The SmoothPicture™ Algorithm: An Overview

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DLP™ TV

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Abstract

This white paper will discuss Texas Instruments (TI) SmoothPicture™ technology. A diamond grid Digital Micromirror Device (DMD) is coupled with an optical actuator to produce smooth, film-like picture in a DLP™ technology-based rear projection display system while revealing the entire resolution of the input image.

Introduction

Over the past five years, DLP technology has made significant progress in the rear projection television market.

First generation DLP TVs used an HD1 1280x720 pixel DMD and demonstrated the feasibility of applying the DMD in rear projection televisions. These first DLP televisions featured outstanding image quality, albeit at a premium price. TI's second generation HD2 chipset, introduced in 2002, improved overall image quality beyond that of HD1 and enabled substantially reduced system costs, moving DLP high definition TVs into a regime of mainstream affordability.

TI's goals for its 3rd generation chipsets were to continue to drive to higher image quality and resolution while simultaneously making system costs even more affordable. Development of the third generation chipset and TI's SmoothPicture™ technology has allowed realization of these goals.

The Diamond Array DMD

With the first two generations of DMDs, TI used an orthogonal pixel array to generate a 1280x720 image. The orthogonal array used a 1:1 image pixel to mirror display ratio. This means that each mirror was dedicated to displaying one image pixel on the display device (see Figure 1).

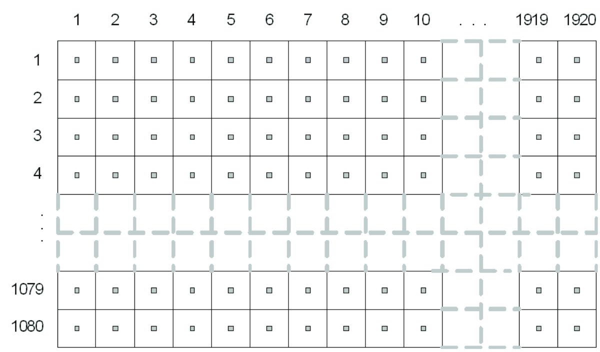

Figure 1. The Orthogonal Pixel Layout used for HD2+, HD2, and HD1 DMDs

In order to realize program goals of creating higher resolution devices while simultaneously decreasing system costs, TI developed an innovative new DMD. This new DMD utilizes an offset diamond pixel layout utilizing mirrors which are rotated 45 degrees with respect to those in an orthogonal DMD (see Figure 2).

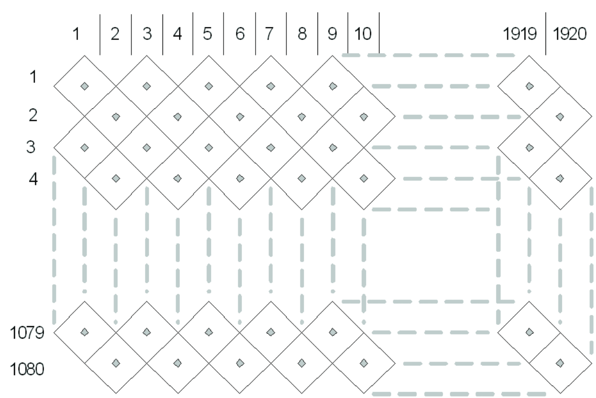

Figure 2. The Offset Diamond Pixel Layout used in the new HD3 and xHD3 DMDs.

Two DMDs were developed oriented around 1280x720p and 1920x1080p high resolution TV standards respectively. The new DMD diamond layout supports, in the case of the 1080p device, 1920x1080 resolution, with 960 distinct column pairs and 540 distinct row pairs (a row pair consists of one black and one white row). This permits display of a 1920x1080 image using ½ the number of pixels in an orthogonal array, with some loss of diagonal resolution. By using the diamond configuration, the 1080p DMD chip size approaches that of the HD2 720p chip, creating a cost effective device which can display additional vertical and horizontal resolution.

