23425

Audio Transport over HDMI

How good do you want it to sound?

John Dawson
President, Arcam
johnd@arcam.co.uk

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High-Definition Multimedia Interface - history

- Developed by 7 companies in 2002/3 – Hitachi, MEI, Philips, Silicon Image, Sony, Thomson, Toshiba

- HDMI is based on DVI (Digital Visual Interface) for *RGB digital video*

- HDMI is backwards compatible with DVI and adds
  - Audio, LPCM to 8 channels or compressed
  - YCrCb digital video support (4:2:2 and 4:2:4)
  - Universal CEC (Consumer Electronics Control)
  - Auto configuration via E-EDID interrogation
  - Compact and sub-miniature connectors
  - A compliance program

High-Definition Multimedia Interface - history

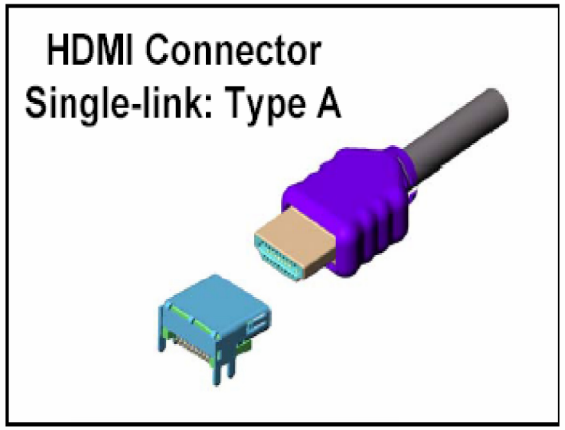
- There have been 5 main versions in 8 years. The additions are all *optional,* for continued backwards support.

- HDMI 1.0 – uncompressed audio, plus SD and HD video, over a single cable at up to 5.1 Gb/s
- HDMI 1.1 – adds DVD-Audio support
- HDMI 1.2 – adds native SACD (DSD) support plus CEC

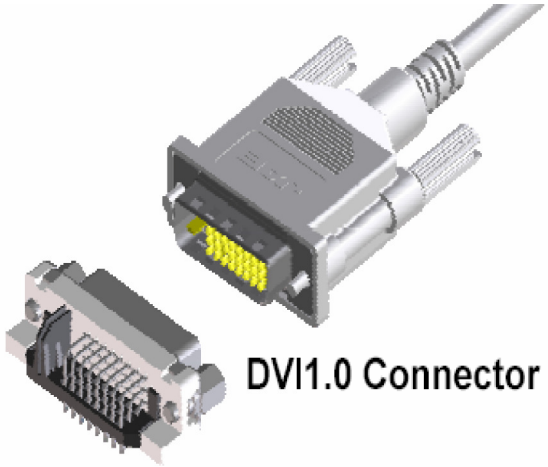
- HDMI 1.3 – doubles bandwidth to 10.2 Gb/s, adds HD codec support (Dolby and DTS)

- HDMI 1.4 – adds 3D video support, plus 100Mb/s Ethernet and ARC (audio return channel)

HDMI Connector vs DVI

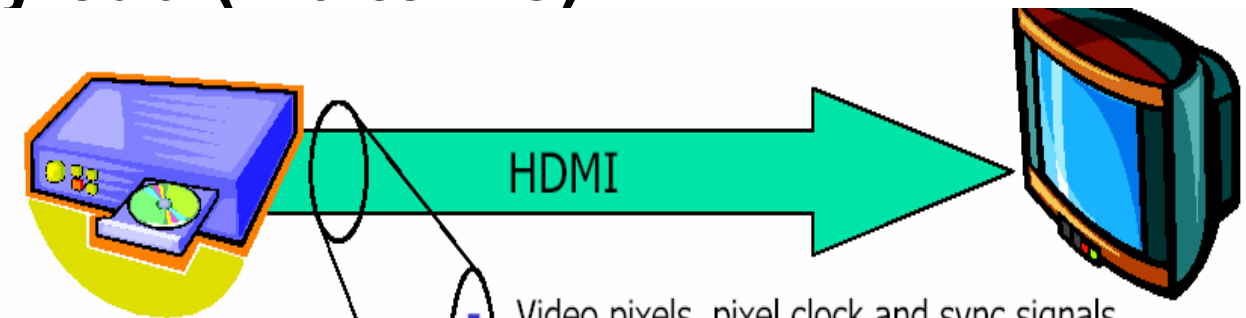


Dual-link: Type B,
5mm wider than Type A.



Type A is meant for CE devices
Type B is meant for PCs

HDMI Payload (1.0 to 1.3)

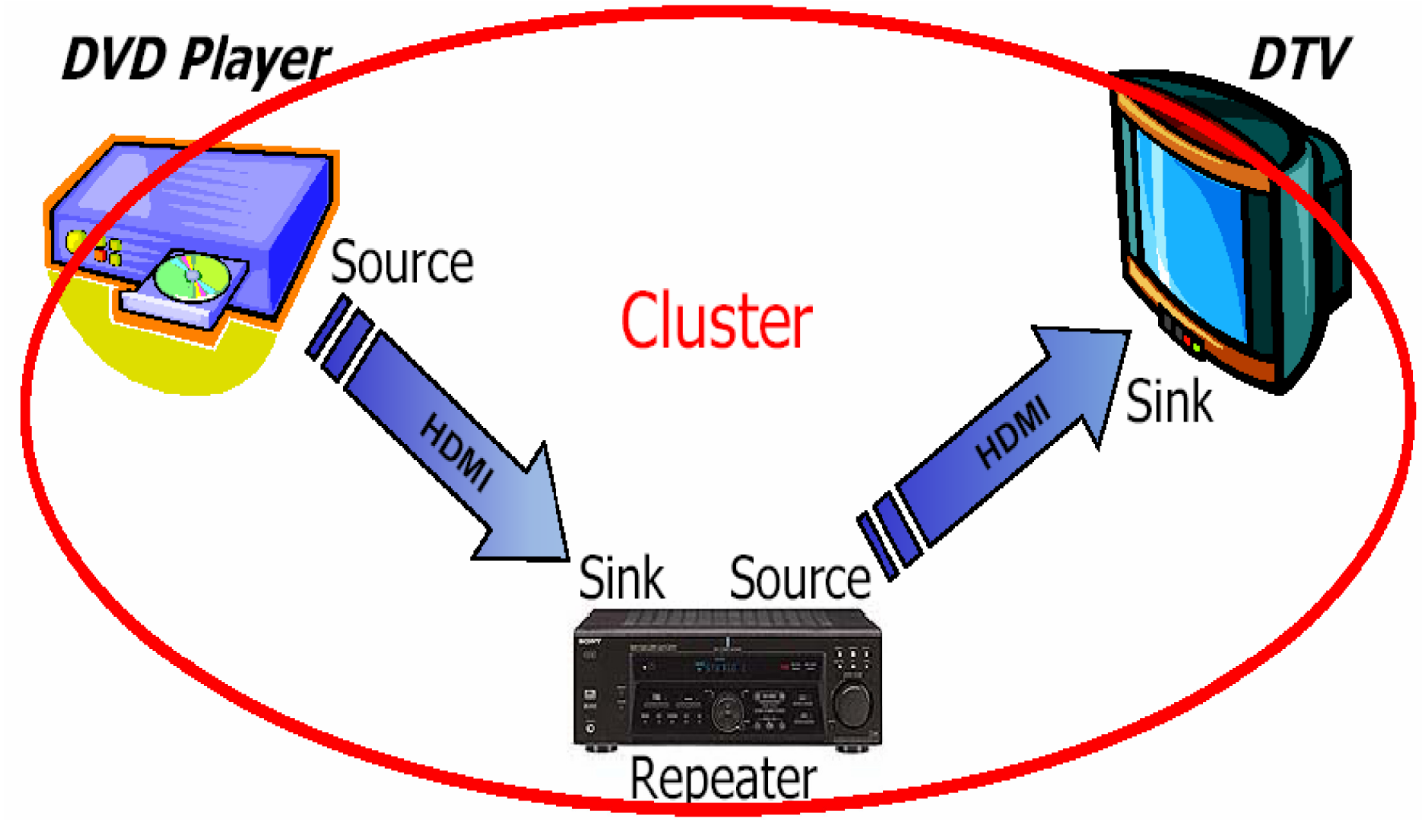


- Video pixels, pixel clock and sync signals
- Video stream information (Aux. Video Information)
- Audio samples & information about audio clock
- Audio stream information (Audio InfoFrame)
- Control and auxiliary information

