

**WHITEPAPER**

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# The Role of Light Pipes in LED Communication:

Enhancing User Experience and Design Flexibility.



**BIVAR**

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# Introduction

Most electrical engineers and product designers are familiar with Light Emitting Diodes (LEDs), but some may not be as familiar with light pipes. These are accessory components to LEDs, used to transfer light from the LED source component to the user interface. This allows more design flexibility for placement of boards inside a device and ensures optimal display visibility.

Light pipes have been around for over 25 years and continue to evolve with the changing expectations of user experience.

In this paper, we'll take an in-depth look at how LEDs and light pipes are used in tandem to make devices communicate more effectively to users. And we'll explore new applications and best practices for common design challenges.

## LED Applications Across Industries

Emitting diodes have been around for many years. LEDs are much smaller than traditional light sources, making them a great choice for a variety of different applications — in everything from blinking indicators in small electronic devices to large-scale illumination systems in commercial and residential settings.

The benefits of LEDs over other light sources are well known: higher efficiency, better durability, and more vibrant colors. LEDs come in a full range of hues and color temperatures that designers can fine-tune to create different moods in architectural spaces.

LED components continue to improve in their lifespan and versatility, which in turn brings more possibilities to visual indicator and interface designs. LED applications are ubiquitous across nearly every sector, showing up in industrial control monitors, consumer devices, and automotive interiors. One significant benefit of the LED is the ability to create space-constrained designs. These diodes are only a few millimeters wide and can be clustered together into small groups.

In certain classes of devices, LEDs are now capable of withstanding a variety of environmental conditions, making them suitable for even the most extreme weather or hazardous environments, such as in agriculture or renewable energy applications.

### **A universal medium**

Today, LEDs used as indicators are so common that they are the default medium to convey information from machines to their users.

For example, recent electric vehicles communicate to the driver through LEDs not only on the dashboard to show what systems are active or inactive, but throughout the interior for ambient mood, in navigation displays and infotainment systems, and around the cockpit for safety alerts. Step outside and find LEDs in EV charging stations, traffic signals, and signage.

### **The bridge between two systems**

In many of these instances, light pipes are employed to transmit the light from the LED component to its destination on the interface, which is often several centimeters away. Light pipes mount securely to the display panel, ensuring LED indication function is structured soundly inside a device.

When several indication lights are adjacent to each other, the light sources may bleed through more than one opening in the display, creating what is referred to as crosstalk. Crosstalk from various light sources can add ambiguity to an interface and increase the potential for user misinterpretation.

Light pipe designs make use of internal reflection and refraction technology, which help to disperse and direct the light for better visibility. The addition of light pipes to a device design isolates each LED to ensure each indicator has a bright, clear signal that is easily read at a glance.

Light pipes aid the engineer by providing a greater degree of flexibility. LEDs are often mounted on printed circuit boards (PCBs) which have their own “real estate” limitations for component placement.



At the same time, the discipline of user experience design (UX) might elect to optimize interface indicators to achieve a spatial consistency or an aesthetic effect. Light pipes — in the form of rigid or flexible light pipes — become the bridge between these two systems that are often designed by different teams.

Light pipes allow for the flexible placement of internal boards and can be customized in modular forms to fit any space constraints. Their unobtrusive profiles also fit into tight spaces among other cabling and wiring.

### More and more data

Recent technology drivers have increased the demand for LED applications across verticals. These trending new applications incorporate LEDs in new ways. Thanks in large part to Internet of Things (IoT) connectivity and the movement towards Industry 4.0 models, the influx of new data is significantly changing the way devices communicate with users.

The output of data analytics — shared with end users in real time and at optimized legibility — is becoming more operationally important in many business situations. On the consumer end, enhanced data features are a mark of a premium product.

We see LEDs used in next-generation applications to help give us notifications, assistance, and feedback. For example, consumer devices like E-bikes, electronic surfboards, or smart paddles for recreational use all rely upon LEDs to communicate data analytics to users. Other examples like access keypads for secure building entry, smart controls integrated into farm equipment, as well as food processing scanners and cutters all depend on LEDs, and by extension, light pipe components.

Any of these interfaces that employ LEDs in close proximity to one another will encounter the challenge of color bleeding and crosstalk between the different LEDs. Therefore, design precautions need to be considered to make clear, safe, and effective interfaces.



