YCbCr to RGB

10-Bit Multiplexed [4:2:2] CCIR-601 YcbCr to Full Range 10-Bit RGB
[Input Cb/Cr Interleaved onto One Channel

Overview

The LF3370 Format Converter is a High Performance Video Processing Engine that has been designed to perform a variety of Format Conversions. The following discussion is meant to give clear and precise guidance in order to configure the LF3370 to perform a YCbCr to RGB format conversion.

The LF3370 performs this conversion by employing the use of input bias (offset) adders, Halfband Decimation Filters, and a Matrix Multiplier function, as seen in Figure 1 of the datasheet.

The Input De-Multiplexer first separates the interleaved Cb/Cr input data into 2 unique Cb and Cr channels and passes them to the Input Offset (bias) adders B and C respectively. The offset contained in the de-multiplexed YCbCr input data is then removed by the Input Bias Adders. After this, the Cb' and Cr' words are fed into the Halfband Interpolator Filters, whereby their resulting data rate is doubled. The Y' channel data rate does not need to be altered, it simply passes through a programmable delay that is matched to the latency of the Halfband Filters. The Matrix Multiplier takes the intermediate Y', Cb', and Cr' channels and mixes them with the coefficients. RGB data emerges at its output.

Input/Output Formats

Table 1 outlines the Input and Output formats and their inclusive ranges for this application. (Alternative Input/Output Word Size Applications Can be Derived From This Application Note)

Table 1

Color Space	Range	Format	Word Size
Y	64-940	Unsigned	10-Bits
Cb	64-960	Unsigned	10-Bits
Cr	64-960	Unsigned	10-Bits
Y' (internal)	0-876	Unsigned	10-Bits
Cb' (internal)	+-448	Signed	10-Bits
Cr' (internal)	+-448	Signed	10-Bits
RGB	0-1023	Unsigned	10-Bits

Input Data Word Alignment

The 10-bit Y, Cb, and Cr input words should be aligned on the A, B, and C input ports respectively, in a manner that preserves their non-signed format. Table 2 illustrates the suggested alignment of the Y input channel. The same alignment is true for the Cb and Cr input words.

Table 2

Input Pin	A12	A11	A10	A09	A08	A07	A06	A05	A04	A03	A02	A01	A00
Input Data	GND	Y9	Y8	Y7	Y6	Y5	Y4	Y3	Y2	Y1	Y0	GND	GND

Input Cb/Cr De-Multiplexing

The Input De-Multiplexer separates the alternating Cb/Cr input data on B12-0 into 2 unique Cb and Cr channels. The synchronous SYNCB pin synchronizes the interleaved Cb/Cr data with the LF3370. Figure 4 of the datasheet illustrates how SYNCB should be brought from HIGH to LOW on an input Cb sample and then held there - or SYNCB can toggle from HIGH to LOW on every Cb sample. This HIGH to LOW SYNCB event also initializes the Halfband Interpolation function.

Input Offset Adjustment

The LF3370 handles the offset removal in the conversion equations by using the 'Input Bias' adders. The input bias adder configuration and a detailed description of the loading method appear near the end of this document.

Interpolation From 4:2:2 to 4:4:4

In this application, the LF3370 uses its 2 Halfband Filters to increase the data rate (Interpolate) the intermediate Cb' and Cr' data by 2. The input 4:2:2 data becomes 4:4:4 data. To this end, the 'Functional Arrangement' should be configured such that the Halfband Filter feeds data to the Matrix Multiplier (see Figure 1of the datasheet).

The bit weighting of the Halfband output and the configuration of the Round/Select/Limit circuit is illustrated in Table 4. A detailed description of the RSL loading method appears later in this document.

