. With LSb of output matching LSb of input.
- This output then may be inverted to produce the best DC balance of the transmitted stream.
- On Sources and Sinks any analog format that is supported will be supported in HDMI, frame rate and color space.
- All HDMI Sources and Sinks shall support RGB 4:4:4
- All Sources shall support either YCbCr 4:4:4 or YCbCr 4:2:2.
- All Sinks shall support both YCbCr 4:4:4 and YCbCr 4:2:2
Video Data Encoding

Transmit Video data in

8B to 10B

NOR

XNOR

Invert

Video data out

Receive Video data in

Invert

XNOR

NOR

10B to 8B

Video data out
Aux Data Information

- **Source Prod Desc**: indicates the Source Product Description that is the name of the manufacturer of the device, if present.
- **Aspect Ratio**: indicates the aspect ratio of the image.
- **ACP Packet**: indicates presence of Audio Content Protection Packet.
- **ISRC Packet**: indicates presence of International Standard Recording Codes.
- **Gamut Packet**: indicates presence of.
- **Vendor Specific Info**: indicates the presence of Vendor Specific Information.
- **AVI Info**: indicates presence of AVI Info frame.
- **Source Prod Desc Info**: indicates the presence of Source Product Description Information.
- **Audio Info**: indicates presence of Audio Information.
- **MPEG Source Info**: indicates presence of MPEG Source Information.

<table>
<thead>
<tr>
<th>Source Prod Desc:</th>
<th>MOTOROLAQIP-7100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspect Ratio:</td>
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</tr>
<tr>
<td>ACP Packet:</td>
<td>Missing</td>
</tr>
<tr>
<td>ISRC Packet:</td>
<td>Missing</td>
</tr>
<tr>
<td>Gamut Packet:</td>
<td>Missing</td>
</tr>
<tr>
<td>Vendor Specific Info:</td>
<td>Present</td>
</tr>
<tr>
<td>AVI Info:</td>
<td>Present</td>
</tr>
<tr>
<td>Source Prod Desc Info:</td>
<td>Present</td>
</tr>
<tr>
<td>Audio Info:</td>
<td>Present</td>
</tr>
<tr>
<td>MPEG Source Info:</td>
<td>Missing</td>
</tr>
</tbody>
</table>

Sent during Data Island periods
Closed Captions

- In NTSC 608 captions are carried on Line 21 of the actual Video
- In HD SDI 708 captions are carried as a Data packet in the Vertical Ancillary space (608 are carried inside of the 708 packet)
- In MPEG 608 are on a Visible Picture line so it is coded with the Video
- In MPEG 708 Captions are carried as user data in the header of each Picture start code
- HDMI knows nothing about Captions!! It is STB or DVD/BluRay player that will overlay the captions on the video
Content protection (HDCP)

- There are three main parts to HDCP’s security system.
  - AKE
    - First, there is the cryptographic Authentication and Key Exchange (AKE). When a company wishes to produce an HDCP-compliant device, that company requests a set of keys from the HDCP licensing body.
    - After the licensing body has determined that the company’s product has been designed in a manner robust enough to withstand attacks and that the keys will be protected, the company will be given a series of unique secret keys.
  - Hand Shake
    - Once both the playback device and the display device have settled on a value with which to encrypt the content, all the video content will be encrypted using this mutual value (this is the second part). Additionally, the system will check every couple of seconds to ensure the integrity of both the keys and the link.
  - Key-revocation list
    - The third aspect of HDCP security is device renewability. This is the ability for media, streaming content, or even other devices to invalidate keys known to be a problem.
Non HDCP receivers

- What happens when a Non HDCP receiver is hooked to a HDCP transmitter.
  - The transmitter tries to handshake the receiver does not respond and the transmitter shuts off in about 3 to 5 seconds.
  - We have not even started the content yet to see if it is protected or not.

