Color Conversion from YUV12 to RGB Using Intel MMX™ Technology

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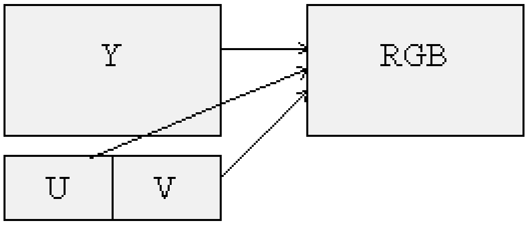
1. Introduction

This application note describes the usage of the new Intel MMX™ instruction set to implement Color Conversion Kernels (CCK) from YUV12 to RGB color space. The MMX™ instructions are Intel's implementation of Single Instruction Multiple Data (SIMD) instructions.

2. Overview

YUV12 color space is the native output for many video decoders including MPEG and H26x. This color space must be converted to RGB color space (the native color space of common PC graphics cards) to be displayed properly. Graphics cards support all or a subset of RGB8, RGB16, RGB24 or RGB32 color depths.

U and V are subsampled 2:1 in both vertical and horizontal directions. As a result, every U and V values are used for 4 Y values and generate 4 RGB pixels. The diagram shows that the number of bytes in the RGB buffer is the same as for the Y buffer. This is only true for RGB8. For RGB16, the number of bytes is twice as much, and for RGB24 it is 3 times as much.



3. Functional Description

For each 2x2 block of *RGB* pixels, 4 Y bytes 1 U and 1V byte are needed as shown in Figure 1.

The input and output signals for *Y*, *U*, *V* fall within this range:

16 *Y* 235
16 *u*,*v* 240

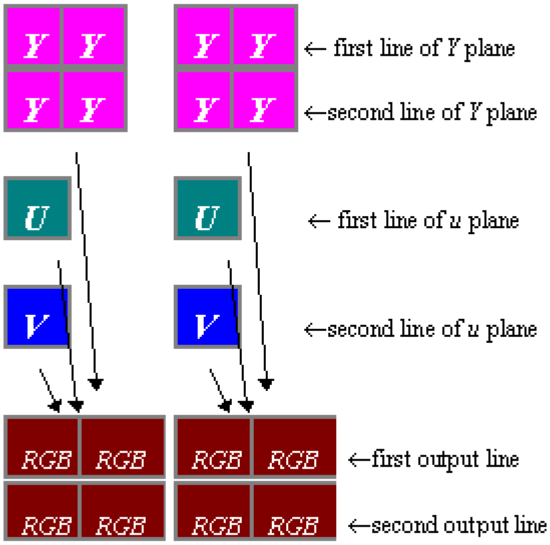


Figure 1- color conversion scheme

Conversion is performed according to the following:

$\boldsymbol{G} = 1.164\,(Y\text{-}16) - 0.391(u\text{-}128) - 0.813(v\text{-}128)$
$\boldsymbol{R} = 1.164\,(Y\text{-}16) + 1.596(v\text{-}128)$
$\boldsymbol{B} = 1.164\,(Y\text{-}16) + 2.018(u\text{-}128)$

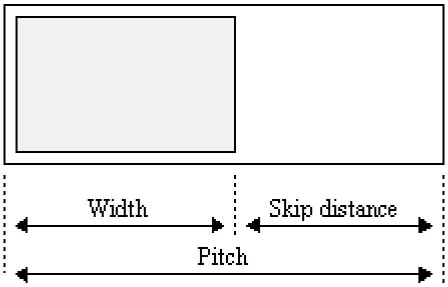
The ranges of *R*,*G*,*B* values can be obtained by substituting the *Y*,*U*,*V* limits into the above equations, as follows:

$\mathbf{-179} = 0 - 179 < R < 255 + 179 = \mathbf{433}$
$\mathbf{-135} = 0 - 135 < G < 255 + 135 = \mathbf{390}$
$\mathbf{-227} = 0 - 227 < B < 255 + 227 = \mathbf{365}$

Once the *R*,*G*,*B* values are calculated, result should be translated to their final range. For example, in the case of *RGB24* format, each output pixel is represented by 24 bits; each color component is represented by one byte. Therefore, each of the *R*,*G*,*B* values must be clamped to within 0..255. The ranges for RGB above shows signed values, which means that the all calculations should use signed arithmetic. On the other hand, the final legal ranges of RGB is 0.255, which requires that the saturation uses unsigned arithmetics. For *RGB16*, the output range is further reduced to fit the RGB values in 16bits. This is done by dropping some of the least significant bits of each color.

4. Color Converter Interface

Each Color Converter Kernel (*CCK*) receives as input three planes: *Y, U, V, a Y* pitch, and *UV* pitch (*U,V* pitches are always the same). It also receives a pointer to the output buffer and its pitch (*CCOPitch*). In addition, it receives an *aspect ratio* adjustment count, which enables adjustment of the destination height to fit a specific aspect ratio of the display device.



5. Choosing Algorithm for Color Conversion To RGB24 Without Zooming

Three different implementations of the *YUV12* to *RGB24* algorithm using the MMX™ technology will be discussed in this section.

The first implementation of the algorithm utilizes the maximum parallelism offered by MMX™ Technology. It performs *byte* operations on 8 pixels at a time. This method uses pre-calculated tables and should yield the best throughput of the methods described here. However, since the temporary results during calculations may be larger than 8 bits, the *YUV* impact data is scaled down before calculations are made. This results in loss of precession of the final *RGB* data. However, this loss of data is not recognized by the naked eye and is very well acceptable.

The second method also uses lookup tables. It obtains precise final results by using MMX™ Technology to operate on *words*. This method has its own drawbacks, since only 4 pixels can be calculated at a time (compared to 8 in the first method). Moreover, the final *word* values have to be packed to *byte* format before storing it to the output buffer. Finally, the lookup tables doubles in size yielding worse cache locality.

The third approach uses direct calculations instead of lookup tables. This approach could be a good alternative to the first because it does not use lookup tables and thus has better cache behavior. Another advantage is realized because memory writes to the graphics card are uncached and slow which gives the CPU enough time to perform the required calculations. On the other hand, this method requires *word* arithmetic which reduces the amount of parallelism in half, and requires repacking the final results to *byte format*. Nonetheless, measurements show that this method can be as fast as the first approach.

6. YUV12 to RGB24 Conversion Using Lookup Tables(first method)

The YUV12 to RGB color conversion formulas could be represented as follows:
R = Y_impact[Y] + + VR_impact[v]
G = Y_impact[Y] + UG_impact[u] + VG_impact[v]
B = Y_impact[Y] + UB_impact[u]

where (values from section 3):
Y_impact(Y) = 1.164(Y-16),
VR_impact(V) = 1.596(V-128)
VG_impact(V) = -0.813(V-128)
UG_impact(U) = -0.391(U-128)
UB_impact(U) = 2.018(U-128)

As mentioned above, for *byte* calculations, the *Y,U,V* impact data have to be scaled down so that the results doe not exceed the data range. Using the scale factor *1/4*, ranges of *U,V impact* can be reduced to -64..64, and *Y impact* can be reduced to 0..64. Adding the impacts together gives an *R,G,B* values between -64..128.

To clamp negative *R,G,B* values to 0, a constant 64 could be included in the *Y impact* tables which puts yields a range between 0..196. As a result, all calculation could be *unsigned byte* operations, which is a perfect fit for the MMX™ technology.

Figure 2. illustrates a block diagram of this algorithm.

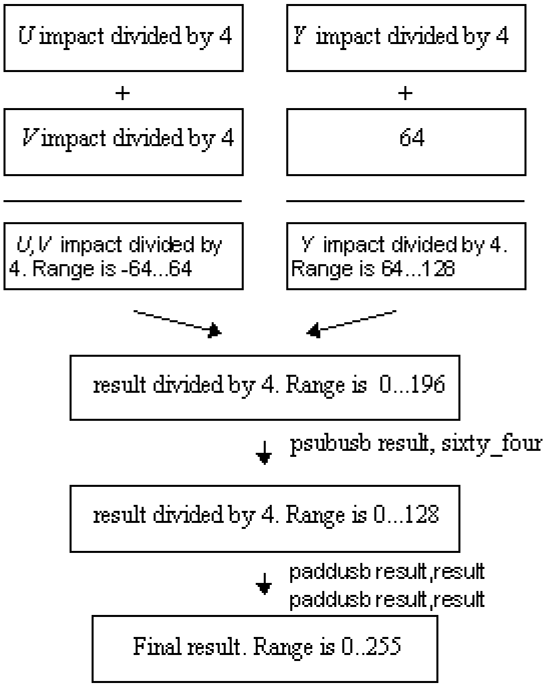

U impact divided by 4
+
V impact divided by 4
Y impact divided by 4
+
64
U,V impact divided by 4. Range is -64...64
Y impact divided by 4. Range is 64...128
result divided by 4. Range is 0...196
psubusb result, sixty_four
result divided by 4. Range is 0...128
paddusb result,result
paddusb result,result
Final result. Range is 0..255

Figure 2- Conversion scheme YUV12 RGB24 using look up tables.

6.1 Extracting Y,U and V Impacts From Lookup Tables

The inner loop of the algorithm generates a 2x4 block of RGB pixels. It processes two lines at a time, since the impact of the *U and V* components is the same for two consecutive lines. Twelve bytes are generated for four RGB24 pixels. Thus three *dwords* are written to the output buffer.

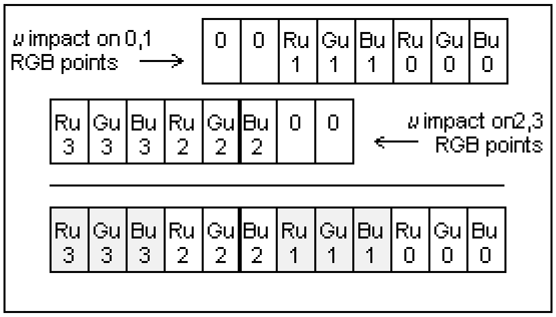

u impact on 0,1 RGB points
0 0 Ru 1 Gu 1 Bu 1 Ru 0 Gu 0 Bu 0
Ru 3 Gu 3 Bu 3 Ru 2 Gu 2 Bu 2 0 0
u impact on2,3 RGB points
Ru 3 Gu 3 Bu 3 Ru 2 Gu 2 Bu 2 Ru 1 Gu 1 Bu 1 Ru 0 Gu 0 Bu 0

Figure 3- obtaining u impact on four RGB points.

As shown in Figure 3, the first *U* input byte is used to reference the *U_impact table* for the first 2 RGB pixels. The second *U* input byte is used to reference the *U_impact table* for the next 2 RGB pixels. The *UV impact* will be used for two consecutive lines.

R uv3	G uv3	B uv3	R uv2	G uv2	B uv2	R uv1	G uv1	B uv1	R uv0	G uv0	B uv0

The *Y impact* is calculated for each line. To get *Y impact* on even-numbered lines (*Ye..*) four *Y impact* values are combined together as follows:

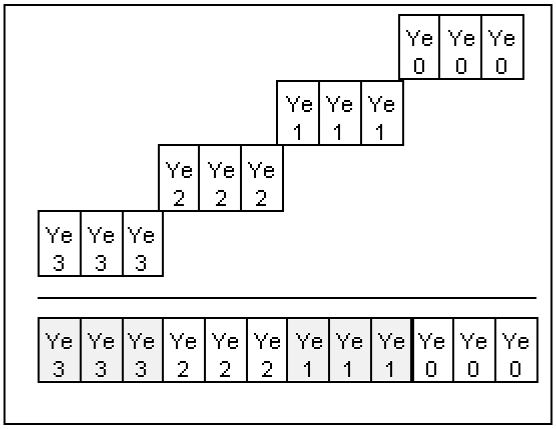
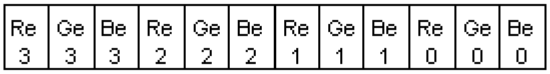


Figure 4- obtaining Y impact.

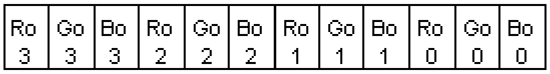
The *Y impact* for odd-numbered lines is calculated in the same manner.

Yo 3	Yo 3	Yo 3	Yo 2	Yo 2	Yo 2	Yo 1	Yo 1	Yo 1	Yo 0	Yo 0	Yo 0

Adding the *Y* lines to the *U,V*-impact, and continuing to perform operations as illustrated in Figure 2, the final *R,G,B* results are generated as follows:



Re	Ge	Be	Re	Ge	Be	Re	Ge	Be	Re	Ge	Be
3	3	3	2	2	2	1	1	1	0	0	0



Ro	Go	Bo	Ro	Go	Bo	Ro	Go	Bo	Ro	Go	Bo
3	3	3	2	2	2	1	1	1	0	0	0

Optimized implementation of this algorithm is found in Appendix 4.

6.2 Aspect Ratio Calculation

The *Aspect ratio* parameter allows for adjustment of picture aspect ratio (width/height). The algorithm only allows for reduction in height of picture by dropping certain lines when generating the output. For example if the aspect ratio is 12 , each 12th line is be dropped. Two solutions were considered. In the first one, each output line is processed separately and if the line number is a multiple of the *aspect ratio*, the line is dropped. The drawback of this solution is that the *UV* impacts, which are common for two consecutive lines, are either calculated twice, or stored in a temporary buffer. Both of them increase the amount of accessing required when no line is dropped, which is most of the cases.

The second solution always processes two lines at time. A line is skipped by writing the second calculated line over the first line. Thus, the amount of work is the same as if no lines are dropped at all. Therefore, the benefit of this method comes from the fact that *U,V* calculation is only done once.

6.3 Size of Lookup Tables

All tables contain 256 elements. The *Y* table contains *dword* entries, which yields 1K tables size. Each *U, V* table has *qword* entries, which yields 2K table each. Therefore, the total *Y,U,V* table size is 5K.

In the *U,V* tables, the *RGB* values in locations 0,1,2 are the same as the values in locations 3,4,5 respectively. This is due to the fact that *U,V* impacts two consecutive pixels. The *U,V* table sizes could be reduced by half eliminating the duplication. This could be done using shifts at run time to generate the proper format. However, this costs more CPU cycles.

To position the *Y* impacts in the right places, a *shift* instruction can be used. It is possible to use four tables for *Y*, and store shifted value in them. However, such tables will consume more memory, which could add additional pressure on the data cache.

7. YUV12 to RGB24 Zoom by Two

In this algorithm each output point is enlarged into 22 block. So now *U* and *V* values impact a 4x4 block, and *Y* values impact a 2x2 block. This algorithm was implemented using direct calculations of RGB values, and it uses the same ideas like RGB16 zoom by two.

Implementation of this algorithm can be found in Appendix 5.

8. YUV12 to RGB16 Conversion Using Lookup Tables

In the *RGB16* color format, every pixel is represented by 16-bit color components. Different graphics cards assign different number of bits for each of the *R,G and B* components, as follows:

x555 [ignore high order bit, then R,G,B where B is low]
655 [R=6(high), G=5, B=5(low)]
565 [R=5(high), G=6, B=5(low)]
664 [R=6(high), G=6, B=4(low)]

For example in x555 allocation, 5 bits are used to encode each color.

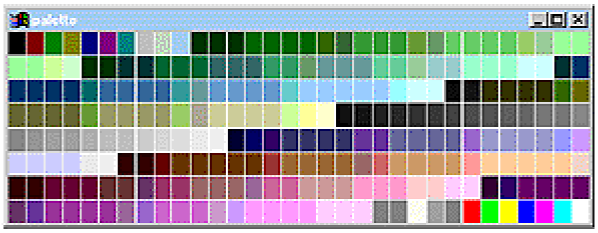
The first stage of *YUV12* to *RGB16* conversion is identical to *YUV12* to *RGB24* conversion. There is an additional step which decimates the *RGB24* color components and packs them into the appropriate 16 bit format.

Implementation of this algorithm can be found in Appendix 5.

9. YUV12 to RGB8 (CLUT8) Conversion Using Lookup Tables

9.1 Algorithm Description

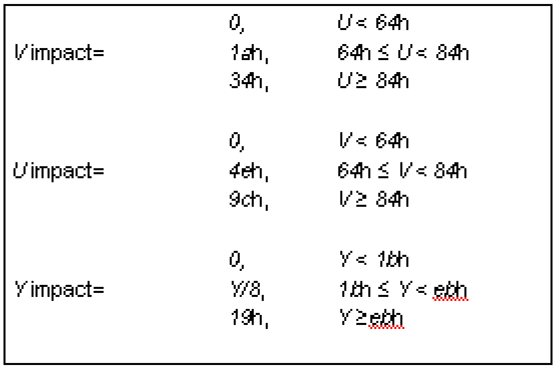
RGB8 format represents each color in 8 bits, yielding a total of 256 colors. The contents of the 8 bits is an index into a *Color Lookup Table* known as a color palette. Graphics adapters are programmed with this palette either by the operating system or by the application. The operating system reserves the first 10 and last 10 entries of the palette for system usage. The rest of the entries are used by the active application.



(In 256 color mode this picture may look wrong. Use 16 or 24 bit color mode to see this picture properly)

The palette used for this implementation of *RGB8* color is divided into 9 zones each with 26 gradients of the same color. *U and V impacts* are used to determine which color zone they represent, and the *Y impact* determines the intensity of the color in that zone. Definition of the palette may can be found in Appendix 1.

The *Y,U,V impacts* are calculated according to the following equations:



$$V\text{impact}= \begin{cases} 0, & U < 64h \\ 1ah, & 64h \le U < 84h \\ 34h, & U \ge 84h \end{cases}$$

$$U\text{impact}= \begin{cases} 0, & V < 64h \\ 4eh, & 64h \le V < 84h \\ 9ch, & V \ge 84h \end{cases}$$

$$Y\text{impact}= \begin{cases} 0, & Y < 10h \\ Y/8, & 10h \le Y < e0h \\ 19h, & Y \ge e0h \end{cases}$$

Table 1 - Color Conversion Rules for RGB8 CCK

In addition, a noise pattern is added to the input *Y,U,V* values to give the picture a smooth look. The noise pattern is shown in Table 2. This extra processing consumes more precious cycles of the CPU, especially since that *U and V impacts* are different on different lines and thus must be calculated separately.

V-noise:

Line 1	*10*h	*8*	*18*h	*0*
Line 2	*18*h	*0*	*10*h	*8*
Line 3	*8*	*10*h	*0*	*18*h
Line 4	*0*	*18*h	*8*	*10*h

U-noise:

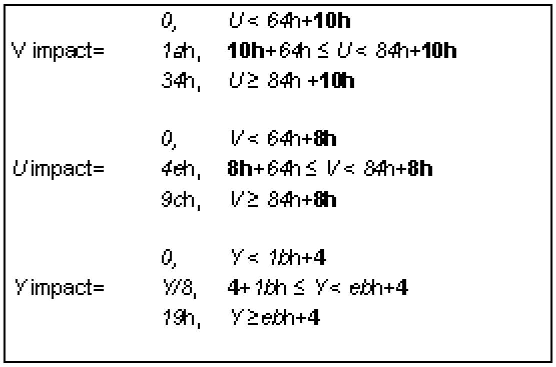
Line 1	*8*	*10*h	*0*	*18*h
Line 2	*0*	*18*h	*8*	*10*h
Line 3	*10*h	*8*	*18*h	*0*
Line 4	*18*h	*0*	*10*h	*8*

Y-noise:

Line 1	4	2	6	0
Line 2	6	0	4	2
Line 3	2	4	0	6
Line 4	0	6	2	4

Table 2 - Noise Matrixes for RGB8 CCK.

Since the noise values are added to the input *Y*,*U*,*V* data, the color conversion rules are different for every pixel in the 44 matrix. For example, consider the first pixel in *Line 1*. With the noise values added to it, a new color conversion table is derived as follows:



$$V\ impact= \begin{cases} 0, & U < 64h+\mathbf{10h} \\ 1ah, & \mathbf{10h}+64h \le U < 84h+\mathbf{10h} \\ 34h, & U \ge 84h+\mathbf{10h} \end{cases}$$

$$U\ impact= \begin{cases} 0, & V < 64h+\mathbf{8h} \\ 4eh, & \mathbf{8h}+64h \le V < 84h+\mathbf{8h} \\ 9ch, & V \ge 84h+\mathbf{8h} \end{cases}$$

$$Y\ impact= \begin{cases} 0, & Y < 1bh+\mathbf{4} \\ Y/8, & \mathbf{4}+1bh \le Y < ebh+\mathbf{4} \\ 19h, & Y \ge ebh+\mathbf{4} \end{cases}$$

Table 3 - Color Conversion Rules for RGB8 CCK.

9.2 Calculating *UV* Impact

This implementation performs color conversion of 8 consecutive pixels at a time, as shown in Figure 5. To calculate the *U impact,* the algorithm loads 4 *U* bytes and duplicates them across the 8 bytes (since every *U* value impacts 2 neighboring pixels). The result is compared against the pre-calculated constants, *U_low_b & U_high_b.* Note that IA MMX^{TM} Technology instructions compare only signed numbers; therefore, arguments should be converted to sign range. *U_low_b & U_high_b* are pre-calculated, such that the only needed conversion so only one conversion is needed at run time, for all of the 8 U bytes . The instruction *psubb mm0, convert_to_sign* does this conversion.

