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User Interface Mitigation of Display Artifacts During Transitions between Display Clock Speeds

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Abstract:

This publication describes techniques for user interface (UI) mitigation of a display artifact that occurs when a display transitions between a high speed (HS) mode and a normal speed (NS) mode. The display may be implemented in a mobile device that supports multiple refresh rates. To conserve power, the mobile device may alter a refresh rate and clock speed of the display from a first refresh rate and clock speed in the HS mode to a second refresh rate and clock speed in the NS mode. Using the techniques described herein, the transition between the HS and NS modes coincides with a change in the UI, thereby mitigating the transition artifact and improving user experience.

Keywords:

Refresh rate (RR), dynamic refresh rate, refresh rate change, display, light-emitting diode (LED) display, organic light-emitting diode (OLED) display, display driver integrated circuit (DDIC), oscillator clock, clock frequency, display artifact, flicker, battery management, battery saving, battery life, user interface (UI), software

Background:

As computational capabilities of mobile devices continue to increase, so does the power draw from the power supply of mobile devices, which effectively reduces their battery life. Accordingly, mobile devices incorporate power-saving techniques to lower their power draw, such as lowering a refresh rate and clock speed of a display when a higher refresh rate and clock speed provide an insignificant difference to a user. However, transitions between refresh rates and clock speeds can cause display artifacts, such as blinking, flickering, or tearing. As a result of such display artifacts, the user of a mobile device may have a less desirable user experience. Consequently, mobile devices may be forced to choose between providing optimal user satisfaction or extended battery life.

Description:

This publication describes techniques for user interface (UI) mitigation of a display artifact that occurs when a display transitions between a high speed (HS) mode and a normal speed (NS) mode. The display may be any one of a variety of displays, including an in-plane switching (IPS) display, a twisted nematic (TN) display, a liquid crystal display (LCD), a light-emitting diode (LED) display, an organic light-emitting diode (OLED) display, or the like. The display supports multiple refresh rates and may be implemented in a mobile device (e.g., smartphone, tablet, smartwatch). Figure 1 illustrates a smartphone having a display that supports multiple refresh rates and the disclosed operating modes.

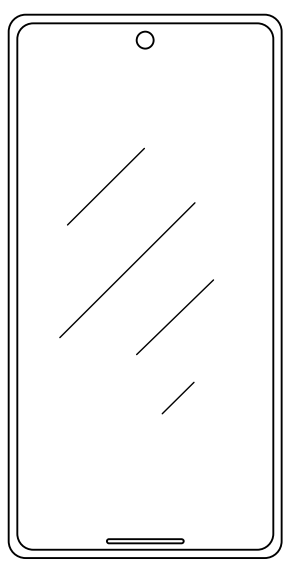

Figure 1

The display may include a display driver integrated circuit (DDIC). The DDIC may send commands to the display at rising and/or falling clock edges of an oscillator clock. The commands can include gray levels, luminance settings, color settings, and so forth. The oscillator clock may operate at various clock speeds, including lower clock speeds (e.g., 500 kHz, 1 MHz) and higher clock speeds (e.g., 5 MHz, 10 MHz). The DDIC may include a timing controller, one or more column line drivers, one or more row line drivers, and the like.

The HS mode provides refresh rates of 1 Hz through 120 Hz, whereas the NS mode provides refresh rates of 1 Hz through 60 Hz. While operating in the HS mode, the oscillator clock may operate at a higher frequency (e.g., frequencies of 5 MHz through 10 MHz). On the other hand, while operating in the NS mode, the oscillator clock may operate at a lower frequency (e.g., frequencies of 500 kHz through 1 MHz). Within each mode, however, the oscillator clock frequency does not vary, so refresh rate transitions within each mode are seamless. The higher refresh rates and oscillator clock frequency of the HS mode provide an optimal viewing experience and optical performance (e.g., a 120 Hz scan rate). The lower refresh rates and oscillator clock frequency of the NS mode provide extended battery life and performance, due to a lower scan rate (e.g., a 60 Hz scan rate). A user of the smartphone having the HS and NS operating modes may select the optimal viewing experience or the extended battery life through a display setting interface. Figure 2 illustrates an example display setting interface of the smartphone having the HS and NS operating modes.

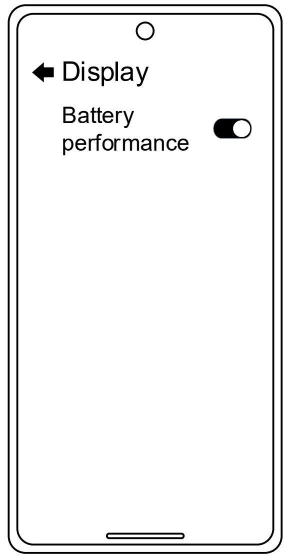

Figure 2

As illustrated in Figure 2, the display setting interface includes a toggle for enabling or disabling a battery performance mode. The battery performance mode (NS mode) is illustrated as enabled in Figure 2. When the battery performance mode is disabled, the HS mode is enabled and an optimal viewing experience and optical performance is provided (e.g., a 120 Hz refresh rate). Only one of the HS and NS operating modes may be enabled at a time, and the mode is selectable by the user. Unfortunately, however, when the operating mode transitions between the HS and NS modes, the changes in refresh rate and oscillator clock speed cause display artifacts that can be observed by the user, potentially causing eye discomfort and hurting user experience. The display artifacts may include tearing, blinking, or flickering.

The disclosed techniques mitigate the display artifacts by overlapping transitions between the display operating modes with transitions of the UI. Rather than immediately transitioning between the display operating modes, transitioning is delayed until content of the UI changes. For example, assuming the HS mode is enabled, the user of the smartphone may wish to conserve battery life. To conserve battery life, the user disables the HS mode and enables the NS mode.

After enabling the NS mode, the user returns to a home screen of the smartphone to cause the exit of the display settings interface (illustrated in Figure 2). As the content of the UI changes from the display settings interface to the home screen, the display operating mode changes from the HS mode to the NS mode. Due to the display mode transition overlapping the UI content change, the user does not notice display artifacts resulting from the transition. Although the example of transitioning from the HS mode to the NS mode was described, the transition can also be from the NS mode to the HS mode. Additionally, the UI content change can be any UI content change, not only the provided example of returning to the home screen. The UI content change can be returning to a previous settings screen, entering a multitasking operation, locking the display, and so forth.

Alternatively, the display operating mode transition may be delayed until the next sleep cycle of the smartphone. Smartphones generally include a display timeout or sleep setting, which can be configured by the user to be various periods of time (e.g., 30 seconds, 1 minute, 5 minutes). Rather than transitioning between the HS and NS modes when UI content changes, transitioning between the display modes coincides with the next sleep cycle. After the user wakes the smartphone from the next sleep cycle, the display operating mode is updated to the operating mode that the user selected.

In conclusion, by delaying display mode transitions to coincide with either a UI content change or a next sleep cycle, the disclosed techniques for UI mitigation of display artifacts are effective to improve user experience by hiding the display artifacts. Therefore, a smartphone user enjoys both visual performance in HS mode and extended battery life in NS mode and does not notice the display artifacts when transitioning between the display modes.

References:

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