Microdisplay Projection HDTV

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Abstract

High definition, digital television has driven consumer expectations to larger screens, higher quality video and audio performance and new functions and applications. Consequently a technology revolution is occurring in which tiny micro-displays are manufactured utilizing silicon CMOS processing techniques. The devices are optically magnified to provide the highest image quality. Liquid crystal on silicon (LCOS) technology most naturally provides true high definition and takes advantage of the steady advances in silicon processing. This talk will summarize LCOS technology and the reasons that it is expected to play a major role in the large screen HDTV market.

Introduction

The rapid acceptance of digital TV, evolving to high definition digital TV, transmitted by satellite, cable and terrestrial broadcast has stimulated an unprecedented development of TV display technology over the past several years. In many markets LCD flat panels have overtaken direct view CRTs as the dominant technology for small to medium size TVs. In the larger screen sizes both plasma and micro-display rear projection technologies are rapidly replacing CRT projection technology. I intend to discuss why these shifts are occurring, why certain of the new technologies have an advantage to "win" as this period of rapid innovation plays out and what characterizes the winning technologies.

It's a simple but important fact that the transition from the standard 4 by 3 screen format to the wider, more cinema-like 16 by 9 format makes the screen appear smaller if the screen diagonal is the same (image size is usually associated with screen height and a 16:9 screen has smaller height than a 4:3 screen of the same diagonal). This fact alone drives the consumer to "need" a larger screen. The higher resolution images, which are provided by HDTV, enable the viewer to "see" more information on the screen, so that at a fixed viewing distance he benefits from a larger screen. Finally, the display technology has evolved to be capable of providing an excellent image on a large screen. As an added benefit, most of the new technologies are capable of displaying excellent text and graphics images as well as video. This, in turn, stimulates the development of new applications, which are evolving concomitant with the technology.

Microdisplay Technology

With the rapid growth of LCD technology into the 37" and above size range, albeit at high but not outrageous prices, plasma and rear projection HDTV find their natural markets in the larger sizes from about 50" and up. In these larger sizes plasma competes and receives a certain amount of consumer "mindshare". However, currently and for the foreseeable future, the cost of true high definition plasma in large sizes exceeds substantially that of the rear projection technologies. The cost of rear projection scales up substantially more slowly in price than it does in size. Plasma, of course, maintains an advantage as a "flat" screen technology (although projection has been making strides in the direction of thinner and almost flat designs).

CRT projection technology has been the standard for large screens for some 20 years. It utilizes three small (5" to 9") CRTs which are driven respectively with red, green and blue video data. The R, G, B images on the three CRTs are magnified and optically converged on the rear projection screen. This technology provided the first and is currently the least expensive large screen TV. However, its limitations in brightness, resolution (exasperated by optical convergence involving the entire mechanical chassis) and its physical weight and bulk are believed by most in the industry to relegate it to the status of an historical relic within a few more years.

Microdisplay rear projection is rapidly replacing CRT projection and has already captured over half of the RPTV market. Microdisplay devices are typically tiny displays (less than an inch in diagonal) manufactured using micro-electronic type processes and facilities. These displays are illuminated by an intense arc lamp (possibly replaced in the future by LEDs or by lasers) and optically magnified and focused onto the rear projection screen. Three types of micro-display technology are currently in use. These include high temperature poly-silicon (HTPS) devices, digital micro-mirror (DMD) devices and liquid crystal on silicon (LCOS) devices. Each has its advantages and weaknesses.

HTPS devices are basically small, transmissive LCDs. Because light has to go through the device and circuitry inevitably blocks some of that, it is difficult to scale the device to very small pixels. Therefore, a full high definition resolution of 1920x1080 pixels results in rather large and expensive devices. Three devices are required to provide full color images (R, G, and B). Other issues associated with the screen door effect due to the transmissive property and response time concerns for fast video are performance limitations of this technology.

Digital light processing associated with the DMD device utilizes a single device and color sequential illumination to achieve full color images. The device must be fast to display three colors without color breakup and to provide a pulse width modulated gray scale. Because the actual DMD micro-mirror does not easily scale to smaller sizes, a wobulation technique has been developed to use each physical pixel on the device to produce two pixels in the image. This enables the device to project a full 1920 by 1080 image from a device with fewer than 1 million pixels. The rapid switching of the individual micro-mirrors on the device to achieve color sequential operation, pulse width modulation gray-scale and wobulation resolution enhancement can lead to color breakup and other forms of digital artifacts including noise and imperfect gray-scale rendition.

