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Certified Double-Sided Led Cob Signage Panel

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ABSTRACT
The paper presents an innovative double-sided LED signage panel designed to provide uniform illumination with low energy consumption and a compact structure. The proposed solution uses a sandwich-type optical assembly with a single COB LED strip positioned on the edge of a central Plexiglas light guide, ensuring efficient light distribution on both sides. Compared with conventional systems, it offers improved reliability, reduced thickness, and simplified maintenance. The study also evaluates LED lifespan, demonstrating that operating time and temperature have a much greater impact on degradation than daily start-stop cycles. Finally, it highlights the benefits of digitalized certification processes through automation and artificial intelligence, improving efficiency and reducing administrative burden.

KEYWORDS: *Signage Panel certification, LED lifespan, Reliability, Uniform illumination*

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I. Introduction

Signage panels fit within the technical field of display and lighting systems designed for safety, wayfinding, advertising, or interior space illumination [1-4].
The technology behind illuminated signage panels encompasses devices and systems used for:
- displaying information, symbols, text, or images visible under any lighting conditions [5-9];
- utilizing light sources (typically LEDs) for direct or indirect illumination, or for guiding light through a transparent or semi-transparent material (such as acrylic or glass).

All solutions found in the specialized literature propose different approaches; however, they fail to achieve uniform illumination on both sides due to interference in light transmission.
There are numerous solutions and technologies for manufacturing signage panels, but these rely on multiple light sources or on light transmission through reflection, without achieving uniform light transmission through the PMMA material using illumination from only one side of the panel, positioned between the aluminum protective frame and the edge of the Plexiglas® sheet [10], [11].
Technical issues that have been resolved:
- Reduced energy consumption through an LED strip mounted in the upper edge of the panel.
- Uniform illumination on both sides across the entire message area.
- Bidirectional visibility and dual display.
- High reliability and easy maintenance.
- Compact assembly with an overall thickness of 13–15 mm.

II. The structure of the panel

The panel housing consist in a rectangular U-shaped aluminium frame. The assembly uses reinforced corners, powder coating, a 24 V DC supply, and a COB (Chip-on-Board) LED strip soldered to the power cable with heat-shrink protection. The innovation consists of a sandwich-type optical assembly using a single LED light source positioned on the upper edge of the Plexiglas Edge Lighting component, with self-adhesive aluminium foil applied to the remaining three edges to maximize internal reflection.
The sandwich assembly follows a strict order of positioning and installation:
- The two outer layers consist of 2 mm XT Clear PMMA (or any transparent material such as solid polycarbonate, PET, etc.), forming the front and rear faces of the product.
- Self-adhesive films, such as Oracal 641 (or any equivalent vinyl film), are applied to both PMMA sheets. These films are cut or printed according to the customized signage message. They are made of monomeric PVC, available in a wide range of glossy or matte colors, specifically designed for decorating and lettering flat surfaces. The film thickness is 75 µm and the adhesive is permanent, water-based polyacrylate.

- Two backlit film sheets (for example Ikonos BUV 130 SM) are then positioned toward the center of the assembly. According to the invention, the glossy side must face outward, toward the two XT PMMA sheets.

The orientation of the backlit film is essential:

- The glossy side faces outward, toward the viewer, enhancing color reproduction and ensuring efficient light transmission.
- The matte side faces inward, helping to diffuse the light and provide uniform illumination from the COB LED strip.

As an alternative customization method, the signage may also be printed directly onto the backlit film.
The Plexiglas Edge Lighting 0E011 L component is positioned at the center of the sandwich structure and carries the LED strip mounted along its upper edge.
The complete signage panel assembly is illustrated in Figure 1.

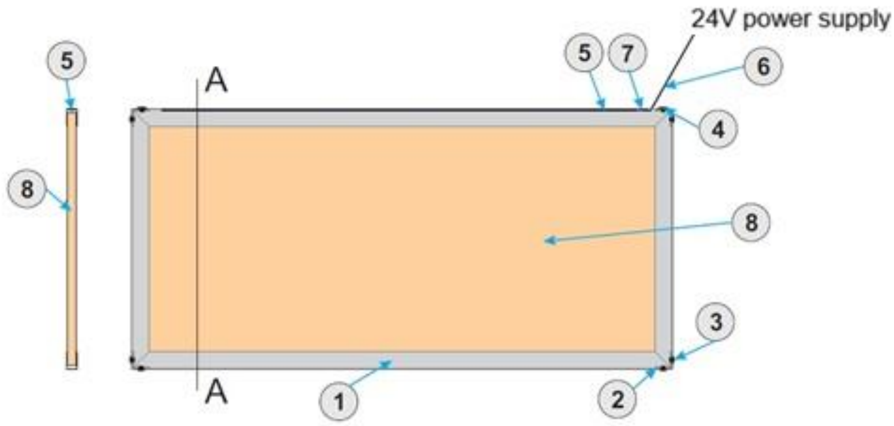

Fig. 1. Assembly and components of the double-sided signboard panel.

