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Display screens with variable refresh rate

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ABSTRACT

Device displays of a mobile device such as a smartphone or tablet have capabilities to support different refresh rates. For optimal operation, the refresh rate of the screen of a mobile device can be refreshed based on the image or frame of video being displayed and on certain other conditions. This disclosure describes low-complexity, low-latency techniques to seamlessly transition between different screen refresh rates with minimal-to-zero changes in display settings.

KEYWORDS

- Screen refresh
- Refresh rate
- 90Hz display
- Vertical synchronization
- Frame skipping
- Smartphone display

BACKGROUND

Fig. 1: Screen refresh in a mobile device

Screen refresh in a mobile phone, tablet, laptop, or other electronic device is illustrated in Fig. 1. An application processor (AP) includes a graphical processing unit (GPU) that generates a video signal, GPU_OUT. A frame memory unit processes the GPU_OUT signal to generate a signal DPU_IN, which is input to a display processor unit (DPU). The DPU has a transmit-side (Tx) and a receive-side (Rx), typically connected by a display serial interface (DSI), although other interfaces such as serial, parallel, or display-port interfaces can also be used.

The receive-side of the DSI is hosted on the display driver, which receives as input over the DSI a video signal, e.g., in MIPI (mobile industry processor interface) standard. As received by the DSI-Rx, the MIPI signal includes display data such as the intensity of pixels in a sequence of frames. The display driver includes a timing controller (TCON) that generates a timing signal (SCAN) that is sent to the physical display panel.

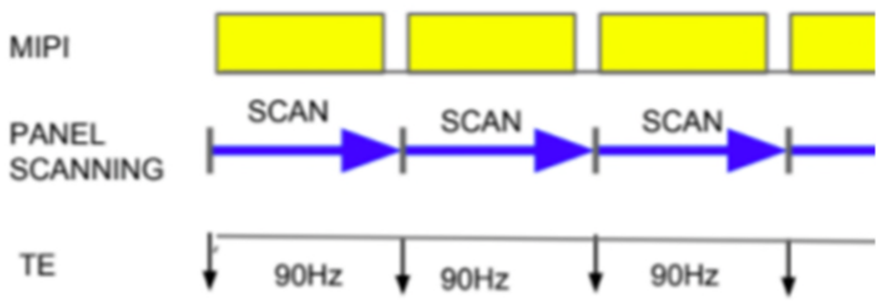

Fig. 2: Signals used to display image frames on a screen

Fig. 2 illustrates the signals used to display frames of images on a screen. The MIPI signal includes display information such as pixel intensity. The TE (tearing effect) signal is generated by the display driver and used for vertical synchronization, e.g., it triggers the redrawing of the screen. The TE signal is also fed back to the application processor. The panel scanning signals are a group of signals that enable pixels to appear at their designated intensities and colors. In the example of Fig. 2, the screen is redrawn at the rate of 90 Hz, e.g., every 11.11 milliseconds.

DESCRIPTION

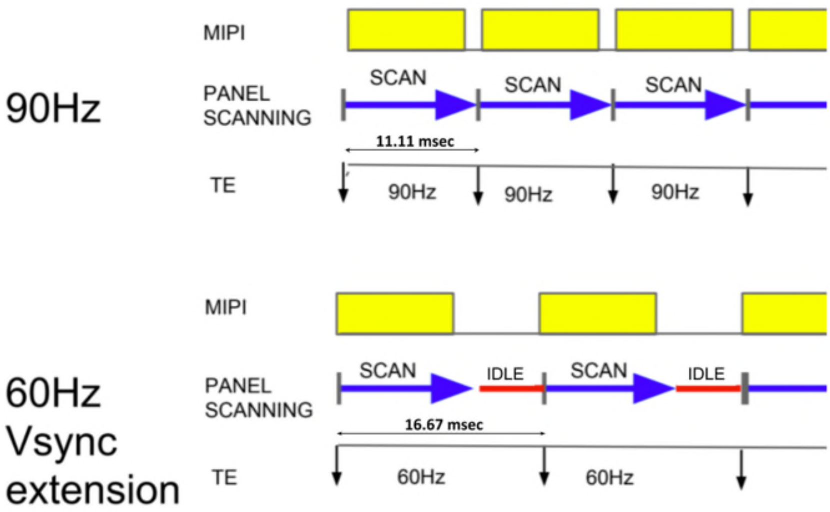

Fig. 3: Vertical synchronization extension to switch refresh rates

This disclosure describes techniques to seamlessly transition between different screen refresh rates with minimal-to-zero changes in display settings. A first technique, referred to as vertical synchronization (vsync) extension, is illustrated in Fig. 3. In the example of Fig. 3, the two screen refresh rates are 90 Hz and 60 Hz. The main (driver IC) oscillator is set to the highest setting that can support the higher (90 Hz) refresh rate. When in 90 Hz mode, the TE signal is issued every 1000/90=11.11 milliseconds. In 60 Hz mode, the TE signal is issued every 1000/60=16.67 milliseconds. Per the technique of vsync extension, when in 60 Hz mode, a display scan is completed in 11.11 milliseconds, and all input display data transactions are completed in the same time window. An idle period is introduced between 11.11 and 16.67 milliseconds wherein the frame that was displayed until 11.11 milliseconds is frozen. The frame is redrawn upon the next TE signal, which, in 60 Hz mode, appears every 16.67 milliseconds.

