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VIDEO SIGNAL TOLERANCE IN DIGITAL TELEVISION SYSTEMS

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Video Signal Tolerance in Digital Television Systems

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TC	2000	2020	2020

Keywords: Gamut, Luminance, RGB Levels, HDR, HLG, PQ, Spatial Filtering, Video Range.

Recommendation

The EBU, considering that,

- video levels have traditionally been measured with devices that display a trace, such as a traditional waveform monitor,
- that readings in mV no longer give relevant information in digital signal infrastructures,
- television systems now include high dynamic range and wide colour space images as well as standard dynamic range and colour space images in the same digital container,
- that a certain tolerance can be allowed in digital signal levels,

recommends that

the guidelines in **Annex 1** be used when measuring and assessing video signal levels.

The EBU encourages users and industry to provide feedback on this document via tech@ebu.ch.
The feedback will be valuable for further revisions of this Recommendation in due time.

Annex 1: Guidelines for measuring and assessing video signal levels

Introduction

There is confusion and some misunderstanding on the use of the terms "narrow" and "full" range video signals and how they are used in the television industry. Television and broadcasting do not primarily use the "full range" of digital sample (code) values available in a given format.

This is often referred to as ***"narrow range"*** or ***"video range"***. Another term, "*extended range*" is not formally defined but is sometimes used for the range 64 – 1019 (10-bit), so including super-whites, whilst maintaining sub-blacks.

Furthermore, it should be remembered that SDI always reserves some code values for its own signal processing requirements. An incorrect interpretation of the video range values used in SDI links and compression technologies for contribution and distribution can seriously compromise the images.

Any signals that contain values that exceed the total video signal range (Table 1) will be clipped (application-specific). Such clipping can cause harmonic distortion and alias artefacts in the video signal, which manifests as compression artefacts and the potential for increased data rates both for contribution and distribution.

At the time of publication[1], both traditional standard dynamic range and high dynamic range programmes are being produced. It is expected that some colours that are present in the HDR colour volume when converted to SDR will be outside of the ITU-R BT.709 volume Nominal Range but within the Preferred Range (Table 1). This allows conversion processing to maintain the saturation and brightness of colours already within the Nominal Range target colour volume.

Care should be taken with live productions, especially those with uncontrolled lighting, to prevent clipping of highlights during temporary excursions to extremes of code values, i.e. camera clippers should be set to Preferred Range limits (as per this document). For pre-produced and colour graded material, the nominal limits contained in this document should be followed closely.

Video Signal

In a video signal, each primary component should lie between 0 and 100% of the narrow video range between black level and the nominal peak level (R and G and B). Ideally, video levels should lie within the specified limits so that programmes can be distributed without adjustment.

When television signals are manipulated in YUV form, it is possible to produce "illegal" combinations that, when de-matrixed, would produce R, G or B signals outside the range 0% - 100%.

Video Signal Tolerance

In practice it is difficult to avoid generating signals slightly out of range, and it is considered reasonable to allow a small tolerance. Therefore,

the EBU recommends that,

the RGB components and the corresponding Luminance (Y) signal should not normally exceed the "Preferred Minimum/Maximum" range of digital sample levels in Table 1, below.

[1] This document will be updated as more is learned from experience gained through extensive use.

Any signals outside the "Preferred Minimum/Maximum" range are described as having a gamut error (or as being out-of-gamut). Signals shall not exceed the "Total Video Signal Range", overshoots that attempt to "exceed" these values may clip.

Table 1

System Bit Depth	Range in Digital Sample (Code) Values		
	Nominal Video Range	Preferred Min. / Max.	Total Video Signal Range
8-bit	16 - 235	5 - 246	1 - 254
10-bit	64 - 940	20 - 984	4 - 1019
12-bit	256 - 3760	80 - 3936	16 - 4079
16-bit	4096 - 60160	1280 - 62976	256 - 65279

Video Signal Filtering

To remove transient over- and under-excursions of the signals, and to minimise the effect of high frequency noise on the colour gamut measurements, the use of appropriate filters in all measurement channels is recommended.

