Application Report

Implementing Analog Thermal Foldback with the LP8867-Q1 and TMP61-Q1

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ABSTRACT

As technology increases in this digital age, visualization technologies are the most vital components of in-vehicle interactions, with overall automotive navigation and connectivity characterizing the cars of this generation. The incorporation of interactive displays have become a key feature of manufacturing processes deployed by prominent automakers. As demand for interactive operations and experiences get stronger, more and more products provide an LCD screen.

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1 Introduction

The LED backlight driver is a key part of this LCD panel system and some engineers may encounter various problems when choosing the right devices and designing such circuits. These LED drivers regulate the output current to the LED’s on the panel. In automotive environments the LED’s on the display panel can get very hot. Temperature sensors are often used to monitor the LED temperature and provide brightness regulation. Additionally, temperature sensors are also used to monitor the LED Driver thermals. With the remote thermistor embedded in the backlight enclosure/panel there are a couple ways to achieve thermal sensing and foldback with an LED Driver. The integrated thermistor can be used with the foldback pin of an LED Driver or provide thermal foldback in a discrete implementation to the LED Driver. This application report shows how to implement TI’s TMP6 family of thermistors with TI’s LP886x family of low EMI Automotive LED Drivers, specifically the LP8867-Q1.

2 Conventional Backlighting vs. Local-Dimming backlighting

There are two types of technologies for controlling the dimming and brightness of an LCD screen, conventional and local dimming. In conventional backlighting black is reproduced as dark gray and details are lost in the shadows. With local dimming techniques, backlighting is optimized for specific areas of the image, resulting in deeper blacks. A local-dimming backlight technology is a direct-lit architecture where the LEDs are directly behind the LCD panel as shown in Figure 2-1.

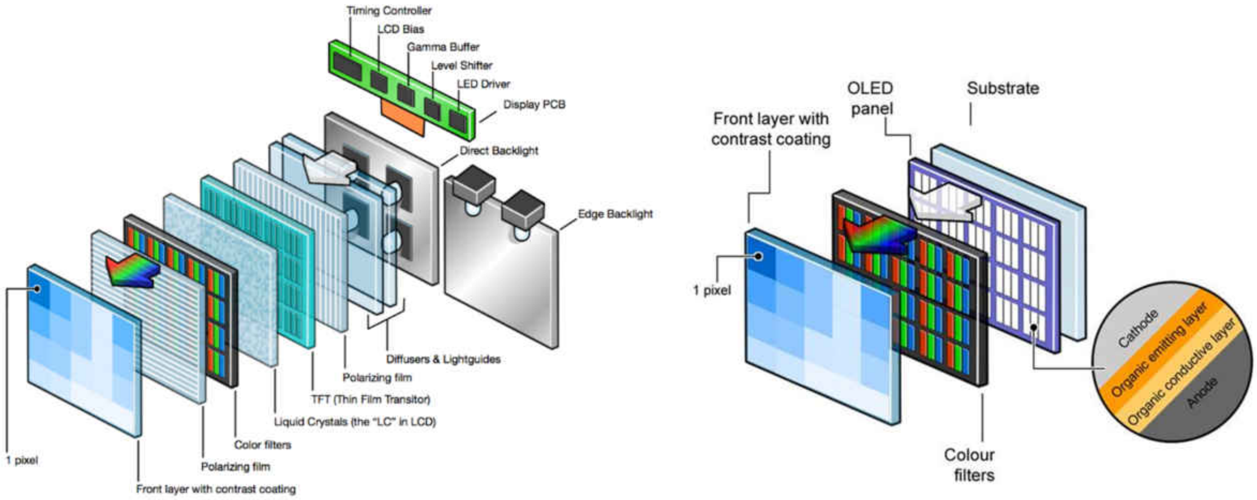

Figure 2-1. LCD Panel Architecture

In local dimming backlight, the LCD panel is divided into many small “zones”. The brightness of each zone is adjusted according to different display content. A local dimming backlight allows the display to have “darker blacks” and “brighter whites”.

