# Video Image Processing Technology

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ADERA.

#### Agenda

- Key trend of "video in FPGA"
- Video image processing basics
  - Color space conversion
  - Chroma sampling
  - Scaling
  - Deinterlacing
  - Image blending
  - Filtering
  - Gamma correction

#### Conclusion



#### Key Trend for "Video in FPGA" – 1

#### High definition (HD) video is ~4x to 6x the size of standard definition (SD) video





#### Key Trend for "Video in FPGA" – 2

MPEG4-2, at a bit rate of 1.2Mbps Resolution (544 x 368) MPEG4-10, at a bit rate of 1.2Mbps Resolution (544 x 3<del>68</del>)



### HD → Dramatic Increase in Bits

Image size	Frame size: (Total # of pixels)	Frame size: (Assume 10 bits per pixel)	Data rate: (Assuming 60 frames per second (FPS))
1920 X 1080p	1920 x 1080 = 2.08M pixels	62 Mbits or 7.78 Mbytes	3,732 Mbps
1920 X 1080i	1920 x 1080 x 0.5 = 1.04M pixels	31 Mbits or 3.89 Mbytes	1,866 Mbps
1280 X 720p	1280 x 720 = 921K pixels	27.7 Mbits or 3.46 Mbytes	1,659 Mbps
SD 720 x 480i	720 x 480 x 0.5 = 173K pixels	5.2 Mbits or 0.65 Mbytes	311 Mbps

These numbers will change when we account for HSYNC and VSYNC signals, as well as for chroma downsampling

However, they are correct in a relative sense









#### **Color Space: Basics**



- A color space is a method by which we can specify, create, and visualize color
- Computers describe a color stimulus in terms of the excitations of red, green, and blue phosphors on the CRT faceplate
- Printers describe a color stimulus in terms of the reflectance and absorbance of cyan, magenta, yellow, and black inks on the paper



#### **Color Space Conversion: Basics**

Y = R\*0.299 + G\*0.587 + B\*0.114 CR = R\*(-0.169) + G\*(-0.332) + B\*0.500 + 128Cb = R\*0.500 + G\*(-0.419) + B\*(-0.0813) + 128



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#### **RGB to YCrCb**





#### **Color Space Conversion IP**

CSC Version 6.1 Parameter Summary Coefficients Trage Data Format Trage Data Format Trage Data Format Coor Plane Configuration Three color planes in sequence Three color planes in sequence Three color planes in sequence Three color planes in sequence Precision Word length Word length consists of an integer part and a fractional part.	MegaWizard Plug-In Manager - CSC		
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Underflow Behavior : Ignore	Underflow Behavior : Ignore		
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#### **Color Space Conversion IP**

MegaWizard Plug-In Manager - CSC         CSC         Version 6.1         Parameter       Simulation         Settings       Coefficients         Compile Time Coefficients       Color model conversion :       Custom         Din and dout refer to the in Studio R'G'B' to Y'CbCr: SDTV       Image: Studio R'G'B' to Y'CbCr: SDTV         dout_0 =       0       Studio R'G'B' to Y'CbCr: HDTV         dout_1 =       0       Computer R'G'B' to Y'LV         dout_2 =       0       Y'LV to Computer R'G'B' computer R'G'B' to Y'LV	▲bout Documentation * din_2 + 0 * din_2 + 0 * din_2 + 0 * din_2 + 0	Choose the color space conversion	
The core can automatically select the co-efficient, or you can enter custom co-efficient	MegaWizard Plug-In Manager - CSC CSC Version 6.1 Parameter Settings Coefficients Color model conversion : Studio R'G'B' to Y Din and dout refer to the input and output cf dout_0 = 0.299  * din_0 + 0.5 dout_1 = -0.172  * din_0 + -0. dout_2 = 0.511  * din_0 + -0.	* din_1 +       0.114         .339       * din_1 +	▲bout Documentation * din_2 + 0 * din_2 + 128 * din_2 + 128

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- Per pixel
  - Y (10 bits)
  - Cr (10 bits)
  - Cb (10 bits)
- Total bits
  - 40 bits for Y
  - 40 bits for Cr
  - 40 bits for Cb
- 4:4:4 chroma subsampling
- Bits for 4 pixels: 120
- Bit/pixel = 30





- Per pixel
  - Y (10 bits)
  - Cr (10 bits)
  - Cb (10 bits)
- Drop Cr, Cb for alternate pixels, total bits
  - 40 bits for Y
  - 20 bits for Cr
  - 20 bits for Cb
- 4:2:2 chroma subsampling
- Bits for 4 pixels: 80
- Bit/pixel = 20

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- Per pixel
  - Y (10 bits)
  - Cr (10 bits)
  - Cb (10 bits)
- Drop Cr, Cb for alternate pixels
- Drop Cr and Cb for the second line
- Total bits
  - 40 bits for Y
  - 10 bits for Cr
  - 10 bits for Cb
- 4:2:0 chroma subsampling
- Bits for 4 pixels: 60
- Bit/pixel = 15

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# Why Chroma Downsampling?

