Improving Thermal Performance of LED Tiles in Outdoor Large Area Displays

Application Brief D-010

Introduction
The key factor in improving the long term optical performance of LEDs (Light Emitting Diodes) is maintaining a low operating temperature. This Application Brief addresses that issue by presenting various methods of reducing the LED junction temperature.

Problem
Sunlight-viewability requirements force designers to drive existing LED tiles at or above their rated limits to get the light output needed. However, operating LED tiles above an ambient temperature of 85°C results in extreme light output degradation and even catastrophic failures.

Solutions
Long term Light Output Degradation of an LED is accelerated as a function of LED junction temperature. To lower this temperature and thus extend the operating life of the LED, several approaches based on the following thermal resistance data may be taken.

Thermal Resistance
The LED junction temperature, T_J (°C), is the sum of the ambient temperature, T_A (°C), and the temperature rise of the LED junction above ambient, ΔT_J(°C), which is the product of the power dissipated within the LED junction, P_D(W), and the thermal resistance LED junction-to-ambient, $R\theta_{J-A}$(°C/W).

$$T_J = T_A + \Delta T_J$$
$$T_J = T_A + P_D \times R\theta_{J-A}$$

The cathode leads of a typical LED device are the primary thermal paths for heat dissipation from the LED junction to the surrounding environment. The data sheet lists the thermal resistance LED junction-to-pin, $R\theta_{J-PIN}$ (°C/W), for each device type listed. This device thermal resistance is added to the pc board mounting assembly thermal resistance-to-ambient, $R\theta_{PC-A}$ (°C/W), to obtain the overall thermal resistance LED junction-to-ambient, $R\theta_{J-A}$(°C/W).

$$R\theta_{J-A} = R\theta_{J-PIN} + R\theta_{PC-A}$$

$R\theta_{J-A}$ is on a per LED die basis. For reliable operation, it is recommended that the value of $R\theta_{PC-A}$ be designed low enough to achieve the lowest possible $R\theta_{J-A}$ to ensure the LED junction temperature does not exceed its absolute maximum when the device is operated in the maximum surrounding ambient temperature of 85°C.

The row-column layout of LED tiles gives them a much higher thermal resistance ($R\theta_{J-PIN}$) than standard lamp packages, on the order of 600°C/W. This, and the inherent isolation of the die from a direct heat dissipation path, limits the designer's options for heatsinking the tile. Most of these solutions, therefore, focus more on reducing the ambient temperature than on sinking heat from the LED.

Reduce the Ambient Temperature (T_A)
A Large Area Display (LAD) panel intended for outdoor use will be exposed to a wide range of ambient temperatures, on the order of -30°F to +125°F (-35°C to +55°C). It is important to realize that this is only the temperature of the air surrounding the sign. It does not take into account the effects of heat absorbed by the enclosure, or generated by the electronics it contains. It is this possibly much higher internal tempera-

ture that should concern the designer. For the purposes of this brief, we will define T_A, the ambient temperature, as the air temperature measured just above the component side of the printed circuit board near the display.

There are several ways to reduce T_A:

Vent the Enclosure
Venting a formerly sealed unit will allow convective cooling of the internal parts. Forming sets of vents near the top and bottom of the sign enclosure will allow the heated air to rise and escape. This heated air will be replaced by the somewhat cooler outside air that can enter through the lower vents. Only a moderate rate of air flow can be obtained through a natural convection process like this. However, the benefits are many: the cost added by venting the enclosure is negligible, ambient temperature will drop by a few degrees, and adding vents does not affect the sign's circuit design, other than allowing the components to run cooler.

Add Cooling Fans
Integrating pairs of cooling fans to an existing design is the most effective way to reduce the ambient temperature. Properly placed, fans will augment convection cooling, forcing a much higher air flow rate and allowing more efficient heat exchange.

Two fans, configured in a diagonal push-pull arrangement as shown in Figure 1, will be more effective than either a single fan or dual units in other locations.

Temperature sensors can be used to control the cooling fans. For extra protection, several sensors can be used — one set to turn on the fans at a preset ambient temperature, and one set at a higher temperature to turn off the displays.

Avoid Black Enclosures
While the majority of signs are housed in black enclosures, black surfaces are detrimental to cool operating environments. Black surfaces absorb light, and thus heat, rather than reflecting it as lighter colored surfaces do. The absorption of this energy serves to raise the internal temperature of the enclosure.

Painting or anodizing a sign in a light color will allow it to reflect some of the energy it receives.

