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Light Control Systems for Automotive Instrumentation

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ABSTRACT Numerous optical problems for instrument panel designers have been created by new trends in automotive exterior and interior design, increasing use of electronic instrumentation, and new display packaging methods. The problems, nighttime reflections, glare, and daytime display viewability, were previously solved using conventional techniques of instrument panel hooding and recessing of displays.

This paper will review the trends in automotive design and instrumentation technology and relate the design objectives to functional performance requirements. It will also describe a technology and product available from 3M which can reduce or eliminate many of the aesthetic and functional design problems now being addressed for automotive instrumentation.

INTRODUCTION: Changing Vehicle Designs

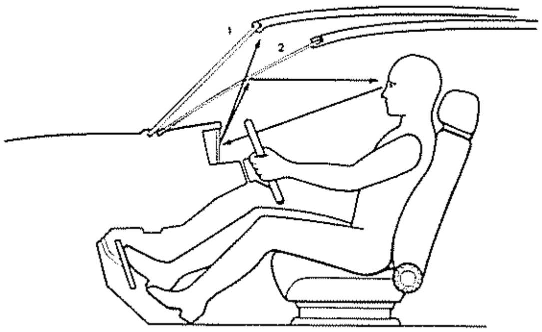
Concern for aerodynamic properties and reduction in fuel consumption has increased and is now resulting in dramatic changes to exterior vehicle designs. The significant changes that effect instrument panel design include:

- decreasing slope of the windshield
- downsizing of vehicles
- increasing passenger space

Reducing the size of the conventional instrument panel is a method to increase interior passenger space. Reduction in the over-all physical size of the instrument panel is achieved by reducing its depth and intrusion into the passenger space. In the past, when passenger compartment space was abundant, and vehicle weight was not critical, hoods and shrouds were used to prevent optical problems of nighttime windshield reflections and daytime glare on instrumentation. Hoods and shrouds consumed significant space, and when combined with recessed displays, were aesthetically unappealing.

Recent changes in the slope of the windshield and reduction in the over-all size and amount of instrument panel shrouding have intensified the optical problems. These problems could be solved with conventional techniques at the sacrifice of passenger space, vehicle weight, and evolution of instrumentation technology. Figure 1. illustrates nighttime windshield reflections with changing windshield position. With past vehicle design, light emitted from instrumentation reflected onto the headliner, thus avoiding windshield reflections. However, given the same interior geometry and a reduction in the slope of the windshield, nighttime reflections occur and are in the driver's direct line of sight. In this example, shrouding the instrumentation is not an acceptable solution because of limited passenger space. Neither is recessing instrumentation to block the windshield from stray light because of limited instrument panel package space. These problems exist with incandescent analog and electronic instrumentation.

With the reduction of instrument panel size and the increase in the use of electronic instrumentation, another optical problem has been introduced – daytime display viewability or loss of display contrast. High levels of ambient light reduce the visibility of certain types of electronic displays. Numerous techniques are used to enhance the visibility of electronic displays in all ambient conditions. However, these techniques do not always yield satisfactory results, and sacrifice display life, performance, and efficiency.



1 Past Vehicle design
2 Present aerodynamic design

Figure 1. Vehicle Design Changes and Effect on Windshield Reflections

In summary, changes in automobile design and increased performance requirements have created automotive interior needs which include:

- Reduction of instrument panel size
- Elimination of daytime glare
- Control of ambient and display generated light (day and night)
- Elimination of nighttime windshield and window reflections
- Enhanced daytime visibility of electronic instrumentation
- New technology including electronics, instrumentation, and display packaging methods

INSTRUMENTATION TRENDS

Three levels of instrumentation exist today – conventional instrumentation, simulated electronic instrumentation, and electronic instrumentation. In all cases the instrumentation must provide information which is easily distinguished in all ambient conditions, be aesthetically pleasing, and provide long-term reliability.

Conventional instrumentation uses passive, analog displays. These types of displays present both quantitative and qualitative information. Daytime visibility is dependent upon ambient illumination of display pointers, scales, graphics, and isosymbols. Nighttime visibility is dependent upon auxiliary illumination, usually from incandescent, white lighting. Multiple color graphics are achieved with screen printing techniques on appliques and graphics panels.

Simulated electronic instrumentation utilizes conventional instrumentation components, but has a psuedo electronic appearance because of variation in component packaging, screen printing techniques, and light source placement.

