The most important parameter to assess the optical performance of a passive monochrome LCD is the display contrast. Therefore the $V_{LCD}$ voltage must be set properly to gain an optimum contrast.
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1. Introduction

The most important parameter to assess the optical performance of a passive monochrome LCD is the display contrast.

2. Display contrast

Assumed an LCD with a certain resolution, a defined LCD drive mode (commonly called multiplex rate) and a defined LCD bias configuration (commonly called bias system), the display contrast depends on the $V_{LCD}$ voltage, also called operating voltage of the display.

For an optimum display contrast, the $V_{LCD}$ voltage must be set in order that the following two conditions are met (see Figure 1):

1. $V_{off}(\text{RMS}) \leq V_{th}$
   where $V_{th}$ is the threshold voltage of the display, defined as the RMS voltage corresponding to 10 % relative transmission, and $V_{off}$ is the voltage supplied to drive the pixel OFF; the condition $V_{off}(\text{RMS}) \leq V_{th}$ means that the pixel is really driven OFF.

2. $V_{off}(\text{RMS}) \geq V_{sat}$
   where $V_{sat}$ is the saturation voltage of the display, defined as the RMS voltage corresponding to 90 % relative transmission, and $V_{on}$ is the voltage supplied to drive the pixel ON; the condition $V_{on}(\text{RMS}) \geq V_{sat}$ means that the pixel is really driven ON.
Higher values of $V_{\text{LCD}}$ lead to a loss of contrast since the pixel cannot be really driven OFF ($V_{\text{off(RMS)}} \geq V_{\text{th}}$), see Figure 2.
Lower values of $V_{LCD}$ lead to loss of contrast since the pixel cannot be really driven ON ($V_{on(RMS)} \leq V_{sat}$), see Figure 3.

There is only a strict range of $V_{LCD}$ values that lead to an optimum contrast: the optimum value is that one, that maximizes the product $(V_{th} - V_{off}) \times (V_{on} - V_{sat})$. This product has always to be positive.
In summary, to optimize the contrast:

1. **V\textsubscript{LCD} must be independent from the V\textsubscript{DD} supply**
   
   To be able to select the LCD voltage value and then optimize the display contrast independently from the V\textsubscript{DD} supply.

2. **V\textsubscript{LCD} must be programmable in a wide range**
   
   To be able to optimize the display contrast for a wide selection of LCDs with different V\textsubscript{th} and V\textsubscript{sat}.

3. **V\textsubscript{LCD} must be programmable with a small programming step and very accurate**
   
   To guarantee that the programmed LCD voltage value is as much as possible close to the optimum value also across process variations.

\[ V_{th} = 1.5 \text{ V}; \quad V_{sat} = 2.5 \text{ V}; \quad \text{MUX 1:4; bias } \frac{1}{3}. \]

**Fig 4. Optimum V\textsubscript{LCD} value to optimize the display contrast**
4. \( V_{LCD} \) must be compensated over temperature to keep a high and stable contrast over the temperature range

Since the display characteristics change over temperature, \( V_{LCD} \) should also change to maintain the best contrast over temperature.

Different solutions can be implemented by using discrete components.

In order to reduce the BOM and the overall system cost, NXP has developed a wide portfolio of LCD drivers with an integrated charge pump and regulator to generate the \( V_{LCD} \) on-chip and allow programming the \( V_{LCD} \) value accurately in a wide range, by simply programming a register through the interface. The capacitors of the charge pump are also integrated on-chip, allowing reducing the number of external components to a minimum. Further, NXP has integrated a temperature sensor and a \( V_{LCD} \) temperature compensation circuitry in order to compensate the \( V_{LCD} \) value with the temperature and to reach an optimum contrast all over the operating temperature range, from \(-40 \degree C\) to \(85 \degree C\) for the industrial and consumer LCD drivers and from \(-40 \degree C\) to \(95 \degree C\) or even \(105 \degree C\) for the automotive qualified LCD drivers.