Back-channel Information (Source ← Sink)

- Sink-supported video formats
- Sink-supported audio formats
- Other Sink characteristics

HDMI - typical system with a Repeater

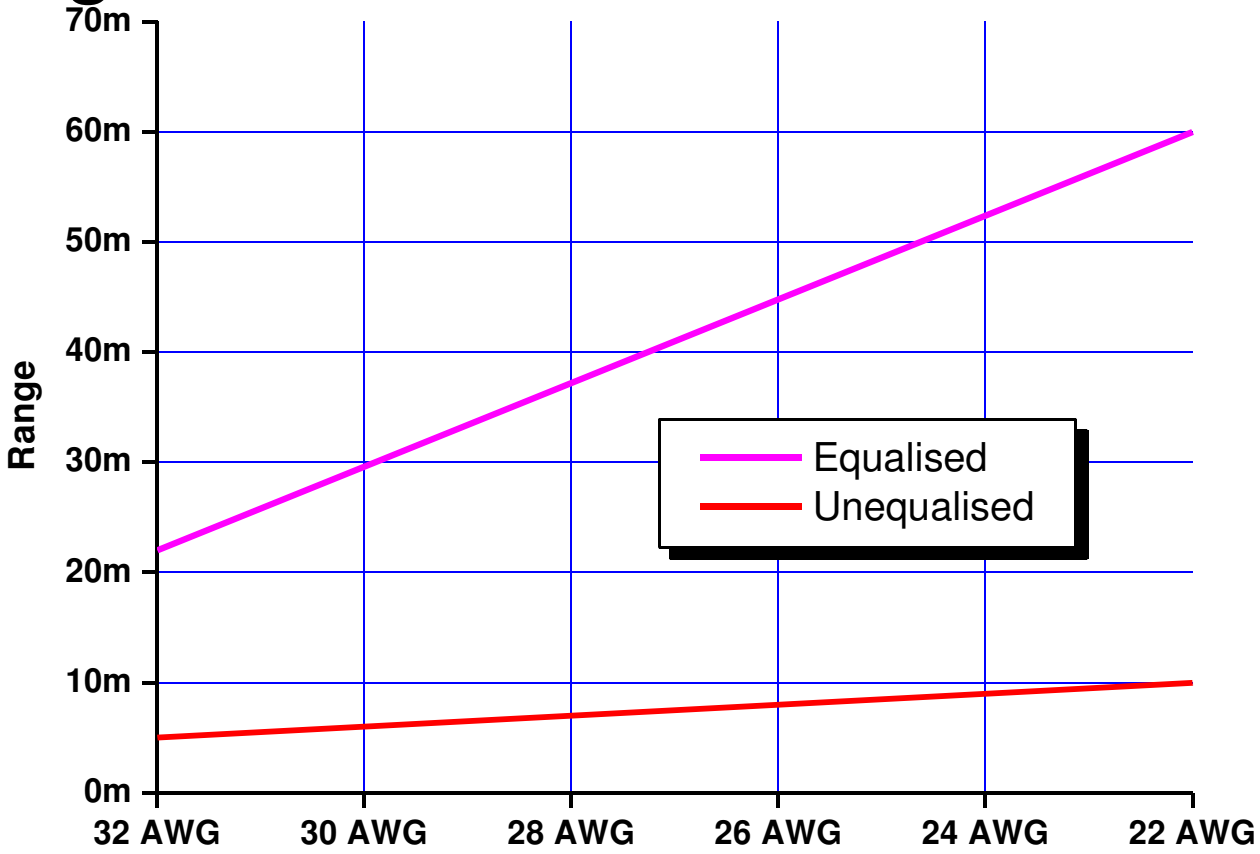


HDMI Digital Link Capabilities

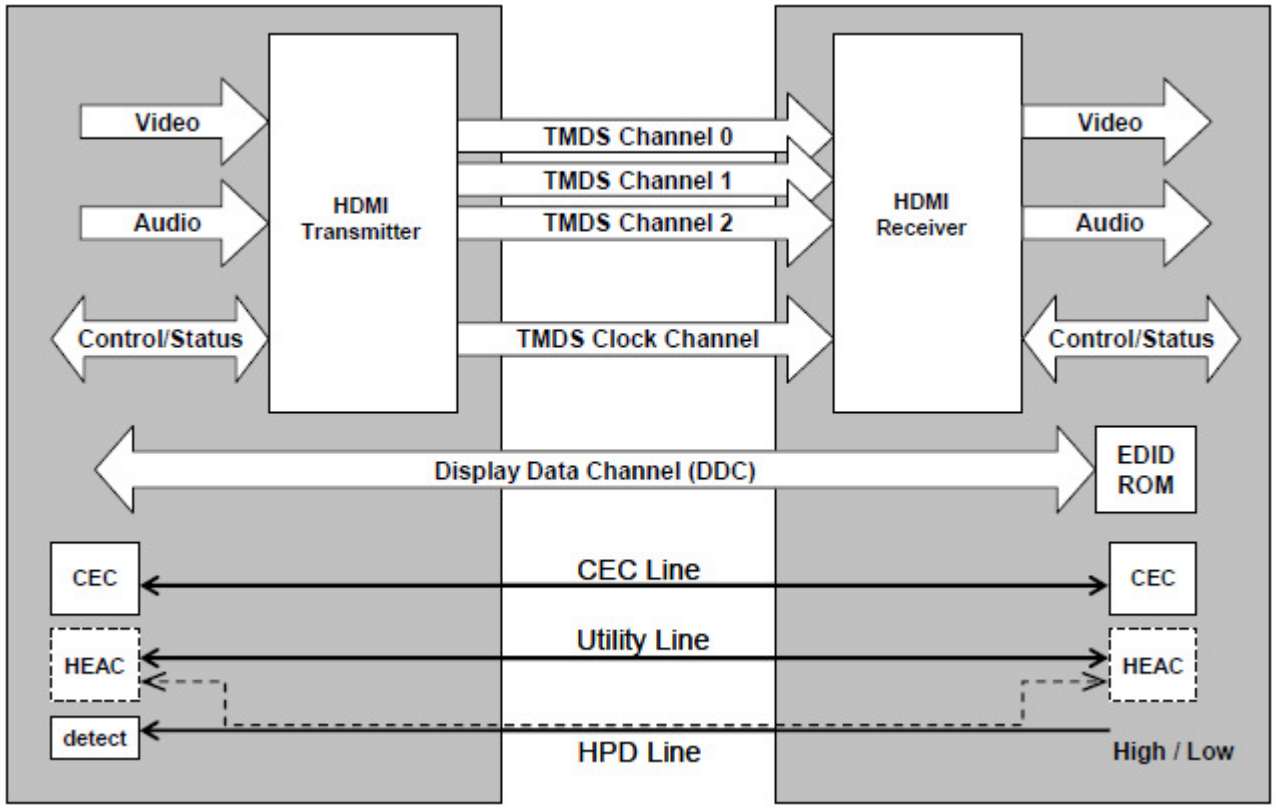
- Bandwidth up to 5.1/10.2 Gb/s
  - 24,30,36,48-bit video at 25 to 165/340 MHz clock
  - 1080p video plus 8ch audio at 24-bits, 192ks/s
  - Ethernet to 100Mb/s (HDMI 1.4 only)

