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## (54) Readable display stucture.

(57) A display structure which is readable even in direct sunlight includes a layered structure formed of a reflective element (42), an LED light source (18), a coloured filter (16), a legend plate (14), and a liquid crystal shutter (12). The reflective element (42) is positioned behind the LED light source (18). The light source is formed of an LED array (26) having a diffusion medium (28) disposed in front of the LED array (26) for scattering light when energized. The liquid crystal shutter (12) permits displayable information on the legend plate (14) to be viewed only when the LED array (26) and the liquid crystal shutter (12) are energized. The reflective element (42) and the diffusion medium (28) reflect and scatter incident sunlight which has passed through the liquid crystal shutter (12), legend plate (14) and coloured filter (16). This light is then reflected back through the coloured filter (16) and legend plate (14) and out the liquid crystal shutter (12). The coloured filter (16) is preferably selected to have certain spectral transmission characteristics. As a result, the contrast of the displayable information on the legend plate is enhanced and is unaffected by washout when viewed in an area of incident sunlight.

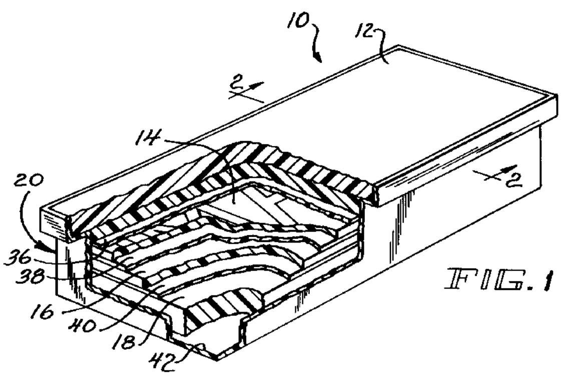


FIG. 1

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This invention relates generally to visual display device and more particularly, it relates to an improved display structure which is readable even in direct sunlight. The present invention has particular applications for use in instrument panels in aircraft cockpits, automobiles, and other vehicles wherein the display should be readable even in direct sunlight and preferably be unaffected by the phenomenon known as "washout."

There are well-known in the art various traditional display devices which utilize a white-light lamp (incandescent or fluorescent) as an illuminating light source which is transmitted through the backside of a legend plate so as to illuminate the same. In order to improve the readability of the legend plate under direct sunlight, it was generally required to increase the intensity of the light source so as to correct for dimness due to the washout phenomenon. However, this approach suffers from the disadvantages of requiring a large operating voltage and a corresponding increase in power consumption and heat dissipation.

While there is also generally known of various display devices which use light-emitting diodes (LED) as a light source so as to reduce power consumption, such display devices have not been utilized to any large extent due to the fact that they still have the drawback of being "washed out" in direct sunlight. In order to enhance the brightness of the LED light source, there is typically needed a separate light transmissive/reflective component to be formed in front of the LED light source so as to allow the light generated by the LED light source to pass therethrough but reflect incoming sunlight back out.

A prior art search directed to the subject matter of this application in the U.S. Patent and Trademark Office revealed the following U.S. Letters Patent:

| | |
|---|---|
| 3,881,809 | 4,772,885 |
| 4,182,553 | 4,791,418 |
| 4,315,258 | 4,799,050 |
| 4,603,973 | 4,915,486 |

In U.S. Patent No. 3,881,809 to James L. Fergason et al., issued on May 6, 1975, there is disclosed a liquid crystal display which includes a layer of liquid crystal material disposed between first and second transparent parallel plates to provide a sandwich structure through which light can pass. A third transparent plate of a glass/plastic material has a diffuse surface on its forward face and a metal layer disposed on its other side having high reflectivity characteristics. Ambient light which has passed through the liquid crystal material is reflected from the metal layer and is passed back through the liquid crystal material so as to increase the contrast.

In U.S. Patent No. 4,315,258 to William H. McKnight et al., issued on February 9, 1982, there is taught a visual display which includes a twisted nematic liquid crystal sandwiched between a pair of linear polarizers having their polarization axes either parallel or mutually orthogonally disposed so that the crystal will present bright or dark areas in response to applied potentials. A partially transmissive mirror is interposed between the sandwiched liquid crystal and a radiating light source so that in ambient light the image contrast is enhanced.

