LEADER
TELEPRODUCTION TEST
VOLUME 3 NUMBER 4

DIGITAL VIDEO LEVELS

The system set up to establish video levels is identical in both SD and HD digital systems. This issue reviews the assignments of levels and ranges within the 10-bit range of numbers for both Y and C, deals with numbers in both binary and hexadecimal (hex), presents some data observations for common signals, explains conversion from analog to digital and presents data levels for all colors in 100% and 75% color bars for both SD and HD systems.

Y Signals

The 10-bit system offers a range of 2^{10} or 1024 discrete levels. But not all are used for video levels. See Fig. 1.The binary numbers at the very bottom and top of the available range are excluded from use as video levels, and reserved for use in the preambles (a sort of "heads up") for sync words. The numbers are zero (000) and 11 1111 1111 in binary (3FF in hex). Note that the black level converts to 040 in hex and peak white converts to 3AC. Keep these numbers in mind. A range of levels above peak white and below black is provided for both headroom and "footroom." However the hex values 000 to 003 and 3FC to 3FF are set aside for sync purposes.

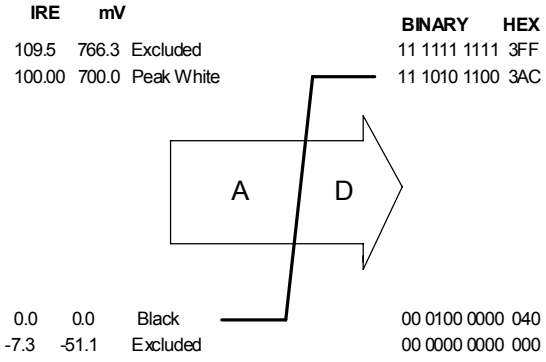

Fig. 1 Y Signal levels

C Signals

The color-difference signals, B-Y and R-Y labeled Cb and Cr, are scaled to fit the full span of 100% (± 350 mV) and placed upon a 50% pedestal so that the full range is in positive numbers. See Fig, 2.

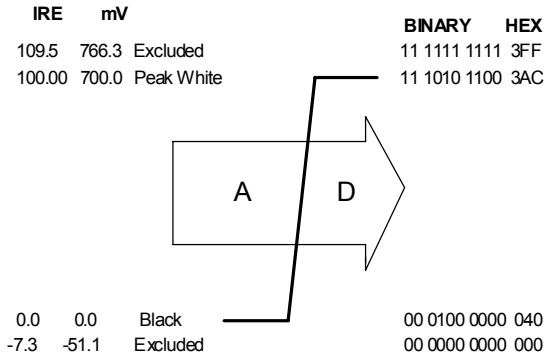

Fig. 2 Chroma Signal levels

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Note that the Cb and Cr swings sit on a pedestal at 200 in hex. In addition the peak extends somewhat higher to 3C0 in comparison to the 3AC peak in Y.

Data Displays

Figure 3 shows the serial data display from the LV 5100D. The signal is 100% color bars and line-select has been set to line 33 to make sure the line to be observed is in the active picture area. The MODE has been set to LINE

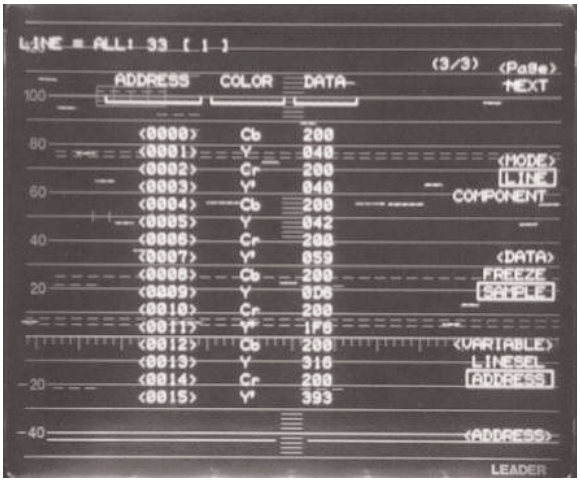


Fig. 3 Serial data display

in which samples are listed in the order in which they occur, starting with Cb and continuing with Y, Cr, Y'. Cb…The sample address has been set to 0000 to show the first sample, Cb, after SAV (Start of Active Video). Since the early samples for 100% bars will be for the white bar the chroma values Cb and Cr are zero so that the value of the chroma pedestal, 200, will appear for Cb and Cr throughout the white bar. Note that Y starts out at 040 (black) and begins

