ROHDE&SCHWARZ

BROADCASTING DIVISION

APPLICATION NOTE

Incorrect colours in the RGB display of the "digital" colour bars

Products:

CCVS + COMPONENT GENERATOR	***SAF***
CCVS GENERATOR	***SFF***
DIGITAL VIDEO ANALYZER	***VCA***

7BM18_0E

Incorrect colours in the RGB display of the "digital" colour bars

For high reproducibility, the 100/0/100/0 and 100/75/0 colour bars are defined by ITU-R BT. 801 in pixels in a format specified by ITU-R BT. 601/656. At the output of a TV generator using these formats the colour bars are therefore available as undistorted, digital Y, C_B, C_R components.

In order to simplify high-precision timing measurements, the rise time of the Y component is reduced to 150 ns. This value has been chosen on purpose although it is outside the ITU-R BT. 470 specifications. (ITU-R BT. 470 also defines video-signal characteristics. A minimum rise time of 200 ms is specified for Y in the 5-MHz system.)
According to the standard, the minimum rise time of C_B and C_R components is 300 ns which is also specified in ITU-R BT. 801.

When working with the digital Y, C_B, C_R components, everything is in compliance with the standard. However, if R,G,B display is chosen with the aid of a (digital) matrix, the primary colours will have impermissible amplitudes as a result of mathematical conversions.

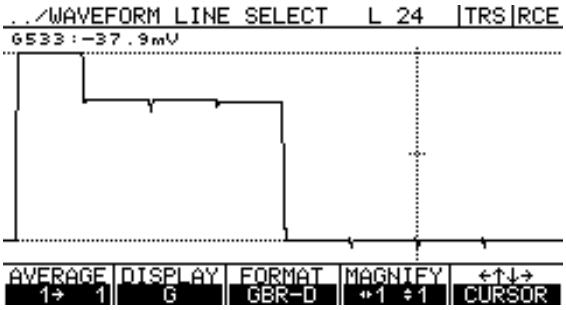

Fig. 1 Green channel of digital 100/0/75/0 colour bar on VCA display

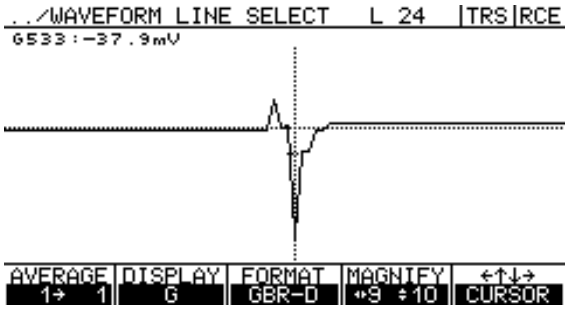

Fig. 2 Spike in green channel at red/blue transition shows an impermissible negative green level (expanded display)

The following calculation shows that, although RGB errors of almost 6% are visible on the VCA, neither the ITU-R BT. 601 option of SAF/SFF supplies faulty signals nor the DIGITAL VIDEO ANALYZER VCA outputs incorrect results as may be caused by rounding procedures in RGB matrixing. This can best be demonstrated by the red/blue transition of the 100/0/75/0 colour bar.

	Clock number acc. to ITU-R BT. 801						
Component	449 to 529	530	531	532	533	534	535 bis 615
Y	65	65	62	50	38	35	35
	Clock number acc. to ITU-R BT. 801						
	226 to 263	264	265	266	267	268	269 bis306
C_B	100	100	111	156	200	212	212
C_R	212	212	202	163	124	115	114

Table 1 Red/blue transition to ITU-R BT. 801

Negative peaks with an amplitude of several percent for R and G are produced in the transition range, and the levels of the three components during the actual colour burst are not correct either. This will be proved in the following calculations:

1 Notes on the structure of digital-parallel signals to ITU-R BT. 601/656

The Y component has twice the bandwidth of the C_B and C_R components. The number of samples of the 150-ns Y slope equals that of the two 300-ns slopes of C_B and C_R. This means that two Y components are assigned to each C_B and C_R value.