- HDCP does not turn on and off. If a device is HDCP compliant the HDCP signaling is always on, even for not protected content.
HDMI Monitoring
How to see the Output of a HDMI device

- You need an HDCP compliant device.

Set Top Box

HDCP compliant Waveform Monitor

Cell Phone or Tablet
How to see the Output of a HDMI device

- You need an HDCP compliant device.

HDCP compliant Picture Quality Tester
Tektronix Transcoder Performance Verification Application

To test the Quality of the Transcoder, capture the output of the Master encoder (the mezzanine file) then Capture the output of the Transcoder at all of the Rates. Run the DMOS test on the PQA600A

- Tektronix PQA600
- Compare Video Quality pre and post Transcoder and at output of the player
Tektronix Transcoder Performance Verification Application

To test the Quality of the System End to End, capture the output of the Transcoder (use the captured file from the previous test) then Capture the output of Playout device if you have the Test Client you can request the different rates. Run the DMOS test on the PQA600A

- Tektronix PQA600
- Compare Video Quality pre and post Transcoder and at output of the player
Pre-introduction Technology Demonstration

**New** Set Top Box Monitoring – WFM/WVR5250

- HDMI (with HDCP)
  - Content Monitor
  - Audio Loudness Monitoring for the CALM “Quick Check”
  - Black / Frozen Video Detection and valid color gamut
  - Advanced Error Logging with Web Server UI Full Control

- HDMI A/B Switched Input
- HDMI Out
HDMI Data Screens
Video Session Screens

- Input Signaled format
- Measured Format
- Input & Output HDCP status

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Status</th>
<th>.Err Secs</th>
<th>.Err Fields</th>
<th>. % Err Fields</th>
</tr>
</thead>
<tbody>
<tr>
<td>RGB Gamut Error</td>
<td>OK</td>
<td>38</td>
<td>1637</td>
<td>0.5453 %</td>
</tr>
<tr>
<td>Cmpt Gamut Error</td>
<td>OK</td>
<td>203</td>
<td>4556</td>
<td>1.5175 %</td>
</tr>
<tr>
<td>Luma Gamut Error</td>
<td>OK</td>
<td>31</td>
<td>1486</td>
<td>0.4950 %</td>
</tr>
</tbody>
</table>

Black Events: 1  Frozen Events: 19
Changed since reset: N/A  Run Time: 0 d, 01:23:32  Running
Press "SEL" to reset. Any "arrow key" stops/starts.
When things are not correct...

- Input format was signaled as 12b
- But received data was only 8b
When things are not correct…

- Input format was signaled as 1080P
- But received data was 601 color space

Color is washed out
When things are not correct…

Video Protected by HDCP

Auxiliary Data Status

Source Prod Desc: dcomBD Player
Aspect Ratio: 16:9
ACP Packet: Missing
EBR Packet: Missing
Gamut Packet: Missing
Vendor Specific Info: Missing
AVI Info: Present
Source Prod Desc Info: Present
Audio Info: Present
MPEG Source Info: Missing

Video Session

Input: HDMI Input 1A  Signal: Locked
Effective: Auto 1080p 59.94 – RGB 4:4:4 8b HDMI – HDMI
Colorimetry: 709
Colorspace: RGB
Color Depth: 8-bit/channel
TMDS Clock: 148.359375 MHz
HDMI/DVI: HDMI
Pixel Rep. Rate: 1X
Quantiz. Range: Default

Statistics

RGE Gamut Error: OK
CMY Gamut Error: OK
Luma Gamut Error: OK

Err Secs  Err Fields  % Err Fields
97  5104  5.9999%
56  2323  3.3185%
66  3843  4.5164%

ID: WVR3250_1f941a
HDMI Audio: ----- -----  
TC: Disabled

Press "SEL" to reset. Any "arrow key" stops/starts.
When things are not correct…

- Color Bars not quite correct look at Red and Magenta
- Other colors are off also
EDID data dump