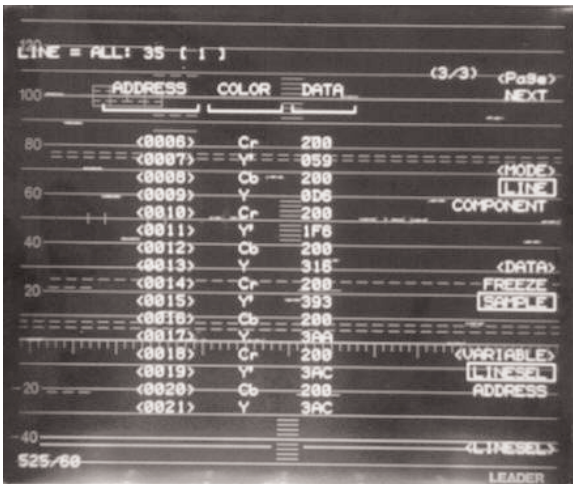


Fig. 4 Y reaches 3AC at address 0019.

rising at address (0005). By advancing the sample address you will see that Y reaches 3AC at address (0019). See Fig. 4. What you have observed in data is the rise time of the white bar.

An alternative data display is obtained by selecting the COMPONENT <MODE>. (Touch F-2 to the right of the screen.) Here the data is rearranged to appear in columns of Y, Cb and Cr. Look at Fig. 5. Of the 1440 active samples per line half (720) are Y. These are shown in pairs for Y and Y' in the left columns, and the

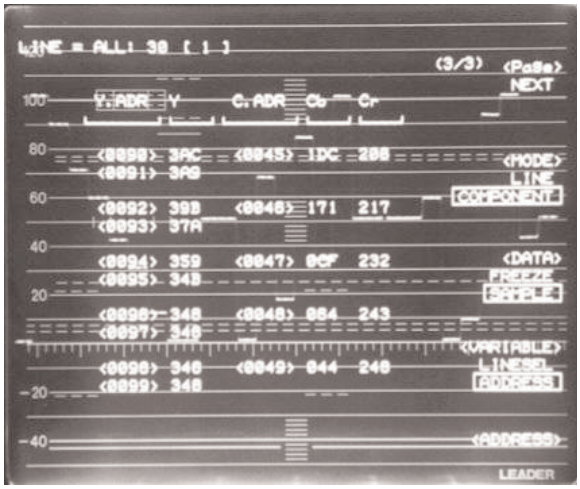


Fig. 5 Component data display

addresses range from 0000 to 0719. The chroma addresses are co-sited with the Y samples. Note that the chroma addresses are half of the address for Y. This particular snapshot for data is near the end of the transition from the white to the yellow bar. Y has reached 348, the correct Y value for yellow in 100% bars, but the slower rise time of Cb and Cr have kept Cb and Cr from reaching 040 and 249 at address 0049.

