ams

Technical Article

Automatic mobile display backlight control: techniques for improved user experience

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In smartphones and tablets, precise management of display backlighting is necessary both to minimize power consumption and to make it possible for the user to comfortably view the content of the display under any ambient light conditions. The system for implementing this backlight control function consists of three parts: light sensor, backlight driver and lux calculation algorithm.

In today's mobile devices, backlight response to ambient light is often controlled by the application processor, which must continuously supply a pulse-width modulation (PWM) signal to the LED driver. This architecture places an undesirable burden on the processor.

The ambient light response systems in use today are often somewhat crude, causing unwanted visual effects such as flickering during transitions from one backlight power level to another. This often leads the user to override the device's automatic backlight control function and to revert to manual settings, which consume more power, reduce battery run-time and deprive the user of the smooth, barely noticeable adjustments to ambient light that an effective backlighting management system can provide.

This article describes a new technique for backlight power management in mobile devices that is aimed at providing smooth transitions in backlight intensity in response to any changes in ambient light, no matter how frequent or large. As important, this technique provides a means to lift the burden of generating PWM signals from the applications processor.

Operation of mobile display backlighting

In smartphones and tablets, the signal from an ambient light sensor (ALS) is interpreted by the applications processor, which controls a lighting management unit (an LED driver IC). This lighting management unit then drives the appropriate level of current to a string or strings of backlight LEDs (see Figure 1). This IC may also control other LEDs (such as RGB event-indicator LEDs and a keypad backlight).

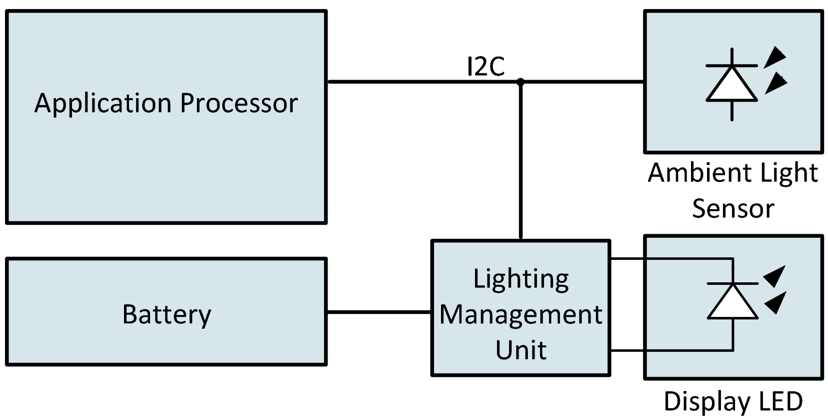

Fig. 1: Architecture of a mobile display management system

The ALS is placed close to the display at the front of the device. Its algorithm for calculating a lux value automatically compensates for the aperture and the light-absorption characteristics of the display's glass. (A lux value represents the intensity of light falling on the location at which the measurement is taken.) When a light sensor is mounted behind attenuating or dark glass, it needs high gain and low noise if it is to be able to report the correct lux value.

A display of around 5" typically requires an LED backlight system consisting of around 12 LEDs. The input current to such a system will peak at around 20mA per LED at a forward voltage of up to 3.2V. It is clear then, that worthwhile savings in power usage can be made when ambient light response is implemented effectively, allowing the intensity of the backlight to be adjusted when the device is used in conditions other than bright sunlight or the equivalent light levels.

Assessing existing implementations

The problem with display backlight control today is that, rather than making the user experience more comfortable and enjoyable, it can actually make it worse. For instance, if there are too many gradations in the backlight power level, even negligible changes in ambient light will trigger changes in the display intensity. Users may experience this as a distracting visual effect. It can even become an irritating flicker if the ambient light level hovers around a transition value at which the applications processor is programmed to trigger a change in backlight power.

The problem is made even worse if the change from one backlight power level to another is sharp and sudden.

Evidence from online forums and other sources of user feedback shows that automatic backlight control is a bugbear, and that some users disable the function entirely to avoid the sense of irritation it invokes.

The goal of the backlight power circuit designer must therefore be to implement a system that provides for comfortable viewing of the display while moderating power consumption, and that changes backlight intensity almost without the user noticing.

A new technique for managing backlight power levels

Recent tests on a successful smartphone have shown how this problem has been taken: when the display is turned on the backlight value is set in response to the ambient light. The phone can then change the backlight current one time only in response to a change in ambient light; the display backlight is then fixed at this second level, no matter how much the ambient light changes. The effect of this is to eliminate the risk of the backlight level oscillating in response to changes in ambient light induced, for instance, by a hand waving slowly in front of the display. But the chief drawback to this approach is obvious: the system foregoes the opportunity to optimize the backlight power for display performance and power consumption after the first change has been made.

Now a new demonstration system developed by ams shows that display backlighting can be made more responsive to ambient light without triggering flicker and other distracting visual phenomena. This can be achieved by combining a number of different control methods. The ams system uses the concept of ‘buckets’ – ranges of lux values sharing the same backlight power input. It then adds hysteresis to the implementation of the buckets, and smooths the transitions from one power level to the next.

While this implementation is more sophisticated and effective than those found in today’s mobile devices, it actually reduces the burden on the applications processor.

