TI DLP® technology for aftermarket head-up display applications

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Introduction

With demand by users to augment their driving experience to react quickly to time-sensitive events, manufacturers and brands seek to display relevant information directly in the user's field of view (FOV) without distracting them from performing a task. This functionality, called head-up display (HUD), is incorporated in some cars today to provide important information to a driver; augmented-reality (AR) cruise control for example (**Figure 1**).

This paper is written for individuals involved in new product development, with the objective of helping them make educated end-equipment decisions for aftermarket HUD design. The paper includes benefits, applications and display design considerations related to HUDs. The paper also covers DLP® technology benefits and product selection for aftermarket HUDs. Refer to application note "TI DLP® Pico™ Technology for Aftermarket HUDs" for an explanation how a DLP head-up display works.

***Figure 1**. Example of an automotive DLP head-up display*

HUD benefits

A head-up display offers unique benefits to both end users and end-equipment manufacturers.

The end user benefits by getting **useful and timely information**:

- **Information displayed within the user's FOV**; first and foremost, the objective of a HUD system is to present information within the user's line of sight while driving. The user can continue to see the real world while useful and timely information is layered within their FOV, thus reducing distractions.
- **In real-time**; The display incorporates time-sensitive information to the user when the information is available. For example, someone using a map application on their cell phone to get turn-by-turn directions in their car. In this case, with the phone app communicating to the HUD, the turn signal can be shown in front of the driver when it is time to turn and without distracting from the user's situational awareness (**Figure 2**).

Figure 2. Head-up display indicating a right turn during navigation

- **Where needed**; With an integrated camera, the HUD display could augment the information such that the information on the HUD could be spatially placed on/over real objects that are within the user's FOV. The HUD could be used to highlight obstacles ahead even with low visibility given high fog coverage (**Figure 3**).

Figure 3. Aftermarket head-up display used to help see road ahead

The manufacturer can benefit by delivering **product differentiation** in the following areas:

- **Display performance**; the main purpose of the HUD is to clearly present information to a user. The more real the perception that the information is embedded in the real world, the higher the value to the end user. Additionally, image quality, brightness and contrast are important factors in achieving a seamless and high-performance display. [Display considerations](#) for HUD will be covered in detail later in the white paper.
- **Connectivity**; the simplest source of HUD information is the vehicle computer system, plus dedicated, predefined storage. While this approach is simple, it has limited flexibility. A higher-value approach is for the HUD to display information acquired from individual, real-time sources that are related to the specific tasks, such has mobile-mapping applications, mobile-search applications, etc. A few common connectivity options that manufacturers use to differentiate their products are USB, *Bluetooth*®

technology, Wi-Fi® and automotive on-board diagnostics (OBD) II.

- **User interface**; Seamless integration of the display and the real-world results in an excellent experience for the user and is one of the key factors that can influence successful adoption of the HUD technology. Such integration includes (a) placement of the information in the right location (b) virtually instantaneous display of the information (low latency), (c) intuitive human interaction with the HUD, (d) usefulness of the information presented to the user and compelling form factor.

Categories and applications

There are a variety of applications that benefit from a HUD. A few of them include:

Application	Use
OEM vehicles	Speed Navigation Collision warning
Industrial, commercial, personal and recreational land transportation equipment including cars, boats, trucks, motorcycles and ATVs	Cell phone connectivity, including navigation, phone calls, texts and music Vehicle gauges, including speedometer, tachometer, fuel and compass
Commercial, personal and sports helmets	Cell phone connectivity, including navigation, phone calls, texts and music Vehicle gauges, including speedometer, tachometer, fuel and compass
Personal and recreational air transportation equipment	Navigation Gauges including speedometer and altimeter

HUD designs can be organized into five different categories. Each category has its unique set of requirements and considerations.

- **Original end-equipment manufacturer head-up display (OEM-HUD)**; Similar to a console subsystem, an OEM-HUD is a car HUD subsystem installed when the car is manufactured. All of its components need to comply with automotive-grade specifications. This type of HUD can utilize projection technology and a combiner optical element to create a virtual image in front of the driver's FOV. This HUD is fully integrated to all the systems and connectivity offered by the car.
- **Aftermarket head-up display (AM-HUD)**; Similar to an aftermarket car stereo that is sold by a retailer, an AM-HUD is a portable device that is placed on a car dashboard or front visor so that the driver can see the road and, within a portion of their FOV, enjoy timely information delivered by the AM-HUD (**Figure 4**).

