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EBU guidelines for Consumer Flat Panel Displays (FPDs)

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1. Scope

This document describes the requirements of the EBU as to how broadcast programmes should be displayed on modern (non-CRT) consumer television sets. It lists the main technical parameters as well as relevant measurement methods. In addition this document recommends an EBU default parameter set.

Any characterisation of a display's performance that references this EBU document shall have been undertaken in full accordance with the measurement procedures outlined below.

2. Background

The diversity of consumer flat panel displays (FPDs) that are currently available has raised concerns over the way that television images are presented to the viewer. Standards for television image capture are aimed at a display with the characteristics typical of a cathode ray tube (CRT). All television programmes produced today in standard definition (SDTV), as well as in high definition (HDTV), comply with these standards. The same is true of all earlier television programmes now stored in broadcasters' archives around the world.

Broadcasters have an obligation towards programme producers to present their productions without distorting their creative intent. Therefore it is essential that manufacturers of consumer television sets should design their displays such that their image rendition adequately reflects the creative values intended by the programme director.

3. Main technical parameters

3a Luminance

On displays of up to 50-inch diagonal, small-area peak white should be adjustable to least 200 cd/m^2 without excessive flare. On larger displays, a lower peak luminance is advisable in most domestic environments. However, more important than the actual peak luminance achieved is the shape of the electro-optical transfer function (EOTF) when set to a realistic peak luminance (the EOTF is defined in section 5d; its gamma value is specified in section 4a).

3b Black level

With a luma signal at black level the luminance level measured from the screen should be adjustable to be below 1 cd/m^2, such that it can match a range of home viewing conditions.

3c Contrast

The contrast obtained will depend on the settings of 3a and 3b, above, which indicates a simultaneous contrast of at least 200:1 (see also section 5c). The contrast figures quoted by a manufacturer should be both the full-screen contrast and the simultaneous contrast, measured as defined below.

3d Frame rate presentation

The display should present images at the frame rate of the source where possible, or at some integer multiple thereof. 60 Hz presentations of 50 Hz input signals and 3:2 pulldown should be avoided.

3e Digital interface (DVI or HDMI) coding range

Television pictures are produced as YC_BC_R digital components with a coding range as defined in ITU-R BT.601 (SDTV) and ITU-R BT.709 (HDTV), i.e. the coding range digital 16 to 235 (8-bit) or digital 64 to 940 (10-bit). Consumer displays with an 8-bit digital interface such as DVI [10] or HDMI [11] shall correctly operate in the 8-bit coding range of digital 16 to 235 for YC_BC_R digital components.

Note 1: HDMI 1.3 allows greater bit depth (deep colour mode). Earlier versions allow increased bit depth when using YC_BC_R 4:2:2 pixel encoding.

Note 2: RGB SDTV and HDTV video signals shall be coded with the video coding range as specified in CEA-861-D [12]

3f HDMI AVI InfoFrame

Because sources (e.g. Set Top Boxes) are expected to set the following bits within the HDMI AVI InfoFrame (described in CEA-861-D [12] Table 7), these should be correctly interpreted by the HDMI input of the display:

Data	Bits	Explanation	CEA-861-D reference [12]
Active Format Info Present	A0	Idicates that Active Format Info is valid	Table 8, AVI InfoFrame Data Byte 1
Bar Info	B1..B0	Provides information about letterbox/ pillarbox when active format information alone is not sufficient	Table 8, Data Byte 1
Scan Information	S1..S0	e.g. display is not to apply overscan	Table 8, Data Byte 1
Colorimetry	C1..C0	e.g. BT.470-2 or BT.709	Table 9, Data Byte 2
Picture Aspect Ratio	M1..M0	e.g. 4:3, 16:9	Table 9, Data Byte 2
Active Format Aspect Ratio	R3..R0	Indicates area of interest within the picture	Table 9, Data Byte 2
RGB Quantisation Range	Q1..Q0	e.g. limited range (16-235)	Table 11, Data Byte 3

The following AVI InfoFrame data may be used to assist input synchronisation:

Pixel encoding	Y1..Y0	e.g. YCbCr 4:2:2, RGB 4:4:4, etc.	Table 8, Data Byte 1
Video Format Ident Code	VIC6..VIC0	e.g. 1080p/50, 1080i/25, 720p/50, 576i/25	Table 3, Data Byte 4

4. Recommended "EBU default" settings

4a Display gamma

The electro-optical transfer function should be a power law (commonly referred to as "Gamma"). The default value of display gamma that is required to match the television programme producer's intent is 2.35 in a "dim-surround" environment [6], as per the measurements reported in section 4.2 in [5]. See also Annex A for further information.

