11-3: A XGA VAN-LCoS Projector

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Abstract

The performance of XGA VAN LCoS panels, integrated in a full color projector, is described. The developed LCoS panels are 0.9" diagonal with a 17.6 µm pixel pitch. The designed interface electronics comes with a graphic interface enabling different settings of the LCoS panels. The projector evaluation comprises both a 1-color PBS set-up and the Unaxis' ColorCorner^{TM} color management. In both cases high contrast ratios were measured and excellent video performance was demonstrated.

1. Introduction

It is believed that LCoS is one of the enabling technologies for HDTV. However HDTV will only make its way to the market if the cost of the complete display system becomes acceptable. At the other hand the LCoS technology is potentially a high-resolution technology at low cost. This means that LCoS becomes a most attractive candidate for lowering the cost of a HDTV display. If one breaks down the cost of an LCoS projector, it is seen that the optical engine is a major cost. The optical engine consists of 3 LCoS panels, colour management optics and a UHP light source. The LCoS panels equal almost half of the cost of the optical engine, but can be made cheaper once LCoS is produced in mass. It is expected that 45" HDTV displays can be made at retail prices below 2000$.

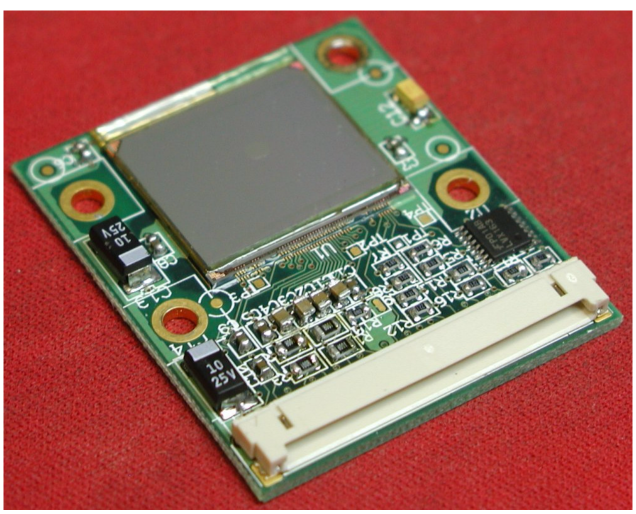

Figure 1 XGA LCOS cell mounted on FR4 carrier

2. LCOS backplane and electronic interface

2.1 Backplane

Looking from the technical side, the LCoS technology chosen has to yield a high contrast ratio, a sufficient light throughput and an excellent video performance. For this reason we have developed a vertically aligned nematic (VAN) XGA LCoS technology with an analog DRAM active matrix addressing architecture. The design and fabrication details are described elsewhere [1,2]. Briefly summarized we designed and fabricated 0.9" diagonal XGA microdisplays with a 17.6 µm pixel pitch and bi-directional row drivers and column scanners integrated on-chip. The silicon backplane was realized using a 4-metal 0.35 µm CMOS technology. A picture of the packaged 0.9" XGA LCoS is shown in [figure 1].

2.2 DC compensation

In liquid crystal displays, alternating voltage is applied to the LC cell to prevent charges from accumulating within the cell. In our approach the common electrode voltage (VCOM) is fixed to a midway voltage between the 2 supply rails. This implies that the output voltage span of the video opamps driving the column scanners is twice the RMS voltage of the LC.

2.3 Color depth

For the S-curve compensation our goal was to obtain a color depth of 8 bits and predefined display gamma value, independent from the liquid crystal parameters. Especially in VAN technology a steep S-curve is observed. It is obvious, but not useful to cover the whole pixel electrode DC range (which is 2 times the LC on-voltage, as mentioned before) with the DA-converter preceding the video opamp, as the voltages in this DC range corresponding with the subtreshold LC behaviour add no additional video information. As the LC modulation voltage is much smaller than the whole pixel electrode voltage range, addressing the voltages outside of this modulation voltage with the DA-converter results in loss of resolution. To exploit the DA-convertor most advantageously, we have chosen an implementation where only the modulation voltage is coded by the DA convertor. An active