- Range
  - Original specification says 5m
  - Depends on cable (thicker is better – skin effect)
  - Can be extended with equalisers

HDMI Range at 165MHz clock rate



HDMI Block Diagram



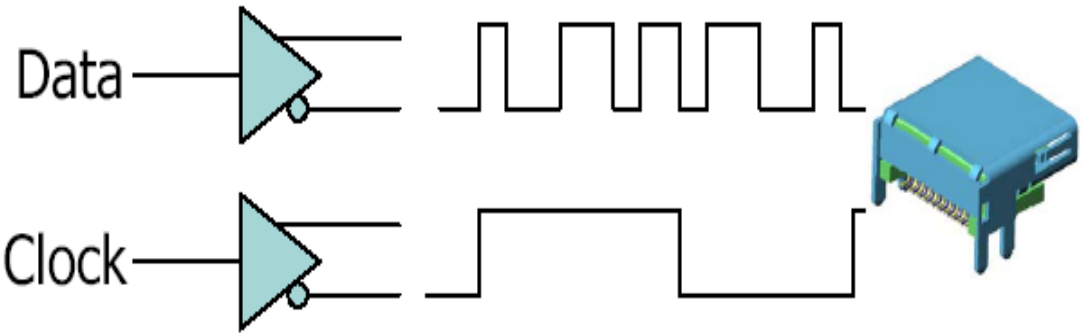
HDMI Signal Coding

- Uses a DC-coupled TMDS link
  - 100 ohm balanced pairs with shields
  - 50 ohm termination
  - Nominal signal level 500mV p-p (10mA current switch)
- 1 clock channel and 3 data channels
  - 6 channels in type B (PC only)
- Coding is 8 to 10 in a transition minimised and DC-balanced sequence

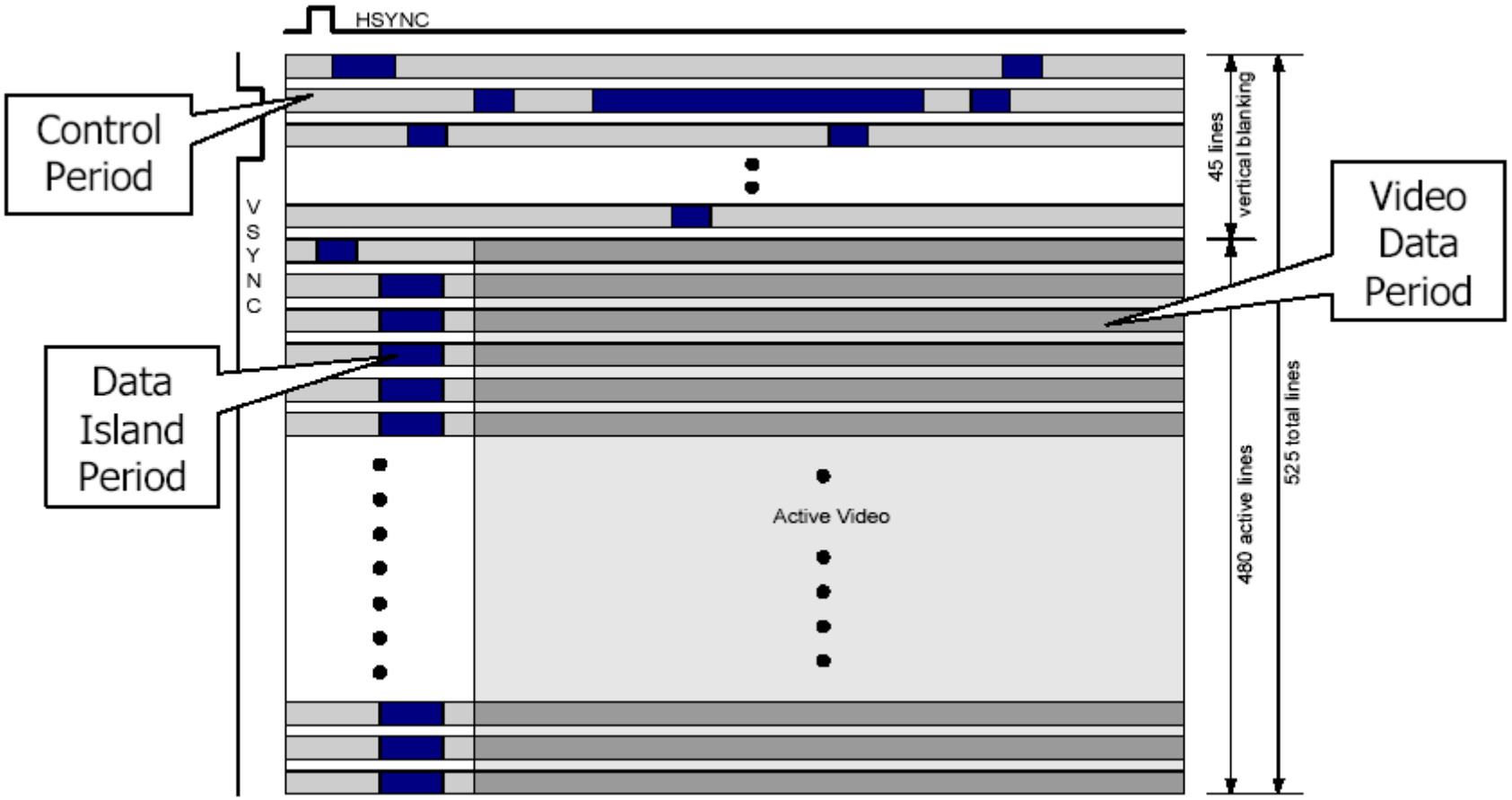
Signals on the HDMI Cable

- 1 clock line, 3 data lines

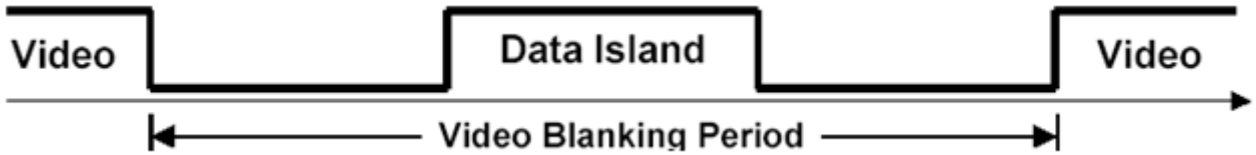
- Non-coherent clock uses PLL in Tx and Rx to align
  - Clock typically 27, 74.25, 165 MHz
  - Pixel rate 1x, 2x, 5x or 10x clock rate



Data Layout in a Video Frame (example)



Data Island Payload



- Audio data and much auxiliary information are carried in Packets within Data Islands
- HSYNC, VSYNC are also carried during the Data Island Periods
- Packet Types:
  - Audio Samples and Audio Stream
  - Audio Clock Recovery data
  - InfoFrames: Auxiliary Video IF (AVI), Audio IF, Vendor-Specific IF (includes 4K and 3D video format info)

Auxiliary Video Info Frame

Sends video control data from source to sink:

- RGB/YCrCb and pixel encoding (4:4:4; 4:2:2)
- Quantisation range (full or limited)
- Colorimetry
- Aspect ratio
- Overscan
- Video Format ID code – 2D, 3D, 4K, additional frame rates
- Pixel repetition factor (SD video requires 2x or more pixel repetitions to carry enough audio data and be >25MHz)
- Content type (video, photo, graphics, game)

