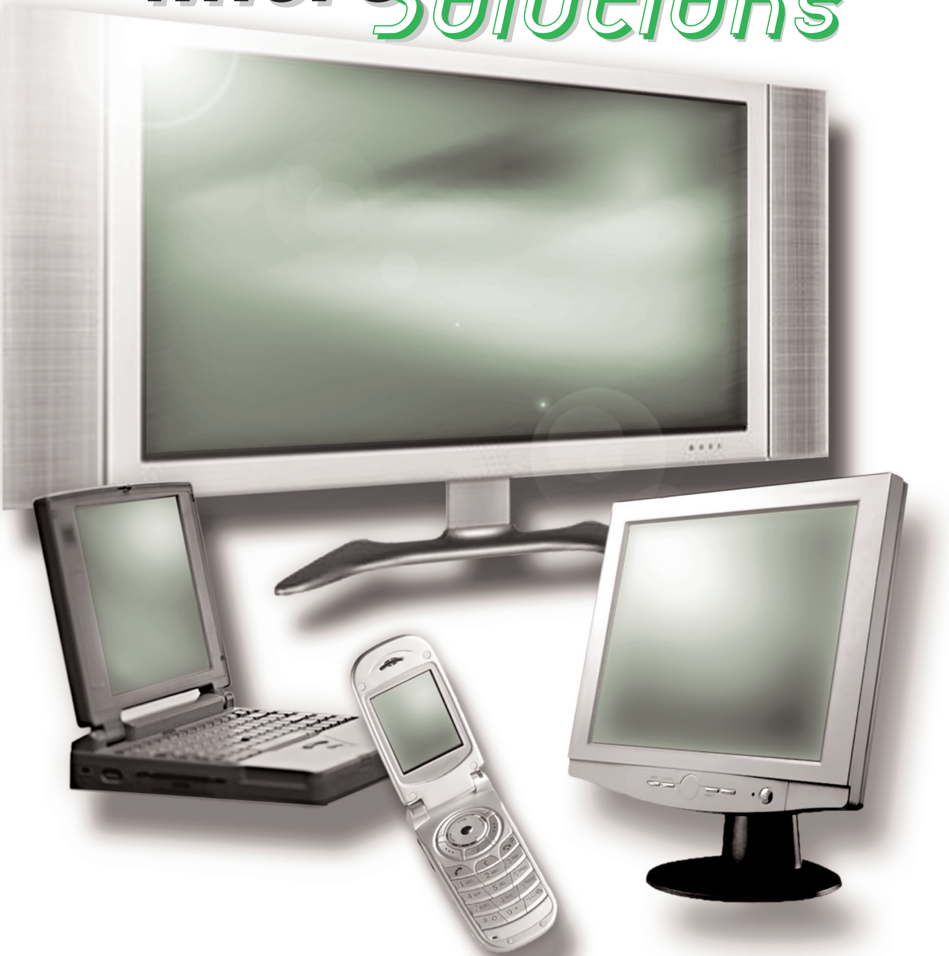
MicroSolutions



New Visible Light Sensor Technology Pays Power Management Dividends in Automatic Brightness Control Applications

By Bruce Ferguson, PE
Sr. Systems Engineer, Microsemi Integrated Products

more than solutions - enabling possibilities

www.Microsemi.com

Microsemi®

An Intel study on "Optimizing Mobile Power Delivery" reveals that display backlights represent 33% of the total battery drain in notebook computers. Thus, finding ways to manage backlight brightness - and the power consumed to achieve it - offers high potential for significant power conservation. Automatic brightness control is one such solution.

Our eyes may hardly notice a 50% reduction in ambient lighting, but if we control display brightness and power consumption by that same 50% we can provide a dramatic impact on battery run time in any portable device - and offer significant reductions in power consumption for stationary applications as well.

While many appliances include a manual capability for adjusting display brightness, few users employ it. Automatic control of backlight brightness is therefore essential to effective power management in all types of display-based devices. It is also a critical factor for ergonomic satisfaction, as displays are often viewed under varying ambient lighting conditions.

Portable devices such as notebook computers and cell phones roam between locations with vastly different ambient lighting - from daylight and well-lit offices to the dimly lit cabin of an international flight. In automotive applications, displays must operate over the entire visual brightness range from a moonless night to a sunny day. Even wall-mounted LCD TVs must function over a wide range of ambient lighting conditions in windowed rooms. Without automatic brightness control, users either strain to view washed out displays in bright environments or over-illuminate their displays in dimmer light conditions.

