

5.1: Large Area, High Resolution Portable ZBD Display

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Abstract

A 7" diagonal 200dpi resolution, ultra low power Zenithal Bistable LCD ideal for portable applications is demonstrated for the first time. The lightweight module exhibits the same high contrast, wide viewing angle and rugged bistability shown previously but the design gives high quality text and graphics using conventional STN drivers.

1. Introduction

Bistable devices offer low power operation in infrequently updated products. As screen area increases, so power consumption by the display becomes the dominant component in decreasing battery life. There are a number of existing electronic reader and large area personal organiser products which bear testimony to the disadvantage of conventional LCD screens for these applications. To fulfil this need, there are now many examples of bistable displays which are based around both liquid crystal and non-liquid crystal technology. However, to our knowledge the grating aligned ZBD device^[1-4] is the only example giving simultaneously: bistability, a high degree of passive-matrix multiplexability and shock stability. Previous publications have demonstrated ZBD's rugged bistability however unlimited multiplexability had been claimed but not shown. In this paper we describe a 1200x700 pixel 7" diagonal display capable of showing high quality text at 200dpi, detailed graphics, and excellent readability. The display uses off-the-shelf components including STN drivers.

2. Results

2.1 Cell Construction

The 7" module shown in figure 1 has a display footprint of 167x104mm and an active area of 152x89mm (6"x3.5"). Glass of thickness 0.55mm was used in order to reduce display parallax. The electrodes were patterned from 13Ω/□ resistivity ITO which was sufficient to carry signals with minimal distortion. The pixel pitch on both the 1200 and the 700 line substrates was 127µm and to avoid adverse optical effects the interpixel gap was made as small as possible, in this case 10µm.

The grating surface which gives ZBD displays unique surface induced bistability may be manufactured by embossing from a master grating or by direct patterning of the grating. For this device, the grating was made using photolithography into an optically clear resist. The grating is then overcoated to give a homeotropic anchoring condition. This process has been described in other publications^[1,2]. The other surface of the cell is coated with JALS 212 polyimide, baked, and rubbed in the direction indicated in figure 1. The cell is assembled using a Norland UVS91 uv-curing adhesive with 4.5micron spacers deposited in the active area by spin coating from dilute solution in isopropanol. The cell is filled at room temperature under vacuum using an off-the-shelf TN material. Interconnection to the cell is made using ACF bonding to 8 chip-on-flex STN drivers. Each driver powers 240 lines with 92µm pitch on the fan-in.

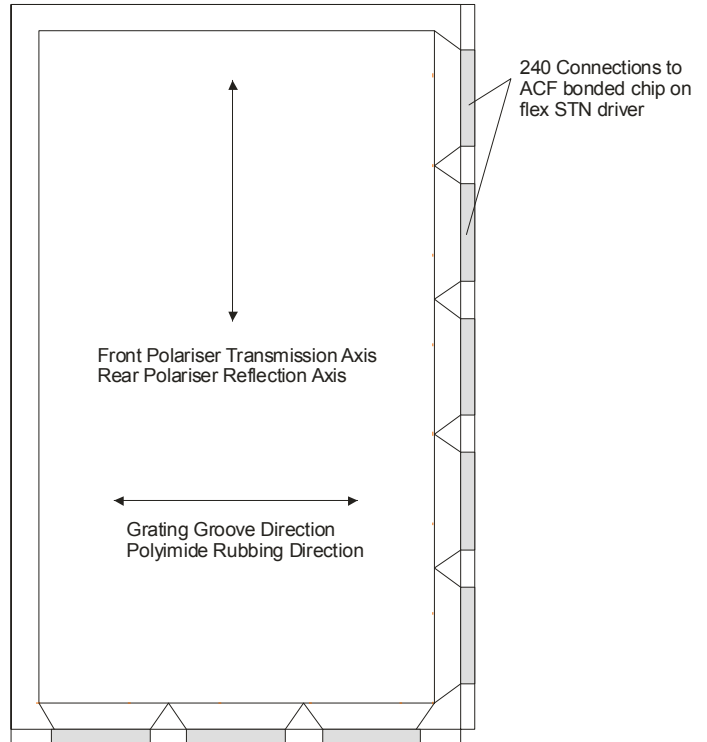


Figure 1: 7" diagonal module layout

The reflective polariser, 3M's RDFB film, is laminated on to the rubbed polyimide side of the cell, whilst the front polariser which is anti-reflection coated (Nitto:HEG1425DUHCARS) is laminated on to the grating substrate. The two optical states afforded by the zenithal bistable grating surface are shown in figure 2. Hence the twisted low-tilt state is black whilst the hybrid high tilt state is clear.