Audio Info Frame

Sends audio control data from source to sink,
(to supplement IEC 60958 Channel Status bits and IEC 61937 Burst Info and/or stream data embedded in the audio packets)

- Channel count
- Sample Frequency or presence of DSD stream
- Channel/speaker allocations
- Level Shift Value (for downmixing)
- LFE channel playback level (0 or +10dB)

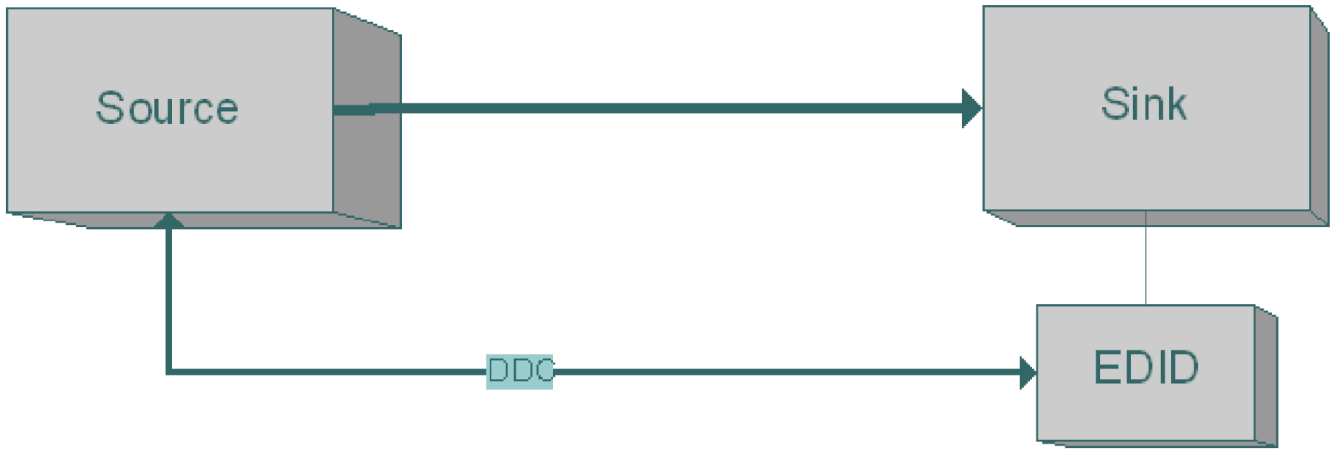
HDMI – Supported Audio Formats

- HDMI 1.0 2ch 24-bit, 32, 44.1, 48 kHz; DD, DTS
- HDMI 1.1 adds 8ch 24-bit, 32 - 96kHz (DVD-A)
- HDMI 1.2 adds native and compressed DSD
- HDMI 1.3 adds 8ch 24/192; Dolby True HD, Dolby Digital+, DTS-HD and DTS Master Audio (HD-DVD and BD formats)
- HDMI 1.4 adds HEAC (Ethernet 100-base TX and Audio Return Channel). ARC must support IEC 60958-1 (6.144MHz clock, 2 ch 16-bit LPCM at 32, 44.1, 48 kHz). Compressed audio support is optional.

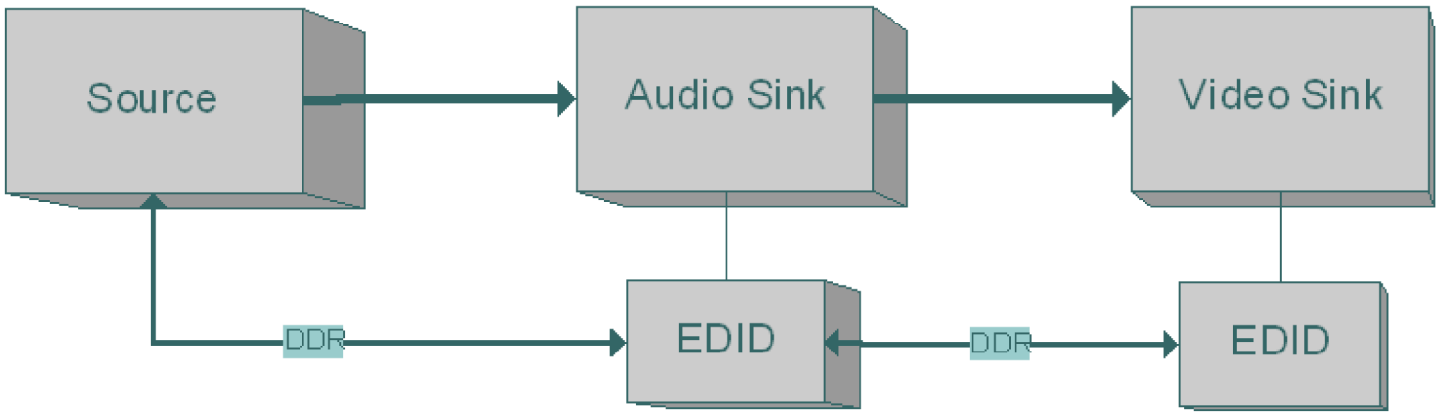
HDMI – DDC Channel

- Allows source to interrogate the capabilities of the sink
- I2C signalling with 100kHz clock
- E-EDID data structure according to:
  - EIA/CEA-861B
  - VESA Enhanced EDID

HDMI – DDC Connection



HDMI – Audio Processor Repeater



HDMI – CEC Channel

- Uses the industry standard AV link protocol, originally used in analogue TVs, VCRs etc
- Used for remote control functions – 1 device to control everything
- One-wire bidirectional serial bus
- Mostly defined in HDMI Specification 1.2a
- *Additions in HDMI 1.3a included a method for improved audio clock recovery for a compatible source and sink/repeater*

Audio Clock Regeneration at an HDMI sink

- There is no audio sample clock transmitted in HDMI – the TDMS clock is *video* related
- HDMI does not in general specify how to do ACR
- ACR is usually carried out in the sink's HDMI receiver IC - an electrically very noisy environment
- If there is any jitter on the recovered audio clock and it is applied to the audio DACs in the sink, then this will affect the final audio quality
- Buffering of the audio data *cannot* fix this

Audio Clock Regeneration at an HDMI sink (2)

- HDMI does specify one possible way which works quite well when the sink has coherent audio and video clocks:
  - Source transmits the ratio of TMDS clock to audio clock as a fraction with integers N and CTS where
    N = Numerator and CTS = Cycle Time Stamp

