PHUND (Portable Head Up Navigation Display) for a Motor vehicle

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Abstract

We have succeeded in designing a PHUND (portable head up navigation display), which has a compact system with a MD panel and full color display device using RGB LED sources. The PHUND has been developed as an alternative to conventional built-in type HUD system targeting the high volume aftermarket with an affordable price.

1. Introduction

An automobile is a must in modern life. As we spend long hours in our car, it won't be too wrong to say our car is our second home. As a manufacturer of home appliances, we have been interested in incorporating our products into our second home, our car.

Two major factors we considered in our study were 'space' and 'safety'.

As for space, the point was how to place flat appliances such as flat screen in the narrow space and curved structure of a car without sacrificing the effectiveness and the size of appliances.

The first concerns that numerous display systems put into the limited space of automobiles. And conventional display with flat panel system is directly unsuitable for automobile application.

The second issue, safety, is more important than the first. Navigation system used in automobiles is required to visualize the location of a vehicle and give directions to a driver in a quick and accurate manner for a driver's safety. Since navigation system is usually located under dashboard or other place off the natural range of view of a driver as shown in Fig.1., it may create a dangerous situation by distracting driver's attention.

The solution we decided on was a virtual projection display as known Head up display without a physical screen space to display a virtual image.

The head up display emerged as a gunsight technology to minimize information overload by centralizing critical flight data within the pilot's field of view, and the technology was adopted by commercial aviation for data displaying such as speed, altitude, a compass and localizer readings. Since 1988, HUD had been becoming increasingly available for vehicle speedometer, tachometer and navigation system and recently developed as a built-in type in a premium model.

We designed the portable head up navigation display system based on the projected display principle. The PHUND is an effective device to increase safety since it allows the driver to view necessary information without taking his eyes off the road. And PHUND is compact enough to be installed in between windshield and dashboard and is designed to display the full map in full color and better still, it has a very affordable price.

2. System Design

We examined to get the optimal point to install PHUND on in between windshield and dashboard. The optimal point means what provides the handiest view of the screen for a driver without interrupting his driving. As a result of our study, we concluded that PHUND system should be a compact to fit in the limited space or be built in the dashboard like conventional HUD.

The conventional HUD has a thick display panel (over 1 inch) and needs more light source and more energy for cooling down, and because of its bulkiness, it's inevitable to be the built-in type, hence high cost

for production and installation as well, and for that reason, it has been an optional item for luxury cars. And its function and display are quite elementary; mono colored display, basic text and indication of directions.

a)Direct Transparency b)Direct Reflection c) Projection

Fig.1. The concept scheme of HUD for a Motor Vehicle

We designed PHUND as an aftermarket item. It is compact and portable and was developed based on 3 main concepts as follows.

The first concept is that the system has a spontaneously direct virtual display by itself on wide panel or on windshield. Unfortunately, we decided that the concept is not quite obtainable by the current technology in terms of virtual distance, brightness et al. The closest technology is the HUD using OLED. It might be possible if OLED have a solution of higher brightness.

The second concept is to display on a wide display panel. This concept can be easily understood. For example, when you stand in front of plate mirror or a sheet of paper is placed on a dashboard reflected on windshield, the virtual image is about the same size of real thing, but there is some difference between the distance from eye to virtual image and the actual distance. If there is such a difference on a navigating system, it may cause some problem with a driver's safety. And the wide panel HUD system is bulky and does not have particular merit. Defi's VSD is similar concept.

And the third concept is projection HUD type by MD (micro display). It should be possible to develop a virtual image overlapping with a foreground scene and obtain the required virtual distance for a driver's safety. So, we decided that the MD projection concept is the most suitable for HUD to create a virtual image in the limited space of a vehicle.

HUD System is basically composed of illumination part, display part and drive part. At illumination part, a light source is necessary for image display system. There is back light unit to guide the illumination and to transmit uniform brightness and color on panel. The display part creates the virtual image by project optical system using micro display. And the PCB is the part that drives the panel according to the external information.

HUD for an automobile must have luminance about 3,000nit to make a virtual display image shown clearly in bright day light. Our new HUD has full color/full map display. The full color/full map display was made possible by the RGB LED package which has higher contrast by a black surface, a wider color temperature and high power 60 lm. UHP lamp and mono color temperature LED are light source of conventional HUD. It can be controlled separately to display various colors including white by independent driving of each chip. We designed the BLU (Back Light Unit) in such a way to maximize the equal distribution of color and image on the display panel by combining a reflected light guide and a diffuser with a direct type BLU.

TABLE 1. shows the MD panel comparison. The major considerations for a portable HUD are compactness, good resolution and high brightness. The OLED panel is not suitable for a HUD because it can't produce high enough brightness. But DMD, which is generally used for the projection, has good contrast, resolution and brightness, but high price. On the other hand, an LCD as the image source for a HUD has many advantages in terms of size, weight, resolution. So, we recognized the best view of panel for a HUD is LCOS or LCD. We used the transmissive 0.44" LCD as compact HUD in this paper.

TABLE 1. The MD panel comparison

Item	Active	Passive		
	OLED	LCD	DMD	LCOS
Contrast	◎	○	◎	◎
Viewing Angle	◎	○	○	○
Response time	◎	○	○	○
Thickness	◎	○	○	○
Color	○	Light source/Color filter dependence		
Brightness	×	Light source dependence		
Life time	△	◎	◎	◎
Resolution	○	◎	◎	◎
Cost	○	△	×	△

An optical design is required to magnify the image of micro display and project the magnified image to a wanted distance. In designing HUD for a vehicle, the

height of driver's eyes, the distance between the eyes and the range of eye movement should be considered according to which the distance and the size of image should be decided. The size of conventional HUD is proportional to the size of the panel, the size of image and the range of eye movement, and so it tends to be quite bulky. Our new HUD has compact size and simple design with just one or two components.