Figure 4. *Aftermarket head-up display*

- In addition, an AM-HUD can also be incorporated into private aircrafts. HUDs can use projection technology and a combiner to create a virtual image that the user will see when the image is within his/her FOV. Connectivity to a mobile device is very typical as most of the times the HUD is packaged with a mobile device application.
- **Commercial helmet HUD**; Helmets can also incorporate HUDs by incorporating the HUD subsystem mounted inside the helmet itself; helmets designed for private airplanes, motorcycles and all-terrain vehicles (ATVs) can also use this approach.
- **Augmented reality head-up display (AR-HUD)**; Although the AM-HUD augments

the experience of the user, the AR-HUD further enhances the experience of the user by incorporating a significantly larger FOV of the user plus sensors and detailed information sources. The end result is virtually portraying objects and information up to 12 meters in front of the user. This category requires a much higher field of view and extremely accurate synchronization of the HUD display and the real world.

- **Augmented reality eyewear**; Another opportunity to experience the right information at the right time is to use augmented reality eyewear. Go to TI.com/DLPAR to learn more about this implementation; **Figure 5**.

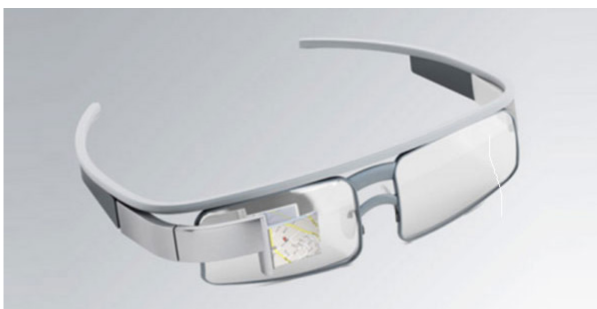

Figure 5*. Augmented reality monocular eyewear*

Display design considerations for aftermarket HUDs

Developers have the opportunity to differentiate their products by the decisions they make during the HUD design phase. This section will present a typical system block diagram, and highlight some of the possible decisions that can be made within the electrical design, optical design and software design.

- **Block diagram**; **Figure 6** illustrates a typical system block diagram for a HUD system based upon DLP technology. The application processor controls the overall functions of the HUD, based upon both user inputs as well as real-world inputs, obtained from sensors and/or connected mobile applications. The application processor outputs video data to the display electronics. The display electronics process the video data as required for the micro-display. Illumination and projection optics then produce the virtual image.

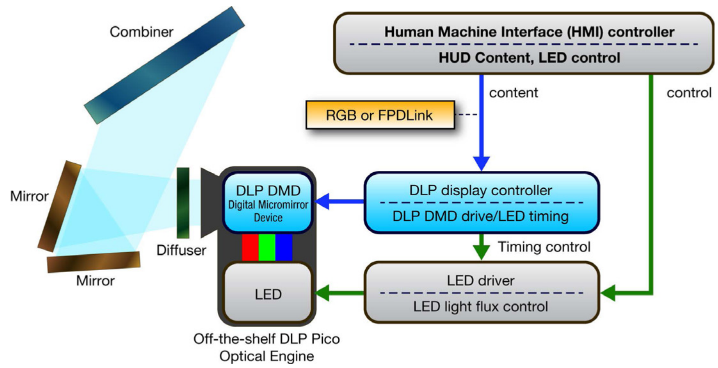

Figure 6*. Head-up display subsystem block diagram*

- **Electronics**; Power, size and cost are the main electrical considerations. Power is primarily influenced by the optical efficiency of the display. System size will depend on the size and selection of the components, thermal efficiency and number of PCB board layers. Cost is mainly driven by the power of the LEDs that light up the HUD and resolution of the display.
- **Display performance**;
  - **Image quality**; This critical design consideration includes color saturation, color gamut, contrast ratio, and fill factor. More detailed information about these considerations can be referenced in the on-line training called “Mobile Smart TV design considerations”
  - **FOV**; This design consideration determines the size of the viewing box available to user; the size of the user box determines the flexibility the user will have to move their head and also determines how much of

the real world will be augmented with the display information. A very small eye box (FOV) "confines" the displayed information to a small portion of the user's overall field of view. A very small eye box also limits the head movement of the user. A very large viewing box may require larger projection optics and a longer distance between the projection lens and the virtual image.

