Usage of the Chameleon Accelerator for Color Transformations

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Abstract

A hardware color transformation accelerator, in CMOS ASIC form, and its usage are described. The CHAMELEON ASIC performs multi-dimensional tetrahaedral interpolations at a speed of 10 Million (32bit) pixels per second. The achieved accuracy of the color transformation is a major topic, which strongly depends upon the kind of interpolation used. A report is made on the application of this ASIC in different fields of the graphics industry and the achieved results are compared to the desired market needs.

Introduction

Color becomes a common product in the graphics industry nowadays. This is due to significant increase in color technology and know how over the last few years. Indeed, we are witnessing the rise of for instance color printers with various kinds of technologies such as inkjet, thermal transfer, dye sublimation. Furthermore four color digital presses, and (digital) copiers emerge or have emerged on the market.

Though color is becoming a commodity, color consistency is not yet as common as color in itself. This is precisely a consequence of the different techniques used to reproduce color images. Every piece of equipment has its own typical characteristics to produce a color image. This commences with the primary colors used in these different devices, but does not stop there. Indeed, the precise technique, used to make a hard copy output is of the same importance as the primary colors. Consider for instance two hypothetical machines that use the same primary color pigments, but apply different techniques to produce a color image. Such machines would produce the same image in two different ways, yielding a color difference between the two printed images. As a consequence of this variety of different printers, it is obvious that the same digital data, sent to different output devices, will result in vastly different hard copies of the same image! In order to obtain a consistent color output on these different devices, a good color management system is needed. A color management system needs to characterize the different devices in a colorimetric way. This should be done by means of a spectrophotometer.

Once this characterisation is done, the color management system needs to provide color transformations in order to achieve color consistency between the different output devices. Color transformations are complex in nature, due to the non-linear relations between the different device coordinates. As a consequence color transformations are time and CPU-power consuming and in order to achieve acceptable performance an accelerator is needed.

The Chameleon Color Accelerator is a CMOS ASIC that provides accurate digital color transformations at very high speed. It can therefore be applied in different areas of the graphics industry. We will describe the exact nature of this ASIC and the achieved results in different applications.

Chameleon Architecture

Choice of Interpolation

A general color transformation can for example be built by means of an interpolator. Indeed, transformations from one device dependent or independent color space to another color space strongly depends upon the type of color spaces involved. The only way to cope with this is to provide a general hardware accelerator that can handle all these different transformations. One way to do this is to build an interpolator that has no knowledge of the precise nature of the transformation. An interpolator only needs data, which it has to use to interpolate with. This does not mean that the type of interpolation may not be well chosen in order to achieve maximum accuracy for a certain group of transformations.

For the Chameleon ASIC we have opted for a tetrahaedral interpolation, since it was experienced that this yields the best results in terms of accuracy. More specifically the different tetrahaedra are chosen in such a way that all of them have an axes parallel to the gray axes. This is particularly useful in for example RGB to CMYK conversions. The human eye is very sensitive to deviations in the gray balance, more commonly used trilinear interpolation results in errors along this gray axes, which do not occur with the type of interpolation as by the Chameleon ASIC.

Input and Output Resolutions and Mapping

The Chameleon requires three or four 8bit input components and produces four or less 8bit output components. Internally a higher calculation precision is used in order to minimize the effect of rounding errors. On input and output side of the ASIC there is a possibility to remap the input and output components before, re-

spectively after, they are used by the actual interpolator. This may be particularly convenient in order to compensate for changes in the tonal behaviour of the devices or in order to have non uniform distribution of sample points. It should be noticed that the ASIC is capable of dealing with the entire input range (0...255), because of the special way this range is divided. Although the Chameleon ASIC not really requires FIFO's to operate, (it could indeed be used as a 4bit deep intelligent memory of 32 bit words) FIFO's are required to obtain the highest possible speed of 10million pixels per second.

Different Operation Modes

Chameleon has basically two different modes of operation. In one mode it can convert four input components to four or less output components, in the other mode it converts three input components to four or less output components. In the four input component mode the number of samples per component is 16. This means that, in case of four output components, 256K of precalculated data has to be stored in RAM, external to the chip. In the three input component mode the number of samples per component is 33, which means that about 140K of precalculated data is required. In this mode the chip operates even a little faster, since it can convert at 12.5 Million pixels per second.

A Two-Channel Device

The Chameleon ASIC has the ability to cope with two different sets of input processes and two different sets of output processes. Each process can have different lookup tables to convert input coordinates to output coordinates. This requires of course twice the amount of external RAM previously mentioned. This allows transformations to be concatenated which can in some cases be very convenient.In Figure 1 you can find an overview of the Chameleon ASIC architecture.

Application of the Chameleon to Perform Color Transformations

Barco Graphics and a number of other companies are now successfully using the Chameleon ASIC in a number of products.

At Barco Graphics we developed a number of boards with the ASIC, such as two types of GIO-bus boards (a GIO32 and a GIO64) for the Silicon Graphics Indigo family, and a VME-board. The performance of the GIO32-bus board is about 4Megapixels per second. It is mainly used to make color accurate conversions from

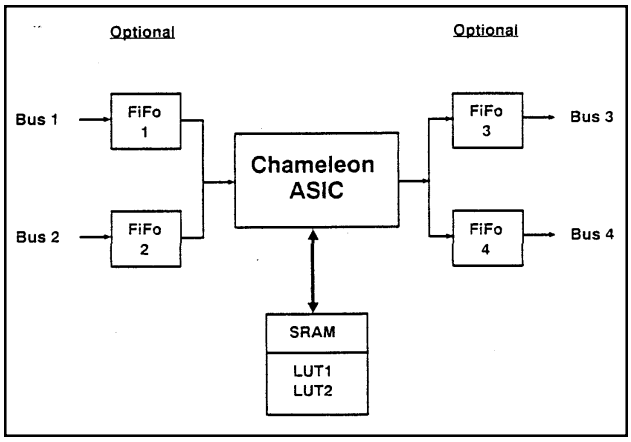

Figure 1. Fully configured chameleon

CMYK to RGB in order to have an accurate preview of prints on the monitor screen. Furthermore the VME-board has been used in more general color transformation applications. One of the applications is the conversion of CMYK data to proofer specific CMYK data in order to obtain color accurate contract proofs, from for example an Iris ink jet printer. In this area of application very accurate results were obtained that showed color deviation of 1 CIELAB delta E or less between the wanted and the actually printed result. From our experience in the graphics market this result is more than acceptable for the needs of this market.

Another typical application that has been developed at Barco Graphics is called InkSwitch. It is meant to convert CMYK scans to a combination of special colors, such as PANTONE colors. This could for instance be a warm red, a brown, a yellow and a black. From our experience we came to the same conclusion: the Chameleon color accelerator can produce very accurate color transformations with a precision better than one delta E.

Conclusion

The architecture of a CMOS ASIC color accelerator has been presented. A number of applications using this ASIC have been described, such as for example CMYK to RGB conversions or conversion from CMYK to a set of special colors. From these applications it was demonstrated that this ASIC can produce very color accurate transformations, at the very high speed of 10Million pixels per second. This high precision and speed is an asset for different applications in the graphics market.