Dynamic Ground Projection using DLP® Technology for Automotive Exterior Lighting

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Introduction

Dynamic ground projection technology, with the ability to display any pattern within the same module, can re-invent consumers' perceptions on external lighting by providing new, innovative lighting capabilities such as automotive light "carpets" that can illuminate the surrounding area outside a vehicle or project vehicle information such as the EV charge level and range remaining, tire pressure warnings, traffic warnings, turn signaling, check engine light warning, gas level/range, etc. from a side mirror. Ground illumination has other enhancement features to help cars communicate with drivers and pedestrians, including corner lighting, reverse lighting, vehicle customization and parking indicators.

Dynamic ground lighting systems enable high-resolution projections for clearer communication and safer driving. These systems also need to be compact and discreet enough (approximately 50 mm in length and 25 mm in width and height) to be mounted in locations such as inside car doors, in side mirrors, embedded in the front or back bumper, or in headlights or taillights.

DLP® technology's ability to project dynamic content on the ground or other surfaces around a vehicle yields an array of benefits, including enabling vehicle-to-pedestrian communication and the transmission of more complex, intuitive messages when alerting surrounding vehicles of a driver's intent.

A brief history of automotive lighting

Automotive lighting systems have had many enhancements over the past few decades, most notably alterations to rear, side and front lighting centered on illumination technologies. Car headlamp light sources evolved from tungsten halogen lamps, to high-intensity discharge bulbs, to high-power white-light LEDs – with improved luminous flux, efficiency and longer operational lifetimes.

Many headlights leverage an integrated light source configuration with a reflective lens and lens system to provide high-beam, low-beam and fog-lamp functions. A similar layout combines rear lights to provide multiple signaling functions as well as rear fog lights. Additional vehicle-mounted lighting includes side-mirror lighting for redundant turn signals and nighttime illumination, as well as the center high-mounted stop lamp (CHMSL). Supplementary vehicle lighting encompasses additional customization such as the illumination of the automaker's logo and even projected logo lights located on the interior of car doors.

Automotive lighting systems must follow regulations from the National Highway Traffic Safety Administration or Economic Commission for Europe for standardized signaling and reflective devices. Headlight safety requirements have also increased in stringency, with mandatory light shape provisions and precise photometry. Designers must comply with these requirements while also meeting the manufacturer's car profile for both practical and decorative purposes. DLP technology can not only help meet these needs with relative ease by supplementing any light source with a digital micromirror device (DMD), which is a programmable microelectromechanical system reflective array but can further enhance the overall function of the light beams.

DLP technology at a glance

DLP technology can display dynamic content through the use of DMDs – which contain up to 8.3 million micromirrors that switch between two positions to redirect incident light based on an electrical input (**Figure 1**) – as well as the subsequent image processing, memory, light source and projection optics necessary to control the system and display dynamic content.

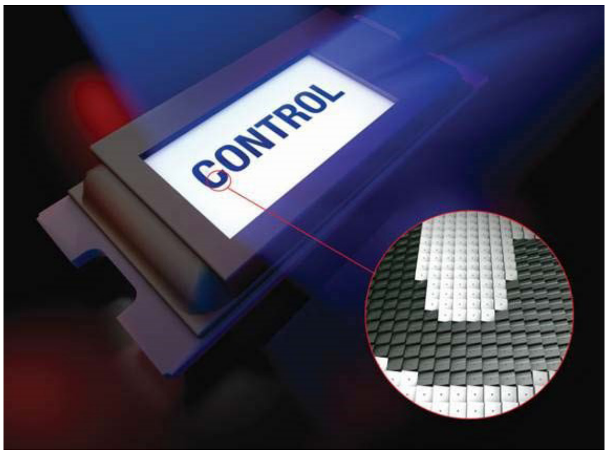

***Figure 1**. DLP technology involves the high-speed control of millions of micromirrors for high-resolution images.*

DMDs replicate patterns by individually switching micromirrors, which represent pixels of the projected content. Let's review five ways where DLP technology has substantial value to provide for automotive lighting systems.

Reprogrammability

DLP technology can dynamically change content without modifying any of the attached optics. The benefits of this capability become more pronounced when compared to common static projection technologies such as "goes before optics" (also known as a gobo), often used in stage lighting applications. A gobo projector creates patterns of projected light with a cutout filter similar to a stencil to create an image. This type of projection technology is already used in custom puddle lights, but the images aren't modifiable, making it necessary to include an entirely separate module just to produce a single static image.

DLP technology is fully programmable and can achieve the projection of multiple images at various times. For instance, it is possible to create custom lighting within the side-mirror light base while also functioning as a door-open warning sign when needed, or update additional complex images based on user needs and road conditions. For example, as a door opens, or when the driver puts their hand on the door handle, a warning would be projected that the door is opening. This would be helpful for cars parked near bike lanes.

Full-color range support

Static projection technologies are typically limited to displaying images in a single color. For instance, a gobo leverages a dichroic stencil for a colorful image projection, but dichroic filters can only produce a single color.

DLP technology achieves full-color support by pulsing red, green and blue LEDs or lasers very quickly to the DMD. The DMD has switching speeds on the order of a few microseconds, enabling the use of a single imager for all three colors to create stunning images and videos.

Light source-agnostic

Because DLP technology is reflective, it can be used with any type of light source, including the LEDs and laser diodes that are replacing incandescent or gas discharge light sources in front and rear lighting. This flexibility allows DLP technology to scale with various illumination technologies across a broad range of wavelengths, including visible and near-infrared, in automotive lighting and communication systems.

Already automotive grade

Automotive-grade DMDs, DMD controllers and power management integrated circuits are already qualified for an operating temperature range from –40°C to 105°C, and are rated for the necessary electrostatic discharge qualifications for automotive integrated circuits. This enables the incorporation of DLP technology into current automotive lighting systems.

