

[招待講演] 高画質液晶テレビの信号処理

吉田育弘、古川浩之、上野雅史、生田英次、Scott Daly†、  
XiaoFang Feng†、Ibrahim Sezan†、菊地雄二、藤根俊之、杉野道幸

シャープ株式会社  
†株式会社 シャープ アメリカ研究所  
E-mail: yoshida.yasuhiro@sharp.co.jp

あらまし: シャープでは、業界最高サイズの HD フルスベック規格液晶テレビ; アクオス LC-45GD1 を開発した。アクオス LC-45GD1 は、従来にない大画面テレビのカテゴリーをはじめて切り開いた製品で、最新の液晶技術と回路技術で実現された。この論文では、同液晶テレビで高い画質を実現する重要な要素技術となった、10 ビット信号処理を中心に述べる。この技術は、フル HD 液晶テレビに向けて特に開発された"The New AQUOS Platform"の中心部をなす、"The LCD Panel Driver Engine" と "The Digital Imaging Engine for Enhanced Picture Quality" に搭載されている。アクオス LC-45GD1 では、大画面液晶テレビとして、フルスベックの HD 液晶パネルと "The Intelligent Environment Illumination Sensor"を、この 10 ビット信号処理と組み合わせることで、高い画質を得ることに成功した。

キーワード: 画質、信号処理、大画面液晶テレビ

[Invited Paper] Signal Processing in High Quality LC-TV

Yasuhiro Yoshida, Hiroyuki Furukawa, Masafumi Ueno, Eiji Ikuta, Scott Daly†,  
Xiaofan Feng†, Ibrahim Sezan†, Yuji Kikuchi, Toshiyuki Fujine, Michiyuki Sugino

SHARP Corporation, JAPAN  
† SHARP Laboratories of America Inc., U.S.A  
E-mail: yoshida.yasuhiro@sharp.co.jp

Abstract: Sharp has developed industry's largest high-definition LC TV. Aquos LC-45GD1. The AQUOS LC-45GD1 is the first-ever product that shows a new picture category of large screen television of more than 40-inch, that it was achieved by the cutting edge LC technologies and circuit technologies. In this paper, we discuss its 10-bit signal processing as one important enabler of its excellent picture quality. This technology is being realized at both "LCD Panel Driver Engine" and "Digital Imaging Engine for enhanced picture quality", that are exclusively developed for the full-HDTV LC TV as the main building blocks of the "New AQUOS Platform". Utilizing 10 bits signal processing, in combination with full-spec High-Definition panel and "Intelligent Environment Illumination Sensor", we have succeeded to realize a beautiful gigantic LC TV.

Keywords: picture quality, signal processing, large screen LC-TV

## 1. Introduction

Sharp Corporation has introduced into the world-wide market the LC-45GD1 AQUOS 45V-inch High Definition LC TV. It is the industry's largest LCD model with HD-ready input, featuring a full-spec high-definition panel of 6.22 million dots (1920Hx1080VxRGB), industry's highest level in a 45V-inch size. This model has been manufactured at Sharp's Kameyama Plant, the world's first integrated production facility for LC TVs – from fabrication of the LCD panel to final assembly.

In this paper we discuss how superior picture quality of the LC-45GD1 is achieved by applying new technologies and its related subjective evaluations and combining such technologies with a full-spec HD LC panel.

Table 1. Specifications of the LC-45GD1

LCD	Screen size	45V 98.6cm(H) · 55.5cm(V)
Panel	Driving	TFT active matrix LCD
	Picture dots	6,220,800dots(1,920(H) × 1,080(V) × RGB)
	Intensity	450cd/m <sup>2</sup>
Power supply	AC100V 50/60Hz	
Power consumption	315W	
Channels	VHF 1 ~12ch, UHF 13 ~62ch, CATV13 ~63ch, BS digital 000 ~ 999ch, CS digital 000 ~999ch, Digital terrestrial 000 ~999ch	

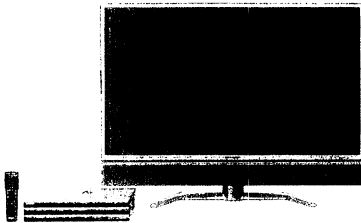


Figure 1. The LC-45GD1

## 2. New-Aquos Platform

We have developed new digital image processing engines that are exclusively developed for the full-HDTV LC TV as

"New AQUOS platform" shown in Figure 2.

At the heart of the new-Aquos platform, there are two new engines that were developed separately for high quality signal processing and quality enhancement of the LC panel, in which both of them were optimized for its requirement respectively. The core technology for both engines is the 10 bits signal processing path for each one of R, G and B color channels. The 10 bits signal processing path makes it possible to display four times higher density of gray levels than the conventional LC TV.

