The color bars puzzle

By Michael Robin

Color bars signals are widely used and often misinterpreted. Their primary function is not, as is often supposed, the testing of transmission channels, but rather the precise alignment and checking of color encoding and decoding equipment. With PAL and NTSC, they can be used as means to verify that a circuit is not suffering from excessive defects in performance. Typical uses are in camera encoders, analog VTR output signal adjustments of gain, setup, saturation and hue, as well as studio color monitors and home receiver color rendition. They cannot replace standard performance measurements.

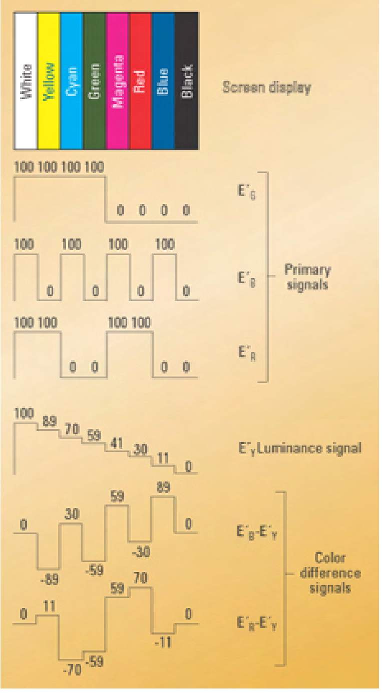

Figure 1. The top part of this figure shows the 100/0/100/0 color-bar signal as it would appear on a video screen. The remaining six rows show this signal as it would appear on an oscilloscope, with amplitudes measuring in percentages of 700 mV.

A number of different color bars signals exist. Many of them are application-specific — that is, they reflect the operational requirements of the specific organization, like color bars optimized for use with amplitude modulated transmitters. They all share a common general form.

The color bars signal produces a sequence of vertical bars displayed on the television screen showing saturated primaries and their complements as well as black and white. In the case of a signal that uses the full frame, the active line is generally divided in eight equal parts. The first is occupied by a luminance reference bar — that is, a white bar of a standard amplitude. The last is a black bar, which is black level only. In between, there are six bars representing the three primary colors and their complements. They are, in order, Yellow, Cyan, Green, Magenta, Red and Blue. The standard order of presentation has been chosen to give a descending order sequence of luminance values. The first row in Figure 1 shows the screen display of this signal.

Color bar nomenclature

A color bar generator has three outputs corresponding to the primary Green, Blue and Red gamma-corrected color signals (E'_G, E'_B, E'_R) as described in the SMPTE 253M Standard and illustrated in the second, third and fourth rows of Figure 1. These signals consist of a sequence of flat-top pulses. They are time-coincident, of equal amplitude and equal bandwidth. By a suitable overlap of the pulses in certain portions of the raster and nonoverlap in others, the three saturated primary colors, as well as the three saturated complementary colors, are produced.

These signals may be used in their original form (component analog GBR signals), matrixed into E'_Y, E'_B-E'_Y and E'_R-E'_Y (scaled or non-scaled), or encoded into an analog (PAL, NTSC or SECAM) or digital (component or composite) signal.

Color bars signals are identified with four numbers, representing percentages of the maximum value of 700 mV (100 percent), with an oblique stroke between them as follows:

- The first number describes the primary color signal level during the transmission of the white bar — that is, the maximum value of E'_G, E'_B, and E'_R.
- The second number describes the primary color signal level during the transmission of the black bar — that is, the minimum value of E'_G, E'_B, and E'_R.
- The third number describes the primary color signal level during the transmission of the colored bars — that is, the maximum value of E'_G, E'_B and E'_R.
- The fourth number describes the minimum level of the primary color signals during the transmission of the colored bars — that is, the minimum value of E'_G, E'_B and E'_R.

