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# Color Conversion Method for a Dark Theme User Interface

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# Color Conversion Method for a Dark Theme User Interface

**Abstract:**

This publication describes systems and techniques for providing a color conversion method for a dark theme user interface (UI) on a portable electronic device when a blue light filtering mode is enabled. Portable electronic devices, such as smartphones, often include a dark theme UI that displays the UI portion of a display of the portable electronic device displaying dark colors. When blue light filtering is enabled on the portable electronic device displaying the dark theme UI, the portable electronic device performs calculations to determine a color transform matrix (M) for blue light filtering and an inverse color transform matrix ($M^{-1}$) of that matrix. The portable electronic device can insert $M^{-1}$ into color metadata of a UI buffer layer to transform the colors of the UI and shift the UI layer towards a blue color. After blending the UI layer with other layers, all the displayed elements (*e.g.*, UI, graphics, text, etc.) are transformed by mapping M to their color metadata to perform blue light filtering. The dark theme user interface retains its true dark colors after transformation by M because it was previously shifted towards blue with $M^{-1}$.

**Keywords:**

Color conversion, color transform matrix, inverse color transform matrix, color metadata, blue light filtering, night mode, dark theme, user interface, UI, layer, per-layer conversion, active matrix organic light-emitting diode, AMOLED, display hardware pipeline

**Background:**

Portable electronic devices include a UI that enables users to interact with the electronic device. The UI is generally a two-dimensional area that includes text, data, and media, which can be displayed to the user on a display. Many portable devices include a display (*e.g.*, Active Matrix Organic Light-Emitting Diode (AMOLED) display) that requires increased power consumption to display white colors as compared to dark colors. Displaying white colors on the majority of a display can prematurely shorten battery life. Accordingly, a user may select to use a dark theme UI on the portable device to extend battery life. A dark theme UI uses dark colors on the majority of the user interface, with text, data, and media provided to the user in a contrasting color.

While the user is viewing a dark theme UI, the user may want to enable a blue light filtering mode (*i.e.*, night mode) to decrease the amount of blue light displayed on the display. However, blue light filtering can cause the dark theme UI colors to appear yellow and nonuniform, especially on an AMOLED display. The display may not display true black color to a user, which causes the user to have an undesirable visual interaction with the display.

Therefore, it is desirable to maintain uniformity of dark colors of a dark theme UI on a portable electronic device when the portable electronic device uses blue light filtering.

**Description:**

This publication describes systems and techniques for providing a color conversion for a dark theme UI on a portable electronic device when a blue light filtering mode is enabled. The portable electronic device performs calculations to determine a color transform matrix, M, for blue light filtering and an inverse color transform matrix, $M^{-1}$, of that matrix. The portable electronic device can insert $M^{-1}$ into color metadata of a UI buffer layer to shift the UI layer towards a blue

color. After blending the UI layer with other layers, all the displayed elements are transformed by mapping M to their color metadata to perform blue light filtering. The dark theme UI retains its true dark colors after transformation by M because it was previously shifted towards blue with $M^{-1}$.

Fig. 1, below, illustrates an example of a portable electronic device and elements of the portable electronic device that support a color transform application.