LCOS is the technology that many in the industry believe will eventually dominate the true high definition RPTV market. An LCOS device consists of a silicon chip, a cover glass with a transparent common electrode and a thin layer of liquid crystal between them. Circuitry on the silicon chip serves to provide the video data to drive the LC to its appropriate orientation. The video voltage is applied between each of the up to 8 million individually addressed mirrors and the common electrode. The individual pixel size (i.e. mirror size) is limited only by silicon processing (virtually no limit), the LC gap width (limited by available LC materials) and by the ability of an optical system to efficiently illuminate a small device (the etendue problem). In practice, 8 micron pixels are in wide spread use, products using 7 micron pixels are on the market and 5 micron pixels are under development. This scalability to smaller pixels and smaller and less expensive devices is a major advantage that LCOS has over the other micro-display technologies.

Many sometimes obvious and many more subtle reasons have caused this rapid transition to micro-display rear projection HDTV. These include size and bulk. Whereas CRT RPTVs are invariably heavy floor standing models, micro-display RPTVs are typically 2X to 3X lighter than a corresponding CRT RPTV and are most often table top designs. MD RPTV cabinets are shallower by typically a third than CRT RPTVs and the industry trend is to still shallower designs that will fit on bookshelves and possibly even be capable of wall hanging. Most MD RPTVs project and magnify the full color image through a single lens; the color convergence is provided in the optical light engine, rather than by converging three images on the screen. This, together with their fixed pixel format of the micro-display device, provides a higher resolution, sharper image. Text and graphics are substantially more “readable” on an MD RPTV compared to a CRT RPTV. Although the black state of a CRT in a dark room is excellent, the MD RPTV black states have improved dramatically over the past couple of years and are now very competitive with CRT RPTV. In a bright room the RPTV screen provides image discrimination against ambient light, providing advantage over plasma.

LCOS Technology

Although widely regarded as the “ideal” technology, LCOS technology has in the past proven to be difficult to manufacture and most of the MD RPTV market has been shared by HTPS and DMD. However, with technological advances LCOS products have begun to appear. Kolin introduced a 50” LCOS 720p RPTV a few years ago. JVC introduced its 720p LCOS RPTV over a year ago. JVC, Sony, Syntax-Brillian and LG have recently introduced full 1080p LCOS RPTVs to some critical and market acclaim.

Part of the reasons for these product introductions are the advances in the device itself. In general the devices are easier to yield and have better performance the smaller they are. Therefore, as the materials and designs have gone to smaller pixels and hence smaller devices they have become less expensive to produce, while improving their performance. Particularly black state level and uniformity have dramatically improved with a vertical aligned LC mode and improved mirror processing on the silicon surface. Uniformity of the device has improved, even while eliminating cell gap spacers (which can be visible in some images) from the imaging area. In general all up stream formatting and signal optimization is done in the digital domain. However, both fully digital pixels (JVC consumer RPTV) and analog pixels (JVC professional and Sony, Syntax-Brillian and LG consumer RPTVs) are in use. Grayscale in a digital device relies on rapid pulse width modulation of the LC. In an analog device the grayscale is voltage controlled. Both can work with the “purists” favoring analog pixels because of the flexibility available to precisely replicate of the desired grayscale. The electronics designed to “drive” the LCOS devices is generally quite specific to the device and usually in FPGA or ASIC form.

Optical “light engines” for LCOS have also progressed dramatically in recent years. Films have been developed by MMM and Colorlink to control polarization leading to novel architectures, which provide high brightness and excellent contrast. Moxtek has developed a line of wire grid polarizers which provide their own unique architecture. The market has yet to determine which architecture, as determined by both cost and performance, will prevail. In addition very high quality projection lenses have been developed, typically using both glass elements and aspherical plastic elements. Very high quality dichroic elements, prisms and integration optics are in high volume manufacturing at low cost. All of these advances are leading to optical architectures which provide outstanding image quality and low cost when combined with state-of-the-art LCOS devices.

The remaining contributors to the performance of an LCOS RPTV include the video processing, the audio, the rear projection screen and the chassis. These tend to be similar if not exactly the same as these components are for other types of MD RPTVs. In that respect LCOS can “piggy back” on the steady advance in these technologies.

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