Image size	Frame size: (Total # of pixels)	Frame size: (Assume 10 bits per pixel and 4:4:4)	Frame size: (Assume 10 bits per pixel and 4:2:2)	Frame size: (Assume 10 bits per pixel and 4:2:0)
1920 X 1080p	1920 x 1080 = 2M pixels	60 Mbits	40 Mbits	30 Mbits
1920 X 1080i	1920 x 1080 x 0.5 = 1M pixels	30 Mbits	20 Mbits	15Mbits
1280 X 720p	1280 x 720 = 900K pixels	27 Mbits	18 Mbits	13.5 Mbits
SD 720 x 480i	720 x 480 x 0.5 = 173K pixels	5.19 Mbits	3.46 Mbits	2.595 Mbits



#### **Chroma Resampling IP**

📉 MegaWizard	Plug-In Manag	jer - Chroma Resampler	
	Chroma Version 6.1	Resampler	About Documentation
1 Parameter Settings	2 Simulation Model	3 Summary	
-Image Data Form	at		
Image resolut		1920×1080 💌	Pixels
	per color plane : onfiguration : Th	8 ree color planes in sequence	Conversion Format
Behavior			4:4:4 -> 4:2:2
Conversion form	nat :	4:4:4 to 4:2:0 💌	4:4:4 -> 4:2:0
Horizontal interp	polation :	Linear	4:2:2 -> 4:4:4
Vertical interpol	ation :	Linear	4:2:0 -> 4:4:4
	2D	erpolation T LINEAR NEAREST N	ish

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#### **Calculating Data Rates**

Image size	Frame size	Chroma sub sample/bits per color plane/FPS	Bit/s transfer rate
1920 x 1080p	2200 x 1125	4:2:2/10/60	2200 x 1125 x 20 x 60 = 2.97 Gbps
1920 x 1080i	2200 x 1125	4:2:2/10/60	2200 x 1125 x 20 x 60 x 0.5 = 1.485 Gbps
1280 x 720p	1650 x 750	4:2:2/10/60	1650 x 750 x 20 x 60 = 1.485 Gbps
720 x 480i	858 x 525	4:2:2/10/60	858 x 525 x 20 x 60 x 0.5 = 270 Mbps ∱
Sync data	Image D	ata 1080p-SDI* rate	e HD-SDI rate HD-SDI rate

#### SDI = serial digital interface

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#### **Scaling: Basics**



D1/SDTV: 720 x 480



#### HDTV 1080p: 1920 x 1080

- Arbitrary input and output resolutions
- Bicubic, bilinear, and nearest neighbor
- Also with 7.1  $\rightarrow$  multi-tap (polyphase scaling)
- Real-time control of the scaling co-efficiency

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### **Scaling: Basics**

- Nearest neighbor
  - Uses one pixel to generate the new pixel
- Bilinear
  - Uses up to 4 (2x2) pixels to generate the new pixel
- Bicubic
  - Uses up to 16 pixels (4x4) to generate the new pixel
- Multi-tap (polyphase ... coming in 7.1)
  - Uses any arbitrary window size (M x N) to generate the new pixel value



#### **Nearest Neighbor Interpolation**





#### **Bilinear Interpolation**





#### **Scaling Comparison by Different Methods**



#### Bitubit Scalingsr

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### **Scaling: Basics**

- Nearest neighbor
  - Uses one pixel to generate the new pixel
- Bilinear
  - Uses up to 4 (2x2) pixels to generate the new pixel
- Bicubic
  - Uses up to 16 pixels (4x4) to generate the new pixel
- Multi-tap (polyphase ... coming in 7.1)
  - Uses any arbitrary window size (M x N) to generate the new pixel value
  - Very useful when downscaling





#### **Nearest Neighbor**

The quick brown fox jumped over the lazy dog 25 The quick brown fox jumped over the laxy dog 34 The quick brown fox jumped over the laxy dog 32 The quick brown fox jumped over the laxy dog 32 The quick brown fox jumped over the laxy sog 32 The quick brown fox jumped over the laxy sog 38 The quick brown fox jumped over the laxy sog 36 The quick brown fox jumped over the laxy sog 36 The quick brown fox jumped over the laxy sog 36 The quick brown fox jumped over the laxy sog 36 The quick brown fox jumped over the laxy sog 36 The quick brown fox jumped over the laxy sog 36 The quick brown fox jumped over the laxy sog 36 The quick brown fox jumped over the laxy sog 36 The quick brown fox jumped over the laxy sog 36