# Collaborating with an Engineering Partner

Large manufacturers have invested heavily in understanding the user experience of their products, either by building in-house teams or outsourcing the analysis to UX design agencies.

These specialist teams research the look and feel and methods of competitors' products, test prototypes with potential users to garner their feedback, and even recommend a design scheme for the best user experience, particularly its user interface (UI). Meanwhile, the engineering of the core functionality of the electronics may be a task for a separate initiative.

In the end, the scrutiny of UX details and the refinement of features pays off for the company since it results in electronic devices that are easy to interpret and operate, and safe and comfortable to use. Thanks to the design partnership, the product is less likely to fail because of usability issues.

Yet another set of engineering tasks remains, which also takes special expertise and can prevent a product from failing prematurely in the field.

Light pipes, lenses, and related mounting components act as connective tissue that integrates an optimized external interface with the product's functional internal hardware. Why consider an outside group to recommend components and design techniques specifically for in-product LEDs? A specialist in light pipes can:



- **Speed up product design and testing timelines**

An outsource partner delivers an integrative design that brings together several subsystems responsibly, which can accelerate the time to market, ensuring sound functionality and reduce the total cost of design and manufacturing.

- **Bring valuable resources to the process**

With advanced engineering simulation and analysis tools, specialist teams can optimize product design and test parameters. Additionally, they may also bring a library of reference design programs that can be used to quickly customize designs to meet specific customer space constraints.

- **Alleviate workloads**

Outsourcing your LED indication and illumination design helps relieve internal engineering resource drain and stress from trimmed down departments. Often core engineering staff are unfamiliar with specialty lighting parts, the best practices for mounting, and common pitfalls. Letting specialists handle interface integration allows your engineers to focus on core system and software platforms.

- **Provide product lifecycle support**

An experienced team of engineers and technicians is always available to provide consultation and assistance throughout the entire product lifecycle.

## Common Challenges in Designing with LEDs and Light Pipes

Next, let's look at common challenges with new designs. No matter what application the design engineer is working on, it requires careful consideration of various factors, such as:

- The type of LED
- The stresses expected from the in-the-field setting
- The line of sight and distance to the user
- The power requirements of the LED
- The luminosity of light transmission to the interface

### Indicators for harsh environments

When a product is designed especially for outdoor use or otherwise exposed to environmental hazards, control panel LEDs become an even greater area of concern, for both user safety and for long-term product survivability.

The LED specialty design team would start early in the design process to help identify and assess key factors in the operating environment. In many applications, like those in the agricultural industry, temperature extremes, exposure to dust, dirt, liquids, shock and vibration are important factors to consider to ensure the LEDs illuminate well in all conditions.

Temperature is one of the most important factors when designing with LEDs. The performance of LED technology is greatly affected by thermal changes. LEDs are typically sensitive to temperatures between minus 40°C and plus 85°C.

If the temperature is too high, the performance of the LED will be reduced. Conversely, if the temperature is too low, the LEDs will not be able to operate at full capacity. In addition, it is important to consider the heat generated by the LEDs themselves and to ensure that the heat is dissipated effectively so as not to damage the LEDs or the surrounding components.

A light pipe acts as a heat sink, drawing heat away from LEDs and other components of the system, keeping the system operating at ideal temperatures and improving longevity.

The design of rugged LED products must also consider the effects of vibration, shock, and other physical forces. These can cause damage to the LEDs and other components, and so the entire design must be robust enough to withstand these forces.

### **Sealing LEDs with IP-rated lenses**

Often outdoor designs require extra measures to prevent dirt, dust, and moisture from entering and damaging the LEDs and other components. The higher the ingress protection (IP) rating, the better the product's ability to protect against these conditions. IP-rated lenses and light pipes offer a robust means of isolating LEDs from harsh and inhospitable environments, utilizing a combination of durable material and specialized coatings.

IP-rated lenses are designed to provide a dependable seal and protection from a variety of elements such as dust, water, temperature extremes, and corrosion.

In addition to lenses, light pipes provide a shield from UV radiation, ambient temperature, shock, vibration, and mechanical damage, while delivering light from the LED through a highly efficient path. When used with LEDs, both IP-rated lenses and light pipes provide assurance that your components remain isolated from harsh conditions and will continue to operate as expected. A newly developed product, SGLC-LD, has an indicator for leak detection. SGLC-LD includes a new color-changing leak detection ring that turns from white to red, alerting users to possible liquid intrusion into mission critical controls.



