
**Liquid Crystals**
Publication details, including instructions for authors and subscription information:
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Online publication date: 11 November 2010

**To cite this Article** Kim, Hyang-Yul , Kim, Eung-Sang and Seo, Dae-Shik(2002) 'Residual d.c. measurement in in-plane switching liquid crystal displays by a new light minimum/maximum method on a polyimide layer', Liquid Crystals, 29: 8, 1055 — 1057
**To link to this Article: DOI:** 10.1080/02678290210149531
**URL:** http://dx.doi.org/10.1080/02678290210149531

LIQUID CRYSTALS, 2002, VOL. 29, NO. 8, 1055–1057

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# Residual d.c. measurement in in-plane switching liquid crystal displays by a new light minimum/maximum method on a polyimide layer

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(*Received 31 December 2001; accepted 15 March 2002*)

The measurement of residual d.c. in in-plane switching liquid crystal displays on a rubbed polyimide surface was investigated. We propose a new residual d.c. measurement method, named the 'light minimum/maximum method'. The precision of residual d.c. measurement by the light minimum/maximum method was found to be greater than that of the conventional flicker minimizing method.



## 1. Introduction

Large-size liquid crystal displays (LCDs) have the advantage of saving space and having low power consumption; but there are many problems, such as viewing angle and response time [1–6]. In-plane switching (IPS) LCDs used for desktop monitors are required to have high resolution, vivid colour performance, and no image sticking [7]. Rubbed polyimide (PI) surfaces have been used to obtain a uniform LC alignment and a high pretilt angle [8–11], and it is well known that a PI layer influences the electrical properties, such as residual d.c., of an LC cell [12–14]. It is also commonly understood that residual d.c. is related to image sticking; for example, where a ghost image remains on changing the display signal after the image has been displayed for a long time. Recently, a residual d.c. of NLCs on rubbed PI layers has been proposed as a possible cause of image sticking [12–14].

We now report on residual d.c. measurement in IPS-LCDs using a new light minimum/maximum method on a rubbed PI surface.

## 2. Experimental

Figure 1 shows the structure of the IPS-LCD used in this study. The electrode width used was 10 μm and electrode distance was 20 μm; the electrode was formed from MoW. The PI (AL-1051; for low pretilt, JSR Co., Ltd.) films were formed on indium tin oxide coated glass substrates by curing at 180°C for 1 h. The rubbing direction was 78° to the electric field on the PI surfaces, as shown in figure 1 (*b*). The IPS-LCDs were assembled with anti-parallel structure; cell thickness was 4.7 μm. The NLCs used had positive dielectric anisotropy, and the fabricated IPS-LCD was in the NB (normally black) mode. Table 1 shows the physical properties of the NLCs.

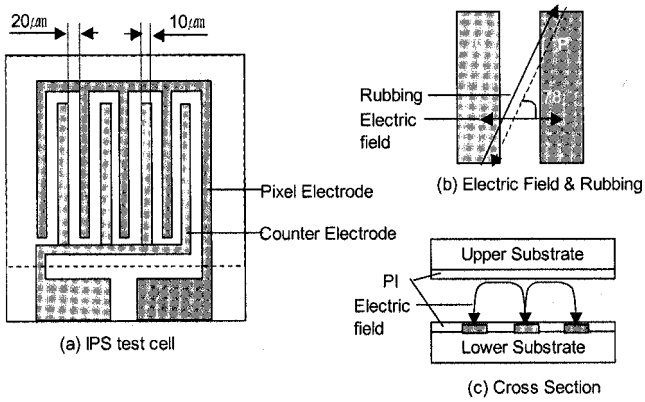


Figure 1. Structure of IPS cell.

### 2.1. *Flicker minimizing method*

The residual d.c. voltage was measured using the LCD evaluation system (LCD7000, Otsuka Co., Ltd.) and oscilloscope as shown in figure 2. We measured the offset voltage in minimizing the flicker.

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*Liquid Crystals* ISSN 0267-8292 print/ISSN 1366-5855 online © 2002 Taylor & Francis Ltd
http://www.tandf.co.uk/journals
DOI: 10.1080/02678290210149531

Table 1. Physical properties of NLCs.

