

# User requirements for Video Monitors in Television Production

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## User requirements for Video Monitors in Television Production

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### Scope

This document defines classes of video broadcast monitors, and their application areas in television production. It also defines the technical characteristics required of those monitors. Broadcast monitors are used in a professional TV production environment for evaluation and control of the images being produced, and must provide reliable and repeatable results. The purpose of a monitor is to display the signal as it is, and it must not attempt to 'enhance' or otherwise alter the image. It is unlikely that consumer devices will be able to meet these requirements in a television production environment. Home television receiver requirements and monitor requirements for computer and data processing techniques are not covered by this document.

Colour measurement standards are lagging behind recent developments in lighting and displays, such that they no longer adequately describe the visual perception of those displays that make use of these developments. Therefore, until new measurement standards are agreed internationally, this document cannot be an absolutely definitive specification of the colour reproduction required, and can only be a guide as to the accuracy expected of a monitor.

### 1. Definition of a Grade 1 monitor

Grade 1 monitors are devices for high-Grade technical quality evaluation of picture capturing, post-production, transmission and storage. These monitors must possess at least the quality properties of the equipment to be controlled. It is expected that all applied technologies are state-of-the-art at this level. This means that artefacts should not be unduly masked nor should additional artefacts be introduced. As a reference device the settings of this type of monitor should be adjustable as well as lockable (mechanically or electrically), so that only authorized access is possible.

The Grade 1 monitor is a 'measuring instrument' for visual evaluation of image quality. Therefore it would be highly desirable to have the ability to reproduce the scanning mode of the signal in the native way (i.e. progressive or interlaced) or as it is intended to be viewed (e.g. 50 Hz presentation of 25p material).

Typical applications for Grade 1 monitors are for example camera control, colour grading and quality control, and possibly lighting control positions, that is areas where video technical quality parameters are evaluated, controlled, and corrected.

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## 2. Definition of a Grade 2 monitor

A Grade 2 monitor may have wider tolerances on its specification than a Grade 1 monitor, for the benefit of a significantly lower price, or smaller size or weight. Grade 2 monitors are used in applications where tighter tolerances (for example on accuracy of colour reproduction and stability) as well as some equipment features, are not necessary.

Areas of application for Grade 2 monitors are for example preview, control walls, edit suites, and control rooms if no picture quality manipulation is carried out.

It should be possible for Grade 2 and Grade 1 monitors to be used together, for example in television production control walls.

## 3. Definition of a Grade 3 monitor

Grade 3 (observation or presence) monitors are devices equivalent in many respects to high end domestic/consumer displays. For television production applications, important considerations include the availability of professional interfaces, mechanical robustness (including the ability to mount in racks or stacks) and transportability, as well as electromagnetic compatibility and acoustic noise.

Application areas for Grade 3 monitors are for example audio production, dialogue dubbing, signal presence monitoring, commentator positions and displays for the audience in a studio.

## 4. Special application of displays

### 4.1 *Viewfinder monitors*

Monitors used as viewfinders for television cameras are similar in many respects to Grade 2 monitors. Picture quality requirements such as geometry and stability are important. A higher maximum brightness will be required, to allow for very different ambient lighting conditions. The viewfinder must provide facilities to assist in focus adjustment.

### 4.2 *Displays used for set design*

In the production area of broadcast companies the use of modern flat panel displays is more and more common, for example to produce large in-shot images as part of the set design. Unique factors for such monitors include the ability to match studio lighting (i.e. tungsten light, white balanced to 3200 K) and that they should have a particularly wide viewing angle and low delay. The issue of compatibility between studio cameras and displays that emit polarized light requires further study.

### 4.3 *Displays used in location shooting, or on set/studio floor*

These are monitors for use by the director, director of photography, or lighting cameraman, on set, both indoors and outdoors, for viewing material live from the camera. There is a potential requirement for such monitors to include the ability to simulate grading or another post-production process. The video data from the camera may for example be raw, logarithmic data, rather than matrixed and gamma-corrected data, and the director may therefore wish to preview a simulation of the intended output appearance achieved at a later stage in TV production.

## 5. Requirements

Note: The specifications in this section are to be measured in accordance with EBU Tech 3325 [8]. All specifications must be capable of being met simultaneously.

### 5.1 Luminance ranges

When a luma signal of 100% white (digital level is 940 in 10-bit systems, see Note 1) is input, the display should provide an adjustable preset including the ability to produce a reference luminance level, for example of 80 cd/m<sup>2</sup>. However, it should be adjustable so that the 100% luminance (see Notes 2&3) on the screen can be set to provide luminance levels within the ranges:

- Grade 1 Monitor: 70 to at least 100 cd/m<sup>2</sup> (Note 4).
- Grade 2 Monitor: 70 to at least 200 cd/m<sup>2</sup>.
- Grade 3 Monitor: 70 to 250 cd/m<sup>2</sup> or to 400 cd/m<sup>2</sup> in adverse conditions.