Reduce P_D, the Total Power Dissipation
Several steps can be taken, in both the product selection and circuit design stages, to reduce the power used by the devices, and thus reduce the heat generated.

Use Efficient Lamps
Hewlett-Packard's AS AlInGaP technology exhibits a luminous performance much higher than that of older technologies. Users of AS AlInGaP can expect to see about 10 - 12 lumens for each watt applied, versus DH AS AlGaAs technology at 4 lumens per watt, and approximately 1 lumen/watt for High Efficiency Red products. Higher performance lamps will yield greater light output for the same power

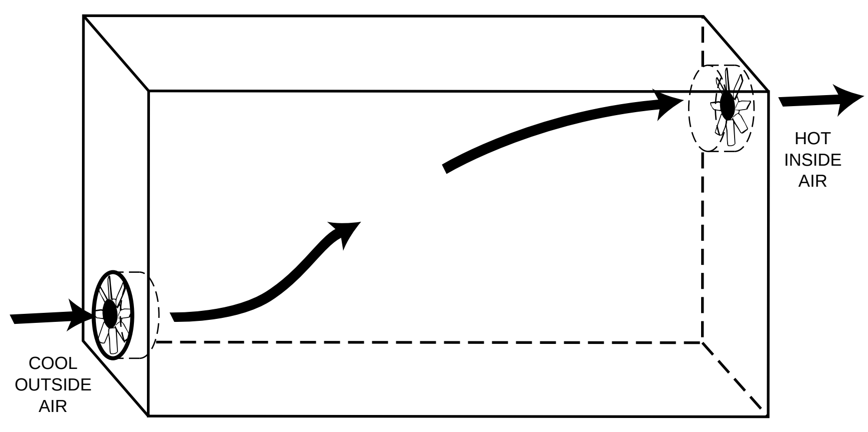

Figure 1. Use of Fans to Augment Convection Cooling.

input. This translates to the ability to either:

a) run the lamps at a lower drive current while maintaining acceptable light output, or
b) project a higher intensity while matching original power dissipation levels.

Designing with high brightness lamps will allow a significant reduction in drive current. This current reduction will reduce the power dissipated by the LED, and hence reduce the junction temperature. As stated before, the ambient temperature must remain below 85°C for acceptable performance.

Adjust Pulse Drive Characteristics

Pulsed operation is allowed by persistence of vision — the same idea that lets us perceive a motion picture moving at 30 frames per second as a moving picture, rather than a stream of still images. A light source pulsed at frequencies greater than 60 - 100 Hz will produce what the viewer believes to be a constant image.

LEDs are often driven by a pulsed current rather than a DC drive. In fact, matrix-connected LED tiles *must* be pulsed for proper operation.

Designers familiar with GaP and GaAsP lamps could be accustomed to pulse driving these lamps using high peak currents and very low duty factors. With these technologies, the efficiency of the LED die actually increased at higher peak currents, and pulsing at these high currents, with low duty factors, produced an average current that gave more light output than the equivalent DC current. AlInGaP technologies ***do not*** exhibit this increased efficiency at higher currents. The efficiency of AlInGaP die remains fairly constant over the useful current range of the device. This means that the following two drive situations will produce equivalent light output:

1) 45 mA peak, 1/5 duty factor: 9 mA average current.
2) 125 mA peak, 1/14 duty factor: 9 mA average current.

At low frequencies (below about 1000 Hz) the peak junction temperature has a greater effect on the LED die than does the average junction temperature. In these cases, it is better to use a low peak current with a larger duty factor, i.e., performing column strobing instead of row strobing. Lower peak currents also promote cooler operation of the source and sink drivers used in the refresh circuitry.

PC Board Design

Heatsinking on the PC board will improve the thermal resistance, reducing the LED junction temperature at a given current. The thermal properties of a board can be improved by replacing standard 0.020" traces with 1/2 or one ounce copper lands. The construction of an LED tile makes this more difficult than with discrete lamps, but the thermal benefits of this technique outweigh any other solution presented here.

Thermally relieving through holes in these lands is recommended for better soldering performance. See Hewlett-Packard Application Note 1027 for more information.

Note:
Thermal Resistance information has been taken from Application Note 1005. See this Note for further details on LED operation.

References:

Application Note 1005: “Operational Considerations for LED Lamps and Display Devices”
Application Note 1027: “Soldering LED Devices”
Application Brief I-007: “Projection of Long Term Light Output Performance for AS AlInGaP LED Technology”

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