Electronic instrumentation use is increasing, and dramatic growth is forecast into the mid-1990's, as shown in Figure 2.[1] U.S. automobile production is forecast to remain fairly stable into the same period. This growth in electronic instrumentation within a fairly stable automotive industry will provide numerous opportunities and challenges for designers, engineers, and suppliers. Figure 2 illustrates U.S. opportunities, but the growth trend is global in nature. On a global basis, this growth will require increased awareness of optical problems associated with new technology and design trends. Instrument panel designers must learn to effectively utilize new display technology to meet functional and aesthetic design objectives.

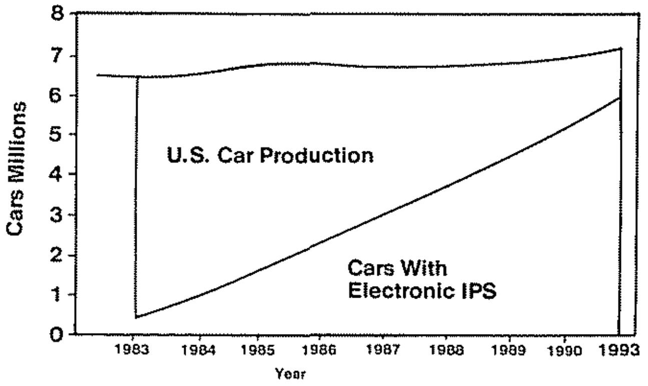


Figure 2. Total Car Production Vs. Cars with Electronic IPs

ELECTRONIC INSTRUMENTATION: Electronic Display Types

Electronic instrumentation offers unique appearance and performance features. If electronic displays are not properly utilized, numerous optical problems will plague their performance and customer acceptance.

Electronic instrumentation and displays can be divided in to two categories – active displays and passive displays. Active displays, such as vacuum fluorescent displays (VFD), light emitting diodes (LED), cathode ray tubes (CRT), and gas discharge displays, are self-illuminating. The light source is also the information source. Liquid crystal displays (LCD), as with conventional displays are passive and rely on external, auxiliary lighting for display viewablility.

Electronic instrumentation offers greater information density within a defined area, when compared to conventional instrumentation. Significant emphasis is now being focused upon electronic displays which are large in display area, pro-

Optical Performance Characteristics

Electronic instrumentation must be easily read under all ambient conditions, from darkness to bright sunlight. Three significant factors contribute to display readability: display brightness, contrast, and glare. Brightness is the amount of light emitted by a display element, or the luminous sterance (intensity/unit area) of illuminated elements. Contrast, or luminance contrast, is the difference in brightness levels between display "on" elements, "off" elements, and their background. Glare, or front surface display reflectivity, can effect apparent contrast and reduce display viewability. Glare defines the response of light upon the external surface of a display or filter; contrast indicates the response of ambient light plus display generated light internal to a display system.

Contrast

Luminance contrast ratios can be determined for electronic displays with and without the use of filtration techniques. There is no single, standardized method for calculation of contrast and contrast ratios. Luminance contrast ratios without the use of a filter are defined as the sum of the display generated light and ambient light reflected off the display element divided by the amount of light reflected off the background, as shown in Equation 1.

1.

$$\text{Luminance Contrast Ratio} \qquad CR = \frac{L_vS + L_vOFF}{L_vB} \qquad (2)$$

where

L_vS = Sterance of illuminated element ("on")
L_vOFF = Sterance of light reflected off the element
L_vB = Sterance of light reflected off the background

Contrast ratios are optimized by maximizing "on" element brightness relative to background and "off" element reflectance. Loss of display readability can be caused by loss of contrast between the "on" elements and the background resulting in "washout", or by the loss of contrast between "on" and "off" elements, making "on" elements indistinguishable from other elements in a display.

When the amount of element generated light equals the amount of light reflected from the background or "off" elements, the contrast ratio equals one. The contrast ratios of electronic displays are thus determined by:

- Contrast between illuminated ("on") elements and background
- Contrast between non-illuminated ("off") elements and background
- Contrast between illuminated ("on") and non-illuminated ("off") elements

Filtration

Display brightness and contrast can be managed by proper filtration techniques. Filters attenuate incident ambient light and reduce the amount of light falling on the display. Neutral density filters can improve contrast by twice attenuating ambient light – by reducing the amount of ambient light entering and exiting a display. But, the disadvantage of low transmission neutral density filters is the attenuation of display generated light. Use of these filters has resulted in increased display brightness requirements. Low transmission filters have been required for automotive applications due to high ambient levels, and the potential for degradation of display readability.