*Note 1: 100% luminance on the screen corresponds to a luma signal of digital level 940 (in 10-bit), and the black level corresponds to a luma signal of digital level 64 (in 10-bit). The highest value of luma signal is digital level 1019 (in 10-bit). The luma level 1019 is called 'Super-white' or '109% white', by the formula  $(1019 - 64)/(940 - 64) = 1.09$ .*

*Note 2: 100% luminance on the screen is defined as the luminance of a luma signal of digital level 940, but levels 941 through 1019 should also be correctly displayed and should track any adjustment made to the 100% luminance level.*

*Note 3: The 100% luminance is measured on a white patch occupying the central 13.13% horizontally and vertically (as described in EBU Tech 3273, § 3.5), perpendicular to the centre of the screen.*

*Note 4: ITU-R BT.500-11 requires monitor brightness up to 200 cd/m<sup>2</sup> for tests simulating domestic viewing conditions.*

*Note 5: Automatic brightness limiters shall not be used for Grade 1 or Grade 2 Monitors.*

### 5.2 Black level

With a luma signal at black level (digital level 64 in 10-bit), with a full-screen black test signal, the luminance level measured from the screen should be adjustable to be

- Grade 1 Monitor: below 0.05 cd/m<sup>2</sup>.
- Grade 2 Monitor: below 0.4 cd/m<sup>2</sup>.
- Grade 3 Monitor: below 0.7 cd/m<sup>2</sup>.

It must be possible to adjust black level with a PLUGE test signal (incl. sub-black) according to the procedure outlined in ITU-R Rec. BT.814. We expect Grade 1 and 2 monitors to be used in control rooms with subdued lighting, for example ISO 12608 'Cinematography - Room and conditions for evaluating television from telecine reproduction'.

Care must be taken to avoid veiling glare in the measurement instrument, by the use of a mask or a frustum, as described in EBU Tech 3325 [8].

*Note: If the viewing conditions are standard dim surround (15% as in ITU-R Rec. BT.500-11) then the remission factor of the display must also be considered.*

*In the case of a CRT, it appears that the black level measured with the screen switched off, in typical production environment, is between 0.05 and 0.1 cd/m<sup>2</sup> and about 0.01 cd/m<sup>2</sup> higher with the screen switched on.*

*For a typical LCD the remission factor is significantly lower and so a higher light output at black can be tolerated. It is the sum of the reflected light and the transmitted light which is important in a typical (dim surround) production environment.*

*Modulation of the back light of a transmissive display (global or local dimming) to improve the black-level performance must neither cause visible artefacts (even if the monitor is viewed from very close viewing distances) nor hide artefacts present in the signal being monitored. If such a feature is present on the display it must be possible to disable the function. It may in the future be necessary to define additional requirements and test conditions to characterise any displays using these techniques.*

### 5.3 Contrast ratio

Depending on the luminance level set for 100% white, the following full screen contrast ratio may be achieved in relation to the appropriate minimum black level.

Full screen (1% patch) contrast ratio shall be:

Grade 1 Monitor:	above 2000 to 1 (1400 to 1 with 100% white at 70 cd/m <sup>2</sup> )
Grade 2 Monitor:	above 500 to 1
Grade 3 Monitor:	above 300 to 1 (142 to 1 with 100% white at 100 cd/m <sup>2</sup> , since black may be 0.7 cd/m <sup>2</sup> )

Simultaneous contrast ratio (with EBU box pattern) should be:

Grade 1 Monitor:	above 200 to 1
Grade 2 Monitor:	above 100 to 1
Grade 3 Monitor:	above 100 to 1

*Note: 'Full screen (1% patch) contrast' is defined in EBU Tech 3325 [8].*

### 5.4 Gamma characteristics

- 1) The luminance gamma characteristic (electro-optical transfer function) of the screen should be equivalent to those of a reference CRT with the rendering intent (dim-surround) expected of a TV system. It is recommended that a nominal value of 2.35 be used.

See Annex A and the Note below.

- 2) The transfer functions of the green, red and blue components of the display must be sufficiently similar as to meet the requirements of § 5.5 below.
- 3) The ideal electro-optical transfer function shall be followed (for Grade 1 and Grade 2 Monitors) such that it remains within a tolerance of  $\pm 0.10$  of the ideal gamma value from 10% to 90% of input signal level, using the analysis technique described in EBU Tech 3325 [8]. The transfer function shall remain monotonic throughout the full signal range. For Grade 1 and Grade 2 Monitors, a 10-bit input signal shall result in a 10-bit presentation on the screen (always allowing that only 877 video levels are specified between black and 100% white).

*Note: The electro-optical transfer function of a monitor is based on the following requirements:*

*Whilst the camera may have a nominal opto-electrical transfer function according to ITU-R Rec. BT.709, this is in practice modified by the intention of the director in camera control or in grading.*

*The television system has been deliberately designed with an end-to-end system gamma of about 1.2, to provide compensation for the 'dim surround' effect [6]. Therefore the*



*monitor gamma is not, and never has been, the inverse of the camera gamma.*

*The reference for archived and current programmes has been a Grade 1 CRT monitor.*

*The measurement is made in a completely darkened room, and the display must be correctly set up using the PLUGE signal under those conditions. The measurement conditions are thus different from normal operational conditions.*

The conclusion must be that any new monitor technology should retain the same electro-optical transfer function as has historically been used.