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#### **Bilinear**

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# 5-Tap (5 x 5)

The quick brown fox jumped over the lazy dog 28 The quick brown fox jumped over the lazy dog 26 The quick brown fox jumped over the lazy dog 24 The quick brown fox jumped over the lazy dog 22 The quick brown fox jumped over the lazy dog 20 The quick brown fox jumped over the lay dog 10 The quick brown fox jumped over the lay dog 10 The quick brown for

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### 9-Tap (9 x 9)

The quick brown fox jumped over the lazy dog 28 The quick brown fox jumped over the lazy dog 26 The quick brown fox jumped over the lazy dog 24 The quick brown fox jumped over the lazy dog 22 The quick brown fox jumped over the lazy dog 20 The quick brown fox jumped over the lazy dog 10 The quick brown fox jumped over the lazy dog 10 The quick brown fox jumped over the lazy dog 10 The quick brown fox jumped over the lazy dog 10 The quick brown fox jumped over the lazy dog 10 The quick brown fox jumped over the lazy dog 10 The quick brown fox jumped over the lazy dog 10 The quick brown fox jumped over the lazy dog 10 The quick brown fox jumped over the lazy dog 10 The quick brown fox jumped over the lazy dog 10

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#### Upscaling

#### 400 x 300 scaled to 800 x 600





#### **Different Upscaling Results**





### **Upscaling: Things to Remember**

- Generally you can get very good results with bicubic or 4-tap scaling
- There is not much improvement beyond 4x4



#### Interlace

First all odd lines scanned (1/60sec)



...then all even lines (1/60sec)



...presenting a full picture (1/30sec)



#### Progressive

All lines scanned in single pass ... presenting a full picture (1/60sec)









- Because of the time intermix (1 frame = field @time 't' + field @time 't+1/60') it is impossible to:
  - Deinterlace a frame AND
  - Keep 60 frames/second AND
  - Keep the full quality (=all information for a picture)
- You will have to alter at least one of those points
  - Except, when there is no motion

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#### How do we deinterlace video?

- 'Bob' deinterlacing
- One field of the video is made into a complete frame
- Because each field has only half the lines of a full frame, additional scan lines have to be added to create a frame



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#### Generating the additional scan line

- Duplication
- Interpolation




## **Deinterlacing: The Basics**

- How do we deinterlace video?
  - 'Weave' deinterlacing
  - This method simply combines the two fields into one frame
  - This methodology is good when there is not much motion between two successive fields
  - Weave leads to artifacts when there is motion





#### **Deinterlacing: With Motion**





#### **Deinterlacing: Without Motion**





# **Deinterlacing Applications**

- Deinterlacing is used whenever you want to
  - Grab still image from video
  - Play video on a noninterlaced display
  - Compress video
- Applications
  - Video surveillance before compression/storage
  - Video conferencing to display on a non-interlaced screen
  - Broadcast before compression and video switching

💐 MegaWizard Plug-In Manager - Deinterlacer			<u>- 🗆 ×</u>
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1 Parameter 2 Simulation 3 Summary Settings Model			
-Image Data Format			1
Image resolution : 1920×1080	) 🔻	Pixels	
Bits per pixel per color plane : 8	-	Bits	
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# Image Blending: For Onscreen Display (OSD) and Picture-in-Picture (PiP)





# **Alpha Image Blending: Basics**

- Alpha image blending is the process of digitally assembling multiple images to make a final image
- The basic operation used is known as 'alpha blending', where an opacity value, 'α', is used to control the proportions of two input <u>pixel</u> values that end up a single output pixel
- Consider three pixels:
  - Foreground pixel, f
  - Background pixel, b
  - Composited pixel, c
- Also alpha ( $\alpha$ ) is the opacity value of the foreground pixel
  - $\alpha$ =1 for opaque foreground,  $\alpha$ =0 for a completely transparent foreground



# **Alpha Blending: Basics**

191	191	191	191	191	R
63	63	63	63	63	G
255	255	255	255	255	в

- The color is RGB (191, 63, 255)
- The alpha values go from 255 (fully opaque) to 0 (fully transparent)
- The actual resulting merged color is computed this way:
  - (image color × alpha) + (background color × (100% - alpha))



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## **Alpha Image Blending: Basics**