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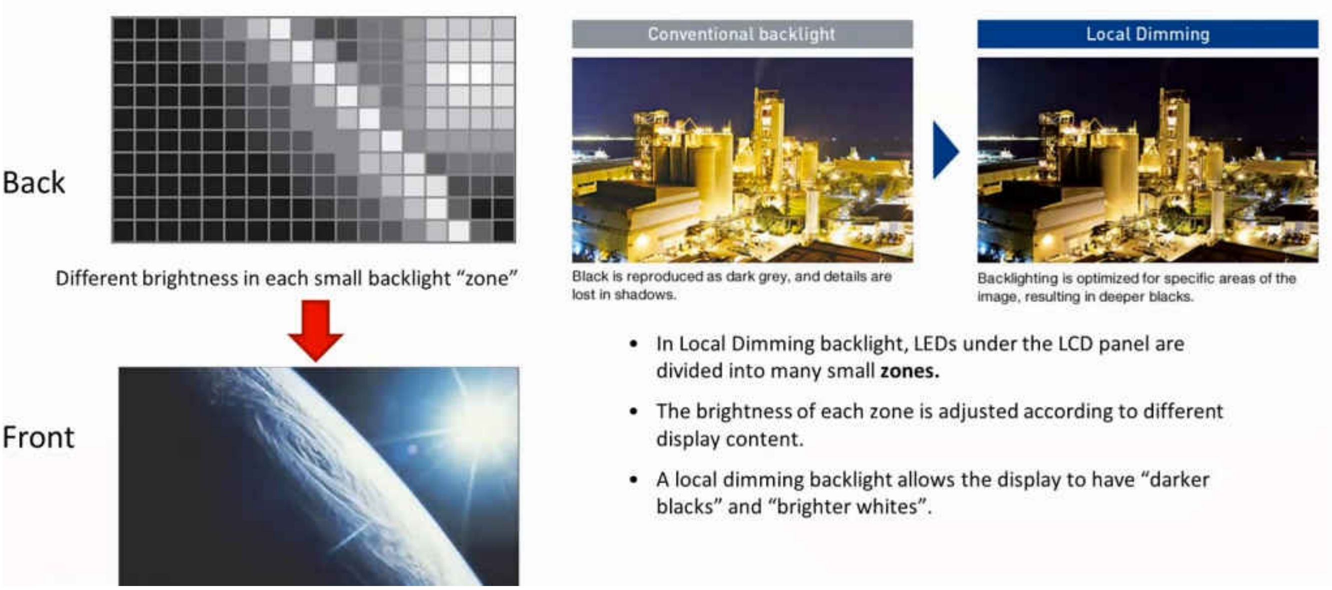

Black is reproduced as dark grey, and details are lost in shadows.

Backlighting is optimized for specific areas of the image, resulting in deeper blacks.

- In Local Dimming backlight, LEDs under the LCD panel are divided into many small **zones.**
- The brightness of each zone is adjusted according to different display content.
- A local dimming backlight allows the display to have "darker blacks" and "brighter whites".

Figure 2-2. Local Dimming vs. Conventional Backlight zones

To optimize the control of the brightness of these small zones, temperature feedback is critical to provide to the system. The LP8869-Q1 has two pins T_{SET} and I_{SET} that can be used in concert with thermistor divider circuits to provide thermal information to the system and allowing for a thermal foldback profile for the LED's, limiting the amount of current after a certain temperature threshold thus protecting them.

3 LP886x-Q1 TSET Implementation

The LP886x-Q1 has an optional feature to decrease automatically LED current when LED overheating is detected with an external PTC sensor. An example of the behavior is shown in Figure 3-1. When the PTC temperature reaches T1, the LP886x-Q1 starts to decrease the LED current. When the LED current has reduced to 17.5% of the nominal value, current turns off until temperature returns to the operation range.

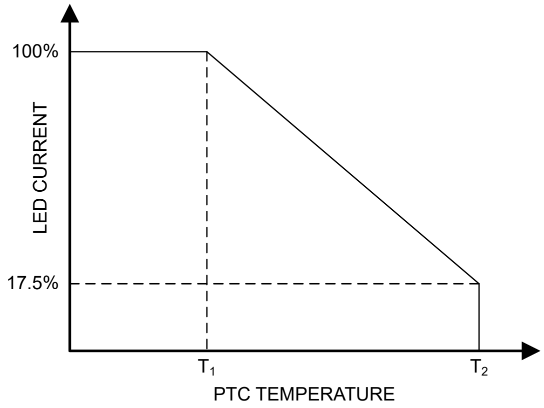

Figure 3-1. Temperature-Based LED Current Dimming Functionality

When external NTC (PTC) is connected, the T_{SENSE} pin current decreases LED output current. Temperature T1 and de-rate slope are defined by external resistors as explained below.