BBC R&D Report RD 1991/6, 'Methods of measuring and calculating display transfer characteristics (gamma)' by Alan Roberts [4], indicates a method of performing such measurements, and has yielded results which indicate that the gamma of a Grade 1 CRT monitor is typically in the region of 2.3 to 2.4. See also [5].

The overall electro-optical transfer characteristic will therefore consist of this gamma curve, sitting on top of an adjustable offset of the light-output at 'black' as set using a PLUGE test signal to meet the requirements of the viewing environment. Annex A gives further information.

*Important Note: This section may be revised in the future to bring it into line with a future ITU-R standard, in preparation.*

## 5.5 Grey scale reproduction

1) Grey scale tracking between colour channels shall be within the circles defined:

Grade 1 Monitor:  $0.5 \Delta u^*v^*$  relative to the measured white point of the monitor (CIE 1976  $L^*u^*v^*$  Colour Space differences [see Annex B]) for luminance from  $1 \text{ cd/m}^2$  to  $100 \text{ cd/m}^2$  and deviation from grey should not be visible for luminances below  $1 \text{ cd/m}^2$

Grade 2 Monitor:  $1 \Delta u^*v^*$  for luminances from  $1 \text{ cd/m}^2$  to  $200 \text{ cd/m}^2$  and deviation from grey should not be visible for luminances below  $1 \text{ cd/m}^2$

Grade 3 Monitor:  $1.5 \Delta u^*v^*$  for luminances from  $1 \text{ cd/m}^2$  to  $250 \text{ cd/m}^2$  and deviation from grey should not be visible for luminances below  $1 \text{ cd/m}^2$

2) When a luma signal of black level (digital level 64 in 10-bit systems) through 109% white (1019) is input, grey scale tracking should be maintained.

*Note: The tolerance for Grade 1 is based on a difference of  $1 \Delta u^*v^*$  being visible, thus a tolerance range of  $0.5 \Delta u^*v^*$  will ensure invisibility.*

## 5.6 Colour gamut and colour reproduction

1) The intention is that colours within the relevant system gamut should be reproduced such that the human eye perceives them to be identical to the presentation on an ideal CRT monitor, that is, a metameric match should be achieved. Reproduction of the EBU test colours (EBU Tech. 3237 and its supplement) should be to a tolerance of  $4 \Delta u^*v^*$ , except in the case of the two skin tone test colours, where the tolerance should be  $2.6 \Delta u^*v^*$  (which corresponds to the tolerance on the skin tone of  $\pm 0.003 \Delta u', \Delta v'$  defined in EBU Tech 3273 [1]). In addition, if there is a variation in the reproduced brightness of test colours,  $\Delta E^*$  should lie within the above tolerances. These tolerances are all relaxed to  $7 \Delta E^*$  for Grade 2 and 3 monitors.

2) The display should present pictures with the colour primaries and reference white specified in the relevant video standard (ITU-R BT.1360, ITU-R BT.601, ITU-R BT.709, ITU-R BT.1700 or

SMPTE 274M, 170M and 296M-2001). The displayed primaries for standard definition signals should fall within the tolerance boxes for EBU primaries (EBU Tech 3213). For high definition signals, the reproduction of the ITU-R Rec. BT.709 primaries should be within  $4 \Delta u^*v^*$  of the target primaries for Grade 1 monitors and  $7 \Delta u^*v^*$  for Grade 2 and 3 monitors. In addition, if there is a variation in the reproduced brightness of the primaries,  $\Delta E^*$  should lie within the above tolerances.

*Note: For displays intended for use in studio sets, some pre-distortion of the colour rendition may be desirable to achieve the required look on camera.*

## 5.7 Colour temperature

- 1) The monitor should present pictures with a reference white colour  $D_{65}$  (see Annex B) when feeding the monitor with primary signals of equal amplitude.
- 2) Monitors to be used in shot in the studio (in set design) must be able to be adjusted to approximately 3200 K.

Grade 1 Monitor: Default  $D_{65}$

Grade 2 Monitor: Default  $D_{65}$  and optionally switchable to 3200K for use in set design

Grade 3 Monitor: Default  $D_{65}$  and optionally switchable to 3200K for use in set design

- 3) Tolerances to be applied to the white point,  $D_{65}$ , should be  $1.3 \Delta u^*v^*$  (which corresponds to the tolerance of  $\pm 0.0010 \Delta u', \Delta v'$ ). The tolerance allowable for Grade 2 and 3 monitors should be  $4 \Delta u^*v^*$  (which corresponds approximately to the tolerance of  $\pm 0.003 \Delta u', \Delta v'$ ).

*Note 1: A difference greater than  $1 \Delta u^*v^*$  might be visible between two colour patches on the same screen, implying a tolerance of  $\pm 0.5 \Delta u^*v^*$ . However, we are here considering the visibility of colour differences between adjacent screens, hence the greater permissible tolerance.*

*Note 2: Whilst the CIE 1931 measurement system has been satisfactory in the measurement of CRT displays, there is some evidence that it may not be sufficiently accurate to characterise and obtain metameric matching with some of the more recent display devices [7].*

## 5.8 Viewing-angle dependency

In many applications, where the monitor is being viewed by more than one person, or where several monitors are being viewed together, then accurate picture reproduction over a range of viewing angles is of vital importance. Even where a single monitor is being viewed by just one person, it is important that the image reproduction is consistent over some more limited, but still significant, range of viewing angles.

