

## INTRODUCTION

Ozone LED Driver is a digital and intelligent Single Channel LED Driver designed for White LED Applications.

This Application Note "**AN2\_Ozone Temperature Sense & 01-10V Dimming**" provides technical information to realize an efficient and cost effective Over Temperature Protection of the LEDs driven by Ozone, and to dim linearly the output current with a 0-10 V or 1-10 V external dimming signal. If you are interested in the PWM Dimming in that case please refer to the Application Note "**AN4\_Ozone DALI & PWM Dimming**".

Ozone includes a dedicated input (Ts) to realize LEDs Over Temperature protection.

Basically, it consists in adopting a Negative Temperature Coefficient sensor (NTC) to detect the PCB Temperature near the LED solder joint, reducing the output current when a critical high temperature is reached.

The Thermal protection described in this Application Note is simple and fast to implement; nevertheless, if this protection is not possible or not necessary to be adopted, consider that the Ozone Thermal sense input pin (Ts) can be leaved unconnected; therefore, if no connection is made, the Driver operates at the nominal output current set point and the LED's temperature does not influence the output current value.

This document contains also all the information necessary to dim LEDs by using a 0-10 V or 1-10 V signal that comes from a standard dimmer or external control circuitry or sensors.

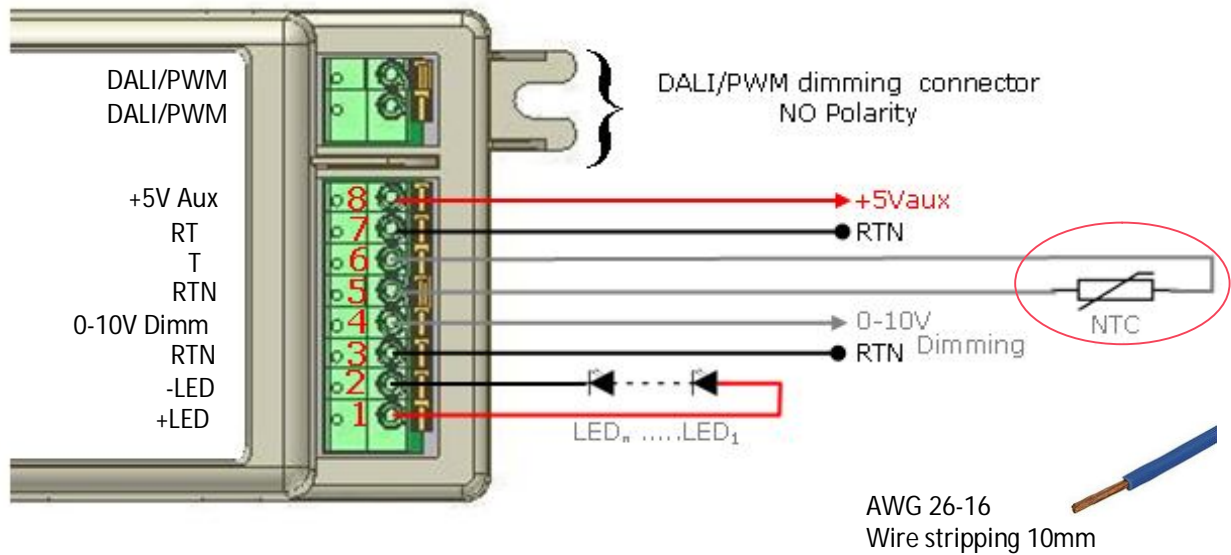
Ozone dimming characteristics have been tailored to meet the requirements of IEC 60929 Annex E.

**THERMISTOR CONNECTING**

This section shows different type of Thermistors and explains how to connect a Negative Temperature Coefficient (NTC) Thermistor to Ozone.

A single Channel LED Driver is typically used to power White LEDs, usually all connected in series. The final application can be a LED Lamp dedicated to Indoor (Wide Area Lighting) or Outdoor Application (Urban and Street Lighting). Regardless the final use in many cases it is important to protect LEDs against an Over Temperature that might occur due to abnormal condition.

