AN113 – EVD1000/1500 Color Space Conversion: YCrCb to RGB, SMPTE 274, 296

INTRODUCTION

The EVD1000/1500 has a very flexible digital I/O structure, and in-circuit applications can be configured in a variety of fashions, utilizing different video data formats, levels of user control, etc. In this series of Application Notes, a number of examples of color space conversion are presented, each of which includes a complete set of conversion matrix coefficient register values as required for operation in that particular example mode. For more complete and general application information, please refer to the EVD1000/1500 Data Sheet. The present Application Note describes the method of conversion from the internal YCrCb space to RGB output, e.g., as per SMPTE 274, 296.

Color Space Conversion

All internal processing in the EVD1000/1500 is performed in YCrCb mode. Additionally Y values are assumed to be in the range of {64…940}. Cr and Cb values are assumed to be in the range of {64…960}. If RGB data is sent to the EVD1000/1500 an RGB to YCrCb conversion must be performed on the input data before it is processed. If RGB data is required to be output from the chip then an YCrCb to RGB conversion is required to be performed on the processed data before it is sent from the chip. Two independent converters perform the conversions. The coefficients in each converter may be programmed to allow for different relationships between RGB and YCrCb as required for different video standards.

YCrCb to RGB Conversion

Output color conversion from YCrCb to RGB is enabled whenever the output mode of the EVD1000/1500 is set to RGB. See the Data Sheet for details.

SMPTE 274, 296

The fundamental relationship between Y, R, G, and B is as follows:

(41) $$Y = .2126 \times R + .7152 \times G + .0722 \times B$$

Where R,G,B Y {0…1}.

From the above equation R-Y and B-Y may be calculated as follows:

(42) $$R - Y = .7874 \times R - .7152 \times G - .0722 \times B$$

(43) $$B - Y = -.2126 \times R - .7152 \times G + .9278 \times B$$

Where R-Y {-.7874…+.7874} and B-Y {-.9278…+.9278}. Scaling appropriately gives the following two equations:

(44) $$Cr = \left(\frac{.5}{.7874}\right) \times (R - Y) = .500 \times R - .4541 \times G - .0458 \times B$$

(45) $$Cb = \left(\frac{.5}{.9278}\right) \times (B - Y) = -.1145 \times R - .3854 \times G + .500 \times B$$

Where R,G,B {0…1} and Cr,Cb {-.5…+.5}

The RGB to YCrCb conversion matrix is as follows:

$$M_{RGB\_to\_YCrCb} = \begin{pmatrix} .2126 & .7152 & .0722 \\ .500000 & -.4541 & -.0458 \\ -.1145 & -.3854 & .500000 \end{pmatrix}$$

The inverse of the $M_{RGB\_to\_YcrCr}$ matrix is the $M_{YCrCb\_to\_RGB}$ matrix, which is shown below:

$$M_{YCrCb\_to\_RGB} = \begin{pmatrix} 1.00000 & 1.57484 & 0 \\ 1.00000 & -.468 & -.187 \\ 1.00000 & 0 & 1.855 \end{pmatrix}$$

Thus the equations for YCrCb to RGB conversion are as follows:

(46) $$R = Y + 1.5748 \times Cr$$

(47) $$G = Y - .468 \times Cr - .187 \times Cb$$

(48) $$B = Y + 1.855 \times Cb$$

Where Y, R, G, B {0…1} and Cr, Cb {-.5…+.5}

For 10-bit digital implementation Y_D is in the range {64…940}, Cr_D, Cb_D are in the range {64…960} and R_D, G_D, B_D are in the range {0…1023}. The above three equations are modified as follows:

(49) $$R_D = \left(\frac{1023}{940 - 64}\right) \times (Y_D - 64) + \left(\frac{1023}{960 - 64}\right) \times 1.5748 \times (Cr_D - 512)$$

(50) $$R_D = \frac{1196 \times (Y_D - 64) + 1841 \times (Cr_D - 512) + 512}{1024}$$