ITU-R BT. 656 specifies a multiplexed transmission of samples in the order
C_B Y C_R Y C_B Y .....
with 27 Msamples/s.

For decoding the data stream to the 13.5-clock level the samples have to be arranged in the correct order:

C_{B1}	Y_1	C_{R1}	Y_2	C_{B2}	Y_3	C_{R2}	Y_4	C_{B3}	Y_5	C_{R3}	Y_6	C_{B4}	Y_7	C_{R4}	Y_8	C_{B5}	Y_9	C_{R5}	Y_{10}	
		Y_1		Y_2		Y_3		Y_4		Y_5		Y_6		Y_7		Y_8		Y_9		Y_{10}
		C_{B1}		C_{B1}		C_{B2}		C_{B2}		C_{B3}		C_{B3}		C_{B4}		C_{B4}		C_{B5}		C_{B5}
		C_{R1}		C_{R1}		C_{R2}		C_{R2}		C_{R3}		C_{R3}		C_{R4}		C_{R4}		C_{R5}		C_{R5}

Table 2 Sorted assignment of parallel ITU-R BT. 601/656 data stream

2 Calculation of red-blue transition in RGB

The red/blue transition defined by ITU-R BT. 801 is determined with the aid of the table below:

Sample number for Y to ITU-R BT. 801																							
528		529		530		531		532		533		534		535		536		537		538		539	
Y1	65	Y2	65	Y3	65	Y4	62	Y5	50	Y6	38	Y7	35	Y8	35	Y9	35	Y10	35	Y11	35	Y12	35
Cb1	100	Cb1	100	Cb2	111	Cb2	111	Cb3	156	Cb3	156	Cb4	200	Cb4	200	Cb5	212	Cb5	212	Cb6	212	Cb6	212
Cr1	212	Cr1	212	Cr2	202	Cr2	202	Cr3	163	Cr3	163	Cr4	124	Cr4	124	Cr5	115	Cr5	115	Cr6	114	Cr6	114
	264				265				266				267				268				269		
Sample number for Cb , Cr to ITU-R BT. 801																							

Table 3 Y, C_B, C_R values of the red-blue transition in the 8-bit system

Using the coefficient defined by ITU-R BT. 601, the following equations for the conversion of Y, C_B, C_R components in digital format to a rescaled R, G, B display in [mV] are:

$R = +4.3813 \times (C_R - 128) + 3.1963 \times (Y - 16)$ [mV]
$G = -1.0741 \times (C_B - 128) - 2.2319 \times (C_R - 128) + 3.1963 \times (Y - 16)$ [mV]
$B = +5.5375 \times (C_B - 128) + 3.1963 \times (Y - 16)$ [mV]

The coefficients of these equations are rounded to five digits. Thus the amplitude of the primary signals is of sufficient accuracy (<<1 mV).

If the associated Y, C_B, C_R samples are substituted in the above equation, the following values are obtained at the red-blue transition for the amplitude of component

R in [mV]

Samplenummer für R nach ITU-R BT. 801																							
528		529		530		531		532		533		534		535		536		537		538		539	
524.648		524.648		480.835		471.246		262.02		223.664		43.205		43.205		3.773		3.773		- 0.609		**- 0.609**	

G in [mV]

Samplenummer für G nach ITU-R BT. 801																							
528		529		530		531		532		533		534		535		536		537		538		539	
- 0.786		- 0.786		+ 9.718		+ 0.129		+ 0.483		**- 37.873**		- 7.678		- 7.678		- 0.48		- 0.48		+ 1.752		**+ 1.752**	

B in [mV]

Samplenummer für B nach ITU-R BT. 801																							
528		529		530		531		532		533		534		535		536		537		538		539	
+1.569		+ 1.569		62.481		52.892		263.724		225.369		459.43		459.43		525.88		525.88		525.88		**525.88**	

The values of samples 528 and 539 show that the theoretical amplitudes of 0 mV or 525 mV (= 0% or 75% of 700 mV) are not attained with the colour bars at red and blue settled.
Samples with the numbers 530 to 534 in the green channel clearly show the spike of V_{pp} = 9.718 + 37.873 = 47.591 mV on colour transition as obtained per calculation. Of course, a negative spike component of 37.873 mV causes an error to be signalled by all colour error monitors. In the ITU-R BT. 801 system using an 8-bit resolution this kind of error is accepted, however.

