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Dynamic Control of Scan Signals in AMOLED Displays to Reduce Power Consumption

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Abstract:

This publication describes systems and techniques to dynamically control the scan signals of an active-matrix organic light-emitting diode (AMOLED) display in portable electronic devices. Displays in portable electronic devices, such as smartphones, include tens of thousands of pixels. Scan signals in the display control the brightness and color of individual pixels. A leading source of power consumption in AMOLED displays, however, is the parasitic capacitance in the scan lines that carry the scan signals. As the frame rate of AMOLED displays has increased, the frequency of scan signals and the associated parasitic capacitance has also increased. This publication discloses a portable electronic device that can dynamically control the number of pulses in scan signals to reduce power consumption without degrading image quality.

Keywords:

AMOLED display, hysteresis, pixel circuit, luminance, scan pulse, scan signal, frame rate, frame time, parasitic capacitance, power consumption.

Background:

Portable electronic devices, such as smartphones, tablets, laptops, handheld video game consoles, and smartwatches, include displays. Many of these displays use AMOLED technology to provide higher refresh rates, reduce display response times, and lower power consumption in comparison to other display technologies. These advantages make AMOLED displays well-suited for portable electronic devices, in large part because power consumption is essential to user experience.

An AMOLED display consists of an array of pixels, as illustrated in Figure 1. The pixels generate light upon electrical activation by a series of scan signals over the horizontal scan lines. The pixels sit on an array of thin-film transistors (TFTs), which function as a series of switches to control the current flowing to each pixel. The vertical data lines provide data to control the luminance of individual pixels.

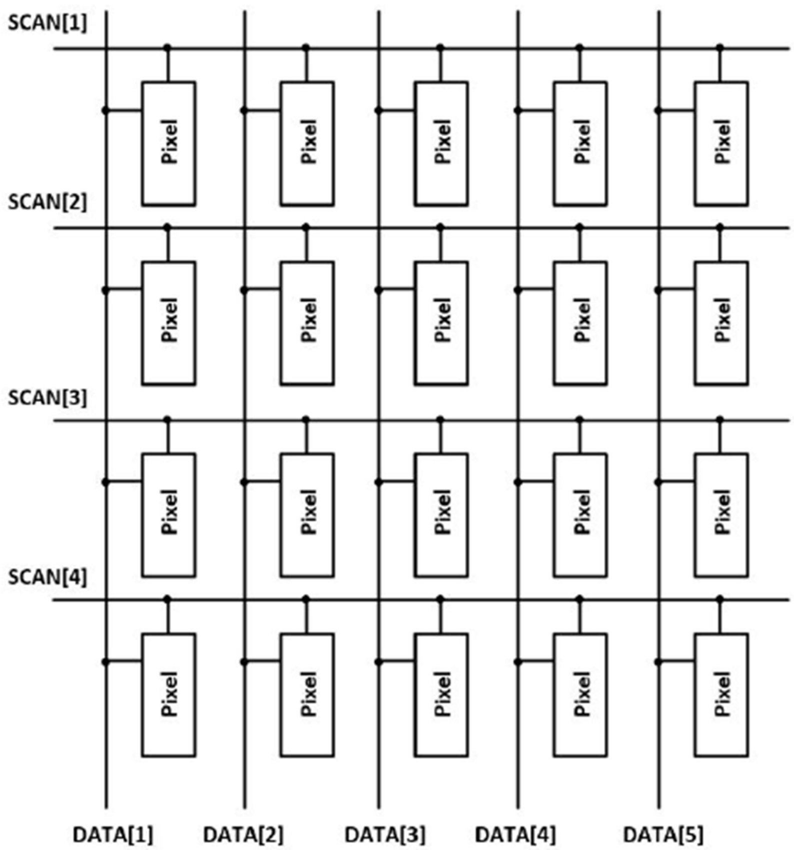

Figure 1

A leading factor for power consumption in AMOLED displays results from dynamic power dissipation in the scan lines. As the display charges and discharges the metal scan lines, parasitic capacitance in the scan lines leads to power loss.

AMOLED displays generally include multiple pulses per frame in the scan signal to improve pixel response time. Figure 2 below illustrates the response of an AMOLED display to a single scan pulse and three scan pulses per frame.

