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APPLICATION NOTE 5396

Dynamic Backlighting Improves Contrast Ratio and Trims Power for Small LCD Panels

By: Walter Chen, Principle Member of the Technical Staff, Applications
Zeeshawn Shameem, Member of the Technical Staff, Applications
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Abstract: The perceived contrast ratio of a cell phone LCD display can be improved by using dynamic LED backlighting for enhanced video viewing. This application note describes how to add instantaneous pulse-width modulation (PWM) intensity control to an existing LED driver, using the MAX6948B as an example.

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Backlit liquid crystal displays (LCDs) are found in many consumer products ranging from tiny mobile phones to large televisions. However, there are often many complaints about the contrast ratio, particularly the black level. Since LCDs require a backlight for illumination— the black level, which is the absence of light, doesn't quite look natural. Dynamic backlighting allows the ability to customize the backlight on LCD screens to increase the contrast ratio by varying the backlight intensity. With more handheld devices capable of playing video files, delivering an improved the viewing experience is a key selling point.

Currently, LCD TVs and handheld devices typically employ screen-edge backlights implemented with static cold-cathode fluorescent lamps (CCFLs) or LEDs. However, future large-area high-end LED backlit LCD TVs will have the screen divided into many rows and columns of cells, with each cell composed of groups of RGB LED clusters. By independently controlling the light output of each cell (based on the image content), dynamic backlighting improves the image contrast ratio. As backlight and driver costs come down, the next-generation high-end TVs could apply the dynamic control to each RGB LED cluster within a cell for an even finer-grain control of the backlighting. All that the system has to do is monitor the video content and feed a control signal back to the backlight controller to dynamically adjust the LED brightness in each cell.

For a cell phone LCD display, the division of the small screen into rows and columns of cells is not necessary. However, backlighting can also leverage the "snooping" of the video content to dynamically adjust the brightness according to the average intensity of the video screen at that particular moment to enhance the viewing experience. This technique could also extend cell-phone battery use time since the backlight may not have to operate at full brightness whenever a video is playing.

LED backlighting drivers (such as the MAX6948B and many others) have an internal pulse-width modulation (PWM) block that controls the intensities of attached LEDs according to commands from a cell phone's baseband controller via a serial interface such as I²C. The baseband controller can then use the internal PWM block of the driver to dynamically adjust the backlighting as responding to a user's key press or to ambient light changes. However, the limited communication speed and the delay caused by the protocol overhead of the serial interface would certainly eliminate the controller's use of the internal PWM block of a LED driver for dynamic backlighting corresponding to video contents.

Varying the backlight intensity corresponding to video contents requires a PWM signal whose duty cycle changes dynamically with video content. This PWM signal can be generated according to the average intensity level of each frame using existing video signal processing circuits inside a cell phone's baseband controller. The PWM signal can be sent to a backlight LED driver via a general-purpose I/Ω (GPIO) pin of the baseband controller.

A LED driver then needs to translate this external PWM signal directly to corresponding LED intensity level variations without causing much interference to its internal PWM function set via the serial interface, also by the baseband controller. For example, an external PWM signal duty cycle of 50% causes no intensity change to that set by the internal PWM block, a PWM signal of less than 50% duty cycle dims the intensity while more than 50% brightens.

Although there is not a particular input pin to accept this external PWM signal for many LED drivers such as the MAX6948B, the additional PWM intensity control for dynamic backlighting can still be accomplished by adding a couple of components to their typical application circuits. Let's examine how to add external PWM intensity control to supplement a device's internal PWM for dynamic backlight control. In this example, the extra backlight control signal is generated by an I/Ω pin from a microcontroller. However that signal could represent the output of a moving light sensor or circuitry that analyzes screen content. The MAX6948 white-LED (WLED) driver serves as the example device. This driver was designed to operate in mobile phones, but the concept can be applied to any system with an LCD screen.

The MAX6948B WLED driver accepts standard input voltages between 2.7V to 5.5V and boosts the output voltage up to 28V to drive the backlight. Although this chip was designed to drive the backlight of a cellphone, the technique to add external PWM for dynamic control of the backlight can be used with LCD TVs, PDAs, laptops, or just about any LED backlit display. An external resistor, R_B, sets the peak backlight intensity (**Figure 1**). The larger the resistor, the lower the peak current and thus, the lower the backlight intensity. However, by adding a transistor (Q1) and a second resistor (R_{B2}), you can modulate the resistance to change the backlight brightness without changing the internal PWM.