![Fig 5. \( V_{LCD} \) generation including temperature compensation](image-url)
### 3. LCD drivers with integrated charge pump

**Table 1. List of LCD drivers with integrated charge pump**

<table>
<thead>
<tr>
<th>Product type</th>
<th>Maximum resolution</th>
<th>Package</th>
<th>$V_{LCD\ programmable \ range}$</th>
<th>Max. charge pump multiplication factor</th>
<th>Temperature range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Packaged LCD segment drivers</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCA8547</td>
<td>4 x 44</td>
<td>TQFP64</td>
<td>2.5 V to 9.0 V</td>
<td>3 x $V_{DD2}$</td>
<td>-40 °C to 95 °C</td>
</tr>
<tr>
<td>PCA8543</td>
<td>4 x 60</td>
<td>LQFP80</td>
<td>2.5 V to 9.0 V</td>
<td>3 x $V_{DD2}$</td>
<td>-40 °C to 105 °C</td>
</tr>
<tr>
<td>PCA8537</td>
<td>8 x 44</td>
<td>TQFP64</td>
<td>2.5 V to 9.0 V</td>
<td>3 x $V_{DD2}$</td>
<td>-40 °C to 95 °C</td>
</tr>
<tr>
<td>PCA9620</td>
<td>8 x 60</td>
<td>LQFP80</td>
<td>2.5 V to 9.0 V</td>
<td>3 x $V_{DD2}$</td>
<td>-40 °C to 105 °C</td>
</tr>
<tr>
<td><strong>Chip-On-Glass LCD segment drivers</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCA8538</td>
<td>9 x 102</td>
<td>bare die</td>
<td>4.0 V to 12.0 V</td>
<td>5 x $V_{DD2}$</td>
<td>-40 °C to 105 °C</td>
</tr>
<tr>
<td>PCA8539</td>
<td>18 x 100</td>
<td>bare die</td>
<td>4.0 V to 16.0 V</td>
<td>4 x $V_{DD2}$</td>
<td>-40 °C to 105 °C</td>
</tr>
<tr>
<td><strong>Chip-On-Glass LCD character drivers</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCA2117</td>
<td>1 line x 40 characters or 2 lines x 20 characters</td>
<td>bare die</td>
<td>4.0 V to 16.0 V</td>
<td>4 x $V_{DD2}$</td>
<td>-40 °C to 105 °C</td>
</tr>
<tr>
<td>PCF2119</td>
<td>2 lines x 20 characters</td>
<td>bare die</td>
<td>2.2 V to 6.5 V</td>
<td>4 x $V_{DD2}$</td>
<td>-40 °C to 85 °C</td>
</tr>
<tr>
<td>PCF21219</td>
<td>2 lines x 20 characters</td>
<td>bare die</td>
<td>2.5 V to 6.5 V</td>
<td>4 x $V_{DD2}$</td>
<td>-40 °C to 85 °C</td>
</tr>
</tbody>
</table>

Choose the NXP LCD drivers with integrated charge pump that allow both, high performance and low cost!
4. References

[1] AN10170 — Design guidelines for COG modules with NXP monochrome LCD drivers

[2] AN11267 — EMC and system level ESD design guidelines for LCD drivers

[3] PCA8547 — 4 x 44 automotive LCD driver with integrated charge pump, product data sheet

[4] PCA8543 — 4 x 60 automotive LCD segment driver with integrated charge pump, product data sheet

[5] PCA8537 — Automotive LCD driver for multiplex rates up to 1:8, product data sheet

[6] PCA9620 — 60 x 8 LCD high-drive segment driver for automotive and industrial, product data sheet


[8] PCA8539 — 100 x 18 Chip-On-Glass automotive LCD dot matrix driver, product data sheet

[9] PCF2119 — LCD controllers/drivers, product data sheet

[10] PCF21219 — LCD driver for character displays, product data sheet

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