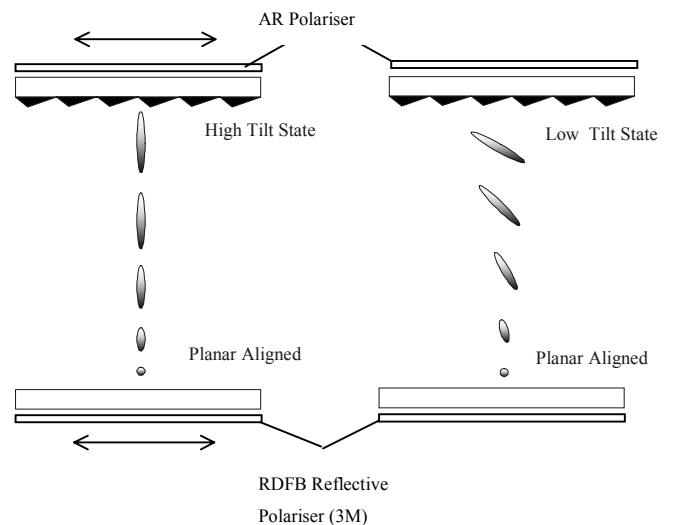


Figure 2: ZBD Optical Configuration

3.2 Addressing ZBD Using STN Drivers

The 7" prototype display uses commercially available 42V STN segment and common drivers. In general the display is switched by applying a pulse greater than the switching threshold across the ZBD cell. One polarity will switch the pixel white; the other will switch it black. In practical implementations the pulse is bipolar to ensure no net DC is applied to the cell (figure 3a).

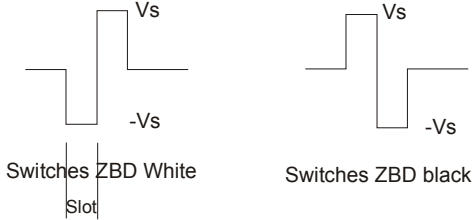


Figure 3a: White and black switching waveforms

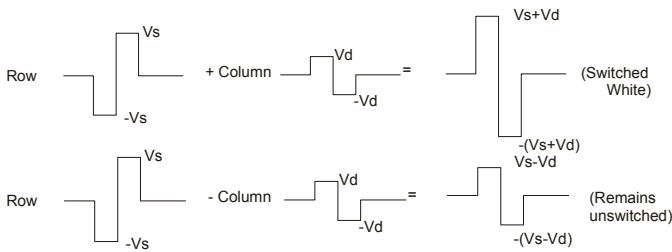


Figure 3b: Modulating the switching waveform with a data waveform.

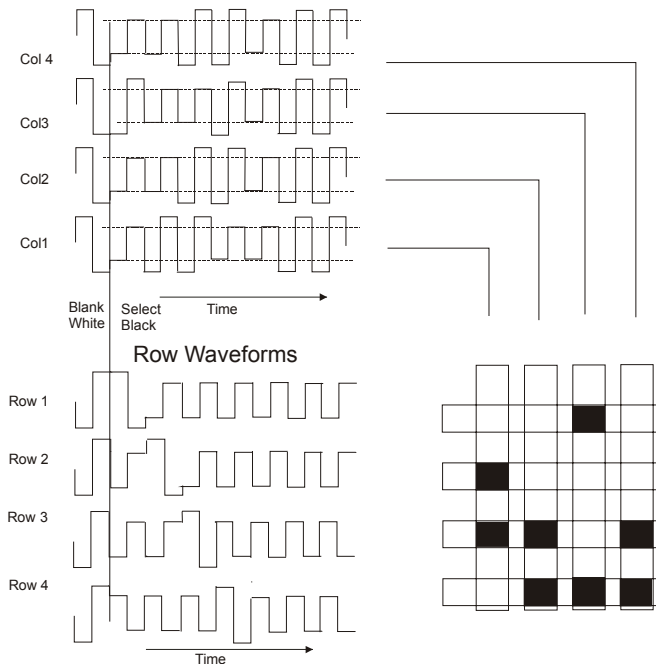


Figure 4: Simultaneously address all rows with white data to blank the display white. Then start at the first row and build the image in black a row at a time

To implement in a matrix display, the switching waveform is split between the rows (common) and columns (segment). The row

select waveform is then modulated by the column waveform to add together and switch the pixel, or subtract and leave the pixel unswitched (figure 3b). If the display is reset to a known state before each update (e.g. white) an image can be drawn on the display a row at a time by selecting the pixels in that row that will be switched to the opposite state (e.g. black).