- 1) For Grade 1 and Grade 2 Monitors, deviations in reproduced colour on the screen should not be visible to a human observer when viewing the screen from an angle of up to  $\pm 45^\circ$  horizontally or  $\pm 20^\circ$  vertically in any direction from the perpendicular axis to the centre of the screen.
- 2) As a guide to an acceptable numerical value for Grade 1 and Grade 2 Monitors,  $\Delta u^*v^*$  (calculated as changes from the measurements made normal to the screen) should be less than 6.8 for 20% grey-scale and 6.0 at 50% grey-scale, white, and with any of the EBU test colours when measured from viewing angles in the range described above. These tolerances can be relaxed to  $9 \Delta u^*v^*$  for Grade 3 Monitors.
- 3) The contrast ratio on the screen for Grade 1 and Grade 2 Monitors, when measured from viewing angles in a rectangle of  $\pm 30^\circ$  horizontally and  $\pm 15^\circ$  vertically should drop by no more than 20% of the contrast measured along an axis perpendicular to the centre of the screen. When measured from viewing angles in a rectangle of  $\pm 45^\circ$  horizontally and  $\pm 20^\circ$  vertically, the

contrast ratio should drop by no more than 50%. These tolerances can be relaxed to 35% ( $\pm 30^\circ$  horizontally and  $\pm 15^\circ$  vertically) and 50% ( $\pm 45^\circ$  horizontally and  $\pm 20^\circ$  vertically) for Grade 3 Monitors.

*Note: Ideally a technology where viewing angle is not an issue should be used. The above tolerances, whilst not ideal, are those which can probably be tolerated.*

*In certain conditions, the viewing angle requirement for some monitors, such as those used in a wall of monitors in a production gallery, may actually be more critical than the Grade 1 monitor placed in the centre of such a wall of displays. However, clearly the viewing angle performance of a monitor used in an environment such as audio editing is less important.*

## 5.9 Motion artefacts

Motion artefacts that are introduced by specific display technologies (such as blur and other effects on moving images) are an area of great concern. It is undesirable for the display to introduce motion artefacts of its own.

On the other hand, motion effects which are included in the input signal by, for example, a failure to anti-alias filter moving graphics, or blurring of the image caused by camera integration over the shutter opening, should be represented on the display.

*Note 1: Reference document about Moving Picture Response Time (MPRT) measurements is available (under development by ICDM as the Display Measurement Standard).*

*Note 2: Motion blur (both in moving edges and texture) in LCDs is caused by a combination of: 'Sample and hold' type presentation; Intrinsic response time of the panel; Signal processing such as de-interlacing.*

*Note 3: Other technologies introduce other motion effects, such as colour fringing on moving edges and false contour generation.*

## 5.10 Screen resolution

The resolution required of a monitor will vary depending on screen size and application.

Grade 1 Monitor: At least as many pixels as the signal format to be displayed, with the ability to display a pixel-mapped image.

Grade 2 Monitor: At least as many pixels as signal format to be displayed.

*Note 1: Large screens intended for multi-viewers may require substantially higher resolution.*

*Note 2: There are some advantages in having super-sampled displays, such that the pixel structure and shape no longer affect the visible image. For example, a 1920 x 1080 image might be displayed on a 4k (horizontal pixel) screen.*

## 5.11 Image scaling, de-interlacing and overscan

- 1) Image scaling should be done in such a way as to avoid the introduction of artefacts, such as excessive ringing, aliases or banding, etc.
- 2) Monitors should offer a choice of de-interlacing modes (see section below on delay). Progressive

(segmented field or film-mode) material should be detected and not passed through a de-interlacer.

- 3) Monitors must have the ability to expose 'field dominance' problems, which occur when the fields of an interlaced signal are presented in the wrong order.
- 4) The default mode should be to display without overscan, that is, showing the full active image area right to its edges. This should be the optimal mode for scaling quality, and often may be one-to-one pixel mapping.
- 5) The edges of the picture must not be obscured by a bezel.
- 6) All monitors should be adjustable to allow overscan of around 2%.

*Note: The requirement for a monitor to detect and not de-interlace film-mode material is incompatible with the traditional requirement that a monitor should indicate that vertical (interlace) twitter is present. This is an issue which broadcasters must be aware of during the transition in the domestic environment from CRTs to flat panels.*

## **5.12 Delay time**

The delay time in each display mode shall be explicitly specified, and optionally indicated on the screen. The delay reported should be the delay between arrival of the serial electrical signal at the monitor input and the 50% point in the rise of the light output from the screen.

In the case of Grade 2 and Grade 3 monitors, it is essential that models should be available that include a 'short delay display mode'. A short delay display mode is useful when strict timing accuracy is required in cases such as video switching or editing, or when used to cue musical performers. This mode may have lower picture quality (for example, due to simpler de-interlacing) than the normal display mode. For this reason, the availability of such a mode is not demanded for Grade 1 monitors.