The next four pages present values for 100% and 75% color bars for both SD and HD systems. Levels for decoded signals are given in % (IRE), millivolts and Hex. The difference between SD and HD values is the result of colorimetry differences between the two systems. SD values are based on the SMPTE formula for Y in use in the NTSC system:

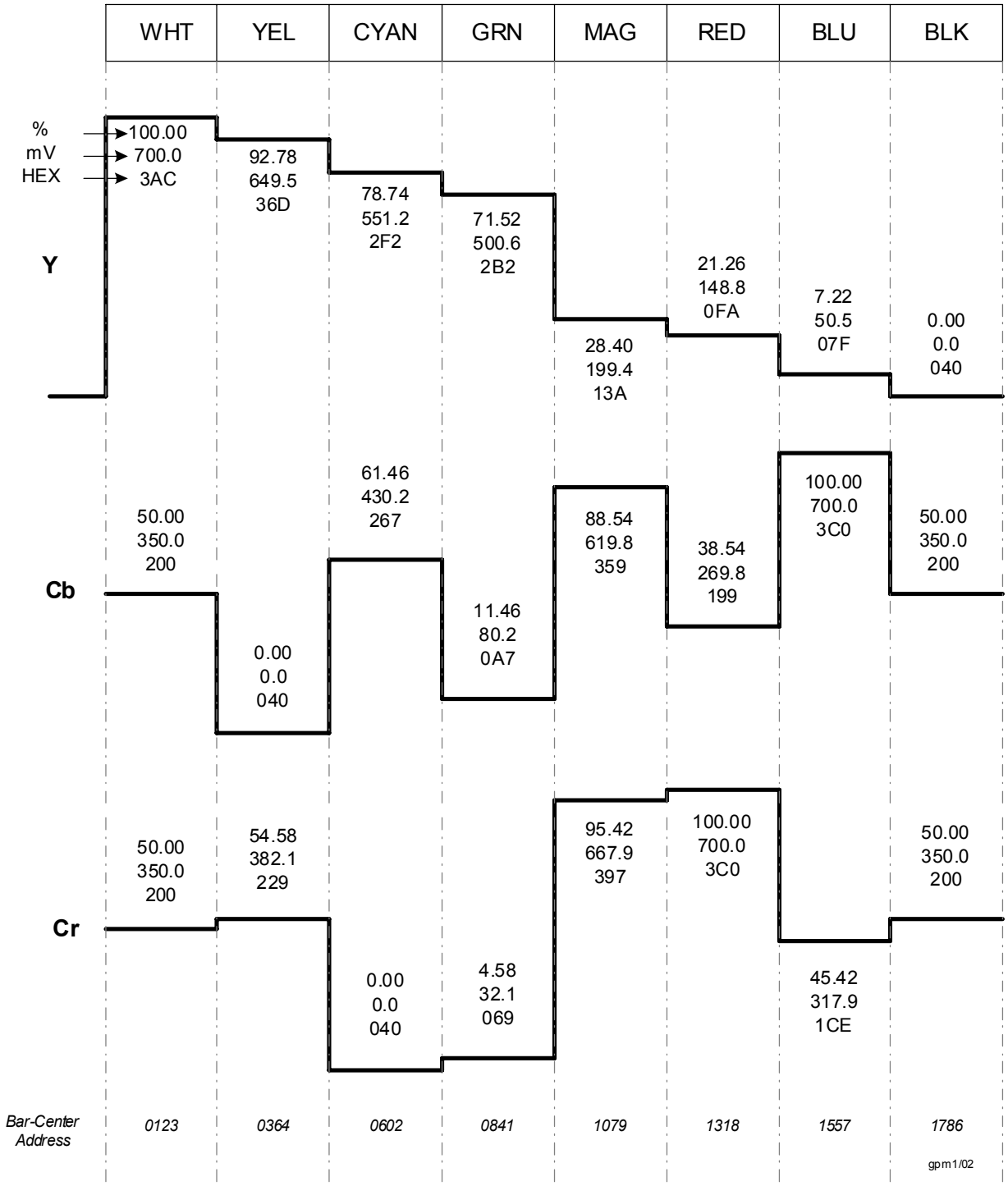
Y = 29.9%R + 58.7%G + 11.4%B

Y for HD systems is calculated using the formula given in SMPTE RP-177 and 274M:

