# Utilization Issues for Large Consumer Video Displays

By Jeffrey B. Sampsell

*The acceptance by U.S. consumers of large screen, rear projection video receivers will grow until this segment of the television market accounts for approximately a million units per year and the largest share of profit from sales. The near term availability of high-definition digital television (DTV) signals in the U.S., Japan, Europe, and elsewhere will continue to drive growth in this sector. New market opportunities will emerge for rear projection, front projection, and flat panel large screen displays. This presentation will briefly review the diverse technologies available to serve these three types of display. Comparisons will be drawn between the quoted/expected display specifications, which tend to be driven by engineering and marketing criteria, and the actual performance required and/or likely to be achieved in the consumer's dwelling, which tends to be determined by architecture, furniture, children, pets, school, work, dinner, and the limits of personal wealth.*

The digital compression systems that create the video signals to feed the large direct view displays of the immediate future are without exception based on the inherent limitations and abilities of the human visual system. The displays themselves have been created with significantly less attention given to the human visual system and the prospective viewing environment. Design of the consumer's dwelling for the most part tends to take such factors into account only in an incidental fashion. The integrated circuits processing video signals immediately before display have only recently begun to acknowledge such factors, and much work is left to be done in this area.

The user's viewing experience will be affected both by the careful consideration given to these factors in some engineering areas and by the relative ignorance of the human visual system and viewing environment in other areas. As the impact of these effects on the viewing experience are considered, it will show that such considerations should be a significant driving force for the engineering tradeoffs involved in designing large, consumer display systems.

This paper will concentrate on four aspects of the display/viewer system: the size of the viewed image, the arrangement and illumination of the viewing room, the type of display system, and the digital processing of the video signal at the display. Attention will be given to impacts on system components, in addition to the impact on the overall display system. Challenges in the marketplace and the end-use home environment will be explored.

## Display Size—How Much is Enough?

Experiments have been conducted in which human subjects are given folding chairs and asked to enter a room illuminated at a comfortable level for viewing and empty save for a video display. The subjected is asked to take his time and place the chair at a comfortable viewing distance from the display. This results in the cluster of the chairs around a "sweet spot."

The location of the sweet spot is generally considered to be driven by the angular resolution capability of human vision. Typically, the human eye can resolve 25-30 light/dark cycles per subtended degree of visual field. An NTSC signal provides 480 scan lines, each constitute of 1/2 of a light/dark cycle at most. This 240 cycle display will match the eye's acuity at a subtended angle around 9°.

A 27 in. diagonal television receiver yields a picture height of 16 in. This 16 in. picture height will subtend a 9° field of view 8.5 ft from the display. If an average viewer sits farther away than this from a 27 in. receiver he will notice a decrease in image resolution. If he sits closer than this he will notice a decrease in image quality, because he will begin to see artifacts of the display technique. So there is a "sweet spot" where the viewer can see what he wants, and the things he doesn't want to see are invisible to him.

We find that most television viewing areas in consumers' homes (and indeed the rooms that contain those viewing areas) are configured to place the prime seating area at or near this "sweet spot." It is interesting to consider how the arrival of high-definition video affects this situation. The U.S. DTV standard specifies high-definition images of 720 lines progressively scanned and 1080 lines scanned in interlace mode. For the "sweet spot" of a 1080 line, 16:9 aspect ratio image to occur at this same 8.5 in. viewing distance, the diagonal measure of the display will be approximately 70 in.

This simple fact places the consumer in a quandary regarding a system upgrade to high-definition capability. The "sweet spot" for appreciating high-definition fidelity from a 36 in. diagonal direct view CRT display is around 50 in. It is unlikely that a large number of consumers will be willing to sit 50 in. from their television receivers. A rear projection receiver can be considered, but the

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bulk of a 70 in. diagonal rear projection unit is enough to overwhelm most rooms. A direct view flat panel display might be a wonderful solution, but 70 in. diagonal panels remain well in the future. A front projection unit can easily achieve the 70 in. diagonal, but front projectors require a significant rearrangement of viewing conditions that may not be reasonable in most homes.

## Room Arrangement and Illumination—Does this Feel Like Home?

The preceding section concluded by considering 70 in. front projection for the home as a near-term solution capable of delivering high-definition quality to viewers seated more than 50 in. from the display surface. But front projection runs afoul of a serious consideration in most homes—room illumination. Display experts disagree over many things, and almost always disagree over the answer to the question, "What is the proper specification for contrast ratio to assure a good display?" This disagreement is driven to a large extent by the existence of many different kinds of displays, many different ways to measure contrast ratio, and many different display applications. It takes courage to even put a number down on the printed page, but for the sake of argument let's say one would want an entertainment display for the home to support a contrast ratio of 250:1.

The ambient surface illumination in a moderately bright viewing room might be 25-ft candles. A fairly dim viewing room, probably dimmer than most consumers would tolerate their living room, might have a surface illumination of 1-ft candle. Under these conditions the ambient light falling on the theoretical 70 in. viewing screen would be 350 lumens and 14 lumens respectively. If we assume a spatial light modulator based front projector capable of putting 1000 lumens on the screen the best contrast ratio achievable in these two cases would be 70:1 and 3:1 respectively. A CRT based front projector, achieving only half this brightness, would achieve only half the contrast ratio as well.

So, given the definition of adequate contrast ratio it is unlikely that front projectors operating outside a room darkened to "theater" levels can achieve a contrast ratio high enough to justify their expense. They cannot deliver the high-quality, high-definition experience that consumers might demand in an environment that most consumers can tolerate and afford.

