



Recommendation ITU-R BT.601-7
(03/2011)

**Studio encoding parameters of digital
television for standard 4:3 and
wide-screen 16:9 aspect ratios**

BT Series
Broadcasting service
(television)



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Series	Title
BO	Satellite delivery
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BT	Broadcasting service (television)
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M	Mobile, radiodetermination, amateur and related satellite services
P	Radiowave propagation
RA	Radio astronomy
RS	Remote sensing systems
S	Fixed-satellite service
SA	Space applications and meteorology
SF	Frequency sharing and coordination between fixed-satellite and fixed service systems
SM	Spectrum management
SNG	Satellite news gathering
TF	Time signals and frequency standards emissions
V	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.601-7

**Studio encoding parameters of digital television for standard 4:3
and wide-screen 16:9 aspect ratios**

(Question ITU-R 1/6)

(1982-1986-1990-1992-1994-1995-2007-2011)

Scope

This Recommendation also covers the pixel characteristics that represent a 525- or 625-line interlace digital television image.

This Recommendation specifies methods for digitally coding video signals. It includes a 13.5 MHz sampling rate for both 4:3 and 16:9 aspect ratio images with performance adequate for present transmission systems.

The ITU Radiocommunication Assembly,

considering

- a) that there are clear advantages for television broadcasters and programme producers in digital studio standards which have the greatest number of significant parameter values common to 525-line and 625-line systems;
- b) that a worldwide compatible digital approach will permit the development of equipment with many common features, permit operating economies and facilitate the international exchange of programmes;
- c) that an extensible family of compatible digital coding standards is desirable. Members of such a family could correspond to different quality levels, different aspect ratios, facilitate additional processing required by present production techniques, and cater for future needs;
- d) that a system based on the coding of components is able to meet these desirable objectives;
- e) that the co-siting of samples representing luminance and colour-difference signals (or, if used, the red, green and blue signals) facilitates the processing of digital component signals, required by present production techniques,

recommends

that the following be used as a basis for digital coding standards for television studios in countries using the 525-line system as well as in those using the 625-line system.

1 Extensible family of compatible digital coding standards

1.1 The digital coding should allow the establishment and evolution of an extensible family of compatible digital coding standards. It should be possible to interface simply between any members of the family.

1.2 The digital coding should be based on the use of one luminance and two colour-difference signals (or, if used, the red, green and blue signals).

1.3 The spectral characteristics of the signals must be controlled to avoid aliasing whilst preserving the passband response. Filter specifications are shown in Appendix 2.

2 Specifications applicable to any member of the family

2.1 Sampling structures should be spatially static. This is the case, for example, for the orthogonal sampling structures specified in this Recommendation.

2.2 If the samples represent luminance and two simultaneous colour-difference signals, each pair of colour-difference samples should be spatially co-sited. If samples representing red, green and blue signals are used they should be co-sited.

2.3 The digital standard adopted for each member of the family should permit worldwide acceptance and application in operation; one condition to achieve this goal is that, for each member of the family, the number of samples per line specified for 525-line and 625-line systems shall be compatible (preferably the same number of samples per line).

2.4 In applications of these specifications, the contents of digital words are expressed in both decimal and hexadecimal forms, denoted by the suffixes “d” and “h” respectively.

To avoid confusion between 8-bit and 10-bit representations, the eight most-significant bits are considered to be an integer part while the two additional bits, if present, are considered to be fractional parts.

For example, the bit pattern 10010001 would be expressed as 145_d or 91_h, whereas the pattern 1001000101 would be expressed as 145.25_d or 91.4_h.

Where no fractional part is shown, it should be assumed to have the binary value 00.

2.5 Definition of the digital signals Y , C_R , C_B , from the primary (analogue) signals E'_R , E'_G and E'_B

This paragraph describes, with a view to defining the signals Y , C_R , C_B , the rules for construction of these signals from the gamma pre-corrected primary analogue signals E'_R , E'_G and E'_B . The signals are constructed by following the three stages described in § 2.5.1, 2.5.2 and 2.5.3. The method is given as an example, and in practice other methods of construction from these primary signals or other analogue or digital signals may produce identical results. An example is given in § 2.5.4.

2.5.1 Construction of luminance (E'_Y) and colour-difference ($E'_R - E'_Y$) and ($E'_B - E'_Y$) signals

The construction of luminance and colour-difference signals is as follows:

$$E'_Y = 0.299 E'_R + 0.587 E'_G + 0.114 E'_B$$

then:

$$(E'_B - E'_Y) = E'_B - 0.299 E'_R - 0.587 E'_G - 0.114 E'_B = -0.299 E'_R - 0.587 E'_G + 0.886 E'_B$$

and

$$(E'_R - E'_Y) = E'_R - 0.299 E'_R - 0.587 E'_G - 0.114 E'_B = -0.299 E'_R - 0.587 E'_G - 0.114 E'_B$$

Taking the signal values as normalized to unity (e.g. 1.0 V maximum levels), the values obtained for white, black and the saturated primary and complementary colours are shown in Table 1.