(51) $$R_D = \frac{1196 \times Y_D + 1841 \times Cr_D - 1{,}018{,}624}{1024}$$

(52)
$$G_D = \left(\frac{1023}{940-64}\right)\times(Y_D-64)-\left(\frac{1023}{960-64}\right)\times.468\times(Cr_D-512) - \left(\frac{1023}{960-64}\right)\times.187\times(Cb_D-512)$$

(53)
$$G_D = \frac{1196\times(Y_D-64)-547\times(Cr_D-512)-219\times(Cb_D-512)+512}{1024}$$

(54)
$$G_D = \frac{1196\times Y_D-547\times Cr_D-219Cb_D+316{,}160}{1024}$$

(55)
$$B_D = \left(\frac{1023}{940-64}\right)\times(Y_D-64)+\left(\frac{1023}{960-64}\right)\times1.855\times(Cr_D-512)$$

(56)
$$B_D = \frac{1196\times(Y_D-64)+2169\times(Cb_D-512)+512}{1024}$$

(57)
$$B_D = \frac{1196\times Y_D+2169\times Cb_D-1{,}186{,}560}{1024}$$

The EVD1000/1500 converts YCrCb to RGB using the following equations:

(58)
$$R_D = \frac{YCRCB2RGB\_K\times Y+YCRCB2RGB\_KRCR\times Cr_D+YCRCB2RGB\_KROFF}{1024}$$

(59)
$$G_D = \frac{YCRCB2RGB\_K\times Y+YCRCB2RGB\_KGCR\times Cr_D+YCRCB2RGB\_KGCB\times Cb_D+YCRCB2RGB\_KGOFF}{1024}$$

(60)
$$B_D = \frac{YCRCB2RGB\_K\times Y+YCRCB2RGB\_KBCB\times Cb_D+YCRCB2RGB\_KBOFF}{1024}$$

The following table shows the values that must be written to the registers in the YCrCb to RGB Converter to perform SMPTE 274 or 296 YCrCb to RGB Conversion. The values in the top line of each row are signed full width register values (24-bits for registers ending in OFF and 16-bits for other registers). The values in the bottom line of each row are 8-bit width register values. Each full width register is implemented by concatenating two or three 8-bit registers.

Register Assignments SMPTE 274, 296 YCRCB to RGB Conversion (8-bit Registers)	Value (decimal)	Value (HEX)
YCRCB2RGB_K (YCRCB2RGB_K_HIGH:YCRCB2RGB_K_LOW)	1,196 (4:172)	04AC (04:AC)
YCRCB2RGB_KRCR (YCRCB2RGB_KRCR_HIGH:YCRCB2RGB_KRCR_LOW)	1,841 (7:49)	0731 (07:31)
YCRCB2RGB_KROFF YCRCB2RGB_KROFF_HIGH:YCRCB2RGB_KROFF_MID:YCRCB2RGB_KROFF_LOW)	-1,018,624 (240:117:0)	F07500 (F0:75:00)
YCRCB2RGB_KGCR (YCRCB2RGB_KGCR_HIGH:YCRCB2RGB_KGCR_LOW)	-547 (253:221)	FDDD (FD:DD)
YCRCB2RGB_KGCB (YCRCB2RGB_KGCB_HIGH:YCRCB2RGB_KGCB_LOW)	-219 (255:37)	FF25 (FF:25)
YCRCB2RGB_KGOFF YCRCB2RGB_KGOFF_HIGH:YCRCB2RGB_KGOFF_MID:YCRCB2RGB_KGOFF_LOW)	316,160 (4:211:0)	04D300 (04:D3:00)
YCRCB2RGB_KBCB (YCRCB2RGB_KBCB_HIGH:YCRCB2RGB_KBCB_LOW)	2,169 (8:121)	0879 (08:79)
YCRCB2RGB_KBOFF YCRCB2RGB_KBOFF_HIGH:YCRCB2RGB_KBOFF_MID:YCRCB2RGB_KBOFF_LOW)	-1,186,560 (237:229:0)	EDE500 (ED:E5:00)

For further questions or clarifications, contact your sales representative or the factory for additional support.

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