Application Report
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How to Calculate TPS92630-Q1 Maximum Output Current for Automotive Exterior Lighting Applications

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ABSTRACT

This application report provides the method of calculating the maximum output current of the TPS92630-Q1 device in exterior-lighting automotive applications. The junction-to-ambient thermal resistance ($R_{θJA}$) of the TPS92630-Q1 device is the key parameter when calculating the maximum output current of the TPS92630-Q1 device. This application report provides a method about how to measure the $R_{θJA}$ of TPS92630-Q1 reference boards. The reference boards are fabricated with different copper thickness. A comparison table of both measured and simulated $R_{θJA}$ of different copper thickness is given in the report for correlation.

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1 Overview

When using the linear LED driver, TPS92630-Q1, thermal performance is one of the most important considerations. Thermal performance limits the power dissipation on the TPS92630-Q1 device, and also limits the maximum output current of the TPS92630-Q1 device. This report describes how to calculate the maximum output current of the TPS92630-Q1 device. The report also describes how to measure the TPS92630-Q1 $R_{\theta JA}$ on the 1-oz, 2-oz, and 3.5-oz copper reference boards and compares the test results with the simulation results.

2 TPS92630-Q1 Maximum Output Current Calculation Method

The TPS92630-Q1 device is typically used in exterior lighting systems for automotive applications. Use Equation 1 to calculate the power dissipation of the device is usually calculated by the formula below.

$$P_D = (V_{IN} - V_{LED(1)}) \times I_{LED(1)} + (V_{IN} - V_{LED(2)}) \times I_{LED(2)} + (V_{IN} - V_{LED(3)}) \times I_{LED(3)} + V_{IN} \times I_Q$$

where

- P_D is the total power dissipation of the device.
- V_{IN} is the input voltage
- $V_{LED(1)}$, $V_{LED(2)}$, and $V_{LED(3)}$ are the LED drop voltages of channel 1, 2, and 3.
- $I_{LED(1)}$, $I_{LED(2)}$, $I_{LED(3)}$ are the output currents of channel 1, 2, and 3.
- I_Q is the quiescent current of the device. (1)

The power dissipation created by the quiescent current is not significant and therefore can be ignored.

After calculating the power dissipation of the device, use Equation 2 to calculate the junction temperature of the device.

$$T_J = T_A + P_D \times R_{\theta JA}$$

where

- T_J is the junction temperature of the device.
- T_A is the ambient temperature (typically 85°C maximum). (2)

When calculating the maximum output current of the TPS92630-Q1 device, one criterion is that the junction temperature should be below 150°C. The maximum ambient temperature is typically 85°C.

The system is typically connected to the car battery and therefore the input voltage typically ranges from 9 V to 16 V.

Based on the previous discussion, the detailed procedure to calculate the maximum output current of the TPS92630-Q1 device is listed as follows:

Step 1. Calculate the maximum power dissipation of the device (P_D) based on the value of $R_{\theta JA}$ and T_A. Select a value of 150°C for T_J and 85°C for T_A.

Step 2. Calculate the maximum output current based on (P_D), the maximum input voltage ($V_{IN(max)}$), and the output voltage (I_{OUT}).

In the previously listed steps, the value of $R_{\theta JA}$ is uncertain. Typically $R_{\theta JA}$ is given in the data sheet of the device, but the value is typically based on the 4-layer, 2-oz copper PCB. For additional information, see *Semiconductor and IC Package Thermal Metrics* application report (SPRA953). In actual applications, 2-layer, 1-oz or 2-oz copper PCBs are common. Therefore, the actual $R_{\theta JA}$ value must be based on the specific PCB board when performing the calculation. Section 3 describes a method to measure the $R_{\theta JA}$. Based on layout of the TPS92630EVM, three different copper thickness boards with 1-oz, 2-oz, and 3.5-oz copper are fabricated. The $R_{\theta JA}$ for each of the three boards is measured based on the method described in Section 3. The values of $R_{\theta JA}$ are also simulated by the FloTHERM® software. Section 4 includes a comparison table of both measured and simulated $R_{\theta JA}$ values for different copper thickness for correlation.