When using Ozone LED Driver, the use of an appropriate Thermistor (NTC) to monitor the PCB's temperature allows to realize an efficient and cost-effective LED Board Over Temperature Protection; the thermistor connection is shown in **Figure 1**.



**Figure 1**  
NTC Connection (output connector pins 5 and 6)

In some cases, the monitoring of the temperature of the PCB or heatsink where LEDs are mounted is not possible or not required. In this case the dedicated Temperature Sense Input (Ts) can be left open (not connected) and the Temperature of the LED Board's PCB will not influence the Ozone output current.

## SMD & NON-SMD NTC THERMISTORS

There are many thermistors with various technologies/case size available in the market and produced by several manufacturers (Epcos, Vishay, Murata, AVX and others).

Thanks to Ozone design a Negative Temperature Coefficient (NTC) thermistor can be used to reduce the output current in case of LED Board Over Temperature Condition.

The most common NTCs used in LED Lighting are SMD devices (see **Figure 2**). This kind of NTC can be quickly mounted during the SMD assembling phase and it is available with different sizes (0805, 1206, 0603 and others).

Of course, if LEDs are placed into the LED Board through the SMD process (e.g. LEDs produced by Lumileds, CREE, Osram, Seoul, Nichia etc.), then the right choice for the NTC is a SMD Thermal Sensor.



**Figure 2**  
SMD NTC thermistor



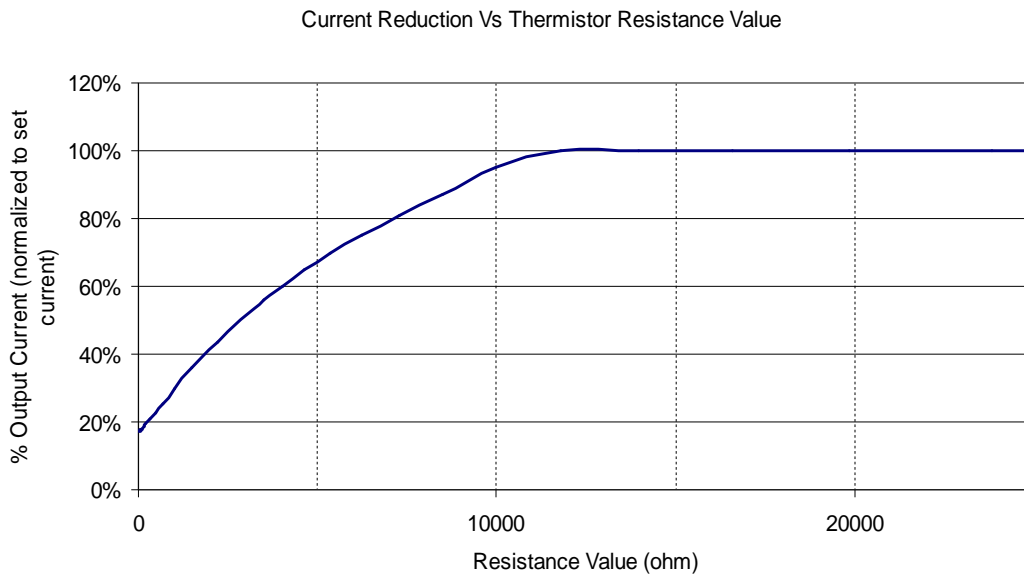
**Figure 3**  
Ring lug NTC thermistor

Nevertheless, some LEDs (e.g. Multichip LEDs) produced by Manufactures like Bridgelux, Citizen, Xicato, etc., are designed to be mounted directly on the heatsink fixing them by the use of screws. In this case the SMD assembling phase is not present in the LED Board production process and a LUG NTC (see **Figure 3**) can be easily adopted because it is assembled as a probe, in order to be assembled on the LED's heatsink by using a screw.

For best performance, the NTC sensing thermistor should be located close to LEDs or in the hot spot of the LED Board, if any.

**CURRENT REDUCTION VERSUS THE RESISTANCE VALUE**

When the temperature increases over a certain limit, the NTC mounted on the LED Board measures the Temperature of the mounting surface (PCB or heatsink) and the Temperature Sense feature allows to reduce the output current of the Driver. The following graph shows the relationship between the resistance connected to the Temperature Sense input and the corresponding output current reduction.