Y = 21.26%R + 71.52%G + 7.22%B

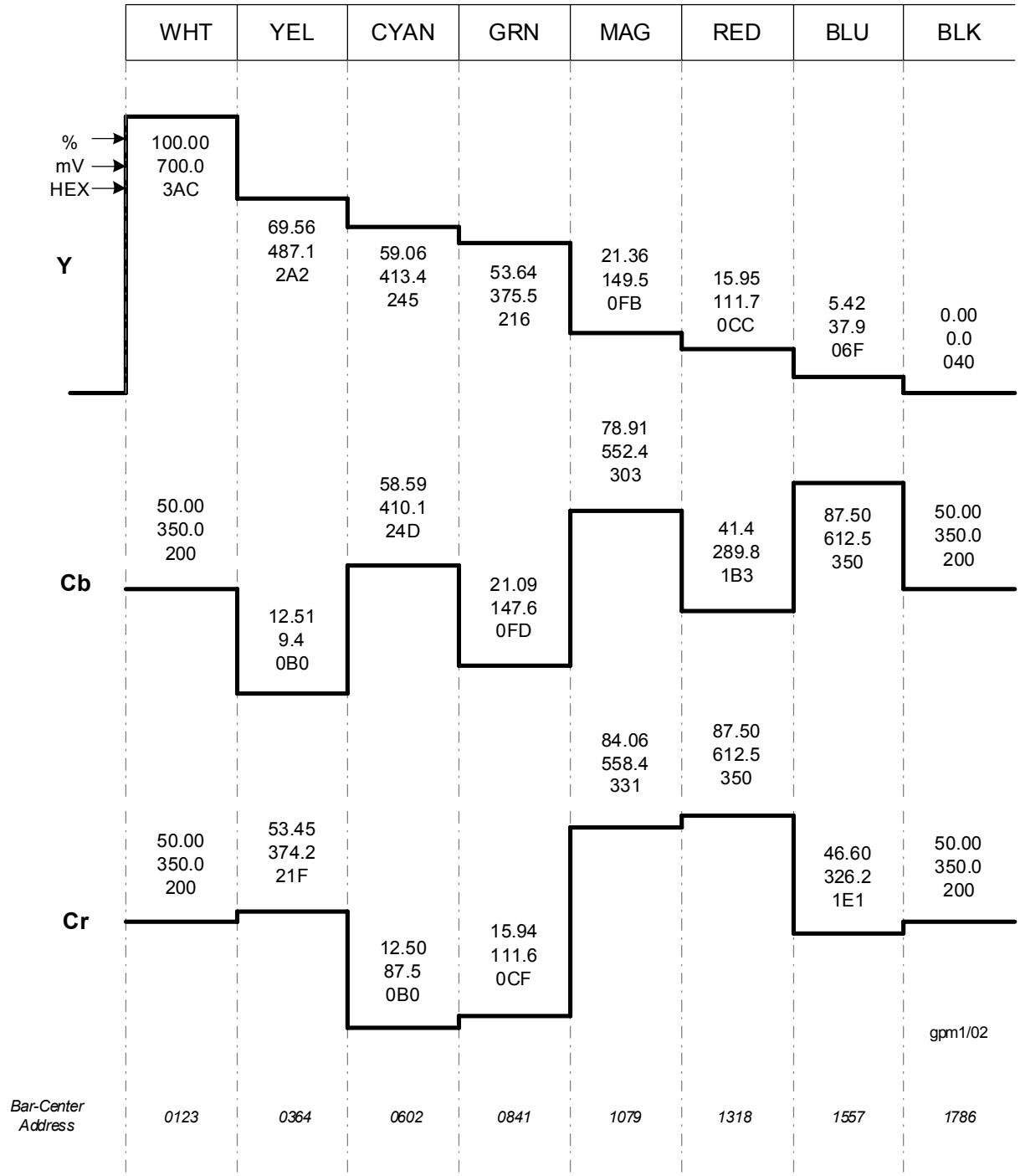
Note the increase in green and the reduction of red and blue.

