TRANSFLECTIVE DISPLAYS

A Comparison of Transflective and Transmissive Mode LCD Displays

Technical report – Adi Abileah, Planar Systems, Inc. (March 2006)

Abstract

This report will show that the contrast ratio (CR) for a transflective LCD is equal to or better than a very bright transmissive mode LCD and has the additional benefits of reduced power consumption, heat, and device volume.

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Introduction

LCD's are increasingly being used in many applications in everyday life. Watches often use a monochrome LCD with a reflector behind the face which reflects the ambient light of day while at night they must rely on a small light source (LED) for the display to be viewed. Other common types of LCD's in displays are laptop screens or flat panel desktop monitors. In these products, the displays incorporate a backlight which uniformly illuminates uniformly the LCD panel from behind allowing it to be viewable.

Liquid Crystal Displays (LCD) behave in some ways like a photographic film. Unlike film, LCD's can change an image dynamically via a computer or other driver means. But like films, LCD's need to be viewed either with a light behind the glass (transmissive mode) or with a reflector behind the glass allowing room-light to reflect through the glass (reflective mode). Each of these modes has benefits. However, in high ambient light situations, utilizing a combination of both modes (called transflective mode) is ideal as it optimizes the ratio between the two modes.

The two modes of illuminating the LCD are the (a) Transmission mode – with a backlight behind and

(b) Reflective mode – with a reflector behind using the front light as source. In the first case the light goes through the display only one way (from behind to the front). In the second case, the light goes through the display twice – once from the front to the back then after it is reflected, going from back to front. As a result, the display properties differ between the two cases.

	Transmissive Mode	**Reflective Mode**
Advantages	• Light goes through the LCD once and is therefore attenuated only once • Can be viewed in dark environment (has its own light source)	• Uses little power since it takes advantage of the ambient light • With low power it can be operated with a battery for long periods
Disadvantages	• Uses more power to drive the light source • Generates heat (mainly in the backlight) • Brightness is limited by the backlight and the LCD transmission	• Cannot be used in dark environment without artificial light (e.g. local LED) • Contrast in some situation is low because the light goes through the LCD twice and therefore is attenuated too much

Figure 1 is a schematic of typical transmissive display mode. In practice, the backlight has several lamps in a reflective cavity or has lamps at the edge of a plastic sheet that distributes the light. In both cases there are diffusing materials to provide a uniform light.

Figure 2 is a schematic of reflective display. In this case the ambient light (the star in the figure) is actually the room light or the outdoor daylight (diffused light of the sun). The ambient light shines in the front of the display and then is reflected from the rear side reflector behind the LCD. Thus, in the reflective mode the light beam goes through the LCD twice which means if the LCD has significant absorption, the light will be attenuated twice. This poses the main limitation of the reflective mode.

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Figure 1 – Transmissive mode display using backlight behind the LCD