1. U-profile (13.1 x 20.8 x 1.3 mm) made of anodized aluminum
2. Aluminum angle (20 x 20 x 2 mm) made of aluminum
3. LumyTools LT 70412 rivets
4. Self-drilling screws 4.2 x 16 mm
Components 1-4 are assembled in the form of a rectangular frame and painted in the assembled state in an electrostatic field
5. COB LED strip Arelux SLS 352 CW8 CRI90
6. Electric cable H03VVH2-F 2x0.75 mm (tinned on the terminals of the LED strip)
7. Protection of tinned connections with heat-shrink tube SRF1-127190 6.4-3.2 mm
8. Sandwich assembly consisting of:
- 2 mm XT PMMA Clear face (2 pcs, on both sides of the panel)
-foil Oracal 641 (2 pcs)
-Plexiglas Edge Lighting 0E011 L (1 pc)
-Self-adhesive aluminum metal foil, glued to the other 3 sides of the Edge Lighting plexiglass, this foil helps to preserve the reflection of the LED strip light
-Backlit film (e.g. Ikonos BUV 130 SM) being compatible with printing technologies such as inkjet and UV (2 pcs)

In the Table 1, the main differences between the proposed solution and those existing in the specialized literature are synthesized.

Table 1. Comparison with Existing Solutions

Criterion	*Existing Solutions*	*Proposed solution*
Light sources	Two or more	Single COB LED strip
LED position	Front/rear, lenses, central	PMMA edge
Distribution	Difficult	Uniform
Structure	Simple diffusers	Optimized sandwich
Thickness	20–50 mm	10–15 mm
Modularity	Limited	Cascade / Plug & Plug

Optics	Reflection/lenses	Controlled reflection + backlit orientation

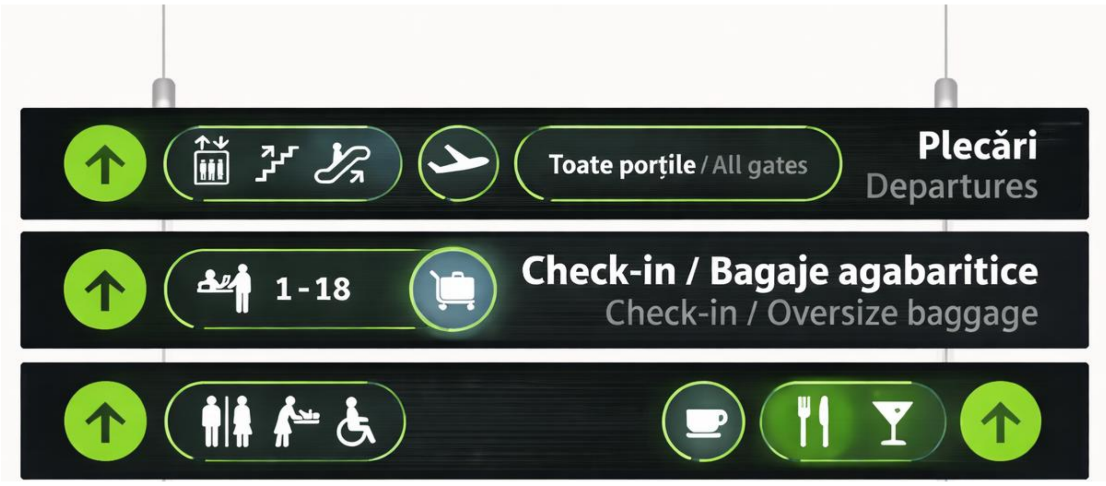

Fig. 2. Cascaded signage panels - Iași International Airport, Romania

An example of a prototype of signaling panels is shown in Fig. 2.

