Backlighting Guide

A Quick & Easy Guide to Enhance your Product's Interface by Leveraging Different Backlighting Solutions

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Overview

From surgical equipment to aircraft cabins, backlit devices and accents are dominating the world around us. Backlighting can not only improve the visual appeal of your device, but also significantly enhance functionality and user experience. Backlighting is the simplest way to lend unparalleled style to your devices and can be integrated in a broad array of applications including user interfaces, integrated displays, and product branding. Boyd Corporation has been developing custom backlighting solutions for decades for a broad range of industries such as medical, automotive, aerospace, and electronics.

This brief guide will explore in detail the most popular backlighting technologies, compare the key characteristics, advantages, and limitations of each backlighting technology. It will also provide you with a framework to approach your next backlighting project.

INTRODUCTION

Backlighting has become an industry standard to augment the functionality and aesthetics of a device. From home appliances to aircraft cabins, and car dashboards to industrial controllers, backlit devices and accents are becoming increasingly ubiquitous.

Backlit buttons and display on a dashboard

Backlighting is a simple way to improve visual appeal, enhance user experience, and lend a distinctive style to your user interfaces. It can assist and guide users towards the correct operation of a device, especially in dimly lit and dark environments. It also provides vital feedback about user actions and interactions. For instance, when you plug in your laptop to the power supply, a green light visually conveys that the laptop has been plugged correctly and is currently in charging mode. The absence of this green indicator light would result in no visible or obvious reaction to your action.

Advantages of Backlighting

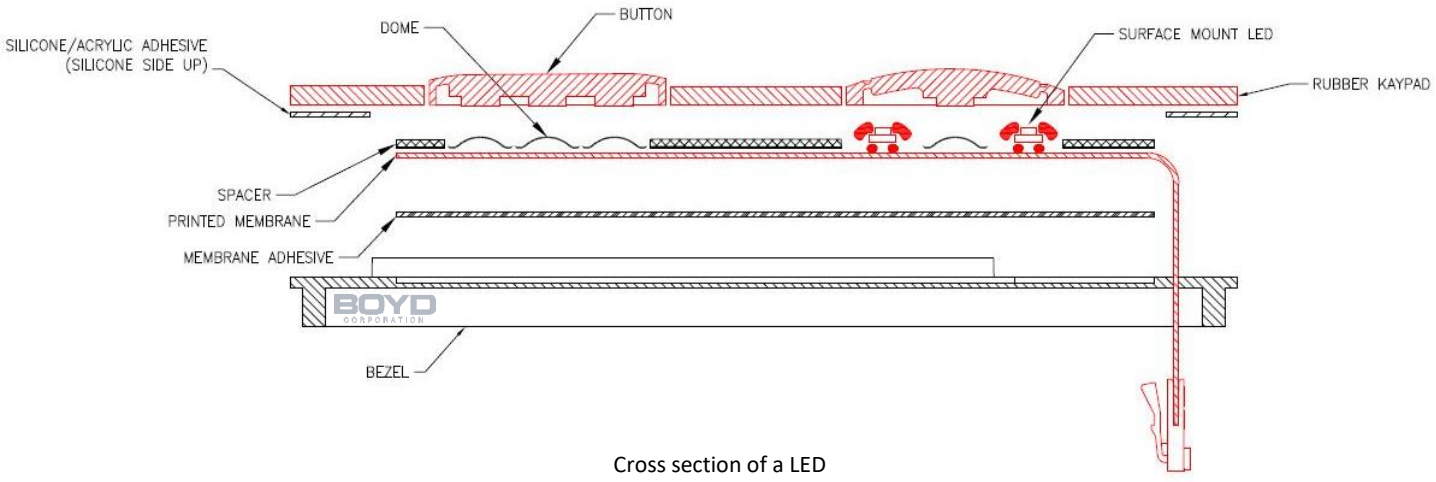
- Prompt user towards the correct operation of device
- Ensure effective use of devices in dimly lit and/or dark environments
- Provide visual feedback about functionality and status of device
- Enhance user experience
- Increase the aesthetic appeal of devices
- Differentiate your device from the competition

BACKLIGHTING TECHNOLOGIES

Of the various backlighting techniques available today, determining the most optimal technology to fit your project needs and requirements can be overwhelming. In this section, we will shed some light on four prominent backlighting solutions, namely discrete LEDs, light guide film, fiber optic, and electroluminescence. By illustrating and comparing key advantages and design concerns when working with each technology, the guide will help you assess and select the best solution.

