Visual Enhancement Engine (VEE) for Image/Video Processing

QuickLogic® White Paper

Introduction

Today's consumers demand multimedia experiences whenever and wherever they want it. Mobile handsets, tablets, smartbooks and netbooks are gaining more popularity as portable multimedia centers. As voice, navigation, productivity and entertainment converge, multimedia continues to be one of the key market drivers. The ability to watch mobile television, view movies, and play video games are key product differentiators.

However, one common problem for mobile multimedia devices is the viewing of video under bright or varying ambient light conditions. Under bright light, content is often not viewable on standard mobile devices. If the screen is viewed under heavy ambient illumination, its effective dynamic range consumption is dramatically reduced. The common solution is to increase the backlight brightness or display power. Unfortunately, doing so increases power consumption significantly, diminishing battery life.

QuickLogic's VEE technology enables a television-quality visual experience on portable devices, while dramatically reducing the backlight or energy level of the display to improve battery life. This technology delivers the next generation of mobile entertainment experience by adapting display data, in real-time, to improve the ability to view video on Liquid Crystal Displays (LCDs) or Organic Light Emitting Diode (OLED) displays under low backlight or in bright ambient light conditions. QuickLogic's proven VEE solution greatly enhances image and video quality for handset users by compressing the dynamic range to match the characteristics of the display, resulting in a substantially better viewing experience. VEE technology is available as a QuickLogic Proven System Block (PSB) option in the PolarPro® and ArcticLink® II solution platform families of products.

VEE Technology

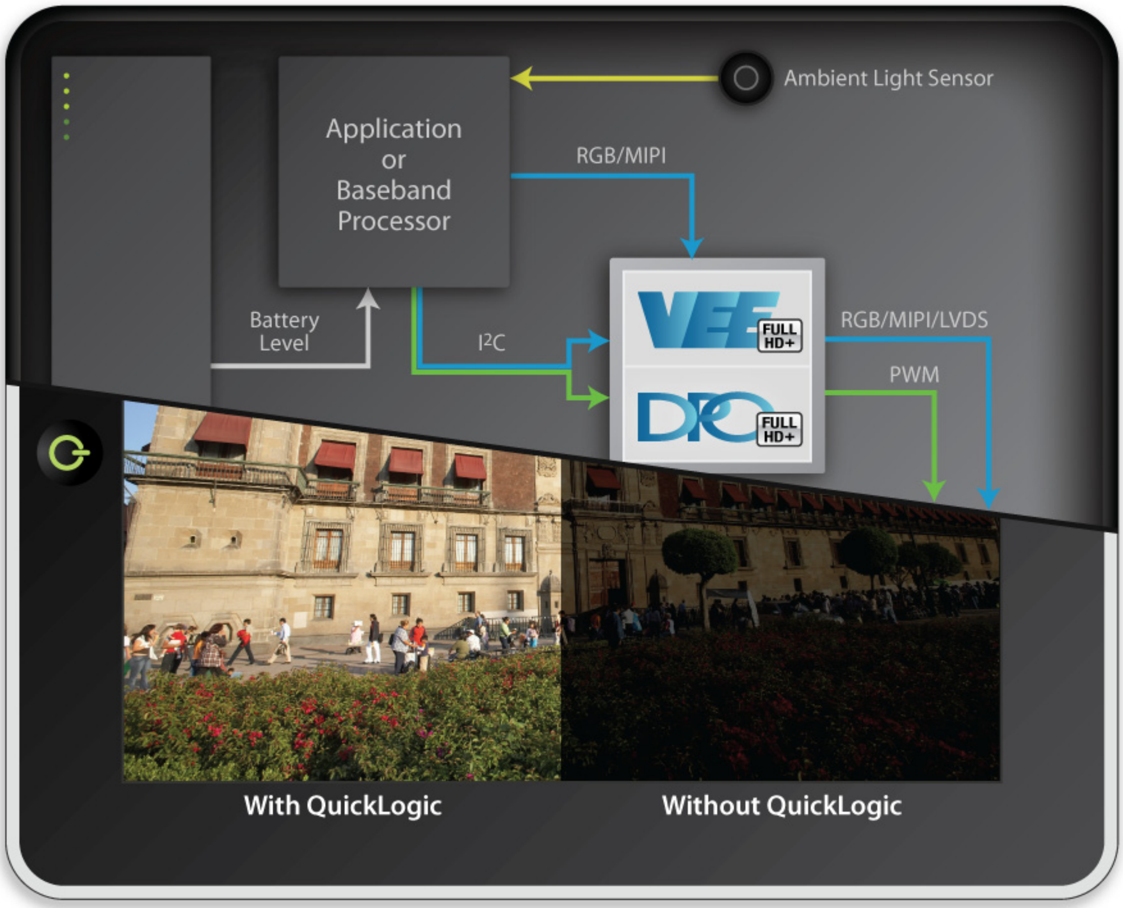
QuickLogic VEE technology is based on the iridix® algorithm from Apical Limited. iridix is an implementation of a set of algorithms based on the Orthogonal Retina-Morphic Image Transform (ORMIT), developed by Apical and protected by multiple patents. It is a sophisticated method of dynamic range compression (DRC), which differs from conventional methods such as gamma correction in that it applies different tonal and color transformations to every pixel in an image. These algorithms implement a model of human perception, which results in a displayed image that retains detail, color and vitality even under difficult viewing conditions. VEE technology specifically addresses the problem of the low contrast ratio of mobile displays to bring a more television-like viewing experience to mobile devices.