(1) LCD Panel Driver Engine: A new engine that is equipped by our original bit depth extension circuit<sup>1)</sup>. This unique algorithm is based on the application of HVS such that it can drive full-spec HD panel under visual accuracy of 10 bits for each of one of the R, G and B channels.

(2) Digital Imaging Engine for enhanced picture quality: An original engine for high quality digital imaging that includes 10 bits signal processing units for all of I/P conversion, scaling, noise reduction, edge enhancement, color management, and active contrast control.

Using 10 bits signal processing, the LC-45GD1 will render extremely high-quality pictures on its large LC screen especially for high SNR signal sources such as digital HDTV broadcasting and DVD movie playback. In addition, with the use of the full-spec HD panel, high definition representation as well as natural representation is realized by LC-45GD1. By taking advantage of both panel and source, even delicate texture of human face can be represented accurately and naturally.

## 3. Key Technologies

One of the new features of the Sharp LC-45GD1 is the 10 bits signal processing circuitry. It reduces the visibility of false contour artifacts significantly. From color perception point of view, Miyahara et al.<sup>2)</sup> have reported that a bit depth of R:G:B=10:12:9 bits is needed to keep the color difference due to quantization error below a detectable threshold for a display with 1000:1 dynamic range and  $\gamma=3.0$ . However, since the threshold is affected by (1)step difference in intensity corresponding to quantization error, (2)spatial frequency content of contours, which determines the visibility of the contour by the human visual system, and (3)light adaptation status of the human visual system. Since the spatial frequency response and light adaptation were not considered at Miyahara's report, we performed a subjective experiment to determine the visibility of contour artifacts at 10 bits under a variety of display and viewing conditions based on the above three attributes<sup>3)</sup>.

### 3.1 Preliminary experiment: Deficiencies of 8 bits

It is widely known that the maximum bit depth of the most LCDs is 8 bit per color channel, i.e. R:G:B =8:8:8 bits. we first initiated a subjective evaluation to determine how much of the contour artifacts are actually visible as a result of 8 bits quantization.

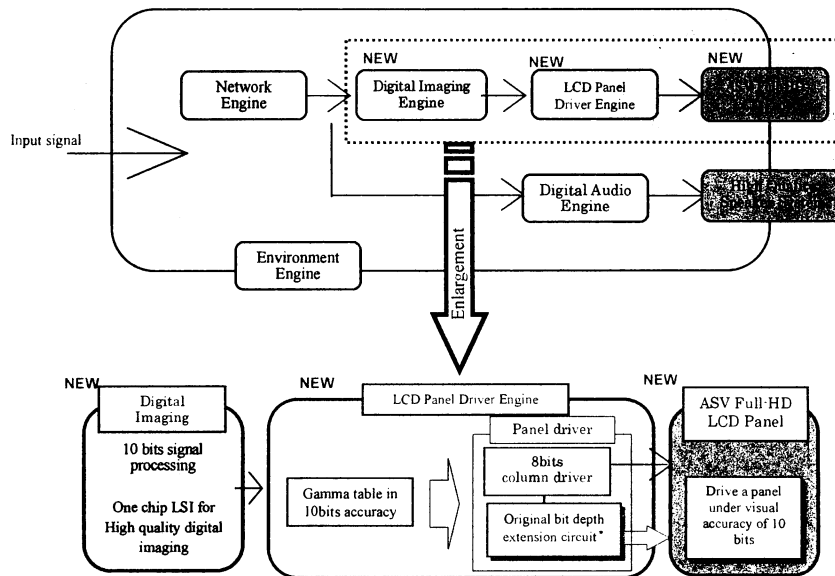


Figure 2. General block diagram of the new generation Aquos platform developed for full-HDTV application.

\*Original bit depth extension circuit. This unique circuit is based on an application of the Human Visual System such that it can drive full-spec HD panel under visual accuracy of 10 bits, that is usually limited for 8 bits due to column driver.

The experimental conditions are listed in Table 2. The LC-45GD1 was set in a room with adjustable lighting system. As shown in Table 2, we have utilized a couple of conditions that relate the above-mentioned attributes. Figure 3 shows a set of test images that we used. The key attributes are zero noise and very low gradient picture at a large and bright screen: the ramps span a very limited span of the total. The quantization to 8 bits causes steps to appear in the ideally smooth ramps.

These test images are generated at PC and displayed on the LC-45GD1. Observers viewed test images at a viewing distance of three picture heights and used a five-grade impairment scale. The legend is as follows: 5:imperceptible, 4:perceptible, but not annoying, 3:slightly annoying, 2:annoying, 1:very annoying that is shown below.