In the short delay display mode, pictures should preferably be displayed with a latency of no more than 10ms between the input signal and the displayed signal. The intent is to minimise the lip-synchronization errors that occur, causing annoyance both to viewers and production staff.

## **5.13 Screen size**

The screen size of the display is at the discretion of users, but may need to be larger (because of the target viewing distance of 3 times picture height) for adequate monitoring of HD. Production spaces are still designed for the same size monitors previously used, because there are often constraints which make moving to larger screen sizes difficult. This may have an impact on the ability to adequately monitor HD quality. Multi-view (tiled) large screen monitors are increasingly used for source monitoring, so are included in the Grade 3 monitor category, but might also be classified as Grade 2 monitors.

## **5.14 Uniformity**

### **Large area uniformity**

The minimum uniformity in large area white level (that is, a smooth drop-off in luminance towards the edges of the screen) that is acceptable is 80% for a CRT, but we require the luminance to be uniform across the screen with a tolerance of  $\pm 5\%$  of the mean luminance in the flat panel environment.

The uniformity of chromaticity should be within  $2.6 \Delta u^*v^*$  of the measured white at the centre of

the screen, for Grade 1 monitors (which corresponds to the tolerance of  $\pm 0.002 \Delta u'$ ,  $\Delta v'$ ), and  $4 \Delta u^*v^*$  for Grade 2 and 3 monitors.

### **Small area uniformity**

The use of a few fixed measurement positions could potentially result in missing a periodic uniformity error or some other pattern. To avoid this, a measurement technique taking into account the whole screen is desirable, and should be used in place of the large area measurement if this is feasible for the organisation making the assessment. A standard deviation (divided by the average level) of 5% in luminance is thought to be realistic for a Grade 1 monitor.

In the extreme, fixed pattern noise is a type of non-uniformity, and if necessary should be counteracted by pre-correction in the display.

### **5.15 Mura (imperfections in LCD panels)**

Mura must not be visually detected on the screen regardless of reproduced luminance levels or colour saturation.

Whilst Mura is not expected to be a problem in practice, for completeness, it is included here.

*Note: 'Mura' is a defect that looks like a small-scale crack with very small changes in luminance or colour. 'Mura' is likely to be noticeable in the flat portions of images even if the size of the Mura is very small. Mura will be revealed in a small area uniformity test.*

### **5.16 Streaking (also known as crosstalk, overspill or shadowing)**

The effect, as shown in Figure 1, is the result of horizontal or vertical crosstalk between the signal in different parts of the line or column in the display.

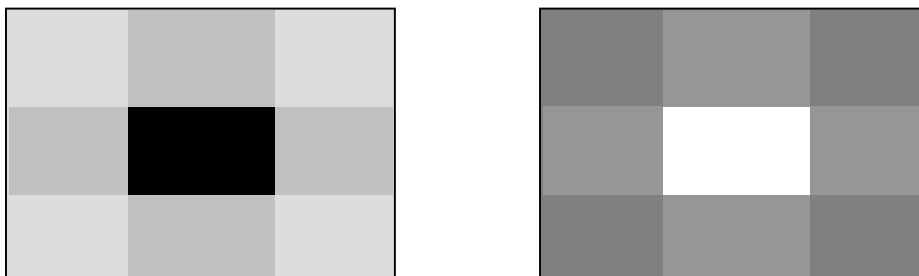


Figure 1: Examples of shadowing (in this case both horizontal and vertical)

When the input signal is a rectangle of 100% white near the centre, surrounded by a grey area, the difference in luminance between the horizontal and vertical belt-like portions and the other grey portions shown in Figure 1 should not be greater than 0.5% for Grade 1 monitors, 1% for Grade 2 monitors, and 2% for Grade 3 monitors. The same should apply to a black rectangle on a grey surround.

### **5.17 Stability and environmental conditions**

The monitor shall perform in accordance with this specification over an ambient temperature range of 0° to +40°C.

Given an ambient temperature within the range specified above, a period of twenty minutes shall be allowed after the monitor is switched on before it is expected to perform in accordance with the specification. The monitor shall then maintain this performance for a period of at least twenty-

four hours.

One minute after it has been switched on, the monitor shall produce subjectively acceptable pictures. For guidance, it is anticipated that the monitor shall perform with tolerances no worse than twice those indicated in this specification during the first twenty minutes of operation.

The monitor, when switched on at a temperature between 0° and +40°C, shall continue to function without failure within the temperature range of +20° to +45°C.

The monitor shall continue to function in accordance with this specification in a humidity range of 10% to 75% (non-condensing).

The monitor shall function in accordance with this specification at a height of up to 3000 m

Within a temperature range of -35° to +70°C, it shall be possible to store the monitor without damage.

### **5.18 Pixel defects**

Defects are classified according to the severity of their visual impact. ISO 13406-2 provides more information and a classification of different types of pixel defects.

- 1) Grade 1 and Grade 2 monitors shall have no visible pixel defects (defined as pixel defect category I in ISO 13406-2).
- 2) Grade 3 monitors shall have no visible pixel defects in the central area covering 50% of the display area, and fulfil pixel defect category II outside this area.
- 3) There should never be coupled pixel defects (defined as pixel cluster defect category I in ISO 13406-2).