Figure 5 illustrates a block diagram of this algorithm.

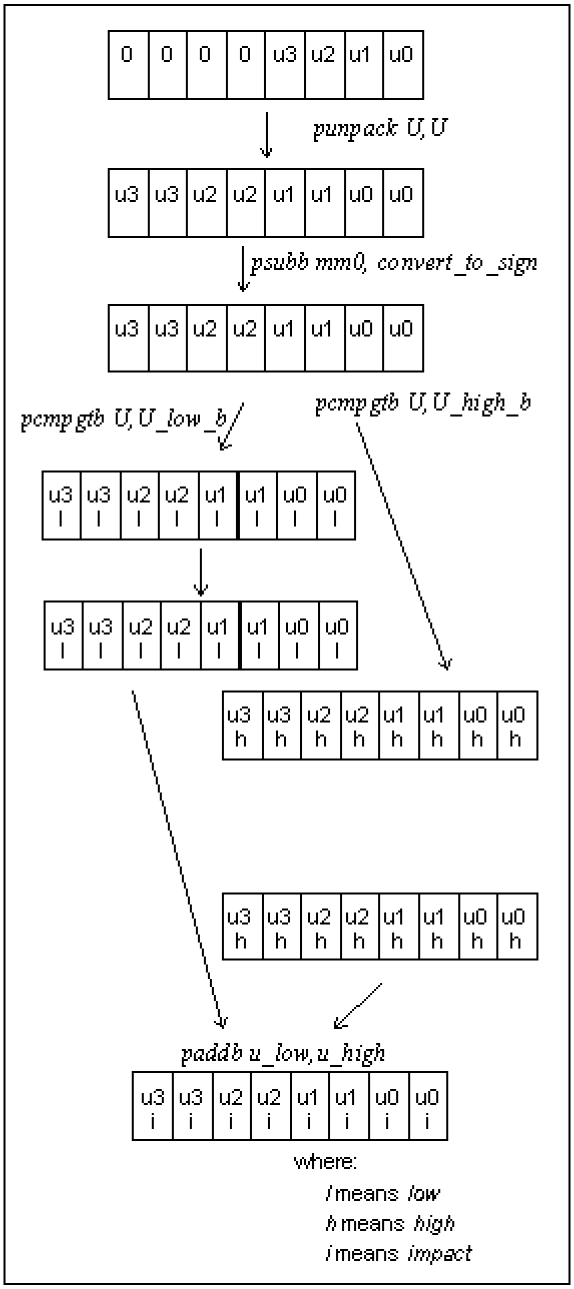

0 0 0 0 u3 u2 u1 u0
punpack U,U
u3 u3 u2 u2 u1 u1 u0 u0
psubb mm0, convert_to_sign
u3 u3 u2 u2 u1 u1 u0 u0
pcmpgtb U,U_low_b
pcmpgtb U,U_high_b
u3 l u3 l u2 l u2 l u1 l u1 l u0 l u0 l
u3 l u3 l u2 l u2 l u1 l u1 l u0 l u0 l
u3 h u3 h u2 h u2 h u1 h u1 h u0 h u0 h
u3 h u3 h u2 h u2 h u1 h u1 h u0 h u0 h
paddb u_low,u_high
u3 i u3 i u2 i u2 i u1 i u1 i u0 i u0 i
where:
l means low
h means high
i means impact

Figure 5 - Calculating u Impact for RGB8 CCK.

The constants *U_low_b* and *U_high_b* are the comparison values in Table 3; calculated for every pixel in the 4x4 matrix. Notice that these values include the noise effect introduced in Table 2 and are already converted to signed values.

U_low_b:
ebf3e3fbebf3e3fbh =6c74647c6c74647c - 8080808080808080
e3fbebf3e3fbebf3h =647c6c74647c6c74 - 8080808080808080

f3ebfbe3f3ebfbe3h =746c7c64746c7c64 - 8080808080808080
fbe3f3ebfbe3f3ebh =7c64746c7c64746c - 8080808080808080

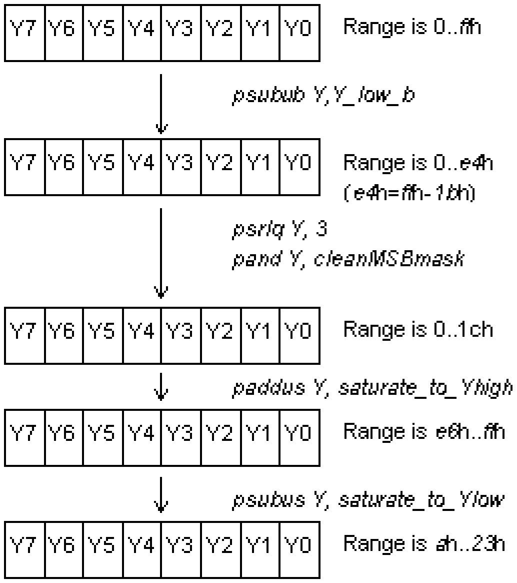
These values are derived in a similar method as shown in Table 3. For the first, the value *6c74647c6c74647c* is equal to the limit value *6464646464646464* added to the noise pattern at that line *0810001808100018.* All constants are converted to signed numbers by subtracting *8080808080808080*

The result of the comparison is *00h* for any byte below the compared corresponding limit, and *FFh* for every byte greater or equal to the corresponding limit. The result of the comparison is *and*ed with the value *4e4e4e4e4e4e4e4eh,* producing an intermediate result of *U impact.*

The comparison of the upper limit is done in a similar fashion and its result is added to the lower limit impact, yielding the total impact of *U.*

9.3 Calculating *Y* impact

A different method is used to calculate the *Y impact.* The input *Y value* is first saturated on the lower end by subtracting *Y_low_b,* which is the lower limit including the effect of the noise, as shown in Table 3. The result is then divided by 8 and clipped to the upper limit by adding *saturate_to_Yhigh.* Finally, the result is brought back to the mid-range by subtracting the *saturate_to_Ylow.*



Notice that the *saturate_to_Ylow* also includes the offset *10,* representing the first 10 reserved system colors.

Constant *Y_low_b* is different for every four consecutive lines. Subtracting *Y_low_b* is equivalent to adding noise value (*0402060004020600* for first line) and subtracting *1bh,*which is a lower limit for *Y*

Y_low_b
1719151b1719151b = 1b1b1b1b1b1b1b1b - 0402060004020600
19171b1519171b15 = 1b1b1b1b1b1b1b1b - 0204000602040006

151b1719151b1719 = 1b1b1b1b1b1b1b1b - 0600040206000402
1b1519171b151917 = 1b1b1b1b1b1b1b1b - 0006020400060204

Adding *saturate_to_Y_high* constant, converts all values above *19h* to *FFh*, which puts it in the range *E6h..FFh.* Subtracting *return_from_Y_high* constant, brings all values to the range *Ah..23h*, which is *Y* range *0..19h* plus *Ah.* The constant *Ah* is added to the result; this is the first 10 reserved colors by the operating system.

saturate_to_Y_high = e6e6e6e6e6e6e6e6 ; e6= ff-19
return_from_Y_high = dcdcdcdcdcdcdcdc ; ff-19-a

Implementation of this algorithm can be found in Appendix 2.

10. Converting to *RGB8*, Zoom by 2

In this algorithm each output point is duplicated into a 22 block. Therefore, each *U* and *V* value impacts a 4x4 block, and each *Y* value impacts a 2x2 block. Before starting to calculate *Y,U,V* impacts from Table 1, the noise values are added (using matrixes from Table 2). To calculate *U* (and *V*) impact on the first line of the 44 block, use the technique shown in Figure 5 (one more *punpack* for duplicating *u* points should be added). *U, V* impacts are added together, giving a *UV* impact for 4 pixels in the block. Since the noise values are the same, but in different byte locations in the 4x4 matrix, the rest of the *UV* impacts for the following three lines could be calculated by shuffling these values accordingly. For example if *UV* impact on first line is:

UV3 UV2 UV1 UV0

then the rest of lines are:

UV1 UV0 UV3 UV2 - second line
UV2 UV3 UV0 UV1 - third line
UV0 UV1 UV2 UV3 - fourth line

The rest of the algorithm is similar to the non-zoomed algorithm.

10.1 Implementation Notes

Two algorithms were implemented for *YUV12* to *RGB8* color conversion..

The First algorithm has two sequential loops. The first loop calculates the common *UV impacts* on four lines. The results are stored in a temporary buffer. The second loop calculates the . The second loop calculates the *Y impact* and combines them with the pre-calculated *UV impacts* to calculate the *RGB* pixel values. Each iteration of the second loop yields a 4x16 block of *RGB* pixels. This algorithm was found to be slow compared to the second algorithm (below), because of the nature of its calculations. The algorithm performs calculations of *RGB pixels,* and then writes them out to the graphics card. Due to the slow bandwidth of the graphics card compared to the CPU, the CPU write buffers were almost always full, causing a slow down in performance.

The second algorithm is based on interleaving the writes to the graphics card with *RGB* calculations. This algorithm is composed of one loop that calculates the *Y,U,V impacts*and combines them to generate the *RGB* values. As a result of the extra calculations of *U,V impacts* inside the loop, the size of the loop is increased, thus spreading the writes to the graphics card between calculations. The change in code structure resulted in a 1.3x speedup.

Implementation of the second algorithm can be found in Appendix 3.

11. Assumptions

For optimal performance, the algorithms assume that the output buffer is aligned on *qword* (8 byte) boundary. If it is aligned on 4 byte boundary, 4 bytes from the previous iteration and 4 bytes from the current iteration should be packed into *qword.* Then, write the 8 bytes to a *qword* aligned address. *Qword* writes are almost twice as fast as *dword* writes.

The code sample found in Appendix 5 are optimized for the Pentium® processor. The code samples for YUV to RGB24 converter with lookup tables is also optimized to avoid partial stalls on the Pentium Pro® processor.

12. Appendix 1. Definition of palette (used for color space conversion to RGB8).

As mentioned before, the first and last 10 colors are reserved by the operating system. Therefore, the first entry in the table corresponds to the 10th entry in the palette table. There are three values for each entry, corresponding to *blue, green* and *red* consecutively.

```
unsigned char
 PalTable[26*9*3] = {
      0,  39+ 15,       0,
      0,  39+ 24,       0,
      0,  39+ 33,       0,
      0,  39+ 42,       0,
-44+ 51,  39+ 51,       0,
-44+ 60,  39+ 60, -55+ 60,
-44+ 69,  39+ 69, -55+ 69,
-44+ 78,  39+ 78, -55+ 78,
-44+ 87,  39+ 87, -55+ 87,
-44+ 96,  39+ 96, -55+ 96,
-44+105,  39+105, -55+105,
-44+114,  39+114, -55+114,
-44+123,  39+123, -55+123,
-44+132,  39+132, -55+132,
-44+141,  39+141, -55+141,
-44+150,  39+150, -55+150,
-44+159,  39+159, -55+159,
-44+168,  39+168, -55+168,
-44+177,  39+177, -55+177,
-44+186,  39+186, -55+186,
-44+195,  39+195, -55+195,
-44+204,  39+204, -55+204,
-44+213,  39+213, -55+213,
-44+222,     255, -55+222,
-44+231,     255, -55+231,
-44+240,     255, -55+240,
      0,  26+ 15,   0+ 15,
      0,  26+ 24,   0+ 24,
      0,  26+ 33,   0+ 33,
      0,  26+ 42,   0+ 42,
-44+ 51,  26+ 51,   0+ 51,
-44+ 60,  26+ 60,   0+ 60,
-44+ 69,  26+ 69,   0+ 69,
-44+ 78,  26+ 78,   0+ 78,
-44+ 87,  26+ 87,   0+ 87,
-44+ 96,  26+ 96,   0+ 96,
-44+105,  26+105,   0+105,
-44+114,  26+114,   0+114,
-44+123,  26+123,   0+123,
-44+132,  26+132,   0+132,
-44+141,  26+141,   0+141,
-44+150,  26+150,   0+150,
-44+159,  26+159,   0+159,
-44+168,  26+168,   0+168,
-44+177,  26+177,   0+177,
-44+186,  26+186,   0+186,
-44+195,  26+195,   0+195,
-44+204,  26+204,   0+204,
-44+213,  26+213,   0+213,
-44+222,  26+222,   0+222,
-44+231,     255,   0+231,
-44+240,     255,   0+240,
      0,  14+ 15,  55+ 15,
      0,  14+ 24,  55+ 24,
      0,  14+ 33,  55+ 33,
      0,  14+ 42,  55+ 42,
-44+ 51,  14+ 51,  55+ 51,
-44+ 60,  14+ 60,  55+ 60,
-44+ 69,  14+ 69,  55+ 69,
-44+ 78,  14+ 78,  55+ 78,
-44+ 87,  14+ 87,  55+ 87,
-44+ 96,  14+ 96,  55+ 96,
-44+105,  14+105,  55+105,
-44+114,  14+114,  55+114,
-44+123,  14+123,  55+123,
-44+132,  14+132,  55+132,
-44+141,  14+141,  55+141,
-44+150,  14+150,  55+150,
-44+159,  14+159,  55+159,
-44+168,  14+168,  55+168,
-44+177,  14+177,  55+177,
-44+186,  14+186,  55+186,
-44+195,  14+195,  55+195,
-44+204,  14+204,     255,
-44+213,  14+213,     255,
-44+222,     255,     255,
-44+231,     255,     255,
-44+240,     255,     255,
  0+ 15,  13+ 15,       0,
  0+ 24,  13+ 24,       0,
  0+ 33,  13+ 33,       0,
  0+ 42,  13+ 42,       0,
  0+ 51,  13+ 51,       0,
  0+ 60,  13+ 60, -55+ 60,
  0+ 69,  13+ 69, -55+ 69,
  0+ 78,  13+ 78, -55+ 78,
  0+ 87,  13+ 87, -55+ 87,
  0+ 96,  13+ 96, -55+ 96,
  0+105,  13+105, -55+105,
  0+114,  13+114, -55+114,
  0+123,  13+123, -55+123,
  0+132,  13+132, -55+132,
  0+141,  13+141, -55+141,
  0+150,  13+150, -55+150,
  0+159,  13+159, -55+159,
  0+168,  13+168, -55+168,
  0+177,  13+177, -55+177,
  0+186,  13+186, -55+186,
  0+195,  13+195, -55+195,
  0+204,  13+204, -55+204,
  0+213,  13+213, -55+213,
  0+222,  13+222, -55+222,
  0+231,  13+231, -55+231,
  0+240,  13+242, -55+240,
  0+ 15,   0+ 15,   0+ 15,
  0+ 24,   0+ 24,   0+ 24,
  0+ 33,   0+ 33,   0+ 33,
  0+ 42,   0+ 42,   0+ 42,
  0+ 51,   0+ 51,   0+ 51,
  0+ 60,   0+ 60,   0+ 60,
  0+ 69,   0+ 69,   0+ 69,
  0+ 78,   0+ 78,   0+ 78,
  0+ 87,   0+ 87,   0+ 87,
  0+ 96,   0+ 96,   0+ 96,
  0+105,   0+105,   0+105,
  0+114,   0+114,   0+114,
  0+123,   0+123,   0+123,
  0+132,   0+132,   0+132,
  0+141,   0+141,   0+141,
  0+150,   0+150,   0+150,
  0+159,   0+159,   0+159,
  0+168,   0+168,   0+168,
  0+177,   0+177,   0+177,
  0+186,   0+186,   0+186,
  0+195,   0+195,   0+195,
  0+204,   0+204,   0+204,
  0+213,   0+213,   0+213,
  0+222,   0+222,   0+222,
  0+231,   0+231,   0+231,
  0+240,   0+240,   0+240,
  0+ 15, -13+ 15,  55+ 15,
  0+ 24, -13+ 24,  55+ 24,
  0+ 33, -13+ 33,  55+ 33,
  0+ 42, -13+ 42,  55+ 42,
  0+ 51, -13+ 51,  55+ 51,
  0+ 60, -13+ 60,  55+ 60,
  0+ 69, -13+ 69,  55+ 69,
  0+ 78, -13+ 78,  55+ 78,
  0+ 87, -13+ 87,  55+ 87,
  0+ 96, -13+ 96,  55+ 96,
  0+105, -13+105,  55+105,
  0+114, -13+114,  55+114,
  0+123, -13+123,  55+123,
  0+132, -13+132,  55+132,
  0+141, -13+141,  55+141,
  0+150, -13+150,  55+150,
  0+159, -13+159,  55+159,
  0+168, -13+168,  55+168,
  0+177, -13+177,  55+177,
  0+186, -13+186,  55+186,
  0+195, -13+195,  55+195,
  0+204, -13+204,     255,
  0+213, -13+213,     255,
  0+222, -13+222,     255,
  0+231, -13+231,     255,
  0+240, -13+240,     255,
 44+ 15, -14+ 15,       0,
 44+ 24, -14+ 24,       0,
 44+ 33, -14+ 33,       0,
 44+ 42, -14+ 42,       0,
 44+ 51, -14+ 51,       0,
 44+ 60, -14+ 60, -55+ 60,
 44+ 69, -14+ 69, -55+ 69,
 44+ 78, -14+ 78, -55+ 78,
 44+ 87, -14+ 87, -55+ 87,
 44+ 96, -14+ 96, -55+ 96,
 44+105, -14+105, -55+105,
 44+114, -14+114, -55+114,
 44+123, -14+123, -55+123,
 44+132, -14+132, -55+132,
 44+141, -14+141, -55+141,
 44+150, -14+150, -55+150,
 44+159, -14+159, -55+159,
 44+168, -14+168, -55+168,
 44+177, -14+177, -55+177,
 44+186, -14+186, -55+186,
 44+195, -14+195, -55+195,
 44+204, -14+204, -55+204,
    255, -14+213, -55+213,
    255, -14+222, -55+222,
    255, -14+231, -55+231,
    255, -14+242, -55+240,
 44+ 15,       0,   0+ 15,
 44+ 24,       0,   0+ 24,
 44+ 33, -26+ 33,   0+ 33,
 44+ 42, -26+ 42,   0+ 42,
 44+ 51, -26+ 51,   0+ 51,
 44+ 60, -26+ 60,   0+ 60,
 44+ 69, -26+ 69,   0+ 69,
 44+ 78, -26+ 78,   0+ 78,
 44+ 87, -26+ 87,   0+ 87,
 44+ 96, -26+ 96,   0+ 96,
 44+105, -26+105,   0+105,
 44+114, -26+114,   0+114,
 44+123, -26+123,   0+123,
 44+132, -26+132,   0+132,
 44+141, -26+141,   0+141,
 44+150, -26+150,   0+150,
 44+159, -26+159,   0+159,
 44+168, -26+168,   0+168,
 44+177, -26+177,   0+177,
 44+186, -26+186,   0+186,
 44+195, -26+195,   0+195,
 44+204, -26+204,   0+204,
    255, -26+213,   0+213,
    255, -26+222,   0+222,
    255, -26+231,   0+231,
    255, -26+240,   0+240,
 44+ 15,       0,  55+ 15,
 44+ 24,       0,  55+ 24,
 44+ 33,       0,  55+ 33,
 44+ 42, -39+ 42,  55+ 42,
 44+ 51, -39+ 51,  55+ 51,
 44+ 60, -39+ 60,  55+ 60,
 44+ 69, -39+ 69,  55+ 69,
 44+ 78, -39+ 78,  55+ 78,
 44+ 87, -39+ 87,  55+ 87,
 44+ 96, -39+ 96,  55+ 96,
 44+105, -39+105,  55+105,
 44+114, -39+114,  55+114,
 44+123, -39+123,  55+123,
 44+132, -39+132,  55+132,
 44+141, -39+141,  55+141,
 44+150, -39+150,  55+150,
 44+159, -39+159,  55+159,
 44+168, -39+168,  55+168,
 44+177, -39+177,  55+177,
 44+186, -39+186,  55+186,
 44+195, -39+195,  55+195,
 44+204, -39+204,     255,
    255, -39+213,     255,
    255, -39+222,     255,
    255, -39+231,     255,
    255, -39+240,     255,
};
```

13. Appendix 2. Color conversion to *RGB8*.

The noise matrix is 4x4 in size. Therefore, even-numbered and odd-numbered lines have different noise values. However, since every loop processes 2 lines at a time, the noise values for the two lines must be calculated before entering the loop and stored in the appropriate variables.