## Size and format

LEDs deployed in tight spaces or with limited space inside a device benefit from light pipes. Beyond eliminating crosstalk to avoid confusing indicators for the end user, light pipes can be a creative space-saving solution. Rigid light pipes provide structured space between the board and exterior panel, leaving room for other conduits. Flexible light pipes can run electronics for controls far from their viewing point, even as much as 100 meters away.

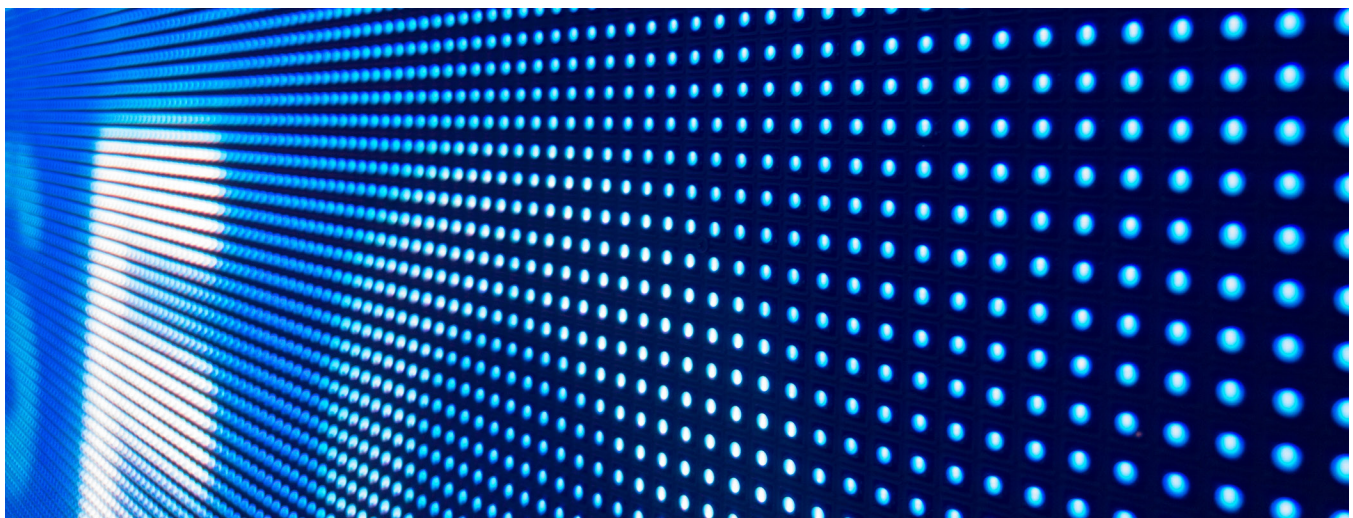
The ease of installation is also a design consideration, especially in hard-to-reach spaces. To ensure a successful installation, it is important to design the light pipe with easy-to-install components and to provide clear instructions for installation and maintenance.

Switching out a vertical light pipe for a right-angle light pipe can help save space during a redesign, or reconsideration of a rigid light pipe in favor of a flexible light pipe that weaves through some obstacles in your design will open up some flexibility for other components.

## Light transmission inside your device

Throughout this discussion, we have discovered the critical role of light pipes in improving products across industries, bringing clearer communication to user experience while protecting electronic devices from ingress and shock and providing engineers with internal space-saving solutions.

Whether outsourcing the design of light pipes or incorporating them in-house, design engineers and managers can overcome the challenges associated with data communication, visibility, and harsh environmental conditions. The expertise and guidance provided by trusted design partners can help companies achieve exceptional user experiences and maintain a competitive edge in their respective industries.





## About Bivar

Bivar is a leading specialty provider of LED indication products and solutions with a long-standing history of more than 40 years of innovation in the optoelectronics industry. With a global base of customers in 35 countries, Bivar's products are designed to meet the increased demand for point-to-point indication and address a growing range of industrial markets and applications. Bivar's focus is on moving and positioning light. An employee-owned company, Bivar's corporate headquarters are located in Southern California, with manufacturing in California, China, and Taiwan. Bivar's Asia Pacific production and logistics centers offer scalable capacity, execution, control, and movement of product around the world. Bivar is widely supported by a highly qualified network of authorized representatives and distributors. For more information, please visit [www.bivar.com](http://www.bivar.com).

