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Enhancing Electronic Displays in High-Ambient Light Conditions

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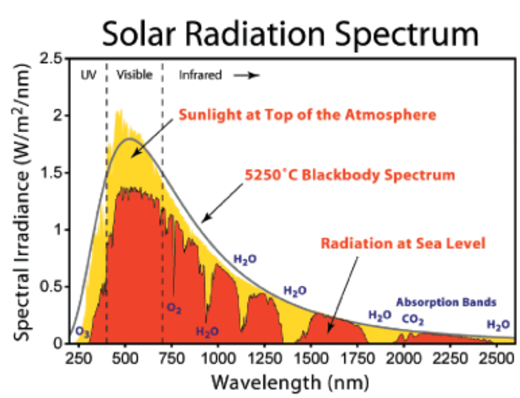
Electronic displays are now commonplace in many demanding applications where both high ambient light readability and environmental compatibility can be achieved only through enhancements to commercial off-the-shelf (COTS) components. The enhancements described here focus on liquid-crystal display (LCD) technology but can also be applied to other optical apertures and display technologies. Design engineers face challenges associated with operating LCDs in high-ambient light conditions – especially direct sunlight, which is common in marine, military and outdoor kiosk applications – to maintain readability and clear heat build up.

High-ambient light conditions are present when the amount of reflected light from the display is close to or exceeds the amount of light emitted by the display. High-ambient light sources typically cause the degradation of display image quality to contrast and color saturation. In extreme cases of direct sunlight, thermal loading on the display system will occur. Thermal loading is the radiant heat gain, primarily from the infrared components, absorbed from the sun. See Graph 1 for a typical spectral distribution from the sun. Note: the actual energy profile irradiated on the display will change with season and location. Field testing should take into account these variations.

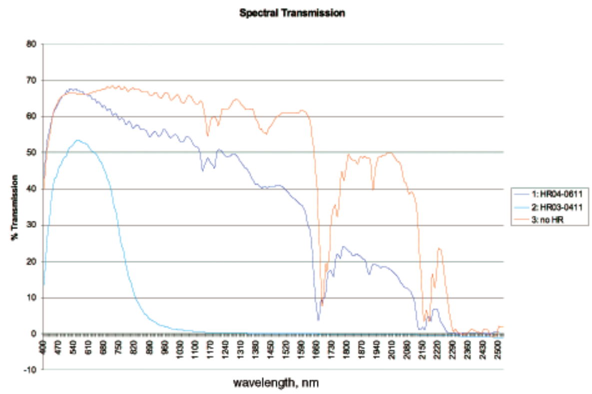
Display system engineering solutions to readability problems caused by high-ambient light conditions primarily involve reflection reduction and contrast enhancement. High levels of ambient light reflected back to the viewer degrade contrast to the point of "washing out" the displayed image. Reflections will occur at each optical element-air interface. An antireflective (AR) coating can be applied directly to surfaces of the display or protective overlay to reduce both ambient and internal light reflections while effectively increasing transmitted light. Reflected light can be reduced by more than 90% by the addition of AR coatings. Optical coupling of the front protective filter to the display panel will also reduce reflections by eliminating internal air-gap interfaces.

Alternatively, front surface antiglare (AG) coatings can be used to scatter reflected light and allow the viewer to focus on the display image. Additionally, contrast enhancement filters made with colored, neutral density, or polarized filters can be employed to improve display readability by increasing the optical difference between the on and off characteristics of the display by more than 5 to 1.



Solar heat absorption is problematic for many displays, especially in the case of LCDs where liquid crystals will eventually go isotropic and loose crystalline properties. At this point the "clearing temperature" of the liquid crystals is exceeded and the picture element switching of transmitting light can no longer be controlled. In this situation, the display will "brown out" or loose significant contrast until its temperature is sufficiently lowered and crystalline state returns. A conventional solution to this dilemma is to include forced air convection or other powered cooling system to remove the heat. For portable applications, this presents the designer with formidable challenges requiring more space and increased power consumption.

A solution to the thermal loading problem is readily available by using a heat reflective or solar reflective coating. This is a low emissivity (low E) coating that allows the visible (shorter wave) energy to pass through while reflecting the longer wave infrared (IR). Additionally, when it is properly designed, the coating can also support high-ambient light readability applications. A properly designed heat reflective coating will pass the dominant portion of the visible spectrum (440 nm - 660 nm) while rejecting a high percentage of the infrared (IR) region (> 780 nm). See Graph 2 for some typical spectral curves.



Heat reflective coatings can be incorporated into mostly all optical substrates and applied directly to the electronic display or protective filter. These coatings will slow the transfer of heat to <15% to 50%. Heat reflective filters appear neutral gray in color with typical photopic transmittances of 65% to 90%. Unfortunately, the heat rejecting properties are inversely related to the visible transmittance. The properties of visual transmittance and IR reflection can be adjusted or tuned to fit the needs of the specific application. It should be noted that the heat reflecting coating still will let heat into the system, although it greatly slows the rate at which it enters. In addition, the heat still needs an exit path (e.g., a passive radiator) or the system could still overload.

A transparent heat reflecting material can be deposited onto an optical medium to create very dense coatings. Typical heat reflective materials include transparent conductive oxides (TCOs), such as indium tin oxide (ITO) and metal alloyed films (e.g., alternating layers consisting of

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silver and ITO). A high density and quantity of free electrons are the properties that determine the IR reflecting performance. For this reason, the highest performing heat reflectors always have metallic layers. Typical conductivities for heat reflecting coatings range from 2 Ω/sq to 50 Ω/sq. Because metal alloys have inferior mechanical and galvanic durability, they are typically embedded in the center of the optical stack or are located on the rear surface.

Incorporating anti-reflection properties is possible. A fully enhanced TCO can have a total luminous reflection of a broadband white light source (e.g., illuminant D65) of less than 0.5%. Furthermore, the photopic absorption of TCOs tends to be very low, often less than a few percent at fairly high conductivities (i.e., <10 Ω/sq). Unfortunately, there is an inverse relationship between conductivity and light transmission. The photopic transmission of metallic coatings quickly decreases as conductivity increases. There is a significant absorption (e.g., 5 to 10%) with metallic layers as opposed to TCOs. The visible properties can be better controlled (i.e., high luminous transmittance and low luminous reflection) by incorporating dielectric layers into the optical stack. Additionally, as mentioned, AR and AG coatings can be incorporated on outer surfaces to reduce reflection and increase transmission.

Although high-ambient and direct sunlight environments create significant design issues, optical techniques are available to help system engineers manage display readability and thermal loading.

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