HD 100% COLOR BARS



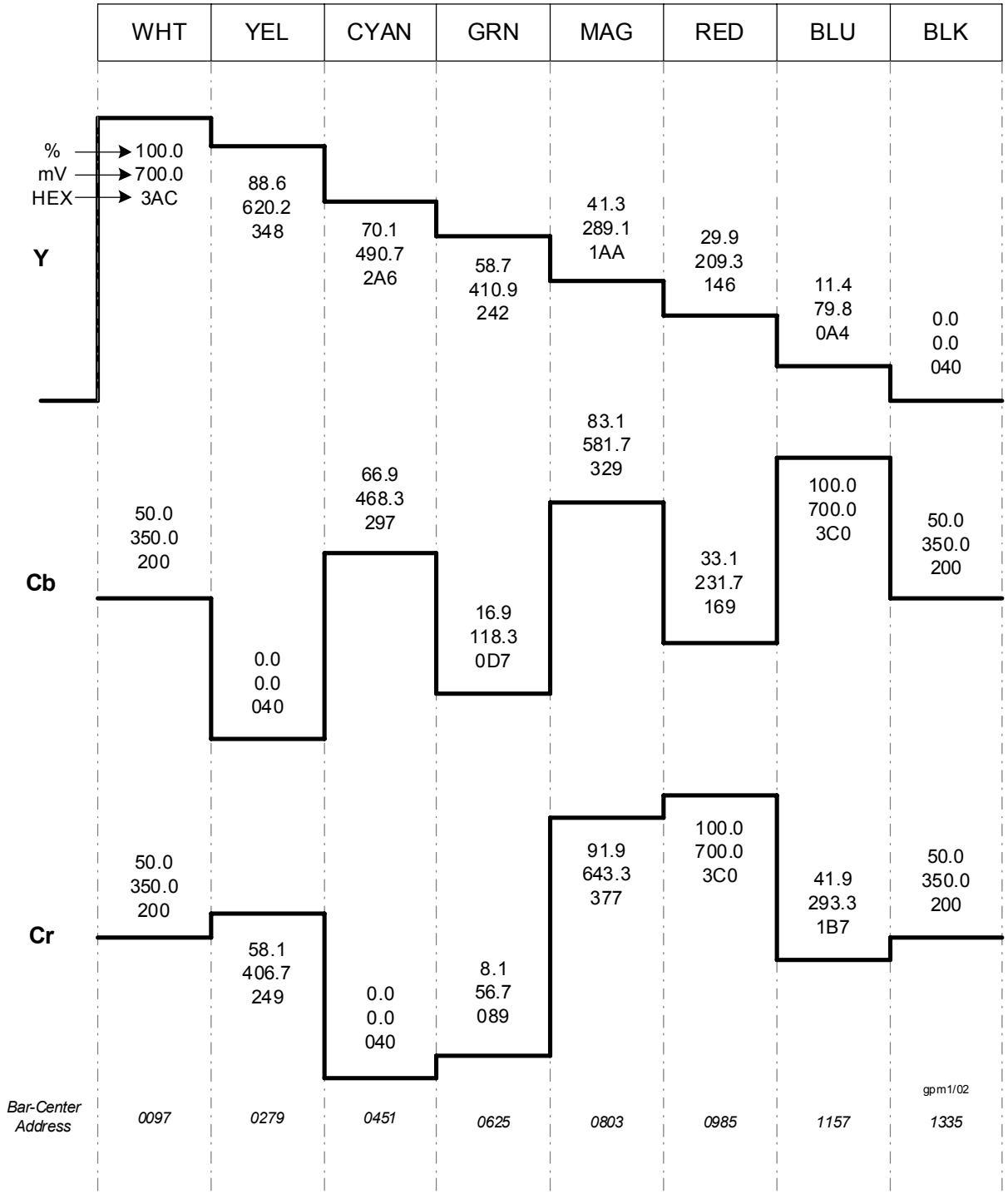
Levels in % (IRE), millivolts and HEX for 100% color bars in accordance with SMPTE RP-177 and 274M based on the formula Y= 21.26%R+71.52%G+7.22%B.