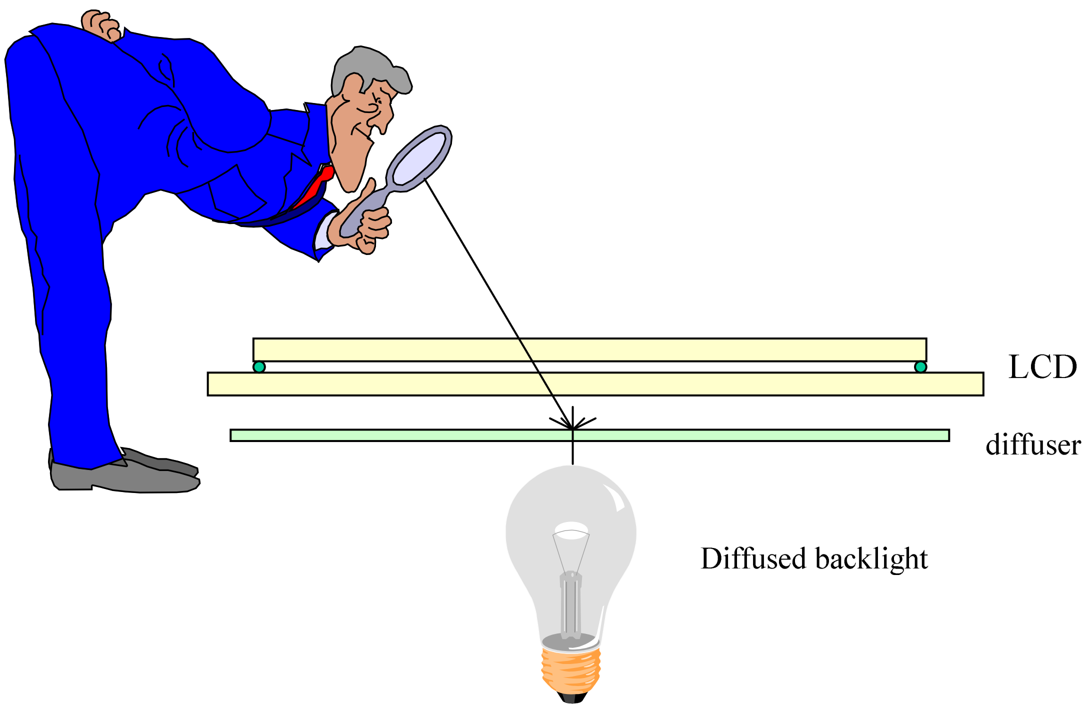
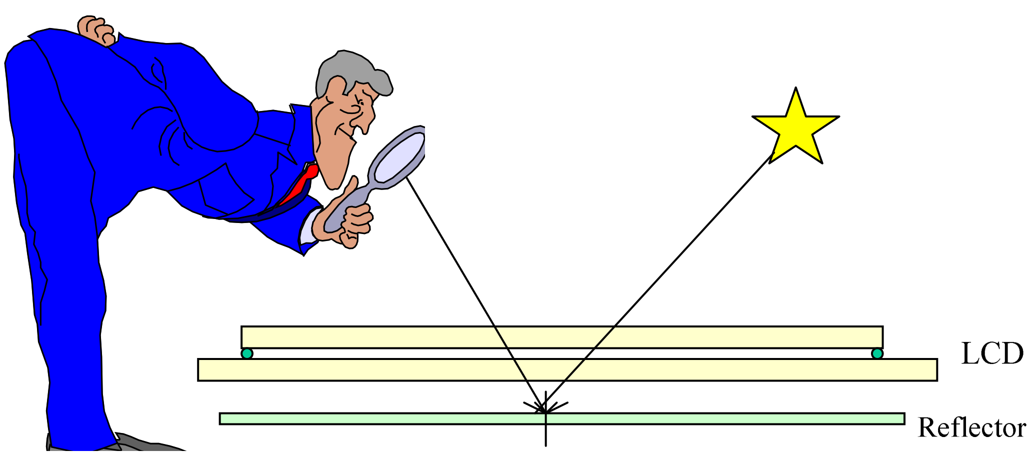


Figure 2 – Reflective mode display using the ambient light (the star) as light source, and a reflector behind the LCD



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High Ambient Light Considerations:

Everyone is aware that a sunbeam coming through the window on a TV set will make the colors fade and the image difficult to see. This is not so much because of brightness, but rather because of contrast. Contrast is differences in the colors and luminance of par ts of the image that can be seen in the image. If the image is very uniform in colors and luminance it would be hard to identify objects and information. Thus, to have good image one needs:

1. Minimum brightness - that is in the order of the ambient lig ht or exceeding to match the eye adaptation (iris opening), and
2. Minimum luminance and color contrast (differences)

When sun light is comes from the window and refracts off the front of the TV set, that adds to the illumination of the set. However, as the reflections are to both bright and dark regions of the images the difference is small and thus the contrast reduced. For example, see Figure 3.

Assuming a TV set with brightness of 100 -cd/m2, typically the dark area of such a set will be at 0.5 -cd/m2 in a dark environment. This makes for a very good contrast ratio (CR) between the bright area and the dark area: CR = 100 / 0.5 = 200. However, if there is bright light coming from the window at illumination level equivalent to 1000-cd/m2 that hits the screen some of this light will be reflected. In CRT's the daylight (diffused) reflectivity can be as high as 80% (this is very similar for Plasma displays). For AMLCD's the reflectivity is much lower (1% ~ 5%).

In the CRT example, 80% reflectivity mea ns that:

R(Reflected ambient) = (1000-cd/m2) * 80% = 800-cd/m2

- will be reflected from all the area of the screen, both from the bright area and the dark area.

Now the contrast will be:

CR(high ambient) = [Bright + Reflected Ambient] / [Dark + Reflecte d Ambient] =

= [100-cd/m2 + 800-cd/m2] / [0.5-cd/m2 + 800-cd/m2] =

= [900] / [800.5] = 1.12

Therefore, the CR went down from 200 • 1.12, which is below the eye's ability to differentiate

(For binary information like letters and numbers, the minimum CR should be ~ 1.3 and preferably above 2 for comfortable viewing).