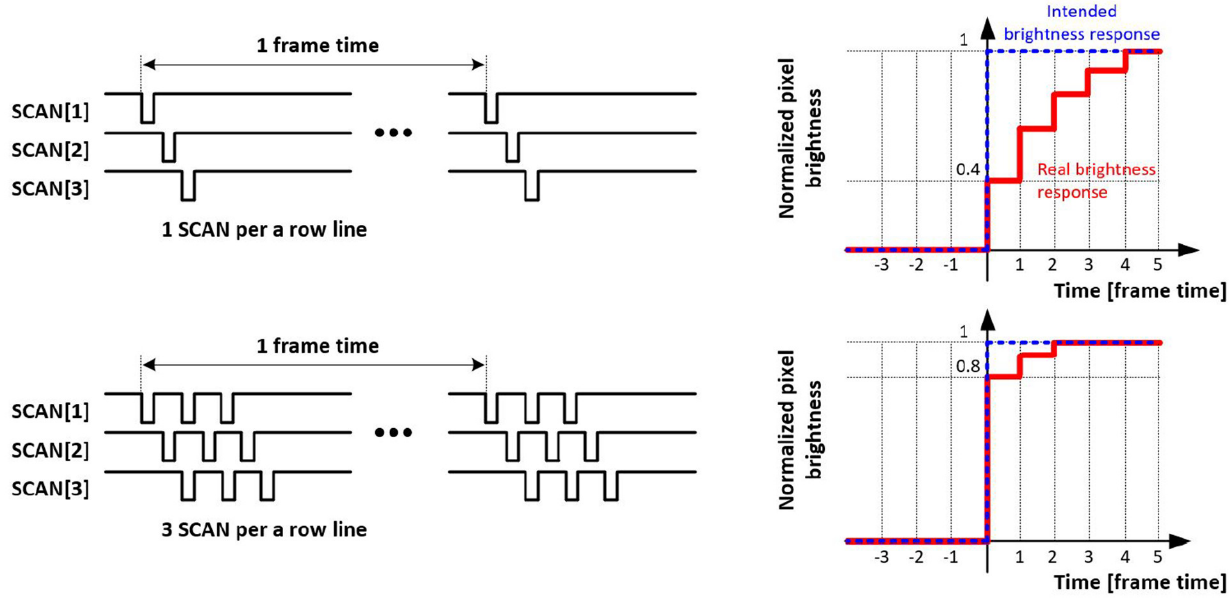

Figure 2

In Figure 2, the AMOLED display changes the luminance of a pixel from black (*e.g.*, gray 0 in 8-bit grayscale) to white (*e.g.*, gray 255 in 8-bit grayscale). If the scan signal includes a single pulse per frame, it can take several frames (*e.g.*, four frames) for the pixel luminance to reach the target luminance. This delay is due to a hysteresis effect of the TFTs, which can cause motion blurring.

AMOLED displays generally use multiple scan pulses per frame to mitigate the hysteresis effects and avoid motion blurring. As illustrated in Figure 2, the scan signal can include three pulses per frame. The display generally reaches the target pixel luminance much faster (*e.g.*, two frames) with multiple scan pulses. The increased number of scan pulses can also cause the pixel luminance after the first frame to be much closer to the target luminance.

Although multiple scan pulses can avoid motion blurring, the increased number of scan pulses per frame also increases the power consumption of the display. It is desirable to provide an AMOLED display with power savings while still avoiding motion blurring.

Description:

This publication describes systems and techniques to dynamically control scan signals in portable electronic devices to reduce power consumption. As described above, scan signals in an AMOLED display can include one or more pulses per frame. The described systems and techniques dynamically change the number of scan pulses per frame depending on image conditions.

When the image on a portable electronic device changes, the scan signals include multiple (*e.g.*, three pulses) per frame. If the image is unchanged, the scan signals include a single pulse per frame. Figure 3 illustrates the variable number of scan pulses based on the image.