**Figure 4**  
Output Current (%) along Thermistor (NTC) Resistance Value

At normal operating condition (where NTC's resistor is more than about 11 kΩ), the temperature sense input has no effect on the driver output current. This means that the Output Current is equal to the Current Set ( $I_{OUT} = 100\% I_{SET}$ ). As the temperature rises determining a NTC resistor value below 10 kΩ-10.5 kΩ, the output current of the driver begins to drop resulting in a reduction in the temperature at the LEDs.

In this graphic, the current reduction is exclusively due to the Over Temperature Condition and the effect of the Dimming is NOT considered (Dimming = 100 %), to avoid to mix the two different current reduction causes.

When the current is reduced due to LED Board Over Temperature condition, many factors, predominately the thermal impedance of the LED heatsink, play a role in determining the ultimate thermal equalization. According to **Figure 4**, when the Over Temperature Condition is removed, the Output current comes back gradually to its original Value ( $I_{OUT} = 100\% I_{SET}$ ).

## NTC SELECTION

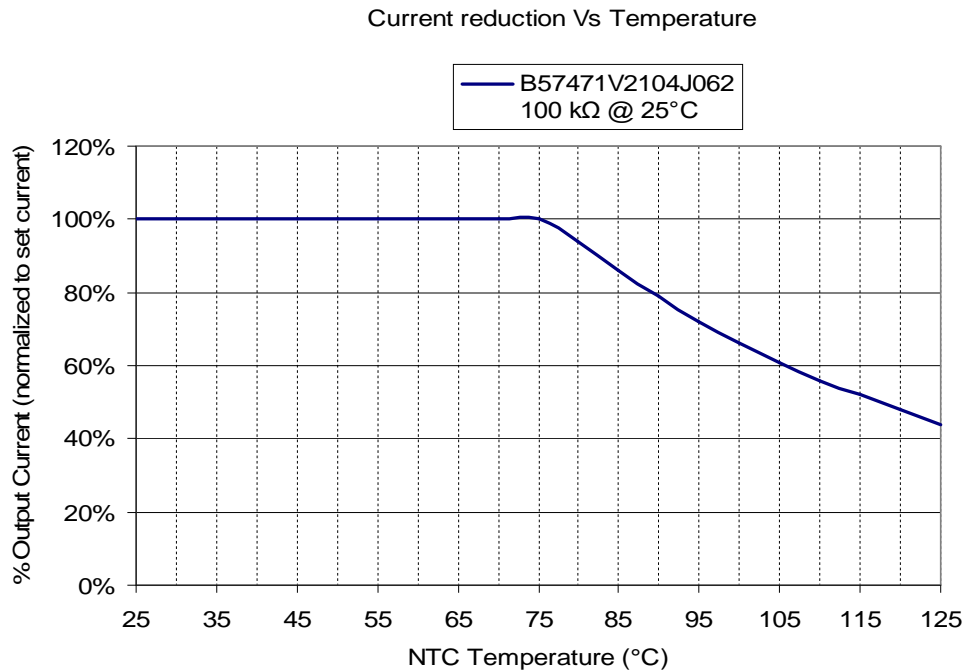
**Figure 4** shows that the Output Current reduction starts when the NTC resistance measured by Ozone is around 10 kΩ. This is the key parameter to take in consideration to choose the more appropriate NTC to realize the required Current Reduction behavior.

For example, if the Current Reduction has to start from around 75-80 °C, an NTC with 10 kΩ-12 kΩ @ 80 °C has to be chosen.

Here below you can find some examples that use SMD NTC devices produced by Epcos; of course, Epcos Codes mentioned are only for a design reference. In fact, different Epcos codes or NTC produced by other manufacturers can be used and the diagram of the Current Reduction Vs NTC Temperature (see **Figures 5** and **Figure 6**) is always obtained starting from **Figure 4** and considering the R(T) characteristic of the chosen thermistor.

Ozone design produces a knee in the output current regulation at approximately 75 °C when it operates with the Epcos Code B57471V2104J062 (100 kΩ @ 25 °C) as shown in **Figure 5**.