| NLC | $\Delta n$ (25°C, 589 nm) | $\Delta\varepsilon$ (1 kHz, 25°C) | $T_{ni}$/°C | $\eta$/mPa s (at 20°C) | $\rho$ (at 25°C) | $\gamma$/mPa s (at 25°C) | CN/wt % |
|---|---|---|---|---|---|---|---|
| C5023 | 0.075 | 7.2 | 72.0 | 18.9 | $>1 \times 10^{13}$ | 90.1 | 0 |
| C5048 | 0.075 | 7.3 | 71.6 | 17.9 | $5.4 \times 10^{12}$ | 88.8 | 5 |
| C5049 | 0.075 | 7.3 | 71.5 | 18.3 | $2.9 \times 10^{12}$ | 84.3 | 10 |
| C5050 | 0.075 | 7.2 | 71.1 | 18.1 | $3.8 \times 10^{12}$ | 82.4 | 15 |
| C5051 | 0.075 | 7.3 | 70.9 | 18.2 | $9.2 \times 10^{12}$ | 80.2 | 20 |
| C5037 | 0.070 | 6.1 | 70.6 | 18.8 | $9.0 \times 10^{10}$ | — | 0 |
| C5038 | 0.070 | 6.1 | 70.5 | 18.8 | $1.0 \times 10^{11}$ | — | 0 |
| C5039 | 0.070 | 6.1 | 70.5 | 18.8 | $8.0 \times 10^{12}$ | — | 0 |
| C5040 | 0.070 | 6.1 | 70.5 | 18.8 | $3.0 \times 10^{13}$ | — | 0 |

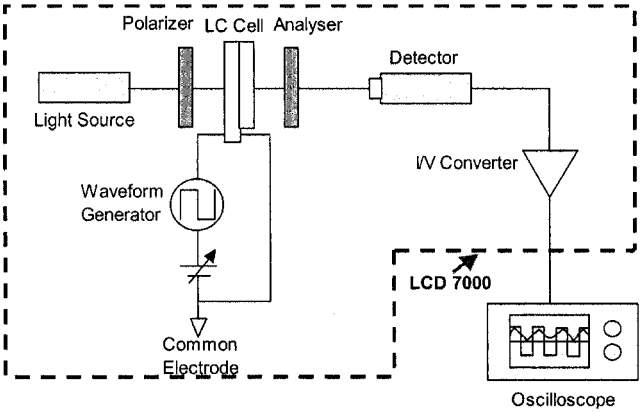



Figure 2. Measurement system of the flicker minimizing method.

### 2.2. *New light minimum/maximum method*

The residual d.c. voltage was measured using the LCD evaluation system (LCD7000, Otsuka Co., Ltd.) as shown in figure 3. The $V_{com}$ offset voltage was measured at light minimum or maximum as follows. (*a*) We measured the light minimum value or offset voltage before stress by applying a voltage from $-1.5$ V to $+1.5$ V on an

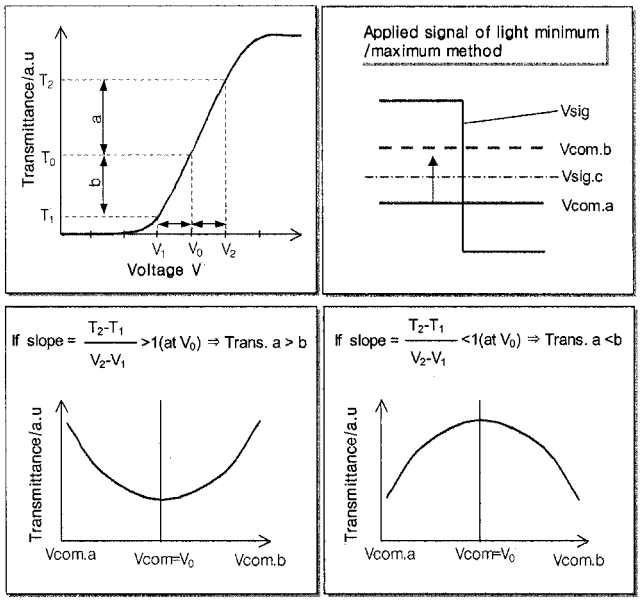
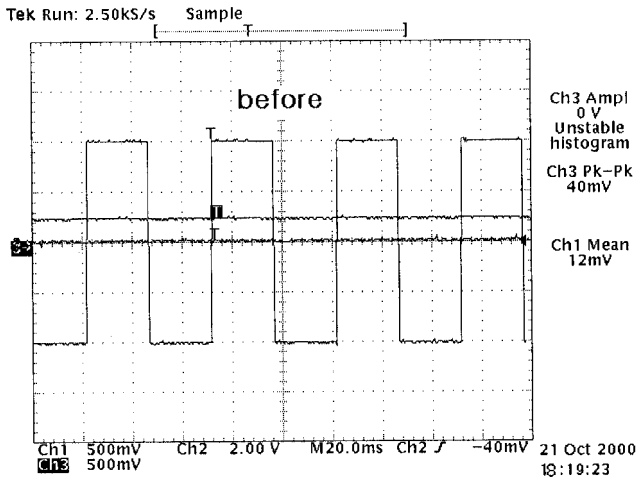



Figure 3. Principle of measurement in the light minimum/maximum method.



