UAV's are being used in many applications from military to oil pipeline inspection. The supporting ground station is deployed with the UAV and requires display systems that can be used not only in indoor facilities but also in the field - in a vehicle or in the open.

Displays used in ground stations for unmanned vehicles must be usable not only in an indoor facility but also deployed in a field location such as a vehicle or out in the open where there may be direct sunlight. To use a standard LCD display several improvements must be made to improve the brightness, contrast and ruggedness of the display.
How Does Brightness and Contrast Effect What We See?

Brightness is the lightness or darkness of the image and contrast is the difference between the light and dark areas. The human visual system, the eye and the brain, is capable of perceiving about one hundred levels of "brightness" and one billion levels of "contrast". Therefore, the human visual system can be saturated with brightness quickly and is much more responsive to contrast. An example is that on a dark night the human visual system is able to see a single candle light from two hundred yards away. A feat achieved not because the candle is bright but because of the contrast difference between the candle light and the surrounding darkness.

Figure 1 Comparison of Contrast and Brightness of a Display.

This is a test

High contrast, easy to read

This is a test

Very low contrast but it is readable

Figure 1 Comparison of Contrast and Brightness of a Display.
Figure 1 is an example of contrast difference. The text in the white box is easy to read due to the high contrast between the text and the white background. The same text in the shaded box is harder to read as the contrast is very low between the text and the shaded area. In both examples the color of the text and brightness level are the same. The eye is able to discern the text even in the low contrast environment but it is more difficult to read. In order to provide the optimum performance for an LCD display both the brightness and contrast levels must be controlled but the best gain in performance can be achieved by improving the contrast levels. Adding more brightness has diminishing returns since the eye will be quickly saturated by the higher brightness level. Also, making an LCD display brighter requires more power which generates more heat. Improving contrast can be achieved by improving the performance of the display in the ambient environment.

Luminance, Illuminance and Reflection in Display Performance.

The LCD display is an emissive display - the image on the display is achieved by light radiating through the display, some getting blocked by the liquid crystal material and the rest passing through the liquid crystal matrix. This light is generated by a backlight system integral to the display. The amount of backlight controls the perceived brightness of the display. In a dark room very little backlight is required to make a visible image. As the ambient light is increased, more and more backlight level is required to provide a viewable image until the ambient light is so high, such as direct sunlight, that the display is not viewable at all. The downside to the backlight system is that it requires more power to develop a higher light level.

Figure 2 shows the three factors that affect the performance of the display. These factors are luminance, illuminance and reflection. Luminance is the level of light coming from the display. Illuminance is the amount of light striking the display surface. Reflection is the amount of light reflected from the surfaces of the display.
To improve the performance of an LCD display in a high-bright ambient environment brightness, luminance, and contrast performance must be increased. One way to improve the contrast is to reduce the illuminance or ambient light, which is not practical. Although some displays are equipped with a hood or shade to limit the light impinging on the display. The other method used to improve contrast is to reduce the loss of contrast due to reflected light.

A typical office-grade LCD display is provided with an anti-glare coating on the front of the display. This is a thin piece of plastic film with a fine-grain etched pattern which disperses reflections in all directions. This works well in a low-light office environment. However, in a high-bright environment, a light source, such as the sun, simply creates a big fuzzy ball of glare on the display making it impossible to discern the underlying image. An anti-reflective coating, on the other hand, doesn't disperse the reflection but uses offset light wavelengths to cancel a reflection. An AR coating is typically ¼ wavelength thick so destructive interference between the
surface reflection and the light reflecting from the other side of the coating occurs which causes that surface reflection to disappear. Because the film thickness is fixed and light is typically multi-spectral, there will still be a reduced reflection but it is typically shifted to a purple color as you are seeing the higher wavelength reflection.

**LCD Enhancements for Extended Environments - Brightness and Contrast**

Based on the previous discussion the main objective is to improve the brightness and the contrast of the LCD display. At the same time it would be beneficial to improve the ruggedness and EMI performance of the display. Fortunately, the methods used to improve the performance also increase the ruggedness and the EMI performance.

To improve brightness, both an active and a passive technique can be used. The active method is pretty simple - increase the amount of luminance from the display. The measure of luminance from a display is measured in candela per square meter (cd/m²), also called a nit. The measurement of one nit is the projected light energy of one candle, a distance one meter away, measured over a one meter square area. A display with high luminance would have a specification of between 700-1500 cd/ m².

