Review of High-PPI Micro-LED Display Drivers with Current-Mode PWM and Compact Pixel Circuits for Near-Eye Applications

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***Abstract*—This paper reviews recent advances in high-pixel-density micro-LED display drivers for near-eye applications. Two micro-LED driver designs fabricated in 0.18-μm CMOS technology are presented, featuring current-mode pulse-width modulation (PWM) and compact pixel circuits. The first design employs a 2-transistor pixel circuit with a precharge scheme for a 1280 × 720 display, while the second introduces a 1.15-transistor pixel circuit using a three-stage pass-transistor structure to achieve 7700 PPI. Both designs adopt down-counter-based PWM generation for accurate grayscale control. The paper further discusses key trade-offs among pixel circuit complexity, driving speed, power consumption, and pixel density, providing insights for next-generation near-eye micro-LED displays.**

***Keywords*—Micro-LED display driver; Pulse-width modulation (PWM); High pixel density; Current-mode driving**

I. INTRODUCTION

To achieve high-resolution displays with small pixel pitch, micro-LED arrays are typically integrated with CMOS display drivers through flip-chip bonding. However, as pixel density increases, the number of pixels connected to each data line grows significantly, resulting in large parasitic capacitance and degraded driving speed. In addition, accurate grayscale generation requires high-speed pulse-width modulation (PWM), which further increases circuit complexity [1]–[2]. This paper reviews two recently proposed micro-LED display driver architectures that address these challenges through compact pixel circuit design and efficient PWM generation. The design trade-offs between driving capability, pixel density, and circuit complexity are analyzed to provide insights for future high-performance micro-LED display systems.

II. REVIEW OF MICRO-LED DISPLAY DRIVER ARCHITECTURES

A conventional micro-LED display driver architecture consists of a timing controller, scan driver, and column driver. The column driver generates PWM signals and converts them into current signals to drive the micro-LED array.

To improve driving speed, a 2-transistor (2T) pixel circuit was proposed [3]. The additional transistor isolates the micro-LED from the data line when the PWM signal is low, thereby reducing discharge time. The second design targets ultra-high pixel density with a 640 × 480 micro-LED driver achieving 7700 PPI [4]. The proposed three-stage pass-transistor pixel circuit reduces the average transistor count to 1.15 per pixel.

III. CONCLUSION

This paper reviewed two state-of-the-art micro-LED display driver designs targeting high-resolution near-eye display applications. The 2T pixel circuit provides enhanced driving speed through isolation and precharge effects, while the 1.15T pixel circuit achieves ultra-high pixel density by reducing transistor count per pixel. Both designs adopt down-counter-based PWM generation, offering a simple and effective solution for grayscale control. These design approaches highlight the fundamental trade-offs among pixel density, driving speed, and circuit complexity. The insights presented in this paper can guide future development of micro-LED display drivers for next-generation AR/VR systems.

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