

Development of 45-inch High Quality LC-TV

45インチ高画質液晶テレビの開発

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Abstract

Sharp has developed industry's largest high-definition LC TV, the AQUOS LC-45GD1. In this paper, we introduce its 10-bit signal processing as one important enabler of its excellent picture quality. How the superior picture quality of the LC-45GD1 is achieved by applying 10 bits signal processing and the "Intelligent Environment Illumination Sensor" and then combining such technologies with a full-spec HD LC panel will be discussed.

シャープでは、業界最大サイズのHD放送対応液晶テレビLC-45GD1を開発した。この論文では、その高画質を実現する重要な技術要素である10ビット信号処理について紹介する。10ビットの信号処理やインテリジェント明るさセンサを用い、さらにこれらをフルHD規格液晶パネルと組み合わせることで、如何にしてLC-45GD1の高画質を実現したかについて述べる。

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 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.

1. 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 **Fig. 2**.



Fig. 1 The LC-45DG1

Table 1 Specifications of the LC-45GD1

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

At the heart of the new AQUOS platform, there are two new engines that were developed separately for high

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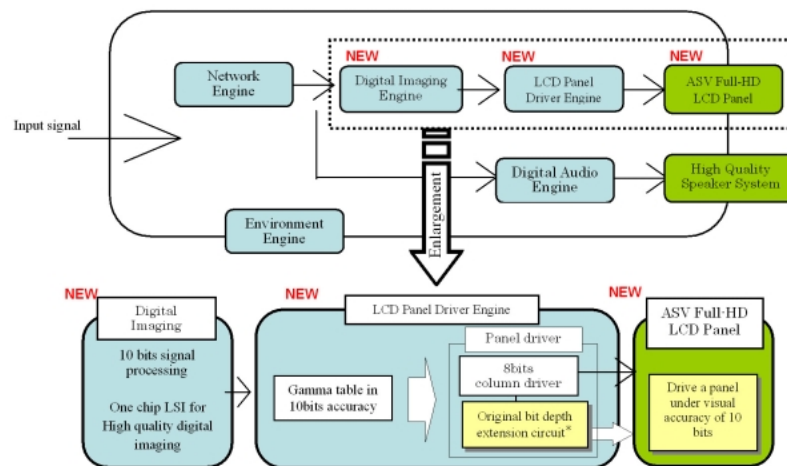


Fig. 2 General block diagram of the new generation Aquos platform developing for full-HDTV application.

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 with our original bit depth extension (BDE) circuit[1]. This unique algorithm is based on the application of human visual system (HVS) models 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 the following steps: 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.

2. 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.[2] 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 $\gamma=3.0$. Such thresholds are 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 HVS. Since the spatial frequency response and light adaptation were not considered at Miyahara's report, and our display gamma and dynamic range are different, 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[3].

2.1 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, so we first initiated a subjective evaluation to determine how much of the contour artifacts are actually visible as a result of 8 bits quantization.

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. Fig. 3 shows a set of test images that we used. The key attributes are zero noise and very low gradient; these 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-

Table 2 Experimental conditions.

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



Fig. 3 Test image used.

Table 3 Specification of the test images used.

Chart No.	Left	Center	Right	Spatial freq. of the har (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

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.

Fig. 4 shows experimental results at the maximum intensity of 320cd/m² 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.

2.2 Picture quality evaluation of 10 bits

We increased bit-depth to 10 bits and performed a similar experiment to the previous experiment. Fig. 5 depicts the results for the 10 bits case. When compared with the 8 bits case as shown in Fig. 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

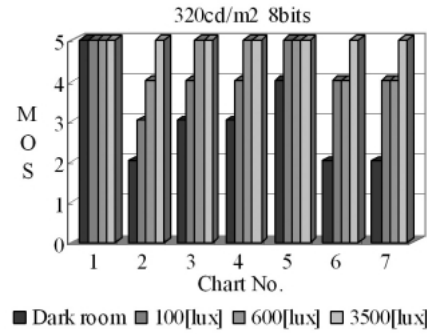


Fig. 4 An example of the subjective evaluation results for the bit depth of 8 bits at 320 cd/m².