There are two methods to provide backlight to improve luminance of an LCD display. The first method uses cold cathode fluorescent lamps (CCFL) and the second uses light emitting diodes (LED) to generate the backlight. The LED method is preferred due to lower power consumption and lower temperature gradient as well as the ability to provide light at a lower ambient temperature. LEDs can also be dimmed over a range of zero to full brightness. Both methods use power and generate heat so a more passive approach would make sense.

Passive methods used to improve luminance consist of adding brightness enhancement films (BEF) to the LCD and using transflective displays. The use of the BEF helps focus the light by using a layer of film that has a prismatic effect. The current BEF technology includes both a layer that focuses the backlight so that more comes out the front of the display but also contains an extra reflective sheet for recycling any light that doesn't hit the prism at the correct angle. In this configuration, light continues to bounce around in the back of the LCD display until it strikes the brightness enhancement film at the optimal angle to be directed out.
toward the viewer. Using the latest BEF technology the backlight generated luminance can be improved by over 90%. In a transflective display brightness is improved by reflecting some of the ambient light back through the display.

With the brightness performance improved by using appropriate backlighting and passive light focusing materials the next step is to improve the contrast. The loss of contrast is caused mainly by reflected light and the higher the ambient light environment the more the contrast is reduced. The reflected light makes whites brighter but dilutes black and other colors. This is due to fact that whites absorb more light and the darker colors reflect more light. The reflection is due to the impedance mismatch between the air and the glass. By using anti-reflection (AR) coatings this impedance mismatch can be improved and the reflected light level will be reduced.

**High Ambient Light Display Systems Developed by Chassis Plans.**

Chassis Plans (www.chassis-plans.com) starts with industrial quality transflective LCD panels selected for optical performance, high reliability and long product life cycle. In order to not only ruggedize the LCD, but to also enhance the mechanical, optical and EMI properties of the finished unit Chassis Plans optically bonds two layers of coated 1.1 mm glass to the front of the LCD panel.

![Figure 3 Details of Optical Stack on Chassis Plans LCDs](image)
The first layer of glass is coated with an Indium Tin Oxide (ITO) coating. The ITO coating, with a surface resistivity of <13.5 ohms/sq inch, provides a conductive surface to the glass and reduces the EMI output of the display. As shown in Figure 3 there is a Copper conductive buss bar that wraps around the edge of the glass to facilitate conduction from the ITO coating to the front surface of the laminated structure to make a complete electrical shield around the face of the LCD. The result is an attenuation of the EMI from the screen (Figure 4).

![Figure 4 EMI Shielding Effectiveness of ITO Coating](image)

The second layer of glass is coated with an Anti-Reflective (AR) coating which matches the index of refraction of air to eliminate surface reflections. This eliminates over 95% of unwanted glare from the screen greatly improving the contrast in direct sunlight applications.

These layers of coated glass are bonded together with an index matching optical adhesive to eliminate internal reflections caused by the index of refraction mismatch between the glass and air. The optical adhesive used is a silicone RTV and offers other benefits mechanically to the LCD as well. The adhesive remains pliable and therefore acts as a shock absorbing medium for the front of the LCD. Together with the additional layers of glass the adhesive provides a very rugged composite structure. Another benefit is that should breakage actually occur the shards of glass will be retained together to prevent injury to personnel. The adhesive also prevents any condensation from building up in the air gap between the layers of glass which would cause fogging of the display. Finally, the added
mass bonded to the front of the LCD display adds a thermal conduction path to help dissipate the heat generated in the backlighting system.

See Figure 5 below for more details.

![Figure 5 Comparison of Reflections With and Without Optical Bonding.](image)

The display system shown in Figure 6 is one example of a Chassis Plans LCD product designed for environments of high ambient light such as direct sunlight as well as vehicular applications that required a more durable display. By improving the contrast in high ambient light applications and providing the necessary backlight system to be effective in low light ambient applications the display system provides the best solution for portable UAV ground station applications.
Figure 6 Chassis Plans display system with up to 1280x1024 resolution with optically bonded AR and ITO coated glass for superior sunlight and low EMI performance.

For more information, visit Chassis Plans at http://www.chassis-plans.com.

Chassis Plans provides concept, design, prototyping, production, integration, and certification into one unique turnkey solution. Some examples of existing markets include Oil Refining, Automation Control, Internet Infrastructure, Computer Telephony, Government, Military and Banking.

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