1) Light Emitting Diodes (LEDs)

Light emitting diodes (LEDs), also referred to as discrete LEDs, are point-source lights that can be lit individually or in a group to illuminate a small area. Thanks to their low cost, thin construction, and long operating life, discrete LEDs have enjoyed widespread popularity and adoption across industries as diverse as medical, aerospace, automotive, and more.



Cross section of a LED

LEDs come in different packages of varying shapes, sizes, types, and heights. The most commonly utilized types include surface-mount LEDs (top-fire or side-fire) and bullet LEDs. LED backlit designs can be constructed in a

range of colors and brightness levels. For example, an indicator light turning green when the device is in use and the same light turning orange when the device is in standby mode.

Advantages of Discrete LEDs

- Thin and robust construction
- Limited impact on the tactile feel of buttons or snap domes
- Long operating life
- Ability to illuminate the same area with different colors
- Varying brightness level and color options
- Cost-effective

In addition to the traditional single and bi-colored LEDs, RGB LEDs have opened doors to a wide gamut of colors and accent lighting options. RGB technology, combining three LEDs in a single package, mixes the three primary colors (red, green, and blue) in varying intensities to generate any color on the RGB spectrum. As a result, a single LED is capable of producing multiple colors.

LEDs are available in different corelated color temperature (CCT) values like the cool blues, warm yellows, and other tints. Whether you need dimmable, flashing, or non-flashing lights, LED designs can be composed in various styles. They can also be configured to light up all at once or selectively, as the design dictates. While surface-mount LEDs can either be mounted on a silver printed membrane, copper-etched flex circuit, or a printed circuit board with a connector that attaches to the main board, bullet LEDs can only be mounted on the latter two.

As point-sources of light, LEDs are great for indicator light applications, communicating the working or the status of the device. However, they usually struggle with lighting up large surfaces uniformly. A high count of LEDs in a concentrated area or placement of them close to a graphic overlay can create unwanted hotspots (bright areas) over or near the light source. Fortunately, both issues can be overcome by utilizing an elastomer keypad or overlay. Rubber overlays optimize light diffusion from LEDs, thereby mitigating hotspots and ensuring consistent brightness over the surface. A common challenge with elastomer is that it has a very different texture compared to a polycarbonate overlay and adds substantial thickness to the construction stack-up. Light dams or barricades often need to be incorporated in the design to overcome light bleed from one LED to the adjacent window.

