

High-Voltage CMOS Backplanes for High-Brightness OLED Microdisplays

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Abstract

OLED are limited in full-color very high brightness applications in harsh environments. This can be addressed by multiply stacking OLED layers on top of each other, limiting the current density (maintaining reliability), while increasing luminance. However, this OLED layer stacking raises forward voltage across the OLED stack. Therefore, a high-voltage CMOS backplane for high-brightness OLED microdisplays has been developed and will be reported here.

Author Keywords

OLED, microdisplay, high-brightness, high-voltage, CMOS, backplane

1. Introduction

OLED microdisplays are the most mature emissive microdisplay technology on the market. They provide very high pixel density, low or even ultra-low power consumption, and slim form factor due to the frontplane being light source and image modulator in the same device. However, OLED are limited in terms of very high full-color brightness in harsh environments. This can be addressed by multiply stacking OLED layers on top of each other, limiting the current density (positively affecting reliability), while increasing luminance. Yet, this OLED layer stacking is adding-up forward voltage across the OLED stack. Therefore, a high-voltage CMOS backplane for High-Brightness OLED microdisplays has been developed and will be reported here.

2. Approach

A common method for enhancing brightness of the OLED-light engine while keeping operating lifetime at a high level, is to use multi-stacked OLEDs. [1, 2] Multi-stacked OLEDs need a higher driving voltage supplied by the complementary metal-oxide semiconductor (CMOS) backplane. We will show and explain the major pixel cell design approach of a new 0.62" SXGA CMOS backplane enabling a voltage swing of >10V (resulting in cathode voltages down to -20...-25V depending on specific OLED stack), thus being capable in driving multiply stacked top-emitting OLED device layers. According to the number of stacked units multiples of the maximum emission in their spectra can be reached, achieved by increased current efficiency, while current density remains. This approach enables full-color maximum luminance of >10knits while maintaining lifetime and reliability.

3. Results

The backplane is capable to drive multi-stack OLEDs with more than 2 stacks. Anyway, initial tests have been carried out using a

standard 2 stack white OLED which also enables comparison to previous backplanes e.g. [3]. This backplane serves as a reference, as it has a similar size and therefore a comparable active area. To implement a higher resolution, the number of sub-pixels was reduced from the previous 4 (quad pixel RGB) to 3 sub-pixels (RGB stripe). Nevertheless, it has been possible to keep the area requirement of the sub-pixel cell constant, which is particularly remarkable in view of the additional feature of driving higher voltages. Driver circuits with higher voltage levels usually require larger transistors and are therefore more difficult to integrate into small pixel cells. The display uses the well-known approach of a highly efficient white OLED stack along with lithographically patterned color filters to realize red, green and blue sub-pixel. Further key facts of the new backplane are given in Table 1. An image of an initial prototype of a full-color version is shown in Figure 1. Detailed power measurements of driver backplane and OLED frontplane for a range of different image content and frame rates are given in Figure 2.

Table 1. Technical key parameters of high-voltage SXGA microdisplay backplane

Parameter	Value
Nom. Display Resolution	1280 x 1024
Total Display Resolution	1296 x 1040
Number of Subpixels	4.04 million
Active Area	12.29 x 9.83 mm ²
Chip Size (nominal)	14.9 x 11.8 mm ²
Display Diagonal	0.62"
Frame Rate	up to 120Hz
Contrast Ratio	>100.000:1
Pixel Setup	RGB-stripe
Pixel Pitch	9.6μm x 9.6μm
Sub-pixel Size	3.2μm x 9.6μm
Color depth	24-bit
Display interface	24-bit RGB digital, parallel + synchronization signals CLK, VS, HS and DE
Display brightness	300 cd/m ² (typ.) 3500 cd/m ² (peak brightness with standard 2-stack white OLED)
Configuration Interface	I ² C (two-wire-interface)
Backplane Type	Common cathode



Figure 1. New high-voltage SXGA microdisplay on HDMI evaluation kit (left), closeup of microdisplay chip (right)