For interlaced and progressive signals

A quarter band filter applied horizontally and a half band filter applied vertically is recommended.

Horizontal Filter Coefficients: 1/16, 2/16, 3/16, 4/16, 3/16, 2/16, 1/16

Vertical Filter Coefficients: 1/4, 1/2, 1/4 (Note: this is applied intra field[2] for interlace signals).

Signal Issues

Certain operations and signal processing may produce relatively benign gamut overshoot errors in the picture. Therefore,

the EBU further recommends that

measuring equipment should indicate an "Out-of-Gamut" occurrence only after the error exceeds 1% of the image[3].

Signals outside the active picture area shall be excluded from measurement.

Note: The term "Out-of-Gamut" refers to code values that exceed the Preferred Min / Max values in Table 1

Experience has shown that colour gamut "legalisers" should be used with caution as they may create artefacts in the picture that are more disturbing than the gamut errors they are attempting to correct. It is advisable not to "legalise" video signals before all signal processing has been carried out.

[2] In certain extreme cases, vertical filtering on interlaced content could cause hue shifts that may affect measurements.

[3] For image systems described in ITU-R BT.601, BT.709 and BT.1847, signals outside the active picture area as described in EBU R 095, shall be excluded from measurement

Annex 2: Background on video signal range in SDI-based infrastructures

Broadcasters have traditionally used narrow-range signals with headroom both below black and in "super-whites" for several reasons. In live production, for instance, it is inevitable that signals will accidentally go outside the nominal range for short periods of time, typically when a camera moves, or when the sun comes out, or in speculars.

In such circumstances, if the signal were clipped this would cause ringing in filters, which would be visible on the image, and any subsequent processing would exacerbate the problem. So, clipping takes place well beyond the nominal signal range.

The introduction of digital processing does not remove the problems of ringing in processing, and in addition, digital compression is less efficient in the presence of both clipping and ringing.

In the blacks, clipping of sub-blacks prevents the alignment of monitors with the PLUGE signal, and thus prevents the accurate line-up of monitors in the production environment. In addition, clipping of blacks adds distortion and harmonics, which are harder to compress, and the increase in quantisation noise also leads to an increase in noise power.

Signal range

Currently nearly all TV studios are equipped with an SDI-based environment using 10-bit video signals with a $Y'C'_BC'_R$ 4:2:2 sub-sampling representing the digital video signal.

In analogue video the normal range corresponds to 0 mV to 700 mV luminance amplitude, but signals can on occasion excurse beyond those limits. When represented digitally, this voltage range is usually mapped into what is now called nominal video range, and any signal outside this range, within certain limits, makes use of the headroom available in this digital signal.

The system using these values for the nominal video range is variously and confusingly called "*Video Range*", "*Limited Range*", "*SMPTE Range*" or "*Narrow Range*". This is to distinguish it from what is known as "*Full Range*" where the nominal video range covers all values allowed in the SDI specification, with no headroom.

In file-based applications, *Full Range* is confusingly slightly larger still, using values that are reserved for timing information in SDI signalling.

Figure 1 shows typical video signal levels in "Video Range" used on an SDI interface, and on either side, the two versions of "Full Range" described above.