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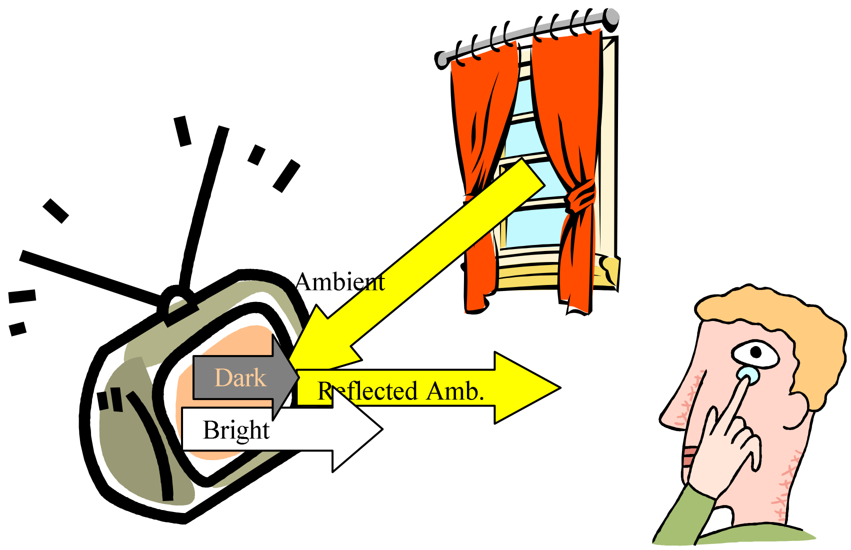
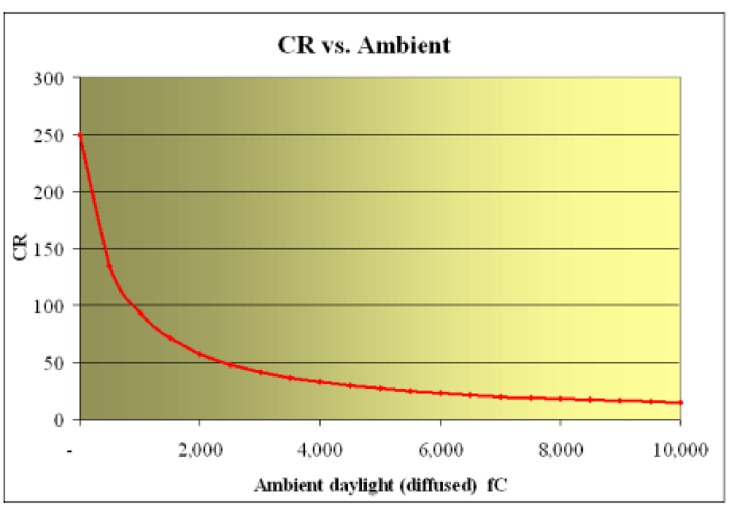
Figure 3 – Ambient light coming from a window is reflected from a TV set and reducing the contrast (Bright to Dark ratio in the image).



Repeating the calculations of the previous example for several ambient light conditions (diffused or scattered light) produces the curve shown in Figure 4. In this case, the dark roo m contrast ratio of the display is 250 and dropping rapidly.

Figure 4 – Contrast Ratio (CR) as a function of ambient daylight (diffused – with Foot-Candle units)



The ambient light is measured in units of Foot -Candles (fC). The photometric units are so metimes complex thus the conversions between the units will not be covered within this paper.

Ideally, one would see a minimum of CR ~ 2 for binary information and a CR ~ 7 if the information is colored maps where one's eye must distinguish between colors .

How can we improve the Contrast Ratio in ambient light?

Again referencing the above example, in order to improve the high ambient contrast ratio (CR) several actions can be taken:

1. Reduce the ambient light
2. Reduce the display reflectivity
3. Increase the display brightness

There are several ways of reducing ambient light. In cars, manufacturers put hood above the dashboard and insert the panel into the hoo d to prevent direct glare reflections. Other applications employ a cover and shade. In the example of a home TV, many simply close the blinds to prevent sunshine glare. This can be somewhat trickier for many types of outdoor applications.

Many techniqu es exist for reducing display reflectivity as it is a very effective way to improve high ambient readability. In desktop monitors, it is common to see a front surface called anti -glare (AG - surface controlled roughness) to minimize mirror -like (glare) reflections. Likewise, CRTs in many office environments have an AG enhancement filter added. Such a technique would not work for displays that are for outdoor applications. For high ambient daylight (diffused light) situations it is recommended to use the same anti-reflections (AR) coatings that are used on optical elements and eye glasses. Recently, active matrix liquid crystal displays (AMLCD) have shown considerable improvements in internal layers and front coatings to achieve minimum specular (glare) and diffused (daylight) reflections and plasma displays panels (PDP) are coming out with AR coatings on the front.