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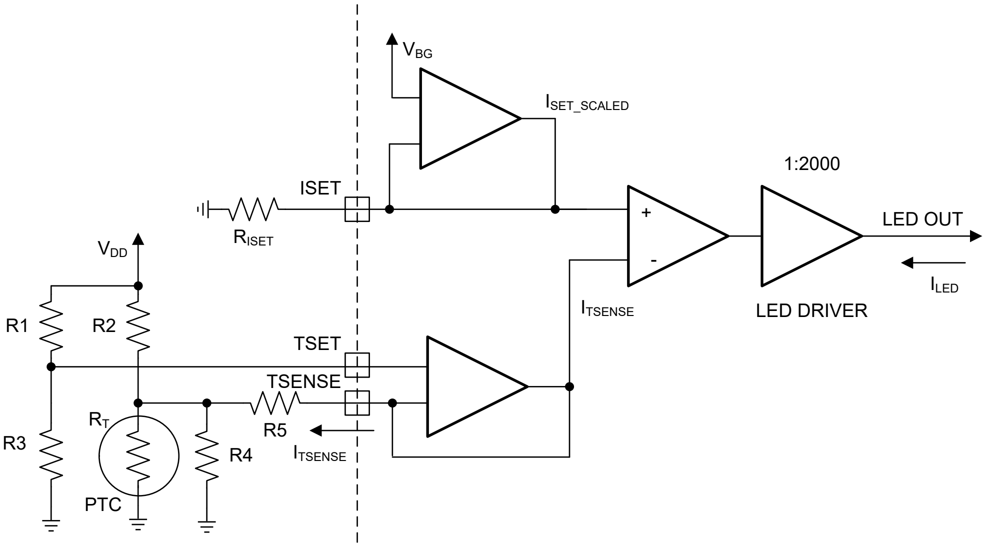

Figure 3-2. TSET Temperature-Based LED Current Dimming Schematic

Parallel resistance of the PTC sensor R_T and resistor R4 is calculated by formula:

$$R_{||} = \frac{R_T \times R4}{R_T + R4} \tag{1}$$

T_{SET} voltage can be calculated with Equation 2.

$$V_{TSET} = V_{DD} \times \frac{R3}{R1 + R3} \tag{2}$$

T_{SENSE} pin current is calculated by Equation 3.

$$I_{TSENSE} = \frac{V_{TSET} - V_{DD} \times \frac{R_{||}}{R_{||} + R2}}{R_{||} + R5 - \frac{R_{||}^2}{R_{||} + R2}} \tag{3}$$

where

- V_{DD} is the bias voltage of the resistor group. It is recommended to connect with chip's internal LDO output (pin 2)

I_{SET} pin current designed by R_{ISET} is:

$$I_{SET\_SCALED} = \frac{V_{BG}}{R_{ISET}} \tag{4}$$

Using:

R1	5kΩ
RT	6.5kΩ
R2	10kΩ
R3	PTC
R4	DNP
R5	1kΩ
R_{ISET}	2.4kΩ

The output current thermal foldback profile in Figure 3-3 is achieved:

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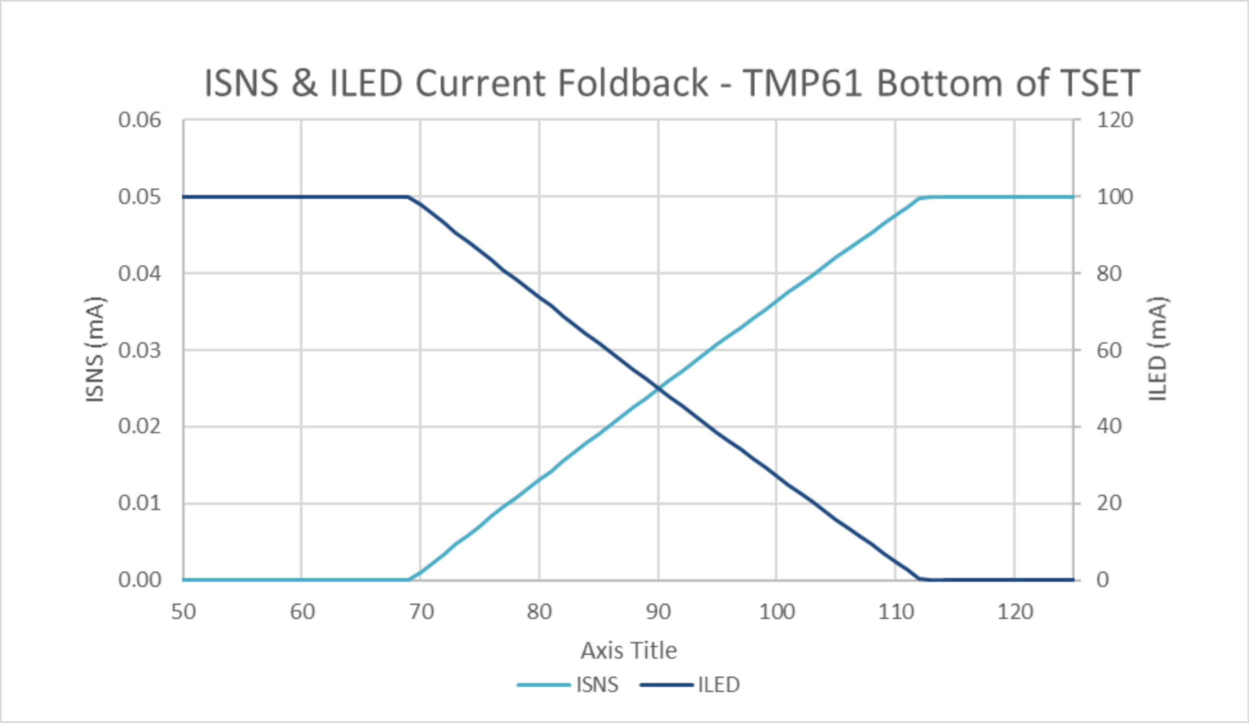