tmpV3_U1low_bound[esp] - constants for odd line
tmpV3_U1high_bound[esp]
tmpU3_V1low_bound[esp]
tmpU3_V1high_bound[esp]

tmpV2_U0low_bound[esp] - constants for even line
tmpV2_U0high_bound[esp]
tmpU2_V0low_bound[esp]
tmpU2_V0high_bound[esp]

tmpY0_low[esp] - Constants for Y values
tmpY1_low[esp]

```
;-------------------------------------------------------------------------
;
; cxm1281  -- This function performs YUV12 to CLUT8 color conversion for H26x.
;             It dithers among 9 chroma points and 26 luma points, mapping the
;             8 bit luma pels into the 26 luma points by clamping the ends and
;             stepping the luma by 8.
;
;                Color convertor is not destructive.
; Requirement:
;                U and V plane SHOULD be followed by 4 bytes (for read only)
;                Y plane SHOULD be followed by 8 bytes (for read only)
.586P
include iammx.inc
 ASSUME ds:FLAT, cs:FLAT, ss:FLAT
;------------------------------------------------------------
PQ      equ PD
PD      equ DWORD PTR
;------------------------------------------------------------
;=============================================================================
_DATA SEGMENT PARA PUBLIC USE32 'DATA'
    align 8
PUBLIC Y0_low
PUBLIC Y1_low
PUBLIC U_low_value
PUBLIC V_low_value
PUBLIC U2_V0high_bound
PUBLIC U2_V0low_bound
PUBLIC U3_V1high_bound
PUBLIC U3_V1low_bound
PUBLIC V2_U0high_bound
PUBLIC V2_U0low_bound
PUBLIC V3_U1high_bound
PUBLIC V3_U1low_bound
PUBLIC return_from_Y_high
PUBLIC saturate_to_Y_high
PUBLIC clean_MSB_mask
PUBLIC convert_to_sign
if  0 ;old_constants
V2_U0low_bound         dq 0f3ebfbe3f3ebfbe3h   ; 746c7c64746c7c64 - 8080808080808080
  U2_V0low_bound       dq 0ebf3e3fbebf3e3fbh   ; 6c74647c6c74647c - 8080808080808080
```

```
    _V2_U0low_bound    dq 0f3ebfbe3f3ebfbe3h   ; 746c7c64746c7c64 - 8080808080808080
U3_V1low_bound         dq 0e3fbebf3e3fbebf3h   ; 647c6c74647c6c74 - 8080808080808080
  V3_U1low_bound       dq 0fbe3f3ebfbe3f3ebh   ; 7c64746c7c64746c - 8080808080808080
    _U3_V1low_bound    dq 0e3fbebf3e3fbebf3h   ; 647c6c74647c6c74 - 8080808080808080
V2_U0high_bound        dq  130b1b03130b1b03h   ; 948c9c84948c9c84 - 8080808080808080
  U2_V0high_bound      dq  0b13031b0b13031bh   ; 8c94849c8c94849c - 8080808080808080
    _V2_U0high_bound   dq  130b1b03130b1b03h   ; 948c9c84948c9c84 - 8080808080808080
U3_V1high_bound        dq  031b0b13031b0b13h   ; 849c8c94849c8c94 - 8080808080808080
  V3_U1high_bound      dq  1b03130b1b03130bh   ; 9c84948c9c84948c - 8080808080808080
    _U3_V1high_bound   dq  031b0b13031b0b13h   ; 849c8c94849c8c94 - 8080808080808080
U_low_value            dq  1a1a1a1a1a1a1a1ah
V_low_value            dq  4e4e4e4e4e4e4e4eh
else ; new constants
V2_U0low_bound         dq 0ebf3e3fbebf3e3fbh   ; 6c74647c6c74647c - 8080808080808080
  U2_V0low_bound       dq 0f3ebfbe3f3ebfbe3h   ; 746c7c64746c7c64 - 8080808080808080
    _V2_U0low_bound    dq 0ebf3e3fbebf3e3fbh   ; 6c74647c6c74647c - 8080808080808080
U3_V1low_bound         dq 0fbe3f3ebfbe3f3ebh   ; 7c64746c7c64746c - 8080808080808080
  V3_U1low_bound       dq 0e3fbebf3e3fbebf3h   ; 647c6c74647c6c74 - 8080808080808080
    _U3_V1low_bound    dq 0fbe3f3ebfbe3f3ebh   ; 7c64746c7c64746c - 8080808080808080
V2_U0high_bound        dq  0b13031b0b13031bh   ; 8c94849c8c94849c - 8080808080808080
  U2_V0high_bound      dq  130b1b03130b1b03h   ; 948c9c84948c9c84 - 8080808080808080
    _V2_U0high_bound   dq  0b13031b0b13031bh   ; 8c94849c8c94849c - 8080808080808080
U3_V1high_bound        dq  1b03130b1b03130bh   ; 9c84948c9c84948c - 8080808080808080
  V3_U1high_bound      dq  031b0b13031b0b13h   ; 849c8c94849c8c94 - 8080808080808080
    _U3_V1high_bound   dq  1b03130b1b03130bh   ; 9c84948c9c84948c - 8080808080808080
V_low_value            dq  1a1a1a1a1a1a1a1ah
U_low_value            dq  4e4e4e4e4e4e4e4eh
endif
convert_to_sign        dq  8080808080808080h
; Y0_low,Y1_low are arrays
Y0_low          dq  1719151b1719151bh   ; 1b1b1b1b1b1b1b1b - 0402060004020600 ; for line%4=0
                dq  19171b1519171b15h   ; 1b1b1b1b1b1b1b1b - 0204000602040006 ; for line%4=2
Y1_low          dq  151b1719151b1719h   ; 1b1b1b1b1b1b1b1b - 0600040206000402 ; for line%4=1
                dq  1b1519171b151917h   ; 1b1b1b1b1b1b1b1b - 0006020400060204 ; for line%4=3
clean_MSB_mask      dq  1f1f1f1f1f1f1f1fh
saturate_to_Y_high  dq 0e6e6e6e6e6e6e6e6h    ; ffh-19h
return_from_Y_high  dq 0dcdcdcdcdcdcdcdch    ; ffh-19h-ah (return back and ADD ah);
_DATA ENDS
;=============================================================================
U_low               equ mm6
V_low               equ mm7
U_high              equ U_low
V_high              equ V_low
LocalsRelativeToEBP = 0
RegisterStorageSize = 16
LocalFrameSize      = End_of_locals
; Arguments:
arg_YPlane                   = LocalsRelativeToEBP + RegisterStorageSize +  4
arg_UPlane                   = LocalsRelativeToEBP + RegisterStorageSize +  8
arg_VPlane                   = LocalsRelativeToEBP + RegisterStorageSize + 12
arg_FrameWidth               = LocalsRelativeToEBP + RegisterStorageSize + 16
arg_FrameHeight              = LocalsRelativeToEBP + RegisterStorageSize + 20
arg_YPitch                   = LocalsRelativeToEBP + RegisterStorageSize + 24
arg_ChromaPitch              = LocalsRelativeToEBP + RegisterStorageSize + 28
arg_AspectAdjustmentCount    = LocalsRelativeToEBP + RegisterStorageSize + 32
arg_ColorConvertedFrame      = LocalsRelativeToEBP + RegisterStorageSize + 36
arg_DCIOffset                = LocalsRelativeToEBP + RegisterStorageSize + 40
arg_CCOffsetToLine0          = LocalsRelativeToEBP + RegisterStorageSize + 44
arg_CCOPitch                 = LocalsRelativeToEBP + RegisterStorageSize + 48
EndOfArgList                 = LocalsRelativeToEBP + RegisterStorageSize + 56
; LocalFrameSize (on local stack frame)
tmpV2_U0low_bound        =   0      ; qw
tmpU2_V0low_bound        =   8      ; qw
tmpU3_V1low_bound        =  16      ; qw
```

```
tmpV3_U1low_bound        =  24      ; qw
tmpV2_U0high_bound       =  32      ; qw
tmpU2_V0high_bound       =  40      ; qw
tmpU3_V1high_bound       =  48      ; qw
tmpV3_U1high_bound       =  56      ; qw
tmpY0_low                =  64      ; qw
tmpY1_low                =  72      ; qw
tmpBlockParity           =  80
AspectCount              =  84
tmpYCursorEven           =  88
tmpYCursorOdd            =  92
tmpCCOPitch              =  96
Old_esp                  = 100
End_of_locals            = 104
LCL EQU <esp+>
;=============================================================================
; extern void "C" MMX_YUV12ToCLUT8 (
;                                     U8* YPlane,
;                                     U8* UPlane,
;                                     U8* VPlane,
;                                     UN  FrameWidth,
;                                     UN  FrameHeight,
;                                     UN  YPitch,
;                                     UN  VPitch,
;                                     UN  AspectAdjustmentCount,
;                                     U8* ColorConvertedFrame,
;                                     U32 DCIOffset,
;                                     U32 CCOffsetToLine0,
;                                     int CCOPitch,
;                                     int CCType)
;
;  The local variables are on the stack.
;  The tables are in the one and only data segment.
;
;  CCOffsetToLine0 is relative to ColorConvertedFrame.
;
PUBLIC C MMX_YUV12ToCLUT8
_TEXT SEGMENT DWORD PUBLIC USE32 'CODE'
MMX_YUV12ToCLUT8:
  push  esi
  push  edi
  push  ebp
  push  ebx
  mov   ebp,esp
  sub   esp,LocalFrameSize
  and   esp,0fffffff8h
  mov   [esp+Old_esp],ebp
    mov     ecx,[ebp+arg_YPitch]
    mov     ebx,[ebp+arg_FrameWidth]
    mov     eax,[ebp+arg_YPlane]
    add     eax,ebx          ; Points to end of Y even line
    mov     tmpYCursorEven[esp],eax
    add     eax,ecx          ; add YPitch
    mov     tmpYCursorOdd[esp],eax
    lea     edx,[edx+2*ebx]  ; final value of Y-odd-pointer
    mov     esi,PD [ebp+arg_VPlane]
    mov     edx,PD [ebp+arg_UPlane]
    mov     eax,PD [ebp+arg_ColorConvertedFrame]
    add     eax,PD [ebp+arg_DCIOffset]
    add     eax,PD [ebp+arg_CCOffsetToLine0]
    sar     ebx,1
    add     esi,ebx
    add     edx,ebx
    lea     edi,[eax+2*ebx]    ; CCOCursor
    mov     ecx,[ebp+arg_AspectAdjustmentCount]
    mov     AspectCount[esp],ecx
    test   ecx,ecx     ; if AspectCount=0 we should not drop any lines
    jnz    non_zero_AspectCount
    dec    ecx
non_zero_AspectCount:
    mov     AspectCount[esp],ecx
    cmp     ecx,1
    jbe     finish
    neg     ebx
    mov     [ebp+arg_FrameWidth],ebx
    movq    mm6,PQ U_low_value     ; store some frequently used values in registers
    movq    mm7,PQ V_low_value
    xor     eax,eax
    mov     tmpBlockParity[esp],eax

;  Register Usage:
;
;  esi -- points to the end of V Line
;  edx -- points to the end of U Line.
;  edi -- points to the end of even line of output.
;  ebp -- points to the end of odd  line of output.
;
;  ecx -- points to the end of even/odd Y Line
;  eax -- 8*(line&2) == 0,  on line%4=0,1
;                     == 8,  on line%4=2,3
;         in the loop, eax points to the end of even Y line
;  ebx -- Number of points, we havn't done yet. (multiplyed by -0.5)
;
;
;------------------------------------------------------------------------------
; Noise matrix is of size 4x4 , so we have different noise values in even pair of lines,
; and in odd pair of lines. But in our loop we are doing 2 lines. So here we are prepairing
; constants for next two lines.
; This code is done each time we are starting to convert next pair of lines.
PrepareNext2Lines:
    mov     eax,tmpBlockParity[esp]
;constants for odd line
    movq    mm0,PQ V3_U1low_bound[eax]
    movq    mm1,PQ V3_U1high_bound[eax]
    movq    mm2,PQ U3_V1low_bound[eax]
    movq    mm3,PQ U3_V1high_bound[eax]
    movq    PQ tmpV3_U1low_bound[esp],mm0
    movq    PQ tmpV3_U1high_bound[esp],mm1
    movq    PQ tmpU3_V1low_bound[esp],mm2
    movq    PQ tmpU3_V1high_bound[esp],mm3
 ;constants for even line
    movq    mm0,PQ V2_U0low_bound[eax]
    movq    mm1,PQ V2_U0high_bound[eax]
    movq    mm2,PQ U2_V0low_bound[eax]
    movq    mm3,PQ U2_V0high_bound[eax]
    movq    PQ tmpV2_U0low_bound[esp],mm0
    movq    PQ tmpV2_U0high_bound[esp],mm1
    movq    PQ tmpU2_V0low_bound[esp],mm2
    movq    PQ tmpU2_V0high_bound[esp],mm3
; Constants for Y values
    movq    mm4,PQ Y0_low[eax]
    movq    mm5,PQ Y1_low[eax]
    xor     eax,8
    mov     tmpBlockParity[esp],eax
    movq    PQ tmpY0_low[esp],mm4
    movq    PQ tmpY1_low[esp],mm5
; if AspectCount<2 we should skip a line. In this case we are steel doing two
; lines, but output pointers are the same, so we just overwriting line which we should skip
    mov     eax,[ebp+arg_CCOPitch]
     mov   ebx, AspectCount[esp]
    xor     ecx,ecx
     sub     ebx,2
    mov    tmpCCOPitch[esp],eax
     ja     continue
    mov     eax,[ebp+arg_AspectAdjustmentCount]
     mov    tmpCCOPitch[esp],ecx     ; 0
    lea     ebx,[ebx+eax]    ; calculate new AspectCount
     jnz     continue         ; skiping even line
;skip_odd_line
    mov    eax,tmpYCursorEven[esp]
; set odd constants to be equal to even_constants
; Odd line will be performed as even
    movq    PQ tmpV3_U1low_bound[esp],mm0
    movq    PQ tmpV3_U1high_bound[esp],mm1
    movq    PQ tmpU3_V1low_bound[esp],mm2
    movq    PQ tmpU3_V1high_bound[esp],mm3
    movq    PQ tmpY1_low[esp],mm4
    mov    tmpYCursorOdd[esp],eax
; when we got here, we already did all preparations.
; we are entering a main loop which is starts at do_next_8x2_block label
continue:
    mov    AspectCount[esp],ebx

    mov     ebx,[ebp+arg_FrameWidth]
    mov     ebp,edi
    add     ebp,tmpCCOPitch[esp]             ; ebp points to the end of odd line of output
    mov     eax,tmpYCursorEven[esp]
    mov     ecx,tmpYCursorOdd[esp]
    movdt   mm0,[edx+ebx]           ; read 4 U points
    movdt   mm2,[esi+ebx]           ; read 4 V points
    punpcklbw mm0,mm0               ; u3:u3:u2:u2|u1:u1:u0:u0
    psubb   mm0,PQ convert_to_sign
    punpcklbw mm2,mm2               ; v3:v3:v2:v2|v1:v1:v0:v0
    movq    mm4,[eax+2*ebx]         ; read 8 Y points from even line
    movq    mm1,mm0                 ; u3:u3:u2:u2|u1:u1:u0:u0
do_next_8x2_block:
    psubb   mm2,PQ convert_to_sign  ; convert to sign range (for comparison)
    movq    mm5,mm1                 ; u3:u3:u2:u2|u1:u1:u0:u0
    pcmpgtb mm0,PQ tmpV2_U0low_bound[esp]
    movq    mm3,mm2

    pcmpgtb mm1,PQ tmpV2_U0high_bound[esp]
    pand    mm0,U_low
    psubusb mm4,PQ tmpY0_low[esp]
    pand    mm1,U_high
    pcmpgtb mm2,PQ tmpU2_V0low_bound[esp]
    psrlq   mm4,3
    pand    mm4,PQ clean_MSB_mask
    pand    mm2,V_low

    paddusb mm4,PQ saturate_to_Y_high
    paddb   mm0,mm1                 ; U03:U03:U02:U02|U01:U01:U00:U00
    psubusb mm4,PQ return_from_Y_high
    movq    mm1,mm5
    pcmpgtb mm5,PQ tmpV3_U1low_bound[esp]
    paddd   mm0,mm2
    pcmpgtb mm1,PQ tmpV3_U1high_bound[esp]
    pand    mm5,U_low
    paddd   mm0,mm4
    movq    mm2,mm3
    pcmpgtb mm3,PQ tmpU2_V0high_bound[esp]
    pand    mm1,U_high
    movq    mm4,[ecx+2*ebx]         ; read next 8 Y points from odd line
    paddb   mm5,mm1                 ; u impact on odd line
    psubusb mm4,PQ tmpY1_low[esp]
    movq    mm1,mm2
    pcmpgtb mm2,PQ tmpU3_V1low_bound[esp]
    psrlq   mm4,3
    pand    mm4,PQ clean_MSB_mask
    pand    mm2,V_low
    paddusb mm4,PQ saturate_to_Y_high
    paddd   mm5,mm2
    psubusb mm4,PQ return_from_Y_high
    pand    mm3,V_high
    pcmpgtb mm1,PQ tmpU3_V1high_bound[esp]
    paddb   mm3,mm0
    movdt   mm0,[edx+ebx+4]     ; read next 4 U points
    pand    mm1,V_high
    movdt   mm2,[esi+ebx+4]     ; read next 4 V points
    paddd   mm5,mm4
    movq    mm4,[eax+2*ebx+8]   ; read next 8 Y points from even line
    paddb   mm5,mm1
    psubb   mm0,PQ convert_to_sign
    punpcklbw mm2,mm2           ; v3:v3:v2:v2|v1:v1:v0:v0
    movq    [edi+2*ebx],mm3     ; write even line
    punpcklbw mm0,mm0           ; u3:u3:u2:u2|u1:u1:u0:u0
    movq    [ebp+2*ebx],mm5     ; write odd line
    movq    mm1,mm0             ; u3:u3:u2:u2|u1:u1:u0:u0
    add     ebx,4
    jl      do_next_8x2_block

; update pointes to input and output buffers, to point to the next lines
    mov     ebp,[esp+Old_esp]
     mov    eax,tmpYCursorEven[esp]
    mov     ecx,[ebp+arg_YPitch]
     add     edi,[ebp+arg_CCOPitch]      ; go to the end of next line
    add     edi,tmpCCOPitch[esp]                 ; skip odd line
     lea     eax,[eax+2*ecx]
    mov    tmpYCursorEven[esp],eax
     add     eax,[ebp+arg_YPitch]
    mov    tmpYCursorOdd[esp],eax
     add     esi,[ebp+arg_ChromaPitch]
    add     edx,[ebp+arg_ChromaPitch]
    sub PD [ebp+arg_FrameHeight],2
     ja      PrepareNext2Lines
;------------------------------------------------------------------------------
finish:

  emms

  mov   esp,[esp+Old_esp]
  pop   ebx
  pop   ebp
  pop   edi
  pop   esi
  ret
_TEXT ENDS
END
```