<table>
<thead>
<tr>
<th>EDID Transmitted on HDMI IN:</th>
<th>Page 3 of 3</th>
</tr>
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<tbody>
<tr>
<td>0x0 0x1 0x2 0x3 0x4 0x5 0x6 0x7 0x8 0x9 0xa 0xb 0xc 0xdd 0xe 0xf</td>
<td></td>
</tr>
<tr>
<td>0x0 00 ff ff ff ff ff ff 00 50 ab 07 11 01 00 00 00</td>
<td></td>
</tr>
<tr>
<td>0x1 33 16 01 03 80 0c 09 78 0a 1e ac 98 59 56 85 28</td>
<td></td>
</tr>
<tr>
<td>0x2 29 52 57 00 00 00 01 01 01 01 01 01 01 01 01 01</td>
<td></td>
</tr>
<tr>
<td>0x3 01 01 01 01 01 01 8c 0a d0 8a 20 e2 2d 10 10 3e</td>
<td></td>
</tr>
<tr>
<td>0x4 96 00 81 60 00 00 00 00 18 01 1d 80 18 71 1c 16 20</td>
<td></td>
</tr>
<tr>
<td>0x5 58 2c 25 00 81 49 00 00 00 9e 00 00 00 fc 00 54</td>
<td></td>
</tr>
<tr>
<td>0x6 45 4b 2d 35 32 35 30 0a 00 00 00 00 00 00 00 00</td>
<td></td>
</tr>
<tr>
<td>0x7 00 17 3d 0d 2e 11 00 0a 20 20 20 20 20 20 20 01 0f</td>
<td></td>
</tr>
<tr>
<td>0x8 02 03 26 71 4d 90 05 01 02 04 01 11 14 13 1f 06 15</td>
<td></td>
</tr>
<tr>
<td>0x9 03 12 23 0f 04 01 83 4f 00 00 6b 03 0c 00 10 00</td>
<td></td>
</tr>
<tr>
<td>0xa 80 2d 20 00 02 1d 01 1d 00 72 00 d0 1e 00 6e 28</td>
<td></td>
</tr>
<tr>
<td>0xb 00 00 81 49 00 00 00 00 18 d6 09 80 a0 00 e0 2d 00</td>
<td></td>
</tr>
<tr>
<td>0xc 10 60 00 00 81 60 00 08 08 18 8c 0a d0 90 00 40</td>
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<tr>
<td>0xd 31 00 0c 40 00 00 81 60 00 00 00 18 00 00 00 00</td>
<td></td>
</tr>
<tr>
<td>0xe 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00</td>
<td></td>
</tr>
<tr>
<td>0xf 00 00 00 00 00 00 00 00 00 00 00 00 00 00 4e</td>
<td></td>
</tr>
</tbody>
</table>

Arrow Left, Up – Previous page, Right, Down – Next page.
## EDID Data fields

<table>
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<tr>
<th>EDID</th>
<th>Column</th>
<th>Value</th>
<th>Description</th>
</tr>
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<tbody>
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<td>0x0</td>
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<td>00 FF FF FF FF FF FF 00</td>
<td>Fixed Header</td>
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<tr>
<td>0x0</td>
<td>0x8 - 0x9</td>
<td>XX XX</td>
<td>Manufacturer ID</td>
</tr>
<tr>
<td>0x0</td>
<td>0xa - 0xb</td>
<td>XX XX</td>
<td>Manufacturer Product Code</td>
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<tr>
<td>0x0</td>
<td>0xc - 0xf</td>
<td>XX XX XX XX</td>
<td>Serial Number</td>
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<td>0x0</td>
<td>XX</td>
<td>Week of Manufacture</td>
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<td>0x0 - 0x2</td>
<td>XX XX XX</td>
<td>Chromaticity Coordinates</td>
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<td>XX XX</td>
<td>Established timing bitmap</td>
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<td>0x6 - 0xf</td>
<td>XX..............XX</td>
<td>Standard timing information</td>
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<tr>
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<td>0x0 - 0x5</td>
<td>XX..............XX</td>
<td>Standard timing information</td>
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<td>0x6 - 0xf</td>
<td>XX..............XX</td>
<td>Descriptor 1</td>
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<td>Descriptor 1</td>
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<td>0x8 - 0xf</td>
<td>XX..............XX</td>
<td>Descriptor 2</td>
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<td>0x5</td>
<td>0x0 - 0x9</td>
<td>XX..............XX</td>
<td>Descriptor 2</td>
</tr>
<tr>
<td>0x5</td>
<td>0xa - 0xf</td>
<td>XX..............XX</td>
<td>Descriptor 3</td>
</tr>
<tr>
<td>0x6</td>
<td>0x0 - 0xb</td>
<td>XX..............XX</td>
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</tr>
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<td>0xc - 0xf</td>
<td>XX..............XX</td>
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<td>0xf</td>
<td>XX</td>
<td>Checksum</td>
</tr>
</tbody>
</table>