In U.S. Patent No. 4,791,418 to Hideo Kawahara et al., issued on December 13, 1988, there is disclosed a traffic signal light which is comprised of a light source and a liquid crystal means. A transparent colored plate is positioned in front of the light source and is coated with a transparent light-scattering paint to enhance contrast in sunlight. A control circuit applies an electric field to both the liquid crystal means and the light source so that they are energized or de-energized simultaneously. Further, a light transparent layer having a light-reflecting film is disposed between the transparent colored plate and the light source so as to increase the visual distinguishability of the colored plate under direct sunlight.

In U.S. Patent No. 4,799,050 to John C. Prince et al., there is disclosed a light valve for use in a full color liquid crystal display in which a layer of liquid crystal material is controlled by a transparent electrode matrix that is fixed to one surface of a fiber optic plate structure. A matrix of phosphors, each being in alignment with a corresponding element in the transparent electrode matrix, is fixed to the opposed surface of the plate structure. A light source of ultraviolet radiation is used to excite the phosphors. A dichroic filter is located behind the fiber optic plate structure to reflect visible light, both ambient and that emitted from the phosphors.

The remaining patents uncovered from the search but not specifically discussed are cited to merely show the state-of-the-art relating to visual display assemblies and thus are considered to be only of general interest.

According to this invention a display structure which is readable even in direct sunlight, comprising:

reflector means;

light source means including an LED array having a diffusion medium disposed on its front portion for radiating a light when energized;

a coloured filter arranged in front of the media of said LED array for transmitting the light radiated from said LED array;

a legend plate disposed in front of said coloured filter and having a transparent image of displayable information against an opaque background or vice versa deposited thereon; and,

electro-optic shutter means disposed in front of said legend plate for permitting the displayable information on said legend plate to be viewed only when said LED array and said shutter means are energized;

is characterized in that the light source means is disposed in front of said reflector means and

said reflector means and said diffusion

medium reflecting incident sunlight which has passed through said shutter means, legend plate, and coloured filter back through said coloured filter, legend plate, and out said shutter means, whereby the contrast of said displayable information on said legend plate is enhanced rather than being washed out by incident sunlight.

It has now been discovered by the inventors that the light transmissive/reflective component between the light source and legend can be eliminated by utilizing a diffusion medium in front of the LED light source and a reflector behind the LED. The reflector functions to reflect incoming sunlight back through the filter and legend. The diffusion medium and the reflector cause the reflected light to be lambertion and the LED light to be lambertion. None of the known display device techniques makes use of the reflective properties behind the light source such as an LED array so as to reflect incident sunlight back out. The elimination of the reflective surface or partially reflective surface from the front of the LED allows more of the LED light to exit out the front and makes the display more efficient.

Further, the inventors have found that the readability of the display structure can be enhanced through the inclusion of a reflective element positioned behind the LED light source. This element may also scatter light to improve viewing angle and uniformity. Also, the rear side of the legend plate can be provided with a reflective material in the opaque regions so as to reflect light striking the rear of the legend plate back into the interior of the display structure for reflection out the transparent region of the legend. This further conserves light energy. In addition, the filter is preferably selected to provide a desired transmittance dependent upon the emission spectral characteristics of both the LED light source and the ambient sunlight. This is done so as to prevent "washout," thus the output colour having the desired chromaticity will be observed by the viewer. In this manner, there is achieved an improved display structure which is compact, has high reliability and is formed of fewer components compared to the various known and proposed display devices.

Thus the present invention provides an improved display structure which is readable in the dark and in direct sunlight without colour shift when ON and is unaffected by "washout." Further, the legend and the legend colour is completely unreadable in any ambient illumination including direct sunlight when it is intended to be OFF. Also it is compact, lightweight, power efficient, has high reliability, and is forced of fewer components than those traditionally available. Further the readability of a display structure is enhanced even in direct sunlight by preventing the colour of the legend image from shifting or becoming desaturated.

A particular embodiment of a display structure in accordance with this invention will now be described with reference to the accompanying drawings; in which:-

Figure 1 is an enlarged perspective view, partly in section, of a sunlight readable display structure;

Figure 2 is a cross-sectional view, taken along the lines 2-2 of Figure 1;

Figure 3 is a front plan view of the display structure, illustrating a "dead face" when the liquid crystal material and the LED light source are deenergized; and,

Figure 4 is a schematic representation of the display structure, illustrating the readability of the legend plate even in direct sunlight when the liquid crystal material and the LED source are both energized.