The chip internally generates the PWM signal that determines the LED intensity based on commands sent from the host over an I²C port. The boost output of the chip that drives the WLEDs can be fully on, fully off, or PWMed with 10 bits resolution (1024 steps). The maximum current is decided by the feedback resistor, R_B. If R_B is 3.3Ω, the maximum current through the LEDs is approximately 30mA (V_{FB}/R_B = 100mV/3.3Ω ≅ 30mA). If R_B is 30Ω, the maximum current is approximately 3.3mA. The regulation voltage, V_{FB}, is stable at around 100mV and controls the maximum current that is driven through the WLEDs. By modulating the feedback resistance, additional control of the WLED intensity can be achieved.

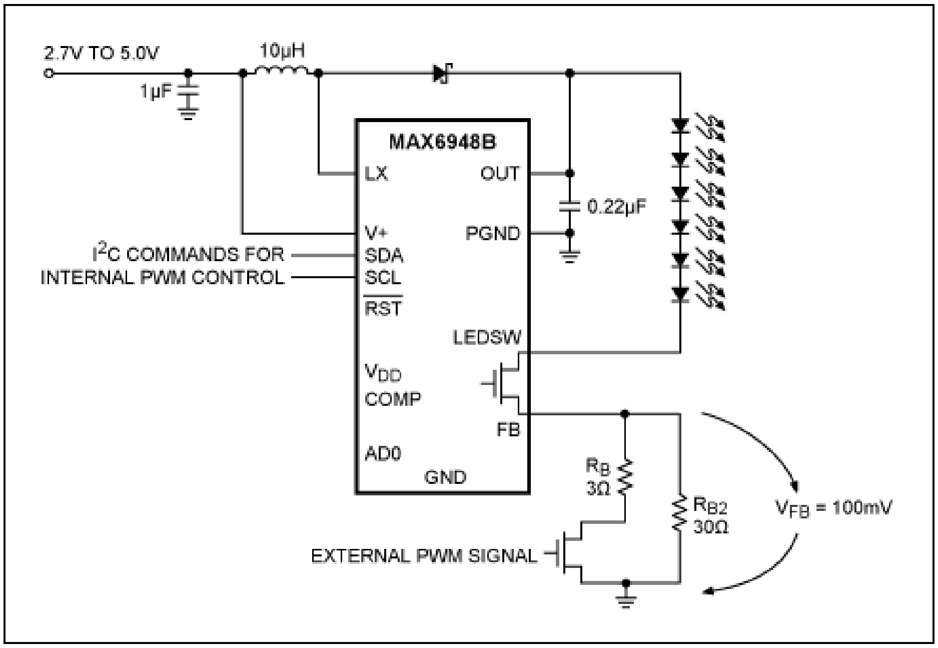
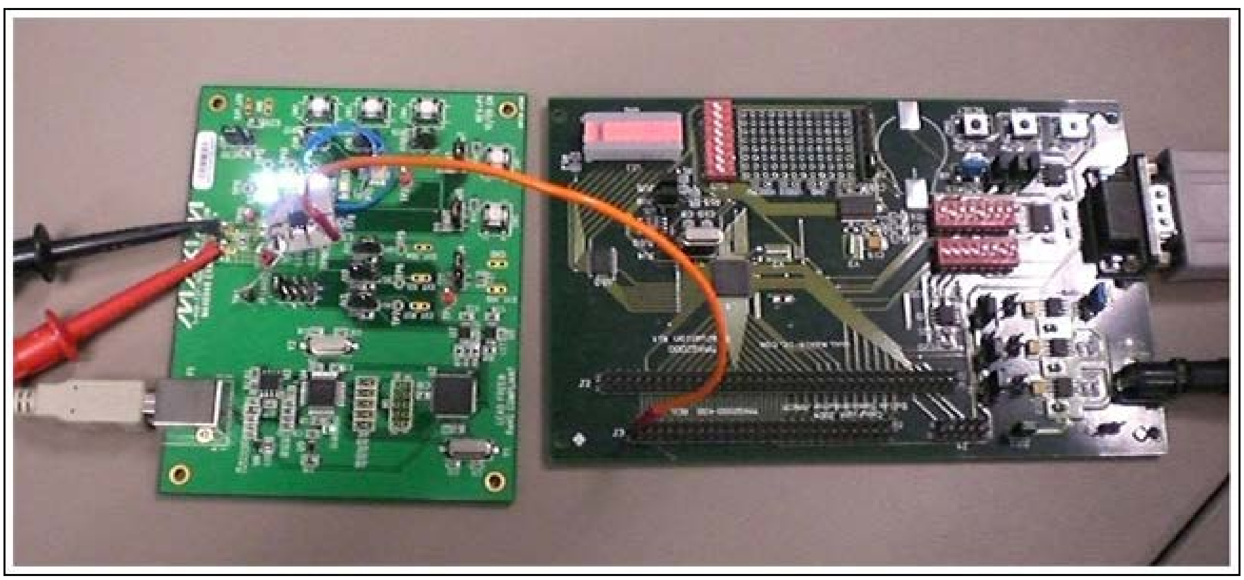


Figure 1. Circuit used to apply external PWM Control to the MAX6948B WLED driver. PWM from a microcontroller at 5kHz is applied with duty cycles from 0 to 100%.