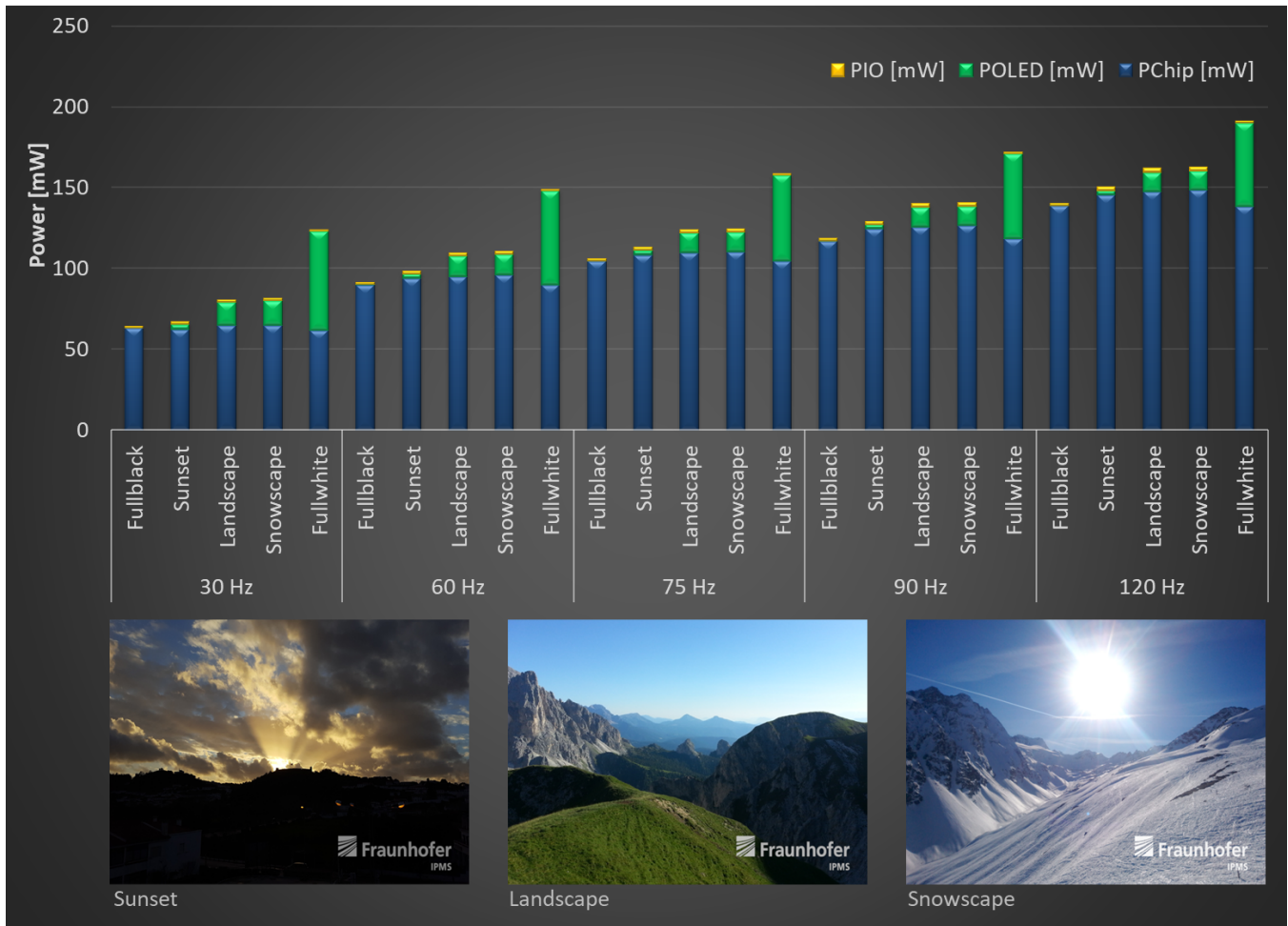


Figure 2. Power consumption of a new SXGA OLED microdisplay for typical frame rates (using the CVT reduced timing scheme, further reduced timing scheme for 120Hz) as well as different display contents ranging from a full black to different sceneries up to a full white screen (full white brightness is calibrated to 300cd/m² for that measurement), power consumption is measured for OLED (POLED, green), CMOS backplane (PChip, blue) and IO (PIO, yellow, can be neglected) separately

4. Impact

OLED are considered to be limited in very high brightness applications and harsh environment scenarios. That's why often microLED are being advertised as an alternative, claiming to achieve luminance even in the 1 Mnits range. However, for very high pixel densities as required in high-resolution microdisplays (e.g., >5000ppi), microLED face a significant efficiency drop, requiring them to be driven at $\gg 1\text{A}/\text{cm}^2$. In addition, that technology is not yet mature, specifically for full-color. In contrast, OLED drive current density for long lifetime operation is typically at $<100\text{mA}/\text{cm}^2$. By that, OLED-on-Silicon technology has reached high maturity and features several established OLED microdisplays on the market. Yet long-lifetime, reliable full-color CW luminance is then limited to a few 1000nits only using 2-stack OLEDs. By applying multiply stacked OLED on top of a high-voltage CMOS backplane this luminance can be extended to about 10knits now, therefore providing expanded market opportunities for high-brightness OLED microdisplays.

5. Conclusion and outlook

This paper presents a new microdisplay backplane approach capable of driving higher voltage swings and enabling stacked OLED frontplanes to address higher luminance at lower pixel currents for a reasonable lifetime. Initial validation of the backplane has been done with a standard 2-stack white OLED with lithographically patterned color filters on top to provide initial power and brightness figures.

The backplane circuitry provides the option of driving multiple stacked OLEDs. The evaluation of these possibilities is the subject of future investigations, which will be carried out in particular by adapting and optimizing the OLED frontplane.

6. References

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