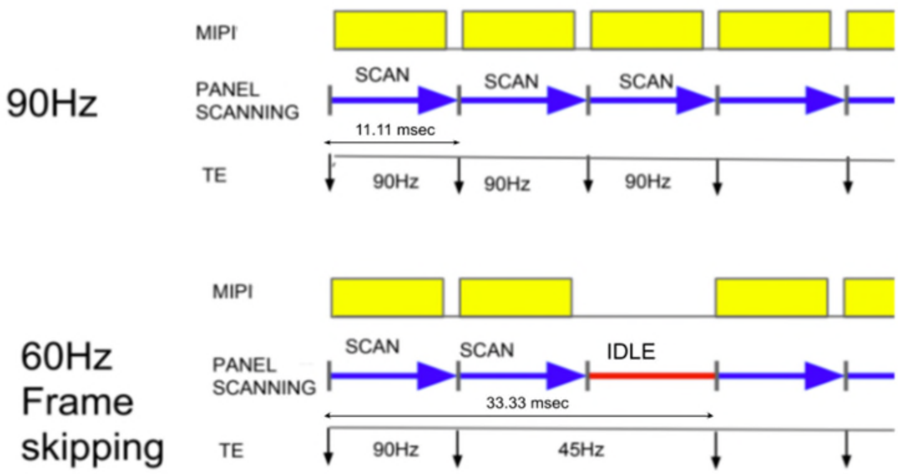

Fig. 4: Frame skipping to switch refresh rates

A second technique to switch refresh rates, referred to as frame skipping, is illustrated in Fig. 4. In the example of Fig. 4, the two refresh rates are 90 Hz and 60 Hz. The main (driver IC) oscillator is set to the highest setting that can support the higher (90 Hz) refresh rate. In both 90 Hz and 60 Hz refresh modes, the TE signal is issued at the higher rate, e.g., every 1000/90=11.11 milliseconds. Per the technique of frame skipping, in 60 Hz mode, an idle period of 11.11 milliseconds is introduced after every two consecutive 11.11 millisecond frames. In this idle period, the refresh of the panel is skipped, e.g., the frame that was displayed at the end of the second 11.11 millisecond period is frozen. The frame is redrawn every three 11.11 millisecond periods. A display scan is completed within the first 11.11 milliseconds, and all input display data transactions are completed in the same time window.

In general, the panel refresh can be skipped by the ratio of lower refresh rate to the higher refresh rate. For example, if the ratio of refresh rates is n/m, the panel refresh is skipped $m-n$ times out of m frame-intervals. The skipped frames are distributed evenly within the m frame-intervals. When a frame is skipped, input display data transactions and panel scanning are paused.

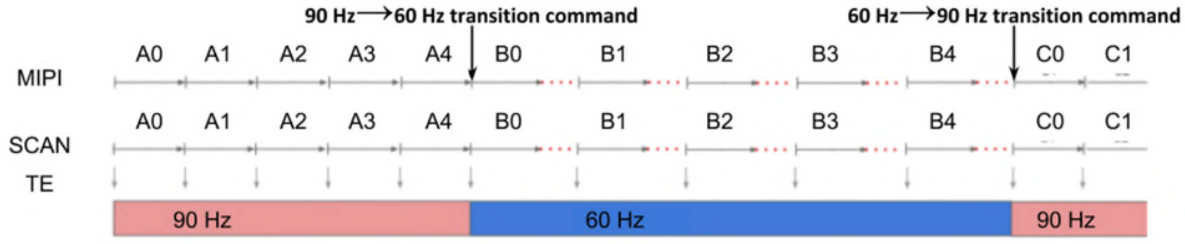

Fig. 5: A transition in refresh rates from 90 Hz to 60 Hz and back

Fig. 5 illustrates a transition in refresh rates from 90 Hz to 60 Hz and back. After five frames (A0-A4) in 90 Hz mode, a 90 Hz → 60 Hz transition command is received. The refresh rate switches to 60 Hz in vsync extension mode. Red dots in the 60 Hz mode indicate idle times. After five frames B0-B4 in 60 Hz mode, a 60 Hz → 90 Hz transition command is received. The refresh rate of the screen is switched back to 90 Hz.

The techniques of this disclosure enable switching refresh rates of a display in a low-complexity, low-latency manner, e.g., with a minimum of command transactions between the application processor and the display module, and with no change in the clock frequency. The described techniques can be used in a display driver, e.g., for a smartphone, tablet, laptop, or other device. Alternative to the techniques described with reference to Figs. 3-5, refresh rates can be switched by changing the oscillator frequency of the driver integrated circuit; in such an implementation, due to oscillator lock time, the application processor is fed with the latency characteristics of the display module.

CONCLUSION

This disclosure describes low-complexity, low-latency techniques to seamlessly transition between different screen refresh rates with minimal-to-zero changes in display settings.