Application Report

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TPS92610-Q1 PCB Thermal Budget Design for Maximum Output Current

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ABSTRACT

The TPS92610-Q1 device is a linear LED driver for the rear light on an automobile and the thermal resistor $R_{\theta JA}$ is an important parameter. This application report uses different layout methods to outline the influences of the printed-circuit board (PCB) on their thermal performance. It also provides evaluation methods for the maximum output current when the junction temperature reaches 150°C during different ambient temperatures.

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1 Introduction

1.1 Application Example

To avoid the impact of LEDs and other functions like PWM dimming, the following applications were used:

- V_{SUPPLY}: 4 V to 25 V
- V_{OUT}: 2-V source meter instead of LEDs
- R_{SNS}: 0.5 Ω (I_{OUT} = 98 mV/0.5 Ω = 196 mA)
- EN/PWM: Pull-up
- DIAGEN: Pull-down
- FAULT: Floating
- SSH: Pull-down
- SSL: Pull-down

1.2 Test Equipment

- Power supply
- Oscilloscope
- Multimeter
- Thermal stream
- Temperature and humidity chamber

2 TPS92610-Q1 Layout Impact Analyze

2.1 Test Methods

Typically, $R_{\theta JA}$ is given in the data sheet of the device, but in actual applications, 2- layer, 1-oz copper PCBs are common. Therefore, the actual $R_{\theta JA}$ value must be based on the specific PCB board when performing the calculation. To analyze the impact of different layouts, 8 kinds of layout including a different copper area, copper thickness, and via number are designed.Table 1 shows the detailed layout information. Figure 1 shows the typical layout of this application.

Table 1. PCB Layout Information

	Copper Area Size	Copper Thickness	Via Number
Area Varies	**2000 mil × 2000 mil (5 cm × 5 cm)**	1 oz	40 vias
	1000 mil × 1000 mil (2.5 cm × 2.5 cm)	1 oz	40 vias
	700 mil × 500 mil (1.8 cm × 1.3 cm)	1 oz	40 vias
Via Number Varies	2000 mil × 2000 mil (5 cm × 5 cm)	1 oz	**80 vias**
	2000 mil × 2000 mil (5 cm × 5 cm)	1 oz	**40 vias**
	2000 mil × 2000 mil (5 cm × 5 cm)	1 oz	**20 vias**
Thickness Varies	**2000 mil × 2000 mil (5 cm × 5 cm)**	**2 oz**	40 vias
	1000 mil × 1000 mil (2.5 cm × 2.5 cm)	**2 oz**	40 vias
	700 mil × 500 mil (1.8 cm × 1.3 cm)	**2 oz**	40 vias

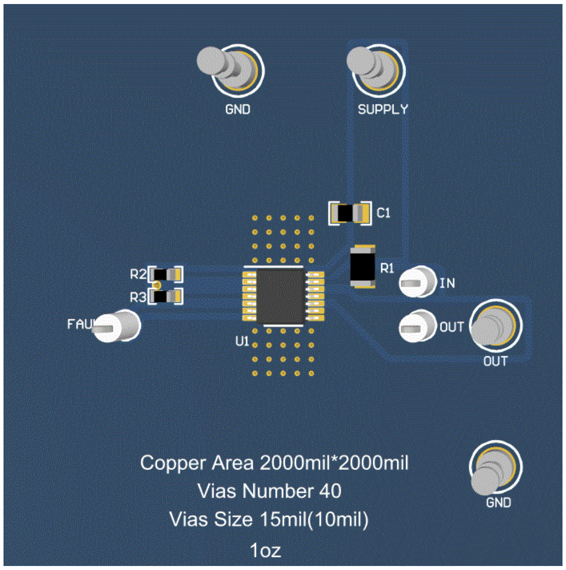


Figure 1. Typical Layout Example

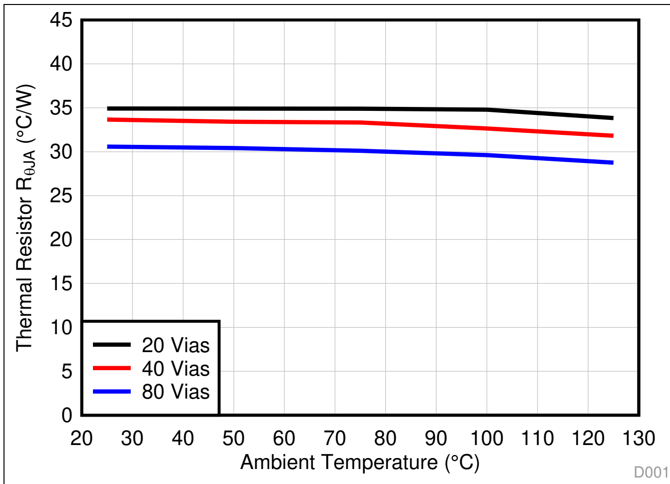
In the standard test procedure, the junction temperature must be measured. However, the junction temperature is hard to measure because of the package, simplified test method to measure the $R_{\theta JA}$ value are used. The detailed test method is:

- Thermal shutdown temperature (T_{SD}) test:
  - Equipment: thermal stream, power supply, oscilloscope
  - Methods: Make output pin floating, which minimizes the output power dissipation on the TPS92610-Q1 device. Under this condition, the ambient temperature is almost the same with the junction temperature. Increase the ambient temperature slowly, and monitor the voltage of the V_{OUT} pin. When the voltage on the V_{OUT} pin changes from high to low, the device enters thermal shutdown mode. Because the ambient temperature is nearly the same with the junction temperature, T_{SD} is equal to the ambient temperature.
- Thermal shutdown power test:
  - Equipment: temperature and humidity chamber, source meter, power supply, oscilloscope
  - Methods: Use the temperature and humidity chamber to create different ambient temperatures (T_A), connect the output pin with the source meter (set to 2-V load). Decrease the supply voltage slowly, and monitor the voltage of the V_{OUT} pin. When the voltage on the V_{OUT} pin does not change from high to low for more than 10 minutes, it can be concluded that this device is on the boundary of thermal shutdown. Record the corresponding supply voltage (V_{SUPPLY}) and output current (I_{OUT})
- Use Equation 1 to calculate the thermal resistor ($R_{\theta JA}$):

$$R_{\theta JA} = \frac{T_{SD} - T_A}{\left(V_{SUPPLY} - V_{OUT}\right) \times I_{OUT}} \tag{1}$$

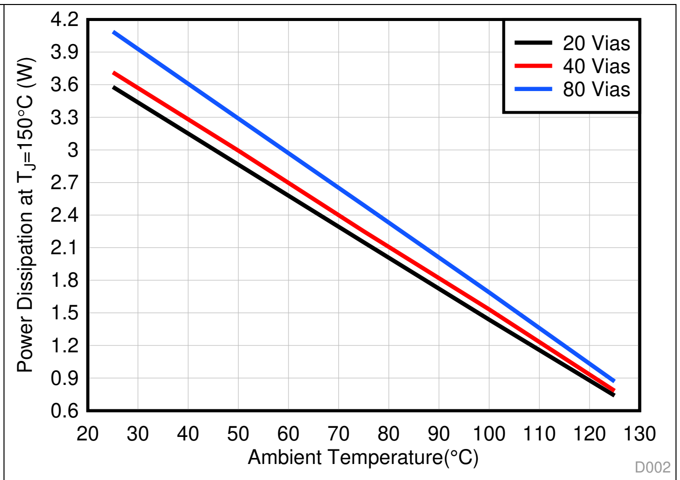
2.2 Test Results

Figure 2 to Figure 5 show the thermal resistor and thermal shutdown power dissipation vs ambient temperature.



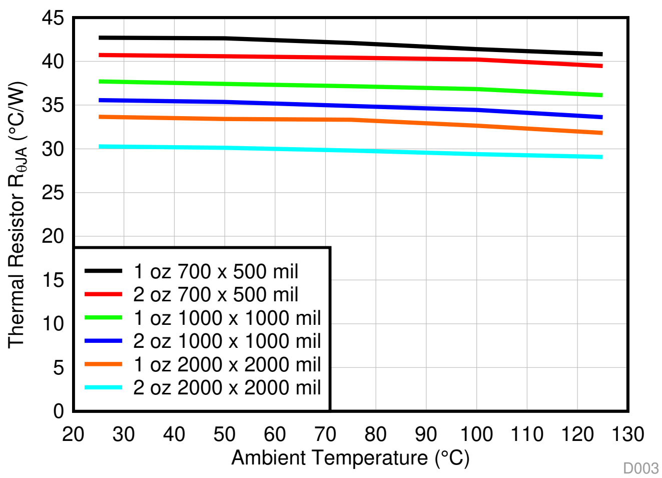
Copper Area: 2000 × 2000 mil Copper Thickness: 1 oz

Figure 2. $R_{\theta JA}$ With Via Number Varies



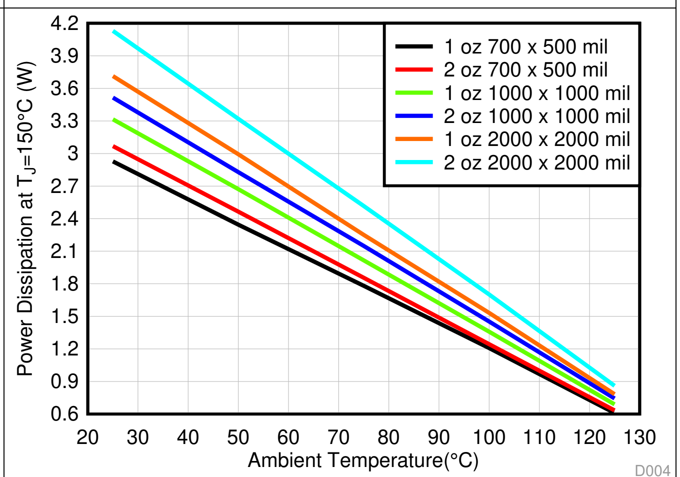
Copper Area: 2000 × 2000 mil Copper Thickness: 1 oz

Figure 3. 150°C Junction Temperature Power Consumption With Via Number Varies



Via Number: 40

Figure 4. $R_{\theta JA}$ With Copper Area and Thickness Varies



Via Number: 40

Figure 5. 150°C Junction Temperature Power Consumption With Copper Area and Thickness Varies

As the measurement and calculated data curve in Figure 2 and Figure 3 show, one result can be concluded. The number of vias has a slight impact to the actual thermal resistance. It is only about 2°C/W lower if the number of vias is increased from 20 to 40. Especially in the high ambient temperature period, they are nearly the same.