$$128 \times Fs = Ftmds\_clock \times N/CTS$$

and

N is around $128 \times Fs/1000$

ACR architecture - source

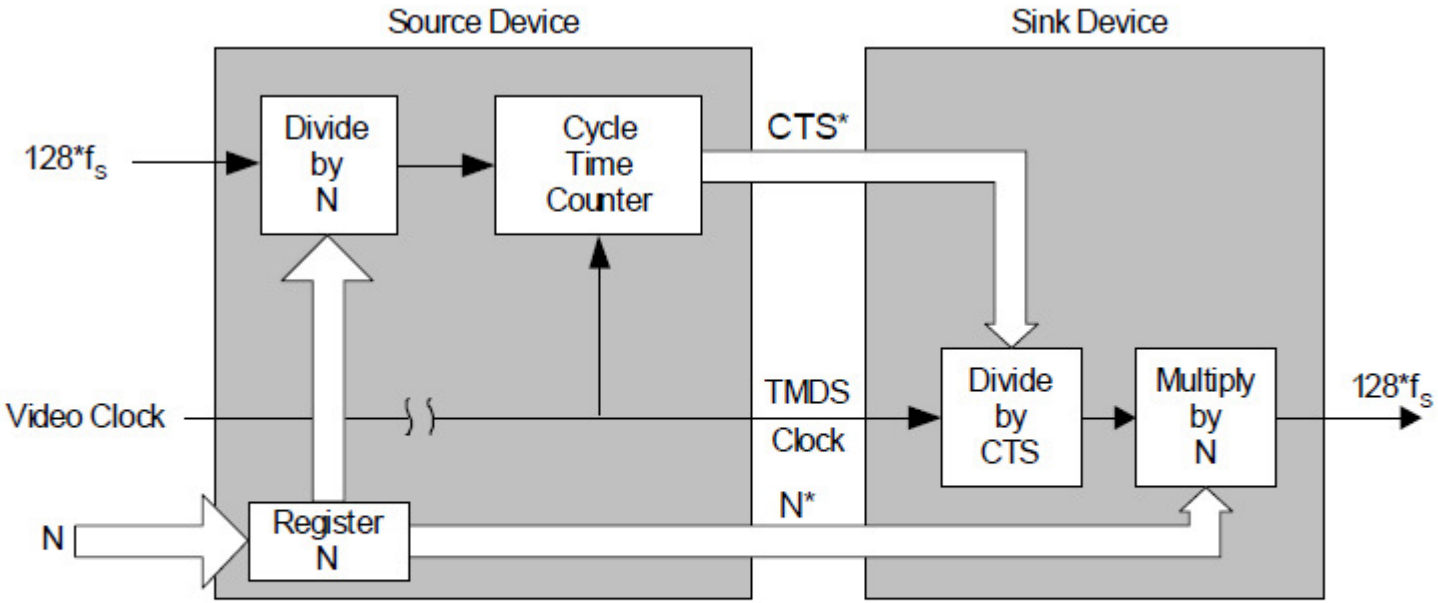


Figure 7-1 Audio Clock Regeneration model

ACR architecture – sink or repeater

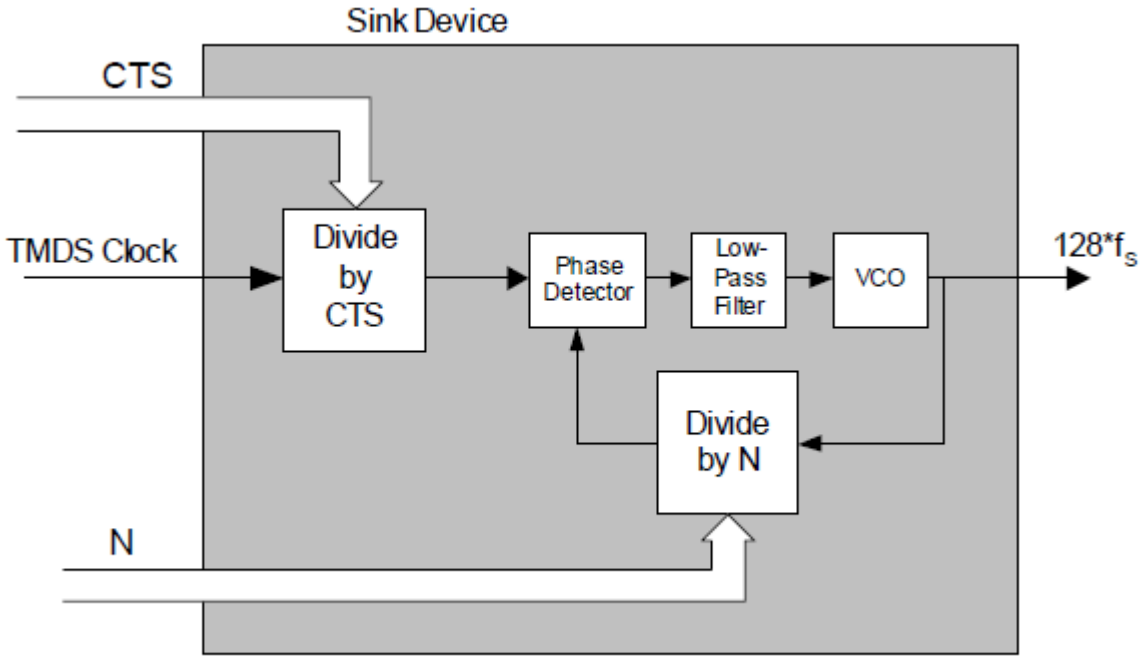


Figure 7-2 Optional Implementation: Audio Sink

ACR architecture – N and CTS at 48kHz

Table 7-3 Recommended N and Expected CTS for 48kHz and Multiples

	48 kHz		96 kHz		192 kHz	
TMDS Clock (MHz)	N	CTS	N	CTS	N	CTS
25.2 / 1.001	6864	28125	13728	28125	27456	28125
25.2	6144	25200	12288	25200	24576	25200
27	6144	27000	12288	27000	24576	27000
27 * 1.001	6144	27027	12288	27027	24576	27027
54	6144	54000	12288	54000	24576	54000
54 * 1.001	6144	54054	12288	54054	24576	54054
74.25 / 1.001	11648	140625	23296	140625	46592	140625
74.25	6144	74250	12288	74250	24576	74250
148.5 / 1.001	5824	140625	11648	140625	23296	140625
148.5	6144	148500	12288	148500	24576	148500
297 / 1.001	5824	281250	11648	281250	23296	281250
297	5120	247500	10240	247500	20480	247500
Other	6144	measured	12288	measured	24576	measured

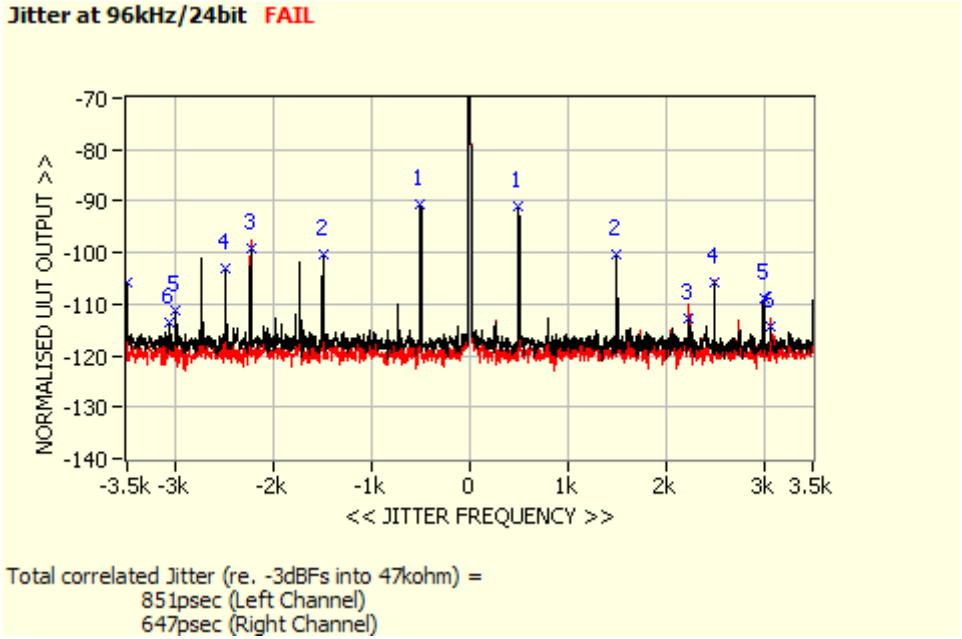
Using CEC for ARC (Audio Rate Control)