3 Test Method of $R_{θJA}$

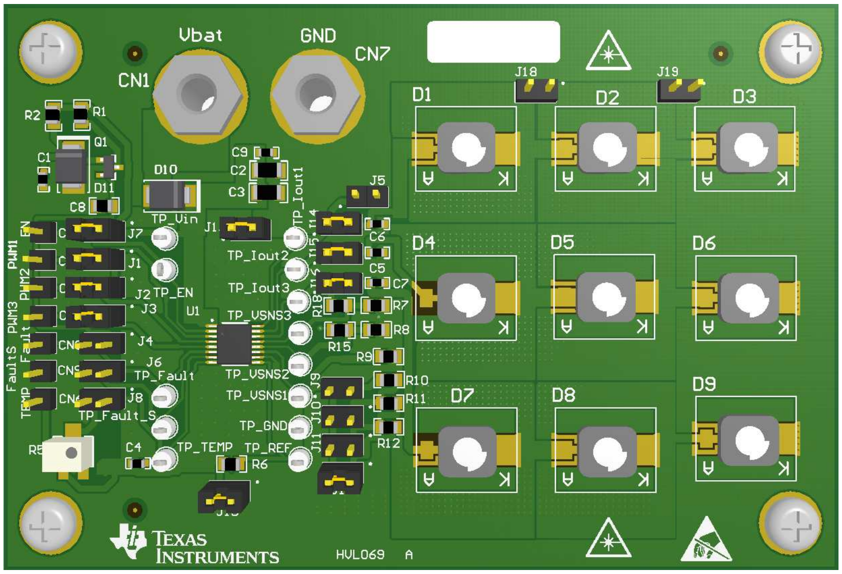

Figure 1. Top View of Test Board

To evaluate the thermal performance of TPS92630-Q1 reference boards, several methods can be used. For a standard test procedure, see *Semiconductor and IC Package Thermal Metrics* (SPRA953). In the standard test procedure, the junction temperature must be measured. In actual applications, the junction temperature is hard to measure because of the package, but a simplified test method can be used to measure the $R_{θJA}$ value. Use the steps that follow as the simplified test method:

Step 1. Test the thermal shutdown temperature ($T_{(SD)}$) of the TPS92630-Q1 device with a thermal steam or a thermal oven.

When testing the thermal shut down temperature, pull all the three PWM inputs low to disable all the outputs, which minimizes the power dissipation on the TPS92630-Q1 device. Under this condition, the ambient temperature is almost the same with the junction temperature. Keep the fault pin floating, increase the ambient temperature slowly, and monitor the voltage of the fault pin. When the voltage on the fault pin changes from high to low, the device enters thermalshut down mode. Because the ambient temperature is nearly the same with the junction temperature, $T_{(SD)}$ is equal to the ambient temperature.

Step 2. Record the ambient temperature (T_A) of the room.

Step 3. Connect the LED loads to the TPS92630-Q1 boards in the room environment. Increase the power dissipation by increasing the input voltage on the TPS92630-Q1 reference board until the device reaches the boundary of thermal shutdown. The blinking of the LED indicates the boundary of thermal shutdown. Calculate the power dissipation P_D under this state according to Equation 1. Under this condition, T_J equals $T_{(SD)}$.

Step 4. Based on the P_D, T_J, and T_A, use Equation 3 to calculate $R_{θJA}$.

$$R_{θJA} = (T_J - T_A) / P_D \quad (3)$$

4 Thermal Performance of Different TPS92630-Q1 Reference Boards

The measurements listed in Table 1 are based on three different types copper boards: 1-oz, 2-oz, and 3.5-oz copper thickness. According to the measurement method discussed in Section 3, Table 1 provides the thermal results for the three boards.

Table 1. TPS92630-Q1 Board Thermal Test Results

Board Type	$T_{(SD)}$ (°C)	Input Voltage (V)	Input Current (A)	Output Voltage (V)	Output Current (A)	Power Dissipation (W)	$R_{\theta JA}$ (°C/W)
1 oz	163.4	27.3	0.1863	9.006	0.1849	3.421	40.46
2 oz	163.8	29.3	0.1874	9.034	0.1861	3.811	36.42
3.5 oz	167.5	35.6	0.1888	9.143	0.1874	5.009	28.44

5 Simulation Results

This section discusses the simulation results performed by the FloTHERM software. The simulation setup is also discussed in this section. Table 2 provides the simulation model setup. Figure 2 shows the modeled PCB board.

Table 2. TPS92630EVM Thermal Model Setup

Package Information	Package	16 PWP
Custom PCB	PCB Size	105 × 71 × 1.6 mm
	PCB layer	2 copper (Cu) layers (coverage 20% Cu + land pads, 95% Cu)
	Copper area	27.6-mm × 35.8-mm Cu land pad
	Vias	5 vias under device, scattered vias in land pad
	Copper thickness	1-oz copper, 2-oz copper, and 3.5-oz copper
Environment	Ambient Temperature	25°C