Filters also change display contrast by adding another variable for analysis. This variable is glare, or reflection from the upon the index of refraction of the filter material to the index of refraction of air, at least four percent of light can be reflected at each air-filter interface. Front surface glare can be either specular or diffuse. The human eye adds the light reflected off the filter surface to the display generated light and reflected background light. The luminance contrast ratio of a display with a filter is defined in Equation 2. as:

2. (3)

$$\text{Luminance Contrast Ratio} \quad CR = \frac{L_VS + L_VOFF + L_VF}{L_VB + L_VF}$$

where

L_VS = Sterance of illuminated element through the filter

L_VOFF = Sterance of light reflected off the element through the filter

L_VB = Sterance of light reflected off the background through the filter

L_VF = Sterance of light reflected off the filter

For the purpose of measuring and determining actual contrast ratios for active displays, the above equation can be expanded to:

3.

$$\text{Contrast Ratio (Display "on")} = CR_{on} = \frac{\text{Element ON} + \text{Element OFF} + \text{Filter Reflectance}}{\text{Background ON} + \text{Filter Reflectance}}$$

$$= \frac{L_VS_{on} + L_VS_{off} + L_VF}{L_VB_{on} + L_VF}$$

$$= \frac{L_VS_{on} + L_VS_{off}}{L_VB_{on}}$$

when including display reflectivity in L_VS_{on}, L_VS_{off}, and L_VB_{on} measurements

and

4.

$$\text{Contrast Ratio (Display "off")} = CR_{off} = \frac{\text{Element OFF} + \text{Filter Reflectance}}{\text{Background OFF} + \text{Filter Reflectance}}$$

$$= \frac{L_VS_{off} + L_VF}{L_VB_{off} + L_VF}$$

$$= \frac{L_VS_{off}}{L_VB_{off}}$$

when including display reflectivity in L_VS_{off} and L_VB_{off} measurements

Vacuum fluorescent displays have bright display areas and dark backgrounds. The bright display elements are very apparent without a filter in the OFF mode under high ambient levels. The use of a filter is needed to maximize the contrast of the "on" elements relative to the background and minimize the contrast of the "off" elements relative to the background. This relationship can be defined as:

5.

$$\text{Contrast Ratio Improvement} = CRI = CR_{on}/CR_{off}$$

CRI is maximized when CR is maximized and CR is

Filters must minimize washout and maximize contrast ratios. In addition, filters for electronic instrumentation must:

- Reduce glare by changing surface texture from glossy to a slight matte
- Serve as an optical window
- Be a durable, lightweight component
- Hide the background and elements in the OFF mode
- Provide color matching for display emission characteristics
- Retain image quality and resolution
- Be easy to mount
- Seal off and enclose display and electronics

LIGHT CONTROL SYSTEMS

A technology known in product form as Light Control Film (LCF), can eliminate many of the aesthetic and functional design problems for automotive instrumentation. Automotive interior and exterior design trends, electronic instrumentation, and new display packaging methods have created a need for LCF or a similar technology. Light Control Film is a unique optical film used for controlling light generated by instrument panel displays and ambient light in the interior of automobiles. The film is a powerful design tool to solve optical problems, and offers designers greater freedom and flexibility in instrument panel design. The film, an optically clear, thin plastic, contains uniformly spaced microlouvers which control light entering and exiting displays. Orientation of the louvers within the film determines the angles at which light can enter or exit displays. When the louvers are properly oriented, the film acts as an extended hood, thereby eliminating the need for hooding or recessing of displays.

Light Control Film is used by many automotive manufacturers on a global basis for functional and aesthetic interior applications. Specific interior automotive applications for the film are shown in Figure 3. The film has four major performance characteristics and can be designed in instrumentation and lighting assemblies to:

- Eliminate nighttime windshield and window reflection
- Improve daytime contrast and readability of electronic instrumentation
- Internally direct light to specific locations within cluster assemblies

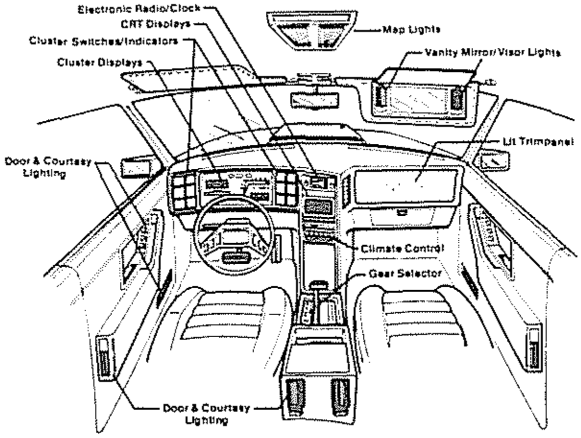


Figure 3. LCF Applications

These combined characteristics could ultimately assist in providing:

- Streamlined, smaller instrument panels
- More efficient use of interior and cluster lighting
- Increased passenger space

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