HD 75% COLOR BARS



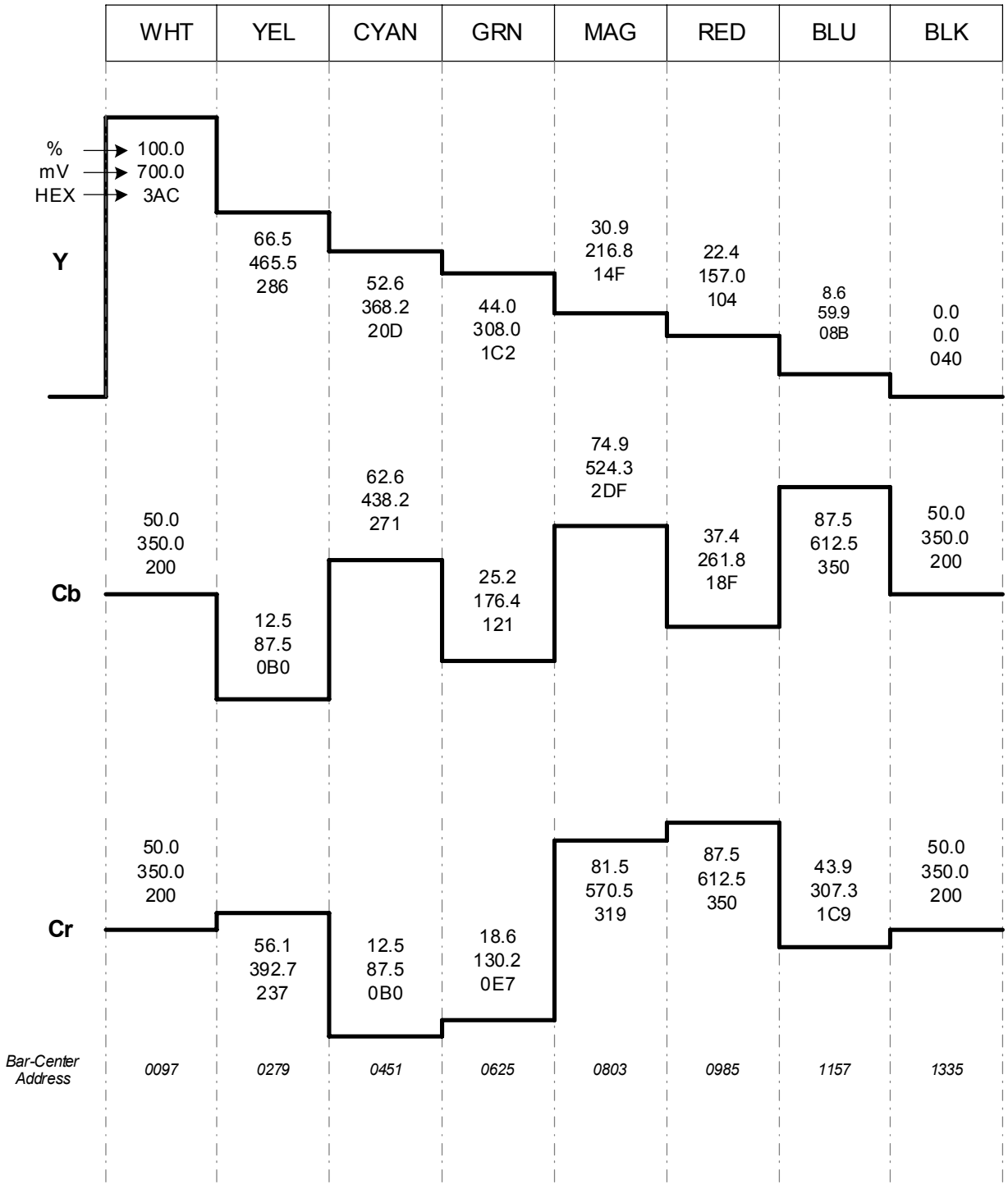
Levels in % (IRE), millivolts and HEX for 75% color bars in accordance with SMPTE RP-177 and 274M based on the formula Y = 21.26%R+71.52%G+7.22%B.