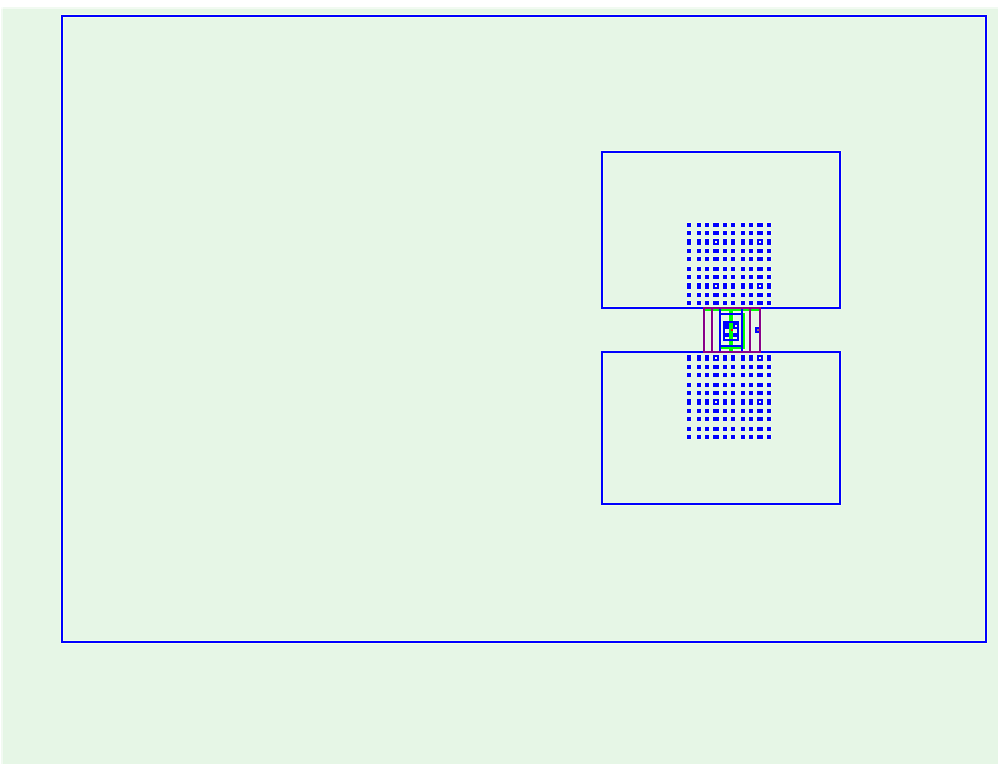

Figure 2. PCB Board Model

Table 3 provides the simulation results. The last column lists the simulated $R_{θJA}$ values. The results correlate well with the test results compared with the measured $R_{θJA}$ values. Therefore, the test results are reliable.

Table 3. TPS92630-Q1 Board Thermal Simulation Results

Board Type	Measured $R_{θJA}$(°C/W)	Simulated $R_{θJA}$ (°C/W)
1 oz	40.46	43.9
2 oz	36.42	34.5
3.5 oz	28.44	27.2

6 Design Example

This section provides a design example for calculating maximum output current using the TPS92630-Q1 device. Table 4 lists the design parameters.

Table 4. Design Parameter

Design Parameter	Example Value
V_{IN}	9 to 16 V
LED	3s3p, OSRAM Red LED, V_F = 2 V
Maximum ambient test temperature, T_A	85°C

Use the equations that follow for the detailed calculation:

$V_{F(tot)} = 2 \times 3\ V = 6\ V$

where

- $V_{F(tot)}$ is the total LED forward voltage. (4)

$P_D = (150°C – T_A) / R_{θJA}$ (5)

$I_{OUT} = P_D / (V_{IN(max)} – V_{F(tot)}) / 3$

where

- I_{OUT} is the maximum output current for each channel. (6)

$R_{REF} = 1.222 \times 100 / I_{OUT}$

where

- R_{REF} is the reference resistor. (7)

Table 5 shows the design results based on the three different $R_{θJA}$ tesed above. It shows the max output current based on different $R_{θJA}$. When using 1oz board, the total max output current is 160.6mA. While using 3.5oz board, the total max output current can be 228.5mA.

Table 5. Design Results

Design Parameter	1-oz Boards	2-oz Boards	3.5-oz Boards
$R_{θJA}$	40.46°C/W	36.42°C/W	28.44°C/W
Total maximum output current	160.6 mA	178.5 mA	228.5 mA
Maximum output current for each channel	53.5 mA	59.5 mA	76.2 mA
Reference resistor	2.28 kΩ	2.05 kΩ	1.60 kΩ

7 References

For additional reference, see the following documents from TI:

- *Semiconductor and IC Package Thermal Metrics* (SPRA953)
- *TPS9263x-Q1 Three-Channel Linear LED Driver With Analog and PWM Dimming* (SLVSC76)
- *TPS92630-Q1 Evaluation Module (EVM)* (SLVUA26)

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