Conserving power when playing back video content is also a significant issue when designing mobile devices. QuickLogic's VEE solution substantially enhances video quality, and enables a superior viewing experience under low backlight or bright ambient light conditions. Combined with an ambient light sensor, system engineers can adjust VEE based on ambient light and display backlight or energy level to achieve optimal battery life.

VEE Architecture

Figure 1 illustrates the QuickLogic VEE architecture.

Figure 1: VEE Architecture



What is Dynamic Range Compression?

All consumer devices employ DRC to render a source image or video stream suitable for display on an output device.

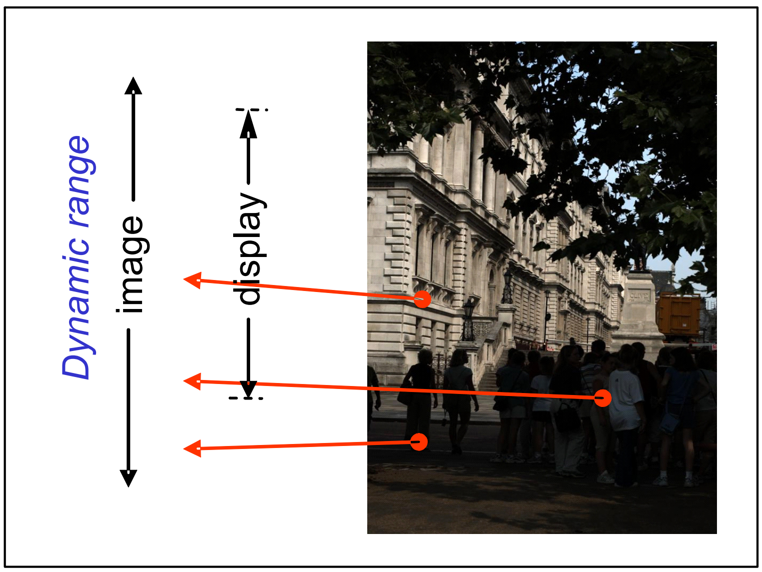
Dynamic range is broadly defined as the difference in intensity between the darkest and brightest of a scene. The human eye can capture a very wide dynamic range of five orders of magnitude. However, typical displays can reproduce information over a range of only a few hundred counts or less.

The dynamic range capability of a display is governed by the display technology (LCD, PDP, or OLED), the power or brightness, the amount of screen reflection and the ambient lighting conditions.

Therefore, to retain as much information from a real-world scene after digital capture, transmission and display, dynamic range must be compressed at each step along the chain. In some applications, dynamic range expansion may be required.

Furthermore, even if the display has a dynamic range capability equal to or exceeding that of the original video, DRC is still required to produce natural-looking video. Because the human eye can apply very strong DRC, a displayed video will only look natural and realistic if the same kind of processing is applied. If the display is large enough that the video fills the viewer's visual field, the eye can apply this processing itself. However, the most common use case in portable devices is that the display fills only the central portion of the field of view. The eye cannot perform this processing optimally and therefore digital processing must be substituted. As shown in **Figure 2**, the dynamic range of the video exceeds the dynamic range of the display resulting in loss of details.

Figure 2: Dynamic Range of Image without VEE Technology



Algorithm Background

ORMIT was developed as a result of research into biological visual systems, with particular emphasis on the human. Pre-existing models to ORMIT suffered from a number of limitations, in particular in the generation of artifacts, lack of adaptivity to different scenes, and computational complexity. The key aims in the development of ORMIT were to:

- develop a set of algorithms which model the dynamic range processing performed by the human visual system
- overcome clear deficiencies in existing algorithms and models
- provide a mathematical framework suitable for efficient implementation in digital devices

iridix has been proven to be:

- non-linear

- adaptive (meaning that the transform is calculated based on a statistical analysis of the source image)
- space-variant (meaning that the transform is sensitive to different regions of an image)
- optimized in QuickLogic's VEE implementation to handle video content with ultra-low power consumption and virtually no CPU overhead

In effect, iridix automatically generates and applies a different tone curve transform to every pixel in the input video (as shown in **Figure 3**), based on global user parameters which control its general behavior.

