Introduction
JDI releases a series of MIP (memory-in-pixel) reflective-type color LCDs which realize high reflectance performance with ultra-low power consumption. In following pages this application note will explain its design concept, optical enhancement feature and command examples.
Design Concept

MIP (Memory-In-Pixel)
In JDI MIP reflective-type color display, there’s a SRAM (static random access memory) in each pixel which can store image without continuous signal input. In this case, controller in customer’s system can be in sleep mode or totally off to achieve ultra-low power consumption (around 1-5 \(\mu\) A for still image for 2.7” panel). As shown in Figure 1, in comparison with transmissive LCD, to use reflective-type LCD can save 80% of power due to no backlight is needed; Additionally, MIP technology can save 19% more power during displaying still image. If partial screen data updates is needed, end user can choose multiple line update or single line update to refresh display instead of re-writing the whole screen.

![Power consumption comparison](image)

Figure 1. Power consumption comparison

Compact Outline Design
MIP reflective-type color LCDs can benefit narrow border (around 1.2~2.2mm for 1.28”) and thin panel thickness (0.8 to 1.4mm) from its LTPS process, new circuit technology and no built-in driver IC design, therefore end user has more flexibility to adapt it into compact application, such as portable equipment.

Simple Interface
The interfaces of current MIP reflective-type color LCDs (1.28”, 2.7” and 4.4”) are 10-pin FPC with 0.5mm pitch which is a common connector type for industrial use, ex. Hirose FH19SC-10S-0.5SH(0.5). Signals are input via SPI (Serial Peripheral Interface) interface with three wires (SCLK, SI and SCS). To drive LCD, only monolithic power rail is needed so that it can avoid unnecessary power waste through boosting voltage. For example, the efficiency to boost few \(\mu\)A from 3V to 5V is around 10%.
Brightness Enhancement

One most outstanding characteristic of reflective-type LCD is its readability under strong ambient light. LCD can be read clearly by the reflection of ambient light without backlight unit (see Picture 1). However, in order to increase its application versatility with color display, readability drops after applying color filter above the reflective layer. The total brightness will reduce by around 70%.

![Picture 1. Readability comparison under direct sunlight](image)

To improve brightness, JDI uses optical light control technologies to optimize viewing angle for specific screen sizes. Refer to Figure 2, when light goes into LCD, the light control technologies help to efficiently reflect more light, resulting in wider viewing angle.

Furthermore, silver material is also used to enhance the reflectivity. JDI uses silver as the reflective material instead of Aluminum because its reflectance is 6~7% better.

![Visible brighter](image)  ![Visible at wider angle](image)

(a) LCF Technology  
(b) Inner scattering

Figure 2. Optical Light Control Technologies
Connection Suggestion

To keep tolerance for signal threshold, please use same power rail voltage for both output device and LCD input (each end of signals). In case you need higher SPI transfer rate, set the power rail voltage higher for both output and input. Below are examples which use CPU as a controller:

- **Typical connection**
  Use same power source to drive CPU and LCD so that signal operations will be within same voltage range.

![Figure 3. Typical connection](image)

- **CPU under 1.5V / LCD 3V**
  For CPU operated in low voltage for lower power consumption, a dual power buffer of CMOS output can bridge the CPU and LCD.

![Figure 4. Connection while CPU under 1.5V / LCD 3V](image)
VCOM frequency

In order to avoid DC bias occurs in MIP LCD while displaying still image for a long time, the voltage (VCOM) of liquid crystal must invert continuously. There are two options to set VCOM driving mode, details listed below:

- By software (via command): For application like watch or timer, in which signals updates regularly, end user can send toggle VCOM command every time data changes. Keeping VCOM duty (H or L) symmetrical is effective to prevent DC bias.

  ![Figure 5. EXTMODE: L mode](image)

- By hardware (via signal line): Independent clock device such as RTC can be used to keep controller sleeping or totally off.

  ![Figure 6. EXTMODE: H mode](image)

Operating frequency is the most critical factor to total power consumption because there are capacitive load in each liquid crystal, the higher the frequency is, the better optical performance you get. However, flicker may be visible if frequency is too low, such as under 1Hz. It is recommended to use higher frequency rate (around 60Hz) while lighting up with backlight unit since the flicker phenomenon is more sensitive.
**LCD commands**

There are several kinds of modes (commands) to write screen data and command structure as listed below:

**SINGLE LINE UPDATE**
Any single line can be updated individually as a minimum unit. Below is the command example if customer would like to update 1\textsuperscript{st} line of panel, in 3BIT-DATA MODE. For details, please refer to specification.

<table>
<thead>
<tr>
<th>Mode selection (6bit)</th>
<th>Gate line address (10bit)</th>
<th>Color Voltage Data (nx3 bit)</th>
<th>Data Trailer (16bit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H L/H L L L _ _ _ 0 0 _ 0 1</td>
<td>H/L H/L H/L H/L H/L H/L - _ _ _</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* n represents horizontal resolution.

**MULTIPLE LINES UPDATE**
Any continuous lines can be written without re-writing whole screen data, ex. 149\textsuperscript{th} ~153\textsuperscript{rd} lines.

**NO-UPDATE**
Make both M0 and M2 high or low to maintain current screen data with VCOM inversion.

**DISPLAY BLINKING COLOR / DISPLAY COLOR INVERSION**
If the application unit would like to attract end users’ attention by blinking/inversion color command is recommended, such as application for special alarm or information signage.

**Power consumption**
Another outstanding feature of MIP reflective-type color LCD is its low power consumption ability while displaying still image and even writing mode. For panel displaying static image, the power consumption of 1.28” LCD is around 2µW. If the screen data changes every second, the power consumption is 10µW. If the screen data updates 10 times per second (10fps, frame per second), the power consumption is 90µW.
Summary

JDI MIP reflective-type color displays bring memory LCD to a colorful world. 8 colors display enable customer to do more design for information demonstration, see Picture 2. With new circuit technology, LCD can be more compact for variety of applications than before. Power consumption is also lower than current solution in the market. Our 1.28”, 2.7”, and 4.4” LCD have market trend’s simple interface which allow easy customer evaluation. In future Eco and IoT world, MIP reflective-type color display is expected to play an important role for its ultra-low power consumption characteristic.

Picture 2. More details (examples) for content design

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