Referring now in detail to the drawings, there is shown in Figures 1 and 2 an improved sunlight readable display structure 10 constructed in accordance with the principles of the present invention. The display structure 10 is comprised of a layered structure which includes an electro-optic shutter 12, a legend plate 14, a colored filter 16, a low-powered light source 18, and a back reflector 42, all contained within a housing or casing 20.

The electro-optic shutter 12 is preferably formed of a layer of liquid crystal material which is of the phase change guest-host type. This type of liquid crystal made is referred to in the literature as the Taylor and White made in honor of the inventors. In the energized condition, a power supply (not shown) is applied across electrical leads 22, 24 (Figure 2) so as to cause the molecules to become aligned and thus permit the passage of light. The electro-optic shutter 12 is similar to the type 103-9 which is manufactured and sold by Hercules.

The legend plate 14 is disposed adjacent and behind the inner surface of the layer of liquid crystal material 12. The legend plate 14 is formed with, or has deposited thereon, a transparent area image of the alphanumeric or graphic information, designated generally as displayable information represented in Figure 4 by a message "IMAGE." The part of the legend plate that is not transparent must be made opaque. This will give a bright image on a dark background. The transparent and opaque areas can be reversed so as to provide a dark image on a bright background. The bright area is made bright by the light from the LED and, if present, the ambient illumination. The back side or rear surface of the legend plate that is in the opaque area may be coated with a transparent light-reflecting film material 14a, which absorbs little light. As a result, any light striking the back side of the legend plate opaque area will not be absorbed but will be reflected back into the interior of the display structure and then subsequently further reflected and scattered back through the filter 16 and the legend plate 14. This serves to conserve the light energy from the

LED and helps prevent the display from becoming hot to touch or overheated.

The filter 16 is arranged behind the inner surface of the legend plate 14 and is fabricated of selected characteristics such that the alphanumeric or graphic information depicted in Figure 4 as IMAGE will appear illuminated as a desired transmission color to the viewer. In order to obtain this desired color output of chromaticity without a color shift even under varying ambient (sunlight) intensity conditions, the colored filter must be designed to have certain spectral transmission characteristics (transmissivity).

However, presently insufficient LED colors exist to achieve the desired color and it would be very costly to manufacture such a unique colored filter. Alternatively, the color filter can be selected from commercially available filters to match available LED colors to achieve acceptable usable colors, based upon conditions and criteria, as discussed below. These filters may be of the industrial grade, in production such as manufactured and sold by Hoya, such as red type R-60. The filter is selected to match available LED colors such as Hewlett-Packard type HLCP-HL100. The advantage to this latter approach is its low cost due to the use of the existing production filters at production thicknesses, and the disadvantage is that there may be a slight color shift due to the limited available filters when the ambient illumination (sunlight) increases in intensity and the color selection is somewhat limited by the available LED colors.

Initially, a first color output of chromaticity coordinates x1 and y1 must be measured when the LED light source is activated and no sunlight exists. Next, a second color output of chromaticity coordinates x2 and y2 must be measured in the presence of ambient illumination and the LED light source is inactivated. Then, the transmittance of the colored filter can be determined when the following factors are known: (1) emission spectral characteristics of the LED light source; (2) emission spectral characteristics of the ambient illumination; and (3) the desired output color with chromaticity coordinates x3 and y3. From a practical standpoint, it is necessary that the emission spectrum of the LED light source overlap the chromaticity coordinates of the desired output color. Further, it is helpful if the ambient illumination has a broad bandwidth such as exist with sunlight.

The filter transmittance is designed such that x1 = x2 = x3 and y1 = y2 = y3. As a consequence, the desired output color with chromaticity coordinates x3 and y3 will remain substantially the same for any combination of the LED light source and the ambient illumination.

The filter transmittance can be computed using optical design computer programs by one skilled in the art. Due to the cost of the filters and the limited availability of LED colors as suggested above, the design was achieved as follows:

(1) Select an LED color as close to the desired color as possible,

(2) Select from available filters a filter with high transmittance for the LED and such that x1 = x2 and y1 = y2 using the same computer program or engineering hand calculations, and

(3) Measure the resulting filter and LED performance.