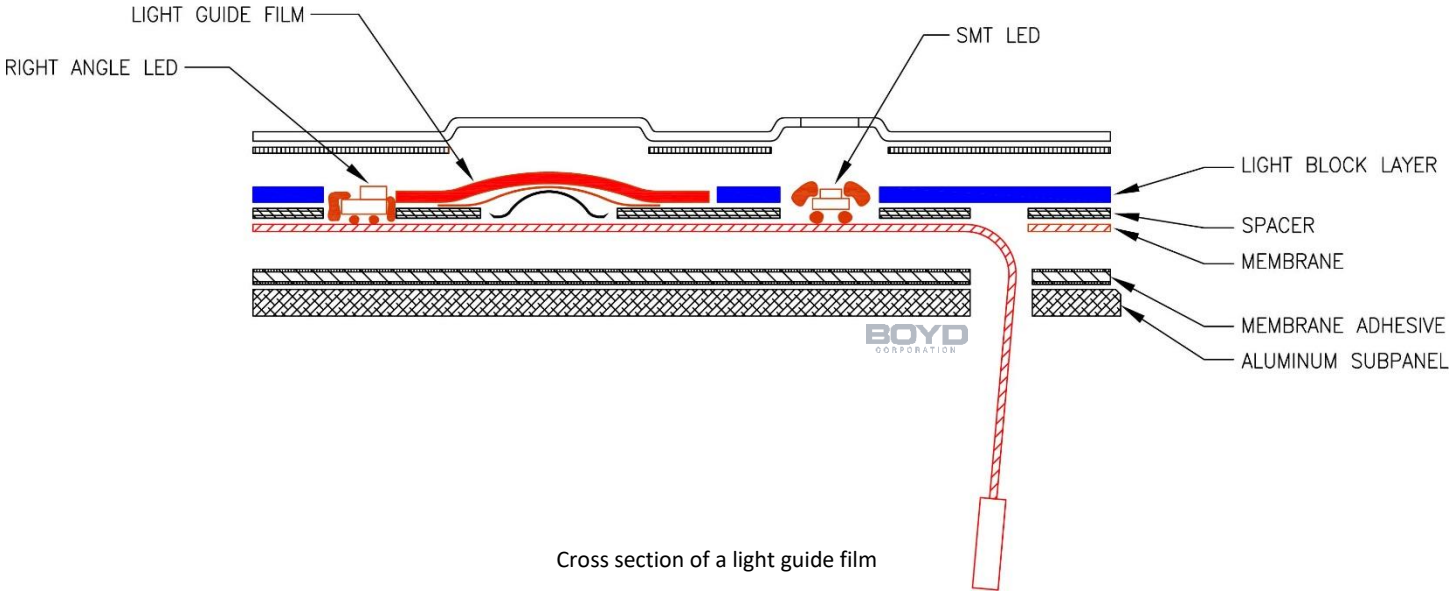
Major Challenges with Discrete LEDs

- Potential hotspots and/or light leaks
- Difficulty illuminating large areas uniformly

If you need to backlight a bigger area without an elastomer overlay, you may want to consider other technologies like a light guide film or fiber optics that are discussed later in the guide.

2) Light Guide Film

Light guide film, as the name indicates, utilizes a thin film to guide the light from LED(s) to the desired area. The film, made of acrylic or polycarbonate, is selectively laser-etched to refract light upwards from the abraded parts. With varying depths and customized etching patterns, the distribution of light can be easily controlled and altered, allowing specific areas to be brighter or dimmer than the rest. Since the light feeds directly into the edge of the film, this technique uses side-fire or right-angled LED(s) to facilitate the optimal diffusion of light through the entire length of the film. The precise alignment and orientation of the film and LED(s) is extremely critical to the success of the design.



Cross section of a light guide film

Seen in three varying thicknesses of 0.2mm, 0.3mm, and 0.45mm, the film's low profile allows it to limit the impact on tactile feedback of metal snap domes or buttons. As a result, it is usually mounted directly below the graphic overlay and can be seamlessly integrated into thin and tight spaces. With minimal loss of light from the source to the other edge of the film, this technique promises uniform lighting across the entire plane with increased efficiency.

Advantages of Light Guide Film

- Uniform lighting and brightness
- Limited impact on the tactile feel of buttons or domes
- Energy efficient
- Ideal for lighting small, large, and curved surfaces
- Suited for thin, compact, and flexible designs

More than one light guide film can be integrated into a design to separately light up distinct areas or backlight different features with different colors. The flex tail of the film can be plugged directly into a printed circuit board or printed membrane, thus simplifying the sealing and insulation of the self-contained design.

While light guide films are gaining momentum across several industries, there are few challenges that need to be addressed while working with this technology. When the light travels from the LED through the film material, the edges are often illuminated very brightly, resulting in unwanted light leaks. This can be overcome by employing an opaque panel filler along the border of the film. Since LED(s) are butted up against one end of the film, it can create hotspots in areas around the light source. This can be eliminated by adjusting the printing process of the overlay to add a printed opaque layer. Given the construction of a light guide film, lighting up the same area with multiple colors is often difficult.