Additional rows 0x8 to 0xf can contain CEA-861 extension block information that contains further audio and video descriptors.
Notes On CALM Act
Audio Monitoring

Loudness

Calm Spot Check
Post - STB
# Audio Monitoring

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<thead>
<tr>
<th>Audio Input:</th>
<th>HDMI A</th>
<th>Signal Loss:</th>
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<td>Clip</td>
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<tr>
<td>Over</td>
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<td></td>
</tr>
<tr>
<td>Loud</td>
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<td></td>
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<tr>
<td>Mute</td>
<td>4 3 1 1 1 1 1 2</td>
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</tr>
<tr>
<td>Silence</td>
<td>1 1 5 4 4 4 4 4</td>
<td></td>
</tr>
<tr>
<td>Peak (dBFS)</td>
<td>-14.8 -14.8 -- -- -- -- -- -12.0</td>
<td></td>
</tr>
<tr>
<td>High (dBFS)</td>
<td>-14.8 -14.8 -- -- -- -- -- -13.4</td>
<td></td>
</tr>
<tr>
<td>Active bits</td>
<td>16 16 16 0 16 16 16 0</td>
<td></td>
</tr>
<tr>
<td>Leq (LKFS)</td>
<td>-19.1 -19.1 -- -- -- -- -- --</td>
<td></td>
</tr>
<tr>
<td>Leq (LKFS)</td>
<td>-16.1 -- -- -- -- -- -- --</td>
<td></td>
</tr>
<tr>
<td>Pgm: 1 LKFS Inf: -15.8 Short: -16.1 Short Pd: 0s Chans: LCRLsRsLfe</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Changed since reset: Yes    Run Time: 0 d, 00:01:56   Running
Press "SEL" to reset. Any "arrow key" stops/starts.
CALM Act Spot Check

- A “spot check” requires monitoring 24 uninterrupted hours of programming with an audio loudness meter employing the measurement technique specified in the RP, and reviewing the records from that monitoring to detect any commercials transmitted in violation of the RP.

- To promote the reliability of the spot check, the station or MVPD must not provide prior notice to the programmer of the timing of the spot check. This requirement applies with respect to all spot checks (annual or in response to a Commission inquiry) on all programming, and for all stations and MVPDs – large and small. Stations (and occasionally MVPDs) may have multiple program suppliers for a single channel/stream of programming.

- In these cases, there may be no single 24-hour period in which all program suppliers are represented. In such cases, an annual spot check could consist of a series of loudness measurements over the course of a 7-day period, totaling no fewer than 24 hours that measure at least one program, in its entirety, provided by each non-certified programmer that supplies programming for that channel or stream of programming.
CALM Act Spot Check

- To verify that the operator’s system is properly passing through loudness metadata, spot checking must be conducted after the signal has passed through the operator’s processing equipment (e.g., at the output of a set-top box or television receiver). If a problem is found, a station or MVPD may check multiple points in its reception and transmission process to determine the source of the noncompliance.