4b Colour primaries and gamut

The colours produced by red, green and blue signals, with each of the others turned off, should be within the EBU tolerance boxes in EBU Tech 3273 [13]. The difference between the gamuts of ITU-R BT.709 [2] (HDTV) and EBU (SDTV) [14] systems is so small as to be negligible.

4c Colour temperature

Whilst television pictures are produced in the studio assuming a display with D65 [3] reference white colour, it is acknowledged that many consumer displays are set up for much higher colour temperatures.

To change current broadcast practice would result in an unwanted and undesirable change to the look of the pictures, and so it is proposed that the current status quo be accepted, namely that broadcasters produce pictures for a white point of D65. Consumer displays may actually be set to a white of significantly higher colour temperature, but should always contain a user-selectable setting that conforms to D65. This setting should be clearly indicated and is part of the EBU default conditions.

5. Measurement methods required to characterise the display

5a Luminance

The 100% luminance level is measured on a white patch occupying the central 13.13% part of the picture, both horizontally and vertically, using the test signal described in section 3.5 of EBU Tech 3273 [13] and in ITU-R Rec.BT.815-1 [7]. The measurement should be taken perpendicular to the centre of the screen.

5b Black level

Black level is measured in a dark room, on the black patches in the test signal described in 5a, above. Care must be taken to avoid veiling glare in the measurement instrument, by the use of a mask or a frustrum, as described in EBU Tech 3325 [1].

5c Simultaneous and full screen contrast

Simultaneous contrast is the ratio of the measurements in 5a and 5b, above.

The expression “Full screen contrast” has created confusion within the industry as it is used with different meanings. For the purpose of reporting contrast measurements on flat panel displays, the EBU defines full screen contrast as follows:

Full screen contrast is the ratio of the luminance of a white patch occupying 10% of the width and 10% of the height (i.e. 1% of the screen area) in the centre of a black screen to the luminance measured from a completely black screen (with the set switched on) in a dark room. This is sometimes known as “Full screen (1% patch) contrast”.

5d Electro-optical transfer function (Gamma)

The electro-optical transfer function (EOTF) is a definition of how the light output (luminance L_R, L_G and L_B) is related to the broadcast R', G' and B' signals thus:

$$L_X = L_{X0} + s\left(\frac{X' - X_0'}{r}\right)^{\gamma}$$

where:

L_X is L_R, L_G or L_B

L_{X0} is the residual light output at ‘black’ (this is a combination of the residual light output of the display with the effect of the ambient room lighting),

s is a scaling factor related to peak light output,

X' is R', G' or B',

X_0' is the electrical signal representing the effective black level, and

γ is the display gamma, which is specified in section 4a.

The value of r will depend on the coding range (for example, analogue voltage, or 8- or 10-bit digital coding) of the television signals.

Measurements of gamma are made by the method defined in EBU Tech 3273 [13]; see also BBC RD 1991/6 [4].

6. Overscan

The EBU would prefer consumer displays to avoid applying overscan on any HD input format (1080p, 1080i, 720p).

However, if a small degree of overscan is unavoidable, it should match the clean aperture, as defined by SMPTE 274-2005 Annex E.4 [8] and SMPTE 296M-2001 Annex A.4 [9].

Further information about overscan is provided in Annex B

7. References

[1] **EBU Tech 3325**: **Methods of measurement of the performance of studio monitors (in preparation)**

[2] ITU-R Rec.BT.709: Basic Parameter Values for the HDTV Standard for the Studio and for International Programme Exchange (1990)

[3] CIE (Commission Internationale de l'Eclairage) Standard S 014-2/E (2006): Colorimetry - Part 2: CIE Standard Illuminants

[4] Roberts, A.: Methods of measuring and calculating display transfer characteristics (Gamma) BBC Research Department Report RD 1991/6.

[5] Roberts, A.: Measurements of display transfer characteristics using test pictures. BBC Research Department Report RD 1992/13.

[6] Hunt, R.W.G: "Corresponding colour reproduction" in *The reproduction of colour*, ed. 6, pp. 173, Wiley & Son, 2004.