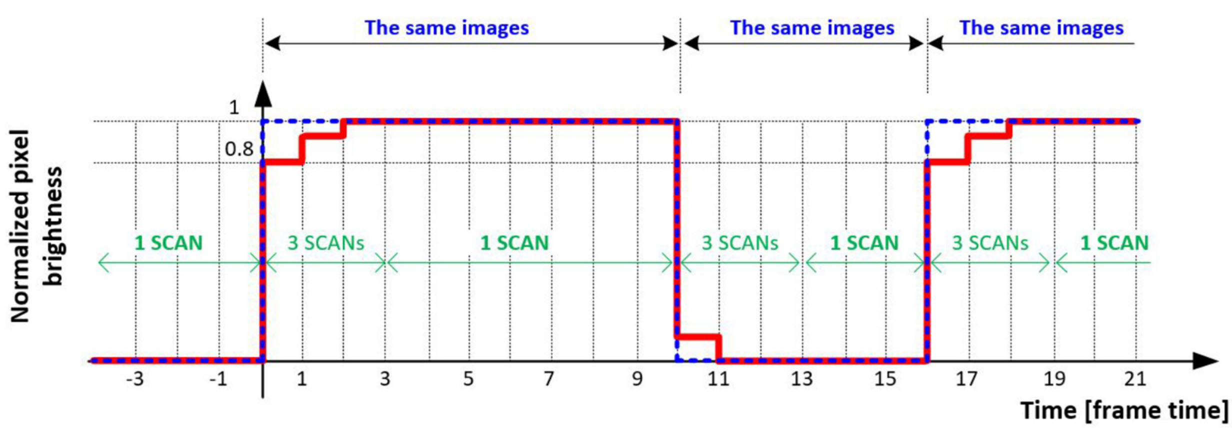

Figure 3

In Figure 3, the image changes at Frame 0. In response to the image change, the scan signal includes three pulses per frame for Frames 1-3. After the third frame, the scan signal reverts to a single pulse per frame to reduce power consumption as long as the image remains unchanged. A still-image display does not require multiple scan pulses to avoid potential motion blurring. By reducing the number of scan pulses for a static display, the AMOLED display can reduce its power consumption.

Portable electronic devices generally include a system-on-chip (SoC), application processor (AP), or a graphics processing unit (GPU) to control the creation and display of images. In the described systems and techniques, the SoC, AP, or GPU can provide a flag signal in the image data to a display driver to indicate whether the current image data is the same as the previous image data. Alternatively, the display driver can detect whether the image data is changed. Figure 4 illustrates this process. Based on the flag signal or its self-detection, the display driver determines the number of scan pulses for each frame. The display driver indicates the number of scan pulses in an input signal to the scan-line drivers. The scan-line drivers then output a scan signal on each scan line.

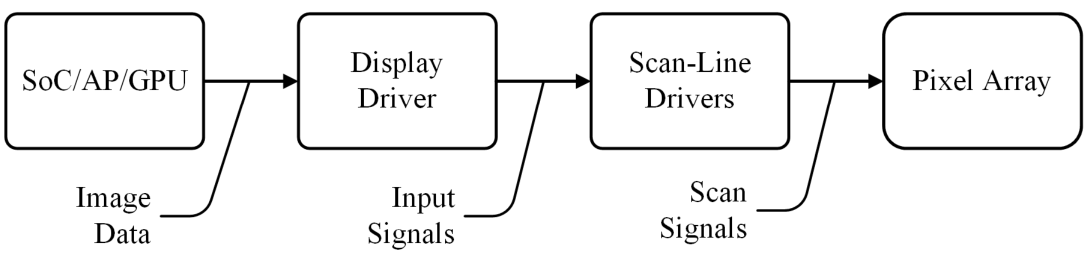

Figure 4

In some instances, the pixel luminance can change when the number of scan pulses is adjusted (*e.g.*, from three pulses per frame to one pulse per frame). If the number of scan pulses changes from three pulses to one pulse per frame, the luminance of the pixels can be noticeably lower. In such situations, the display driver can cause a transitional number of pulses per frame to adjust the pixel luminance gradually. Figure 5 illustrates an example of slowly changing the number of scan pulses.