- For a spot check to be considered valid, a station or MVPD must be able to demonstrate appropriate maintenance records for the audio loudness meter, and to demonstrate, at the time of any enforcement inquiry, that appropriate spot checks had been ongoing. (FCC 11-182 Paragraph 38 Pg. 25)
CALM Act 24 hour run

<table>
<thead>
<tr>
<th>Date &amp; Time</th>
<th>LKFS</th>
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<tbody>
<tr>
<td>Tue, 16 Oct 2012 10:00:08</td>
<td>-26</td>
</tr>
<tr>
<td>Tue, 16 Oct 2012 11:00:15</td>
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<tr>
<td>Tue, 16 Oct 2012 12:00:45</td>
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<td>Tue, 16 Oct 2012 13:00:45</td>
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<td>Tue, 16 Oct 2012 14:01:44</td>
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<td>21</td>
</tr>
<tr>
<td>Tue, 16 Oct 2012 00:01:44</td>
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<tr>
<td>Wed, 17 Oct 2012 01:04:46</td>
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<tr>
<td>Wed, 17 Oct 2012 02:04:46</td>
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<tr>
<td>Wed, 17 Oct 2012 03:04:46</td>
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<tr>
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<tr>
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<td>-24</td>
</tr>
<tr>
<td>Wed, 17 Oct 2012 09:00:45</td>
<td>-26</td>
</tr>
</tbody>
</table>
HDMI 3D formats
3D Formats

- Frame Pack

3D horizontal total pixel is equal to 2D horizontal total pixel.
3D vertical total line is x2 of 2D vertical total line.
3D pixel clock frequency is x2 of 2D pixel clock frequency.
This structure can be applied only for progressive video format.

3D video

Vact_space = Vblank
3D Formats

- Frame Pack Interlace

- 3D horizontal total pixel is equal to 2D horizontal total pixel.
- 3D vertical total line is x2 of 2D vertical total line.
- 3D pixel clock frequency is x2 of 2D pixel clock frequency.
- 3D Vsync pulse is inserted per frame. (2D Vsync pulse is inserted per field)
- Vactive is number of active lines per field.
- This structure can be applied only for interlaced video format.
3D Formats

- Side by Side (Half)

2D video
- 3D horizontal total pixel is equal to 2D horizontal total pixel.
- 3D vertical total line is equal to 2D vertical total line.
- 3D pixel clock frequency is equal to 2D pixel clock frequency.
- For interlaced formats, Vactive is number of active lines per field

3D video
3D Formats

- Top Bottom (Half)

2D video
- 3D horizontal total pixel is equal to 2D horizontal total pixel.
- 3D vertical total line is equal to 2D vertical total line.
- 3D pixel clock frequency is equal to 2D pixel clock frequency.
- For interlaced formats, Vactive is number of active lines per field

3D video
3D Formats

- Field alternative

2D video

- 3D horizontal total pixel is equal to 2D horizontal total pixel.
- 3D vertical total line is x2 of 2D vertical total line.
- 3D pixel clock frequency is x2 of 2D pixel clock frequency.
- Vactive is number of active lines per field
- This structure can be applied only for interlaced video format.
3D Formats

- Line alternative

2D video
- 3D horizontal total pixel is equal to 2D horizontal total pixel.
- 3D vertical total line is \( x2 \) of 2D vertical total line.
- 3D pixel clock frequency is \( x2 \) of 2D pixel clock frequency.
- This structure can be applied only for progressive video format.
3D Formats

- **Side by Side (Full)**

- 3D horizontal total pixel is $x2$ of 2D horizontal total pixel.
- 3D vertical total line is equal to 2D vertical total line.
- 3D pixel clock frequency is $x2$ of 2D pixel clock frequency.
- For interlaced formats, Vactive is number of active lines per field.

(Note) Hfront, Hback and Hsync of 3D video timing are $x2$ of the original 2D video timing which is defined by each VIC.