What users need is a closed loop system that allows them to set display brightness to their personal comfort level once, and that will automatically adjust brightness thereafter as dictated by changes in ambient light, optimizing the display and conserving power.

A complicating factor concerning light control involves the necessity of ignoring the effects of infrared light that is detected by conventional light sensors, but not by our eyes. Sunlight and incandescent light have large concentrations of infrared content, as do some heat sources.

Beyond ergonomics, avoiding "over-bright" displays not only reduces power consumption, it also reduces stress on the LEDs or CCFL lamps that illuminate the display. Many LCD display specifications show lamp life is improved by as much as three times, when the CCFL lamps are run at 50% of maximum brightness; this translates into longer product lifetimes for notebook computers, LCD monitors, and LCD TVs, where the lamps are not intended to be user replaceable items.

Implementing Automatic Brightness Control

In brightness control applications, two design parameters can be used to quantify the effect of ambient light that tends to wash out information on a display. Eq.**(1)** below represents the Pixel Contrast Ratio (PCR) - essentially the brightness of one pixel (typically fully on) divided by the brightness of another pixel (typically off). The PCR is more a function of the display itself and how well it minimizes unwanted reflections. The other is Display Brightness Ratio (DBR), which is the brightness of the display relative to the surrounding ambient. This can be a little more difficult to quantify for a portable device, because it depends on where you are using it.

For the general case:

T# = Light Transmittance of a pixel as determined by the Liquid Crystal drive
BL = Brightness of the LCD Backlight
R# = Reflectivity of the display surface at a pixel location
A = ambient light incident on the display (illumination)

$$PCR = [(T1 \times BL) + (R1 \times A)] / [(T2 \times BL) + (R2 \times A)] \quad (1)$$

Eq. **(1)** can be reduced to Eq.**(2)** as below.

$$BL = \{[R1 - (PCR \times R2)] / [(PCR \times T2) - T1]\} \times A \quad (2)$$

Since the goal of any brightness control system is to keep the Pixel Contrast Ratio (or PCR) constant for the user in a varying ambient, we can set PCR equal to a constant. The transmittance and reflectivity of the display can also be assumed constants for a given set of displayed content. This allows equation 2 to be reduced to:

$$BL = K \times A \quad (3)$$

This relationship clearly indicates that Pixel luminance or backlight brightness can and should be scaled directly to the external ambient to maintain display readability. Assuming the pixel brightness is proportional to the dimming control signal amplitude, this implies that a signal from a light sensor can be used to directly adjust the backlight controller and provide automatic brightness control that keeps the display readable in all ranges of ambient conditions.

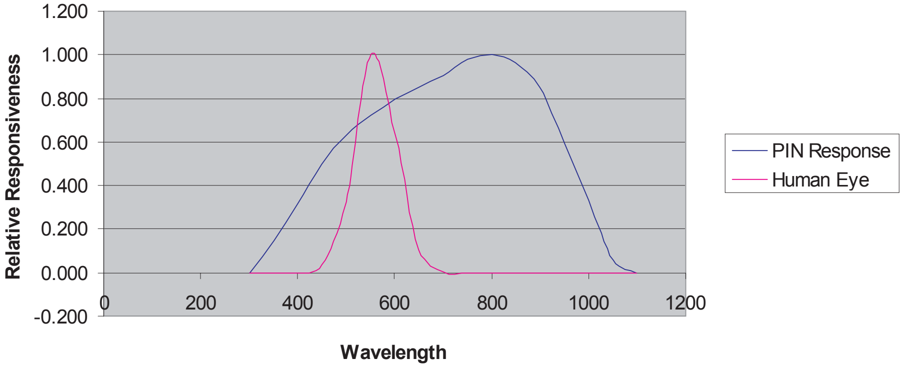
Such an automatic brightness control strategy would also certainly improve display readability in a hybrid system, where users manually select the initial display PCR that satisfied their visual needs, and the automatic brightness control system maintained that level with varying ambient lighting conditions.

Traditional Light Sensor Technology

With ergonomic factors clearly dictating that display brightness be automatically tailored to the ambient conditions encountered by the user, the selection of a light sensor to accurately detect ambient conditions becomes the critical factor in implementing the control system. The most common light sensors in use today are phototransistors and PIN diodes. Both types of sensor generate signals that vary with incident ambient light intensity, but each has significant drawbacks in a number of brightness control applications.

