



**Recommendation ITU-R BT.1886**  
(03/2011)

**Reference electro-optical transfer function  
for flat panel displays used in HDTV  
studio production**

**BT Series**  
**Broadcasting service**  
**(television)**

## Foreword

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### Series of ITU-R Recommendations

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Series	Title
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<b>BR</b>	Recording for production, archival and play-out; film for television
<b>BS</b>	Broadcasting service (sound)
<b>BT</b>	<b>Broadcasting service (television)</b>
<b>F</b>	Fixed service
<b>M</b>	Mobile, radiodetermination, amateur and related satellite services
<b>P</b>	Radiowave propagation
<b>RA</b>	Radio astronomy
<b>RS</b>	Remote sensing systems
<b>S</b>	Fixed-satellite service
<b>SA</b>	Space applications and meteorology
<b>SF</b>	Frequency sharing and coordination between fixed-satellite and fixed service systems
<b>SM</b>	Spectrum management
<b>SNG</b>	Satellite news gathering
<b>TF</b>	Time signals and frequency standards emissions
<b>V</b>	Vocabulary and related subjects

*Note: This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.*

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## RECOMMENDATION ITU-R BT.1886

**Reference electro-optical transfer function for flat panel displays<sup>1</sup> used in HDTV studio production**

(2011)

**Scope**

This Recommendation specifies the reference electro-optical transfer function (EOTF) that the displays used in HDTV programme production should follow in order to facilitate consistent picture presentation<sup>2</sup>. The reference EOTF is specified as a simple equation, with exponent function, based on measured characteristics of the Cathode Ray Tube (CRT).

The ITU Radiocommunication Assembly,

*considering*

- a) that reference displays play a crucial role in television programme production as they are used as reference for picture presentation;
- b) that the characteristics of reference displays should be unified to ensure consistent picture presentation of programmes produced for use in broadcasting;
- c) that historically, picture presentation characteristics were determined based on Cathode Ray Tube (CRT) characteristics, and the opto-electronic transfer characteristics were implicitly based on the CRT physical characteristics;
- e) that CRT reference displays are no longer available;
- f) that the electro-optical transfer function (EOTF) of CRT displays differs amongst manufacturers, amongst models, and amongst regions, as well as varying with the settings of contrast and brightness;
- g) that for the consistency of picture presentation, it is desirable that newly introduced display technologies have an EOTF that closely matches that of the CRT;
- h) that the reference EOTF for a non-CRT display has not been defined in any ITU-R Recommendation;
- j) that Recommendation ITU-R BT.709, provides specifications for the opto-electronic transfer characteristics at the source, and a common electro-optical transfer function should be employed to display signals mastered to this format,

*recommends*

- 1 that the reference EOTF for displays used in HDTV production and programme interchange should be the one specified in Annex 1;

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<sup>1</sup> May also include projectors and other display devices.

<sup>2</sup> The term picture presentation is intended to indicate the monitoring of picture characteristics to ensure that image characteristics do not vary between different signal sources, and different programme segments.

2 that an alternative EOTF may be used in some cases where programme interchange is not required, a suggested equation is contained in informative Appendix 1.

## Annex 1

### Reference electro-optical transfer function

The reference EOTF is specified by the equation:

$$L = a(\max[(V + b), 0])^\gamma$$

where:

$L$ : Screen luminance in  $\text{cd/m}^2$

$L_W$ : Screen luminance for white

$L_B$ : Screen luminance for black

$V$ : Input video signal level (normalized, black at  $V = 0$ , to white at  $V = 1$ . For content mastered per Recommendation ITU-R BT.709<sup>3</sup>, 10-bit digital code values “D” map into values of  $V$  per the following equation:  $V = (D - 64)/876$

$\gamma$ : Exponent of power function,  $\gamma = 2.40^4$

$a$ : Variable for user gain (legacy “contrast” control)

$$a = (L_W^{1/\gamma} - L_B^{1/\gamma})^\gamma$$

$b$ : Variable for user black level lift (legacy “brightness” control)

$$b = \frac{L_B^{1/\gamma}}{L_W^{1/\gamma} - L_B^{1/\gamma}}$$

Above variables  $a$  and  $b$  are derived by solving following equations in order that  $V = 1$  gives  $L = L_W$  and that  $V = 0$  gives  $L = L_B$ :

$$L_B = a \cdot b^\gamma$$

$$L_W = a \cdot (1 + b)^\gamma$$

NOTE 1 – This Recommendation defines the reference EOTF equation, if it is required to confirm that a display device meets the reference equation it is recommended that the measurement be conducted in a dark room.

<sup>3</sup> For reference black,  $D = 64$ , for reference white,  $D = 940$ .

<sup>4</sup> This value has been shown to be a satisfactory match to the legacy CRT display.



## Appendix 1 (Informative)

### EOTF-CRT matching

The EOTF specified in Annex 1 is considered to be a satisfactory, but not exact, match to the characteristic of an actual CRT. When it is desired to match a CRT, the  $L_w$  and  $L_B$  parameters of the EOTF can be set to the corresponding values of the CRT that are being matched. For moderate black level settings, e.g.  $0.1 \text{ cd/m}^2$ , setting the  $L_B$  of the EOTF to 0.1 will give a satisfactory match to the CRT. In the event the CRT is operated at a lower black level, e.g.  $0.01 \text{ cd/m}^2$ , the EOTF will provide a better match with  $L_B$  set to a lower value such as  $0.0 \text{ cd/m}^2$ . When it is necessary to more precisely match a flat panel display characteristic to a CRT, the alternative EOTF formulation specified below may provide a solution.

