論文

7 inch Digital Micro Shutter Display Driven by InGaZnO Oxide TFT

InGaZnO MEMSディスプレイ開発

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Digital Micro Shutter (DMS) Display based on MEMS design and process technologies provides wide color gamut, wide operating temperature range and low power consumption, compared with LCD and OLED which are widely used at the present time.

Conventionally, DMS display was driven by LTPS TFT because of its high frequency operation.

Oxide TFT as represented by InGaZnO has higher performance and reliability than a-Si TFT, as well as better productivity for large display than LTPS TFT. The InGaZnO oxide TFT can be applied to drive DMS display with good performance. It means that uniquely high performance and large size DMS displays can be produced without significant investment.

In this paper, technologies and performance of 7 inch diagonal DMS display are explored.

MEMS技術に基づくデジタルマイクロシャッターディスプレイは，広色再現性，かつ，低消費電力の実現を可能とする。従来は，デジタルマイクロシャッターディスプレイは，高移動度を特徴とするLTPS TFTで駆動されていた。一方，InGaZnO TFTは，a-Si TFTと比較し，高い性能と信頼性を有し，かつ，LTPS TFTと比較するとより大型の基板で製造できるため，将来の大型化においても有利である。本稿では，7″のInGaZnO MEMSディスプレイを紹介する。

1. Introduction

Digital Micro Shutter (DMS) Display based on MEMS design can provide a lot of unique characteristics[(1)(2)].

However, because MEMS shutter is driven digitally with either open or close state, it is necessary to set both color and gray scale by digital field sequential driving. That requires high frequency driving in comparison with LCD and OLED. For example, in the case of 24 bit color, it is necessary to refresh the MEMS panel at 1440Hz (24 * 60) as minimum frequency. Sharp has been developed and produced InGaZnO LCD Display[(3)(4)].

Oxide TFT can achieve higher mobility, such as approx. $10cm^2/Vs$, in comparison with a-Si TFT, and can be manufactured on larger size mother glass with smaller mask numbers in comparison with LTPS.

Therefore, we have focused on above merits of oxide TFT backplane technology, and we have successfully developed a prototype of 7″ WXGA MEMS display as shown in **Fig. 1**.

Fig.1 Prototype of 7″ WXGA MEMS display.

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2. Outline of 7″ MEMS Display

Fig. 2 shows the block diagram of the 7″ MEMS display prototype.

The configuration is similar to other displays.

A Control IC receives image data and commands from host side. The control IC needs to rearrange image data to match it with a field sequential driving of MEMS display. Therefore, the IC needs to have a frame memory. Thus, as a module I/F, it will be adequate to select a standard I/F that supports an option of display modules contains a frame memory internally.

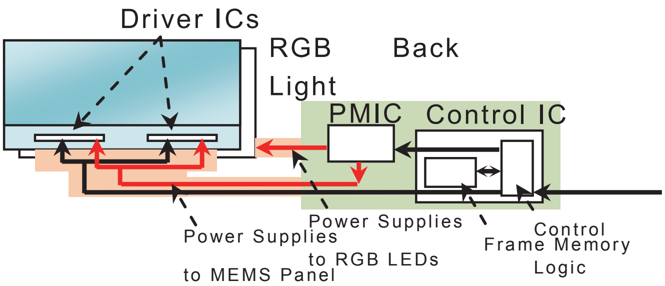


Fig. 2 Block Diagram of Prototype of 7″ WXGA MEMS display.

A power management IC (PMIC) needs to generate power supplies for both RGB LEDs and MEMS panel.

A driver IC sends binary voltages to a MEMS panel for controlling shutter either open or close state. Therefore, the chip does not need to have circuits for controlling analog voltages of each output, and can be designed quite simply.

3. Results

The outline specification of the prototype is as follows:

Table 1 A summary of CR and NTSC ratio.

Size	7.0″
Resolution	1280 x 800 (217ppi)
Contrast	3000
NTSC Ratio	120%

Regarding a brightness and power consumption, it has been targeted to achieve a half of power consumption of LCD. As of today, a MEMS panel is driven with FPGA board, and a chip set is needed to realize the target.

Fig. 3 shows characteristics of color coordinate including data measured from slanted angle. Theoretically, MEMS display does not show any color shift on all axis.

Therefore, there is a potential to utilize MEMS display for a professional use.

Fig. 4 shows characteristics of contrast vs viewing angle. Contrast above 10 at +/- 80 deg can be achieved.

Especially, the Y direction, parallel with long side of a shutter slot can achieve extremely wider viewing angle compared to LCD display.

Regarding a response time, **Fig. 5** provides a comparison of waveform detected by photo diode when a display switching from black to white. In the case of MEMS display, one frame is consisted by several sub-frames and many pulses can be observed. That means a change of luminance can be different depending on start and end point of gray scale level (Patterns of Shutter Open/Close) in the case of MEMS display.