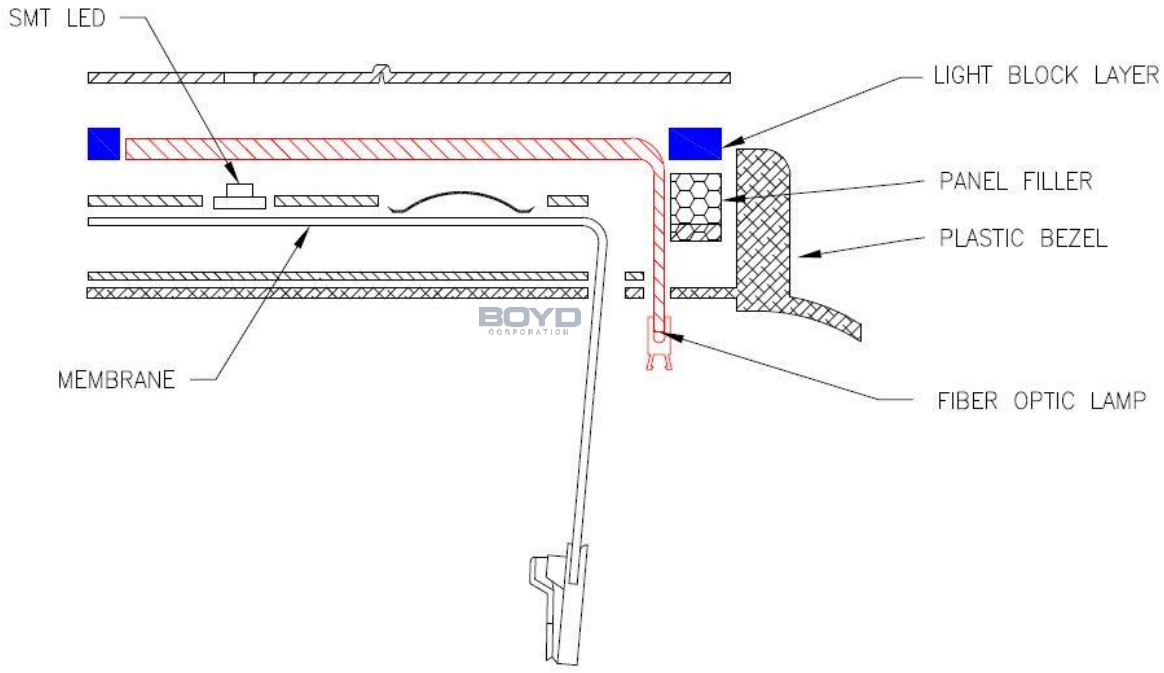
Major Challenges with Light Guide Film

- Light leaks from the edges
- Potential hotspots around the LEDs
- Limitations to backlighting the same area with multiple colors

Despite the above drawbacks, light guide film is increasingly becoming the preferred solution for membrane switches, capacitive sensors, and more.

3) Fiber optic

Fiber optic technology utilizes of a bundle of thin optic fibers that transport light from a single LED to a large surface. Made of acrylic, every individual optic strand is thin, pliable, and extremely durable. However, it should be noted that the LED used is always a bullet LED, which requires a printed circuit board or copper flex circuit as a base. Bullet LEDs cannot be mounted directly on printed membranes.



Cross section of a fiber optic

The light travels through the fibers with very little bleed out on the sides. As a result, no light blocking layers are required in between the construction. However, as the light travels from the bullet LED through the entire length of the optic bundle, it makes the end of each strand brighter than the rest. Hence, a light blocking layer or panel filler is required on the edges to eliminate light leaks.

Advantages of Fiber Optic

- Ability to illuminate large surfaces with a single bullet LED
- Low power consumption
- Minimal impact on tactile feedback over metal domes

Given the working mechanism of fiber optics, the color of the lit area or assembly is dictated by the color of the bullet LED. RGB bullet LEDs can be employed to achieve a wide array of color options. Lighting up different sections with different colors can be achieved by utilizing separate layers (separate optic bundles) and using desired colored LEDs as the light source. Alternatively, you can also use a white bullet LED and regulate the colors through the printed graphic overlay.

Fiber optics are often integrated in tandem with discrete LEDs, where surface-mount LEDs are used for indicator lighting and fiber optics are utilized to light up the larger area, including icons, texts, patterns, or graphics. As this backlighting technology requires only one LED to illuminate the entire assembly, the power consumption is low.

While using a single LED is one the biggest advantages of a fiber optic technology, it may not be bright enough to illuminate a very large area, especially if the device is primarily designed for use in ambient light. This issue can be addressed by configuring more than one fiber optic bundle in the design to increase the brightness of the assembly. However, integrating multiple bundles often translates to a thicker stack-up and increased cost. It is important to bear in mind that a bulky design may diminish the tactile feedback of buttons.