At temperatures less than 75 °C, the temperature sense input has no effect on the driver output current ( $I_{OUT} = 100\% I_{SET}$ ); as the NTC temperature rises above 75 °C, the output current of the driver begins to drop resulting in LED temperature reduction.



**Figure 5**  
Output Current (%) along NTC Temperature

The graphic represented in **Figure 5** refers to the current reduction caused only by the LED Over Temperature protection. The effect of the current reduction due to dimming is excluded (Dimming = 100%).

Of course, the changing of the nominal value of the NTC @25 °C (typically this parameter is indicated as  $R_{25}$  in the NTC datasheets) generates a different current reduction behavior in particular with a different derating starting point (knee). The following section clears up how to do it.

## CHANGING THE CURRENT REDUCTION BEHAVIOUR BY USING A DIFFERENT NTC

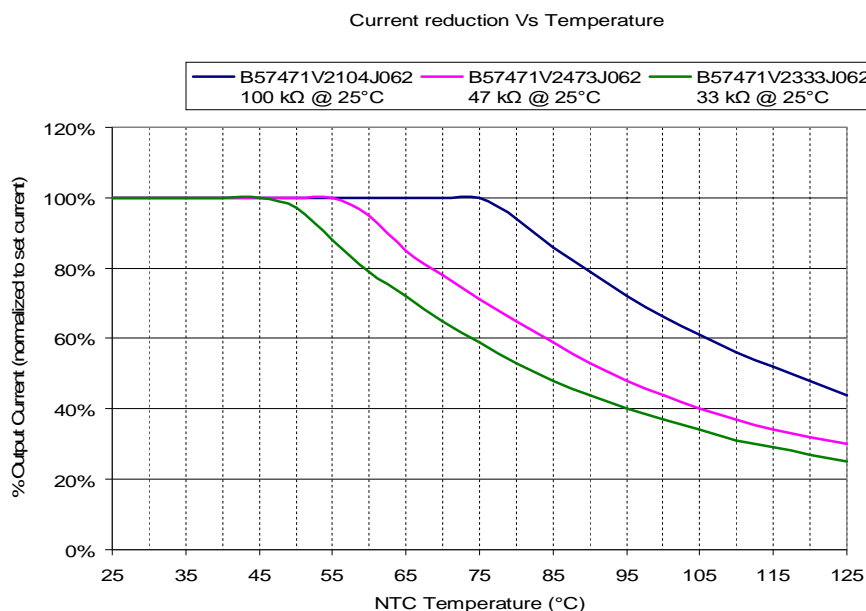
If a current reduction with a different knee is required, it can be easily obtained by choosing an NTC with a different nominal resistance value @ 25 °C ( $R_{25}$ ).

The graph depicted in **Figure 4** can be used to determine the required resistance characteristics of alternate NTC resistors; the general rule that comes from it is that if a knee at lower temperature is required, then the resistance value @25 °C has to be reduced, whereas if a knee with a higher temperature is admitted then the  $R_{25}$  value has to be increased.

For example, the **Figure 6** shows the different curves depending on different NTC used.

Starting from the NTC used in the **Figure 5** (B57471V2104J062 (100 k $\Omega$  @ 25 °C), if a lower maximum PCB temperature is required, an NTC with lower  $R_{25}$  has to be used.

For example, the Epcos NTC code B57471V2473J062 (47 k $\Omega$  @25 °C) produces a curve with a knee at around 55 °C; the device code B57471V2333J062 (33 k $\Omega$  @25 °C) produces a curve with a knee at around 45 °C and so on, as shown in the **Figure 6** below.



**Figure 6**  
Output Current (%) along Temperature, by using different NTC Thermistors (Epcos)

Generally moving from one code to another to change the  $R_{25}$  value, the size case of the NTC can remain the same (in this case a 0805 size has been selected), so that the LED Board layout is not required to be modified.

The graphics showed in the **Figure 6** refer to the current reduction caused only by the LED Over Temperature protection. The effect of the current reduction due to dimming is excluded (Dimming = 100%).

All the examples mentioned above use Surface-mount NTC thermistors (Epcos, **Series B574\*\*V2**).