14. Appendix 3. Color conversion to RGB8 zoom by 2.

This algorithm uses the same constants as the previous RGB8 algorithm

```
;-------------------------------------------------------------------------
;
; cxm1282  -- This function performs YUV12 to CLUT8 zoom-by-2 color conversion
;             for H26x.  It dithers among 9 chroma points and 26 luma
;             points, mapping the 8 bit luma pels into the 26 luma points by
;             clamping the ends and stepping the luma by 8.
;
;             1. The color convertor is destructive;  the input Y, U, and V
;                planes will be clobbered.  The Y plane MUST be preceded by
;                1544 bytes of space for scratch work.
;             2. U and V planes should be preceded by 4 bytes (for read only)
;
include locals.inc
include iammx.inc
 ASSUME ds:FLAT, cs:FLAT, ss:FLAT
.586
.xlist
.list
;------------------------------------------------------------
PQ      equ PD
;------------------------------------------------------------
;=============================================================================
MMXDATA1 SEGMENT PARA USE32 PUBLIC 'DATA'
ALIGN 8
;convert_to_sign     dq  8080808080808080h
;V2_U0low_bound         dq 0f3ebfbe3f3ebfbe3h   ; 746c7c64746c7c64 - 8080808080808080
;V2_U0high_bound        dq  130b1b03130b1b03h   ; 948c9c84948c9c84 - 8080808080808080
;U2_V0low_bound         dq 0ebf3e3fbebf3e3fbh   ; 6c74647c6c74647c - 8080808080808080
;U2_V0high_bound        dq  0b13031b0b13031bh   ; 8c94849c8c94849c - 8080808080808080
;U_low_value               dq  1a1a1a1a1a1a1a1ah
;V_low_value               dq  4e4e4e4e4e4e4e4eh
;Y0_correct          dq  1b1519171b151917h   ; 1b1b1b1b1b1b1b1b - 0006020400060204
;Y1_correct          dq  19171b1519171b15h   ; 1b1b1b1b1b1b1b1b - 0204000602040006
;Y2_correct          dq  151b1719151b1719h   ; 1b1b1b1b1b1b1b1b - 0402060004020600
;Y3_correct          dq  1719151b1719151bh   ; 1b1b1b1b1b1b1b1b - 0600040206000402
;clean_MSB_mask      dq  1f1f1f1f1f1f1f1fh
;saturate_to_Y_high  dq 0e6e6e6e6e6e6e6e6h   ; ffh-19h
;return_from_Y_high  dq 0dcdcdcdcdcdcdcdch   ; ffh-19h-ah (return back and ADD ah);
extrn convert_to_sign:qword
extrn V2_U0low_bound:qword
extrn V2_U0high_bound:qword
extrn U2_V0low_bound:qword
extrn U2_V0high_bound:qword
extrn U_low_value:qword
extrn V_low_value:qword
extrn Y0_low:qword
extrn Y1_low:qword
extrn clean_MSB_mask:qword
extrn saturate_to_Y_high:qword
extrn return_from_Y_high:qword
Y0_correct          equ Y1_low+8
Y1_correct          equ Y0_low+8
Y2_correct          equ Y1_low
Y3_correct          equ Y0_low
U_high_value        equ U_low_value
V_high_value        equ V_low_value
MMXDATA1 ENDS
;=============================================================================
LocalFrameSize      = 24
RegisterStorageSize = 16
; Arguments:
YPlane                   = LocalFrameSize + RegisterStorageSize +  4
UPlane                   = LocalFrameSize + RegisterStorageSize +  8
VPlane                   = LocalFrameSize + RegisterStorageSize + 12
FrameWidth               = LocalFrameSize + RegisterStorageSize + 16
FrameHeight              = LocalFrameSize + RegisterStorageSize + 20
YPitch                   = LocalFrameSize + RegisterStorageSize + 24
ChromaPitch              = LocalFrameSize + RegisterStorageSize + 28
AspectAdjustmentCount    = LocalFrameSize + RegisterStorageSize + 32
ColorConvertedFrame      = LocalFrameSize + RegisterStorageSize + 36
DCIOffset                = LocalFrameSize + RegisterStorageSize + 40
CCOffsetToLine0          = LocalFrameSize + RegisterStorageSize + 44
CCOPitch                 = LocalFrameSize + RegisterStorageSize + 48
EndOfArgList             = LocalFrameSize + RegisterStorageSize + 56
; Locals (on local stack frame)
CCOCursor                =   0
DistanceFromVToU         =   4
AspectCount              =   8
CCOLine1                 =  12
CCOLine2                 =  16
CCOLine3                 =  20
LCL EQU <esp+>
;=============================================================================
MMXCODE1 SEGMENT PARA USE32 PUBLIC 'CODE'
; extern void "C" MMX_YUV12ToCLUT8ZoomBy2 (
;                                     U8* YPlane,
;                                     U8* UPlane,
;                                     U8* VPlane,
;                                     UN  FrameWidth,
;                                     UN  FrameHeight,
;                                     UN  YPitch,
;                                     UN  VPitch,
;                                     UN  AspectAdjustmentCount,
;                                     U8* ColorConvertedFrame,
;                                     U32 DCIOffset,
;                                     U32 CCOffsetToLine0,
;                                     int CCOPitch,
;                                     int CCType)
;
;  The local variables are on the stack.
;  The tables are in the one and only data segment.
;
;  CCOffsetToLine0 is relative to ColorConvertedFrame.
;
PUBLIC C MMX_YUV12ToCLUT8ZoomBy2
MMX_YUV12ToCLUT8ZoomBy2:
  push  esi
  push  edi
  push  ebp
  push  ebx
  sub   esp,LocalFrameSize
  mov   ebx,PD [esp+VPlane]
  mov   ecx,PD [esp+UPlane]
  sub   ecx,ebx
  mov   PD [esp+DistanceFromVToU],ecx
  mov   eax,PD [esp+ColorConvertedFrame]
  add   eax,PD [esp+DCIOffset]
  add   eax,PD [esp+CCOffsetToLine0]
  mov   PD [esp+CCOCursor],eax
;   Ledx  FrameHeight
;   Lecx YPitch
;  imul  edx,ecx
```

```
   Ledi CCOPitch
  Lesi YPlane                   ; Fetch cursor over luma plane.
  Seax  CCOCursor
;   add  edx,esi
;  Sedx  YLimit
   Ledx AspectAdjustmentCount
  Sedx  AspectCount
   mov     edi,esi
  Lebx    FrameWidth
   Leax    CCOCursor
  sar     ebx,1
   sub     ebx,4               ; counter starts from maxvalue-4, and in last iteration it
equals 0
  mov     ecx,eax
   ADDedi  YPitch              ; edi = odd Y line cursor
  ADDecx  CCOPitch
   Sebx    FrameWidth
  Secx    CCOLine1
   Lebx    CCOPitch
; in each outer loop iteration,  4 lines of output are done.
; in each inner loop iteration block 4x16 of output is done.
; main task of outer loop is to prepare pointers for inner loop
NextFourLines:
 ; prepare output pointers
 ; ebx=CCOPitch
 ; eax=CCOLine0
 ; ecx=CCOLine1
    Lebp    AspectCount
    sub     ebp,2
     ja      continue1               ; jump if it still>0
    ADDebp  AspectAdjustmentCount
     mov     ecx,eax                 ; Output1 will overwrite Output0 line
    Secx    CCOLine1
continue1:
    lea     edx,[ecx+ebx]
     sub     ebp,2
    Sedx    CCOLine2
     ja      continue2               ; jump if it still>0
    ADDebp  AspectAdjustmentCount
     xor     ebx,ebx                 ; Output1 will overwrite Output0 line
continue2:
    Sebp    AspectCount
     lea     ebp,[edx+ebx]
    Sebp    CCOLine3
; output pointers are done
;  Inner loop does 4x16 block of output points
;  Register Usage
;
;    esi -- Cursor over even Y line
;    edi -- Cursor over odd Y line
;    edx -- Cursor over V line
;    ebp -- Cursor over U line.
;    eax -- cursor over Output
;    ecx -- cursor over Output1,2,3
;    ebx -- counter
    Lebp    VPlane
     Lebx    FrameWidth
    mov     edx,ebp
     ADDebp  DistanceFromVToU    ; Cursor over U line.
    movdt   mm3,[ebp+ebx]       ; read 4 U points
    movdt   mm2,[edx+ebx]       ; read 4 V points
     punpcklbw mm3,mm3           ; u3:u3:u2:u2|u1:u1:u0:u0
prepare_next4x8:
    psubb   mm3,PQ convert_to_sign
    punpcklbw mm2,mm2           ; v3:v3:v2:v2|v1:v1:v0:v0
    psubb   mm2,PQ convert_to_sign
    movq    mm4,mm3
    movdt   mm7,[esi+2*ebx]     ; read even Y line
    punpcklwd mm3,mm3           ; u1:u1:u1:u1|u0:u0:u0:u0
    Lecx    CCOLine1
    movq    mm1,mm3
    pcmpgtb mm3,PQ V2_U0low_bound
    punpcklbw mm7,mm7                 ; y3:y3:y2:y2|y1:y1:y0:y0
    pand    mm3,PQ U_low_value
    movq    mm5,mm7
    psubusb mm7,PQ Y0_correct
    movq    mm6,mm2
    pcmpgtb mm1,PQ V2_U0high_bound
    punpcklwd mm2,mm2           ; v1:v1:v1:v1|v0:v0:v0:v0
    pand    mm1,PQ U_high_value
    psrlq   mm7,3
    pand    mm7,PQ clean_MSB_mask
    movq    mm0,mm2
    pcmpgtb mm2,PQ U2_V0low_bound
; empty slot !!!!
    pcmpgtb mm0,PQ U2_V0high_bound
    paddb   mm3,mm1
    pand    mm2,PQ V_low_value
    pand    mm0,PQ V_high_value
; two empty slots !!!!
    paddusb mm7,PQ saturate_to_Y_high
    paddb   mm3,mm2
    psubusb mm7,PQ return_from_Y_high   ; Y impact on line0
    paddd   mm3,mm0                     ; common U,V impact on line 0
    psubusb mm5,PQ Y1_correct
    paddb   mm7,mm3                     ; final value of line 0
    movq    mm0,mm3                     ; u31:u21:u11:u01|u30:u20:u10:u00
    psrlq   mm5,3
    pand    mm5,PQ clean_MSB_mask
    psrld   mm0,16                      ;    :   :u31:u21|   :   :u30:u20
    paddusb mm5,PQ saturate_to_Y_high
    pslld   mm3,16                      ; u11:u01:   :   |u10:u00:   :
    psubusb mm5,PQ return_from_Y_high   ; Y impact on line0
    por     mm0,mm3                     ; u11:u01:u31:u21|u10:u00:u30:u20
    movdt   mm3,[edi+2*ebx]             ; odd Y line
    paddb   mm5,mm0                     ; final value of line 0
    punpcklbw mm3,mm3                 ; y3:y3:y2:y2|y1:y1:y0:y0
    movq    mm2,mm0                   ; u11:u01:u31:u21|u10:u00:u30:u20
    movq    [ecx+4*ebx],mm5           ; write Output1 line
    movq    mm1,mm3
    movq    [eax+4*ebx],mm7           ; write Output0 line
    psrlw   mm0,8                     ;    :u11:   :u31|   :u10:   :u30
    psubusb mm1,PQ Y3_correct
    psllw   mm2,8                     ; u01:   :u21:   |u00:   :u20:
    psubusb mm3,PQ Y2_correct
    psrlq   mm1,3
    pand    mm1,PQ clean_MSB_mask
    por     mm0,mm2                   ; u01:u11:u21:u31|u00:u10:u20:u30
    paddusb mm1,PQ saturate_to_Y_high
    psrlq   mm3,3
    psubusb mm1,PQ return_from_Y_high
    movq    mm5,mm0                   ; u01:u11:u21:u31|u00:u10:u20:u30
    pand    mm3,PQ clean_MSB_mask
    paddb   mm1,mm0
    paddusb mm3,PQ saturate_to_Y_high
    psrld   mm5,16
    psubusb mm3,PQ return_from_Y_high
    pslld   mm0,16
    Lecx    CCOLine3
    por     mm5,mm0                   ; u21:u31:u01:u11|u20:u30:u00:u10
    movdt   mm2,[esi+2*ebx+4]         ; read next even Y line
    paddb   mm5,mm3
    movq    [ecx+4*ebx],mm1           ; write Output3 line
    punpckhwd mm4,mm4                 ; u3:u3:u3:u3|u2:u2:u2:u2
; start next 4x8 block of output
; SECOND uv-QWORD
; mm6, mm4 are live
    Lecx    CCOLine2
    movq    mm3,mm4
    pcmpgtb mm4,PQ V2_U0low_bound
    punpckhwd mm6,mm6
    movq    [ecx+4*ebx],mm5           ; write Output2 line
    movq    mm7,mm6
    pand    mm4,PQ U_low_value
    punpcklbw mm2,mm2                 ; y3:y3:y2:y2|y1:y1:y0:y0
    pcmpgtb mm3,PQ V2_U0high_bound
    movq    mm5,mm2
    pand    mm3,PQ U_high_value
    pcmpgtb mm6,PQ U2_V0low_bound
    paddb   mm4,mm3
    pand    mm6,PQ V_low_value
    pcmpgtb mm7,PQ U2_V0high_bound
    paddb   mm4,mm6
    pand    mm7,PQ V_high_value
    psubusb mm2,PQ Y0_correct
    paddd   mm4,mm7
    psubusb mm5,PQ Y1_correct
    psrlq   mm2,3
    pand    mm2,PQ clean_MSB_mask
    movq    mm3,mm4                   ; u31:u21:u11:u01|u30:u20:u10:u00
    paddusb mm2,PQ saturate_to_Y_high
    pslld   mm3,16                    ; u11:u01:   :   |u10:u00:   :
    psubusb mm2,PQ return_from_Y_high
    psrlq   mm5,3
    pand    mm5,PQ clean_MSB_mask
    paddb   mm2,mm4         ; MM4=u31:u21:u11:u01|u30:u20:u10:u00, WHERE U STANDS FOR UNATED U
AND V IMPACTS
    paddusb mm5,PQ saturate_to_Y_high
    psrld   mm4,16                    ;    :   :u31:u21|   :   :u30:u20
    psubusb mm5,PQ return_from_Y_high
    por     mm4,mm3                   ; u11:u01:u31:u21|u10:u00:u30:u20
    paddb   mm5,mm4
    Lecx    CCOLine1
    movdt   mm0,[edi+2*ebx+4]         ; read odd Y line
    movq    mm7,mm4                   ; u11:u01:u31:u21|u10:u00:u30:u20
    movq    [ecx+4*ebx+8],mm5           ; write Output1 line
    punpcklbw mm0,mm0                 ; y3:y3:y2:y2|y1:y1:y0:y0
    movq    [eax+4*ebx+8],mm2           ; write Output0 line
    movq    mm1,mm0
    psubusb mm1,PQ Y2_correct
    psrlw   mm4,8                     ;    :u11:   :u31|   :u10:   :u30
    psubusb mm0,PQ Y3_correct
    psrlq   mm1,3
    pand    mm1,PQ clean_MSB_mask
    psllw   mm7,8                     ; u01:   :u21:   |u00:   :u20:
    paddusb mm1,PQ saturate_to_Y_high
    por     mm4,mm7                   ; u01:u11:u21:u31|u00:u10:u20:u30
    psubusb mm1,PQ return_from_Y_high
    psrlq   mm0,3
    pand    mm0,PQ clean_MSB_mask
    movq    mm5,mm4                   ; u01:u11:u21:u31|u00:u10:u20:u30
    paddusb mm0,PQ saturate_to_Y_high
    psrld   mm5,16
    psubusb mm0,PQ return_from_Y_high
    paddb   mm0,mm4
    Lecx    CCOLine3
    movdt   mm3,[ebp+ebx-4]             ; read next 4 U points
    pslld   mm4,16
    movq    [ecx+4*ebx+8],mm0           ; write Output3 line
    por     mm5,mm4                     ; u21:u31:u01:u11|u20:u30:u00:u10
    paddb   mm5,mm1
    Lecx    CCOLine2
    movdt   mm2,[edx+ebx-4]             ; read next 4 V points
    punpcklbw mm3,mm3           ; u3:u3:u2:u2|u1:u1:u0:u0
    movq    [ecx+4*ebx+8],mm5           ; write Output2 line
    sub     ebx,4
    jae     prepare_next4x8
    Lebx    CCOPitch
    Lecx    CCOLine3
    Lebp    YPitch
    Ledx    VPlane
    lea     eax,[ecx+ebx]         ; next Output0 = old Output3 + CCOPitch
    lea     ecx,[ecx+2*ebx]       ; next Output1 = old Output3 + 2* CCOPitch
    ADDedx  ChromaPitch
    Secx    CCOLine1
    lea     esi,[esi+2*ebp]         ; even Y line cursor goes to next line
    lea     edi,[edi+2*ebp]         ; odd  Y line cursor goes to next line
    Sedx    VPlane                  ; edx will point to V plane
    sub     PD FrameHeight[esp],2
    ja      NextFourLines
  emms
  add   esp,LocalFrameSize
  pop   ebx
  pop   ebp
  pop   edi
  pop   esi
  retn
MMXCODE1 ENDS
END
```

15. Appendix 4. Color conversion to *RGB24*.

This code sample is an optimized version of color conversion from *YUV12* to *RGB24* format.

```
;-------------------------------------------------------------------------
; cx512241 -- This function performs YUV12-to-RGB24 color conversion for H26x.
;             It is tuned for best performance on the Pentium(r) Microprocessor.
;             It handles the format in which the low order byte is B, the
;             second byte is G, and the high order byte is R.
;
;             The YUV12 input is planar, 8 bits per pel.  The Y plane may have
;             a pitch of up to 768.  It may have a width less than or equal
;             to the pitch.  It must be DWORD aligned, and preferably QWORD
;             aligned.  Pitch and Width must be a multiple of four.  For best
;             performance, Pitch should not be 4 more than a multiple of 32.
;             Height may be any amount, but must be a multiple of two.  The U
;             and V planes may have a different pitch than the Y plane, subject
;             to the same limitations.
;
;             The color convertor is destructive;  the input Y, U, and V
;             planes will be clobbered.  The Y plane MUST be preceded by
;             3104 bytes of space for scratch work.
OPTION PROLOGUE:None
OPTION EPILOGUE:ReturnAndRelieveEpilogueMacro
include iammx.inc
include locals.inc
.xlist
.list
.DATA
; any data would go here
    ALIGN 8
sixty_four  dd  40404040h, 40404040h
include     small_ta.asm
.CODE
 ASSUME ds:FLAT, cs:FLAT, ss:FLAT
; void FAR ASM_CALLTYPE MMX_YUV12ToRGB24 (
;                                     U8* YPlane,
;                                     U8* UPlane,
;                                     U8* VPlane,
;                                     UN  FrameWidth,
;                                     UN  FrameHeight,
;                                     UN  YPitch,
;                                     UN  VPitch,
;                                     UN  AspectAdjustmentCount,
;                                     U8* ColorConvertedFrame,
;                                     U32 DCIOffset,
;                                     U32 CCOffsetToLine0,
;                                     IN  CCOPitch,
;                                     IN  CCType)
;
;  The local variables are on the stack.
;  The tables are in the one and only data segment.
;
;  CCOffsetToLine0 is relative to ColorConvertedFrame.
;
PUBLIC C YUV12ToRGB24
; due to the need for the ebp reg, these parameter declarations aren't used,
; they are here so the assembler knows how many bytes to relieve from the stack
LocalFrameSize = 40
RegisterStorageSize = 16
; Arguments:
; Arguments:
```

```
YPlane                   = LocalFrameSize + RegisterStorageSize +  4
UPlane                   = LocalFrameSize + RegisterStorageSize +  8
VPlane                   = LocalFrameSize + RegisterStorageSize + 12
FrameWidth               = LocalFrameSize + RegisterStorageSize + 16
FrameHeight              = LocalFrameSize + RegisterStorageSize + 20
YPitch                   = LocalFrameSize + RegisterStorageSize + 24
ChromaPitch              = LocalFrameSize + RegisterStorageSize + 28
AspectAdjustmentCount    = LocalFrameSize + RegisterStorageSize + 32
ColorConvertedFrame      = LocalFrameSize + RegisterStorageSize + 36
DCIOffset                = LocalFrameSize + RegisterStorageSize + 40
CCOffsetToLine0          = LocalFrameSize + RegisterStorageSize + 44
CCOPitch                 = LocalFrameSize + RegisterStorageSize + 48
EndOfArgList             = LocalFrameSize + RegisterStorageSize + 52
; Locals (on local stack frame)
CCOCursor                =   0
CCOSkipDistance          =   4
ChromaLineLen            =   8
YSkipDistance            =  12
YCursor                  =  16
DistanceFromVToU         =  20
tmpYCursorEven           =  24
tmpYCursorOdd            =  28
tmpCCOPitch              =  32
AspectCount              =  36
LCL EQU <esp+>
YUV12ToRGB24:
  push  esi
  push  edi
  push  ebp
  push  ebx

  sub   esp,LocalFrameSize
  mov   ebx,PD [esp+VPlane]
  mov   ecx,PD [esp+UPlane]
  sub   ecx,ebx
  mov   PD [esp+DistanceFromVToU],ecx
  mov   eax,PD [esp+ColorConvertedFrame]
  add   eax,PD [esp+DCIOffset]
  add   eax,PD [esp+CCOffsetToLine0]
  mov   PD [esp+CCOCursor],eax
;  Ledx  FrameHeight
   Lecx YPitch
;  imul  edx,ecx         ; FrameHeight*YPitch
  Lebx  FrameWidth
   Leax CCOPitch
  sub   eax,ebx         ; CCOPitch-FrameWidth
   sub  ecx,ebx         ; YPitch-FrameWidth
  sub   eax,ebx         ; CCOPitch-2*FrameWidth
   Secx YSkipDistance
  sub   eax,ebx         ; CCOPitch-3*FrameWidth
   Lesi YPlane          ; Fetch cursor over luma plane.
  sar   ebx,1           ; FrameWidth/2
   Seax CCOSkipDistance ; CCOPitch-3*FrameWidth
  add   edx,esi         ; YPlane+Size_of_Y_array
   Sebx ChromaLineLen   ; FrameWidth/2
;  Sedx  YLimit
   Sesi YCursor
  Ledx  AspectAdjustmentCount
   Lesi VPlane
     test   edx,edx     ; if AspectCount=0 we should not drop any lines
     jnz    non_zero_AspectCount
     dec    edx
non_zero_AspectCount:
  Sedx  AspectAdjustmentCount
```

```
   xor  eax,eax
  Lebp  DistanceFromVToU
  Ledi  YCursor                       ; Fetch Y Pitch.
    Lebx    FrameWidth

    add     edi,ebx
    Sedi    tmpYCursorEven
    Leax    YPitch
    add     edi,eax
    Sedi    tmpYCursorOdd
    sar     ebx,1
    add     esi,ebx
    add     ebp,esi
    neg     ebx
    Sebx    FrameWidth
  Ledi  CCOCursor

;  Register Usage:
;
;  edx -- Y Line cursor.  Chroma contribs go in lines above current Y line.
;  esi -- V Line cursor.
;  ebp -- U Line cursor
;  edi -- Cursor over the color converted output image.
;  ebx -- Number of points, we havn't done yet.
;
;
;  ecx -- V contribution to RGB; sum of U and V contributions.
;  eax -- Alternately a U and a V pel.
;------------------------------------------------------------------------------
    sub     edi,12
    movq    mm7,sixty_four
    Leax    AspectAdjustmentCount
    Seax    AspectCount
    cmp     eax,1
    jbe     finish
PrepareChromaLine:
    Lebx  FrameWidth
    Leax    AspectCount
    Ledx    CCOPitch
    xor     ecx,ecx
    sub     eax,2
    Sedx    tmpCCOPitch
    ja     continue
    Leax    AspectAdjustmentCount
    Secx    tmpCCOPitch     ; 0
    jnz      skip_even_line
skip_odd_line:
    Ledx    tmpYCursorEven
    Seax    AspectCount
    Sedx    tmpYCursorOdd
    jmp     do_next_4x2_block
skip_even_line:
    dec     eax

continue:
    Seax    AspectCount
    Ledx    tmpYCursorEven

    xor     eax,eax
    mov     cl,[edx+2*ebx]     ; Ye0
    mov     al,[edx+2*ebx+1]   ; Ye1
    movdt   mm1,PD Y0[eax*4]   ;   0:   0:   0:   0|   0:Ye1:  Ye1: Ye1
do_next_4x2_block:
    movdt   mm3,PD Y0[ecx*4]   ;   0:   0:   0:   0|   0:Ye0:  Ye0: Ye0
    psllq   mm1,24             ;   0:   0: Ye1: Ye1| Ye1:   0:   0:  0
    xor     ecx,ecx
    mov     al,[edx+2*ebx+2]   ; Ye2

    mov     cl,[edx+2*ebx+3]   ; Ye3
    xor     edx,edx
    mov     dl,[esi+ebx+1]     ; v1
    add     edi,12             ; output
    movdt   mm4,PD Y0[eax*4]   ;   0:   0:   0:   0|   0:   0:Ye2 : Ye2
    por     mm3,mm1            ;   0:   0: Ye1: Ye1| Ye1:Ye0:  Ye0: Ye0

    movdt   mm5,PD Y0[ecx*4]   ;                  0|   0: Ye3: Ye3: Ye3
    psllq   mm4,48             ;Ye2 : Ye2:   0:   0|   0:   0:   0:   0
    mov     cl,[ebp+ebx]       ; u0
    mov     al,[esi+ebx]       ; v0
    movq    mm2,PD v0[edx*8]   ;   0:   0: Rv3: Gv3| Bv3: Rv2: Gv2: Bv2   u,v impact on RGB[0]
and RGB[1] is equal
    por     mm3,mm4            ;Ye2 : Ye2: Ye1: Ye1| Ye1: Ye0: Ye0: Ye0
    movq    mm0,PD u0[ecx*8]   ;   0:   0: Ru1: Gu1| Bu1: Ru0: Gu0: Bu0   u,v impact on RGB[0]
and RGB[1] is equal
    psllq   mm5,8              ;                  0| Ye3: Ye3: Ye3:   0
    mov     cl,[ebp+ebx+1]     ; u1
    Ledx    tmpYCursorOdd
    paddb   mm0,PD v0[eax*8]   ;   0:   0:Ruv1:Guv1|Buv1:Ruv0:Guv0:Buv0
    psrlq   mm4,56             ;   0:   0:   0:   0|   0:   0:   0: Ye2

    paddb   mm2,PD u0[ecx*8]   ;   0:   0:Ruv3:Guv3|Buv3:Ruv2:Guv2:Buv2
    por     mm4,mm5            ;                  0| Ye3: Ye3: Ye3: Ye2
    movq    mm1,mm2
    psllq   mm2,48             ;Guv2:Buv2:   0:   0|   0:   0:   0:  0

    psrlq   mm1,16             ;   0:   0:   0:   0|Ruv3:Guv3:Buv3:Ruv2
    por     mm0,mm2            ;Guv2:Buv2:Ruv1:Guv1|Buv1:Ruv0:Guv0:Buv0
    paddb   mm3,mm0            ; r0:g0:b0:r1|g1:b1:r2:g2
    mov     cl,[edx+2*ebx+1]   ; Yo1
    mov     al,[edx+2*ebx]     ; Yo0
    psubusb mm3,mm7            ; mm7=sixty_four
    movdt   mm6,PD Y0[ecx*4]   ;   0:   0: Ye1: Ye1| Ye1:Ye0:  Ye0: Ye0
    paddb   mm4,mm1            ;  x:    x:   0:   0|  b2:  r3:  g3:  b3
    movdt   mm5,PD Y0[eax*4]   ;   0:   0:   0:   0|   0:Ye0:  Ye0: Ye0
    psubusb mm4,mm7            ; mm7=sixty_four
    psllq   mm6,24             ;   0:   0:   0:   0|   0:Ye0:  Ye0: Ye0
    mov     al,[edx+2*ebx+2]   ; Yo2
    paddusb mm3,mm3
    por     mm5,mm6
    movdt   mm6,PD Y0[eax*4]   ;  0:    0:   0:   0|   0:   0: Ye2: Ye2
    paddusb mm3,mm3
    paddusb mm4,mm4
    psllq   mm6,48             ;Ye2:  Ye2:   0:   0|   0:   0:   0:   0
    movdf   [edi],mm3
    paddusb mm4,mm4
    mov     cl,[edx+2*ebx+3]   ; Yo3
    psrlq   mm3,32
    movdf   [edi+8],mm4
    por     mm5,mm6            ;Ye2:  Ye2: Ye1: Ye1| Ye1: Ye0: Ye0: Ye0
    movdt   mm2,PD Y0[ecx*4]   ;                  0| Ye3: Ye3: Ye3: Ye2
    paddb   mm5,mm0            ; r0:g0:b0:r1|g1:b1:r2:g2
    psllq   mm2,8
    Ledx    tmpYCursorEven
    psubusb mm5,mm7            ; mm7=sixty_four
    psrlq   mm6,56             ;  0:    0:   0:   0|   0:   0:   0: Ye2
    por     mm6,mm2            ;                  0| Ye3: Ye3: Ye3: Ye2
    paddusb mm5,mm5
    Leax    tmpCCOPitch
    paddusb mm5,mm5
    paddb   mm6,mm1            ;  x:    x:   0:   0|  b2:  r3:  g3:  b3
    mov     cl,[edx+2*ebx+1+4]   ; Ye1
    movdf   [edi+eax],mm5
    psrlq   mm5,32
    movdf   [edi+4],mm3
    psubusb mm6,mm7            ; mm7=sixty_four
    movdf   [edi+eax+4],mm5
    paddusb mm6,mm6
    movdt   mm1,PD Y0[ecx*4]   ;   0:   0:   0:   0|   0:Ye1:  Ye1: Ye1
    paddusb mm6,mm6
    mov     cl,[edx+2*ebx+4]     ; Ye0
    add     ebx,2
    movdf   [edi+eax+8],mm6
    mov     eax,zero
    jl      do_next_4x2_block
    Leax    YPitch
    ADDedi  CCOSkipDistance ; go to begin of next line
    ADDedi  tmpCCOPitch ; skip odd line
    Ledx    tmpYCursorEven
    lea     edx,[edx+2*eax]
    Sedx    tmpYCursorEven
    ADDedx  YPitch
    Sedx    tmpYCursorOdd
    ADDesi  ChromaPitch
    ADDebp  ChromaPitch
    sub PD FrameHeight[esp],2   ; Done with last line?
    ja      PrepareChromaLine
;------------------------------------------------------------------------------
finish:
  add   esp,LocalFrameSize
    emms
  pop   ebx
  pop   ebp
  pop   edi
  pop   esi
  rturn
END
```