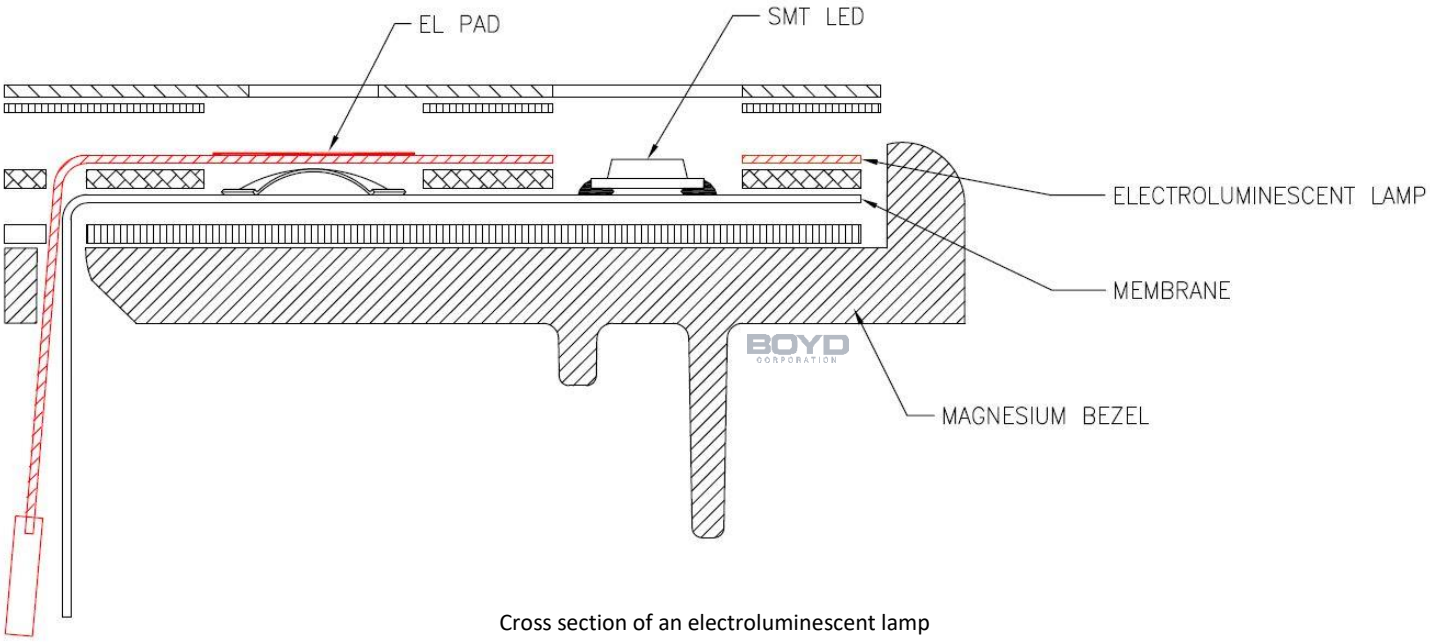
Major Challenges with Fiber Optic

- Thick construction
- Can potentially dampen the tactile feedback of buttons
- Not ideal for use in ambient light

Overall, fiber optic backlighting works great with most switch applications and designs with metal domes and buttons.

4) Electroluminescence (EL Lamps)

Popularized in the 1980s, electroluminescence (EL) technology works by sending an electric current through phosphorus, a semiconductor that emits light when charged. EL can be mounted on printed membranes or printed circuit boards.



Cross section of an electroluminescent lamp

Governed by the design requirements, EL can be zoned in selective areas to ensure optimum diffusion of light. With minimal light bleed, it doesn't require blocking layers between different sections that are lit. Like fiber optic technology, EL can also be integrated with discrete LEDs to have indictor lights and light up large areas simultaneously.

Advantages of Electroluminescence

- Ability to illuminate large surfaces
- Limited impact on the tactile feed of buttons or domes
- No light bleed
- Varied color options via overlay printing

Unlike light guide films and fiber optics where the light color can be changed at the source, there are certain limitations with the EL backlighting method. The core colors that phosphorus can produce are white and blue green. While generating other exotic colors is possible, it can significantly add to the cost of the design. One way to navigate this shortcoming is to have the EL light in one color (preferably white) and then print the graphic overlay in the desired color scheme. If you need different colored lighting for separate areas, the sections can be isolated by adding additional traces.

The biggest challenge with EL is the half-life of phosphorus. After 4,000 hours, the phosphorus begins to degrade, thereby dimming the backlit area. EL also requires a DC to AC power conversion which may not be possible to integrate in many designs. This typically means that EL backlighting needs to be designed in from the very beginning of the design cycle and cannot be added as a last-minute drop-in feature.