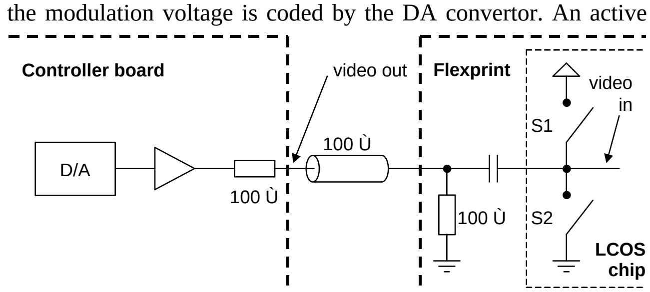

Figure 2 Video signal interface with active clamping circuit

clamping circuit, as shown in figure 2, adds the remaining treshold voltage of the LC.

The output impedance of the video opamp is matched to the

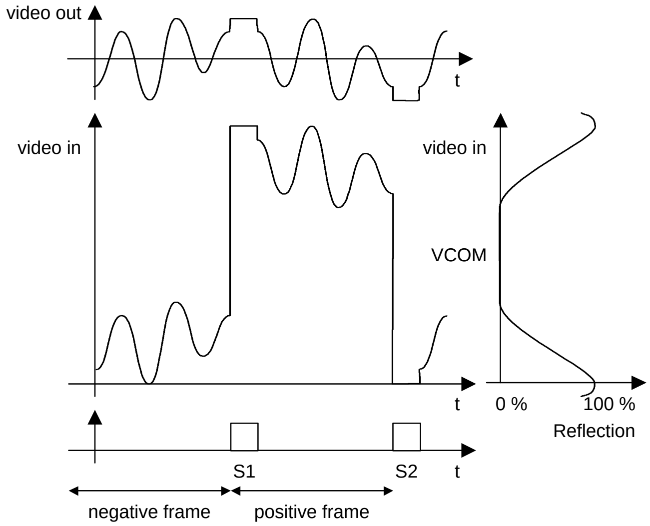

Figure 3 Video signals in the active clamping circuit scheme

impedance of the video signal cable; the video signal is capacitively coupled to the input of the LCOS chip. On the LCOS chip an 'active clamping' circuit is implemented to add the desired DC component to this video signal. This DC component is added during the vertical and horizontal blanking times [figure 3].

When starting a positive frame (which means that all pixel electrode voltages are driven positive with respect to the common electrode voltage), the output signal of the video opamp is brought high; meanwhile the input pad of the video signal of the LCOS chip is brought to a positive reference voltage VRAC, which is 2 times the LC on-voltage. On the other side, when starting a negative frame, the output signal of the video opamp is brought low; meanwhile the input pad of the LCOS chip is brought to the ground potential.

Using this electronic circuit allows us to address the modulation voltage range with true 10-bit resolution. This results in a programmable accurate gamma-value, without contouring or other image artefacts.

2.4 Electronic Interface

The designed interface electronics support

- a programmable look-up table with 10-bit voltage values, or
- a programmable gamma-value and a programmable maximum intensity for defining the white point
- a programmable threshold voltage or black level;
- a programmable VCOM voltage;
- programmable registers for rotating and/or flipping the image, horizontal and vertical position of the image.

3. VAN LC

Using evaporated SiO2 alignment layers cell contrast ratio's of 17000:1 could be achieved in case of monochrome illumination ((=543 nm) while the on and off switching times where well below 15 ms [3]. So basically we could match hardware-wise the theoretically expected performance of a VAN LCoS technology.

4. Projector Test Bench

In order to evaluate the performance of the LCoS technology developed, a projector test bench was set up. In this paper we will report on the characteristics obtained on this test bench. The test bench is shown in figure 4.

4.1 Monochrome Test Bench

First a monochrome projection test was performed. In this case a PBS replaced the colour management. The PBS was either a cubic glass PBS or a sheet type (ProFlux^{TM}) PBS. A remarkable difference in on-off contrast ratio (CR) was found. In case of the ProFlux^{TM} PBS we measured a CR exceeding 1900:1 on screen, while the glass PBS resulted in a CR of 700:1. In both cases an additional ë/4 retarder was used. In case this 1/4 wave plate was