[7] ITU-R Rec.BT.815-1: Specification of a signal for measurement of the contrast ratio of displays

[8] SMPTE 274M-2005: Annex E.4 in 1920 x 1080 Image Sample Structure, Digital Representation and Digital Timing Reference Sequences for Multiple Picture Rates

[9] SMPTE 296M-2001: Annex A.4 in 1280 x 720 Progressive Image Sample Structure — Analog and Digital Representation and Analog Interface

[10] Digital Display Working Group, 1999-last update, digital visual interface [Homepage of Digital Display Working Group], [Online]. Available: http://www.ddwg.org/ [June, 20, 2005]

[11] HDMI, 2007-last update, high-definition multimedia interface [Homepage of HDMI], [Online]. Available: http://www.hdmi.org [March 14, 2007]

[12] CEA 861 –D: A DTV Profile for Uncompressed High Speed Digital Interfaces (2006)

[13] EBU Tech 3273: Methods of Measurement of the Colorimetric Performance of Studio Monitors (1993)

[14] EBU Tech 3213-E: Standard for Chromaticity Tolerances for Studio Monitors (1975)

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Annex A - Gamma

Television has evolved to give pleasing results in a viewing environment described by colour scientists as ‘dim surround’ [6].

This outcome includes three invariant components:

- the requirement to match luminance level coding (whether analogue or digital) to the approximately logarithmic characteristic of the human vision system by means of an appropriate nonlinear coding or “perceptual” coding of level. Such a characteristic has the effect of equalizing the visibility over the tone scale of quantizing in a digital signal, or noise in an analogue one. A linear or other non-perceptual based characteristic would require greater dynamic range (bandwidth or bit rate) for the same perceptual quality, with adverse economic consequences;
- the immovable legacy effect of the CRT gamma characteristic on which the entire television system was empirically founded. This legacy consists of both archived content and world-wide consumer display populations;
- gamma is also the characteristic which coding schemes such as MPEG-2 and MPEG4-AVC are designed to match, and any other characteristic will be less than ideal in terms of artefact and noise visibility, to the extent that much of the impairment seen these days on transmitted television material, when viewed on flat screen displays, is caused by the failure of the display to adhere closely to a gamma characteristic, particularly near black.

It has been found that the end-to-end or “system” gamma for images captured in nominal daylight conditions, adapted for the dim-surround consumer viewing environment is approximately 1.2, i.e. definitely not linear.

The system gamma can be expressed as:

System gamma = camera encoding gamma (OETF[1]) x display gamma (EOTF[2])

It has been found from measurement techniques, progressively refined over several decades, that a correctly designed CRT display has an EOTF gamma of approximately 2.35 [5]. This is part of the “immovable legacy effect” of the CRT.

Therefore our system gamma equation is rewritten as

System gamma = 1.2 = OETF gamma x 2.35

Therefore OETF (camera) gamma = 0.51.

Since a pure gamma curve would require infinite gain to be applied to camera signals near black, resulting in unacceptable noise; in practice this curve is modified to consist of a small linear region

[1] OETF: Opto-electrical transfer function

[2] EOTF: Electro-optical transfer function

near black in combination with a reduced gamma curve of 0.45 [2]. Note however, that a “best fit” single power law curve for this characteristic comes out as 0.51, the same as in the calculation above.

From the above, since the consumer viewing environment does not, in general, change, and the OETF gamma cannot change (for compatibility reasons and for the continuation of an optimal perceptual coding characteristic), the EOTF gamma must also remain at 2.35, regardless of which new physical display device is used to implement it.

Annex B - Issues concerning overscan

The CRT has historically applied overscan of around 5% at each edge. This was required because of the difficulty of aligning the scan geometry at the edges of a screen. Edge artefacts on analogue TV content (and digitised versions of this) have been masked by the presence of overscan in the display.

In the modern all-digital environment, it is expected that edge artefacts are well contained.

Overscan has been applied on early flat panel displays to mimic the appearance of the image on CRTs.

There is an inevitable move towards the broadcast signal containing essential content to the edge of the screen. The consumer should be able to see this complete image, rather than only 80% of the image area.

If the display has greater resolution than the incoming signal, scaling is needed. This scaling should not be confused with overscan.

If a display is a close match to the resolution of the incoming signal, one-to-one pixel mapping will always provide a better picture than scaling by a small percentage.

For SDTV the legacy of the installed base of consumer CRT displays, and the legacy of archive content may prevent any change to existing broadcasting practises for some years to come.