Small form factor

A major goal for automotive lighting systems is to enhance a vehicle's aesthetic appeal. Outside of a vehicle's overall profile and materials, lighting systems are key components in creating the appearance of a sophisticated vehicle. Much work goes into the design of an automotive lamp's shape, often leading to tighter tolerances for circuits on the interior. The complete DLP subsystem can easily fit into a small slot inside a sideview mirror or other constrained regions around the vehicle.

DLP technology use cases

Considering the benefits, the automotive lighting applications for DLP technology are virtually endless. Here are some potential applications for DLP technology and automotive lighting systems.

Small exterior lights

DLP technology can greatly expand the functionality of a vehicle's small exterior lights, including on the interior of the door, rocker panel or bottom of the side mirror (**Figure 2**). DLP technology's ability to create dynamic images without the need for additional movable components makes it possible to use small exterior lights to project low tire pressure or door open warnings from the side mirror

Figure 2*. Small exterior lighting projecting a logo onto the ground from sideview mirrors.*

as drivers approach their vehicle, or to allow the projection of vehicle logos or other styling images and videos from the bottom of the door panel in a small form factor. These features can allow original equipment manufacturers to fully customize messaging and branding from small exterior lights instead of static logos from today's lights, which can only display a single pattern and cannot be used for communicating with pedestrians or drivers.

Automotive light carpets

The side mirror lights can perform multiple functions at once, operating as a standard turn signal as well as projecting a light carpet on the side areas of the vehicle that span the entire length of the vehicle (**Figure 3**). This type of illumination is particularly useful when the driver is leaving or approaching the vehicle in an area that is dimly lit, or at night.

Figure 3*. Automotive light carpet projected from multiple locations on the vehicle.*

Warning drivers and passengers

DLP technology offers a step beyond the flashing lights and hand gestures that drivers currently use to warn others. Warnings produced using DLP technology can come in the form of visual information on the road and can signal things such as hazardous road conditions, or special traffic areas such as construction or school zones. A driver may also be able to project a crosswalk or select a preset message that displays the words "safe to cross" on the ground to directly communicate to pedestrians attempting to cross the street.

Broadcasting intent: private vehicles

The ability to broadcast intent has the potential to prevent many accidents caused by nervousness, indecisiveness or a general confusion caused by not knowing another driver's next move. DLP projection can transmit simple intentions that are notoriously difficult to communicate, such as a U-turn or a K-turn. Taxis can use symbol projection to warn ongoing traffic that a vehicle is about to stop entirely and a message can be projected to the ground to announce that a passenger will be exiting the vehicle.

Vehicles pulling out of driveways with a blind spot may be able to project the intent to pull out. Autonomous functions such as parallel parking or moving in reverse can be projected as a path backwards to an eventual parking position, clearly communicating intentions to passing vehicles and cyclists (**Figure 4**).

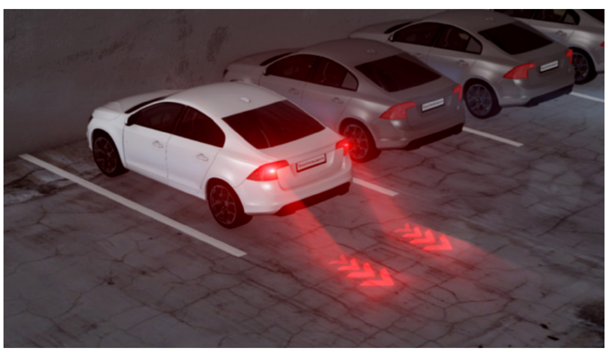

Figure 4*. A driver can broadcast their intended trajectory by projecting a path on the ground behind their vehicle through the rear lights.*

Broadcasting intent: public-use vehicles

A firetruck, ambulance or police vehicle could publicize their exact path, enabling the drivers of nearby vehicles to better understand exactly where to move to get out of the way. A police vehicle could communicate the need for a driver in front to either pull over or switch lanes so that it could pass.

Large vehicles such as buses and tractor trailers that take wide turns may need to communicate to oncoming drivers that they need to back up in order for the driver to make a successful turn. Public buses can project a path to and from bus stops so that drivers in nearby vehicles can better understand their trajectory. Tractor trailers with oversized loads could project the exact amount of space a vehicle should give when passing through tight spaces. School buses can also project intent for passenger safety. For instance, instead of a standard stop sign, a school bus could project a stop sign across all lanes.

Route guidance

A DLP subsystem can assist with navigation by augmenting the driver's field of vision with graphics such as lane lines in instances where there may be none. This idea can be built upon with real-time visual directions, assisting drivers while simultaneously announcing to vehicles in the vicinity the direction in which the driver will next move.

Conclusion

Dynamic ground projection is the next step in automotive lighting systems and a logical progression from adaptive driving beam technologies. The ability to individually control millions of pixels in a projection system enables a myriad of potential vehicular applications. Compared to other static projection technologies like gobo, DLP technology offers far more flexibility, with a high-resolution, reprogrammable multichromatic platform in a small package. Additionally, DLP technology holds its own against dynamic, digital projection technologies due to its relative cost-effectiveness, flexibility in differing light sources and overall efficiency.

The fact that DLP chipsets are already qualified as automotive grade with custom processing specific to automotive applications decreases their potential time to market. The automotive lighting industry can potentially benefit greatly from taking advantage of these technological leaps with the implementation of spatial light modulators such as DMDs for agile beam illumination and message/symbol projection.

Additional resources

- "Create high resolution adaptive headlights using DLP technology."
- "Symbol projection with high resolution headlights featuring DLP technology."

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