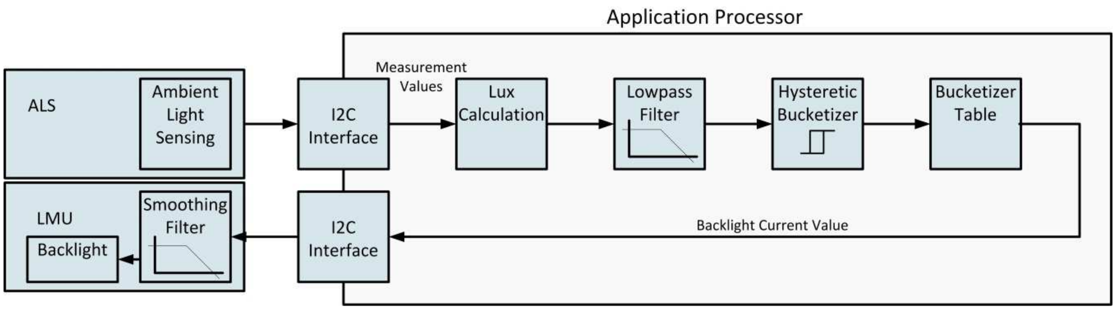

Fig. 2: functional flow diagram of a circuit that provides smooth and comfortable transitions between backlight power levels

The reference system implements the flow shown in Figure 2. The purpose of the low-pass filter is to slow down the system's response to changes in lux value reported by the ALS. Without this low-pass filter, the device would instantly change backlight power in response to every change in ambient light. In other words, if the user in a well-lit room repeatedly waved a hand over the ALS, the display's output would flicker at the same frequency as the hand-waving. This is clearly an undesirable visual effect.

The low-pass filter requires a new lux value to be sustained for a given duration before it is fed through to the algorithm. In a number of Android phones on the market today, this duration is set at around 5 seconds. The filter can be realised in the form of a counter or IIR filter. The function has the ALS's lux values as its input and smoothed lux values as its output. These smoothed lux values are operated on by the algorithm (see Figure 3).

If the smoothed lux value hovered around the transition value of two buckets (the lower limit of one bucket and the upper limit of its neighbour), the backlight intensity could oscillate – another irritating visual distraction for the user.

The combination of the smoothing filter and a hysteresis at the border between one bucket and the next prevents such oscillation.

An important design decision is the number of buckets. Too many buckets, and the backlight level will change too frequently, to the irritation of the user. Too few, and the opportunity to save power as ambient light changes is reduced. Practical evaluation by ams suggests that four is the right number of buckets in a mobile phone application.

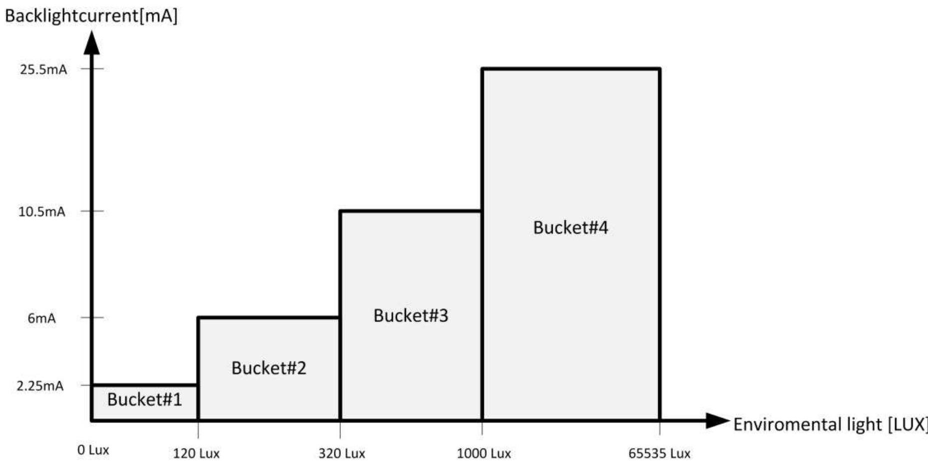

Fig. 3: Real-world evaluation of prototype systems shows that a system with four buckets provides the right trade-off between efficiency and the user experience. Bucket 1 = night-time in a dark room, bucket 2 = dimly lit room, bucket 3 = typical office environment, bucket 4 = full daylight.

The final element of the system is the transition from one power level to the next, implemented by the LED backlight driver. A typical transition is from 5mA to 10mA. Implementing this change suddenly (<1ms) would be distracting for the user.

Extending this change in power output out over a period of around 1s provides a smooth and almost unnoticeable transition to the user. A slower transition risks appearing step-wise and jerky rather than smooth to the viewer, because of the quantization error induced by the limited number of bits at the backlight current sink.

A practical implementation of the techniques described

A demonstration tool that implements the techniques described above has been developed by ams. A TSL2772 light sensor offers the high gain and precision required in smartphone applications, in which the sensor will be mounted behind dark glass. The lux values reported by the TSL2772 are operated on by an applications processor, which implements a hysteretic algorithm developed by ams.

The control signal from the processor is fed to an AS3677, a lighting management unit for smartphones with integrated backlight DC-DC converter and three high-voltage current sinks. This IC features a hardware smoothing filter. This hardware filter makes it possible that only the new current value has to be downloaded to the chip, without any time-critical path in the applications processor.

The AS3677 lighting management unit supplies power to an LED array suitable smartphones. Developers may test the response of the backlighting unit as the TSL2772 is exposed to varying levels of ambient light.

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