

Seamless Automotive Instrument Cluster

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ABSTRACT

An optical configuration has been developed which offers a seamless appearance where the display aperture is less visible in the “off” condition and is minimized in the “on” condition.

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INTRODUCTION

As electronic displays such as thin film transistor displays (TFTs) are utilized increasingly in automotive instrument clusters, there is a desire from the original equipment manufacturers (OEMs) to hide the display opening and present a “seamless” appearance to the user such that the user cannot see any apertures or margin gaps to the display. This “seamless” lens may also provide analog gauge graphics functionality. The seamless lens may also have functionality to hide the location of the display and gauge graphics in the unlit condition, this is called “deadfront” (a.k.a. “secret until lit” or “blackpanel” or “dark panel” effect). In addition, there is a desire to minimize the appearance of the rectangular display opening in the “on” condition caused by the black luminance leakage of most TFT displays. Organic Light Emitting Diode (OLED) displays may be utilized to eliminate the “on” effect, but generally do not have sufficient luminance capability to utilize a neutral density film in front of the display that helps generate the seamless dark panel effect; but this may change as OLED luminance technology evolves.

The most relevant art is demonstrated by the instrument cluster as shown in [Figure 1](#) where the display is at the bottom.

In the seamless cluster shown in [Figure 1](#), the Bayer LM296 film with a neutral density transmission factor of 25% is placed over the printed applique film as shown in [Figures 2 and 3](#) with an air gap between the Bayer film and the applique. The effect of having the air gap behind the front Bayer film is to increase the reflections from both the front and rear surfaces of the film thereby increasing the net

ambient reflection to help hide the display opening. In addition to the complexity of a two film structure, the net reflections are increased over the display area thereby requiring more display luminance for visibility under daytime lighting conditions. Similar concepts are revealed by reference [1], with the use of polarization films to increase the optical efficiency of the system.

Instead of using two films, an alternate instrument cluster utilizes a one-film approach where the applique black print is applied to the rear surface of the LM296 film as shown in [Figure 4](#). In addition to help provide additional display aperture hiding, the TFT polarizer has a smooth hard coat (HC) coating instead of an anti-glare (AG) surface used on the model shown in [Figure 1](#).

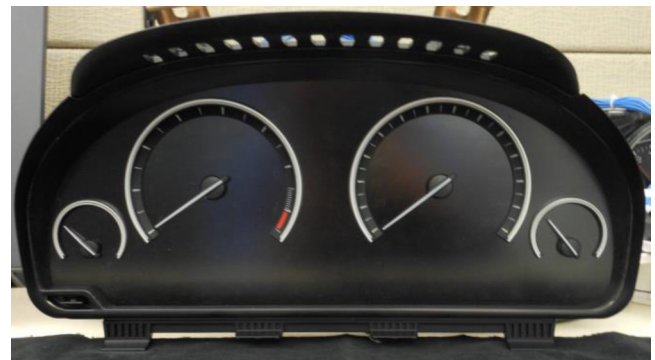


Figure 1. Seamless Cluster Example



Figure 2. Printed Applique behind Bayer LM296 Film

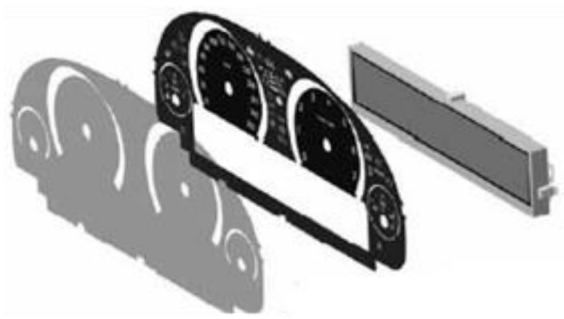


Figure 3. Film Stack & Display



Figure 4. One-Film Example

The new proposed optical solution:

1. Improves the deadfront hiding
2. Reduces overall reflection
3. Uses a one-film approach instead of a multi-film solution thereby reducing complexity
4. Improves optical clarity and reduced sparkle [2].
5. Allows the use of an air gap solution compared to an optically bonded solution which is difficult to manufacture with a flimsy applique film.