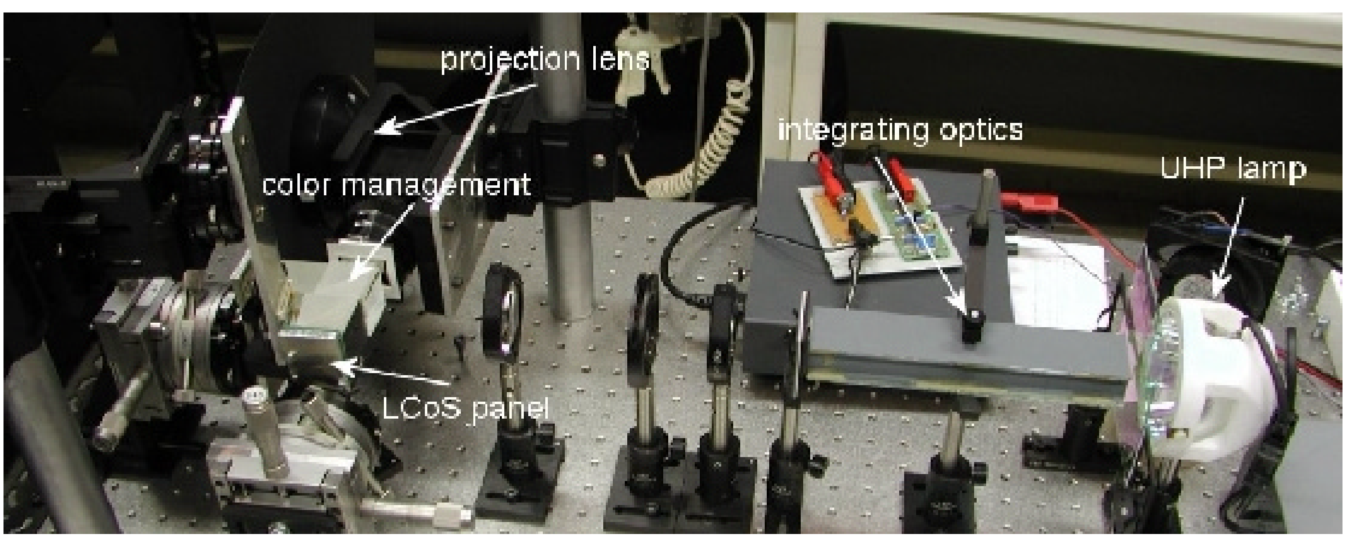

Figure 4 Projection test bench

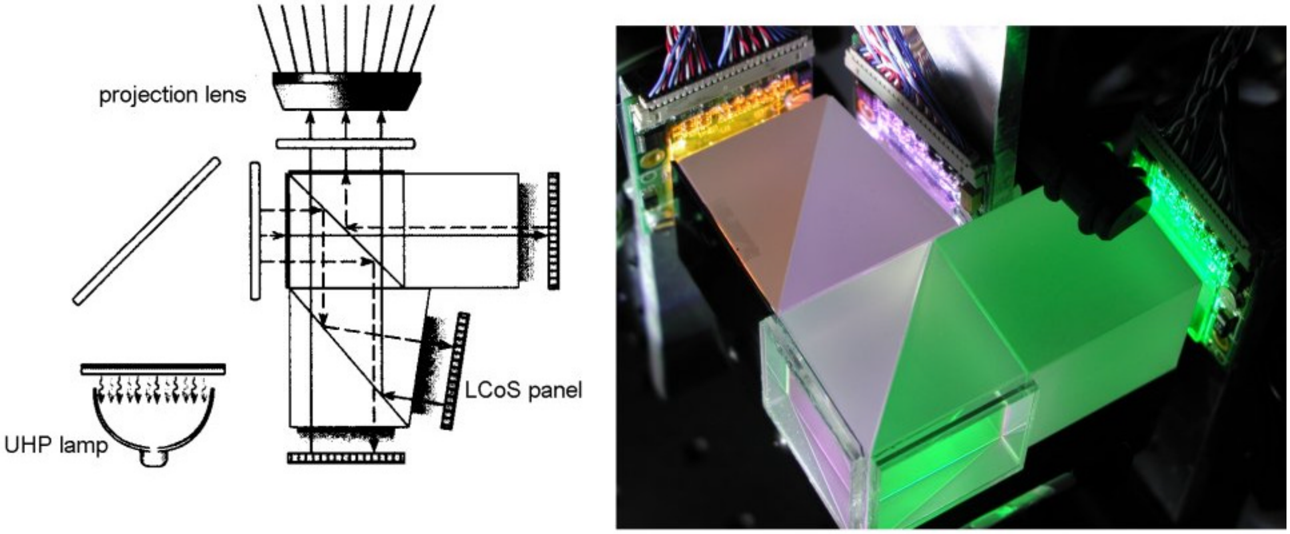

Figure 5 ColorCorner arrangement

omitted, a considerable lower CR was measured. Although the optical test bench was not optimised for 0.9" XGA panels, the measured data proved that VAN panels are most suited for achieving high contrast ratios in projection applications. Moreover the performance of the VAN LCoS panels is sufficiently independent of the wavelength, which enables the use of only one type of LCoS panel in full colour projectors.

4.2 Color Test Bench

Secondly a full colour projection test was carried out. The performance of the projector is highly dependent on the colour management system used. In our case we used the compact ColorCorner™ arrangement of Unaxis [4], shown in figure 5. The ColorCorner™ arrangement is quite attractive due to its simple and compact system. In figure 7 a picture taken from a projected

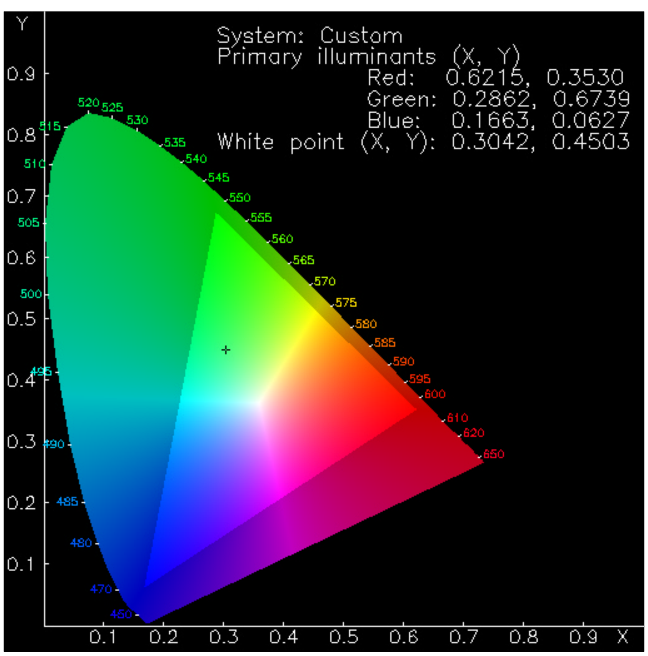

Figure 6 CIE diagram with color gamut

image with the ColorCorner™ arrangement is shown.

For our measurements we used a Philips UHP lamp as light source, but no ë/4 retarders were used. We were pleasantly surprised by the wide colour gamut that can be achieved by such a compact system [figure 6]. The results of our measurements are shown in the image below. However, for displaying pure white (6500K) about 62% of green must be suppressed. It is clear that the ColorCorner™ is optimised for the green colour channel [4]; on the other hand our set-up can still be further improved.

4.3 Image Holding Ratio

The light shield and the storage capacitor are so effective that the image holding ratio between two consecutive frame times is hard to measure directly. In this case, it is more useful to measure the decay time of a non-refreshed image. The f-number of the optical set-up in this measurement is 3.0. We have found decay times between 10 and 20 seconds for a 1’000’000 lux illumination intensity on the surface of the LCOS panel. This corresponds to an image holding ratio of about 99.9% for a 60 Hz refresh rate. The error due to photoconductive leakage currents is therefore less than 1 LSB of the 10-bit DAC.

5. Conclusion

So in conclusion it can be stated that the developed 0.9" XGA VAN LCoS confirmed the performance that is expected from analog addressed reflective VAN LC cells. Moreover VAN LCoS panels can be easily adapted to different projector set-ups. Set-ups with a 1 PBS arrangement as well as a Unaxis' ColorCorner™ were evaluated. In both systems our VAN LCoS panels performed excellently, yielding high contrast ratios and good video performance.

6. Acknowledgements

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Figure 7 Projected image

7. References

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