## Type of Display—Does Anything Fill the Bill?

The preceding sections, while illustrating some things that humans need in order to feel they are seeing "good video," have inadvertently discussed the pros and cons of some display types. It was discovered that the diagonal measure of direct view CRTs is not adequate to provide the high-definition experience to viewers seated at a "conventional" distance from the screen. It is evident that front projection displays do not provide adequate quality images on screens of the diagonal measure required to convey high-definition quality to a room of viewers.

Direct viewing of video on flat panel displays (FPDs) tends to be in small windows, at low resolution and low frame rates. The inherent limitations of such applications make the quality of the display device somewhat irrelevant—the video was bad, how good did the display need to be?

Several factors are driving a change in this situation: display technology advances are yielding viable, full color plasma, and LCD panels with diagonals in excess of 40 in., wireless communication systems are creating demand for more capable mobile information solutions, and high-definition digital video has arrived. In this environment consumer acceptance of FPDs as video display platforms will be high if they can deliver high-quality at high-definitions. Technical viability of such direct view FPDs has yet to be shown, and commercial viability will lie several years past the technical threshold.

Rear projection systems seem the logical candidate for high definition in the near future. Currently, this market segment is dominated by projectors using three non-shadowmask CRTs to superimpose red, green, and blue information on a lenticular screen. Rear projection receivers based on projection from spatial light modulators (SLMs), most commonly LCDs, have some presence in the market, but their cost/performance trade-off has not favored them.

The transition from standard-definition (480 NTSC or 576 line PAL) video to high-definition (in excess of 1000 lines) video seems to favor projectors based on SLMs. As seen, high-definition calls for larger screens and larger screens will place higher convergence tolerances on the rear projection optical system. The dimensional stability of SLMs should be superior to that of the CRT scan geometry. The increased number of scan lines requires a tighter spot size from the CRT, while correct pixel size is inherent in the construction of an SLM. Larger screens also call for greater light output. Rear projection CRTs seem to yield higher brightness each year, but it has been an incremental progression. High-definition SLMs, being physically larger than standard definition SLMs, will be easier to illuminate.

Additionally, without the glass envelopes of the CRTs, the structure to keep them aligned, and the need to design for the space they fill should be possible to build an SLM-based rear projection unit with much less of the bulk and weight of CRT-based units. This may be the most important issue from the consumer's point of view. Consumers' intolerance of the way in which a bulky rear projection unit dominates a room has perhaps been the major limitation to increased market penetration by this class of products.

## Digital Video Processing—Where's the "Vertical Size" Adjustment?

If we decide that at least for a few years our future lies with SLM-based rear projection, an examination of the digital processing required to display high-quality video on pixelated SLMs is in order. The requirements for SLM specific digital processing are best understood by enumerating the critical differences between CRTs and SLMs.

1) SLMs are pixelated. In systems that support more than one input video format this assures the necessity of sampling the video input signal on a grid disparate to the one from which the original image was created.

2) SLMs in almost every case have no inherent capability to implement interlaced scanning of video material. In systems that must support interlaced video inputs this assures the necessity of executing a conversion from interlace scanning to progressive scanning.

3) SLMs lack an inherent ability to brighten small, high-intensity image areas in a non-linear manner. Hence, adaptive processing of the video signal is required for SLMs to produce anything like the "sparkle" or "life" that we have come to expect from watching direct view CRTs.

Considering these factors, especially in light of a U.S. DTV standard that supports 18 broadcast formats and several more that will likely be used for cable television, the importance of high-quality algorithms to execute spatial and temporal image scaling, interlace to progressive scan conversion, and adaptive brightness adjustment on a pixel-by-pixel basis is evident.

Manufacturers of SLMs have an opportunity to sell such algorithms (embedded in support ICs) along with their SLMs. Niche market IC manufacturers see an opportunity for their products to become critical components in volume television receivers. Display system integrators find themselves facing the possibility that key contributions to the perceived quality of their display may be out of their control for the first time in decades. It is clear that digital video processing has assumed a larger role in display manufacture then ever before.

## Other Components —What Else Do I Need?

The direct view CRTs and rear projection CRTs that have provided essentially all the video needs for decades will be challenged at the discontinuity represented by the advent of high-definition television. There are strong reasons that suggest SLM-based rear projection will mount this challenge, but there are also limitations to the challenge that may leave CRTs with the upper hand.

SLM-based projectors require a lamp to illuminate the SLMs. These lamps need to be replaced periodically, and they are expensive. Significant penetration in the home market will require a significant combination of lamp lifetime increases and lamp price decreases. Work is ongoing in this area by several manufacturers, but the ultimate solution remains in the future.

It is straightforward to see how SLM-based projectors will be less bulky than CRT-based projectors. It is also straightforward to see how SLM-based projectors can be smaller than CRT-based projectors. However, most of the size reduction takes place in the base of the projector, close to the floor where bulk is less obtrusive. The true promise of bulk reduction in rear projectors will be seen with optical innovations that take advantage of the "point source" nature of SLM imaging as opposed to the large dispersed source nature of a CRT-based projector. Such optical innovations remain in the future with better lamps.

## Conclusion

We've seen that in order for the transition to digital television to be synonymous with the transition to high-definition television, prices for receivers with high-definition displays will have to fall (so that high-definition becomes "painless" for the consumer) or the true high definition experience will have to be delivered to the consumer so that the increased price is justified by a commensurate increased value.

CRTs and front projectors probably cannot deliver this high-definition experience in a conventional home environment. Direct view flat panels are not a threat to deliver it in the near future. CRT based rear projectors of the required diagonal measure are unlikely to capture a significant market share.

A strong argument can be made that SLM-based rear projectors are the high definition display of choice for the near future. The unique requirements of pixelated SLM-based projectors suggest that new research areas in lamps, optics, and video processing can yield important near term results.

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