The photodiode or PIN diode offers a very linear response to incident light intensity, producing a current proportional to the ambient lighting. The output current from the photodiode is very small (typically nanoamps) so some sort of signal amplification is needed. In addition, the spectral response of a photodiode is most sensitive in the infrared area so it typically requires the additional expense of an infared filter to ignore light outside the visible spectrum. (Fig.1). In fact, contributions from both the infrared and ultraviolet regions of the spectrum tend to increase the detector signal far beyond the ambient level sensed by a user's eye.

Figure 1: PIN Diode and Human Eye Spectral Responsiveness



Phototransistors have a response similar to a typical bipolar transistor with a photodiode driving the base. The transistor Beta provides the necessary current gain, which amplifies the weak signal of the photodiode input. Unfortunately, the transistor beta is not a particularly stable parameter so the gain of the phototransistor circuit varies with supply voltage, with temperature and with manufacturing process tolerance; this means the phototransistor has limited usefulness as a calibrated linear light sensor and is not recommended for automatic ambient tracking systems.

In many portable applications, designers have tended to accommodate or mask the broad spectral response of PIN diodes in their brightness control strategies. But in several new brightness control application areas, like LCD TVs and automotive mirrors, response to light outside the visible spectrum can cause severe performance problems.

For example, almost all remote controls for TVs use infrared signals to change channels or adjust volume. These signals can actually be sensed as incident ambient light by a light sensor controlling the TV display brightness, resulting in a significant change in brightness of the TV screen without an apparent cause visible to the user.

Similar out-of-visible-spectrum illumination effects have plagued the development of brightness controls for automotive mirrors and/or headlamps, which are becoming increasingly necessary with the use of new high intensity discharge head-lights and LED tail-lights. The sensitivity of commonly used sensors to the red area of the spectrum like that emitted by tail lights can produce faulty control signals, dimming the mirror reflectivity or lamp brightness at very inconvenient times.

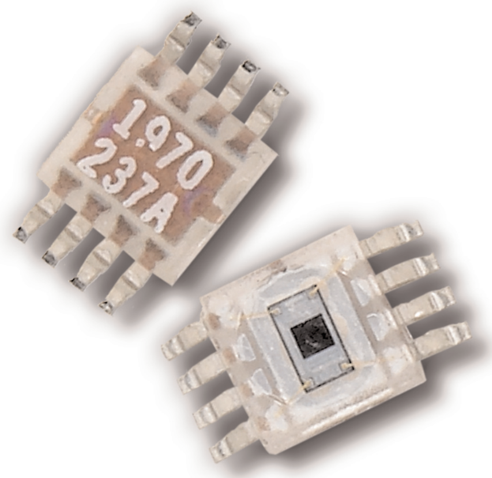
New Integrated Circuit Visible Light Detectors

A new class of integrated circuit visible light detectors is just emerging on the market. These devices typically consist of an array of PIN diodes on a single substrate, with individual diode characteristics within the array controlled in such a way as to match its overall spectral response very closely to that of the human eye (Fig.2).

With PIN diodes it's possible to filter out the response to visible light. When the response of an infrared sensitive PIN is subtracted from an otherwise matched full spectrum PIN, the result is a diode that is sensitive only to visible light. Using current mirrors, it is possible to accurately amplify the PIN diode current by adjusting the physical size characteristics of the current mirror transistors (which is straightforward on an integrated circuit). This way, the good temperature coefficient and linearity of the PIN diode is reflected in the sensor output.

As an added benefit, the quiescent current of these sensors is typically negligible and the devices are useful at extremely low light levels.

When such a device - like one of Microsemi's LX1970™ family - is used with an appropriate controller for LEDs or CCFL, the signal from the sensor can be employed to directly control display brightness for ambient variations perceived by the human eye.



The LX1970 visible light sensor has two outputs that produce currents that are proportional to the intensity of light that reaches the sensor. The SRC output is designed to source current into a resistor wired to ground. The SNK output is designed to sink current from a resistor wired to a high potential such as the VCC. When only one output is used, the other output is left unconnected to reduce power consumption.