Composite RGB image can be calculated by





#### **Alpha Blending IP Core**

MegaWizard Plug-In Manager - Alpha Blending Mixer				
Alpha Blen Version 6.1	ding Mixe	r	About Documen	tation
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Image Data Format				
Number of layers being mixed :	8	-		
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Background image resolution:	1920×1080 🔻	Pixels		
Layer 2 resolution :	64x64	Pixels		
Layer 3 resolution :	128×128	Pixels		
Layer 4 resolution :	256x256	Pixels		
Layer 5 resolution :	640x480	Pixels		
Layer 6 resolution :	720x486	Pixels		
Layer 7 resolution :	1280×720 ▼	Pixels		
Foreground image resolution :	1920x1080	Pixels		
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Behavior				
🔽 Enable alpha blending				
Alpha bits per pixel : 2	-			
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- In PIP, background video is played in the center of the screen, while smaller square video clips are played in corners of the screen
- Multi-layer mixing (2 to 8 layers)
- Every foreground layer can use a different alpha value to control its transparency, resulting in true image blending effects

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# Filtering in Video Image Processing (VIP)

- Various video image processing signal chains have to filter the input signals to
  - Remove noise
  - Smooth the image
  - Sharpen the image
  - Implement custom processing
- Altera<sup>®</sup> VIP solutions provide options to implement this filtering



#### **2D Filtering to Enhance Images**





#### **2D Filtering to Enhance Images**





#### **2D Median Filter**

- Noise gets introduced into video data set via any electrical system used for storage, transmission, and/or processing
- Median filtering is a simple and very effective noise removal filtering process
- Median filtering:
  - Each pixel is determined by the median value of all pixels in a selected neighborhood (mask, template, window)
  - The median value m of a population (set of pixels in a neighborhood) is that value in which half of the population has smaller values than m, and the other half has larger values than m



# **2D Filtering**

- 2D finite impulse response (FIR) filter and 2D median filter
  - 3x3, 5x5, or 7x7 filter sizes

 Useful for noise reduction, smoothing, and edge enhancement

100	<b>FIR Filter</b>	2D		
MegaCore'	Version 6.1	20		About Documentation
1 Parameter	2 Simulation	3 Summary		
Settings	Piloudi			
General	Coefficients			
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Input			Output	
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Data type :		Unsigned	Data type :	Unsigned
🗌 🕅 Guard bar	ids M	lax : 1 💌	Guard bands	Max: 1
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Precision The result of th	- ETD colculation is up	sizeed binary fived point data (	with 8 magnitude bits and 9 fractio	n hite
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# **2D Median Filter IP**

- The 2D Median Filter MegaCore<sup>®</sup> function provides a means to perform 2D median filtering operations using matrices of 3×3, 5×5, or 7×7 kernels
- Each output pixel is the median of the input pixels found in a 3x3, 5x5, or 7×7 kernel centered on the corresponding input pixel
- Where this kernel runs over the edge of the input image, zeros are filled in

🔌 MegaWizard Plug-In Manager - Median Filter 2D
Median Filter 2D Version 6.1 <u>About</u> <u>Documentation</u>
1 Parameter 2 Simulation 3 Summary Settings Model
Image Data Format
Image resolution : 1920×1080  Pixels
Bits per pixel per color plane : 8 💌 Bits
Number of color planes in sequence : 3 Planes
Behavior Filter size : 3x3 Pixels 3x3 5x5 7x7
Cancel < Back Next > Finish



#### **Gamma Correction: Basics**

- There is a nonlinear relationship between pixel value and its displayed intensity on a monitor
- This nonlinear relationship is roughly a power function displayed\_intensity (L) = pixel\_value (V)^gamma





#### **Gamma Correction: Basics**

To correct this annoying little problem, the input signal to the monitor (the voltage) must be "gamma corrected"





#### **Gamma Correction: Basics**







# **VIP Basics – Summary**

Core	Function
Color space converter	Converts image data between a variety of different color spaces
Chroma resampler	Changes the sampling rate of the chroma data for image frames
Scalar	Resizes and clips image frames
Deinterlacer	Converts interlaced video formats to progressive video format
Alpha blending mixer	Mixes and blends multiple image streams, including PIP
2D filter	Implements a 3x3, 5x5, or 7x7 FIR filter on an image data stream to smooth or sharpen images
Gamma corrector	Performs gamma correction on a color space



#### **DSP Total Solutions**





#### Summary

#### Key trend of "video in FPGA"

- SD transitions to HD
- MPEG4-2 moves to MPEG4-10
- Video image processing technology consists of:
  - Color space conversion
  - Chroma sampling
  - Scaling
  - Deinterlacing
  - Image blending
  - Filtering
  - Gamma correction

#### Altera provides total solution for video image processing technology