16. Appendix 5. Color Conversion to *RGB24 Zoom by 2*.

```
;-------------------------------------------------------------------------
OPTION PROLOGUE:None
OPTION EPILOGUE:ReturnAndRelieveEpilogueMacro
include iammx.inc
include locals.inc
.586
.xlist
.list
 ASSUME ds:FLAT, cs:FLAT, ss:FLAT
MMXCODE1 SEGMENT PARA USE32 PUBLIC 'CODE'
MMXCODE1 ENDS
MMXDATA1 SEGMENT PARA USE32 PUBLIC 'DATA'
MMXDATA1 ENDS
MMXDATA1 SEGMENT
; any data would go here
    ALIGN 8
;constants for direct RGB calculation: 4x10.6 values
Minusg              dd  00800080h,00800080h
VtR                 dd  00660066h,00660066h ;01990199h,01990199h
UtB                 dd  00810081h,00810081h ;02050205h,02050205h
Ymul                dd  004a004ah,004a004ah ;012a012ah,012a012ah
Yadd                dd  10101010h,10101010h
UVtG                dd  00340019h,00340019h ;00d00064h,00d00064h
MASK_036                 dd  0ff0000ffh,00ff0000h
MASK_147                 dd  0000ff00h,0ff0000ffh
tmpYCursorEven      dd  0
tmpYCursorOdd       dd  0
tmpBuffer           db  48 dup (?)  ; aligned on 8 byte boundary scratch buffer
MMXDATA1 ENDS
LocalFrameSize = 20
RegisterStorageSize = 16
; Arguments:
YPlane                = LocalFrameSize + RegisterStorageSize +  4
UPlane                = LocalFrameSize + RegisterStorageSize +  8
VPlane                = LocalFrameSize + RegisterStorageSize + 12
FrameWidth            = LocalFrameSize + RegisterStorageSize + 16
FrameHeight           = LocalFrameSize + RegisterStorageSize + 20
YPitch                = LocalFrameSize + RegisterStorageSize + 24
ChromaPitch           = LocalFrameSize + RegisterStorageSize + 28
AspectAdjustmentCount = LocalFrameSize + RegisterStorageSize + 32
ColorConvertedFrame   = LocalFrameSize + RegisterStorageSize + 36
DCIOffset             = LocalFrameSize + RegisterStorageSize + 40
CCOffsetToLine0       = LocalFrameSize + RegisterStorageSize + 44
CCOPitch              = LocalFrameSize + RegisterStorageSize + 48
CCType                = LocalFrameSize + RegisterStorageSize + 52
EndOfArgList          = LocalFrameSize + RegisterStorageSize + 56
; Locals (on local stack frame)
CCOCursor                =   0
CCOSkipDistance          =   4
ChromaLineLen            =   8
R3G3B3R2                 =  12
G2B2R1G1                 =  16
AspectCount              =  20
LCL EQU <esp+>
MMXCODE1 SEGMENT
; extern void "C" MMX_YUV12ToRGB24ZoomBy2 (U8 * YPlane,
;                                            U8 * UPlane,
;                                            U8 * VPlane,
;                                            UN  FrameWidth,
;                                            UN  FrameHeight,
;                                            UN  YPitch,
;                                            UN  VPitch,
;                                            UN  AspectAdjustmentCount,
;                                            U8 FAR * ColorConvertedFrame,
;                                            U32 DCIOffset,
;                                            U32 CCOffsetToLine0,
;                                            IN  CCOPitch,
;                                            IN  CCType)
;
;  CCOffsetToLine0 is relative to ColorConvertedFrame.
;
;extrn finish_next_iteration:proc
;extrn start_next_iteration:proc
PUBLIC C MMX_YUV12ToRGB24ZoomBy2
; due to the need for the ebp reg, these parameter declarations aren't used,
; they are here so the assembler knows how many bytes to relieve from the stack
MMX_YUV12ToRGB24ZoomBy2:
  push  esi
  push  edi
  push  ebp
  push  ebx
  sub   esp,LocalFrameSize
  mov   eax,PD [esp+ColorConvertedFrame]
  add   eax,PD [esp+DCIOffset]
  add   eax,PD [esp+CCOffsetToLine0]
  mov   PD [esp+CCOCursor],eax
  Ledx   FrameHeight
  add    edx,edx
  Sedx   FrameHeight
   Lecx YPitch
  Lebx  FrameWidth
   Leax CCOPitch
  lea   esi,[ebx+2*ebx] ; 3*FrameWidth
   Ledx  AspectAdjustmentCount
  sar   ebx,1           ; FrameWidth/2
   sub   eax,esi         ; CCOPitch-3*FrameWidth
  Sebx ChromaLineLen   ; FrameWidth/2
   sub   eax,esi         ; CCOPitch-6*FrameWidth
  Seax CCOSkipDistance ; CCOPitch-3*FrameWidth
   Lesi VPlane
  test  edx,edx
   jnz  non_zero_AspectCount
  inc   edx
   Sedx  AspectAdjustmentCount
non_zero_AspectCount:
  Sedx  AspectCount
   xor  eax,eax
  Ledi  CCOCursor
  mov   edx,PD [esp+UPlane]
  sub   edx,esi
  Lebp  YPlane                       ; Fetch Y Pitch.
    Lebx    FrameWidth
    add     ebp,ebx
    mov     tmpYCursorEven,ebp
    Leax    YPitch
    add     ebp,eax
    mov     tmpYCursorOdd,ebp
    sar     ebx,1
    add     esi,ebx
    add     edx,esi  ; edx is distance from V plane to U plane
    neg     ebx
    Sebx    FrameWidth
;  Register Usage:
```

```
;
;  ebp -- Y Line cursor.  Chroma contribs go in lines above current Y line.
;  esi -- V
;  edx -- U
;  edi -- Cursor over the color converted output image.
;  ebx -- Number of points, we havn't done yet.
;
;
;  ecx -- 3*CCOPitch
;  eax -- CCOPitch.
;------------------------------------------------------------------------------
PrepareChromaLine:
    Lebp    AspectCount
     Leax   CCOPitch
    sub     ebp,4
     Lebx   FrameWidth
    lea     ecx,[eax+2*eax] ; pointer to fourth output line
     ja     continue
    lea     ecx,[2*eax]
    ADDebp  AspectAdjustmentCount
continue:
     Sebp  AspectCount
align 16
do_next_8x2_block:
;;;;;;; trsansformation U, V
        movdt    mm1, [edx+ebx]      ; 4 u values
        pxor     mm0,mm0              ; mm0=0
        movdt    mm2, [esi+ebx]       ; 4 v values
        punpcklbw   mm1,mm0        ; get 4 unsign u
        psubw       mm1,Minusg     ; get 4 unsign u-128
        punpcklbw   mm2,mm0        ; get unsign v
        psubw       mm2,Minusg       ; get unsign v-128
        movq        mm3,mm1          ; save the u unsign
        mov  ebp,tmpYCursorEven
        punpcklwd   mm1,mm2         ; get 2 low u,v unsign pairs
        pmaddwd     mm1,UVtG
        movq        mm5,mm3  ; save u-128
        movq     mm6,[ebp+2*ebx]      ; mm6 has 8 y pixels
        punpckhwd   mm3,mm2         ; create high 2 unsign uv pairs
        pmaddwd     mm3,UVtG
        psubusb  mm6,Yadd             ; mm6 has 8 y-16 pixels
                 packssdw  mm1,mm3        ; packed the results to signed words
        movq     mm7,mm6              ; save the 8 y-16 pixels
        punpcklbw mm6,mm0              ; mm6 has 4 low y-16 unsign
        pmullw    mm6,Ymul
        punpckhbw mm7,mm0              ; mm7 has 4 high y-16 unsign
        pmullw    mm7,Ymul
        movq      mm4,mm1
        movq     PD [tmpBuffer],mm1 ; save 4 chroma G values
        punpcklwd mm1,mm1            ; chroma G replicate low 2
        movq      mm0,mm6              ; low  y
        movq      mm3,mm7              ; high y
        punpckhwd mm4,mm4            ; chroma G replicate high 2
        psubw    mm6,mm1              ;  4 low G
        movq      mm1, mm5     ; 4 u values
        psraw    mm6,6              ; low G

        psubw    mm7,mm4              ; 4 high G values in signed 16 bit
        punpcklwd mm1,mm1                ; replicate the 2 low u pixels
        pmullw    mm1,UtB
        punpckhwd mm5,mm5
        pmullw    mm5,UtB
        psraw    mm7,6              ; high G
        movq      PD [tmpBuffer+8],mm1   ; low chroma B
        packuswb mm6,mm7            ; mm6: G7 G6 G5 G4 G3 G2 G1 G0
        movq      PD [tmpBuffer+16],mm5   ; high chroma B
        paddw     mm5,mm3              ; 4 high B values in signed 16 bit
        paddw     mm1,mm0              ; 4 low B values in signed 16 bit
        psraw    mm5,6              ; high B
        movq    mm7, mm2
        punpcklwd  mm2,mm2            ; replicate the 2 low v pixels
        psraw    mm1,6              ; low B
        pmullw    mm2,VtR
        punpckhwd  mm7,mm7
        pmullw    mm7,VtR
        packuswb mm1,mm5            ; mm1: B7 B6 B5 B4 B3 B2 B1 B0
        movq      PD [tmpBuffer+24],mm2  ; low chroma R
        paddw     mm2,mm0            ; 4 low R values in signed 16 bit
        psraw    mm2,6              ; low R
        movq      PD [tmpBuffer+32],mm7  ; high chroma R
        paddw     mm7,mm3            ; 4 high R values in signed 16 bit
        psraw    mm7,6              ; high R
                 movq             PD [tmpBuffer+40],mm1 ; save B in memory
        packuswb mm2,mm7           ; mm2: R7 R6 R5 R4 R3 R2 R1 R0
                 movq             mm3,mm6                  ; save G in mm3
                 punpcklbw        mm1,mm1                  ; mm1: B3 B3 B2 B2 B1 B1 B0 B0
                 movq             mm0,mm1
                 punpcklwd        mm1,mm1                  ; mm1: B1 B1 B1 B1 B0 B0 B0 B0
                 pand             mm1,MASK_036     ; mm1:  0 B1  0  0 B0  0  0 B0
                 punpcklbw        mm6,mm6                  ; mm6: G3 G3 G2 G2 G1 G1 G0 G0
                 movq             mm5,mm6
                 punpcklwd        mm6,mm6                  ; mm6: G1 G1 G1 G1 G0 G0 G0 G0
                 movq             mm4,mm2                  ; save R in mm4
                 punpcklbw        mm2,mm2                  ; mm2: R3 R3 R2 R2 R1 R1 R0 R0
                 pand             mm6,MASK_036     ; mm6:  0 G1  0  0 G0  0  0 G0
                 movq             mm7,mm2
                 punpcklwd        mm2,mm2                  ; mm2: R1 R1 R1 R1 R0 R0 R0 R0
                 pand             mm2,MASK_036     ; mm2:  0 R1  0  0 R0  0  0 R0
                 psllq            mm6,8                    ; mm6: G1  0  0 G0  0  0 G0  0
                 psllq            mm2,16                   ; mm2:  0  0 R0  0  0 R0  0  0
                 por              mm1,mm6
                 por              mm2,mm1          ; mm2: G1 B1 R0 G0 B0 R0 G0 B0
                 movq             mm1,mm0                  ; mm1: B3 B3 B2 B2 B1 B1 B0 B0
            movq         PD [edi],mm2                      ; store result
                 psrlq            mm1,24                   ; mm1:  0  0  0 B3 B3 B2 B2 B1
                 movq             PD [edi+eax],mm2         ; store result
                 punpcklwd        mm1,mm1                  ; mm1: B3 B2 B3 B2 B2 B1 B2 B1
;; 2nd phase
                 pand             mm1,MASK_036     ; mm1:  0 B2  0  0 B2  0  0 B1
                 movq             mm6,mm5                  ; mm6: G3 G3 G2 G2 G1 G1 G0 G0
                 psllq            mm1,8                    ; mm1: B2  0  0 B2  0  0 B1  0
                 psrlq            mm6,16                   ; mm6:  0  0 G3 G3 G2 G2 G1 G1
                 movq             mm2,mm7
                 pand             mm6,MASK_036     ; mm6:  0 G2  0  0 G2  0  0 G1
                 psrlq            mm2,16                   ; mm2:  0  0 R3 R3 R2 R2 R1 R1
                 psllq            mm6,16                   ; mm6:  0  0 G2  0  0 G1  0  0
                 punpcklwd        mm2,mm2                  ; mm2: R2 R2 R2 R2 R1 R1 R1 R1
                 por              mm1,mm6
                 pand             mm2,MASK_036     ; mm2:  0 R2  0  0 R1  0  0 R1
                 movq             mm6,mm5                  ; mm6: G3 G3 G2 G2 G1 G1 G0 G0

                 por              mm2,mm1          ; mm2: B2 R2 G2 B2 R1 G1 B1 R1
                 movq             mm1,mm0                  ; mm1: B3 B3 B2 B2 B1 B1 B0 B0
            movq         PD [edi+8],mm2                    ; store result
                 psrlq            mm1,48                   ; mm1:  0  0  0  0  0  0 B3 B3

                 movq             PD [edi+eax+8],mm2                ; store result
                 punpcklwd        mm1,mm1                  ; mm1:  0  0  0  0 B3 B3 B3 B3
```

```
;; 3nd phase
                 pand             mm1,MASK_036     ; mm1:  0  0  0  0 B3  0  0 B3
                 psrlq            mm6,40                   ; mm6:  0  0  0  0  0 G3 G3 G2
                 punpcklwd        mm6,mm6                  ; mm6:  0 G3  0 G3 G3 G2 G3 G2
                 movq             mm2,mm7
                 pand             mm6,MASK_036     ; mm6:  0 G3  0  0 G3  0  0 G2
                 psllq            mm1,16                   ; mm1:  0  0 B3  0  0 B3  0  0
                 punpckhwd        mm2,mm2                  ; mm2: R3 R3 R3 R3 R2  0 R2  0
                 por                      mm1,mm6
                 pand             mm2,MASK_147     ; mm2: R3  0  0 R3  0  0 R2  0
                 movq             mm6,mm3                  ; restore mm6 with G
                 por                      mm2,mm1          ; mm2: R3 G3 B3 R3 G3 B3 R2 G2
                 movq             mm1,PD [tmpBuffer+40]    ; restore mm1 with B
            movq         PD [edi+16],mm2                   ; store result
                 punpckhbw        mm1,mm1                  ; mm1: B7 B7 B6 B6 B5 B5 B4 B4

                 movq             PD [edi+eax+16],mm2              ; store result
                 movq             mm2,mm4                  ; restore mm2 with R
; 4th phase
                 movq             mm0,mm1
                 punpckhbw        mm6,mm6                  ; mm6: G7 G7 G6 G6 G5 G5 G4 G4
                 punpcklwd        mm1,mm1                  ; mm1: B5 B5 B5 B5 B4 B4 B4 B4
                 movq             mm5,mm6
                 pand             mm1,MASK_036     ; mm1:  0 B5  0  0 B4  0  0 B4
                 punpcklwd        mm6,mm6                  ; mm6: G5 G5 G5 G5 G4 G4 G4 G4
                 pand             mm6,MASK_036     ; mm6:  0 G5  0  0 G4  0  0 G4
                 punpckhbw        mm2,mm2                  ; mm2: R7 R7 R6 R6 R5 R5 R4 R4
                 psllq            mm6,8                    ; mm6: G5  0  0 G4  0  0 G4  0
                 movq             mm7,mm2

                 punpcklwd        mm2,mm2                  ; mm2: R5 R5 R5 R5 R4 R4 R4 R4
                 pand             mm2,MASK_036     ; mm2:  0 R5  0  0 R4  0  0 R4
                 psllq            mm2,16                   ; mm2:  0  0 R4  0  0 R4  0  0
                 por                      mm1,mm6
                 por                      mm2,mm1          ; mm2: G5 B5 R4 G4 B4 R4 G4 B4
                 movq             mm1,mm0                  ; mm1: B7 B7 B6 B6 B5 B5 B4 B4
            movq         PD [edi+24],mm2                   ; store result
                 psrlq            mm1,24                   ; mm1:  0  0  0 B7 B7 B6 B6 B5
                 movq             PD [edi+eax+24],mm2              ; store result
