Color Space Conversion (RGB to YC_RC_B) for Arrix™ FPOA™

September 2006 **Preliminary Product Brief**

Features

- Processes color pixels at rates up to 1 gigapixel/sec
- Implements the ITU-R BT.601.5 specification
- Supports 8-, 10- and 12-bits input/output wordlength
- Uses 16-bit wordlength for coefficients and 32-bit internal precision
- May be integrated with other cores in MathStar's Machine Vision Library

Applications

- Machine vision
- Professional video
- Military / aerospace
- High-performance digital imaging
- Medical imaging

FPOA Background

The MathStar Field-Programmable Object Array™ (FPOA) architecture is comprised of an array of silicon objects, each performing a specific function at data rates up to 1 GHz. The architecture supports three kinds of 16-bit core objects: an Arithmetic Logic Unit (ALU), a Multiply-Accumulator (MAC) and a Register File (RF). The objects are interconnected by a two-tier interconnect structure. The interconnect structure allows for 1-gigahertz connectivity between Nearest Neighbor connections as well as 1-gigahertz connectivity between non-adjacent objects through patented Party Line interconnects. These objects are coupled with distributed internal RAM (IRAM), dedicated external memory controllers (XRAM) and a wide range of high-speed and general-purpose I/O to form the complete FPOA architecture. Because of its high performance, an FPOA can run many applications up to four times faster than FPGA architectures.

Functional Overview

The ITU-R BT.601-5 document specifies the conversion from the RGB color space into YC_RC_B color space and subsampling from 4:4:4 components to 4:2:2 components. The Color Space Conversion core for Arrix FPOA performs these conversions. The color space conversion function operates at the core clock speed, producing one YC_RC_B triplet every clock cycle, as long as an RGB triplet is supplied every clock cycle. The down-sample function produces one Y value and one C_R or one C_B value every clock cycle. The converter also includes files for mapping the FPOA objects in the COAST placement / assignment tool.

Color Conversion

The equations for the conversion for RGB to YC_RC_B are defined in the BT.601 specification

$$E_Y^{'} = 0.299R + 0.587G + 0.114B$$

$$(E_R^{'} - E_Y^{'}) = 0.701R - 0.578G - 0.114B$$

$$(E_B^{'} - E_Y^{'}) = -0.299B - 0.587G + 0.886B$$

$$\overline{Y} = 219(E_Y^{'}) + 16$$

$$\overline{C_R} = 160(E_R^{'} - E_Y^{'}) + 128$$

$$\overline{C_B} = 126(E_B^{'} - E_Y^{'}) + 128$$

These six equations can be reduced to three equations in terms of Y, the luma component, and Cb and Cr, the chroma components.

$$\overline{Y} = 65.481R + 128.553G + 24.966B + 16$$

$$\overline{C_R} = 112.16R - 93.92G - 18.24B + 128$$

$$\overline{C_B} = -37.674R - 73.962G + 111.636B + 128$$

For efficient FPOA implementation, these three equations are then implemented as fixed-point. Using 16-bit coefficients and allowing a variable offset based on the number of bits in the input color values yields the following set of equations that are implemented in the Color Space Conversion core.

$$Y = (16{,}763R + 32{,}910G + 6{,}391B + Offset_Y) >> 16$$

$$C_R = (28{,}713R - 24{,}044G - 4{,}669B + Offset_C) >> 16$$

$$C_B = (-9{,}645R - 18{,}934G + 28{,}579B + Offset_C) >> 16$$

Use of 16-bit coefficients is well-suited to the FPOA architecture because the shifts in the implemented equations don't consume a shift operation. Instead, after the 32-bit addition of the offsets, the low word for the 32-bit result is dropped leaving the high word as the correct value for the color component.

4:4:4 to 4:2:2 Conversion

The Color Space Conversion core performs subsampling to convert from 4:4:4 to 4:2:2 format.

Estimated Performance

The table below summarizes the estimated performance of the Color Space Converter core.

Variable/parameter	Value
Input pixel wordlength	8, 10 or 12 bits
Output pixel wordlength	8, 10 or 12 bits
Throughput	1 gigapixels/sec
Frequency (max)	1 GHz
Target device	Arrix MOA2400D-10

Image size	Frame rate (max)
1024 x 768	1270 frames/sec
1280 x 1024	760 frames/sec
2048 x 2048	230 frames/sec

Note: Frame rate data above should be considered as an estimate.

Support

The Color Space Conversion core for Arrix FPOA is warranted against defects for one year from purchase. Twelve months of phone and email technical support are included. Licensing terms are available from MathStar.

Deliverables

The Color Space Conversion core for Arrix FPOA includes the following components.

- Cycle-accurate, bit-true simulation model for Visual Elite™ simulator
- Testbench
- OHDL files
- Mapping files for MathStar's COAST tool
- Design guide

Ordering Information

The Color Space Converter Core for Arrix FPOA is available as part number MIP-CSC02-P12. For further information, contact MathStar, Inc. at info@mathstar.com