In this manner, the chromaticity of the LED light source and the reflected light of the LED light source passing through the colored filter 16 and the legend plate 14 and out the electro-optic shutter 12 will be substantially the same as the chromaticity of the ambient illumination (sunlight) passing through the electro-optic shutter 12, the legend plate 14 and colored filter 16 and reflected back again through the colored filter, legend plate and out the electro-optic shutter. Consequently, the colored filter selected based upon this afore-mentioned technique will be optimized so that the light having the desired output color of chromaticity will be transmitted, thereby insuring image (or contrast) enhancement of display structure even in the presence of sunlight.

In order to increase the readability of the displayable information or symbol on the legend plate 14, a first seal 36 functioning as an optical coupling is interposed between the inner surface of the layer 12 of liquid crystal material and the legend plate 14. A second seal 38 functioning as an optical coupling is interposed between the inner surface of the legend plate 14 and the colored filter 16. Further, a third seal 40 functioning as an optical coupling is interposed between the inner surface of the colored filter 16 and the LED media 28 of the light source. The edges and the bottom of the assembly are painted with a white reflective paint to prevent any light loss and reflect inward all light so that it will exit the image area. The assembly of the layer of liquid crystal material, legend plate, colored filter and light source is installed snugly against adjacent surfaces in the casing 20 so as to eliminate unwanted reflection of incident sunlight along the edges of the casing which might decrease the image contrast.

Moreover, the readability of the displayable information or symbol has been increased by the inclusion of the reflective and light-scattering element 42 positioned behind the LED light source 18. The light-scattering element may be preferably formed of a layer of light-scattering paint, glass, plastic or some other diffusive material. The light-scattering material is suitably applied by coating the inner back surface of the casing 20 directly behind the LED light source 18. Alternatively, a light-scattering material may be applied to the entire inside wall surfaces of the casing 20 so as to provide a diffusive condition.

The low-powered light source 18 is preferably formed of a light-emitting diode (LED) array 26 having the diffusion medium 28 disposed on its front portion.

The medium 28 is transparent plastic and has scattering optical characteristics to diffuse the light coming from the points of each diode in the array 26 into a uniform film of light emitting from the source 18. It is to be noted that the inventive concept described herein requires the reflector 42 to be behind the light source 18 for the best results as opposed to a transmissive/reflective component (transflector) placed in front of the light source 18 as found in prior art patent Nos. 4,315,258; 4,791,418; and 4,799,050. This reflector 42 serves to eliminate the necessity of a separate light transmissive/reflective component between the light source and the filter which causes a reduction in the efficiency of the LED array 26. The light source 18 with back reflector 42 and electrical leads 30 and 32 is of the type similar to HLCP H100 and HLMP-2685 which are commercially available from Hewlett Packard. The Hewlett Packard components HLCP H100 and HLMP-2685 are manufactured with the medium 28, the LED array 26, and back reflector 42 with power leads 30 and 32 all in one assembly.

The light source 18 further includes electrical leads 30, 32 for receiving power from the power supply. When the power supply is turned off, the LED array 26 is de-energized and the layer of liquid crystal material is in the,OFF condition. As a result, the displayable information defined by the symbol IMAGE on the legend plate 14 will not be visually observable by the viewer in front of the display structure 10, as shown in Figure 3. In particular, it can be seen that the front of the display structure 10 presents a so-called "dead-face."

Referring now in particular to Figures 2 and 4, when the power supply is turned on, the LED array 26 is energized and the layer of liquid crystal material is in the ON condition. Consequently, the viewer will be able to see an image contrast attributed simultaneously by the internally reflected ambient sunlight 34 and by the transmitted radiating light from the LED array 26.

In other words, the ambient sunlight 34 from the viewer's side of the display structure 10 will be passed through the layer 12 of liquid crystal material which is in the ON condition. After subsequently passing through the legend plate 14, the colored filter 16, and the medium 28, then reflected back from the element 42, this will cause the ambient sunlight to be dispersed and reflected back through the medium 28, colored filter 16, legend plate 14, and the layer 12 of liquid crystal material and towards the viewer. Simultaneously, the light generated by the LED array 26 and the LED light as reflected by the light-scattering element 42 will pass through the medium 28, colored filter 16, legend plate 14, and the layer 12 of liquid crystal material towards the viewer.