In this example a PWM control signal is generated by a MAXQ2000 microcontroller, which is on an evalution board shown in **Figure 2**. The PWM control signal ranges from 0V to +3.3V; the frequency is 5kHz; the duty cycle can be adjusted from 0% to 100%. The MAX6948B is also mounted on an evaluation board and a Vishay® SI4800BD n-FET transistor (Q1) modulates the feedback resistance. For cell-phone applications, a smaller size n-FET transistor with a low drain-to-source resistance, RDSON, can be used; otherwise the resistance of R_B can be reduced to compensate for the larger RDSON. Because of the low 5kHz PWM switching frequency, the gate charge has a negligible effect when the MAXQ2000's drivers are used. The power consumption of the transistor is negligible because the switching losses are low and the average current passing through it is also low.



More detailed image. (PDF, 3MB)

Figure 2. The MAXQ2000 evaluation kit (right) generates the PWM control signal. The MAX6948 evaluation kit (left) has an extra FET added to dynamically control the lighting.

Test Results

The waveforms in **Figure 3** were captured using a current probe, and show the currents passing through the series WLEDs. The MAX6948B's internal PWM function was on and its duty cycle was set to 50%. **Figure 3a** shows the LED current with an external PWM duty cycle of 15%; **Figure 3b** shows the current with an external duty cycle of 85%, and **Figure 3c** shows the effect of the external PWM on the current through the WLEDs in series.

The data show that, due to the time constant and the feedback behavior of the MAX6948B, the LED current level is not switched between the lowest current level determined by the 30Ω resistor and the highest level determined by the 3.3Ω resistor. The average amplitude and the PWM swing change according to the external PWM duty-cycle settings.

The external PWM control in this case is delivered by changing the instant and average resistance of the n-FET transistor. This, in turn, changes the current going through the series LEDs. There are two important facts to note about this configuration. First, the external PWM frequency of 5kHz is much higher than the internal frequency of 125Hz. Second, the external PWM control is also regulating the DC portion of the LED current. Because of these two features, the solution avoids the common "beating" problem associated to dual-PWM intensity control. External PWM control of varied duty cycles has been applied with internal PWMs from 0% to 100%, and the external control is effective. No beating is observed in different duty-cycle settings.

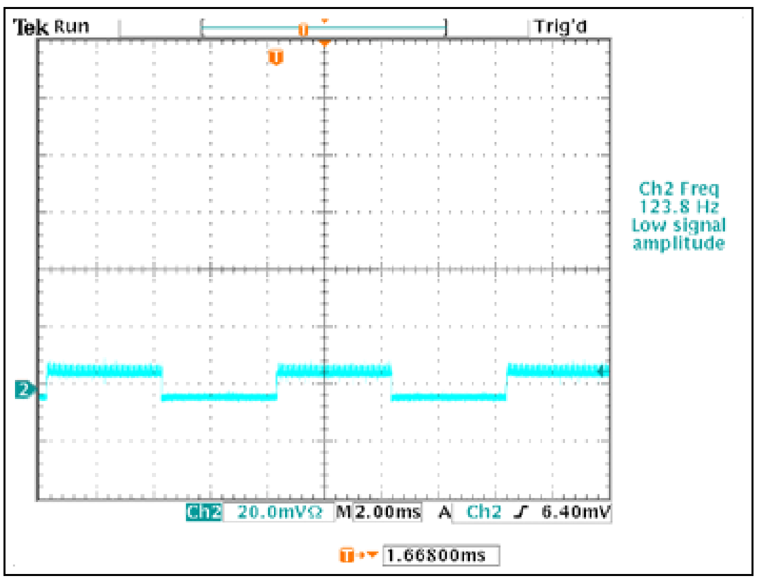


Figure 3a. LED current with a 15% external PWM duty cycle.