*Note:* A useful explanation is given at:

[http://www.maxdata.com/repository.com/downloads/Pixel\\_monitors.pdf](http://www.maxdata.com/repository.com/downloads/Pixel_monitors.pdf)

### **5.19 Ringing and handling of under- and over-shoots**

Ringing or overshoots should not be introduced by any processing in the display if the input signal is suitably conditioned (i.e. is within Nyquist limits). See also below.

Grade 1 and Grade 2 monitors should not have a 'sharpness' control and should not introduce any other image 'enhancements'.

Monitors should not cut off under- and over-shoots, or sub-black and super-white levels.

### **5.20 Treatment of illegal signals**

Signals which contain significant frequency components outside the Nyquist limit (i.e. have not been anti-alias filtered) should be displayed in such a way that any ringing or aliasing inherent in such signals DOES become visible.

Professional interfaces and standards for the carriage and gamut mapping on a display of wide-colour gamut signals in the broadcast environment have not yet become established. It is also unclear exactly how a monitor should handle out-of-gamut signals, but Grade 1 and Grade 2 monitors are expected to have a mode (or modes) which will indicate out of gamut colours, and not attempt to correct such colours.

### 5.21 Image sticking (long-term after-image)

The characteristics for image sticking (long-term afterimage) on the screen should be comparable to or better than that of the CRT monitor.

Broadcasters should bear in mind that fixed service idents on multi-viewer screens may cause problems on some displays. In general, guidelines [9] for avoiding image sticking should be adhered to.

### 5.22 Supported Standards, and signal interfaces

The monitors should handle the signal formats listed below. It is not necessary for a monitor to support all formats (but see EBU D97-2005). The manufacturer must state which of the formats are supported by each available interface.

Format	Relevant standard
480i/30 (29.97)	ITU-R Rec. BT.601-5
576i/25	ITU-R Rec. BT.601-5
720p/50	SMPTE 296M-2001
720p/60 (59.94)	SMPTE 296M-2001 ITU-R Rec. BT.1543
1080i/25	SMPTE 274M-2005 ITU-R Rec. BT. 709-5
1080i/30 (29.97)	SMPTE 274, ITU 709

Format	Relevant standard
1080p/24 (23.98)	SMPTE 274, ITU 709
1080psf/24 (23.98)	SMPTE 274, ITU 709
1080p/25	SMPTE 274, ITU 709
1080psf/25	SMPTE 274, ITU 709
1080p/30 (29.97)	SMPTE 274, ITU 709
1080psf/30 (29.97)	SMPTE 274, ITU 709
1080p/50	SMPTE 274, ITU 709
1080p/60 (59.94)	SMPTE 274, ITU 709

Some signal formats are available in 4:4:4 in addition to 4:2:2, and these formats shall also be supported where applicable.

All inputs should provide an indication of the signal standard detected. The monitors should have the following interfaces:

	Grade 1	Grade 2	Grade 3	Set design	Relevant standard
SDI *	A, at least 2	A, at least 2	A	A	SMPTE 259M, ITU-R Rec. BT.656-4
HD-SDI *	A, at least 2	A, at least 2	A	A	SMPTE 292M-2008
Dual HD-SDI ** or 3Gbit/s	B	B	B		SMPTE 372M-2002 ** SMPTE 424M, 425M
HDMI ***	B	B	B	B	High-Definition Multimedia Interface ( <a href="http://www.hdmi.org">www.hdmi.org</a> )
DVI 1.0 ***	B	B	B	B	<a href="http://www.ddwg.org">www.ddwg.org</a>
Component RGB, Y C <sub>r</sub> C <sub>b</sub>	B	B	B	B	
CVBS (PAL, SECAM & NTSC)	B	B	B	B	ITU-R BT.470
RF (Analogue)			C	C	
RF (DTT)			C		DVB-T

A = mandatory, B = available as an option, C = should be available at least as an external module

\* Should be auto-sensing SDI/HD-SDI.

\*\* Dual link ancillary data packet for channel identification according to SMPTE 372M.

\*\*\* HDCP must be available on the input, so that the picture is always shown.

*Note: At present there are a number of additional candidate interface technologies to carry the*

highest data rate signals, in compressed and uncompressed forms. The adoption of these interfaces in the professional broadcasting environment is still open. Examples include 10 Gbit Ethernet and forms of intermediate (quasi-lossless) compression.

### 5.23 Other facilities

The following switchable features are also necessary:

Features	Grade 1	Grade 2	Grade 3	Set design
4:3 and 16:9 aspect ratio mode	M	M	M	M
safe title and aspect ratio markers	M	M		
tally lamp (red, green, yellow)	M	M	*	
RS 232 and/or GPI remote control	M	M		
over scan / full screen / 1 to 1 pixel-map modes	M	M		
H/V delay	M	M		
blue only mode	M	M		
mono mode	M	M		
ext. sync in	M	M		
Stereo loudspeaker			**	

M = Mandatory

\* required in some applications

\*\* required in some applications, and may include an indication of the audio standard

### 5.24 Acoustic Noise

Acoustic noise standards used are the Noise Rating (NR) curves defined by Kosten and van Os [10] and standardised in now-withdrawn versions of ISO 1996. The relevant curves are reproduced in Figure 2, below.