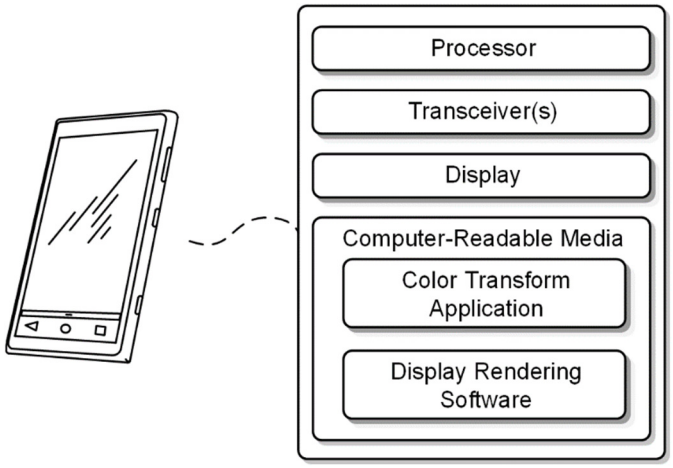


**Figure 1**

As illustrated, the portable electronic device is a smartphone. However, other portable electronic devices (*e.g.*, a tablet, a laptop computer, a wearable device, handheld video game consoles, electronic readers, and the like) can also support the color transform application described in this publication. The portable electronic device includes processor(s), transceiver(s) for transmitting data to and receiving data from an access point of a wireless network, a display screen (*e.g.*, AMOLED display), and computer-readable media (CRM) that includes a color transform application and display rendering software, which are executable by the processor(s) to enable color conversion. The CRM may include any suitable memory or storage device such as random-access memory (RAM), static RAM (SRAM), dynamic RAM (DRAM), non-volatile RAM (NVRAM), read-only memory (ROM), or flash memory. The color transform application

represents functionality that generates a color transform matrix (M), generates an inverse color transform matrix ($M^{-1}$), and provides these matrices to the display rendering software. The display rendering software represents functionality that receives M and $M^{-1}$, applies $M^{-1}$ to an individual layer buffer in the hardware of a display pipeline, blends layer buffers to create a blended image, and applies M to the blended image in the hardware of the display pipeline.

Figure 2 illustrates a process 200 performed on a portable electronic device for enabling color conversion with a dark theme user interface.

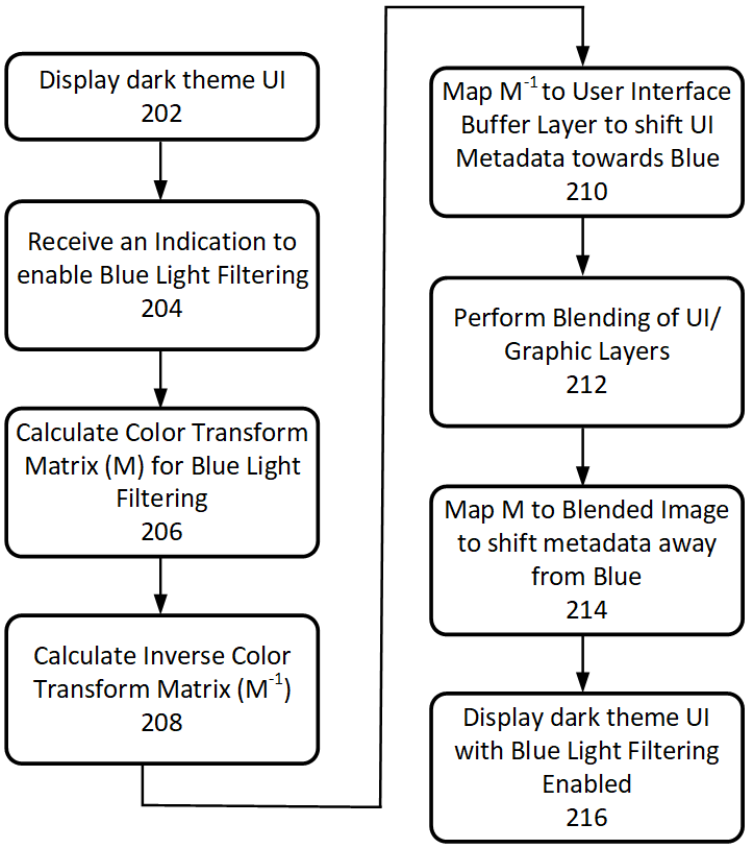


**Figure 2**

In a first operation 202, a portable electronic device displays a dark theme UI with dark colors on the majority of the user interface with text, data, and media provided in a contrasting color. At 204, the portable electronic device receives an indication (*e.g.*, user input, light sensor, etc.) to enable a blue light filtering mode. At 206, a color transform application calculates a color

transform matrix for blue light filtering, M. M can be calculated by using a ratio method from 0 to 1 (*e.g.*, blue light equal to 0.5, green light equal to 0.7, and red light equal to 1) to modify individual light-emitting diodes (LEDs) that compose a pixel. At 208, the color transform application calculates an inverse color transform matrix, $M^{-1}$. At 210, $M^{-1}$ is applied to the UI layer by a display rendering application that maps $M^{-1}$ to the color metadata of the UI layer buffer in the display hardware pipeline. This applies $M^{-1}$ to only a portion of the display and causes the UI layer to be shifted towards blue light values, performing a per-layer conversion of color. At 212, the display hardware pipeline performs blending of the UI layer and graphics layers to create a blended image. At 214, the display rendering application maps M to the blended image. An AMOLED display displays colors by directly activating individual pixels. Using a ratio method matrix, once M is applied, individual LEDs that compose a pixel on the display would emit less blue light with an overall effect of blue light filtering. As noted previously, since the UI layer color metadata was shifted towards blue with $M^{-1}$, the overall effect of applying M causes the UI portion of the display to return to its original color. At operation 216, the display displays dark theme UI with the blue light filtering mode enabled.