Since the colored filter 16 has been chosen to have a desired transmittance dependent upon both the emission spectrum of the LED light source 18 and the emission spectrum of the ambient sunlight 34 rather than being matched only to the emissivity of the LED light source, the final transmission of the visible light from the colored filter 16 will be at the chromaticity of the desired output color. Therefore, the displayable information represented by the message IMAGE being visible through the layer 12 of liquid crystal material is enhanced rather than being "washed out" and appears to the viewer with the desired transmission color and at a higher luminescence in proportion to the ambient illumination.

From the foregoing detailed description, it can thus be seen that the present invention provides an improved display structure readable even in direct sunlight, which includes an LED array with a front diffusion medium and a back reflective layer. The reflection/diffusion media reflects and scatters incident sunlight which is passed through a layer of liquid crystal material, legend plate, and colored filter back through the colored filter, legend plate and out the layer of liquid crystal material by using the reflective characteristics of the layer 42 so as to enhance rather than washout the contrast of the displayable information on the legend plate. In order to further increase the readability of the display structure, the colored filter is selected to have certain spectral transmission characteristics dependent upon the emission spectrum of the LED light source, the emission spectrum of the ambient sunlight, and the desired transmission color.

## Claims

1. A display structure which is readable even in direct sunlight, comprising:

   reflector means (42);

   light source means (18) including an LED array (26) having a diffusion medium (28) disposed on its front portion for radiating a light when energized;

   a coloured filter (16) arranged in front of the media (28) of said LED array (26) for transmitting the light radiated from said LED array (18);

   a legend plate (14) disposed in front of said coloured filter and having a transparent image of displayable information against an opaque background or vice versa deposited thereon; and,

   electro-optic shutter means (12) disposed in front of said legend plate (14) for permitting the displayable information on said legend plate to be viewed only when said LED array (26) and said shutter means (12) are energized;

   characterized in that the light source means is disposed in front of said reflector means (42) and

   said reflector means (42) and said diffusion medium (28) reflecting incident sunlight which has passed through said shutter means (12), legend plate (14), and coloured filter (16) back through said coloured filter (16), legend plate (14) and out said shutter means (12), whereby the contrast of said displayable information on said legend plate (14) is enhanced rather than being washed out by incident sunlight.

2. A display structure as claimed in Claim 1, further comprising optical coupling means (36,38,40) interposed between said layer of liquid crystal material (12) and said legend plate (14) for facilitating the readability of said displayable information, or between said legend plate (14) and said coloured filter (16) for facilitating the readability of said displayable information, or between said coloured filter (16) and said reflection/diffusion media (28) of said light source (18) for facilitating the readability of said displayable information.

3. A display structure as claimed in Claim 1 or 2, wherein said light means (18), coloured filter (16), legend plate (14) and shutter means (12) are disposed as a layered structure within a casing (20).

4. A display structure as claimed in Claim 3, wherein said reflector means comprises a reflective light-scattering paint (42) which is coated to the inner back surface of said casing (20) directly behind said LED array (26).

5. A display structure as claimed in Claim 3 or 4, wherein the entire inside wall surfaces of said casing (20) is coated with said reflective light-scattering paint (42) to provide a diffusive condition.

6. A display structure as claimed in any of the preceding claims, wherein said coloured filter (16) is selected to have certain spectral transmission characteristics dependent upon the emission spectrum of the LED light source (18), the emission spectrum of the ambient sunlight, and the desired transmission colour.

7. A display structure as claimed in any one of the preceding Claims, wherein the back side of the non-transparent area of said legend plate (14) is coated with a light-reflecting film material (14a).