                 punpcklwd        mm1,mm1                  ; mm1: B7 B6 B7 B6 B6 B5 B6 B5
;; 5th phase
                 pand             mm1,MASK_036     ; mm1:  0 B6  0  0 B6  0  0 B5
                 movq             mm6,mm5                  ; mm6: G7 G7 G6 G6 G5 G5 G4 G4
                 psllq            mm1,8                    ; mm1: B6  0  0 B6  0  0 B5  0
                 movq             mm2,mm7
                 psrlq            mm6,24                   ; mm6:  0  0  0 G7 G7 G6 G6 G5
                 psrlq            mm2,16                   ; mm2:  0  0 R7 R7 R6 R6 R5 R5
                 punpcklwd        mm6,mm6                  ; mm6: G7 G6 G7 G6 G6 G5 G6 G5
                 pand             mm6,MASK_036     ; mm6:  0 G6  0  0 G6  0  0 G5
                 punpcklwd        mm2,mm2                  ; mm2: R6 R6 R6 R6 R5 R5 R5 R5
                 pand             mm2,MASK_036     ; mm2:  0 R6  0  0 R5  0  0 R5
                 psllq            mm6,16                   ; mm6:  0  0 G6  0  0 G5  0  0
;>>>>
                 por                      mm2,mm6
                 por                      mm2,mm1          ; mm2: B6 R6 G6 B6 R5 G5 B5 R5
                 movq             mm1,mm0                  ; mm1: B7 B7 B6 B6 B5 B5 B4 B4
                 psrlq            mm1,48                   ; mm1:  0  0  0  0  0  0 B7 B7
                 movq             mm6,mm5                  ; mm6: G7 G7 G6 G6 G5 G5 G4 G4
            movq         PD [edi+32],mm2                   ; store result
                 punpcklwd        mm1,mm1                  ; mm1:  0  0  0  0 B7 B7 B7 B7
                 movq             PD [edi+eax+32],mm2              ; store result
                 psrlq            mm6,40                   ; mm6:  0  0  0  0  0 G7 G7 G6
;; 6th phase
                 pand             mm1,MASK_036     ; mm1:  0  0  0  0 B7  0  0 B7
                 punpcklwd        mm6,mm6                  ; mm6:  0 G7  0 G7 G7 G6 G7 G6
                 pand             mm6,MASK_036     ; mm6:  0 G7  0  0 G7  0  0 G6
                 psllq            mm1,16                   ; mm1:  0  0 B7  0  0 B7  0  0
                 movq             mm2,mm7
                 por                      mm1,mm6
        mov  ebp,tmpYCursorOdd
                 punpckhwd        mm2,mm2                  ; mm2:  0 R7  0 R7 R7 R6 R7 R6
                 pand             mm2,MASK_147     ; mm2:  0 R7  0  0 R7  0  0 R6
;                lea              ecx, [eax+2*eax]
                 por                      mm2,mm1          ; mm2: R7 G7 B7 R7 G7 B7 R6 G6
;- start odd line
        movq   mm1,[ebp+2*ebx]      ; mm1 has 8 y pixels
                 pxor   mm0, mm0
        psubusb mm1,Yadd            ; mm1 has 8 pixels y-16
        movq    mm5,mm1
        punpcklbw  mm1,mm0        ; get 4 low y-16 unsign pixels word
        pmullw  mm1,Ymul            ; low 4 luminance contribution
        punpckhbw  mm5,mm0        ; 4 high y-16
        pmullw  mm5,Ymul            ; high 4 luminance contribution
            movq         PD [edi+40],mm2                   ; store result
                 movq             PD [edi+eax+40],mm2              ; store result
        movq    mm2,mm1
        paddw   mm2,PD [tmpBuffer+24]  ; low 4 R
        movq    mm6,mm5
        paddw   mm5,PD [tmpBuffer+32]  ; high 4 R
        psraw   mm2,6
        psraw   mm5,6
        packuswb mm2,mm5            ; mm0: R7 R6 R5 R4 R3 R2 R1 R0
        movq    mm0,mm1
        paddw   mm0,PD [tmpBuffer+8]  ; low 4 B
        movq    mm5,mm6
        paddw   mm5,PD [tmpBuffer+16]  ; high 4 B
        psraw   mm0,6
        movq    mm3,PD [tmpBuffer]  ;  chroma G  low 4
        psraw   mm5,6
        packuswb mm0,mm5            ; mm2: B7 B6 B5 B4 B3 B2 B1 B0
        movq    mm4,mm3
        punpcklwd mm3,mm3            ; replicate low 2
        punpckhwd mm4,mm4            ; replicate high 2
        psubw    mm1,mm3             ;  4 low G
        psubw    mm6,mm4             ;  4 high G values in signed 16 bit
        psraw    mm1,6              ; low G
                 movq             PD [tmpBuffer+40],mm0 ; save B in memory
        psraw    mm6,6              ; high G
        packuswb mm1,mm6            ; mm1: G7 G6 G5 G4 G3 G2 G1 G0
                 movq             mm4,mm2                  ; save R in mm4
                 movq             mm6,mm1
                 movq             mm1,mm0
                 movq             mm3,mm6                  ; save G in mm3
                 punpcklbw        mm1,mm1                  ; mm1: B3 B3 B2 B2 B1 B1 B0 B0
                 movq             mm0,mm1
                 punpcklwd        mm1,mm1                  ; mm1: B1 B1 B1 B1 B0 B0 B0 B0
                 pand             mm1,MASK_036     ; mm1:  0 B1  0  0 B0  0  0 B0
                 punpcklbw        mm6,mm6                  ; mm6: G3 G3 G2 G2 G1 G1 G0 G0
                 movq             mm5,mm6
                 punpcklwd        mm6,mm6                  ; mm6: G1 G1 G1 G1 G0 G0 G0 G0
                 pand             mm6,MASK_036     ; mm6:  0 G1  0  0 G0  0  0 G0
                 punpcklbw        mm2,mm2                  ; mm2: R3 R3 R2 R2 R1 R1 R0 R0
                 psllq            mm6,8                    ; mm6: G1  0  0 G0  0  0 G0  0
                 movq             mm7,mm2
                 punpcklwd        mm2,mm2                  ; mm2: R1 R1 R1 R1 R0 R0 R0 R0
                 por                      mm1,mm6
                 pand             mm2,MASK_036     ; mm2:  0 R1  0  0 R0  0  0 R0
                 movq             mm6,mm5                  ; mm6: G3 G3 G2 G2 G1 G1 G0 G0
                 psllq            mm2,16                   ; mm2:  0  0 R0  0  0 R0  0  0

                 por                      mm2,mm1          ; mm2: G1 B1 R0 G0 B0 R0 G0 B0
                 psrlq            mm6,24                   ; mm6:  0  0  0 G3 G3 G2 G2 G1
            movq         PD [edi+ecx],mm2                  ; store result
                 movq             mm1,mm0                  ; mm1: B3 B3 B2 B2 B1 B1 B0 B0
                 movq             PD [edi+2*eax],mm2                ; store result
                 psrlq            mm1,24                   ; mm1:  0  0  0 B3 B3 B2 B2 B1
;; 2nd phase
                 punpcklwd        mm1,mm1                  ; mm1: B3 B2 B3 B2 B2 B1 B2 B1
                 movq             mm2,mm7
                 pand             mm1,MASK_036     ; mm1:  0 B2  0  0 B2  0  0 B1
                 punpcklwd        mm6,mm6                  ; mm6: G3 G2 G3 G2 G2 G1 G2 G1
                 pand             mm6,MASK_036     ; mm6:  0 G2  0  0 G2  0  0 G1
                 psllq            mm1,8                    ; mm1: B2  0  0 B2  0  0 B1  0
                 psllq            mm6,16                   ; mm6:  0  0 G2  0  0 G1  0  0
                 psrlq            mm2,16                   ; mm2:  0  0 R3 R3 R2 R2 R1 R1
                 por                      mm1,mm6
                 punpcklwd        mm2,mm2                  ; mm2: R2 R2 R2 R2 R1 R1 R1 R1
                 movq             mm6,mm5                  ; mm6: G3 G3 G2 G2 G1 G1 G0 G0
                 pand             mm2,MASK_036     ; mm2:  0 R2  0  0 R1  0  0 R1
                 psrlq            mm6,40                   ; mm6:  0  0  0  0  0 G3 G3 G2
                 por                      mm2,mm1          ; mm2: B2 R2 G2 B2 R1 G1 B1 R1
                 movq             mm1,mm0                  ; mm1: B3 B3 B2 B2 B1 B1 B0 B0
            movq         PD [edi+ecx+8],mm2                         ; store result
                 punpckhwd        mm1,mm1                  ; mm1:  B3 B3 B3 B3 0  0  0  0
                 movq             PD [edi+2*eax+8],mm2              ; store result
                 punpcklwd        mm6,mm6                  ; mm6:  0 G3  0 G3 G3 G2 G3 G2
;; 3nd phase
                 pand             mm1,MASK_147     ; mm1:  0  0  0  0 B3  0  0 B3
                 movq             mm2,mm7
                 psrlq            mm1,16                   ; mm1:  0  0 B3  0  0 B3  0  0
                 pand             mm6,MASK_036     ; mm6:  0 G3  0  0 G3  0  0 G2
                 psrlq            mm2,40                   ; mm2:  0  0  0  0  0 R3 R3 R2
                 punpcklwd        mm2,mm2                  ; mm2:  0 R3  0 R3 R3 R2 R3 R2
                 por                      mm1,mm6
                 pand             mm2,MASK_036     ; mm2:  0 R3  0  0 R3  0  0 R2
                 movq             mm6,mm3                  ; restore mm6 with G
                 psllq            mm2,8                    ; mm2: R3  0  0 R3  0  0 R2  0

                 por                      mm2,mm1          ; mm2: R3 G3 B3 R3 G3 B3 R2 G2
                 movq             mm1,PD [tmpBuffer+40]    ; restore mm1 with B
            movq         PD [edi+ecx+16],mm2                        ; store result
                 psrlq            mm1,32          ;  0  0  0  0 B7 B6 B5 B4
                 movq             PD [edi+2*eax+16],mm2             ; store result
                 psrlq            mm6,32          ;  0  0  0  0 G7 G6 G5 G4
                 movq             mm2,mm4                  ; restore mm2 with R
                 punpcklbw        mm1,mm1                  ; mm1: B7 B7 B6 B6 B5 B5 B4 B4
; 4th phase
                 psrlq            mm2,32          ;  0  0  0  0 R7 R6 R5 R4
                 movq             mm0,mm1
                 punpcklwd        mm1,mm1                  ; mm1: B5 B5 B5 B5 B4 B4 B4 B4
                 pand             mm1,MASK_036     ; mm1:  0 B5  0  0 B4  0  0 B4
                 punpcklbw        mm6,mm6                  ; mm6: G7 G7 G6 G6 G5 G5 G4 G4
                 punpcklbw        mm2,mm2                  ; mm2: R7 R7 R6 R6 R5 R5 R4 R4
                 movq             mm5,mm6
                 punpcklwd        mm6,mm6                  ; mm6: G5 G5 G5 G5 G4 G4 G4 G4
                 movq             mm7,mm2
                 pand             mm6,MASK_036     ; mm6:  0 G5  0  0 G4  0  0 G4
                 punpcklwd        mm2,mm2                  ; mm2: R5 R5 R5 R5 R4 R4 R4 R4
                 pand             mm2,MASK_036     ; mm2:  0 R5  0  0 R4  0  0 R4
                 psllq            mm6,8                    ; mm6: G5  0  0 G4  0  0 G4  0
                 psllq            mm2,16                   ; mm2:  0  0 R4  0  0 R4  0  0
                 por                      mm1,mm6
                 por              mm2,mm1                  ; mm2: G5 B5 R4 G4 B4 R4 G4 B4
                 movq             mm1,mm0                  ; mm1: B7 B7 B6 B6 B5 B5 B4 B4
                 psrlq            mm1,24                   ; mm1:  0  0  0 B7 B7 B6 B6 B5
                 movq             mm6,mm5                  ; mm6: G7 G7 G6 G6 G5 G5 G4 G4
            movq         PD [edi+ecx+24],mm2                        ; store result
                 punpcklwd        mm1,mm1                  ; mm1: B7 B6 B7 B6 B6 B5 B6 B5

                 movq             PD [edi+2*eax+24],mm2             ; store result
                 psrlq            mm6,24                   ; mm6:  0  0  0 G7 G7 G6 G6 G5
;; 5th phase
                 pand             mm1,MASK_036     ; mm1:  0 B6  0  0 B6  0  0 B5
                 punpcklwd        mm6,mm6                  ; mm6: G7 G6 G7 G6 G6 G5 G6 G5
                 pand             mm6,MASK_036     ; mm6:  0 G6  0  0 G6  0  0 G5
                 psllq            mm1,8                    ; mm1: B6  0  0 B6  0  0 B5  0
                 psllq            mm6,16                   ; mm6:  0  0 G6  0  0 G5  0  0
                 movq             mm2,mm7
                 psrlq            mm2,16                   ; mm2:  0  0 R7 R7 R6 R6 R5 R5
                 por                      mm1,mm6
                 punpcklwd        mm2,mm2                  ; mm2: R6 R6 R6 R6 R5 R5 R5 R5
                 movq             mm6,mm5                  ; mm6: G7 G7 G6 G6 G5 G5 G4 G4
                 pand             mm2,MASK_036     ; mm2:  0 R6  0  0 R5  0  0 R5
                 psrlq            mm6,40                   ; mm6:  0  0  0  0  0 G7 G7 G6
                 por              mm2,mm1                  ; mm2: B6 R6 G6 B6 R5 G5 B5 R5
                 punpcklwd        mm6,mm6                  ; mm6:  0 G7  0 G7 G7 G6 G7 G6
                 pand             mm6,MASK_036     ; mm6:  0 G7  0  0 G7  0  0 G6
                 movq             mm1,mm0                  ; mm1: B7 B7 B6 B6 B5 B5 B4 B4
            movq         PD [edi+ecx+32],mm2                        ; store result
                 punpckhwd        mm1,mm1                  ; mm1: B7 B7 B7 B7  0  0  0  0
                 movq             PD [edi+2*eax+32],mm2             ; store result
                 movq             mm2,mm7
;; 6th phase
                 pand             mm1,MASK_147     ; mm1: B7  0  0 B7        0  0  0  0
                 psrlq            mm2,40                   ; mm2:  0  0  0  0  0 R7 R7 R6
                 punpcklwd        mm2,mm2                  ; mm2:  0 R7  0 R7 R7 R6 R7 R6
                 pand             mm2,MASK_036     ; mm2:  0 R7  0  0 R7  0  0 R6
                 psrlq            mm1,16                   ; mm1:  0  0 B7  0  0 B7  0  0
                 psllq            mm2,8                    ; mm2: R7  0  0 R7  0  0 R6  0
                 por              mm1,mm6
                 por              mm2,mm1                  ; mm2: R7 G7 B7 R7 G7 B7 R6 G6
            movq         PD [edi+ecx+40],mm2                        ; store result
                 movq             PD [edi+2*eax+40],mm2             ; store result
    add     edi,48  ; ih take 48 instead of 12 output
    add     ebx,4   ; ? to take 4 pixels together instead of 2
    jl      do_next_8x2_block  ; ? update the loop for 8 y pixels at once
    ADDedi  CCOSkipDistance
    add     edi,ecx             ; set output pointer after fourth line
    Leax    YPitch
    mov     ebp,tmpYCursorOdd
    lea     ebp,[ebp+2*eax]     ; skip two lines
    mov     tmpYCursorOdd,ebp
    mov     ebp,tmpYCursorEven
    lea     ebp,[ebp+2*eax]
    mov     tmpYCursorEven,ebp
    ADDesi  ChromaPitch
    ADDedx  ChromaPitch
    sub     PD FrameHeight[esp],4
    ja      PrepareChromaLine
;------------------------------------------------------------------------------
finish:
  add   esp,LocalFrameSize
  emms
  pop   ebx
  pop   ebp
  pop   edi
  pop   esi
  ret
MMXCODE1 ENDS
END
```