III. Evaluation of the effects of start-stop cycles on the lifespan of LED panels.

The aim of the analysis is to mathematically evaluate the influence of start-stop cycles on the reliability of LED panels and to compare it with the degradation caused by operating time.
Matematical model:

Cycle degradation index: $D_c = N/N_{max}$ (1)

Operational degradation: $D_h = H/H_{L70}$ (2)

Combined model: $$D_{total} = \alpha \frac{H}{H_{L70}} + \beta \frac{N}{N_{max}} \qquad (3)$$

where:
N is number of cycles, N_{max} maximum number of cycles, H operating hourss, H_{L70} nominal service life, and α and β are weighting coefficients.

LED degradation mechanism

LEDs degrade primarily due to temperature and operating time. On/off cycles mainly affect the power supply and the thermomechanical stress on solder joints. With two start-ups per day, the magnitude of this stress is low.
Case study
Input data (assumptions):
- 2 start-ups/day
- 12 hours of operation/day
- H_{L70} = 100,000 hours
- N_{max} = 100,000 cycles

Calculation:
N = 2 × 365 = 730 cycles/year
N(10 years) = 7,300 cycles
D_c = 7,300 / 100,000 = 0.073 (7.3%)

H = 12 × 365 = 4,380 hours/year
H(10 years) = 43,800 hours
D_h = 43,800 / 100,000 = 0.438 (43.8%).
Comparison: 24/7 vs. 12 h/day
Continuous operation: 8,760 hours/year.
12 h/day operation: 4,380 hours/year.

Operating hours are reduced by approximately 50%, which proportionally lowers the wear associated with LED aging and decreases the average operating temperature. The two daily start-up events result in negligible wear compared to the savings gained from reduced operating hours.
In technical literature, LED lifespan is primarily characterized by the LM-80 and TM-21 standards, while thermal fatigue mechanisms can be described using the Coffin–Manson relationship. For applications involving only two cycles per day, the impact of cycling is generally secondary to operating time and thermal management.
The *Coffin–Manson relationship* is one of the most widely used models in reliability engineering for estimating thermal fatigue lifespan. It describes how repeated heating and cooling cycles cause cracking in materials, particularly in the solder joints of electronic components.
In the case of LED panels, the relationship does not apply directly to the semiconductor LED itself, but rather to:
- solder joints between the LED and the circuit board;
- electrical connections;
- power supply components;
- other mechanical joints that expand and contract during each start-up and shutdown.

The equation is expressed as follows:

$$\frac{\Delta\varepsilon_p}{2} = \varepsilon'_f(2N_f)^{-c} \tag{4}$$

where:
$\Delta\varepsilon_p$ = plastic deformation amplitude
ε'_f = ductility coefficient
N_f = number of cycles until the defect appears
c = the Coffin-Manson exponent (approximately 0.5–0.7 for many alloys)
Findings:
- Two start-ups per day result in only 730 cycles annually.
- After 10 years, this amounts to approximately 7,300 cycles, representing about 7.3% of a 100,000-cycle capacity.
- Over the same period, 12 hours of daily operation consumes approximately 43.8% of a 100,000-hour service life.
- From an engineering perspective, operating time and temperature are the dominant factors in degradation, and two start-ups per day do not significantly affect system reliability [12-16].

1. The automation of verification and certification processes

A significant advantage of digitizing product certification is the automation of verification and certification processes. Using advanced technologies, such as artificial intelligence (AI), it is possible to automate the processes of assessing product conformity [15], [16]. For example, algorithms can analyze the technical documentation of a product and compare it with the regulations and standards in force, providing a fast and accurate assessment of it.