However, Figure 4 and Figure 5 show that as copper area varies from 700 mil × 500 mil to 2000 mil × 2000 mil, the thermal resistance changes more than 10℃/W. Although in the same copper area, 2 oz is better than 1 oz.

From the previous results, it can be concluded that the impact of thermal performance is:

copper area > copper thickness > via number

Besides, in actual projects, 2-oz thick PCB is about 20% more expensive than 1-oz thickness. So, the copper area is important in the thermal performance of the device.

3 Design Example for Thermal Budget

This section provides a design example for calculating maximum power consumption using the TPS92610-Q1 device. Table 2 lists the design parameters.

Table 2. Design Parameter

Design Parameter	Example Value
V_{SUPPLY}	9 V to approximately 16 V
LED	3s1p, OSRAM Red LED, VF = 2 V
Maximum ambient test temperature, T_A	85°C

The calculation methods follow:

$$V_{OUT} = 2 \times 3\ V = 6\ V \quad (2)$$

$$P_D = (150°C - T_A) / R_{θJA}$$

where

- P_D is the maximum power dissipation when junction temperature is equal to 150°C (3)

$$I_{OUT} = P_D / (V_{SUPPLY\_MAX} - V_{OUT})$$

where

- I_{OUT} is the maximum output current for each channel. (4)

$$R_{SNS} = 0.098 / I_{OUT}$$

where

- R_{SNS} is the sense resistor. (5)

Table 3 shows the design results based on the four different $R_{θJA}$ tested previously. It shows the maximum output current based on different $R_{θJA}$. When using 1 oz, 700 × 500 mil, 40 vias board, the total maximum output current is 155 mA. While using 2 oz, 2000 × 2000 mil, 40 vias board, the total maximum output current can be 217 mA.

Table 3. Design Results

Design Parameter	1 oz, 2000 × 2000 mil, 40 Vias	1 oz, 700 × 500 mil, 40 Vias	1 oz, 2000 × 2000 mil, 20 Vias	2 oz, 2000 × 2000 mil, 40 Vias
$R_{θJA}$	33°C/W	42°C/W	35°C/W	30°C/W
Maximum output current	197 mA	155 mA	186 mA	217 mA

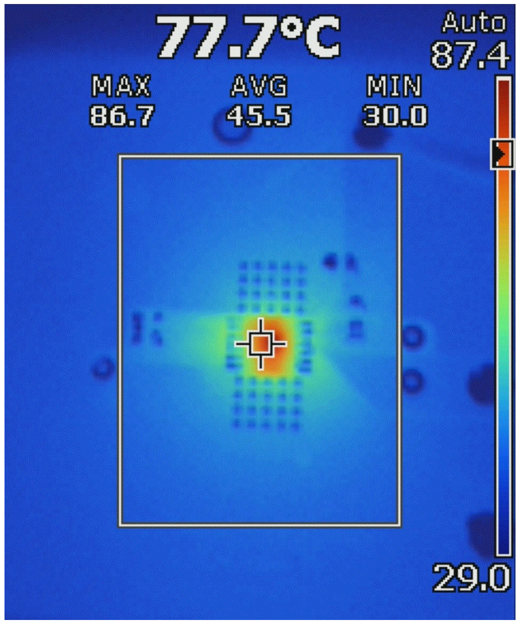


Figure 6. Thermal Distribution of 1 oz, 2000 × 2000 mil, 40 Vias Board Under Room Temperature

Figure 6 shows the thermal distribution under a thermal imager. The test condition is the same as the design example of 1-oz, 2000 × 2000-mil, 40 vias board version in Table 2 except the ambient temperature is 20°C instead of 85°C. The temperature rise of the junction is 86.7°C – 20°C = 66.7°C, which approaches the design parameter in Table 2 as 150°C – 85°C = 65°C.

In real applications, TI recommends leaving some current margin; for example, 10% current less to avoid the impact of other factors on the radiation.

4 Summary

This application report outlines the influences of different layout methods on TPS92610-Q1 thermal performance. The impact factor ranking is:

copper area > copper thickness > via number

When testing the PCB for 1 oz, 2000 × 2000 mil, 40 vias version, the thermal resistor is about 33°C/W. Always keep in mind that different layout design can get different thermal resistor.

5 References

1. Texas Instruments, *TPS92610-Q1 Automotive Single-Channel Linear LED Driver Data Sheet*