Increasing the display brightness is a straightforward way to compete with reflections from ambient light but it comes with several costs:

(a) More power

(b) More heat, and problems related to heat management

(c) Noise in case of ventilators cooling

(d) Shorter device life, or backlight lamp life in the case of AMLCD

(e) Bigger volume

Since option (A) – reduction of ambient light - is not always possible, and (C.) – increase of display brightness – is not desirable, combining option (B) – reduction of display reflectivity – with another method, formed from the combination of transmissive and reflective modes and called the transflective mode, is optimal. This is discussed below.

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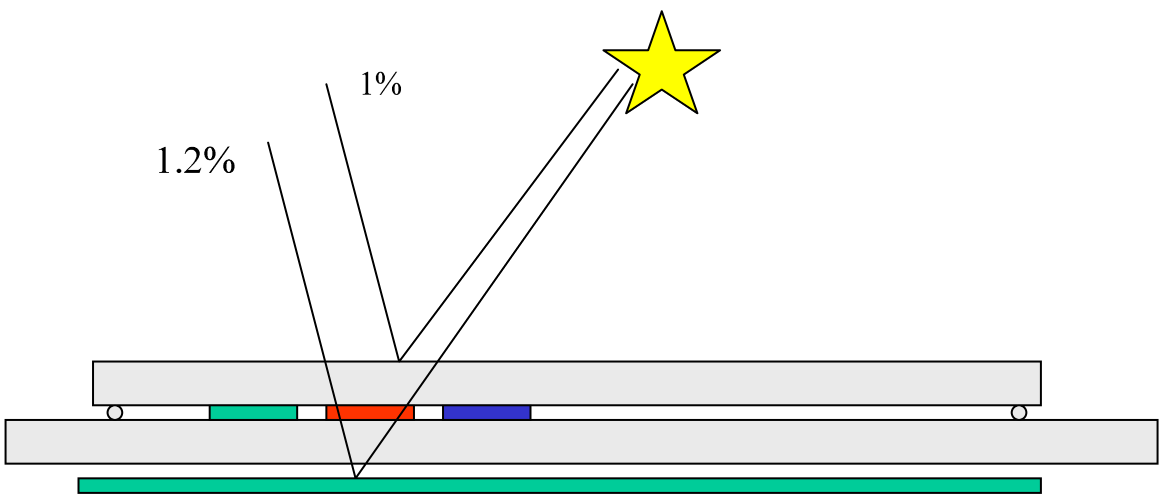
Reflective Mode in High Ambient light:

An AMLCD in transmissive mode, which is similar to emissive display, experiences a quick CR decline in high ambient light much like the home TV set example and the reflective mode that it is often used for watches and other applications is not the choice for every LCD. Figure 5 shows a schematic cross section of a reflective LCD. While a simplified model, it shows the main problem, that the ambient light is reflected from the front surface at a rate of about 1%. This ambient light penetrates the display, going through a front polarizer, then the color filter and matrix structure, through the rear polarizers, and is reflected at the bottom. On the way back it again goes through the matrix, color filters, and front polarizer. When all these factors are added up, only a small fraction of the ambient light is reflected to the top (typically 1.2%).

Figure 5 – Reflective mode reflectivity factors with ambient light



Assume that the display in transmissive mode will have a contrast of CR ~ 200, meaning that the dark area will reduce the ambient light by x200 and that area will reflect only 1.2% / 200 = 0.006% (very low). Now to determine the high ambient light contrast (similarly to the previous method):

CR(High Ambient) = [(reflected light from bright area) + (front reflections)] / [(reflected light from dark area) + (front reflections)]

CR(high ambient) = [(Ambient * 1.2%) + (Ambient * 1%)] / [(Ambient * 0.006%) + (Ambient * 1%)] =

[1.2% + 1%] / [0.006% + 1%] = [2.2%] / [1.006%] = 2.19

As mentioned above, this is a range that is acceptable for legibility, but there is great room for improvement. The good news is that this high ambient CR is the same at all light levels. As shown above, the ambient light in the equation is cancelled since it is in both the nominator and denominator. Thus, at high ambient light the preference is utilization of the reflective mode since the transmissive mode affords only CR ~ 1.12 even with decent backlight.