Alternatively, Epcos offers a similar thermistor (**Series B57703M**), specifically designed for Surface temperature measurement, e.g. on housings and heat sinks, with a probe assembly (see **Figure 3**), useful to measure the temperature close to LEDs in non-SMD applications.

The method explained above that allows to obtain the Current Reduction Vs NTC Temperature diagram (see **Figure 5** and **Figure 6**) is valid regardless of the NTC used.

In the non-SMD applications also the NTCs Series **NTCALUG**, produced by Vishay are designed to be fixed directly to the LED Board heatsink.

### 0-10 V OR 1-10 V DIMMING

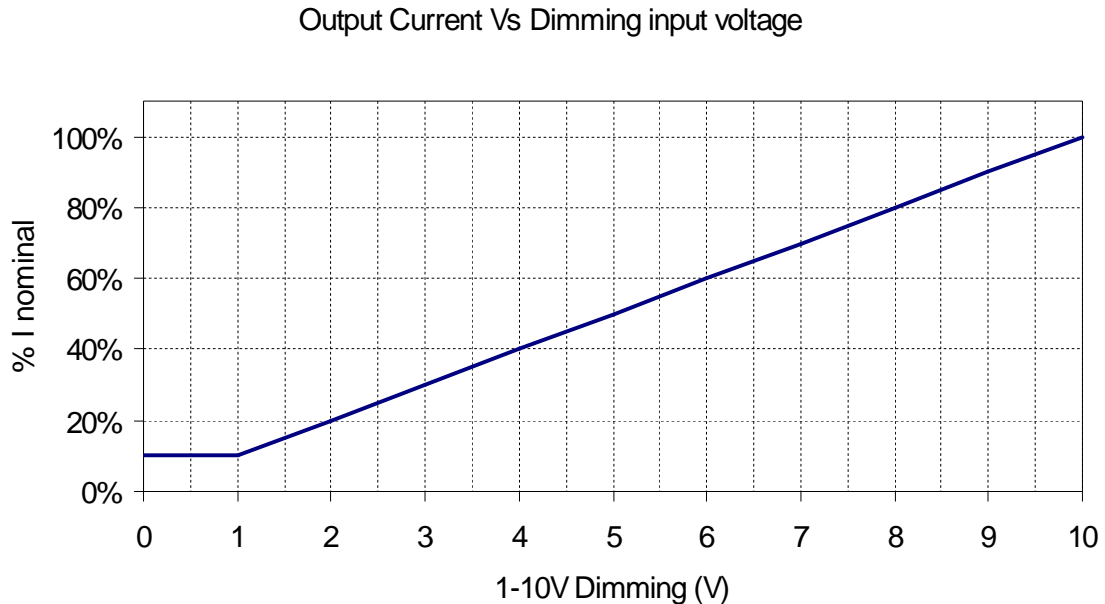
By controlling the voltage at the dimming input between 1 V and 10 V or between 0 V and 10 V, the output current of the driver will change linearly from 10 % to 100 % of the current set ( $I_{SET}$ ). Usually White LED Light applications require a linear dimming.

Nevertheless, in some case where there are stringent requirements in terms of CCT stability, the solution is the adoption of a PWM Dimming. In that case please refer to the Application Note “AN4\_Ozone DALI & PWM Dimming”.

The Dim inputs can be connected in parallel with other Ozone drivers to enable control of multiple fixtures from a single control point.

The driver includes an internal pull-up; therefore, if no connection is made to the dimming input, the driver will operate at the nominal set point ( $I_{OUT} = 100 \%I_{SET}$ ). If the dimming input (0-10 V Dimm) is shorted to the RTN, the output current will be 10 % of the current set ( $I_{OUT} = 10 \%I_{SET}$ ). The external dimming control is not required to inject current into the driver but must be capable of sinking current (100  $\mu A$ ) provided by the driver at the dimming input connection. If the external dimming control does provide a 0-10 V source, it must also be capable of sinking the current from the dimming input.

**Figure 7** is a graph showing the output current versus the Voltage at the dimming input. The output current is normalized to 100 % of the current set (100 % means  $I_{OUT} = 100 \%I_{SET}$ ).