Although MEMS display is a field sequential color display, response time adopting MRPT (Moving Picture Response Time) has been evaluated and the result is shown

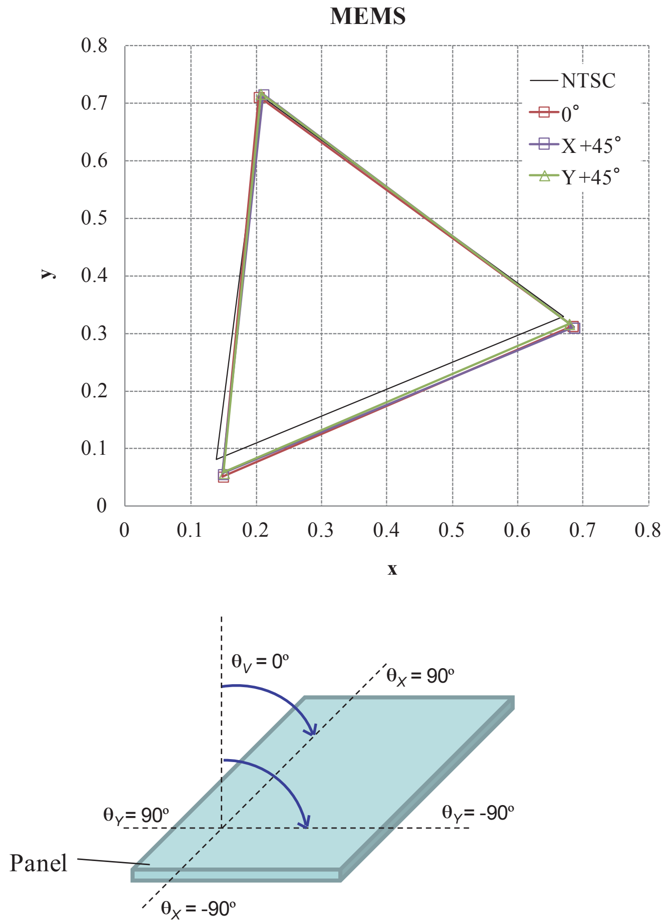


Fig. 3 Color Coordinate from slanted angle.

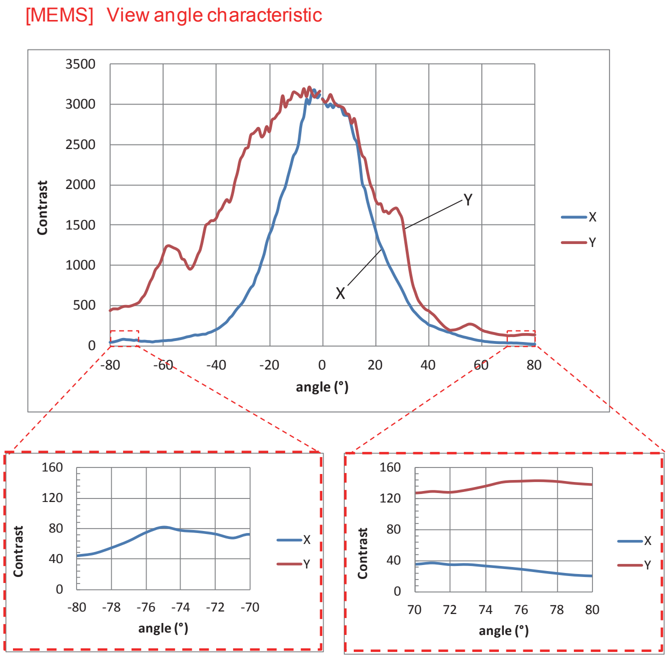
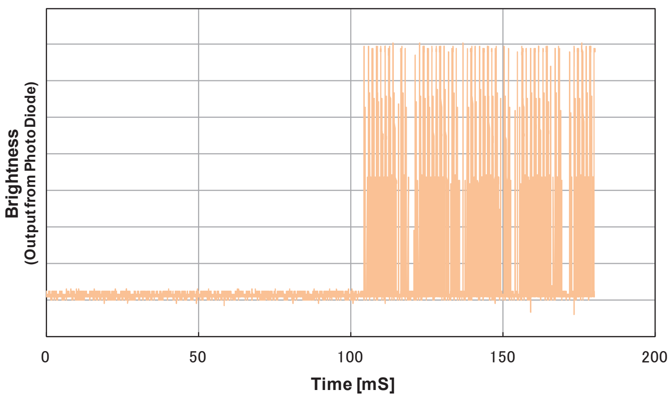
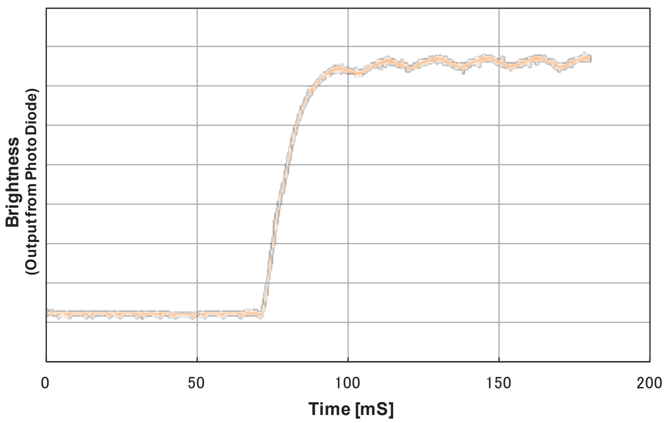