SmoothPicture™ Technology

While the diamond grid DMD effectively improves system cost, by itself it is insufficient to display all of the original image pixels on the screen. The original image would have to be filtered to produce an image with half the number of pixels of the original image in order to be displayed on the DMD. TI's SmoothPicture™ technology combines the diamond grid DMD, with its inherently high mirror switching speed and an optical actuator to create a system which can display a full resolution image onscreen containing all of the original image pixels. With SmoothPicture™, the actuator optically displaces the DMD image horizontally, coordinated with the display of two separate subframes of data on the DMD (see Figure 3). Utilizing the high switching speed of the DMD, both subframes of data containing all of the original pixels in the

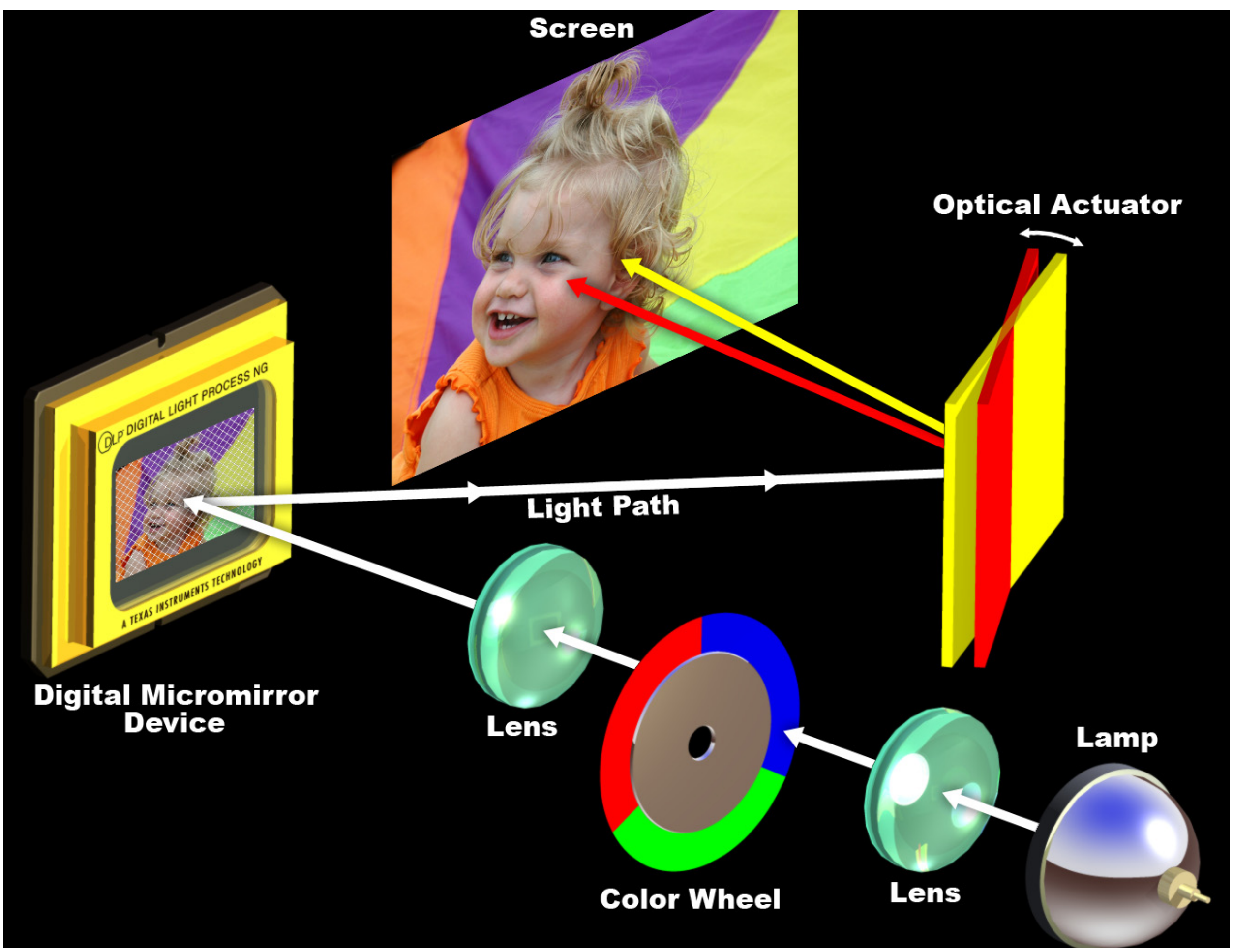

Figure 3. SmoothPictureTM Light Path

image can be displayed within one 16ms field time.