**Figure 7**  
Output Current (%) along dimming input voltage

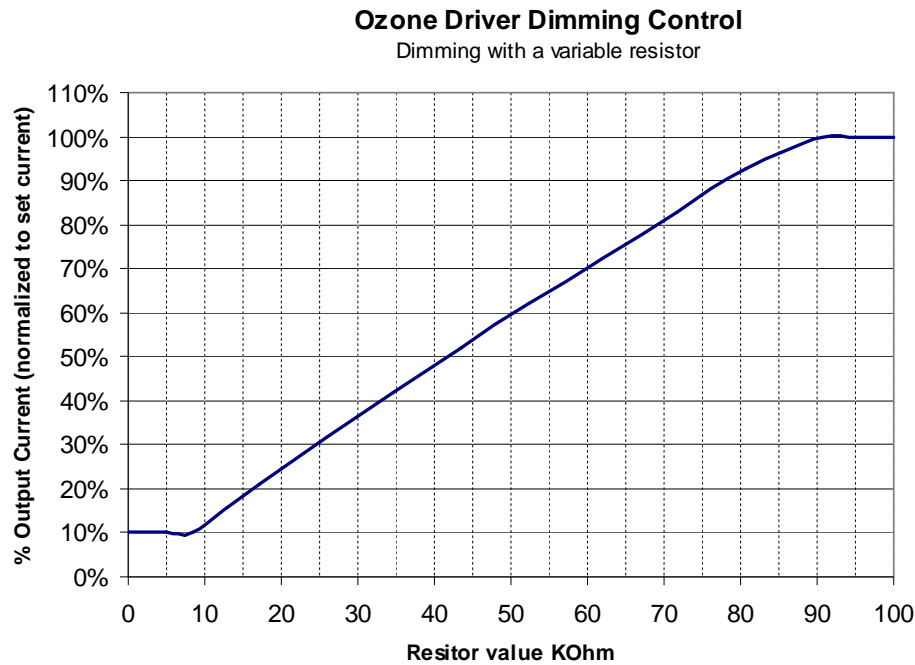
**DIMMING OPTIONS**

Ozone LED driver accepts various control options to dim the output current. The following table summarizes the most common configurations along with the corresponding electrical requirements.

Interface	Circuitry	Requirements / Limitations
<p><b>Variable Resistor</b></p>		<p>Resistor range of <math>&lt;10\text{ k}\Omega</math> to reduce output current to 10 % and <math>&gt;90\text{ K}\Omega</math> to achieve 100 % current. Refer to <b>Figure 8</b> for a graph of output current versus value of the resistor for a single driver.</p>
<p><b>Adjustable Power Supply</b></p>		<p>Power supply must be capable of sinking 100 <math>\mu\text{A}</math> from each driver. If multiple drivers are to be connected to a single power supply, the Power Supply must be capable of sinking 100 <math>\mu\text{A}</math> per driver.</p>
<p><b>0-10V or 1-10V Wall Dimmer</b></p>		<p>0-10 V and 1-10 V dimmers are not well characterized. Therefore, performance may vary between manufacturers. As additional drivers are added to a single dimmer, the dimming value may change due to the increased current into the dimmer. If multiple drivers are to be connected to a single Dimmer, the Dimmer must be capable of sinking 100 <math>\mu\text{A}</math> per driver.</p>



Figure 8 shows the relationship between the value of the resistor connected across the dimming input versus the output current of a single driver.



**Figure 8**  
Output Current (%) along Resistance value connected to the dimming input.

When using a power supply, control equipment/circuitry or similar device, care must be taken to ensure the equipment is isolated from the AC power source. If the dimming connections are to be wired as a Class II circuit, all connected equipment must have the appropriate safety approvals for Class II circuits.

When connecting multiple drivers to a single control device, it must be appropriately rated and capable of sinking 100  $\mu$ A of current from each connected driver. As the number of drivers increase, the dimming performance characteristics may change due to the increased current into the dimming control circuitry (depending on the characteristics of the external circuit).

The length of the dimming circuit wiring, wire size and the number of drivers connected to the dimming control must be designed so that the total voltage drop is less than 0.2  $\div$  0.3 V between the drivers and the dimming control.

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