Fig. 4 Contrast from slanted angle.

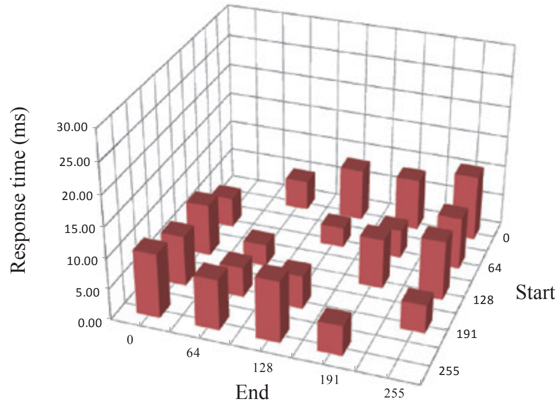


(a) MEMS Display

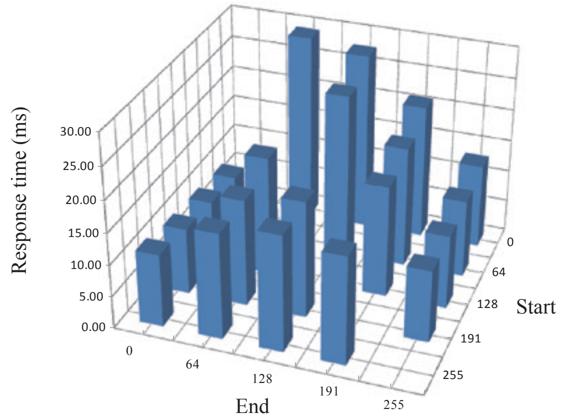


(b) LCD

Fig. 5 Waveforms detected by photo diode.



(a) MEMS Display



(b) LCD Display

Fig. 6 Response time of MEMS Display between gray levels (MPRT).

in **Fig. 6**. MEMS display can surely switch within one frame period. On the other hand, as well known, LCD shows longer response time than one frame on some areas depending on start and end of gray scale.

Also, MEMS display has a potential to secure good image quality in the very low temperature range such as -20C. As shown in **Fig. 7**, MEMS display demonstrates stable characteristic over a wide range of temperature.

Lastly, as shown in **Fig. 8**, in comparison with a LCD panel, a MEMS panel is flipped and placed on a backlight module to have a light recycling effect.

Therefore, it is important to reduce unexpected reflectance from metal patterns of TFT layers.

Fig. 9 and 10 show the optical performance under 20,000lux lighting. **Fig. 9** shows module brightness versus contrast, while **Fig. 10** shows NTSC ratio versus module brightness.

It is confirmed that equivalent optical performance can

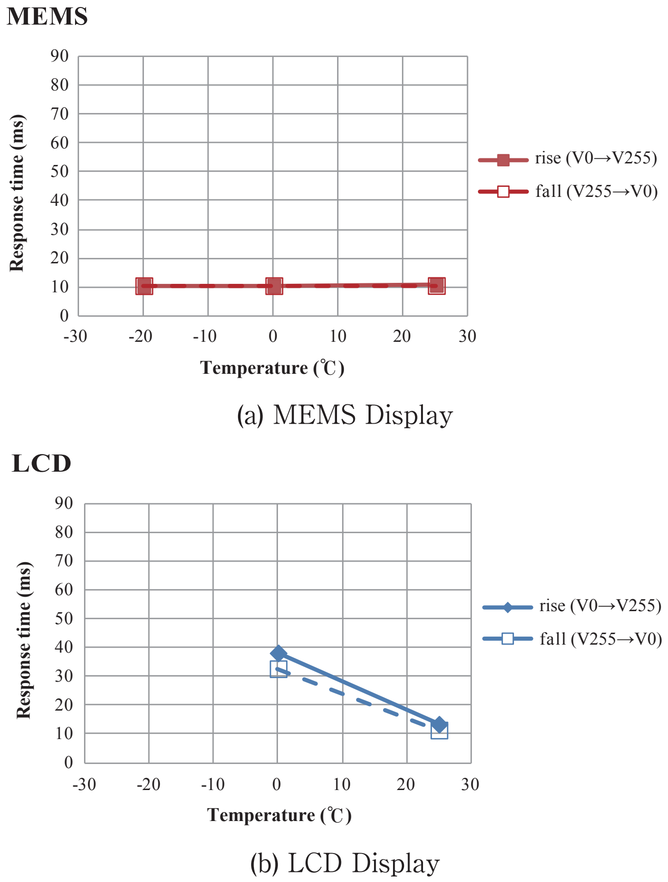


Fig. 7　Response time of MEMS Display over the temperature (MPRT).