Figure 4 shows experimental results at the maximum intensity of 320cd/m<sup>2</sup> with 4 different lighting levels. The subjective mean opinion score (MOS) for two observers are reported at the bar graph. The MOS is dependent on both the lighting condition and the test charts. The false contours of the LCD at R:G:B=8:8:8 bits were clearly visible for most lighting conditions.

Table 2. Experimental conditions

Attributes	Corresponding parameter	Conditions
Amount of quantization error	Maximum brightness	450cd/m <sup>2</sup> , 320cd/m <sup>2</sup> , 150cd/m <sup>2</sup>
Spatial frequency of the contour	Slope of grating	Table 3.
Adaptation status	Illuminating condition	Dark room, 100lux, 600lux, 3500lux

Table 3. Specification of the test images used

Chart No.	Left	Center	Right	Spatial freq. of the bar (cpd)
1	0	127	255	5.6
2	0	31	63	1.6
3	64	95	127	1.6
4	128	159	191	1.6
5	192	223	255	1.6
6	32	39	47	0.4
7	48	55	63	0.4

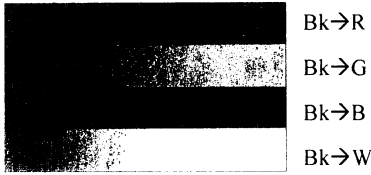


Figure 3. Test image used

### 3.2 Picture quality evaluation of 10 bits

We increased bit-depth to 10 bits and performed a similar experiment to the previous experiment. Figure 5 depicts the results for the 10 bits case. When compared with the 8 bits case as shown in Figure 4, all subjective scores are improved significantly for all test images under all evaluation conditions. The subjective results show a drastic decrease in the perceived visibility of false contours.

Also we confirmed that the contour artifacts were not visible under all experimental conditions down to the room lighting of 100 lux. Under the dark room conditions, the contours were slightly perceived for the high intensity test images of 6 and 7<sup>(\*)</sup>. This means that even in the 10 bits system, there is still a perceptible false contour, according to a mutual relationship between maximum intensity of the display and environmental illumination condition.

However, in other words, this means that LC TVs in which contour artifacts are never perceived (i.e., contour-free) can be realized with 10 bits if only the maximum intensity would be adaptively controlled according to the environment illumination condition.

### 4. Adaptive Brightness Control for Picture Quality Optimization

In order to optimize the picture quality under 10 bits signal processing, the LC-45GD1 is equipped with a picture quality optimization technology called "Intelligent Environment Illumination Sensor", which makes it possible to control the intensity of backlighting system depending on an environment illumination condition. As shown in Figure 6, when the LC-45GD1 is placed at dark room, the sensor automatically controls a maximum intensity of its screen to become darker than 150 cd/m<sup>2</sup>.

Thus the LC-45GD1 has achieved the highest quality picture, without contour artifact. For example, for any possible ambient condition, LC-45GD1 is capable of representing visually optimal pictures, even for a low contrast source picture under a dim viewing condition such as shown in Figure 7.

<sup>(\*)</sup>They have the same spatial frequency content of contours in Table 2, and 1/4th of the brightness difference, i.e., a gentler slope than the previous case.

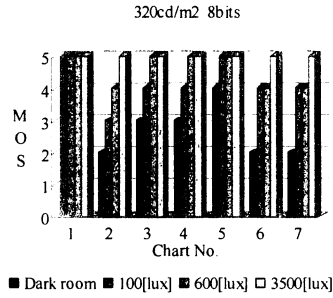


Figure 4. An example of the subjective evaluation results for the bit depth of 8 bits at 320 cd/m<sup>2</sup>.

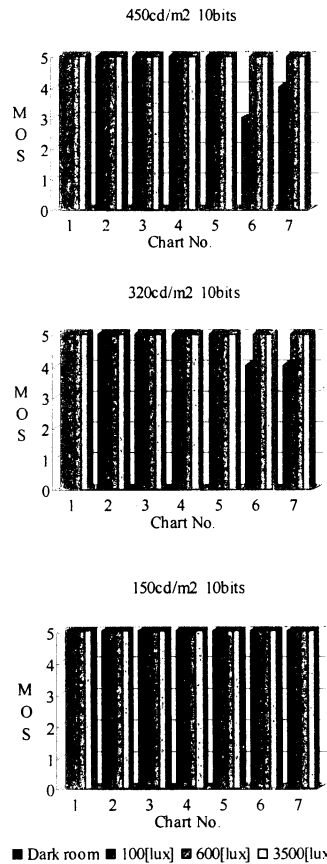


Figure 5. Subjective evaluation results for the bit depth of 10 bits. From top to bottom, the graphs show maximum brightness of 450cd/m<sup>2</sup>, 320 cd/m<sup>2</sup> and 150 cd/m<sup>2</sup>, respectively.