- 1) Monitors intended for use in audio-edit areas, in set design or as camera viewfinders shall not produce acoustic noise in excess of NR5.
- 2) Monitors that may be used on the studio floor or in edit areas shall not produce acoustic noise in excess of NR10.
- 3) Monitors used in technical areas shall not produce acoustic noise in excess of NR20.

### 5.25 Surface reflectivity (glare)

Surface reflectivity is likely to be a greater issue in monitors used in less controlled viewing environments (i.e. with high ambient light levels), so is likely to be more important for a Grade 3 monitor than Grade 1 or 2. Because every such viewing condition is different, it is not possible to specify a required limit on reflectivity, but it is an issue of which users may need to be aware.



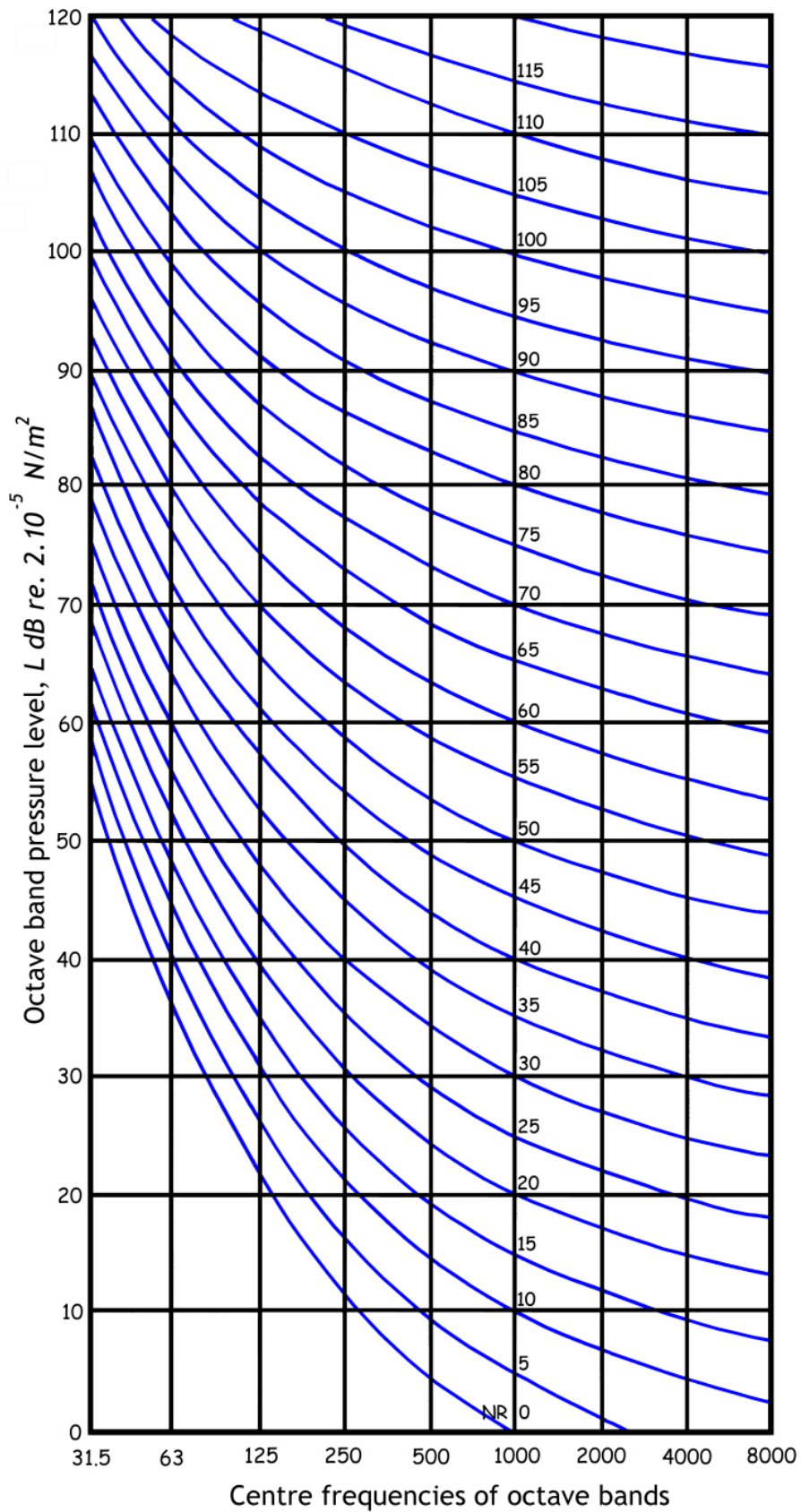


Figure 2: Noise Rating (NR) Curves

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- [10] Kosten and van Os, 'Community reaction criteria for external noises,' National Physical Laboratory Symposium, No. 12, 1962, p. 377, London H.M.S.O.