SD 100% COLOR BARS



Levels in % (IRE), millivolts and HEX for 100% color bars for SD (601) signals based on the formula Y = 29.9%R + 58.7%G + 11.4%B.

SD 75% COLOR BARS



Levels in % (IRE), millivolts and HEX for 75% color bars for SD (601) signals based on the formula Y = 29.9%R + 58.7%G + 11.4%B.

HD Data

HD data is shown in a fashion similar to SD. The levels used are the same, i.e. 40 is black in hex for Y and 3AC is equivalent to 100%. The normal span of color signals ranges from 40 to 3C0. Look back at Figs.1 and 2, and the drawings on the previous pages. There are some differences in presentation, however. See Fig. 6 which shows data for a 1080i 59.94 signal in the SERIAL form on the LV 5152DA (called LINE in the LV 5100D).

Fig. 6 Serial HD data on the LV 5152DA

The first thing you will notice is that there appears to be twice as many addresses. There are eight SAV addresses instead of the four you see in SD. The reason is that Y and C are carried by separate cables in the parallel output feeds of the A/D converter. These are joined at the input to the serializer so we see SAV signals for both Y and C. (This is also the reason that the final serial data rate is 1.483 Mbs.) The sample frequency for Y and C is 74.17 Mbs. These are joined at the serializer to become 148.34 Mbs. The 10-bit serializer multiplies by 10 to yield the 1.483-Gbs serial signal.

Number Crunching

What follows is a simplified illustration of how the numbers on the previous pages are arrived at. Levels in %, mV and hex for the yellow bar in HD 100% bars are worked out. The starting point is the HD Y formula:

Y = 0.2126R + 0.7152G + 0.0722B

Considering yellow from a perfect source of 100% signals R and G are at 100%. B is at zero. Taking the above fractions for R and G we get Y for the yellow bar to be 21.26 + 71.52 = 92.78%. Multiplying 700mV by 0.9278 yields 649.46 rounded to 649.5.

To find the hex value we have to consider the range in decimal values from black to 100% white. Black is 040 in hex which coverts to 064 in decimal. This conversion is done easily on the WINDOWS® calculator. Go to ACCESSORIES then CALCULATOR on your PC. When the calculator page appears hit VIEW and select SCIENTIFIC. Here you can select HEX and enter 40. Then select DEC and read 64. The same procedure for peak white: 3AC in hex, yields 940. Thus in decimal the range from black to peak white is 940-64 = 876. Now we'll take 0.9278 of 876 to find the value above black in decimal to be 813. Add this to the black level at 64 to find the total decimal value of 877. Enter this number in DEC on your PC calculator and hit HEX to read 36D.

The color difference signals are a little more involved because the Cb and Cr swings exceed 100% and we have to add in that 50% pedestal. Consider Cb (B-Y). The blue signal is at zero so B-Y becomes 0-92.78 or -92.78. The B signal for the blue bar is 100 - 7.22 = +92.78. This yields a p-p swing for B-Y of 185.66%. This would clearly overload a system set up for a span of 100%. To remedy this situation a "Squash" factor of 100/185.66 or 0.5389 is applied to B-Y. Applying the squash factor to the calculated B-Y for the yellow bar yields -92.78 x 0.53891 =- 50.00.
Now to add that 50% pedestal to find the value of Cb (B-Y) for the blue bar to be zero, which (as you have learned) is 040 in hex.

If you look at the HD 100% color bar signals for Cb on the previous pages you will see that it swings to zero at the yellow bar and to 100% at the blue bar. Similarly Cr (R-Y) has its peak excursion at the cyan and red bars. If we redo for R-Y what we just did for B-Y we would find that the p-p swing between cyan and red is 157.48% p-p requiring a squash factor of 0.635 to bring Cr into the 100% limit.