8. A display structure which is readable even in direct sunlight, comprising:

reflective means (42) for reflecting light;

light source means (18) disposed in front of said reflective means (42) for radiating a light when energized;

a coloured filter (16) arranged in front of said light source means (18) for transmitting therethrough the radiated light;

said coloured filter (16) being selected to have certain spectral transmission characteristics dependent upon the emission spectrum of said light source means (18), the emission spectrum of the ambient sunlight, and a desired transmission colour;

a legend plate (14) disposed in front of said coloured filter (16) and having displayable information deposited thereon; and,

said reflective means (42) reflecting incident sunlight which has passed through said legend plate (14) and coloured filter (16) back through said coloured filter (16) and legend plate (14) to provide a final transmission of visible light with the chromaticity of the desired output colour,

whereby the contrast of said displayable information on said legend plate (14) is enhanced rather than being washed out to a viewer located in an area of the incident sunlight.

9. A display structure as claimed in Claim 8, further comprising electro-optic shutter means (12) disposed in front of said legend plate (14) for permitting the displayable information on said legend plate (14) to be viewed only when said LED light source means (18) and said shutter means (12) are energized.

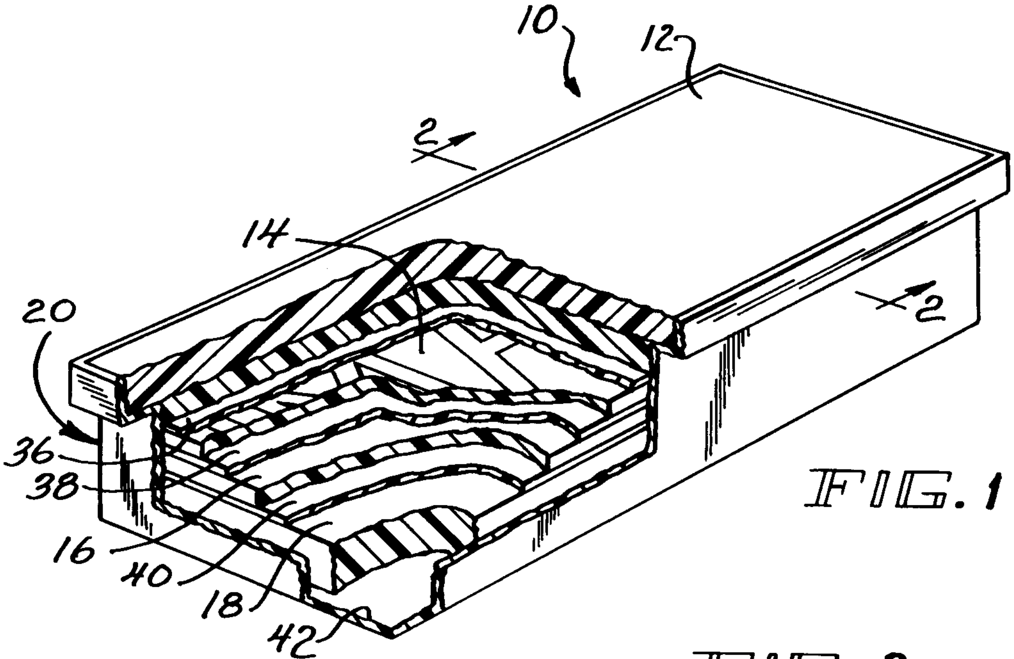


FIG. 1

FIG. 2

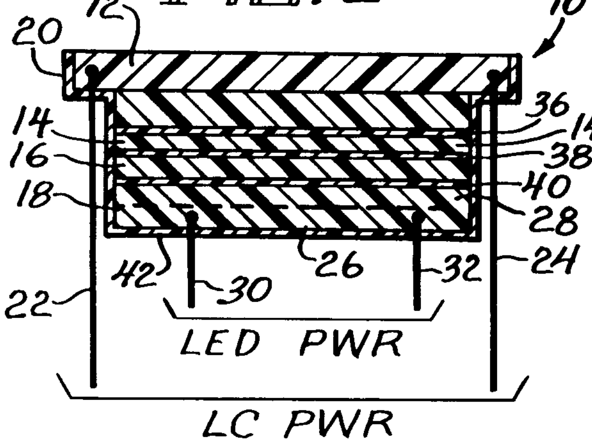


FIG. 3

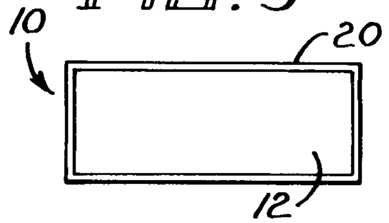


FIG. 4