A practical implementation of these waveforms is shown in figure 4, where the display is first erased white, then selectively switched black.

3.3 Temperature Compensation

As with all bistable LCDs, the energy required to latch the desired state is temperature dependent. Using data obtained from test cells a simple temperature compensation scheme was applied to the device. The results shown in figure 5 below represent maximum and minimum values for selection voltage V_s+V_d . This representation maps well onto the operating window as a function of temperature.

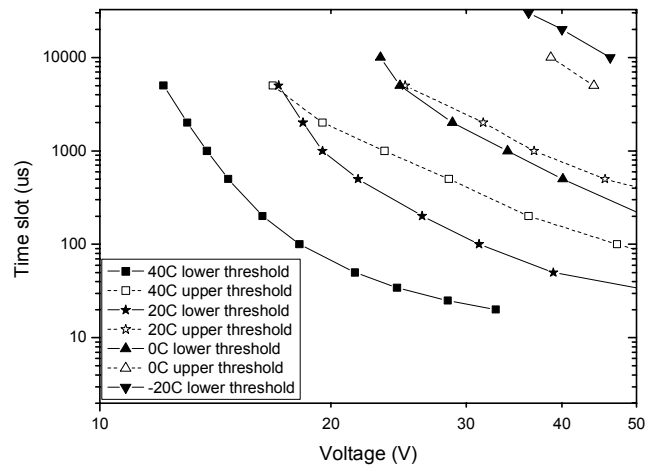


Figure 5: Operating window as a function of temperature for simple bipolar switching.

From the graph it is clear that by varying both voltage and line address time we may operate the module across a 60° temperature range using standard 42V drivers. In the first simple temperature compensation scheme, V_s is varied at a fixed line address time of 800µs (where 1 line address time=2 time slots). In this way 1200 rows may be addressed across a temperature range of more than 40°C. This shows multiplexability well beyond the range of the most complex STN displays using a simple passive matrix. In a more advanced scheme, by simultaneously varying V_s , V_d , and the line address time, it is more appropriate to operate the device with a room temperature line address time of ~400µs halving the update speed to <1s.

3.4 Power Consumption

All bistable displays offer great power saving potential as compared with continuously driven STN or TFT displays. However in order to take advantage of the bistable display, the surrounding electronics must power down between screen updates. Bistable display technologies therefore present a challenge to the wider portable applications industry, if the whole device is to be power-optimised. For this prototype device, we have ensured that there is no power drain between updates. The

operating system is as simple as possible which also saves some power. However, individual sub-assemblies, for example power supplies are non-optimal. While continuously updating (@ 1Hz), the device draws 100mW from 1.5V batteries capable of supplying 1400mAH. This equates to 21hrs continuous operation. Each page displayed contains nearly 1 million pixels, and at 200dpi, the display can show, with excellent readability, a standard page of text from a paperback book. If we assume it takes a person 1 minute to read the displayed information, then we can calculate that the batteries will provide enough power to update >75000 pages. This equates to ~1500 books and 1250hrs of continuous reading or 312 days reading at 4 hours per day. Further device optimization – rather than display optimization will result in further significant increase in battery life. By comparison, a transmissive colour 7.5” STN device with (640x3)x480 pixels (Optrex F 51202NC-FW-AA) consumes 350mW in normal operation neglecting the power drawn by the backlight which clearly dominates the overall power consumption of the device. Figure 6 shows the trade-off in power as a function of update rate.