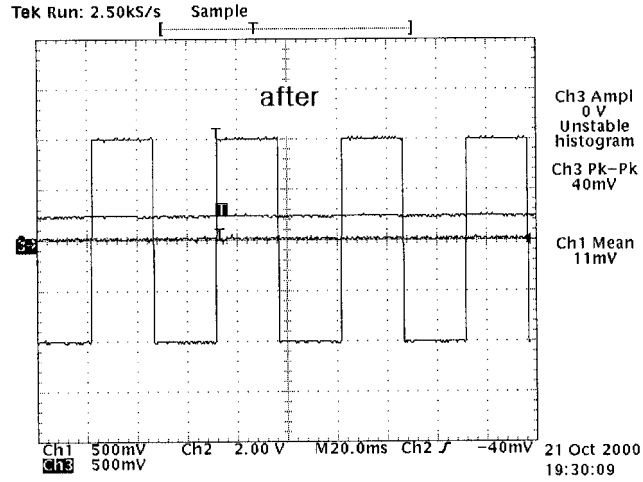




Figure 4. Offset voltage before and after stress in the flicker minimizing method.

opposing electrode. The pixel electrode had an applied a.c. voltage of 4 V at 25 Hz. (*b*) A stress was applied to the LC cell for 1 h at 50°C. The applied voltage was 5 V a.c. and 10 V d.c. for the driving voltage of the LC cell and the offset voltage, respectively. (*c*) The two electrodes were shorted between the pixel electrode and the opposing electrode for 1 min at 20°C. (*d*) In order to stabilize the LC cells, we applied 5 V a.c. (30 Hz) to the IPS-LCD for 10 min. (*e*) The offset voltage was measured after stress. (*f*) We defined the residual d.c. voltage as the difference in values before and after the stress.

## 3. Results and discussion

### 3.1. *Flicker minimizing method*

Figure 4 shows the offset voltage in the IPS-LCD (C5023) without cyano LCs on rubbed PI surfaces by the flicker minimizing method. It can be seen that the residual d.c. voltage of the IPS-LCD was close to 0 V. It is considered that the sensitivity of residual d.c. measurement in the IPS-LCD by flicker minimization was limited.

### 3.2. *New light minimum/maximum method*

Figure 5 shows the offset voltage in the IPS-LCD (C5023) without cyano LCs on rubbed PI surfaces by the light minimum/maximum method. The offset voltage before stress was measured at 0 V; after stress it was measured at about −0.1 V. The residual d.c. voltage was thus about 0.1 V. Table 2 shows the residual d.c. voltages in various IPS-LCDs by the light minimum/maximum method on rubbed PI surfaces. It is considered that the small residual d.c. voltages in the IPS-LCDs were easily measured. Consequently, the new measurement method for residual d.c. is more accurate than the conventional flicker minimizing method, since the resolution level of measurement is in the region of 0.1 V.

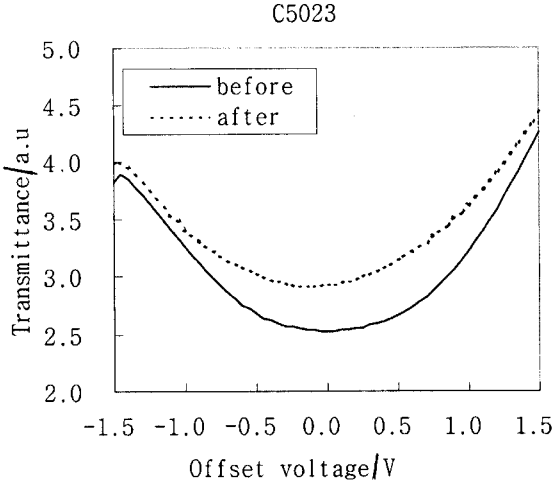



Figure 5. Offset voltage before and after stress in the light minimum/maximum method.

Table 2. Offset voltage and residual d.c. voltage before and after stress by light minimum/maximum method.

| | Voltage | | |
|---|---|---|---|
| LC materials | before/V | after/V | residual d.c./V |
| C5023(CN 0%) | 0.00 | −0.10 | 0.10 |
| C5048(CN 5%) | 0.05 | 0.00 | 0.05 |
| C5049(CN 10%) | 0.20 | 0.05 | 0.15 |
| C5050(CN 15%) | 0.10 | 0.00 | 0.10 |
| C5051(CN 20%) | 0.10 | 0.05 | 0.05 |
| C5037(ρ $E^{10}$) | −0.10 | 0.10 | 0.20 |
| C5038(ρ $E^{11}$) | 0.05 | −0.15 | 0.20 |
| C5039(ρ $E^{12}$) | 0.05 | −0.20 | 0.25 |
| C5040(ρ $E^{13}$) | 0.00 | −0.20 | 0.20 |

## 4. Conclusion

Residual d.c. in IPS-LCDs was successfully measured by a new light minimum/maximum method. We confirmed that the precision of the new method is better than that of the flicker minimizing method, and found it to be more accurate, since the resolution level of measurement is in the region of 0.1 V.

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