Figure 3-3. Current Foldback Profile with TMP61

4 LP886x-Q1 ISET Implementation

Some LED Drivers don't have a built T_{SET} pin to allow for easy connection of a thermistor divider for the temperature sensing. The circuit below provides a discrete solution for using a current sensing pin with LED Drivers that don't have the T_{SET} option. The output current of the LED outputs is controlled with external R_{ISET} resistor. R_{ISET} value for the target LED current per channel can be calculated usingEquation 5 .

$$I_{LED} = 2000 \times \frac{V_{BG}}{R_{ISET}} \tag{5}$$

where

- V_{BG} = 1.2 V
- R_{ISET} is current setting resistor, kΩ
- I_{LED} is output current OUTx pin, mA

For example, if R_{ISET} is set to 20kΩ, I_{LED} will be 120 mA per channel. (6)

The simulation in Figure 4-1 shows a discrete circuit that performs a derating current from 70ºC to 85ºC on the LED Low Side Current Limit.

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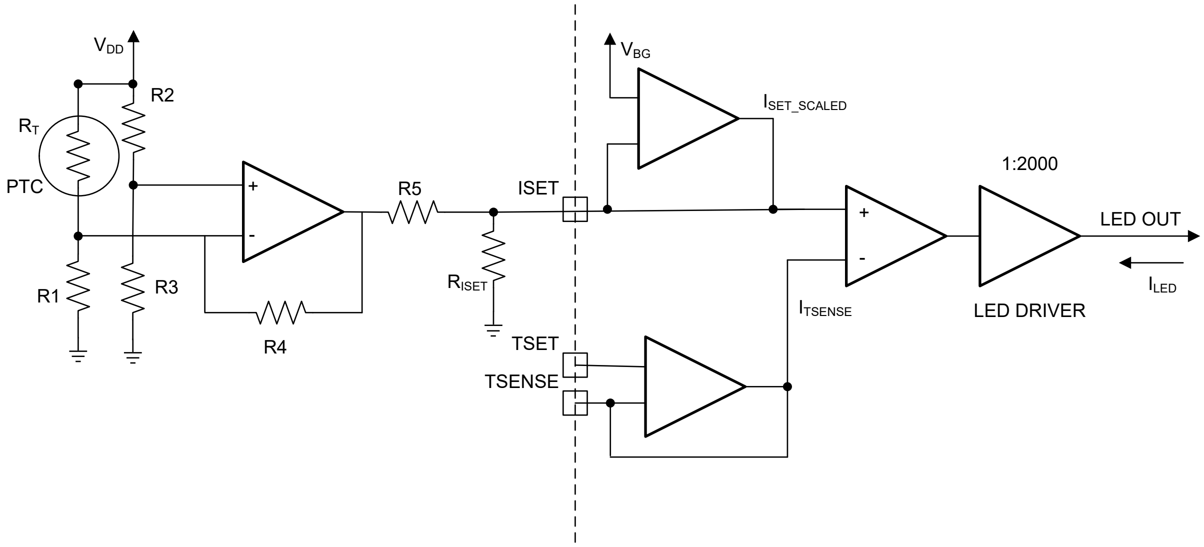

Figure 4-1. ISET Temperature-Based LED Current Dimming Schematic

Simulations results are shown in Figure 4-2:

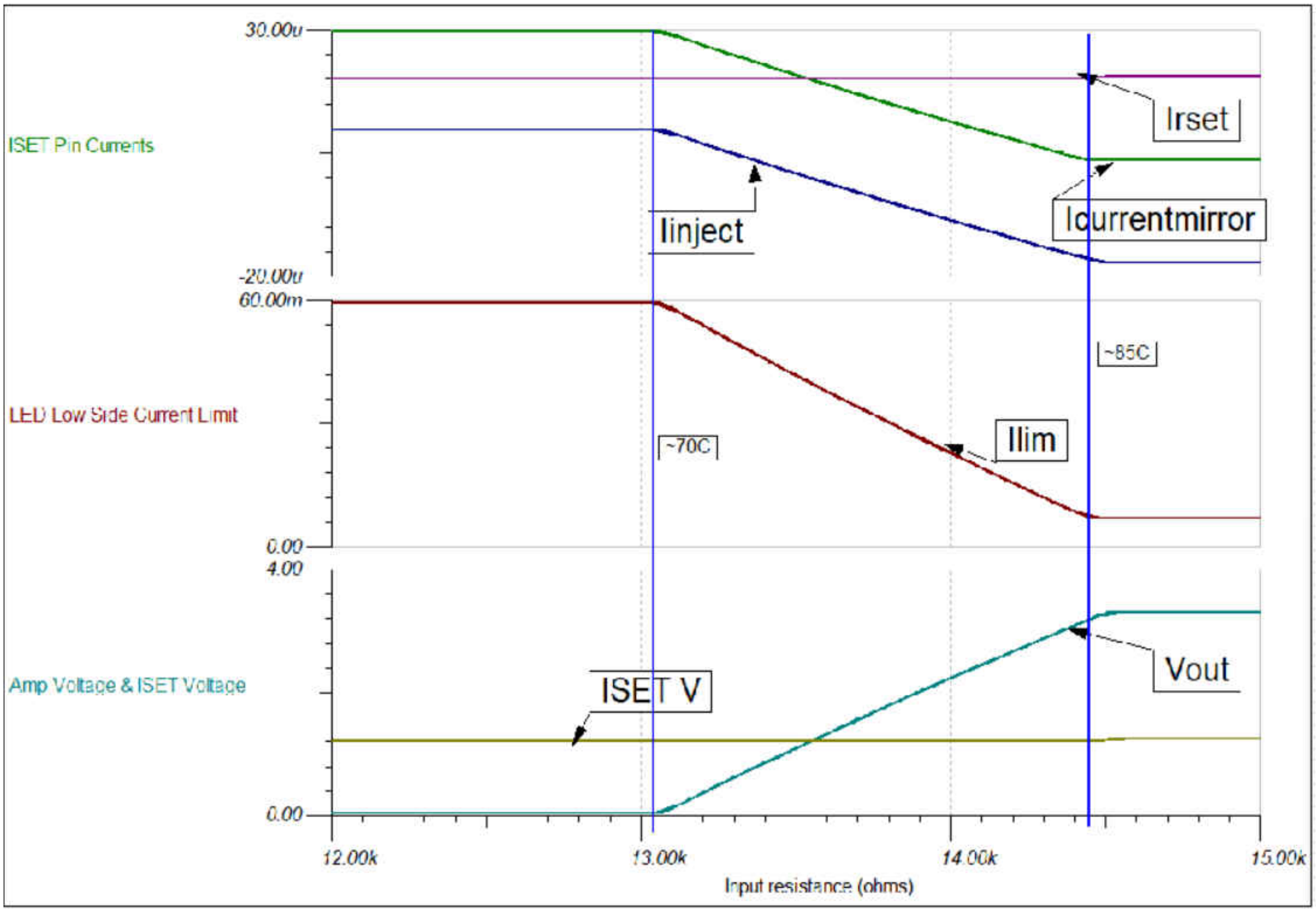

Figure 4-2. Simulation Results

The discrete implementation gives complete control of the output current to the LED Driver. The current derates from 60mA to 15mA from 70 to 85ºC. The linearity of the TMP61-Q1 ensures a reliable solution for accurate current output profiles.

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5 Summary

In conclusion designers can use the TMP61-Q1 linear thermistor with a LED Driver such as the LP886x-Q1 to monitor the LED temperature and provide brightness regulation or to monitor the LED Driver thermals through implementation with either the T_{SET} or I_{SET} approach. All in all, this provides a simple yet effective way of protecting LEDs from thermal damage in critical Automotive Lighting applications.

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