#### An example of an alternative approximation of an EOTF of a CRT display

An example of an EOTF that has alternative characteristics of a CRT's EOTF:

$$L = k (Vc + b)^{(\alpha_1 - \alpha_2)} [V + b]^{\alpha_2} \quad \text{for } V < Vc$$

$$L = k [V + b]^{\alpha_1} \quad \text{for } Vc \leq V$$

where

$Vc$ : 0.35,  $\alpha_1 = 2.6$ ,  $\alpha_2 = 3.0$

$L$ : Screen luminance ( $\text{cd/m}^2$ )

$L_w$ : Screen luminance for white, reference setting is  $L_w = 100 \text{ cd/m}^2$

$V$ : Input video signal level (normalized, black at 0, to white at 1. 10-bit digital code values "D" map into values of  $V$  per the following equation:

$$V = (D - 64) / 876$$

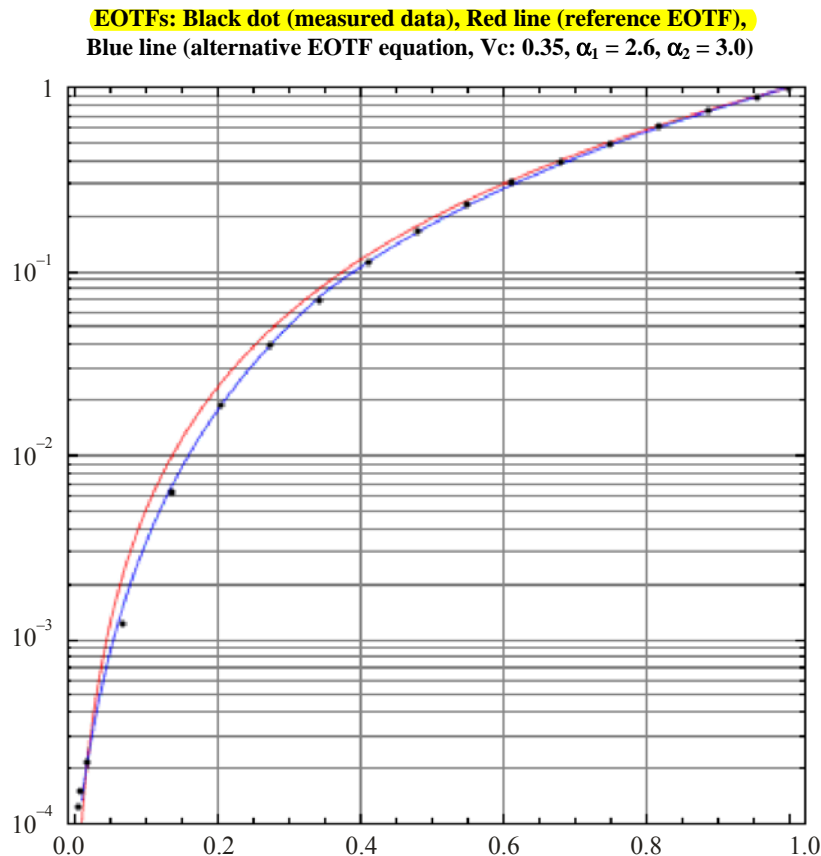
$k$ : Coefficient for normalization (so that  $V = 1$  gives white), ( $k = L_w / [1 + b]^{\alpha_1}$ )

$b$ : Variable for black level lift (legacy "brightness" control).

The value of  $b$  is set so that the calculated luminance can be the same as the measurement data at input signal level 0.0183 ( $= (80 - 64) / 876$ ).

The value of  $b$  changes depending on "brightness" control.

FIGURE 1



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## Appendix 2

### (Informative)

#### Historic overview

CRT displays have been used as the reference display in HDTV programme production and monitoring for many years. Displays based on different physical technology are now being employed to replace the aging CRT displays. It is important to specify the characteristics for this next generation of display technologies so that consistent results may be achieved in future programme production. It is useful for the EOTF specified for the new display technologies to closely match the EOTF of the legacy CRT display. However, the legacy CRT EOTF was never documented, as all CRTs naturally behaved similarly. This Recommendation specifies a reference EOTF that should be employed in displays used in HDTV programme production.

While the image capture process of Recommendation ITU-R BT.709 had an optical to electrical transfer function, there has never been an EOTF documented. This was due in part to the fact that display devices until recently were all CRT devices which had somewhat consistent characteristics device to device.

This Recommendation does NOT change any signal parameters defined in Recommendation ITU-R BT.709; legacy installations are not impacted.

### Opto-electronic conversion Recommendation ITU-R BT.709

Item	Parameter	Value	
1.1	Opto-electronic transfer characteristics before non-linear precorrection	Assumed linear	
1.2	Overall opto-electronic transfer characteristics at source	$V = 1.099 L^{0.45} - 0.099$ for $1 \geq L \geq 0.018$ $V = 4.500 L$ for $0.018 > L \geq 0$ where: $L$ : luminance of the image $0 \leq L \leq 1$ $V$ : corresponding electrical signal	
1.3	Chromaticity coordinates (CIE, 1931) Primary – Red ( $R$ ) – Green ( $G$ ) – Blue ( $B$ )	$x$	$y$
		0.640	0.330
		0.300	0.600
		0.150	0.060
1.4	Assumed chromaticity for equal primary signals (Reference white)  $E_R = E_G = E_B$	$D_{65}$	
		$x$	$y$
		0.3127	0.3290

With the introduction of new display technologies which have entirely different characteristics to the CRT displays, it is necessary to define the EOTF of new devices that emulate that of the CRT displays. In measuring the EOTF of a large number of CRTs it was determined that the EOTF of the CRT was in fact highly variable when the brightness/contrast was adjusted, it is therefore not possible to 100% emulate CRT capability (or limitations).

Users of this Recommendation in combination with the new technologies should be able to achieve a higher degree of image presentation repeatability than that offered in the past.