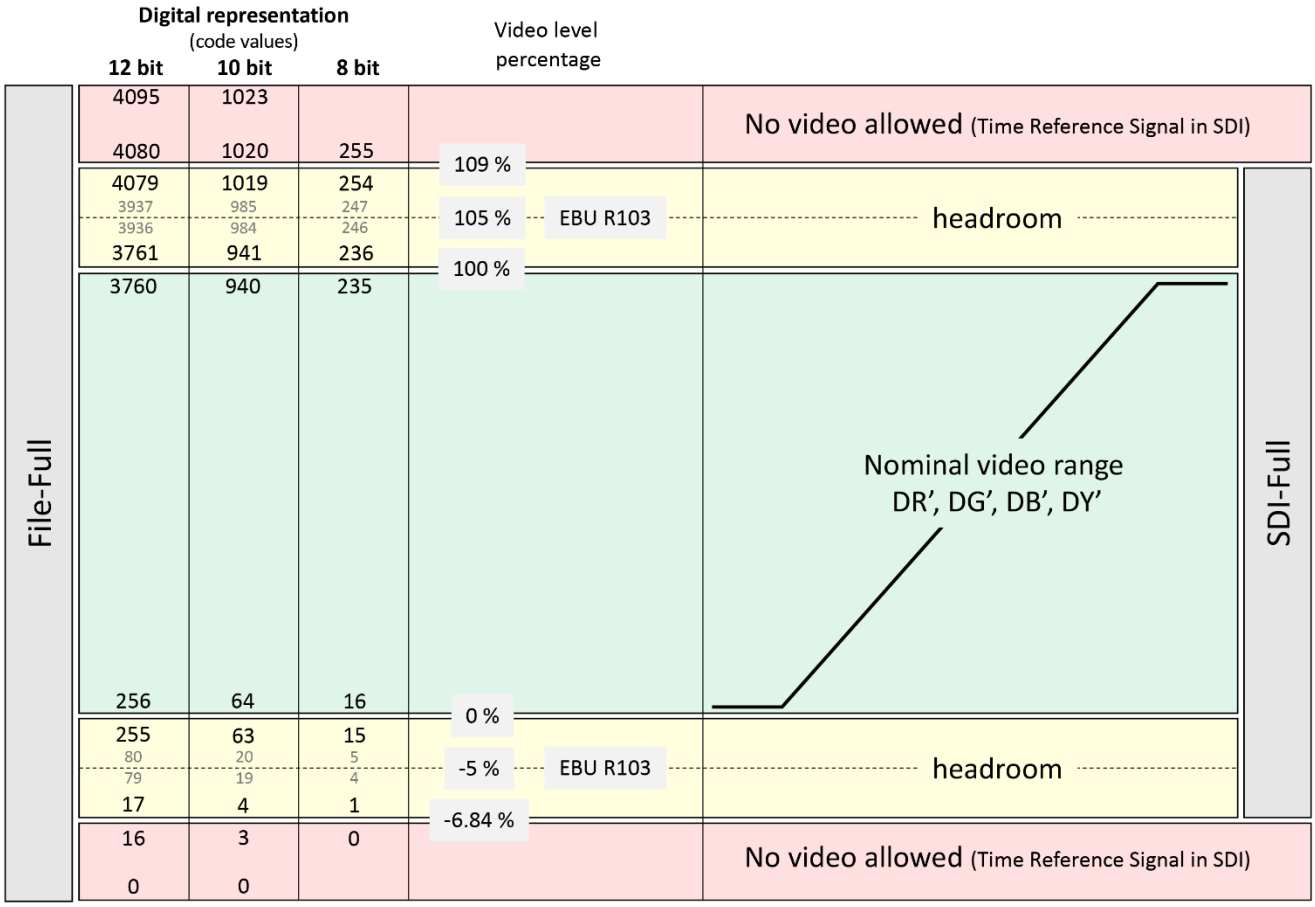

Figure 1: Typical signal levels for SDI

Usually, the video components should not exceed the nominal video range (see Annex 1), but there are circumstances where video levels are above 100% or below 0% video range, which is allowed and no correction is needed (no hard clipping, no legalizing needed).

Full Range (SDI-based):

Full Range SDI based means that code values having the 8 most-significant bits all zero or all one are excluded from video and/or ancillary data but all code values in between are allowed to be video (see also Figure 1).

Full Range (file-based):

Within file-based production environments, the permitted values of quantisation steps for Full Range (10-bit) video can be 0 through 1023 (decimal). If so, this shall be signalled within the file container.

But when transmitting these Full Range files through real-time interfaces it is recommended that the interface characteristics be checked: 10-bit-SDI does not allow digital codes 0 through 3 (decimal) and 1020 through 1023 (decimal) as these codes are used for synchronisation purposes (for further examples, see Figure 1).