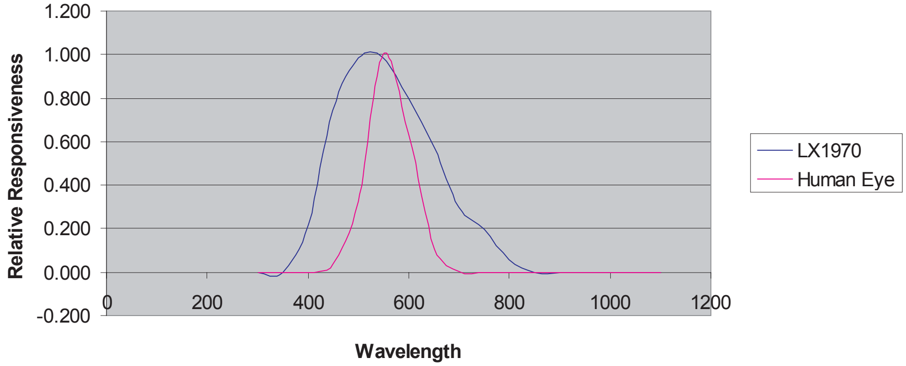
The value of the current source I-to-V conversion resistor can be used to scale the voltage produced at the LX1970 output within limits. The upper limit is determined by the short circuit saturation current of the LX1970, which occurs at approximately 1000uA of output current; 1000uA flows at approximately 2500 lux for the LX1970. Attenuating the light allowed to reach the sensor can extend the upper range of the sensor at the system integration level. This can be done using a gray filter or reducing the aperture of the hole in the cover above the light sensor to let in less light.

The lower limit is determined by the dark current of the device which for the LX1970 occurs around 1 lux. The supply voltage used will impose a maximum voltage limit termed the compliance voltage of the LX1970 current source. The current source needs about 300mV of headroom. If a large resistor is used, the current source may run out of headroom and essentially clamp the output voltage such that further increases in light have no effect; in this case, lowering the value of resistor can extend the range. Normally the output compliance voltage is strategically used to limit the maximum output voltage since most light control systems have a peak brightness limitation that can be programmed in this way.

One precaution regarding the use of the visible light sensors like the LX1970 is response time. Typically, the LX1970 is much faster than the human eye. Most light sources produce light that varies considerably over a 60Hz cycle and the LX1970 can easily track this. To avoid this variation affecting sensitive downstream circuitry, we recommend putting a capacitor across the resistor to set the time constant to around ½ a second.

When the dimming control is done manually, the user will normally change the intensity of the LCD each time the room ambient changes. With an automatic light control system, the user makes an initial "one time" adjustment to their preference, and as the ambient lighting changes, the display brightness adjusts to make the display appear to stay consistent at the same perceived level. Fig.3 illustrates how a light sensor control system can be designed to interact with user preferences to provide various brightness contours over a limited range of ambient lighting conditions.

Figure 2: LX1970 and Human Eye Spectral Responsiveness



In Fig.3, it can be seen that at any ambient light level, with the LX1970 prescribed dimming control, the user can adjust the Dimming output from "off" (0% Duty) to an ambient specific maximum level (100% Duty). Furthermore, for a given user adjustment level (or fixed PWM duty cycle), the Dimming signal will increase (decrease) as the ambient light increases (decreases). The design parameters are the two corners on the maximum brightness setting contour: the percent full-scale at 0 lux, and the ambient level that produces a full-scale output. These two points will be programmed to give the desired response.

The best approach to designing the brightness control system is as follows:

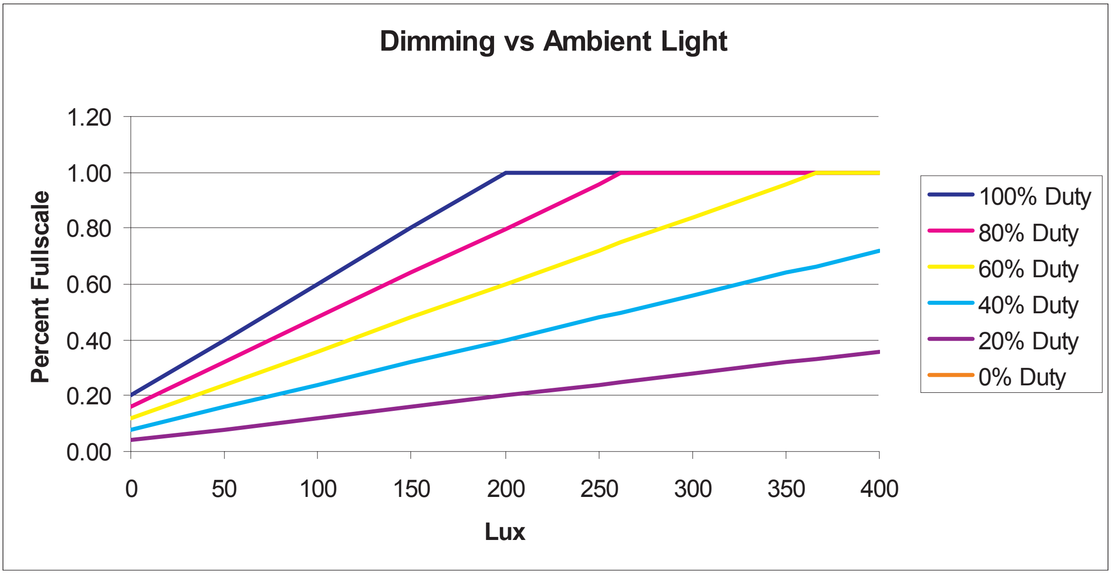
1) Determine the level of display brightness desired in total darkness (at full-scale dimming setting) and the light source dimming control voltage that corresponds to this display brightness. Design dark level brightness control bias.