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Conclusions so far:

(1) At low ambient light the transmissive mode is preferred because it proves a CR > 10

(2) At high ambient light the reflective mode is better

(3) In both cases the front reflection must be minimized, but for reflective mode it is more critical

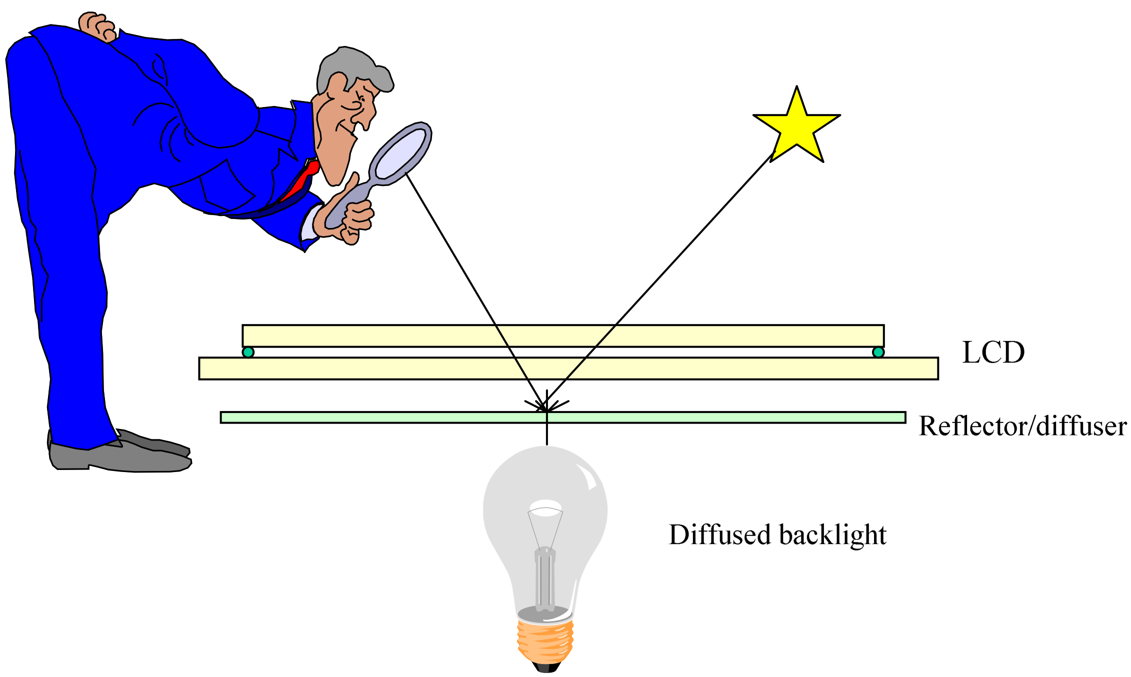
(4) Utilizing a very bright backlight for the reasons detailed above makes little sense

Thus, we must look for a optimal solution which can be found in the hybrid transflective mode:

In this mode, th e rear reflector in the LCD is partially transmitting (and diffusing) the light of the backlight and partially reflecting the ambient light. The ratio of transmission to reflection is optimized by the display manufacturer as well as by reducing the color filter absorption factor (to increase the 1.2% from Figure 5 to much higher reflectivity through the display).

Figure 6 shows the transflective concept schematically in similar notations to Figures 1 and 2.

Figure 6 – Transflective mode LCD



The light that the viewer sees at low ambient light is mainly the backlights' brightness through the display. In the case of Planar's LX1200 unit this is about 450 -cd/m2. As the ambient light increases, so does the reflectivity of the display which contribu tes to the total brightness and exceeds 1000 -cd/m2 at outdoor light levels. This guarantees the minimum brightness needed for the adaptation of the eye while maintaining the contrast ratio (CR > ~ 2) for good readability.

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Summary and Conclusions:

We showed that the contrast ratio (CR) for a transflective LCD is better than a very bright transmissive mode LCD. Most companies assume that the increase of the display brightness by adding more backlight power is the best way to get high ambient CR. Howev er, with an optimum transflective mode, we can use some of the ambient light to our benefit.

This concept has to be done carefully, because there is a competition between ambient light reflections from the front of the display, which are reducing contra st. We have to maximize the reflections from the back side of the LCD, which carry the image information. With optimized design we get the benefit of the ambient light to our advantage.

This design has several merits:

- It maintain the CR even as the am bient light is increasing
- Total brightness is increasing as ambient light increases, and is comparable with bright backlight
- Low power
- Lower heat
- Lower volume

The transflective LCD is best for high ambient situations, as long as the parameters and the design is optimized.