## 7. Bibliography

- Video Electronics Standards Association (VESA) Flat Panel Display Measurements Task Group - FLAT PANEL DISPLAY MEASUREMENTS STANDARD Version 2.0 (FPDm<sup>2</sup>)
- Tolerances on 'Illegal' colours in television, EBU Technical Text R103-2000 (<http://tech.ebu.ch/docs/r/r103.pdf>)
- Measuring Colour (Third Edition, Fountain Press, 1998) R.W.G. Hunt
- Circles of Confusion (EBU, 2009) A. Roberts

## Annex A: Gamma considerations

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 MPEG-4 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 [6] 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. it is definitely not linear.

The system gamma can be expressed as:

$$\text{System gamma} = \text{camera encoding gamma (OETF}^*) \times \text{display gamma (EOTF}^{**})$$

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

$$\text{System gamma} = 1.2 = \text{OETF gamma} \times 2.35$$

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 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 the calculation above.

From the above, since the consumer viewing environment does not 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.

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\* OETF: Opto-electrical transfer function

\*\* EOTF: Electro-optical transfer function



## Annex B: CIE 1976 - the L\*u\*v\* uniform colour space

The comparison of colour differences on chromaticity diagrams such as CIE 1976 Yu'v' is only applicable at one given luminance level, because the perception of colour differences is dependent on the luminance level. The CIE L\*u\*v\* (or CIELUV) space is therefore used to provide tolerances of approximately equal visibility. It is used here as a compromise between a standardised and easily calculated measure of colour differences, and more sophisticated and complex models of colour vision. L\* is termed 'Lightness'.

### General formula:

$$\begin{aligned} L_{a/n}^* &= 116(Y_a/Y_n)^{1/3} - 16 && \text{for } Y_a/Y_n > 0.008856 \\ L_{a/n}^* &= 903.3 (Y_a/Y_n) && \text{for } Y_a/Y_n \leq 0.008856 \\ u_a^* &= 13 L_{a/n}^* (u'_a - u'_n) \\ v_a^* &= 13 L_{a/n}^* (v'_a - v'_n) \end{aligned}$$

$Y_n$ ,  $u'_n$  and  $v'_n$  are the chromacities of the reference white. The  $a$  index is for the desired calculation point (can be substituted by  $m$ ,  $w$ ,  $D65$  or  $ref$  in function of which L\*, u\* or v\* is desired)

$$\begin{aligned} \Delta u_m^* &= u_m^* - u_{ref}^* \\ \Delta u_m^* &= u_m^* - u_{ref}^* \\ \Delta u_m^* &= 13 L_{m/n}^* (u'_m - u'_n) - 13 L_{ref/n}^* (u'_{ref} - u'_n) \\ \Delta v_m^* &\text{ is calculated in the same way} \end{aligned}$$

where  $m$  is for the measured chromacity, and  $ref$  is the reference from which  $\Delta u_m^*$  is calculated.

### For tolerances to be applied to the white point:

- $ref$  is  $D65$  with chromaticity coordinates  $u'_{D65} = 0.1978$  and  $v'_{D65} = 0.4683$  [6].
- $m$  becomes  $w$  for measured white
- $n$  is  $D65$
- For Grade 1 monitors  $Y_n$  is taken as  $100 \text{ cd/m}^2$ , for Grade 2,  $200 \text{ cd/m}^2$ , and for Grade 3 as  $250 \text{ cd/m}^2$
- The generalized formula can be simplified as:

$$\begin{aligned} \Delta u_w^* &= 13 L_{w/n}^* (u'_w - u'_{D65}) \\ \Delta v_w^* &= 13 L_{w/n}^* (v'_w - v'_{D65}) \end{aligned}$$

### For grey-scale tracking calculations:

- $ref$  is the measured white point and becomes  $w$
- $m$  becomes  $g$  for grey-scale
- $n$  is the measured white point,  $w$
- The generalized can be simplified as:

$$\begin{aligned} \Delta u_g^* &= 13 L_{g/w}^* (u'_g - u'_w) \\ \Delta v_g^* &= 13 L_{g/w}^* (v'_g - v'_w) \end{aligned}$$

### For test colour and primary reproduction calculations:

- $ref$  is the expected test colour and becomes  $ex$
- $m$  becomes  $c$  for colour
- $n$  is the measured white point,  $w$

- The generalized formula can be simplified as:

$$\Delta u_c^* = 13 L_{c/w}^* (u'_c - u'_w) - 13 L_{ex/w}^* (u'_{ex} - u'_w)$$

but  $L_{ex/w}^*$  is replaced by  $L_{c/w}^*$  to remove the effect of EOTF error of the display

$$\Delta u_c^* = 13 L_{c/w}^* (u'_c - u'_{ex})$$

$$\Delta v_c^* = 13 L_{c/w}^* (v'_c - v'_{ex})$$

***Deltas:***

$$\Delta u^*v^* = \sqrt{(\Delta u^*)^2 + (\Delta v^*)^2}$$

$$\Delta E_{uv}^* = \sqrt{(\Delta L^*)^2 + (\Delta u^*)^2 + (\Delta v^*)^2} \quad (\text{simplified in this document as } \Delta E^*)$$

For further information, please refer to §§ 3.8 to 3.10 of 'Measuring Colour' (see bibliography).