- **Connectivity**; The purpose of the head-up display is to communicate information relevant to the vehicle (for example: speed), information relevant to the driver's situation (for example: obstacles ahead) and information relayed from a smart phone (voice call for example). With that purpose in mind, the head-up display needs to acquire and transmit information in a timely manner by using a variety of wired and wireless interfaces compatible with the vehicle computer, vehicle sensors and smart phone. USB, Bluetooth technology, Wi-Fi and automotive on-board diagnostics (OBD) II are the most common connectivity options.
- **User interface**; Design considerations for user interface include appropriate presentation of the information on the HUD and user inputs (gestures and buttons for example). An excellent user experience is a big area of differentiation, and is a result of the manufacturer's ability to seamlessly integrate this functionality into the HUD.

Benefits of DLP Pico technology for AM HUD

DLP Pico Products offer effective solutions for HUD projection display. This section includes a brief overview of DLP technology and the benefits it offers.

- **What is TI DLP technology?** Texas Instruments DLP technology consists of a microelectro-mechanical systems (MEMS) device that modulates light. This device is called a digital micromirror device (DMD). Each micromirror on a DMD is independently actuated, in sync with color sequential illumination, to create stunning bright and colorful displays. DLP technology powers the displays of products worldwide, from digital cinema projectors (DLP Cinema® products) to projectors inside of tablets and smartphones (DLP Pico products). DLP Pico chipsets include a DMD, a display controller and a power management integrated circuit (PMIC). The projection subsystem consists of these components combined along with optics and additional electronics. Learn more about DLP technology at ti.com/dlp
- **Benefits**; DLP technology benefits HUDs through low latency, high image quality, low power consumption and the flexibility inherent in projection technology. Developers also benefit from the extensive DLP ecosystem, which enables quick time to market.
- The benefits of DLP technology can be summarized as follows:

Benefit	Description
Excellent image quality	There are several image quality benefits that DLP technology offers: • **Vibrant images**, enabled by wide color gamut and DMD technology spawned from DLP Digital Cinema technology • **High frame rate**, DLP technology can enable frame rates higher than 120 Hz depending on input resolution, enabling fast-moving video and minimizing motion blur
Low latency	DLP Products offer low latency. For TRP products, single-frame rate allows a tiny frame lag of 8.3 ms at 120 Hz

Benefit	Description
Clear display virtually anytime and anywhere	The high contrast capability of DLP technology enables a high-transparent display. DLP technology is polarization-agnostic, which allows end users to clearly see the displayed image even with polarized sun glasses.
Low power consumption	DLP Pico technology has a high optical efficiency architecture that results in high lumens per watt that maximizes the brightness output. Some of its products feature DLP IntelliBright™ algorithms that allow displays to increase brightness or power efficiency up to 50%.
Quick time to market	High demand for DLP Pico technology has resulted in a wide range of optical module makers that provide production-ready optical engines for a wide variety of DMD products, brightness levels and projection distances. These optical module makers are part of the robust and experienced ecosystem of companies that DLP Products has established to support optics, electronics and systems solutions. In addition, DLP Products offer a wide variety of evaluation modules (EVMs) and reference designs that allow designers to prototype and design quickly and easily.

DLP technology product selection

HUDs designs can vary by the desired FOV and resolution. The following table can help developers select the right DLP solution for their target product.

DMD part number	DLP2000	DLP2010	DLP3010
Field of view*	10°	14°	21°
Resolution	640×360	854×480	1280×720
*Field of view based on "TI DLP Pico Technology for AM-HUDs"			

DLP Products has a specific offering for automotive OEM HUDs; learn more at www.dlp.com.

Summary and getting started

Aftermarket head-up display is a product that can provide extremely useful and timely information to the end user without distracting them as they perform critical tasks. There are HUDs in the marketplace today, including OEM HUDs, aftermarket HUDs and military pilot helmets. There are a wide variety of design considerations for this end equipment, including display image quality, connectivity and user interface. DLP technology provides an excellent micro-display choice for this end equipment. DLP Pico technology benefits include low latency, excellent image quality, high contrast, low power and quick time to market. Product designers can get started now with the following resources:

- "Getting started with DLP technology" application report
- "TI DLP Technology for aftermarket head-up displays" application note
- DLP Pico evaluation modules
- DLP Products
- System trade-offs:
  - "Brightness requirements and trade offs" application note
  - "Optical Module Specifications" application note
  - "TI DLP® IntelliBright™ algorithms for the DLPC343x controller" application note
  - "Real-time color management for DLPC343x" application note
- Design guidelines:
  - "DLP2010 DMD optical engine reference design" application note
  - "PCB design requirements for TI DLP Pico TRP digital micromirror devices" application note