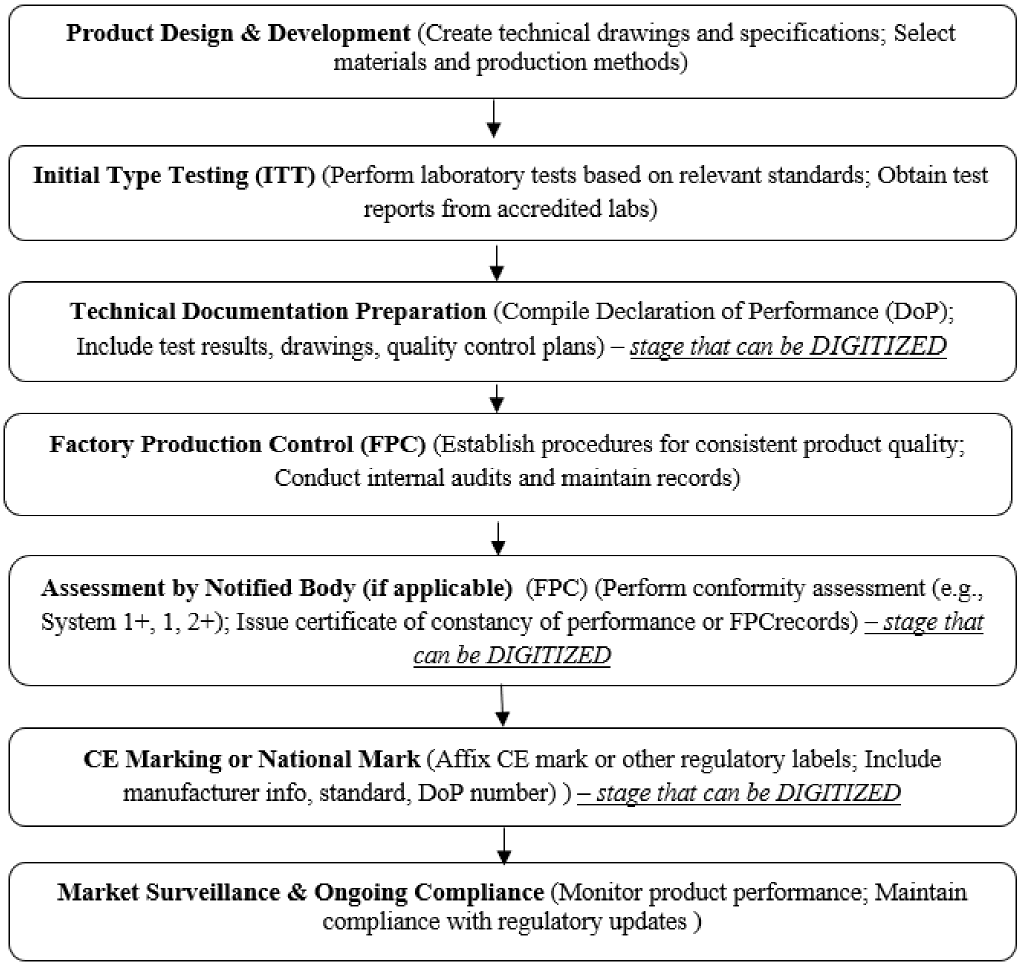

Fig. 3. The stages of the certification process

Automating processes not only reduces the risk of human error, but also allows for a much faster certification process. This is particularly important in industry, where short lead times can make the difference between a successful construction and costly delays [17]. By automating these processes, authorities can issue certificates of conformity in a much shorter time, and manufacturers and distributors can quickly obtain the necessary approvals to put their products on the market. In addition, automation reduces bureaucracy, eliminating the need to manually handle and verify documents, which helps reduce costs and administrative risks (Fig. 3). Thus, advanced technologies can speed up the certification process, while reducing the possibility of errors or non-compliance.

IV. Conclusions

The signaling panel proposed in this paper differs from other solutions presented in the specialized literature:
- Signage panel with LED edge lighting and uniform luminescence on both sides, is characterized in that it is made in the form of a sandwich assembly mounted in a U-profile aluminum frame, in which the following components are arranged successively, from the outside to the inside [18]:
– two transparent PMMA/transparent polycarbonate/transparent PET plates that form the outer faces of the panel;
– two self-adhesive foils applied to the inner surface of the PMMA plates, inscribed according to the signaling message (in the first case).
– two translucent backlit film foils, having a glossy side and a matte side inscribed (in the second case)
– a Plexiglas Edge Lighting 0E011 L plate located centrally, which constitutes the light guide;
- The lighting being made with a COB (Chip On Board) LED strip or with independent diodes is mounted on the upper edge of the Plexiglas Edge Lighting plate.

The signage panel allows the cascade connection of multiple units through the "Plug & Play" system and is equipped with a Wi-Fi connectivity module, which allows remote switching on, off and monitoring of lighting and integration into Building Management System (BMS) systems.

From an engineering perspective, operating time and temperature are the dominant factors in degradation of the signboards.

The digitalization of product certification represents a major change in the industry, with significant benefits in terms of efficiency, transparency, safety and risk reduction. By implementing digital technologies, certification authorities and manufacturers can issue certificates of conformity faster, and IT platforms allow for continuous tracking and verification of products, ensuring that they comply with all actual regulations. The automation of verification processes and the integration of advanced technologies, such as blockchain, support the traceability and integrity of products. At the same time, digitalization contributes to reducing bureaucracy, accelerating the certification process and facilitating international trade. However, the implementation of these technological solutions requires attention to data security and process standardization.

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