TABLE 1
Normalized signal values

Condition	E'_R	E'_G	E'_B	E'_Y	$E'_R - E'_Y$	$E'_B - E'_Y$
White	1.0	1.0	1.0	1.0	0	0
Black	0	0	0	0	0	0
Red	1.0	0	0	0.299	0.701	-0.299
Green	0	1.0	0	0.587	-0.587	-0.587
Blue	0	0	1.0	0.114	-0.114	0.886
Yellow	1.0	1.0	0	0.886	0.114	-0.886
Cyan	0	1.0	1.0	0.701	-0.701	0.299
Magenta	1.0	0	1.0	0.413	0.587	0.587

2.5.2 Construction of re-normalized colour-difference signals (E'_{C_R} and E'_{C_B})

Whilst the values for E'_Y have a range of 1.0 to 0, those for $(E'_R - E'_Y)$ have a range of +0.701 to -0.701 and for $(E'_B - E'_Y)$ a range of +0.886 to -0.886. To restore the signal excursion of the colour-difference signals to unity (i.e. +0.5 to -0.5), re-normalized red and blue colour-difference signals E'_{C_R} and E'_{C_B} respectively can be calculated as follows:

$$E'_{C_R} = \frac{E'_R - E'_Y}{1.402} = \frac{0.701E'_R - 0.587E'_G - 0.114E'_B}{1.402}$$

and

$$E'_{C_B} = \frac{E'_B - E'_Y}{1.772} = \frac{-0.299E'_R - 0.587E'_G + 0.886E'_B}{1.772}$$

The symbols E'_{C_R} and E'_{C_B} will be used only to designate re-normalized colour-difference signals, i.e. having the same nominal peak-to-peak amplitude as the luminance signal E'_Y thus selected as the reference amplitude.

2.5.3 Quantization

In the case of a uniformly-quantized 8-bit or 10-bit binary encoding, 2^8 or 2^{10} , i.e. 256 or 1 024, equally spaced quantization levels are specified, so that the range of the binary numbers available is from 0000 0000 to 1111 1111 (00 to FF in hexadecimal notation) or 0000 0000 00 to 1111 1111 11 (00.0_h to FF.C_h in hexadecimal notation), the equivalent decimal numbers being 0.00_d to 255.75_d, inclusive.

In this Recommendation, levels 0.00_d and 255.75_d are reserved for synchronization data, while levels 1.00_d to 254.75_d are available for video.

Given that the luminance signal is to occupy only 220 (8-bit) or 877 (10-bit) levels, to provide working margins, and that black is to be at level 16.00_d, the decimal value of the quantized luminance signal, Y , is:

$$Y = \text{int}\{(219E'_Y + 16) \times D\} / D$$

where D takes either the value 1 or 4, corresponding to 8-bit and 10-bit quantization respectively. The operator $\text{int}()$ returns the value of 0 for fractional parts in the range of 0 to 0.4999 ... and +1 for fractional parts in the range 0.5 to 0.999 ..., i.e. it rounds up fractions above 0.5.

Similarly, given that the colour-difference signals are to occupy 225 (8-bit) or 897 (10-bit) levels and that the zero level is to be level 128.00_d, the decimal values of the quantized colour-difference signals, C_R and C_B , are:

$$C_R = \text{int}\{(224E'_{C_R} + 128) \times D\} / D$$

and

$$C_B = \text{int}\{(224E'_{C_B} + 128) \times D\} / D$$

The digital equivalents are termed Y , C_R and C_B .

2.5.4 Construction of Y , C_R , C_B via quantization of E'_R , E'_G , E'_B

In the case where the components are derived directly from the gamma pre-corrected component signals E'_R , E'_G , E'_B , or directly generated in digital form, then the quantization and encoding shall be equivalent to:

$$E'_{R_D} \text{ (in digital form)} = \text{int}\{(219E'_R + 16) \times D\} / D$$

$$E'_{G_D} \text{ (in digital form)} = \text{int}\{(219E'_G + 16) \times D\} / D$$

$$E'_{B_D} \text{ (in digital form)} = \text{int}\{(219E'_B + 16) \times D\} / D$$

Then:

$$Y = \text{int}\{(0.299E'_{R_D} + 0.587E'_{G_D} + 0.114E'_{B_D}) \times D\} / D$$

$$\approx \text{int}\left\{\left(\frac{k'_{Y1}}{2^m}E'_{R_D} + \frac{k'_{Y2}}{2^m}E'_{G_D} + \frac{k'_{Y3}}{2^m}E'_{B_D}\right) \times D\right\} / D$$

$$C_R = \text{int}\left[\left\{\left(\frac{0.701E'_{R_D} - 0.587E'_{G_D} - 0.114E'_{B_D}}{1.402}\right) \frac{224}{219} + 128\right\} \times D\right] / D$$

$$\approx \text{int}\left[\left\{\left(\frac{k'_{CR1}}{2^m}E'_{R_D} + \frac{k'_{CR2}}{2^m}E'_{G_D} + \frac{k'_{CR3}}{2^m}E'_{B_D}\right) + 128\right\} \times D\right] / D$$