NEW SEAMLESS SOLUTION

The new proposed seamless design utilizes the following principles:

1. Reduce reflections in the display aperture to mimic the black reflection characteristics in the surrounding non-display area.
2. Use a sinusoidal fade pattern to hide the display opening
3. Select an AG film with good light scattering, low sparkle, and good image clarity characteristics.
4. Use white graphics around the display aperture perimeter

Reduced Reflection Design

The proposed solution is outlined in Figure 5. The principal idea behind the solution is to reduce reflections behind the front “first” surface of the applique film. By reducing the reflections, the display opening area appears black to the eye and is similar in appearance to the surrounding black printed area.

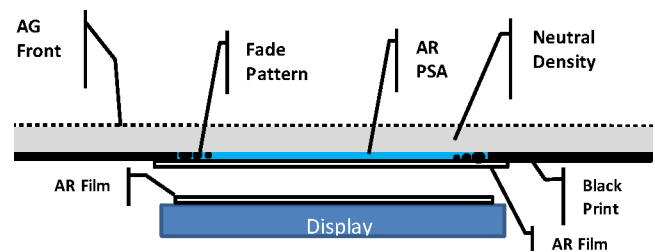


Figure 5. Optical Solution (AR=anti-reflection, PSA=pressure sensitive adhesive).

Historically, the primary method to reduce the effect of reflections behind the front surface of the AG film is to use a neutral density (ND) tinted film with the highest possible transmission rate. Lower transmission films do a better job of hiding the display opening, but do so at the expense of display luminance or the amount of power necessary to obtain the desired luminance through the ND film. The transmission of ND films used for seamless cluster applications ranges from about 25% to 50%. As an example, if there is a rear reflection rate of R_R on the rear surface of the film, the ND film will reduce the rear reflection by the square of the transmission rate, T , as shown in Equation 1 and as depicted in Figure 6.

$$R = T^2 \times R_R \quad (1)$$

Where,

T = transmission rate of the ND film

R_R = reflection rate from the rear surface of the ND film

R = resulting rear reflection rate due to ND film transmission

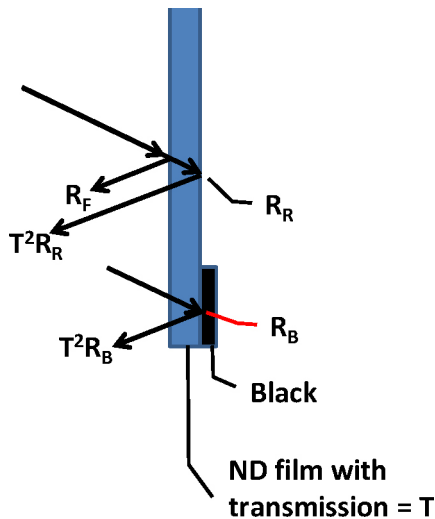


Figure 6. ND Film Reflection Diagram

The contrast ratio (CR) between the black and the display aperture areas may be determined by Equation 2 which approaches the desired value of unity as the transmission rate is decreased.

$$CR = \frac{R_F + T^2 \times R_R}{R_F + T^2 \times R_B} \quad (2)$$

Where,

R_F = reflection rate from the front of the film

R_B = reflection rate from the rear of the ND film in the area around the display opening that is printed with a black ink

In order to reduce reflections and/or allow the use of a higher transmission rate film, the new concept is to apply an anti-reflection (AR) film to the rear surface of the applique film in the display opening area. In addition, a smooth AR coating may be applied to the front surface of the display polarizer. It is important to note that it is desirable for the display surface to be smooth in nature and not have an anti-glare (AG) surface structure which would scatter the light back to the user as shown in Figure 7 (bottom). One of the best AR films available is moth-eye (ME) film which is very effective at off angle incident light conditions. Moth-eye film also has the lowest available anti-reflection qualities. One of the reasons this configuration is so effective is because the AR films cancel the reflection of the incident light that is scattered by the front AG surface. The front applique film may have one or more of the following attributes.