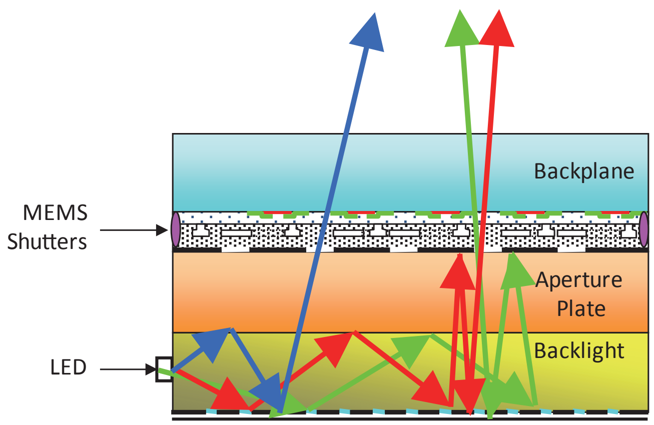


Fig. 8　Cross Section of MEMS Display.

be achieved without attaching polarizer at the same brightness setting with LCD.

Moreover, if the half power consumption of LCD can be successfully achieved, it will be possible to make the brightness higher utilizing the power difference under normal usage, and to enjoy better viewability at outside.

Also, in the case of MEMS display, it can be proposed to reduce bit plane numbers for outside usage because it is

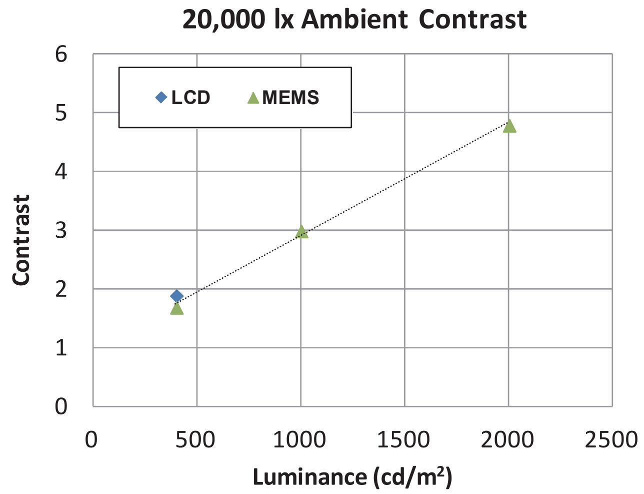


Fig. 9　Contrast under 20,000 lux.

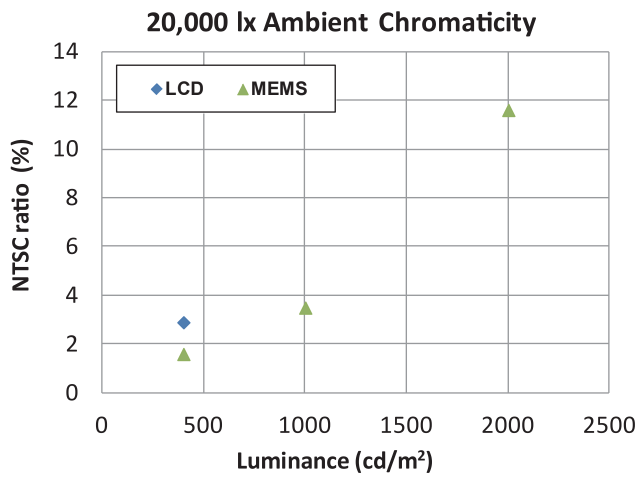


Fig. 10　NTSC Ratio under 20,000 lux.

difficult for human eyes to recognize full color gray scale levels when the display surface was illuminated with strong light and contrast of the display becomes lower. By doing so, higher brightness can be realized with lower power consumption .

4. Summary

7″ MEMS display we have developed can achieve ultra low power consumption with high optical efficiency, exceptional image quality with ultra wide color gamut, agility to further reduce the power based upon bit planes required, and good operation under wide range of environmental temperature

By using oxide TFT as backplane technology for MEMS display, it will be possible to widen not only the choice of MEMS display size, but also the range of applications.

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