17. Appendix 6. Color Conversion to RGB16.

```
;-------------------------------------------------------------------------
; cxm12161 -- This function performs YUV12-to-RGB16 color conversion for H26x.
;             It handles any format in which there are three fields, the low
;             order field being B and fully contained in the low order byte, the
;             second field being G and being somewhere in bits 4 through 11,
;             and the high order field being R and fully contained in the high
;             order byte.
;
;             The YUV12 input is planar, 8 bits per pel.  The Y plane may have
;             a pitch of up to 768.  It may have a width less than or equal
;             to the pitch.  It must be DWORD aligned, and preferably QWORD
;             aligned.  Pitch and Width must be a multiple of four.  For best
;             performance, Pitch should not be 4 more than a multiple of 32.
;             Height may be any amount, but must be a multiple of two.  The U
;             and V planes may have a different pitch than the Y plane, subject
;             to the same limitations.
;
include iammx.inc
include locals.inc
.586
.xlist
.list
 ASSUME ds:FLAT, cs:FLAT, ss:FLAT
MMXCODE1 SEGMENT PARA USE32 PUBLIC 'CODE'
MMXCODE1 ENDS
MMXDATA1 SEGMENT PARA USE32 PUBLIC 'DATA'
MMXDATA1 ENDS
MMXDATA1 SEGMENT
ALIGN 8
RGB_formats:
    dd  RGB565
    dd  RGB555
    dd  RGB664
    dd  RGB655
Minusg              dd   00800080h, 00800080h
Yadd                dd   10101010h, 10101010h
VtR                 dd   00660066h, 00660066h ;01990199h,01990199h
VtG                 dd   00340034h, 00340034h ;00d000d0h,00d000d0h
UtG                 dd   00190019h, 00190019h ;00640064h,00640064h
UtB                 dd   00810081h, 00810081h ;02050205h,02050205h
Ymul                dd   004a004ah, 004a004ah ;012a012ah,012a012ah
UVtG                dd   00340019h, 00340019h ;00d00064h,00d00064h
VtRUtB              dd   01990205h, 01990205h
fourbitu            dd  0f0f0f0f0h, 0f0f0f0f0h
fivebitu            dd  0e0e0e0e0h, 0e0e0e0e0h
sixbitu             dd  0c0c0c0c0h, 0c0c0c0c0h
MMXDATA1 ENDS
LocalFrameSize = 156
RegisterStorageSize = 16
; Arguments:
YPlane                   = LocalFrameSize + RegisterStorageSize +  4
UPlane                   = LocalFrameSize + RegisterStorageSize +  8
VPlane                   = LocalFrameSize + RegisterStorageSize + 12
FrameWidth               = LocalFrameSize + RegisterStorageSize + 16
FrameHeight              = LocalFrameSize + RegisterStorageSize + 20
YPitch                   = LocalFrameSize + RegisterStorageSize + 24
ChromaPitch              = LocalFrameSize + RegisterStorageSize + 28
AspectAdjustmentCount    = LocalFrameSize + RegisterStorageSize + 32
ColorConvertedFrame      = LocalFrameSize + RegisterStorageSize + 36
```

```
DCIOffset                = LocalFrameSize + RegisterStorageSize + 40
CCOffsetToLine0          = LocalFrameSize + RegisterStorageSize + 44
CCOPitch                 = LocalFrameSize + RegisterStorageSize + 48
CCType                   = LocalFrameSize + RegisterStorageSize + 52
EndOfArgList             = LocalFrameSize + RegisterStorageSize + 56
; Locals (on local stack frame)
CCOCursor                =   0
CCOSkipDistance          =   4
ChromaLineLen            =   8
YCursor                  =  12
DistanceFromVToU         =  16
EndOfChromaLine          =  20
AspectCount              =  24
AspectBaseCount          =  28
tmpYCursorEven           =  32
tmpYCursorOdd            =  36
tmpCCOPitch              =  40
temp_mmx                 =  44  ; note it is 48 bytes
RLeftShift               =  92
GLeftShift               = 100
RRightShift              = 108
GRightShift              = 116
BRightShift              = 124
RUpperLimit              = 132
GUpperLimit              = 140
BUpperLimit              = 148
MMXCODE1 SEGMENT
; extern void "C" MMX_YUV12ToRGB16 (
;                                     U8* YPlane,
;                                     U8* UPlane,
;                                     U8* VPlane,
;                                     UN  FrameWidth,
;                                     UN  FrameHeight,
;                                     UN  YPitch,
;                                     UN  VPitch,
;                                     UN  AspectAdjustmentCount,
;                                     U8* ColorConvertedFrame,
;                                     U32 DCIOffset,
;                                     U32 CCOffsetToLine0,
;                                     IN  CCOPitch,
;                                     IN  CCType)
;
;  The local variables are on the stack,
;  The tables are in the one and only data segment.
;
;  CCOffsetToLine0 is relative to ColorConvertedFrame.
;  CCType  used by RGB color convertors to determine the exact conversion type.
;    RGB565 = 0
;    RGB555 = 1
;    RGB664 = 2
;    RGB655 = 3
PUBLIC C MMX_YUV12ToRGB16
MMX_YUV12ToRGB16:
  push       esi
  push       edi
  push       ebp
  push       ebx
  sub        esp, LocalFrameSize
  mov        eax, [esp+CCType]
  cmp        eax,4
  jae        finish
  jmp        RGB_formats[eax*4]
RGB555:
  xor        eax, eax
  mov        ebx, 2   ; 10-8 for byte shift
  mov        [esp+RLeftShift], ebx
  mov        [esp+RLeftShift+4], eax
  mov        ebx, 5
  mov        [esp+GLeftShift], ebx
  mov        [esp+GLeftShift+4], eax
  mov        ebx, 9
  mov        [esp+RRightShift], ebx
  mov        [esp+RRightShift+4], eax
  mov        [esp+GRightShift], ebx
  mov        [esp+GRightShift+4], eax
  mov        [esp+BRightShift], ebx
  mov        [esp+BRightShift+4], eax
  movq       mm0, fivebitu
  movq       [esp+RUpperLimit], mm0
  movq       [esp+GUpperLimit], mm0
  movq       [esp+BUpperLimit], mm0
  jmp        RGBEND
RGB664:
  xor        eax, eax
  mov        ebx, 2   ; 8-6
  mov        [esp+RLeftShift], ebx
  mov        [esp+RLeftShift+4], eax
  mov        ebx, 4
  mov        [esp+GLeftShift], ebx
  mov        [esp+GLeftShift+4], eax
  mov        ebx, 8
  mov        [esp+RRightShift], ebx
  mov        [esp+RRightShift+4], eax
  mov        [esp+GRightShift], ebx
  mov        [esp+GRightShift+4], eax
  mov        ebx, 10
  mov        [esp+BRightShift], ebx
  mov        [esp+BRightShift+4], eax
  movq       mm0, sixbitu
  movq       [esp+RUpperLimit], mm0
  movq       [esp+GUpperLimit], mm0
  movq       mm0, fourbitu
  movq       [esp+BUpperLimit], mm0
  jmp        RGBEND
RGB655:
  xor        eax, eax
  mov        ebx, 2   ; 8-6
  mov        [esp+RLeftShift], ebx
  mov        [esp+RLeftShift+4], eax
  mov        ebx, 5
  mov        [esp+GLeftShift], ebx
  mov        [esp+GLeftShift+4], eax
  mov        ebx, 8
  mov        [esp+RRightShift], ebx
  mov        [esp+RRightShift+4], eax
  mov        ebx, 9
  mov        [esp+GRightShift], ebx
  mov        [esp+GRightShift+4], eax
  mov        [esp+BRightShift], ebx
  mov        [esp+BRightShift+4], eax
  movq       mm0, sixbitu
  movq       [esp+RUpperLimit], mm0
  movq       mm0, fivebitu
  movq       [esp+GUpperLimit], mm0
  movq       [esp+BUpperLimit], mm0
  jmp        RGBEND
RGB565:
  xor        eax, eax
  mov        ebx, 3   ; 8-5
  mov        [esp+RLeftShift], ebx
  mov        [esp+RLeftShift+4], eax
  mov        ebx, 5
  mov        [esp+GLeftShift], ebx
  mov        [esp+GLeftShift+4], eax
  mov        ebx, 9
  mov        [esp+RRightShift], ebx
  mov        [esp+RRightShift+4], eax
  mov        [esp+BRightShift], ebx
  mov        [esp+BRightShift+4], eax
  mov        ebx, 8
  mov        [esp+GRightShift], ebx
  mov        [esp+GRightShift+4], eax
  movq       mm0, fivebitu
  movq       [esp+RUpperLimit], mm0
  movq       [esp+BUpperLimit], mm0
  movq       mm0, sixbitu
  movq       [esp+GUpperLimit], mm0
;  jmp        RGBEND
RGBEND:
  mov        ebx, [esp+VPlane]
  mov        ecx, [esp+UPlane]
  sub        ecx, ebx
  mov        [esp+DistanceFromVToU], ecx
  mov        eax, [esp+ColorConvertedFrame]
  add        eax, [esp+DCIOffset]
  add        eax, [esp+CCOffsetToLine0]
  mov        [esp+CCOCursor], eax
  Lecx       YPitch
  Lebx       FrameWidth
  Leax       CCOPitch
  sub        eax, ebx         ; CCOPitch-FrameWidth
  sub        eax, ebx         ; CCOPitch-2*FrameWidth
  sar        ebx, 1           ; FrameWidth/2
  Lesi       YPlane           ; Fetch cursor over luma plane.
  Sebx       ChromaLineLen    ; FrameWidth/2
  Seax       CCOSkipDistance  ; CCOPitch-3*FrameWidth
  Sesi       YCursor
  Ledx       AspectAdjustmentCount
  Lesi       VPlane
  cmp   edx,1
  je    finish
  Sedx       AspectCount
  Sedx       AspectBaseCount
  xor        eax, eax
  Ledi       ChromaLineLen
  Sedi       EndOfChromaLine
  Ledi       CCOCursor
  Ledx       DistanceFromVToU
  Lebp       YCursor                       ; Fetch Y Pitch.
  Lebx       FrameWidth
  add        ebp, ebx
  Sebp       tmpYCursorEven
  Leax       YPitch
  add        ebp, eax
  Sebp       tmpYCursorOdd
  sar        ebx, 1
  add        esi, ebx
  add        edx, esi
  neg        ebx
  Sebx       FrameWidth
;  Register Usage:
;
```

```
;------------------------------------------------------------------------------
PrepareChromaLine:
  Lebp   AspectCount
   Lebx   FrameWidth
  sub    ebp,2
   Leax   CCOPitch
  Seax    tmpCCOPitch
   ja     continue
  xor    eax,eax
   ADDebp AspectAdjustmentCount
  Seax   tmpCCOPitch
continue:
  Sebp  AspectCount
do_next_8x2_block:
  Lebp       tmpYCursorEven
; here is even line
  movdt      mm1, [edx+ebx]         ; 4 u values
   pxor       mm0, mm0               ; mm0=0
  movdt      mm2, [esi+ebx]         ; 4 v values
   punpcklbw  mm1, mm0               ; get 4 unsign u
  psubw      mm1, Minusg            ; get 4 unsign u-128
   punpcklbw  mm2, mm0               ; get unsign v
  psubw      mm2, Minusg            ; get unsign v-128
   movq       mm3, mm1               ; save the u-128 unsign
  movq       mm5, mm1               ; save u-128 unsign
   punpcklwd  mm1, mm2               ; get 2 low u, v unsign pairs
  pmaddwd    mm1, UVtG
   punpckhwd  mm3, mm2               ; create high 2 unsign uv pairs
  pmaddwd    mm3, UVtG
  movq       temp_mmx[esp], mm2     ; save v-128
  movq       mm6, [ebp+2*ebx]       ; mm6 has 8 y pixels
  psubusb    mm6, Yadd              ; mm6 has 8 y-16 pixels
   packssdw   mm1, mm3               ; packed the results to signed words
  movq       mm7, mm6               ; save the 8 y-16 pixels
   punpcklbw  mm6, mm0               ; mm6 has 4 low y-16 unsign
  pmullw     mm6, Ymul
   punpckhbw  mm7, mm0               ; mm7 has 4 high y-16 unsign
  pmullw     mm7, Ymul
   movq       mm4, mm1
  movq       temp_mmx[esp+8], mm1   ; save 4 chroma G values
   punpcklwd  mm1, mm1               ; chroma G replicate low 2
  movq       mm0, mm6               ; low  y
   punpckhwd  mm4, mm4               ; chroma G replicate high 2
  movq       mm3, mm7               ; high y
   psubw      mm6, mm1               ;  4 low G
  psraw      mm6, [esp+GRightShift]
   psubw      mm7, mm4               ; 4 high G values in signed 16 bit
  movq       mm2, mm5
   punpcklwd  mm5, mm5               ; replicate the 2 low u pixels
  pmullw     mm5, UtB
   punpckhwd  mm2, mm2
  psraw      mm7, [esp+GRightShift]
   pmullw     mm2, UtB
  packuswb   mm6, mm7               ; mm6: G7 G6 G5 G4 G3 G2 G1 G0
  movq       temp_mmx[esp+16], mm5  ; low chroma B
   paddw      mm5, mm0               ; 4 low B values in signed 16 bit
  movq       temp_mmx[esp+40], mm2  ; high chroma B
   paddw      mm2, mm3               ; 4 high B values in signed 16 bit
  psraw      mm5, [esp+BRightShift] ; low B scaled down by 6+(8-5)
  psraw      mm2, [esp+BRightShift] ; high B scaled down by 6+(8-5)
  packuswb   mm5, mm2               ; mm5: B7 B6 B5 B4 B3 B2 B1 B0
  movq       mm2, temp_mmx[esp]     ; 4 v values
   movq       mm1, mm5               ; save B
  movq       mm7, mm2
```

```
   punpcklwd  mm2, mm2               ; replicate the 2 low v pixels
  pmullw     mm2, VtR
   punpckhwd  mm7, mm7
  pmullw     mm7, VtR
  paddusb    mm1, [esp+BUpperLimit] ; mm1: saturate B+0FF-15
  movq       temp_mmx[esp+24], mm2  ; low chroma R
  paddw      mm2, mm0               ; 4 low R values in signed 16 bit
  psraw      mm2, [esp+RRightShift] ; low R scaled down by 6+(8-5)
   pxor       mm4, mm4               ; mm4=0 for 8->16 conversion
  movq       temp_mmx[esp+32], mm7  ; high chroma R
   paddw      mm7, mm3               ; 4 high R values in signed 16 bit
  psraw      mm7, [esp+RRightShift] ; high R scaled down by 6+(8-5)
  psubusb    mm1, [esp+BUpperLimit]
   packuswb   mm2, mm7               ; mm2: R7 R6 R5 R4 R3 R2 R1 R0
  paddusb    mm6, [esp+GUpperLimit] ; G fast patch ih
  psubusb    mm6, [esp+GupperLimit] ; fast patch ih
  paddusb    mm2, [esp+RUpperLimit] ; R
  psubusb    mm2, [esp+RUpperLimit]
; here we are packing from RGB24 to RGB16
; input:
       ; mm6: G7 G6 G5 G4 G3 G2 G1 G0
       ; mm1: B7 B6 B5 B4 B3 B2 B1 B0
       ; mm2: R7 R6 R5 R4 R3 R2 R1 R0
; assuming 8 original pixels in 0-H representation on mm6, mm5, mm2
; when  H=2**xBITS-1 (x is for R G B)
; output:
;        mm1- result: 4 low RGB16
;        mm7- result: 4 high RGB16
; using: mm0- zero register
;        mm3- temporary results
; algorithm:
;   for (i=0; i<8; i++) {
;     RGB[i]=256*(R[i]<<(8-5))+(G[i]<<5)+B[i];
;   }
  psllq      mm2, [esp+RLeftShift]  ; position R in the most significant part of the byte
   movq       mm7, mm1               ; mm1: Save B
; note: no need for shift to place B on the least significant part of the byte
;   R in left position, B in the right position so they can be combined
  punpcklbw  mm1, mm2               ; mm1: 4 low 16 bit RB
   pxor       mm0, mm0               ; mm0: 0
  punpckhbw  mm7, mm2               ; mm5: 4 high 16 bit RB
   movq       mm3, mm6               ; mm3: G
  punpcklbw  mm6, mm0               ; mm6: low 4 G 16 bit
  psllw      mm6, [esp+GLeftShift]  ; shift low G 5 positions
  punpckhbw  mm3, mm0               ; mm3: high 4 G 16 bit
   por        mm1, mm6               ; mm1: low RBG16
  psllw      mm3, [esp+GLeftShift]  ; shift high G 5 positions
  por        mm7, mm3               ; mm5: high RBG16
  Lebp       tmpYCursorOdd          ; moved to here to save cycles before odd line
  movq       [edi], mm1             ; !! aligned
;- start odd line
  movq       mm1, [ebp+2*ebx]       ; mm1 has 8 y pixels
   pxor       mm2, mm2
  psubusb    mm1, Yadd              ; mm1 has 8 pixels y-16
  movq       mm5, mm1
   punpcklbw  mm1, mm2               ; get 4 low y-16 unsign pixels word
  pmullw     mm1, Ymul              ; low 4 luminance contribution
   punpckhbw  mm5, mm2               ; 4 high y-16
  pmullw     mm5, Ymul              ; high 4 luminance contribution
  movq       [edi+8], mm7           ; !! aligned
   movq       mm0, mm1
  paddw      mm0, temp_mmx[esp+24]  ; low 4 R
   movq       mm6, mm5
  psraw      mm0, [esp+RRightShift] ; low R scaled down by 6+(8-5)
  paddw      mm5, temp_mmx[esp+32]  ; high 4 R
   movq       mm2, mm1
  psraw      mm5, [esp+RRightShift] ; high R scaled down by 6+(8-5)
  paddw      mm2, temp_mmx[esp+16]  ; low 4 B
   packuswb   mm0, mm5               ; mm0: R7 R6 R5 R4 R3 R2 R1 R0
  psraw      mm2, [esp+BRightShift] ; low B scaled down by 6+(8-5)
   movq       mm5, mm6
  paddw      mm6, temp_mmx[esp+40]  ; high 4 B
  psraw      mm6, [esp+BRightShift] ; high B scaled down by 6+(8-5)
  movq       mm3, temp_mmx[esp+8]   ; chroma G  low 4
  packuswb   mm2, mm6               ; mm2: B7 B6 B5 B4 B3 B2 B1 B0
   movq       mm4, mm3
  punpcklwd  mm3, mm3               ; replicate low 2
  punpckhwd  mm4, mm4               ; replicate high 2
   psubw      mm1, mm3               ;  4 low G
  psraw      mm1, [esp+GRightShift] ; low G scaled down by 6+(8-5)
   psubw      mm5, mm4               ;  4 high G values in signed 16 bit
  psraw      mm5, [esp+GRightShift] ; high G scaled down by 6+(8-5)
  paddusb    mm2, [esp+BUpperLimit] ; mm1: saturate B+0FF-15
   packuswb   mm1, mm5               ; mm1: G7 G6 G5 G4 G3 G2 G1 G0
  psubusb    mm2, [esp+BupperLimit]
  paddusb    mm1, [esp+GUpperLimit] ; G
  psubusb    mm1, [esp+GUpperLimit]
  paddusb    mm0, [esp+RUpperLimit] ; R
  Leax       tmpCCOPitch
  psubusb    mm0, [esp+RUpperLimit]
; here we are packing from RGB24 to RGB16
       ; mm1: G7 G6 G5 G4 G3 G2 G1 G0
       ; mm2: B7 B6 B5 B4 B3 B2 B1 B0
       ; mm0: R7 R6 R5 R4 R3 R2 R1 R0
; output:
;        mm2- result: 4 low RGB16
;        mm7- result: 4 high RGB16
; using: mm4- zero register
;        mm3- temporary results
  psllq       mm0, [esp+RLeftShift] ; position R in the most significant part of the byte
   movq        mm7, mm2              ; mm7: Save B
; note: no need for shift to place B on the least significant part of the byte
;   R in left position, B in the right position so they can be combined
  punpcklbw  mm2, mm0               ; mm1: 4 low 16 bit RB
   pxor       mm4, mm4               ; mm4: 0
  movq       mm3, mm1               ; mm3: G
   punpckhbw  mm7, mm0               ; mm7: 4 high 16 bit RB
  punpcklbw  mm1, mm4               ; mm1: low 4 G 16 bit
  punpckhbw  mm3, mm4               ; mm3: high 4 G 16 bit
  psllw      mm1, [esp+GLeftShift]  ; shift low G 5 positions
   por        mm2, mm1               ; mm2: low RBG16
  psllw      mm3, [esp+GLeftShift]  ; shift high G 5 positions
  por        mm7, mm3               ; mm7: high RBG16
  movq       [edi+eax], mm2
  movq       [edi+eax+8], mm7       ; aligned
  add        edi, 16                ; ih take 16 bytes (8 pixels-16 bit)
   add        ebx, 4                 ; ? to take 4 pixels together instead of 2
  jl         do_next_8x2_block      ; ? update the loop for 8 y pixels at once
  ADDedi     CCOSkipDistance        ; go to begin of next line
  ADDedi     tmpCCOPitch          ; skip odd line (if it is needed)
; Leax       AspectCount
; Lebp       CCOPitch               ; skip odd line
; sub        eax, 2
; jg         @f
; Addeax     AspectBaseCount
; xor        ebp, ebp
;@@:
;  Seax       AspectCount
;  add        edi, ebp
  Leax       YPitch
  Lebp       tmpYCursorOdd
  add        ebp, eax        ; skip one line
;  lea        ebp, [ebp+2*eax]        ; skip two lines
  Sebp       tmpYCursorEven
;  Sebp       tmpYCursorOdd
  add        ebp, eax        ; skip one line
  Sebp       tmpYCursorOdd
;  Lebp       tmpYCursorEven
;  lea        ebp, [ebp+2*eax]
;  Sebp       tmpYCursorEven
  ADDesi     ChromaPitch
  ADDedx     ChromaPitch
;  Leax       YLimit                   ; Done with last line?
;  cmp        ebp, eax
;  jbe        PrepareChromaLine
   sub      PD FrameHeight[esp],2
   ja       PrepareChromaLine
;-------------------------------------------------------------------------------
finish:
  emms
  add        esp, LocalFrameSize
  pop        ebx
  pop        ebp
  pop        edi
  pop        esi
  retn
MMXCODE1 ENDS
END
```