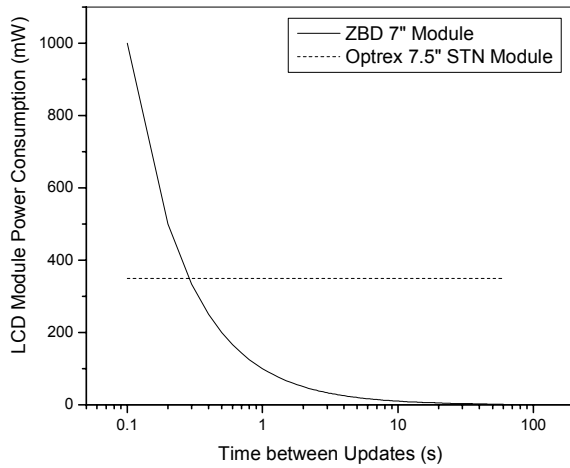


Figure 6: A comparison between ZBD and STN. The graph shows the variation of LCD module power consumption as a function of the time

3.5 Optical Performance

ZBD’s optical configuration was shown earlier in figure 2. The twisted state gives a highly uniform black state between parallel polarisers, and the contrast and angle dependent viewing is almost completely determined by the hybrid bright state configuration.

At normal incidence, there is no contribution to birefringence from the hybrid state, hence in figure 7a, the peak reflectivity of 33% obtained near normal incidence is very close to the theoretical limits imposed by the absorption of the polariser and the 13Ω/□ ITO electrodes.

The reflectivity and contrast measurements were made on an Eldim EZ Contrast 160R device under fully diffuse illumination. Peak contrast under these conditions is >25:1, as shown in figure 7b. Fully diffuse illumination is a very harsh test of device performance - using specular illumination for example; we have recorded figures in excess of 100:1. However, the specular

measurements may be highly variable according to the chosen angle of illumination and by the nature of the rear reflector. Hence in reflective display characterization, we hope that the standard for comparison will become the fully diffuse measurement.

Due to the hybrid configuration of the bright state, we see some asymmetry in the angle dependent viewing; this gives a preferred viewing axis for the device. No compensation films were used in the fabrication of this prototype. If necessary, compensation could be used for a higher degree of circular symmetry.

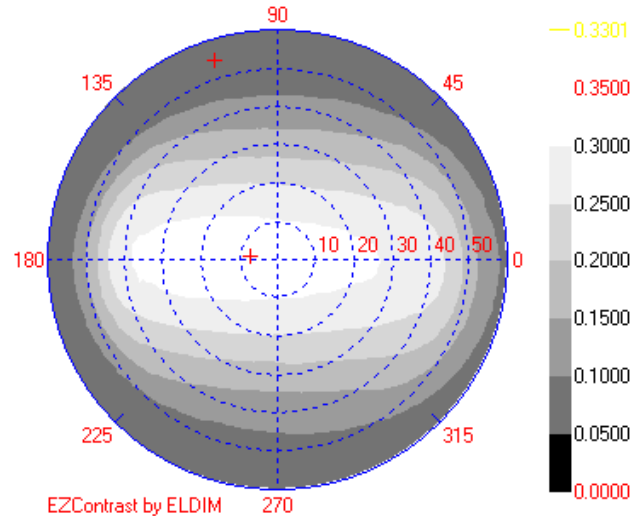


Figure 7a: Reflectivity obtained from ZBD device under diffuse illumination

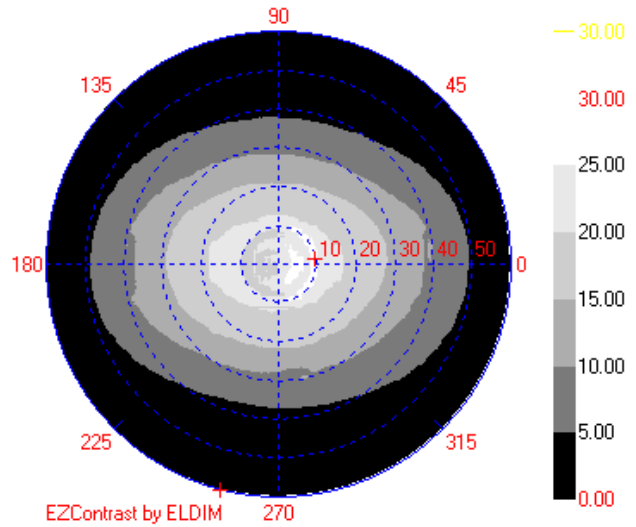


Figure 7b: ZBD angle dependent contrast measured under diffuse illumination