The process illustrated in Figure 2 describes enabling the dark theme UI with blue light filtering. Once enabled, the portable electronic device may continue to perform the color conversion method using the display hardware pipeline. An advantage of using the display hardware pipeline to implement $M^{-1}$ is that there is no significant power consumption demand on a processor of the portable electronic device. Figure 3 illustrates an example of a portable electronic device with dark theme UI enabled and the display hardware pipeline performing a color conversion.

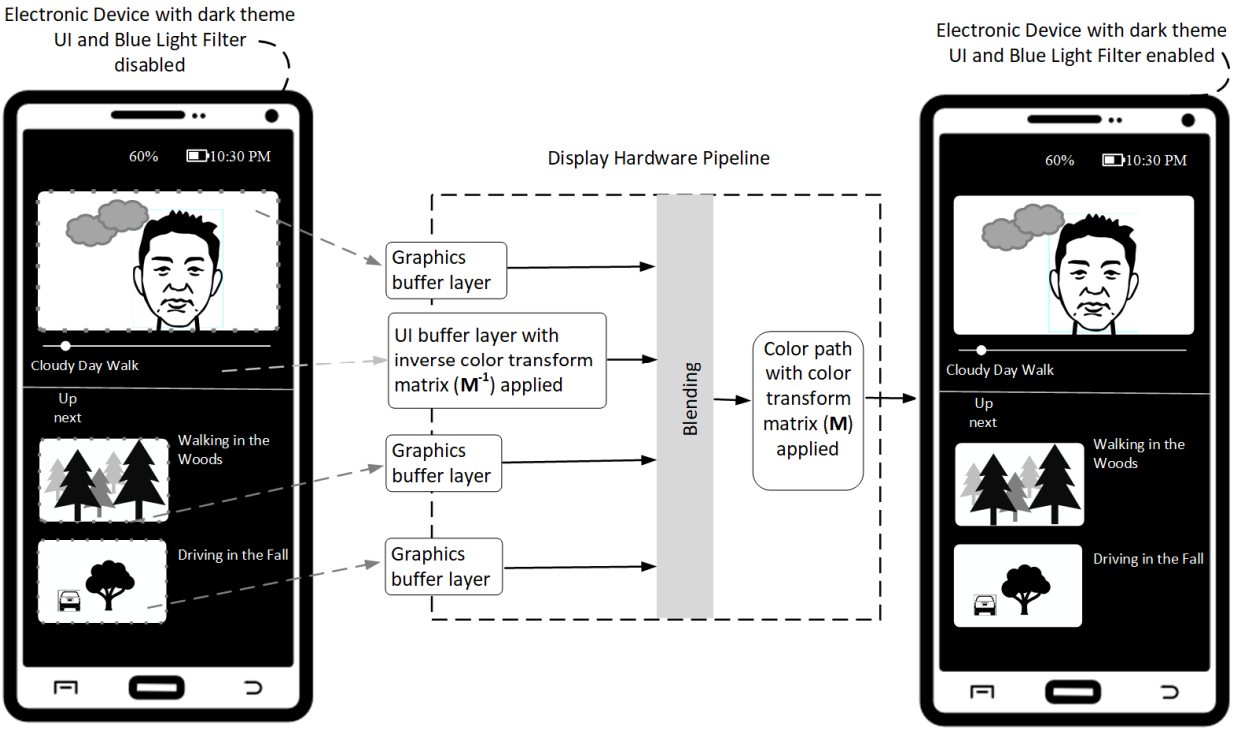


**Figure 3**

The described system and techniques provide color conversion features for UI elements on a portable electronic device. The portable electronic device can insert an inverse color conversion matrix, based on an indication for blue light filtering, into a dark theme UI metadata in order to maintain accurate dark colors. These systems and techniques improve the user's viewing of the user interface on the portable electronic device.

**References:**

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