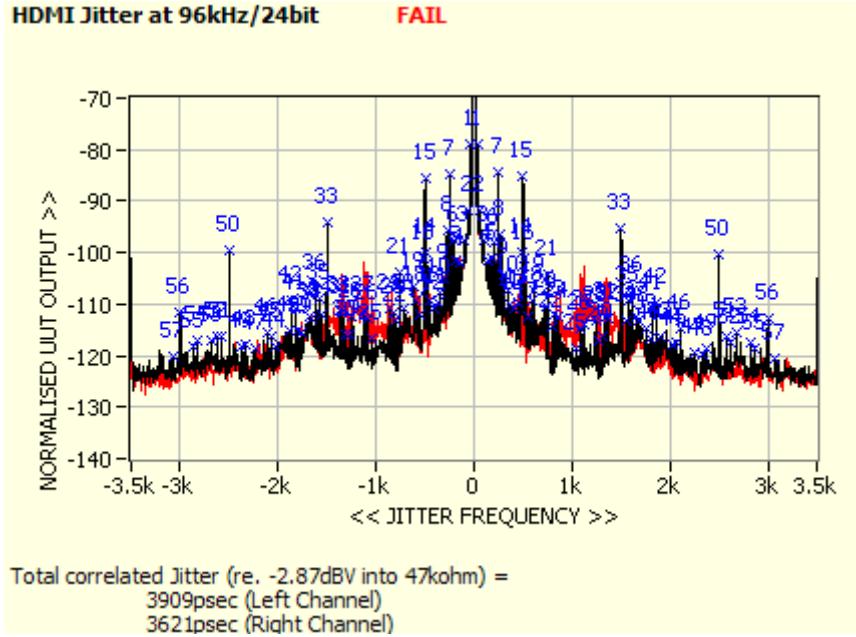
- Since HDMI 1.3 a CEC command called <set audio rate> allows a sink or repeater to instruct a *compatible* source slightly and continuously to vary its audio clock to track a stable master clock in the sink

- Has been used by several large CE vendors, e.g.
  - Pioneer PQLS
  - Sony HATS
  - Denon Link (uses CAT5 for control)

- BUT - all proprietary – need BD player /AVR from the same brand – *cannot mix and match!*

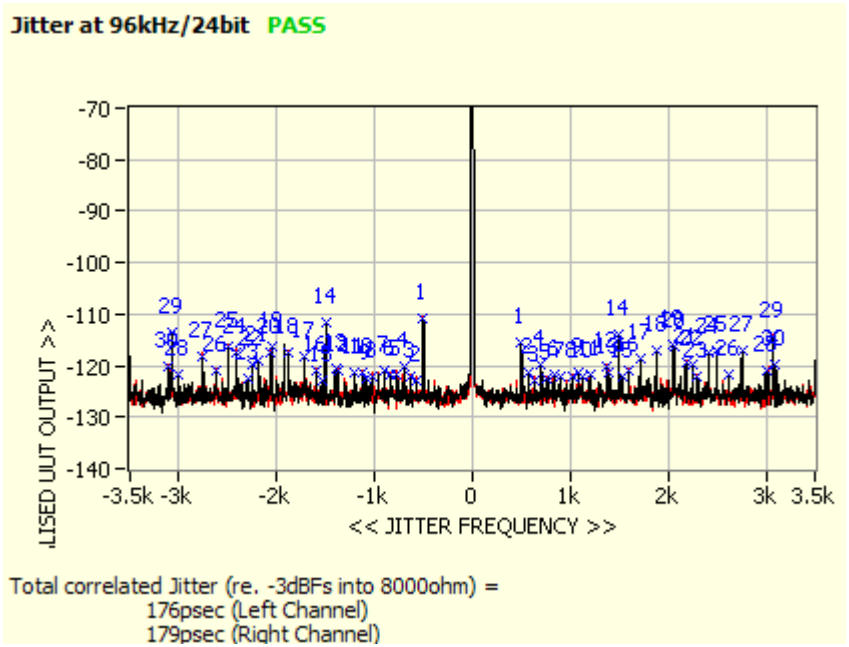
Examples of audio jitter over S/PDIF & HDMI

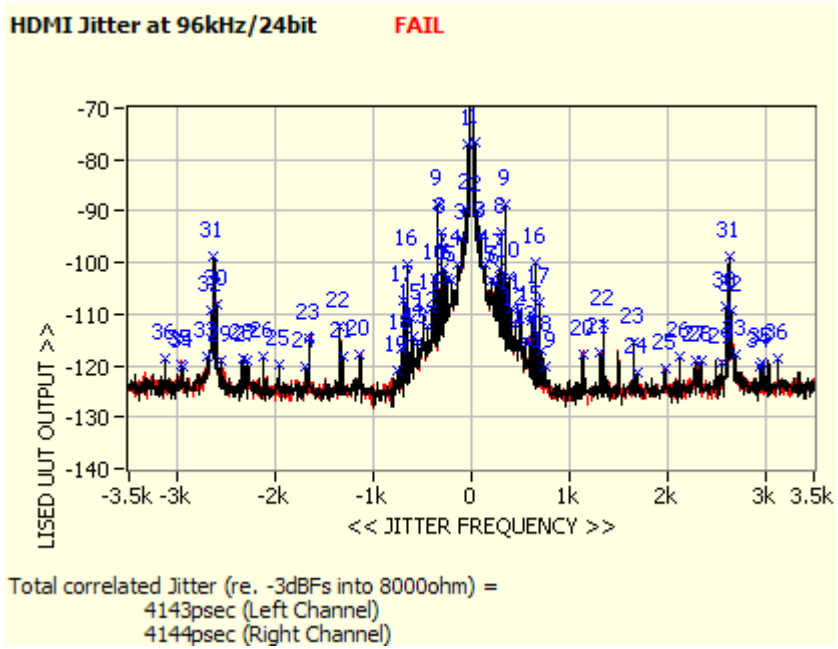




Denon AVR-3808A – Hi-Fi News Feb 2009

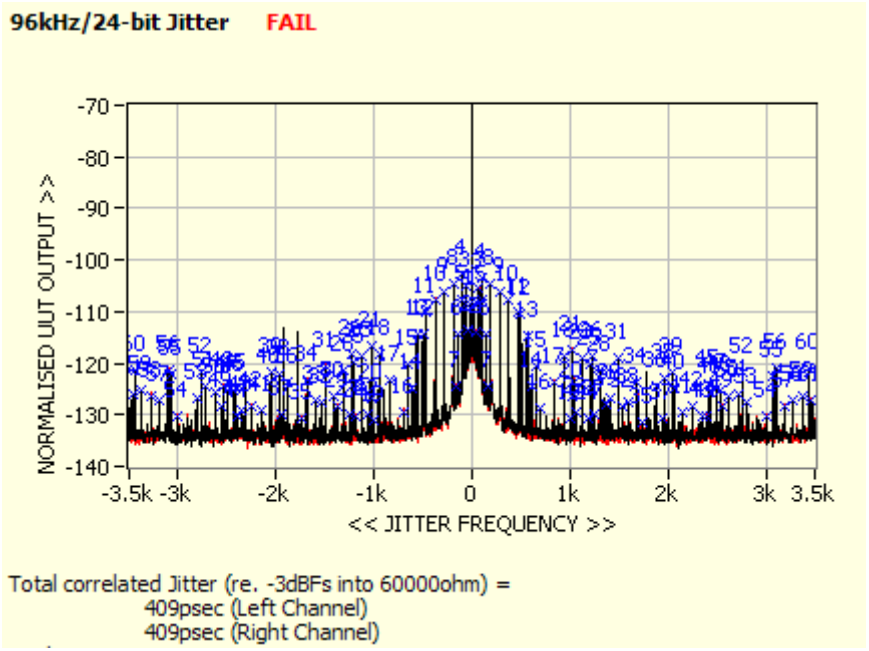
Examples of audio jitter over S/PDIF & HDMI (2)