(<100 lux), the contours were slightly perceived for the high intensity test images of 6 and 7(*). 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

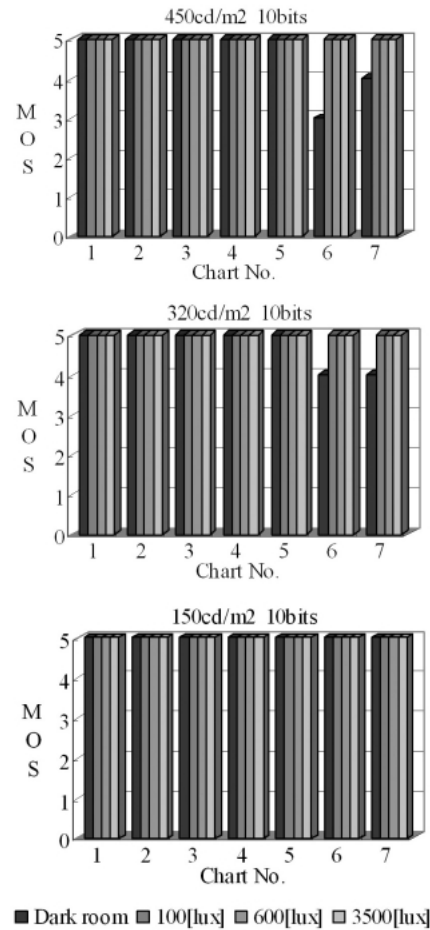


Fig. 5 Subjective evaluation results for the bit depth of 10 bits. From top to bottom, the graphs show maximum brightness of 450 cd/m², 320 cd/m² and 150 cd/m², respectively.

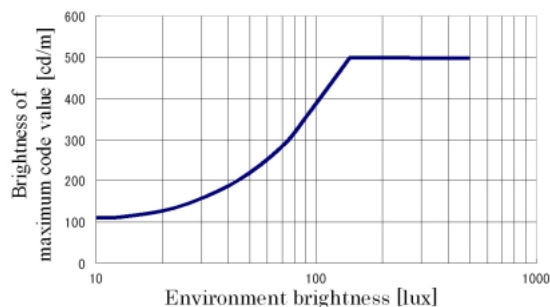


Fig. 6 An example of the system characteristics.

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.

(*)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.

3. 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 Fig. 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/m².

Thus the LC-45GD1 has achieved the highest quality

picture, without contour artifact. For example, for any possible ambient condition, the 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 Fig. 7.

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 in both the "LCD Panel Driver Engine" and the "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.

References

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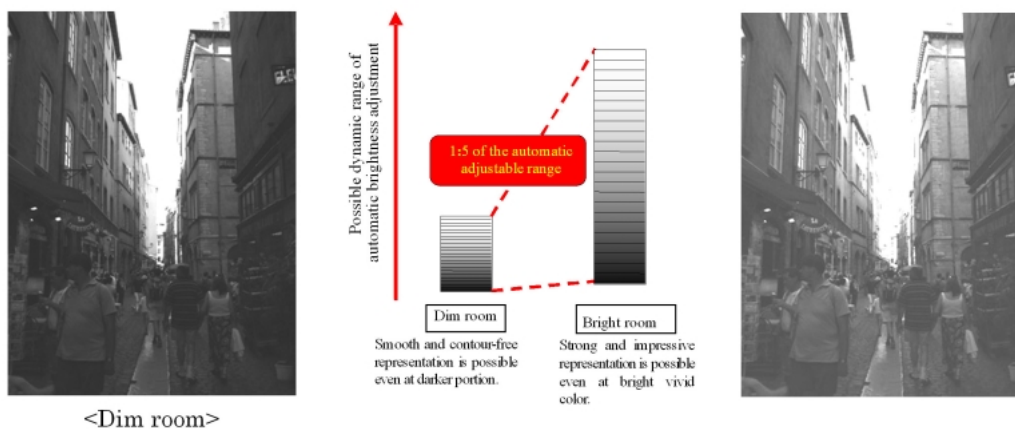


Fig. 7 Automatic brightness control according to the ambient light by means of the “Intelligent Environment Illumination Sensor”.

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