1. Neutral density factor around 25% or greater
2. A combination of polarization film and optically bonded neutral density (ND) films [1]
3. A polarization film alone [1]

For instructional purposes, the bottom display in Figure 7 has an AG polarizer surface which scatters more light and makes the display aperture more visible than a smooth surface on the polarizer as shown

on the top display in Figure 7. By reducing the reflected scatter back to the eye via the use of smooth AR surfaces and the use of a ND filter in front of the black print, the display aperture becomes almost invisible because no reflection looks black to the eye and becomes similar in appearance to the black printed area. The AG front surface on the applique is also important to raise the ambient reflected level to the point where it reduces the contrast ratio difference between the display aperture and black printed areas.

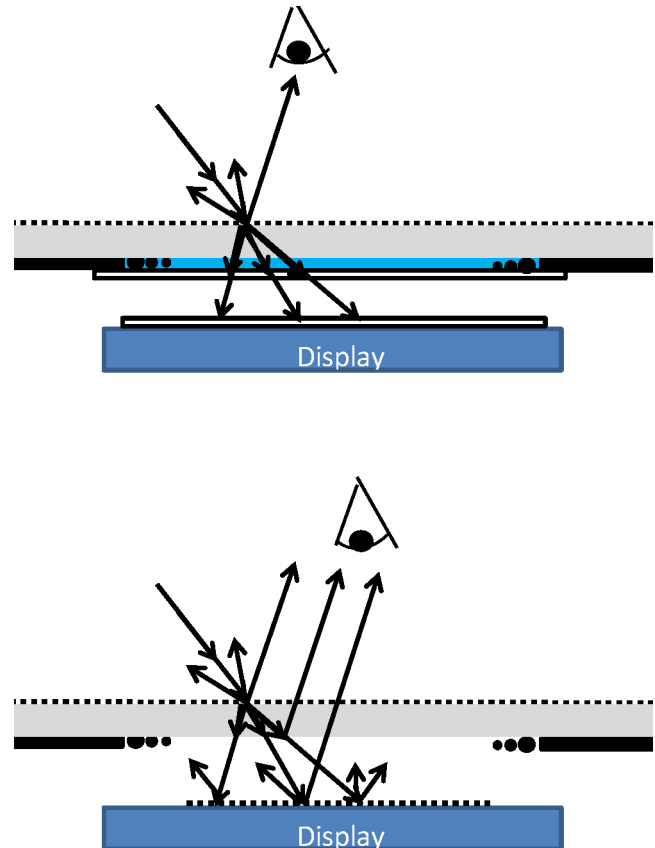


Figure 7. Anti-reflective (top) versus Anti-glare (bottom)

It is important to note that a secondary configuration may be utilized where no AR is used and the front of the display is a smooth glossy surface, such as is commonly realized with a hard coat (HC) surface treatment to reduce scratch susceptibility. This smooth glossy surface provides a decent seamless deadfront look because the light from the sides is specularly reflected around the eye and only light from the face is reflected back to the user when viewed perpendicularly. The benefit of using the moth-eye AR film on the rear of the applique film and the use of AR on the display polarizer surface can be ascertained by analyzing experimental data as shown in Table 1 with the use of a 22% ND film. The first configuration (1.) in Table 1 shows the following reflectance components from the AG applique film with black screen printing on the back side of the film:

1. SCI (specular component included) = 4.63%
2. SCE (specular component excluded) = 0.99%
3. SCI-SCE = 3.64% (this is a measure of the specular reflection component)