PIXEL LEAKAGE AND INTERNAL RESISTANCE COMPENSATION SYSTEMS AND METHODS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to and the benefit of U.S. Provisional Patent Application No. 62/906,619, filed Sep. 26, 2019, entitled "Pixel Leakage and Internal Resistance Compensation Systems and Methods," and U.S. Provisional Patent Application No. 62/906,615, filed Sep. 26, 2019, entitled "Pixel Leakage and Internal Resistance Compensation Systems and Methods," both of which are incorporated herein by reference in their entireties for all purposes. This application is related to U.S. application Ser. No. _____, filed Aug. 26, 2020, entitled "Pixel Leakage and Internal Resistance Compensation Systems and Methods," (Attorney Docket No. P43285US1; APPL:1022A), which is incorporated herein by reference in its entirety for all purposes.

SUMMARY

[0002] A summary of certain embodiments disclosed herein is set forth below. It should be understood that these aspects are presented merely to provide the reader with a brief summary of these certain embodiments and that these aspects are not intended to limit the scope of this disclosure. Indeed, this disclosure may encompass a variety of aspects that may not be set forth below.

[0003] Numerous electronic devices—including televisions, portable phones, computers, wearable devices, vehicle dashboards, virtual-reality glasses, and more—display images on an electronic display. As electronic displays gain increasingly higher resolutions and dynamic ranges, they may also become increasingly more susceptible to image display artifacts due to current leakage between pixels and/or a voltage drop across pixel circuitry associated with an internal resistance (IR) of the pixel circuitry. Furthermore, although a pixel may be commonly considered singularly, each pixel may include a grouping of sub-pixels separate from each other and potentially "cross talking" with each other and with other surrounding sub-pixels. For example, intra-pixel current leakage may occur between sub-pixels of the same pixel, and inter pixel current leakage may occur between sub-pixels of surrounding sub-pixels that may be associated with other pixels. The lateral leakage of current between sub-pixels and/or IR drop within a sub-pixel's circuitry may alter the luminance output of the sub-pixels and induce perceivable artifacts such as banding, color inaccuracies, edge effects, etc. As such, image processing circuitry, such as implemented in a display pipeline, may be used to compensate for current leakage and/or IR drop.

[0004] In one embodiment, one or more 3-dimensional (3D) lookup tables (LUTs) may be used to compensate for intra-pixel current leakage and/or IR drop. For example, the 3D LUT may take as an input the luminance values for each of the sub-pixels (e.g., a red sub-pixel, a blue sub-pixel, and/or a green sub-pixel) of the pixel and output a compensated luminance value for each sub-pixel. As should be appreciated, although discussed herein as using a 3D LUT, any suitable LUT or computational algorithm may be used to calculate the compensated values, depending on implementation. However, in some scenarios, LUTs may prove less taxing on system resources (e.g., processor bandwidth, communicational bandwidth, and/or memory bandwidth). The compensated values may take into account the values of each sub-pixel, relative to the other sub-pixels, and boost the luminance of sub-pixels that would have otherwise decreased in luminance output and/or attenuate the luminance of sub-pixels that would have otherwise increased in luminance output.

[0005] Additionally or alternatively, a LUT may be used to compensate for IR drop by boosting the luminance of a sub-pixel based on the luminance level of the sub-pixel and/or the luminance of the surrounding sub-pixels. For example, a sub-pixel with a higher target luminance may receive a larger boost to compensate for a larger IR drop because the higher amount of current associated with the higher target luminance may induce a larger IR drop. Additionally or alternatively, the compensation for the IR drop and the intra-pixel current leakage may be combined into a single 3D LUT.

[0006] The LUT(s) for IR drop and current leakage may have equal or approximately equal tap points such that interpolation (e.g., linear or non-linear) may be accomplished to specify compensation values between those of the LUT. However, in some scenarios, the rate of change of the current leakage at lower brightness may change more quickly than at high brightness. In other words, the concavity of the current leakage as a function of luminance value may lead to greater errors in interpolation at lower brightness than at higher brightness. To help reduce such potential variations in the interpolation, the input image data may be mapped to a non-linear space (e.g., a gamma color space or other non-linear space) before the 3D LUT is applied to "squeeze" the tap points of the 3D LUT at lower brightness and spread out the tap points of the 3D LUT at higher brightness. Indeed, in the non-linear space, the 3D LUT may provide higher fidelity for interpolation of the compensation values at lower brightness settings than at higher brightness. Moreover, when the brightness of the display is less than a threshold value (e.g., 500 nits, 100 nits, 50 nits, 10 nits, etc.) the non-linear mapping may be engaged, the 3D LUT applied, and an inverse mapping may be utilized to return the image data to the original color space. Further, because of the lack of variation in tap point spacing, the original, linear, color space may provide better resolution at higher brightness than tap points in the non-linear color space. Therefore, when the brightness of the display is greater than the threshold value, the non-linear mapping and corresponding inverse mapping may be disengaged/bypassed. As such, the same 3D LUT may be utilized in different color spaces depending on a brightness (e.g., a luminance output and/or a brightness setting) of the electronic display relative to a threshold to obtain better interpolation resolution between tap points in both low brightness and high brightness.

[0007] Additionally or alternatively to the 3D LUT(s) for IR drop and/or intra-pixel current leakage, compensation for inter-pixel current leakage may be applied. For example, a compensation value attributable to each sub-pixel surrounding a sub-pixel of interest, whether grouped as a single pixel with the sub-pixel of interest or grouped with a different pixel, may be calculated, summed, and applied to the luminance value of the sub-pixel of interest. In one embodiment, a two dimensional (2D) LUT may be referenced for each type (e.g., color) of sub-pixel acting on another type of