Matrix Multiply

At the heart of the Color-Space Conversion is the Matrix-Multiply calculation. The Multiplier coefficients depend on two variables: the range of the RGB output word and the range of the YCbCr input word.
(Note: the removal of the 64 and 512 offsets indicated in these equations are accomplished in a separate 'bias adder' function near the input)

The YcbCr to RGB Matrix-Multiply And Offset Equations are as follows:

Y' = Y - 64
Cb' = Cb - 512
Cr' = Cr - 512

R = (RGB Range /Y Range)(1Y') + (RGB Range /Cr Range)(1.402Cr')
G = (RGB Range /Y Range)(1Y') + (RGB Range /Cb Range)(-0.3441Cb' - 0.714Cr')
B = (RGB Range /Cr Range) (1Y') + (RGB Range /Cb Range)(1.772Cb')

Since the RGB Output Range is 1023 (1023-0), the Y Input Range is 876 (940-64), and the Cb/Cr Input Range is 896 (960-64), the equation for this application becomes:

R = (1.1678Y' + 0 + 1.6007Cr')
G = (1.1678Y' - 0.3929Cb' - 0.81532Cr')
B = (1.1678Y'+ 2.0232Cb' + 0)

The 13-bit coefficients, their bit weighting with respect to the Y'Cb'Cr' data, and the configuration of the Round/Select/Limit circuit is illustrated in Table 4. A detailed description of the loading method appears later in this document.

Gamma Correction

Newly created RGB data is typically passed through the output Gamma correction stage. It is assumed that it is not needed in this application in order to reduce the size of this Application Note.

Output Word Alignment

Table 3 illustrates the alignment of the 10-bit Red output word on the W output port. (Please note that the same alignment is true for the Green and Blue output words on the X and Y output ports respectively)

Table 3

Output Pin	W12	W11	W10	W09	W08	W07	W06	W05	W04	W03	W02	W01	W00
Output Data	NC	NC	NC	R9	R8	R7	R6	R5	R4	R3	R2	R1	R0

Configuration Register Loading

The following tables refer to the addresses and data that need to be loaded into the LF interface in order to configure the part to perform this YcbCr to RGB Conversion. Loading the entire sequence of address and data words from these tables into the CF12-0 bus will achieve the desired configuration. (For more information on the LFinterface please refer to the LF3370 data sheet)

Note: For this application we assume that the Blanking Feature, Core Bypass Feature and the Key Channel are not being used. (If these features are required, please refer to the LF3370 data sheet for their descriptions)

Address/Data	Description
0000	Matrix Coefficient Address 0
04AB	1.1678 = Bank 0
0000	0 = Bank 1
0667	1.6007 = Bank 2
04AB	1.1678 = Bank 3
1E6E	-0.3929= Bank 4
1CBE	-0.81532 = Bank 5
04AB	1.1678 = Bank 6
0817	2.0232 = Bank 7
0000	0 = Bank 8

Address/Data	Description
0201	Gamma LUT, Blanking, and Bias Enables
1000	Disable LUT, No Blanking, Enable Input Offset

Address/Data	Description
0200	Input/Output Format and Functional Arrangement
00AE	2 Ch. In /3 Ch. Out, Halfband to Matrix, Interpolation

Address/Data	Description
0203	Y Channel Filter Bypass Delay
0021	35-2 = 33

Address/Data	Description
0600	Input Bias For Y Channel
1F00	Input Bias = -64
0700	Input Bias For Cb Channel
1800	Input Bias = -512
0800	Input Bias For Cr Channel
1800	Input Bias = -512

Address/Data	Description
0E00	Matrix RSL For Y Channel
0008	LSB Rounding
0000	Select Window = 0
03FF	Upper Limit = 1023
0000	Lower Limit = 0

Address/Data	Description
0F00	Matrix RSL For Cb Channel
0008	LSB Rounding
0000	Select Window = 0
03FF	Upper Limit = 1023
0000	Lower Limit = 0

Address/Data	Description
1000	Matrix RSL For Cr Channel
0008	LSB Rounding
0000	Select Window = 0
03FF	Upper Limit = 1023
0000	Lower Limit = 0

Address/Data	Description
1200	Halfband Filter RSL For Cb Channel
0020	LSB Rounding
0200	Select Window = 2
0700	Upper Limit = +448
1900	Lower Limit = -448