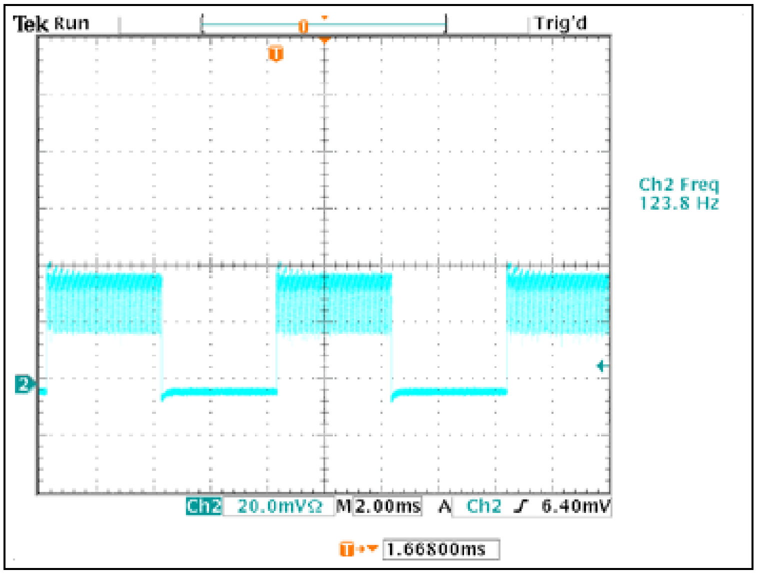


Figure 3b. LED current with an 85% eternal PWM duty cycle.

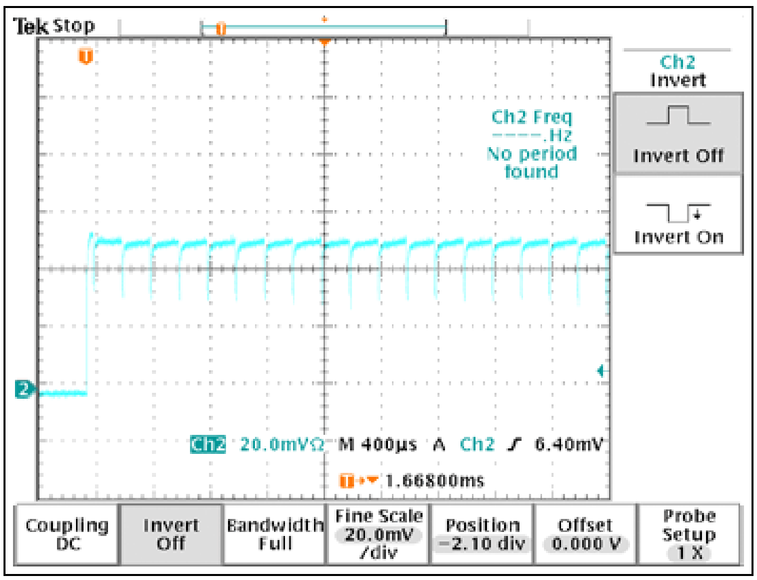


Figure 3c. Details of the external PWM effects.

The luminescence of an LED varies linearly with the forward current over a limited section. **Figure 4** plots the WLED luminous intensity versus forward current for the Kingbright WLED used on the MAX6948 EV board. Modulating R_B resistance between 3.3Ω and 30Ω produces a forward current between 30mA and 3.3mA. The current-to-luminescence relationship in the region between 3mA to 30mA is close to linear, as Figure 4 shows. A 0% external PWM duty cycle produces the luminous intensity at 3mA, and a 100% duty cycle at 30mA. These results assume that the internal PWM intensity is fully on. The intensity level can be adjusted lower with the device's internal PWM control by using I²C PWM commands.

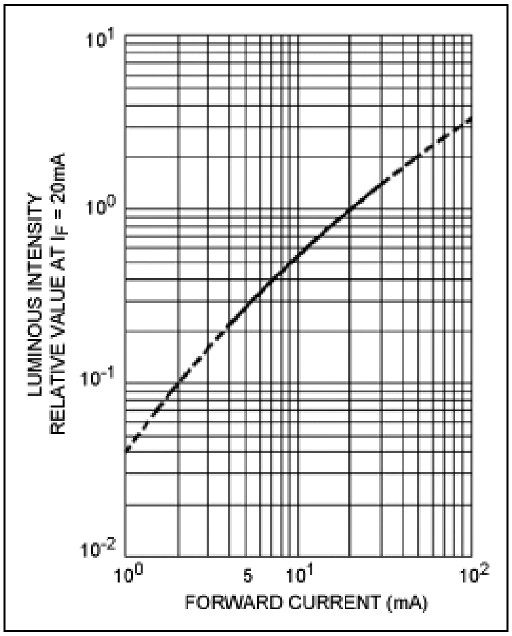


Figure 4. Luminescence and current relationship.

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Related Parts	
MAX6948B	High-Efficiency PWM LED Driver with Boost Converter and Five Constant-Current GPIO Ports

More Information
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