Major Challenges with Electroluminescence

- Half-life of 4,000 hours (phosphorus begins to degrade after)
- Requires DC to AC converter
- Expensive

Considering the limited life span of this backlighting solution and the price point of this mature technology, it is a viable backlighting solution in exceptionally few cases.

COMPARING BACKLIGHTING TECHNOLOGIES

The below table summarizes the key similarities and differences between all the four backlighting technologies discussed before.

Specification	Discrete LEDs	Light Guide Film	Fiber Optics	EL Lamps
Construction thickness	Varies ~0.020”	0.008” to 0.018”	~0.013”	~0.015”
Impact to tactile feedback	Low	Low-medium	Low	Low-medium
Power source	DC	DC	DC	DC to AC
Ability to light individual icons	Yes	Limited	Limited	Yes
Ability to light selective areas	Yes	Yes	Limited	Yes
Ability to light large areas	Limited	Yes	Yes	Yes
Operating life span	High	High	High	Low
Additional tail connection	Not required	Not required	Required	Required
Good in ambient light	Yes	Yes	Depends on design	Yes
Hot spots	Yes	No	No	No
Cost	$	$$	$$$	$$$$

BACKLIGHTING DESIGN CONSIDERATIONS

Designers and product development teams often wonder when the right time is to start thinking about backlighting when developing new products? Ideally, backlighting should be considered at the very beginning of the design phase. This gives you the flexibility to evaluate available technologies and allows engineers to integrate backlighting seamlessly with the other technologies and features of the design.

To determine the most optimal backlighting solution to fit your needs, some key questions to ask during the design cycle include –

- What environment will the device be primarily used in - indoor or outdoor?
- Will the device be primarily used in ambient light, bright sunlight, or dimly lit spaces?
- Do you want to light up a small indicator window or backlight large areas like texts and graphics?
- How many colors do you need?
- Will all the areas be lit at once or do they need to be independently controlled?
- Are there any buttons or snap domes that need to be integrated in the design as well?
- What power type is available – is it a portable unit or a plug-in?
- What are the cost constraints?

Once you have evaluated and selected the most appropriate technology, you need to address all the design concerns and challenges that the technology presents. A few parameters to address include –

- Will the light source create hotspots? If yes, how can they be mitigated?
- Will the light bleed from one section to the other? Do I need a light blocking layer?
- Is the construction stack-up too thin or too thick for the design?
- Is the backlighting affecting the tactile feedback of the buttons or switch technology?
- What brightness level does the design demand?
- Should the light source be mounted on a printed circuit board or printed membrane?
- What is the minimum and maximum size of the light source that can used in the design?
- How many light sources do I need?