In Figure 1, the maximum amplitudes are 100 percent (700 mV), and the minimum amplitudes are 0 percent (0 mV). The green channel signal usually has a negative-going sync pulse of an amplitude of 300 mV. As generated, these signals have no setup. This type of color bar signal is called 100/0/100/0. For certain applications, it may be convenient to reduce the amplitudes of the signals to 75 percent of their maximum value. This type of signal would be identified as 75/0/75/0. In certain cases, the white bar is maintained at 100 percent, and the colored bars are reduced to 75 percent. This type of color bar is called 100/0/75/0. It is sometimes erroneously referred to as 75 percent color bars.

Matrixed color bars signals

G,B,R component color bars have relatively limited practical uses. They are mainly used to verify and adjust the gain of component analog G,B,R distribution systems and serve as a signal source for matrixed and encoded color bars signals. The matrixed color bars signal is derived from component E'_G, E'_B, E'_R signals by a specific process. It consists of matrixing the three component analog signals into a new set of component signals: a wideband luminance signal with or without setup (E'_Y) and two narrow-band color-difference signals ($E'_B - E'_Y$ and $E'_R - E'_Y$).

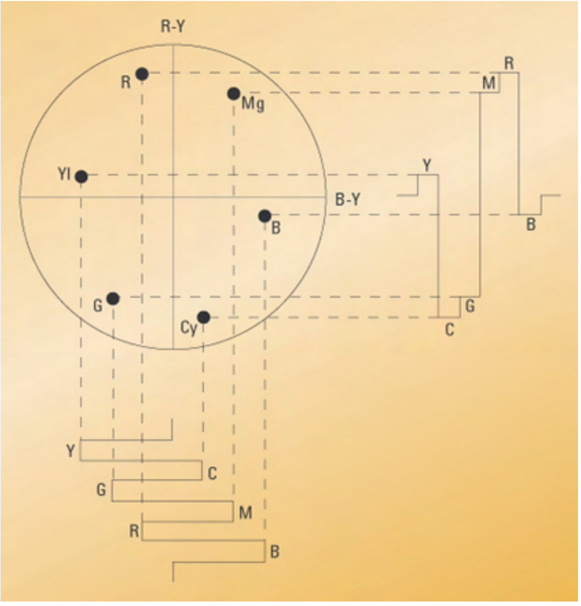

Figure 2. A vector representation of the color-difference components of a matrixed 100/0/100/0 color-bar signal.

For standard definition video, the E'_Y signal is given by the following expression:

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

The fifth row of Figure 1 shows the formation of the 100/0/100/0 E'_Y signal from the primary E'_G, E'_B, E'_R signals. The amplitudes of the eight steps are expressed in percentages of the full-amplitude signal (700 mV).

The color-difference signals are bipolar and have equal positive and negative excursions. The sixth and seventh rows of Figure 1 show the graphic representation of the two color-difference signals. Their amplitudes are expressed in percentages of the full amplitude primary signals (700 mV). These signal amplitudes are reduced by scaling factors to meet specific signal amplitude range requirements. When the allowed amplitude range of these signals is 700 mV (±350 mV), as specified in the EBU N10 Standard and the ITU-R BT 601 recommendation, the color-difference signals are given by the following expressions:

$E'_{CB} = 0.564\ (E'_B - E'_Y)$, also known as P_B in North America

$E'_{CR} = 0.713\ (E'_R - E'_Y)$, also known as P_R in North America

Different and incompatible scaling factors are used by North American versions of the Betacam and MII component analog videotape recording formats. The dominant European versions of these formats use the EBU N10 scaling factors.

The color-difference signals can be displayed on a regular component waveform monitor, either sequentially or individually, to allow for the measurements of such parameters as signal amplitude and relative time delay with reference to the luminance component. In addition, a vector display, similar to the NTSC vector display, may be obtained by feeding the P_B signal to the horizontal input and the P_R signal to the vertical input of an oscilloscope as shown in Figure 2 on page 21. Specialized component analog vectorscopes with electronically generated reference graticules are available from several manufacturers. Note the absence of the burst in the display.

Digital and contemporary studio analog video equipment can handle 100 percent color bars without difficulty.