18. Appendix 7. Color Conversion to RGB16 Zoom by 2

```
;-------------------------------------------------------------------------
; cx512162 -- This function performs zoom-by-2 YUV12-to-RGB16 color conversion
;             for H26x.  It handles 555, 655, 565, and 664 formats.
;
;             The YUV12 input is planar, 8 bits per pel.  The Y plane may have
;             a pitch of up to 768.  It may have a width less than or equal
;             to the pitch.  It must be DWORD aligned, and preferably QWORD
;             aligned.  Pitch and Width must be a multiple of eight.
;             Height must be a multiple of two.  The U and V planes may have
;             a different pitch than the Y plane, subject to the same limitations.
;
;             The color convertor is non destructive.
;-------------------------------------------------------------------------
include iammx.inc
include locals.inc
.586
.xlist
.list
 ASSUME ds:FLAT, cs:FLAT, ss:FLAT
RTIME16=1
DITHER=1
MMXDATA1 SEGMENT PARA USE32 PUBLIC 'DATA'
ALIGN 8
RGB_formats:
    dd  RGB565
    dd  RGB555
    dd  RGB664
    dd  RGB655
Minusg              dd   00800080h,  00800080h
VtR                 dd   00660066h,  00660066h ;01990199h,01990199h
VtG                 dd   00340034h,  00340034h ;00d000d0h,00d000d0h
UtG                 dd   00190019h,  00190019h ;00640064h,00640064h
UtB                 dd   00810081h,  00810081h ;02050205h,02050205h
Ymul                dd   004a004ah,  004a004ah ;012a012ah,012a012ah
Yadd                dd   10101010h,  10101010h
UVtG                dd   00340019h,  00340019h ;00d00064h,00d00064h
VtRUtB              dd   01990205h,  01990205h
fourbitu            dd  0f0f0f0f0h, 0f0f0f0f0h
fivebitu            dd  0e0e0e0e0h, 0e0e0e0e0h
sixbitu             dd  0c0c0c0c0h, 0c0c0c0c0h
shiftone            dd   02020202h,  02020202h
shifttwo            dd   04040404h,  04040404h
shiftthree          dd   08080808h,  08080808h
MMXDATA1 ENDS
LocalFrameSize           = 174
RegisterStorageSize      =  16
; Arguments:
YPlane                   = LocalFrameSize + RegisterStorageSize +  4
UPlane                   = LocalFrameSize + RegisterStorageSize +  8
VPlane                   = LocalFrameSize + RegisterStorageSize + 12
FrameWidth               = LocalFrameSize + RegisterStorageSize + 16
FrameHeight              = LocalFrameSize + RegisterStorageSize + 20
YPitch                   = LocalFrameSize + RegisterStorageSize + 24
ChromaPitch              = LocalFrameSize + RegisterStorageSize + 28
AspectAdjustmentCount    = LocalFrameSize + RegisterStorageSize + 32
ColorConvertedFrame      = LocalFrameSize + RegisterStorageSize + 36
DCIOffset                = LocalFrameSize + RegisterStorageSize + 40
CCOffsetToLine0          = LocalFrameSize + RegisterStorageSize + 44
CCOPitch                 = LocalFrameSize + RegisterStorageSize + 48
```

```
CCType                   = LocalFrameSize + RegisterStorageSize + 52
EndOfArgList             = LocalFrameSize + RegisterStorageSize + 56
; Locals (on local stack frame)
CCOCursor                =   0
CCOSkipDistance          =   4
ChromaLineLen            =   8
YCursor                  =  12
DistanceFromVToU         =  16
EndOfChromaLine          =  20
AspectCount              =  24
tmpYCursorEven           =  28
tmpYCursorOdd            =  32
temp_mmx                 =  36 ; 48 bytes
RLeftShift               =  84
GLeftShift               =  92
RRightShift              = 100
GRightShift              = 108
BRightShift              = 116
RUpperLimit              = 124
GUpperLimit              = 132
BUpperLimit              = 140
RDither                  = 148
GDither                  = 156
BDither                  = 164
; Switches used by RGB color convertors to determine the exact conversion type.
LCL EQU <esp+>
MMXCODE1 SEGMENT PARA USE32 PUBLIC 'CODE'
; void FAR ASM_CALLTYPE YUV12ToRGB16ZoomBy2 (
;                                     U8* YPlane,
;                                     U8* UPlane,
;                                     U8* VPlane,
;                                     UN  FrameWidth,
;                                     UN  FrameHeight,
;                                     UN  YPitch,
;                                     UN  UVPitch,
;                                     UN  AspectAdjustmentCount,
;                                     U8* ColorConvertedFrame,
;                                     U32 DCIOffset,
;                                     U32 CCOffsetToLine0,
;                                     int CCOPitch,
;                                     int CCType)
;
;  The local variables are on the stack,
;  The tables are in the one and only data segment.
;
;  CCOffsetToLine0 is relative to ColorConvertedFrame.
;
PUBLIC C MMX_YUV12ToRGB16ZoomBy2
MMX_YUV12ToRGB16ZoomBy2:
  push  esi
  push  edi
  push  ebp
  push  ebx
  sub        esp, LocalFrameSize
  mov        eax, [esp+CCType]
  cmp        eax,4
  jae        finish
  jmp        RGB_formats[eax*4]
RGB555:
  xor        eax, eax
  mov        ebx, 2   ; 10-8 for byte shift
  mov        [esp+RLeftShift], ebx
  mov        [esp+RLeftShift+4], eax
  mov        ebx, 5
  mov        [esp+GLeftShift], ebx
  mov        [esp+GLeftShift+4], eax
  mov        ebx, 9
  mov        [esp+RRightShift], ebx
  mov        [esp+RRightShift+4], eax
  mov        [esp+GRightShift], ebx
  mov        [esp+GRightShift+4], eax
  mov        [esp+BRightShift], ebx
  mov        [esp+BRightShift+4], eax
  movq       mm0, fivebitu
  movq       [esp+RUpperLimit], mm0
  movq       [esp+GUpperLimit], mm0
  movq       [esp+BUpperLimit], mm0
  movq       mm0,shifttwo      ; 1<<(7-5) for dither
  movq  [esp+RDither],mm0
  movq  [esp+GDither],mm0
  movq  [esp+BDither],mm0
  jmp   RGBEND
RGB664:
  xor        eax, eax
  mov        ebx, 2   ; 8-6
  mov        [esp+RLeftShift], ebx
  mov        [esp+RLeftShift+4], eax
  mov        ebx, 4
  mov        [esp+GLeftShift], ebx
  mov        [esp+GLeftShift+4], eax
  mov        ebx, 8
  mov        [esp+RRightShift], ebx
  mov        [esp+RRightShift+4], eax
  mov        [esp+GRightShift], ebx
  mov        [esp+GRightShift+4], eax
  movq       mm0, sixbitu
  movq       [esp+RUpperLimit], mm0
  movq       [esp+GUpperLimit], mm0
  mov        ebx, 10
  mov        [esp+BRightShift], ebx
  mov        [esp+BRightShift+4], eax
  movq       mm0, fourbitu
  movq       [esp+BUpperLimit], mm0
  movq  mm0,shiftone      ; 1<<(7-6) for dither
  movq  [esp+RDither],mm0
  movq  [esp+GDither],mm0
  movq  mm0,shiftthree    ; 1<<(7-4) for dither
  movq  [esp+BDither],mm0
  jmp   RGBEND
RGB655:
  xor   eax, eax
  mov   ebx,2   ; 8-6
  mov        [esp+RLeftShift], ebx
  mov        [esp+RLeftShift+4], eax
  mov   ebx,5
  mov        [esp+GLeftShift], ebx
  mov        [esp+GLeftShift+4], eax
  mov   ebx,9
  mov        [esp+GRightShift], ebx
  mov        [esp+GRightShift+4], eax
  mov        [esp+BRightShift], ebx
  mov        [esp+BRightShift+4], eax
  mov   ebx,8
  mov        [esp+RRightShift], ebx
  mov        [esp+RRightShift+4], eax
  movq  mm0,fivebitu
  movq       [esp+GUpperLimit], mm0
  movq       [esp+BUpperLimit], mm0
  movq  mm0,sixbitu
  movq       [esp+RUpperLimit], mm0
  movq  mm0,shifttwo      ; 1<<(7-5) for dither
  movq  [esp+GDither],mm0
  movq  [esp+BDither],mm0
  movq  mm0,shiftone      ; 1<<(7-6) for dither
  movq  [esp+RDither],mm0
  jmp   RGBEND
RGB565:
  xor        eax, eax
  mov        ebx, 3   ; 8-5
  mov        [esp+RLeftShift], ebx
  mov        [esp+RLeftShift+4], eax
  mov        ebx, 5
  mov        [esp+GLeftShift], ebx
  mov        [esp+GLeftShift+4], eax
  mov        ebx, 9
  mov        [esp+RRightShift], ebx
  mov        [esp+RRightShift+4], eax
  mov        [esp+BRightShift], ebx
  mov        [esp+BRightShift+4], eax
  movq       mm0, fivebitu
  movq       [esp+RUpperLimit], mm0
  movq       [esp+BUpperLimit], mm0
  mov        ebx, 8
  mov        [esp+GRightShift], ebx
  mov        [esp+GRightShift+4], eax
  movq       mm0, sixbitu
  movq       [esp+GUpperLimit], mm0
  movq  mm0,shifttwo      ; 1<<(7-5) for dither
  movq  [esp+RDither],mm0
  movq  [esp+BDither],mm0
  movq  mm0,shiftone      ; 1<<(7-6) for dither
  movq  [esp+GDither],mm0
;  jmp   RGBEND
RGBEND:
  mov   ebx, [esp+VPlane]
  mov   ecx, [esp+UPlane]
  sub   ecx, ebx
  mov   [esp+DistanceFromVToU], ecx
  mov   eax, [esp+ColorConvertedFrame]
  add   eax, [esp+DCIOffset]
  add   eax, [esp+CCOffsetToLine0]
  mov   [esp+CCOCursor], eax
   Lebx  FrameWidth
   Leax  CCOPitch
   Lesi  YPlane                           ; Fetch cursor over luma plane.
   shl   ebx, 2                           ; FrameWidth*2
   sub   eax, ebx                         ; CCOPitch-2*FrameWidth
   shr   ebx, 3                          ; FrameWidth*3
   Sesi  YCursor
   Sebx  ChromaLineLen                   ; FrameWidth*3
   Seax  CCOSkipDistance                 ; CCOPitch-3*FrameWidth
   Leax  AspectAdjustmentCount
   Lesi  VPlane
   Seax  AspectCount
   xor   eax, eax
   Ledi  ChromaLineLen
   Sedi  EndOfChromaLine
   Ledi  CCOCursor
   Ledx  DistanceFromVToU
   Lebp  YCursor                       ; Fetch Y Pitch.
   Lebx  FrameWidth
    add     ebp, ebx
    Sebp    tmpYCursorEven
    Leax    YPitch
    add     ebp, eax
    Sebp    tmpYCursorOdd
    sar     ebx, 1
    add     esi, ebx
    add     edx, esi
    neg     ebx
    Sebx    FrameWidth
;  Register Usage:
;
;  ebp -- Y Line cursor.  Chroma contribs go in lines above current Y line.
;  esi -- Chroma Line cursor.
;  edx -- Distance from V pel to U pel.
;  edi -- Cursor over the color converted output image.
;  ebx -- Number of points taken together.
;
;
;  ecx -- Point to Far line (2 lines away)
;  eax -- Line Pitch
;------------------------------------------------------------------------------
PrepareChromaLine:
    Lebx  FrameWidth
    Leax      CCOPitch
do_next_8x2_block:
        Lebp tmpYCursorEven
        movdt    mm1, [edx+ebx]                      ; 4 u values
        pxor     mm0, mm0                              ; mm0=0
        movdt    mm2, [esi+ebx]                       ; 4 v values
        punpcklbw   mm1, mm0                        ; get 4 unsign u
        psubw       mm1, Minusg                     ; get 4 unsign u-128
        punpcklbw   mm2, mm0                        ; get unsign v
        psubw       mm2, Minusg                       ; get unsign v-128
        movq        mm3, mm1                          ; save the u-128 unsign
        movq        mm5, mm1                          ; save u-128 unsign
        punpcklwd   mm1, mm2                         ; get 2 low u, v unsign pairs
        pmaddwd     mm1, UVtG
        punpckhwd   mm3, mm2                         ; create high 2 unsign uv pairs
        pmaddwd     mm3, UVtG
        movq        temp_mmx[esp], mm2                  ; save v-128
        movq     mm6, [ebp+2*ebx]                      ; mm6 has 8 y pixels
        psubusb  mm6, Yadd                             ; mm6 has 8 y-16 pixels
        packssdw  mm1, mm3                        ; packed the results to signed words
        movq     mm7, mm6                              ; save the 8 y-16 pixels
        punpcklbw mm6, mm0                             ; mm6 has 4 low y-16 unsign
        pmullw    mm6, Ymul
        punpckhbw mm7, mm0                             ; mm7 has 4 high y-16 unsign
        pmullw    mm7, Ymul
        movq      mm4, mm1
        movq     temp_mmx[esp+8], mm1                 ; save 4 chroma G values
        punpcklwd mm1, mm1                           ; chroma G replicate low 2
        movq      mm0, mm6                           ; low  y
        punpckhwd mm4, mm4                           ; chroma G replicate high 2
        movq      mm3, mm7                             ; high y
        psubw     mm6, mm1                             ;  4 low G
                ;        movq      mm1, mm5                             ; 4 u values
        psraw     mm6, [esp+GRightShift]
        psubw     mm7, mm4                             ; 4 high G values in signed 16 bit
        movq      mm2, mm5
        punpcklwd mm5, mm5                              ; replicate the 2 low u pixels
        pmullw    mm5, UtB
        punpckhwd mm2, mm2
        pmullw    mm2, UtB
        psraw    mm7, [esp+GRightShift]
        packuswb mm6, mm7                            ; mm6: G7 G6 G5 G4 G3 G2 G1 G0
        movq      temp_mmx[esp+16], mm5                   ; low chroma B
        paddw    mm5, mm0                               ; 4 low B values in signed 16 bit
        movq     temp_mmx[esp+40], mm2                    ; high chroma B
        paddw    mm2, mm3                               ; 4 high B values in signed 16 bit
        psraw    mm5, [esp+BRightShift]                       ; low B scaled down by 6+(8-5)
        psraw    mm2, [esp+BRightShift]                      ; high B scaled down by 6+(8-5)
        packuswb mm5, mm2                            ; mm1: B7 B6 B5 B4 B3 B2 B1 B0
        movq    mm2, temp_mmx[esp]                ; 4 v values
        movq    mm1, mm5                            ; save B
        movq    mm7, mm2
        punpcklwd  mm2, mm2                             ; replicate the 2 low v pixels
        pmullw    mm2, VtR
        punpckhwd  mm7, mm7
        pmullw    mm7, VtR
        paddusb  mm1, [esp+BUpperLimit]                     ; mm1: saturate B+0FF-15
        movq      temp_mmx[esp+24], mm2                   ; low chroma R
        paddw     mm2, mm0                             ; 4 low R values in signed 16 bit
        psraw    mm2, [esp+RRightShift]                      ; low R scaled down by 6+(8-5)
        pxor      mm4, mm4                              ; mm4=0 for 8->16 conversion
        movq      temp_mmx[esp+32], mm7                   ; high chroma R
        paddw     mm7, mm3                             ; 4 high R values in signed 16 bit
        psraw    mm7, [esp+RRightShift]                      ; high R scaled down by 6+(8-5)
        psubusb  mm1, [esp+BUpperLimit]
        packuswb mm2, mm7                            ; mm2: R7 R6 R5 R4 R3 R2 R1 R0
        paddusb   mm6, [esp+GUpperLimit]                    ; G
        psubusb   mm6, [esp+GupperLimit]
        paddusb   mm2, [esp+RUpperLimit]                    ; R
        psubusb   mm2, [esp+RUpperLimit]
        psllq     mm2, [esp+RLeftShift]                   ; position R in the most significant
part of the byte
        movq      mm7, mm1                        ; mm1: Save B
; note: no need for shift to place B on the least significant part of the byte
;   R in left position, B in the right position so they can be combined
        punpcklbw mm1, mm2                        ; mm1: 4 low 16 bit RB
        pxor      mm0, mm0                        ; mm0: 0
        punpckhbw mm7, mm2                        ; mm7: 4 high 16 bit RB
        movq      mm3, mm6                        ; mm3: G
        punpcklbw mm6, mm0                        ; mm6: low 4 G 16 bit
        psllw     mm6, [esp+GLeftShift]                   ; shift low G 5 positions
        punpckhbw mm3, mm0                        ; mm3: high 4 G 16 bit
        psllw     mm3, [esp+GLeftShift]                   ; shift high G 5 positions
        por       mm1, mm6                        ; mm1: low RBG16
        movq      mm2, mm1
        por       mm7, mm3                        ; mm7: high RBG16
        punpcklwd mm1, mm1
        movq      [edi], mm1                           ; !! aligned
        punpckhwd mm2, mm2
        movq      [edi+eax], mm1                       ; !! patch
        movq      [edi+8], mm2                         ; !! patch
        movq      [edi+eax+8], mm2                     ; !! patch
        movq    mm6, mm7
        punpcklwd  mm7, mm7                          ; get 4 low y-16 unsign pixels word
        movq    [edi+16], mm7                        ; !! aligned
        punpckhwd  mm6, mm6                          ; get 4 low y-16 unsign pixels word
        movq    [edi+eax+16], mm7                    ; !! aligned
        movq    [edi+24], mm6                        ; !! aligned
        movq    [edi+eax+24], mm6                    ; !! aligned
;- start odd line
        Lebp   tmpYCursorOdd                   ; moved here to save cycles before odd line
        movq   mm1, [ebp+2*ebx]                      ; mm1 has 8 y pixels
        pxor   mm2, mm2
        psubusb mm1, Yadd                            ; mm1 has 8 pixels y-16
        movq    mm5, mm1
        punpcklbw  mm1, mm2                          ; get 4 low y-16 unsign pixels word
        pmullw  mm1, Ymul                            ; low 4 luminance contribution
        punpckhbw  mm5, mm2                          ; 4 high y-16
        pmullw  mm5, Ymul                            ; high 4 luminance contribution
        movq    mm0, mm1
        paddw   mm0, temp_mmx[esp+24]                  ; low 4 R
        movq    mm6, mm5
        psraw   mm0, [esp+RRightShift]                     ; low R scaled down by 6+(8-5)
        paddw   mm5, temp_mmx[esp+32]                  ; high 4 R
        movq    mm2, mm1
        psraw   mm5, [esp+RRightShift]                     ; high R scaled down by 6+(8-5)
        paddw   mm2, temp_mmx[esp+16]                 ; low 4 B
        packuswb mm0, mm5                            ; mm0: R7 R6 R5 R4 R3 R2 R1 R0
        psraw   mm2, [esp+BRightShift]                      ; low B scaled down by 6+(8-5)
        movq    mm5, mm6
        paddw   mm6, temp_mmx[esp+40]                 ; high 4 B
        psraw   mm6, [esp+BRightShift]                      ;high B scaled down by 6+(8-5)
        movq    mm3, temp_mmx[esp+8]                 ;  chroma G  low 4
        packuswb mm2, mm6                            ; mm2: B7 B6 B5 B4 B3 B2 B1 B0
        movq    mm4, mm3
        punpcklwd mm3, mm3                            ; replicate low 2
        punpckhwd mm4, mm4                            ; replicate high 2
        psubw    mm1, mm3                             ;  4 low G
        psraw    mm1, [esp+GRightShift]                     ; low G scaled down by 6+(8-5)
        psubw    mm5, mm4                             ;  4 high G values in signed 16 bit
        psraw    mm5, [esp+GRightShift]                     ; high G scaled down by 6+(8-5)
        pxor     mm3, mm3                            ; B
        paddusb  mm2, [esp+BUpperLimit]                    ; mm1: saturate B+0FF-15
        packuswb mm1, mm5                            ; mm1: G7 G6 G5 G4 G3 G2 G1 G0
        psubusb  mm2, [esp+BupperLimit]
        paddusb   mm1, [esp+GUpperLimit]                   ; G
        psubusb   mm1, [esp+GUpperLimit]
        paddusb   mm0, [esp+RUpperLimit]                   ; R
        psubusb   mm0, [esp+RUpperLimit]
        lea       ecx, [eax+2*eax]                    ; ecx - point to next 3 line
        psllq     mm0, [esp+RLeftShift]                 ; position R in the most significant
part of the byte
        movq      mm7, mm2                        ; mm7: Save B
; note: no need for shift to place B on the least significant part of the byte
;   R in left position, B in the right position so they can be combined
        punpcklbw mm2, mm0                        ; mm1: 4 low 16 bit RB
        pxor      mm4, mm4                        ; mm4: 0
        movq      mm3, mm1                        ; mm3: G
        punpckhbw mm7, mm0                        ; mm7: 4 high 16 bit RB
        punpcklbw mm1, mm4                        ; mm1: low 4 G 16 bit
        punpckhbw mm3, mm4                        ; mm3: high 4 G 16 bit
        psllw     mm1, [esp+GLeftShift]                 ; shift low G 5 positions
        por       mm2, mm1                        ; mm2: low RBG16
        psllw     mm3, [esp+GLeftShift]                 ; shift high G 5 positions
        movq      mm4, mm2                        ; mm4: save low RBG16
        por       mm7, mm3                        ; mm7: high RBG16
        punpcklwd mm2, mm2                        ; replicate low low RGB16
        movq      [edi+2*eax], mm2
        punpckhwd mm4, mm4                        ; replicate high low RGB16
        movq      [edi+2*eax+8], mm4                 ; patch
        movq      mm5, mm7                        ; save high RBG16
        movq      [edi+ecx], mm2
        punpcklwd mm7, mm7
        movq      [edi+ecx+8], mm4                 ; patch
        punpckhwd mm5, mm5
        movq      [edi+ecx+16], mm7                 ; aligned
        movq      [edi+2*eax+16], mm7                 ; aligned
        movq      [edi+ecx+24], mm5                 ; aligned
        movq      [edi+2*eax+24], mm5                 ; aligned
```

```
    add     edi, 32                  ; ih take 16 bytes (8 pixels-16 bit)
    add     ebx, 4                   ; ? to take 4 pixels together instead of 2
    jl      do_next_8x2_block                  ; ? update the loop for 8 y pixels at once
    ADDedi  CCOSkipDistance                 ; go to begin of next line
    ADDedi  CCOPitch                 ; skip odd line
    ADDedi  CCOPitch                 ; skip odd line
    ADDedi  CCOPitch                 ; skip odd line
    Leax    CCOPitch
    Leax    YPitch
    Lebp    tmpYCursorOdd
    lea     ebp, [ebp+2*eax]                     ; skip two lines
    Sebp    tmpYCursorOdd
    Lebp    tmpYCursorEven
    lea     ebp, [ebp+2*eax]
    Sebp    tmpYCursorEven
    ADDesi  ChromaPitch
    ADDedx  ChromaPitch
     sub    PD FrameHeight[esp],2
     ja     PrepareChromaLine
;------------------------------------------------------------------------------
finish:
  emms
  add          esp, LocalFrameSize
  pop          ebx
  pop          ebp
  pop          edi
  pop          esi
  retn
MMXCODE1 ENDS
END
```

19. References

[1] Recommendation and Reports. Recommendation 601-1. Encoding Parameters of Digital Television For Studios