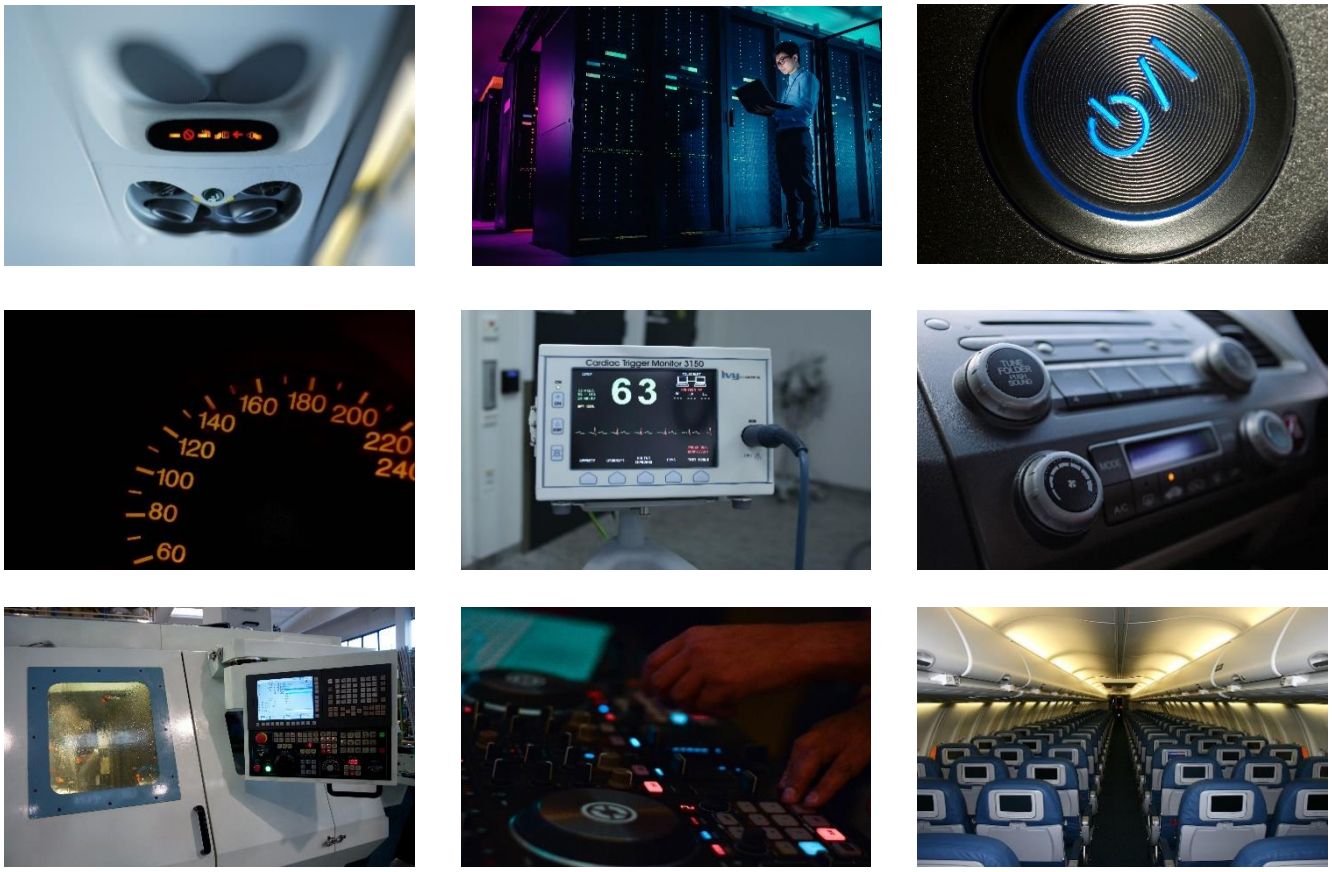
It is the interplay of several factors that ultimately dictate and influence the design, each of which is important when examining the cost structure of the project. While this is not an exhaustive list of design considerations and concerns, it provides a framework to effectively begin to approach your backlighting project by forecasting design hurdles and addressing them in a timely manner.

BACKLIGHTING APPLICATIONS

As seen earlier, backlighting can be integrated into a vast range of applications including membrane and capacitive switches, displays, user interfaces, and even branding components such as nameplates and logos.

Whether you want to create a relaxing ambiance in the airplane cabin or simply make your branded sill plate stand out, backlighting can effortlessly amplify the user experience and visual appeal of any product or environment. The functional aspect of backlighting is particularly important in industries such as medical, aerospace, and automotive. For instance, in the aerospace industry, backlighting can communicate essential safety instructions to passengers and allow pilots for easier control panel detection.

Seen below is just a glimpse into some of the many backlighting applications. Bringing the perfect synthesis of elegance and functionality, the applications of backlighting are truly endless!



Examples of backlighting applications

WHAT'S NEXT?

Meeting at the critical crossroads of aesthetics and functionality, backlighting can truly differentiate your device from the rest. Whether it's commercial appliances, industrial controllers, or military vehicles, applications of backlighting are spreading widely over a vast gamut of products and industries.

In the last few decades, Boyd has worked with leading companies to create custom backlighting solutions. Equipped with a state-of-the-art light lab for testing backlighting technologies, and dedicated in-house design engineering and prototyping teams, Boyd is committed to resolve your toughest design challenges. Boyd's backlighting assemblies also meet the ISO 2001 quality standards.

It's time to light up your devices. Start by contacting Boyd Corporation to discuss your current design challenges or learn more about the backlighting technologies. With decades of expertise and manufacturing experience, Boyd Corporation is here to help you evaluate the various backlighting options and integrate the most optimal solution in a streamlined product.

To receive more information, please visit www.boydcorp.com.