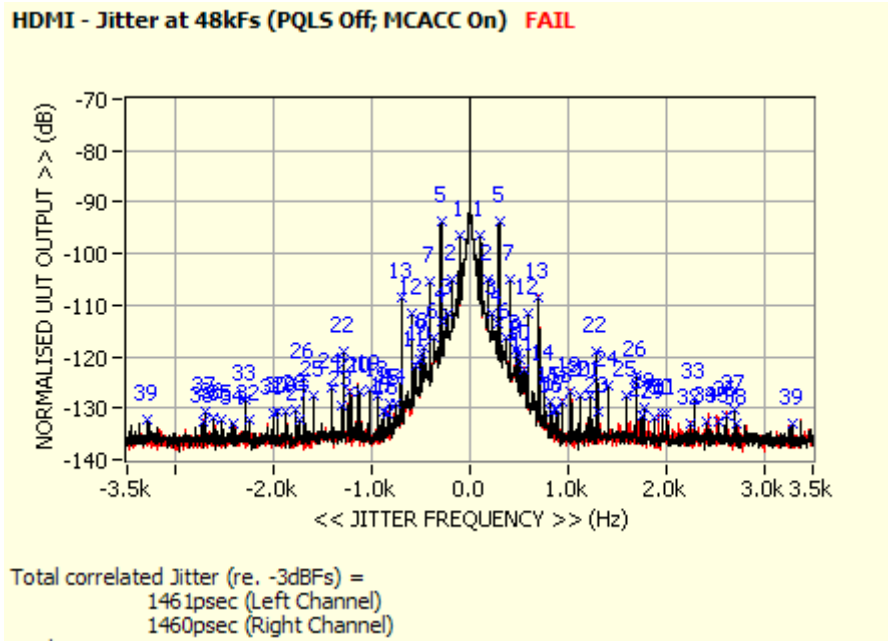




Onkyo TX-NR906 - Hi-fi News Feb 2009

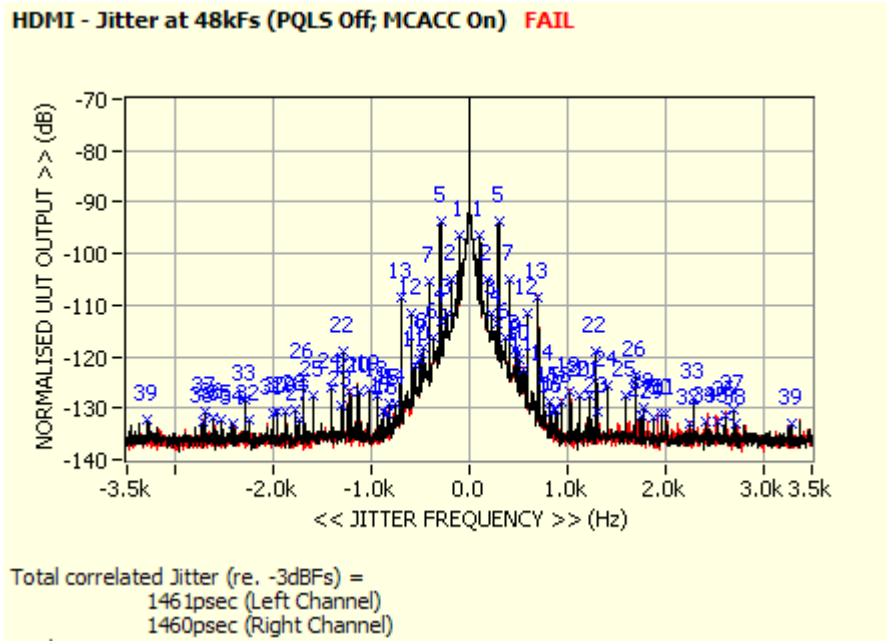
Examples of audio jitter over S/PDIF & HDMI (3)

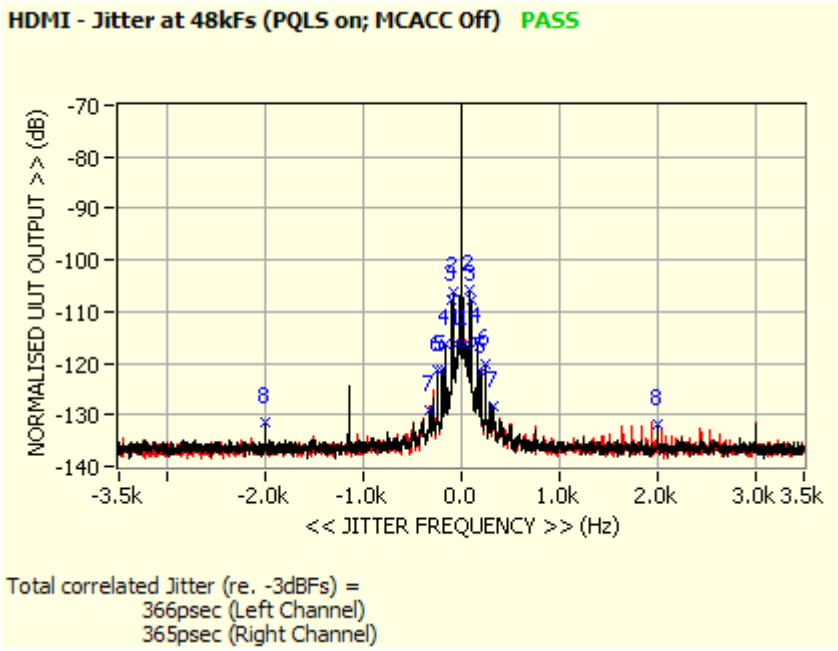




Pioneer SC-LX83 - Hi-fi News Sept 2010

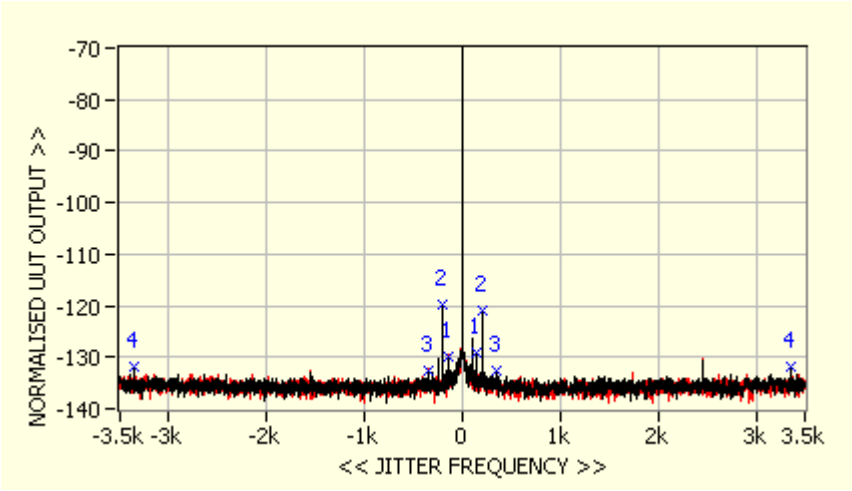
Examples of audio jitter over HDMI with ARC