Address/Data	Description
1300	Halfband Filter RSL For Cr Channel
0020	LSB Rounding
0200	Select Window = 2
0700	Upper Limit = +448
1900	Lower Limit = -448

Table 4. 10 Bit YCbCR CCIR-601 to 10 Bit RGB Format Conversion

	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12
INPUT PINS							A12	A11	A10	A9	A8	A7	A6	A5	A4	A3	A2	A1	A0										
							0	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	0	0										
INPUT PINS							B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	B0										
							0	CB	CB	CB	CB	CB	CB	CB	CB	CB	CB	0	0										
INPUT PINS							C12	C11	C10	C9	C8	C7	C6	C5	C4	C3	C2	C1	C0										
							0	CR	CR	CR	CR	CR	CR	CR	CR	CR	CR	0	0										
							0	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	0	0										
INPUT BIAS A							1	1	1	1	1	0	0	0	0	0	0	0	0		-64		1F0						
							0	CB	CB	CB	CB	CB	CB	CB	CB	CB	CB	0	0										
INPUT BIAS B							1	1	0	0	0	0	0	0	0	0	0	0	0		-51		180						
							0	CR	CR	CR	CR	CR	CR	CR	CR	CR	CR	0	0										
INPUT BIAS C							1	1	0	0	0	0	0	0	0	0	0	0	0		-51		180						
Cb'Cr' HALFBAND OUTPUT																													
							Cb'	Cb'	Cb'	Cb'	Cb'	Cb'	Cb'	Cb'	Cb'	Cb'	Cb'	Cb'	Cb'	Cb'	Cb'	Cb'	Cb'	Cb'	Cb'	Cb'			
R							0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0				
S															SEL								RND=00020						
							Cb'	Cb'	Cb'	Cb'	Cb'	Cb'	Cb'	Cb'	Cb'	Cb'	Cb'	Cb'	Cb'										
UL							0	0	1	1	1	0	0	0	0	0	0	0	0			448		700					
LL							1	1	0	0	1	0	0	0	0	0	0	0	0			-44		19000					
MATRIX MULT INPUT WORDS																													
							Y'	Y'	Y'	Y'	Y'	Y'	Y'	Y'	Y'	Y'	Y'	Y'	Y'										
							Cb'	Cb'	Cb'	Cb'	Cb'	Cb'	Cb'	Cb'	Cb'	Cb'	Cb'	Cb'	Cb'										
							Cb'	Cb'	Cb'	Cb'	Cb'	Cb'	Cb'	Cb'	Cb'	Cb'	Cb'	Cb'	Cb'										
COEFFICIENT FORMAT															C12	C11	C10	C9	C8	C7	C6	C5	C4	C3	C2	C1	C0		
R/G/B MATRIX OUTPUT																													
	R'	R'	R'	R'	R'	R'	R'	R'	R'	R'	R'	R'	R'	R'	R'	R'	R'	R'	R'	R'	R'								
R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0								
S																SEL						RND=00008						
				R'	R'	R'	R'	R'	R'	R'	R'	R'	R'	R'	R'	R'	R'													
UL				0	0	0	1	1	1	1	1	1	1	1	1	1	1			102		3FF						
LL				0	0	0	0	0	0	0	0	0	0	0	0	0	0			0		0						
OUTPUT PINS							W12	W11	W10	W9	W8	W7	W6	W5	W4	W3	W2	W1	W0										
							NC	NC	NC	R	R	R	R	R	R	R	R	R	R	R OUTPUT WORD									
OUTPUT PINS							X12	X11	X10	X9	X8	X7	X6	X5	X4	X3	X2	X1	X0										
							NC	NC	NC	G	G	G	G	G	G	G	G	G	G	G OUTPUT WORD									
OUTPUT PINS							Y12	Y11	Y10	Y9	Y8	Y7	Y6	Y5	Y4	Y3	Y2	Y1	Y0										
							NC	NC	NC	B	B	B	B	B	B	B	B	B	B	B OUTPUT WORD									