Note: These transients on colour change take place in a slightly different form for the analog colour bars (see RGB outputs of COMPONENT + CCVS GENERATOR SAF). Like at the digital level, they are caused by the different rise times of the Y, C_B and C_R components and can be easily measured with the aid of the amplitude test lines of VIDEO MREASUREMENT SYSTEM VSA or every other oscilloscope.

The same applies to the 0% or 75 (100)% values. For the complete colour bar, they (nominal values 0 mV or 525 mV) are calculated as

	Yellow	Cyan	Green	Magenta	Red	Blue
R	527.998	- 0.455	+0.154	524.039	524.648	- 0.609
G	525.638	524.979	523.227	+0.966	- 0.786	+1.752
B	1.51	522.625	-3.255	527.448	+1.569	525.88

Only the values for white at the beginning and for black at the end of the line are correct 700 mV or 0 mV (not listed in the table).
If measurements are carried out with the DIGITAL VIDEO COMPONENT ANALYZER VCA, CCVS + COMPONENT GENERATOR SAF or CCVS GENERATOR SFF with ITU-R BT. 601 interface option, the VCA displays exactly the values listed in the table (except for deviations caused by rounding) so that results are in compliance with the ITU-R BT. 801 specifications.

This 100/0/75/0 signal, which attains -3.255 in the blue channel even in the settled state, causes a colour error monitor to respond at the negative "0% values". A monitor operating in the RGB format must respond to the negative spike of -37.837 mV (5.4%!) in the green channel.
Colour error monitors should therefore
- allow a gap around the colour transition and
- measure the colour bar with an adjustable amplitude tolerance of ≤5 mV.

3 Slopes of RGB signals in the digital format during colour transition

The typical shape - rising and falling - of the R, G and B edges is demonstrated with the aid of a colour transition in the digital form. As shown in the drawing below the ideal $\int \sin^2$ form is obtained neither for the rising nor for the falling edge even if the falling edge approaches the ideal form. Particular attention should be paid to the glitch in the middle of the rising edge. It will be eliminated after analog reconstruction filtering.

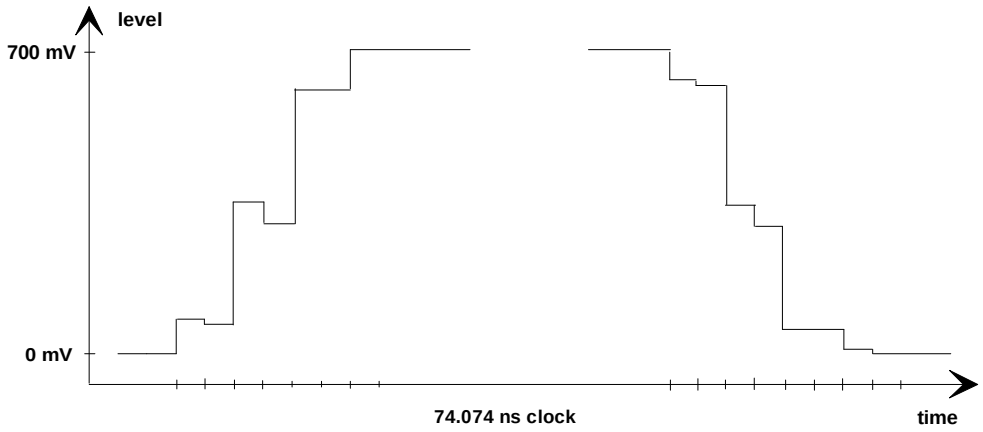

Fig. 3 The rising and falling edge in the digital R,G,B format at the digitally defined colour bar to ITU-R BT. 801