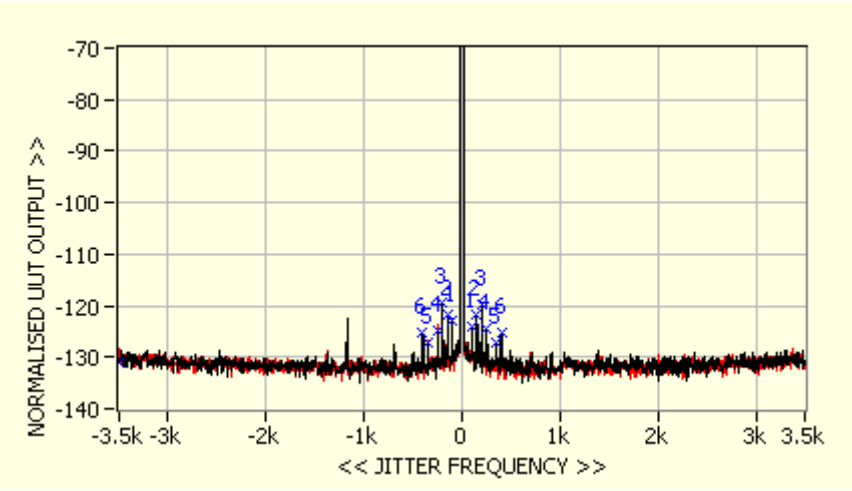


Pioneer SC-LX83 - Hi-fi News Sept 2010

And finally – jitter using analogue interface from DVD at 48 and 96 kHz (Arcam DV139)

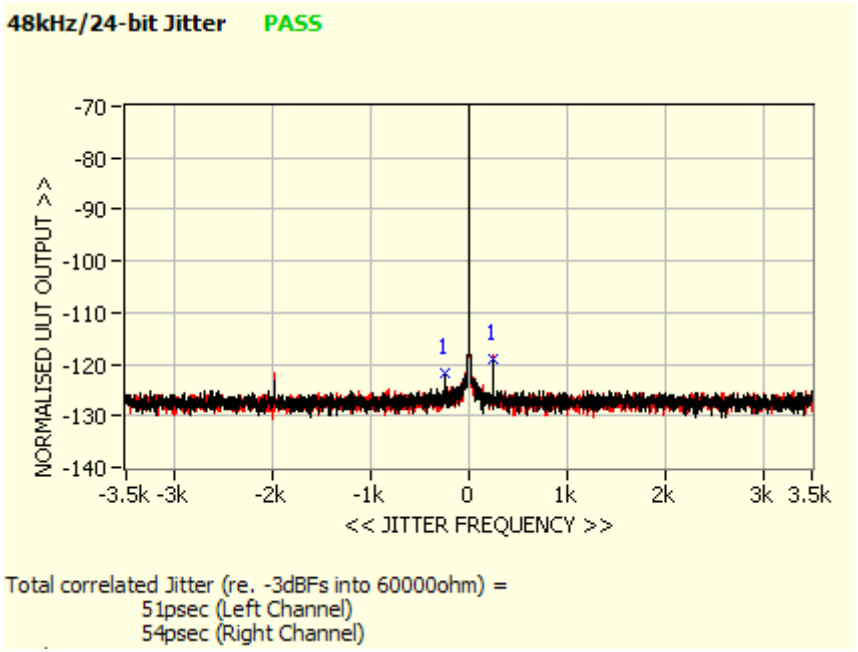


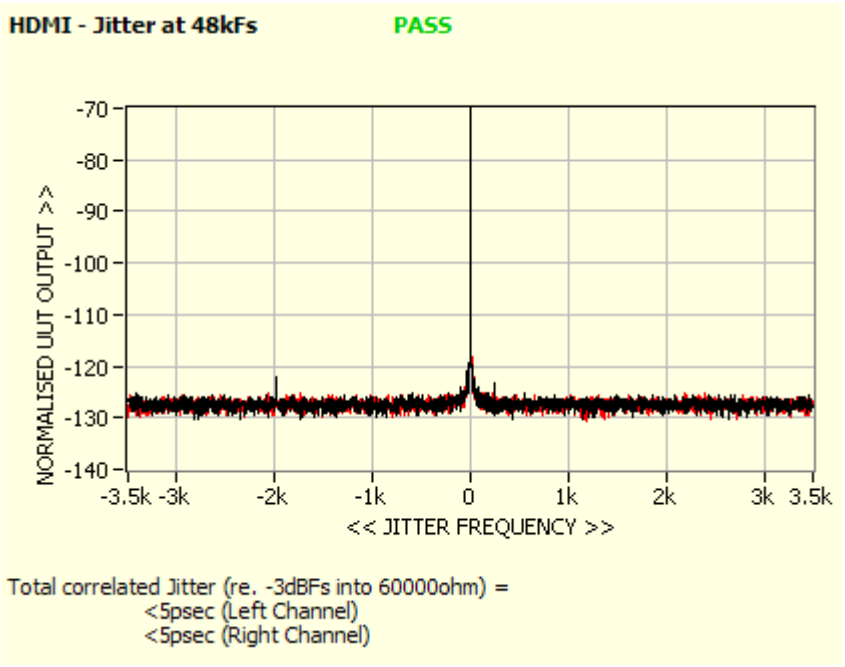
Audio output at 48 kHz
Total correlated jitter = 57ps



Audio output at 96 kHz
Total correlated jitter = 47ps

Examples of audio jitter over S/PDIF & HDMI (4)





Arcam AVR600 - Hi-fi News July 2009

Audio Transport over HDMI - conclusions

- In CE space HDMI is here to stay. It supports all SD and HD audio formats to 8 channels and now includes an (SD) Audio Return Channel
- Many more channels than 8 with BD audio formats
- *But….*the audio clock is only loosely related to the dominant TMDS (video) clock.
- Most CE companies still implement ACR poorly

The End!

Thank you for your time and attention!

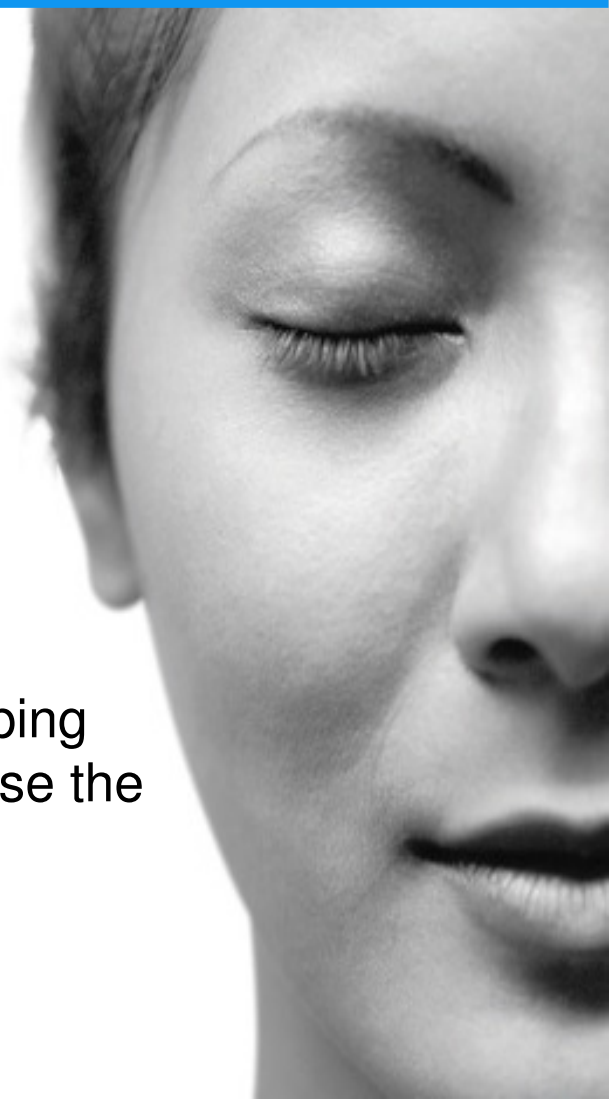
John Dawson
johnd@arcam.co.uk

Acknowledgements

- Julian Dunn for the J-test and numerous AES papers on the nature of jitter

- Andrew Dutton, Peter Gaggs and others at Arcam for their enthusiasm and great hardware design skills

- Paul Miller of Miller Audio Research for developing the remarkable “QC suite” and permission to use the graphs and other data shown here and at **www.milleraudioresearch.com**



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