Fig.2. shows the optical ray tracing design for displaying the virtual image 7" at virtual distance 2.3 m. The designed virtual optical systems consist of simple components by off-axis, asymmetric and aspheric optical systems as shown in Fig.2. We used less than half aspheric reflected surface which has 15.8 magnifications. In order to increase the field of view, either the pupil size (combiner size) must be increased or the distance from eye point to the pupil must be reduced. If the eye is too far back from the lens then the entire optical FOV may not be visible owing to the limited diameter of the magnifier lens. Generally, HUD for automobiles has that the diameter of the magnifier lens, combiner, is small for the eye position distance from the lens as shown in Fig.2. So, the actual FOV available to the eye must be calculated using Eq.1.:

$$FOV = 2 \arctan (D/2L_e) \quad (1)$$

where, FOV: Field of view (actual)
D: Diameter of combiner
L_e: Eye distance from lens

FOV (field of view) of HUD should be considered the relationship between a diameter of combiner (D) and an Eye distance from lens (Le).

Combiner is a partial transmissive aspheric optical component. The ratio between transmission and reflection was adjusted to minimize obscuration and to maximize brightness. And, to remove the unwanted double image, we used the method by coated AR (anti reflectivity) less 0.5% on surface and the calculated thin thickness.

It is designed in such a way to keep the distortion of image lower than 5% to prevent the image mismatch caused by distortion according to MIL-STD-1472D.

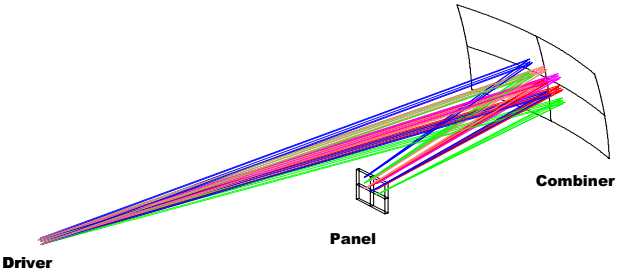

Fig.2. The virtual optical design

3. Results

The portable HUD prototype was designed and built to present virtual image 7" with Full color, Full map at the virtual distance, 2.3 m.

Table1 shows the specification of PHUND. Combiner size was defined by the designed optical clear aperture with eye motion area H80 mm x V20 mm. Optical component which is used less than half aspheric reflected optical surface created virtual image size 7" from 0.44" panel.

PHUND is compact and slim (30 mm in thickness) by the folding combiner's structure and easy to install and portable, and it's detachable as well to avoid theft. Considering all these features, PHUND is most feasible item for the aftermarket.

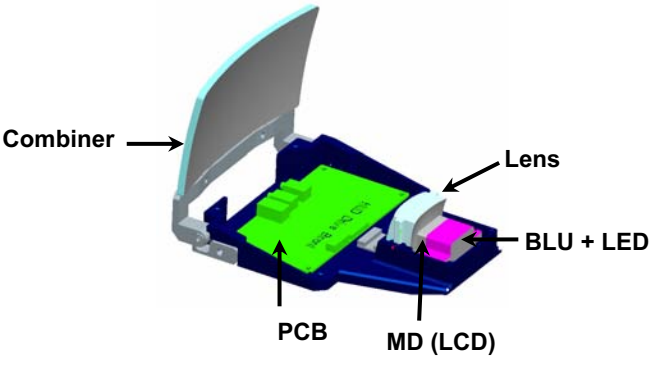

Fig.3. HUD Mechanical system design

PHUND has a sufficient brightness for a driver to recognize the virtual display image in a day light as shown in TABLE.2. Since power requirement is less than 5 W, PHUND is suitable for a vehicle with a low electricity and is sufficiently powered by the battery of navigation system.

PHUND is also applied to display the night vision by IR camera, rearview image by wide angle lens and AV (Film, DMB, game, etc).

TABLE 2. The specification of PHUND

Items	Specification
Display Panel	0.44 " LCD
Resolution	320x240xRGB
System size(W x D x H)	110x120x30mm
Virtual image size(H x V)	142x106 (7")
Magnification	15.8 X
Distance :eye to device	680 mm
Distance: eye to virtual image	2,300 mm
Distortion	<±2%
Display Brightness	~ 3000 cd/m^2
Color	Full color
Combiner(H x V)	110x55 (AR coating <0.5%)
Power consumption	<5W

4. Summary

The conventional HUD for a vehicle is a bulky and complicated system and it only comes in a built-in-the-dashboard type. And the function and display of conventional HUD is elementary. On the other hand, designed by MD projection's principle, the PHUND is compact and displays full map in full colors.

We are confident that the PHUND is ideally suited for the aftermarket application because PHUND has a simple structure and compact size and very affordable price compared to conventional built in type HUD.
And we are going to keep improving the quality PHUND, especially in terms of better visibility and durability against temperature, vibration.

5. References

1.Okabayashi.S. and Sakata.M. et al, Development of Practical Head-Up Display for Production Vehicle Application. SAE890559, (1989)

2.Weihrauch.M., Meloeny.G.G., and Goesh.T.C., The First Head Up Display Introduce by General Motors., SAE890288.(1989)

3.James E. Melzer, and Kirk Moffitt, Head-Mounted Displays, p60-p63 (1997)

4.MIL-STD-1472D, Human engineering design criteria for military systems, equipment and facilities. U.S. Department of Defense. (1989)