Getting back to Cr for the yellow bar we see that the red signal for yellow is at 100% making R-Y 100%- 92.78= 7.22. Applying the Cr squash factor of 0.635 yields 4.58. Adding the 50% pedestal brings Cr level for the yellow bar to 54.58%. In millivolts this is 700 x 0.5458 or 382.1 mV. Now for the hex value: The total chroma excursion is from 040 to 3C0. Converting this to decimal the range becomes 064 to 960 for a number span of 896. Now 896 x 0.5458 = 489 + the 64 at black yields 553 as the decimal level for Cr at the yellow bar. Converting to hex via the PC calculator yields 229.

Those "squash" factors developed above are found in all current color systems. The factors are 0.492 for B-Y and 0.877 for R-Y in the

NTSC system. The effect of the squash factors must be reversed when converting back to GBR from Y, B-Y and R-Y. For example, Cb in HD must be amplified by 1/0.5389 = 1.8556. Similarly Cr must be amplified by 1/0.635 = 1.5748. In effect B-Y is almost doubled and R-Y also given a big boost in the recovery of GBR. G-Y, it turns out receives very little boost. (Ever wonder why chroma noise always looks purple?)

Data in the Blanking Intervals

A very useful feature of the data display is the ability to show embedded audio and special codes. Let's look at two examples. The first is in the SD format and is the EDH (Error Detection & Handling) codes. If EDH is present in the signal (enabled in the generator) the EDH LED on the front panel of the LV 5100D or DE will glow. This signal is placed on line 9 and 272, and the preamble starts at address 1689. Figure 7 shows the setup using the LINE (serial) data display with line 9 selected and address 1688 at the top.

Fig. 7 EDH Codes

The preamble is 000, 3FF, 3FF at addresses 1689-1691. This is followed by a data block ID (1F4), a Block Number (200) and a Data Count (110) at addresses 1692, 1693 and 1694 respectively. The next three, at addresses 1695-1697 are the CRC data words for the active picture area of the field. For test signals, like color bars, these numbers will not change with data updates. However, the data words at addresses 1698-1700 form the FF (full field) CRCs, and these will be seen to change with each data update if embedded audio has been switched on at the generator. (The test tones are not synched to video.

A signal worth looking for in the HD format is the control signal for embedded audio. This appears on line 9 in the 1080i 59.94 format. The control signal is embedded in the Y signal while the audio data is placed in Cr and Cb. Figure 8 shows the control signal and start of embedded audio in Cb and Cr in the COMPONENT data display of the LV 5152DA.

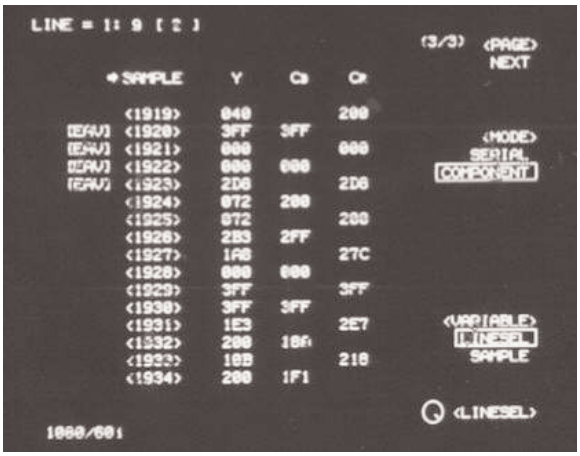


Fig. 8 Audio Control Signal

Compare this COMPONENT display with the SERIAL display shown in Fig. 6. Note that the four EAV signals appear in sequence for Y, but also appear in Cb and Cr. The audio control pulse has some value as a timing reference when dealing with timing errors that exceed a line duration. (See Teleproduction Test Volume 3 Number 3.

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