2) Determine how the sensor will be mounted and create a mockup to determine the sensor sensitivity in your application.

3) Determine the maximum level of allowable display brightness and the corresponding display dimming control voltage. Then determine the minimum level of ambient light where this maximum level of brightness may be needed. Measure the light sensor output current using the mockup in this level of ambient.

4) For further assistance in calculating resistor values, consult Microsemi for application information.

Figure 3: User Interactive Dimming Control using LX1970

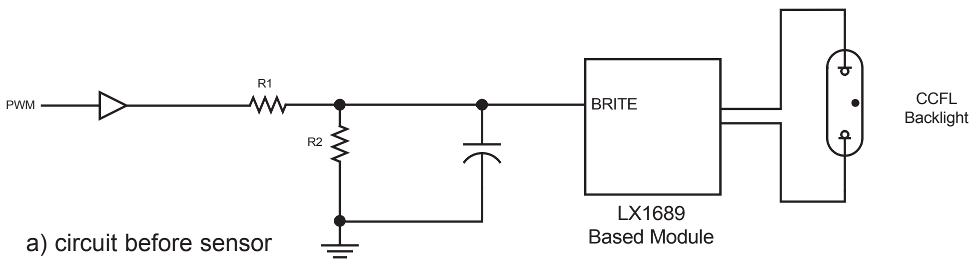


PWM Dimming Interface Conversion

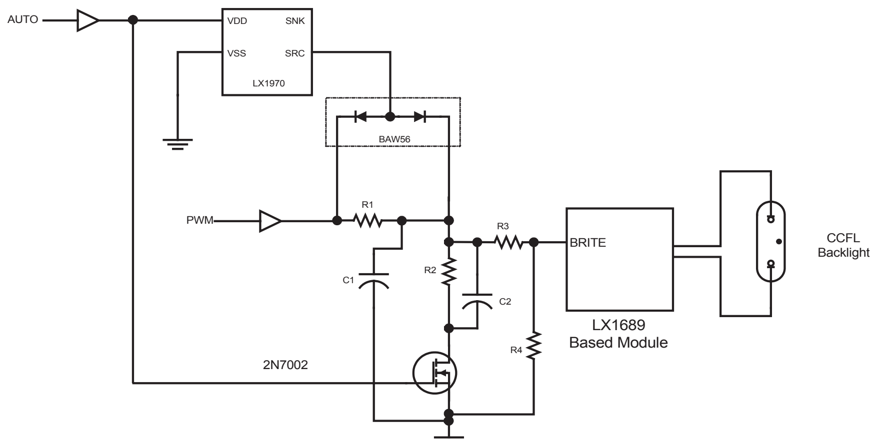
The majority of applications for the LX1970 involve using it in conjunction with a lighting control system that is dimmed using a PWM signal from a microprocessor; usually the resultant brightness of the controlled light source is a function of the duty cycle of the PWM signal. In this type of system the light sensor is best integrated by creating a resultant dimming signal that is the product of the light sensor output multiplied by the PWM duty cycle.

Typically there is a minimum level of brightness required in total darkness, so there is some control from the PWM signal that must get through when the light sensor output is zero (which wouldn't happen if they were truly a product function only). The circuit used to perform this function is illustrated below in Fig. 4. This circuit supports two modes of operation, an auto mode, which allows the user to adjust their brightness contour and works in conjunction with the light sensor and a non-auto or manual dimming mode where the user directly controls dimming and the sensor influence is removed.

Figure 4: Adding a visible light sensor to a PWM dimming system



a) circuit before sensor



b) new circuit with visible light sensor added

TM

more than solutions - enabling possibilities

Microsemi Integrated Products
11861 Western Ave.
Garden Grove, CA 92841-2119
USA

Phone: (714) 898-8121
Fax: (714) 893-2570

www.microsemi.com