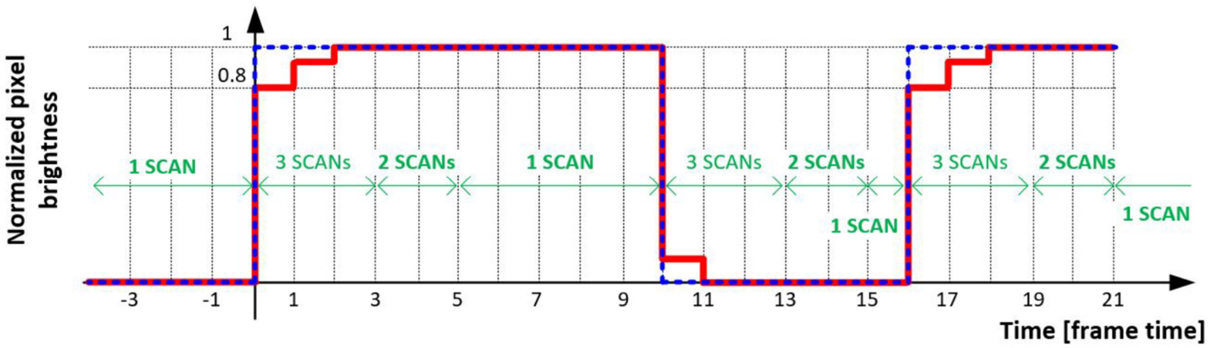

Figure 5

Figure 5 is similar to the example illustrated in Figure 3, but it includes two scan pulses as a transition from three pulses to one pulse per frame. After Frame 3, the scan signals for Frames 4 and 5 include two pulses. At Frame 6, the scan signals have a single pulse. The number of frames with the transitional number of pulses can be determined, for example, empirically from user-impact studies. The display driver repeats a similar pattern after the image changes at Frames 10 and 16.

A recent trend in portable electronic devices is for AMOLED displays to provide a high frame rate (*e.g.*, 90 Hz, 120 Hz). For example, some electronic devices use a dynamic refresh rate that varies the frame rate based on the type of content to be displayed (*e.g.*, higher frames rates for videos and games that generally have moving images). As the frame rate increases, motion blurring may not be perceptible to users because of the improved response time. Figure 6 illustrates response times of an AMOLED display with a 60-Hz frame rate and three scan pulses per frame to a display with a 120-Hz frame rate and one scan pulse.

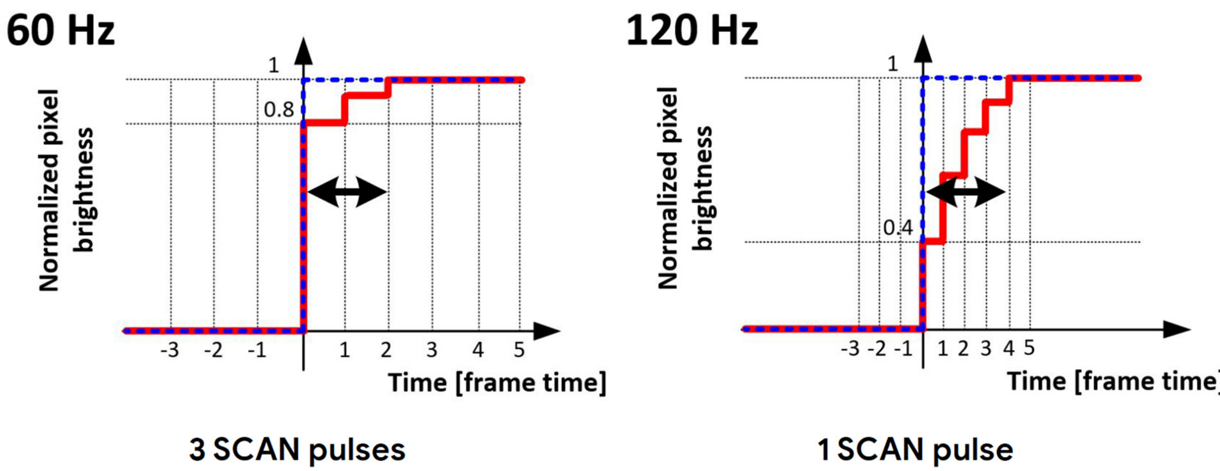

Figure 6

As illustrated in Figure 6, if the portable electronic device doubles the display's frame rate (*e.g.*, from 60 Hz to 120 Hz), the pixel response time can be approximately the same even with fewer scan pulses. Although the 120-Hz display takes four frames to reach the target luminance, it reaches the target in the same amount of time as the 60-Hz display. In situations when the electronic device operates at higher frame rates (*e.g.*, 90 Hz or 120 Hz), the display driver can reduce the number of scan pulses to reduce power consumption without noticeably affecting the display's performance. Similarly, the portable electronic device can use a single scan pulse when the device switches to a power-saving mode. In such situations, the device can alert the user that there may be some motion blurring for moving images.

Alternatively, the portable electronic device can vary the number of scan pulses when the display is using a dynamic refresh rate. When the display is using a low frame rate, a single scan pulse drives the pixel array. The scan signal includes multiple scan pulses when the device is using a high frame rate. In combination with the dynamic refresh rate, the changing number of scan pulses can improve the optical performance of the display (*e.g.*, reduced motion blur), while also reducing power consumption for still images.

The described systems and techniques provide dynamic control of scan signals in AMOLED displays to reduce power consumption and maintain optimal display performance.