Figure 3: Various Tone Curves Based on Image Context

Most current consumer devices use transforms which are non-linear, fixed (non-adaptive) and uniform (space-invariant). A familiar example is gamma correction, commonly used in consumer devices. More sophisticated systems employ tone curve correction, and in some cases (adaptive) histogram-based correction.

Transforms, while well-established and straightforward to implement, suffer from considerable drawbacks such as:

- damage to regions of the source image which are already well-balanced (leading to over-saturation if applied strongly)
- loss of contrast which tends to produce undesired color changes that must be compensated for

Acceptable image quality is achieved only if these transforms are applied weakly. As a result, important visual information is lost between capture and display in conventional systems, and videos do not look as natural as possible.

To overcome these limitations, an adaptive, space-variant transform must be used. However, constructing such a transform that performs reliably and without artifacts under all conditions is not a trivial task. Such algorithms tend to suffer from:

- halo
- edge and color artifacts
- unstable black and white points
- excessive computational complexity

iridix is one of several space-variant algorithms (for a recent review of others, see Ledda et al., *ACM Transactions on Graphics (TOG)* V24, Issue 3 (2005)). However, iridix is to date the only method that has found successful application in digital imaging products, due to its combination of high image quality, lack of artifacts, ability to achieve strong DRC, and high efficiency. The current version is the result of years of intensive development based on the core algorithms, and is robust, high-quality and well-proven.

iridix provides strong enhancement of dark and bright areas of a video, while leaving midtones unchanged. As shown in **Figure 4**, contrast and color is preserved in all areas. iridix DRC is powerful enough to compress a 16-bit original image into an 8-bit format with no loss of image detail.

Figure 4: Improved Image Quality Using VEE Technology

The principal factor limiting the strength of iridix processing is the signal-to-noise ratio of the source video. The basic algorithm does not distinguish between video detail and noise; noise in very dark or bright areas may be rendered visible after processing. Practical implementations of iridix include a gain control feature which limits the strength of processing in different intensity ranges, so that noise is always kept outside the visible range.

More recent developments and additions to the core iridix algorithms have been the incorporation of modules for non-linear space-variant color correction, noise reduction, and preservation of fine detail.

To further improve display quality, VEE technology has been supplemented by additional image and video enhancement blocks such as dithering, hue rotation, color correction, and non-linear sharpness filtering.

Key Parameters of the VEE

There are three fundamental parameters:

- *Strength:* Sets the overall degree of DRC. It is directly related to the ratio between the dynamic range of source and output device.

- *Variance*: Sets the spatial sensitivity of the algorithm, or the area in which iridix samples in order to generate the tone curve for each pixel. Measurements have established a default value which matches most closely the effect of the human visual system, but other values can be chosen in applications where, for example, maximum detail visibility is required and most natural appearance is of secondary importance.
- *Asymmetry:* Sets the weighting given by the transform to dark areas compared to bright areas (shadows versus highlights). Measurements have established a default value which matches most closely the effect of the human visual system (which enhances dark regions much more strongly than bright ones) but other values can be chosen, such as those which enhance shadows and highlights symmetrically.

Summary

Space-variant DRC algorithms offer significant advantages in video quality over standard algorithms, and are applicable to any video device. If wide dynamic range source images are to be rendered on typical displays without significant loss of information, or a natural-looking image is desired, a space-variant method must be used. This is an active and developing area of imaging research, but such algorithms are not trivial to design or implement effectively. Of the available approaches, QuickLogic's VEE technology has specific advantages which have resulted in its adoption in a range of applications.

QuickLogic's VEE technology is available on the PolarPro and ArcticLink II solution platforms targeting the fast growing mobile multimedia segments including:

- Mobile (Handsets): Smartphones, multimedia phones, and high-end feature phones
- Compute: Tablets, netbooks and smartbooks
- Consumer Electronics: personal media player (PMP), personal navigation device (PND) with video capability, and digital camera/camcorder

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Revision History

Revision	Date	Originator and Comments
A	May 2008	First release.
B	April 2010	Paul Karazuba and Kathleen Bylsma
C	May 2010	Kathleen Bylsma
D	May 2010	Paul Karazuba and Kathleen Bylsma

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