## 5. Color Tracking

In addition to the features explained above, the use of 10 bits signal processing has other advantages. The LC-45GD1 is equipped with gamma correction table in 10 bits accuracy for each one of the R, G and B channels independently. This is very effective for not only accurate gamma correction but also for making it possible to achieve accurate color balance. As shown in Figure 8 and 9, this in effect improves gray color tracking significantly for the entire gray scale and reduces the visibility of a color non-uniformity at inflection points of the gamma curve<sup>4)</sup>.

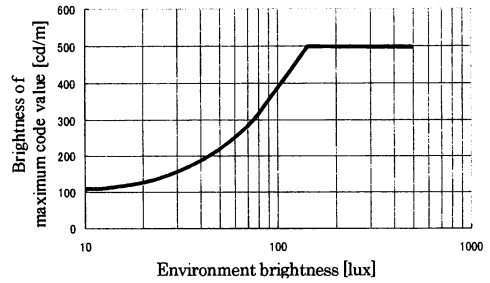


Figure 6. An example of the system characteristics.

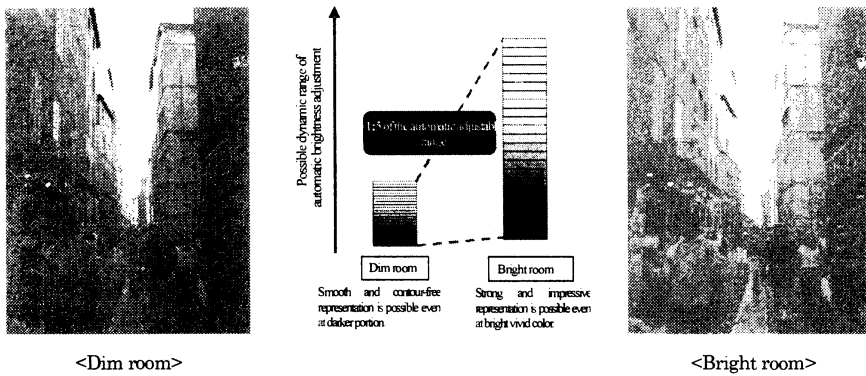
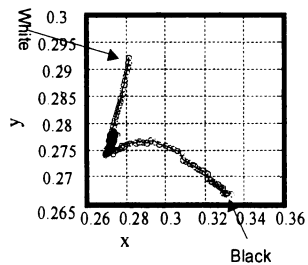


Figure 7. Automatic brightness control according to the ambient light by means of the "Intelligent Environment Illumination Sensor".

Plots: 0-255 every 4 steps (8 bits)



0-1023 every 16 steps (10 bits)

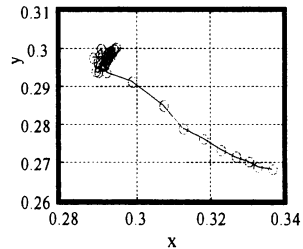


Figure 8. Color tracking improvement

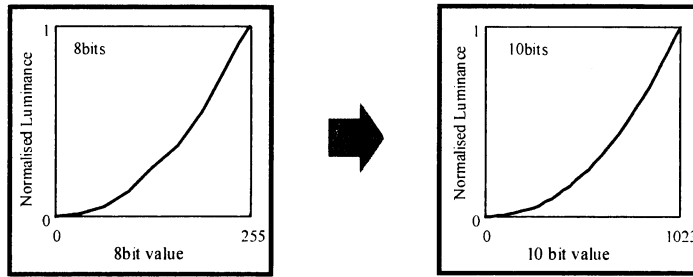


Figure 9. Comparison of gamma curve of a conventional 8bits circuit with 10 bits circuit.

Left: 8bits case. Some broken-line approximation due to an analogue compensation appears in low-key portion as well as the residual of the S-shape property in high light.

Right: 10 bits case. a drastic improvement in smoothness of tone scale reproduction, free from any influence of the broken line was achieved.

## 6. Conclusion

In this paper, we have explained important features of the 45-inch LC TV of LC-45GD1. Especially, we have concentrated on improvements to picture quality by means of 10 bits signal processing. The technology that supports these features is being realized at both "LCD Panel Driver Engine" and "Digital Imaging Engine for enhanced picture quality", that are exclusively developed for the full-HDTV LC TV as the main building blocks of the "New AQUOS platform".

By combining a full-spec HD panel and the 10 bits circuit, it is possible for LC-45GD1 to reproduce an extremely fine and smooth representation of the source on the screen.

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