Referring to Figure 4, each incoming video frame is parsed into the two separate subframes, one subframe containing all of the odd image pixels, the other containing all of the even pixels. The 16ms video field time is subdivided into two 8ms subfield times. During the first subfield time, the odd subframe data is displayed. At the beginning of the second subfield time, the actuator horizontally shifts the DMD image by ½ pixel, and the even subframe data is displayed. The resulting onscreen image contains all of the pixels in the original image frame, and is constructed within one 60Hz video field time.

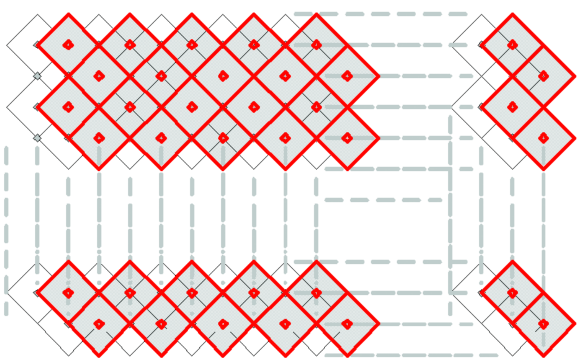

Figure 4. The result of moving the offset diamond DMD by 1/2 pixel.

Note that even though a diamond grid DMD is used, the horizontal displacement methodology recreates the original orthogonal grid of the HD image frame. An additional benefit of the ½ pixel displacement is that it effectively softens the pixel edges. In static orthogonal displays (using a 1 mirror to 1 pixel display ratio) the mirror edges are distinctly visible which in some display technologies results in the familiar screen door effect. With SmoothPicture™, this artifact is mitigated resulting in a seamless, more film-like image.

Effective SmoothPicture™ Display Resolution

The effective resolution of a display device can be quantified by measuring the display system Modulation Transfer Function, or MTF.

The MTF of a display system is a measure of the display's spatial frequency response. It quantifies the display contrast at a given spatial frequency relative to the display contrast at DC (i.e. a flat field). MTF is typically measured in the form of line pairs per unit distance, a line pair consisting of a bright line coupled with a dark line. High spatial frequencies correspond to fine image detail. The more fine image detail that can be displayed, the sharper the image.

During the development of SmoothPicture™ Technology, Texas Instruments evaluated the MTF performance of the SmoothPicture™ based display systems with respect to other display technologies used in 1080p rear projection television displays. Figure 5 shows the MTF of a SmoothPicture™ based 1080p DLP display relative to the MTF of two leading, commercially available LCOS based 1080p rear projection TVs. Note that the DLP display curve rolls off at a higher spatial frequency, indicating that it more effectively translates the 1920 x 1080 addressed image resolution into effective resolution at the eyeball.

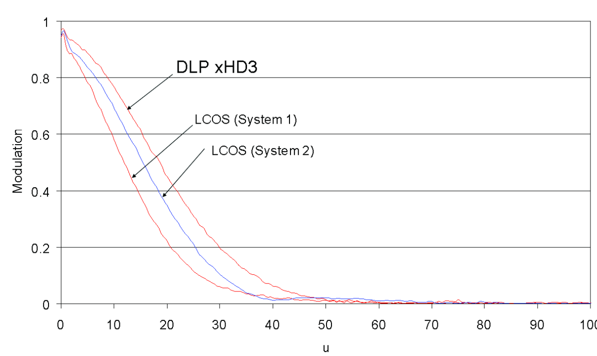

Figure 5. A comparison of normalized MTF

Conclusions

Continuing a tradition of display excellence, Texas Instruments has invented SmoothPicture™ Technology that enables high resolution digital display systems at an affordable price point.

These new displays use DMDs with a new diamond pixel layout pattern. In order to achieve full orthogonal resolution, Texas Instruments has coupled the unique diamond DMD architecture with an optical actuator to implement SmoothPicture™ Technology.

The technology displaces the optical image by ½ pixel thus utilizing each DMD mirror to display two pixels on the display face. The SmoothPicture™ technology results in a smooth film-like image without visible pixelization while displaying all of the image data supplied by the video source.

Acknowledgments

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