Application Report
SLVAEP6–March 2020

# TPS92611-Q1 PCB Thermal Budget Design for Maximum Output Current

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## ABSTRACT

TPS92611-Q1 is a linear LED driver for automotive rear light so that the thermal performance is an important parameter. This application report uses TPS92611-Q1 for an example to outline the influences of different layout shapes on their thermal performance. This application report also provides a method about how to evaluate the maximum output current when junction temperature reaches 150°C during different ambient temperatures.

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# 1 Typical Application Requirements

## *1.1 Application Example*

To avoid the impact of LED's and other functions like PWM dimming, the applications listed below:

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

## *1.2 Test Equipment*

- Power supply
- Oscilloscope
- Multi-meter
- Thermal stream
- Temperature & humidity chamber

# 2 TPS92611-Q1 PCB Copper Area Deep Dive

## *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. In order to analysis different layout's impact, 6 different area and shape are designed as below:

- 1cm*1cm(1cm$^2$)
- 1cm*2cm(2cm$^2$ rectangle)
- 1.4cm*1.4cm(2cm$^2$ square)
- 1.7cm*1.7cm(3cm$^2$)
- 2cm*2cm(4cm$^2$)
- 2cm*3cm(6cm$^2$)

In the standard test procedure, the junction temperature must be measured. However, the junction temperature is hard to measure because of the package, so a simplified test method to measure the $R_{\theta JA}$ value is designed. 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 TPS92611-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 temperature and humidity chamber to create different ambient temperature ($T_A$), connect output pin with source meter(set to 2V load). Decrease the supply voltage slowly, and monitor the voltage of the $V_{OUT}$ pin. When the voltage on the $V_{OUT}$ pin doesn't change from high to low for more than 10 minutes, we consider this device is on the boundary of thermal shutdown. Record the corresponding supply voltage ($V_{SUPPLY}$), output current ($I_{OUT}$)

- Calculate thermal resistor ($R_{\theta JA}$)

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

## 2.2 Test Results

Figure 1 and Figure 2 shows the thermal resistor and 150°C junction temperature power dissipation vs ambient temperature. Just taken square options into consideration, the result is the same as our consumption: the bigger copper area, the better thermal performance.

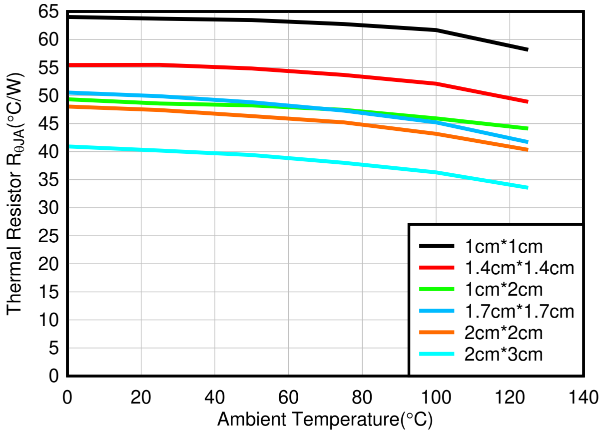

**Figure 1. $R_{\theta JA}$ with Copper Area Varies**

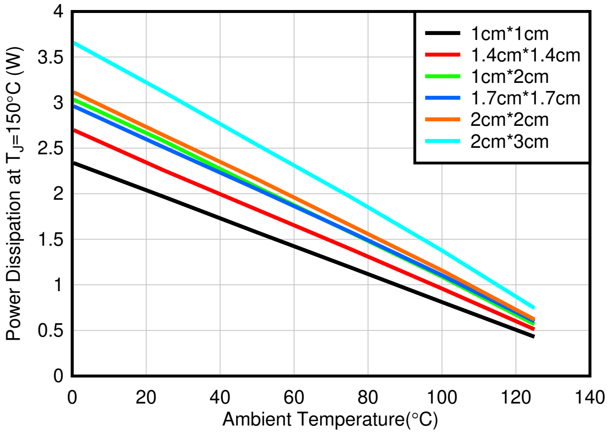

**Figure 2. 150°C Junction Temperature Power Consumption with Copper Area Varies**

However, with the same area, 2cm$^2$ rectangle is better than 2cm$^2$ square, even better than 3cm$^2$ square in low ambient temperature. That's because the package is MSOP(8) and the pins are distributed on the left and right side, see Figure 3 and Figure 4. Because of the pins' influence, square layout has a smaller effective cooling area than the rectangle layout.

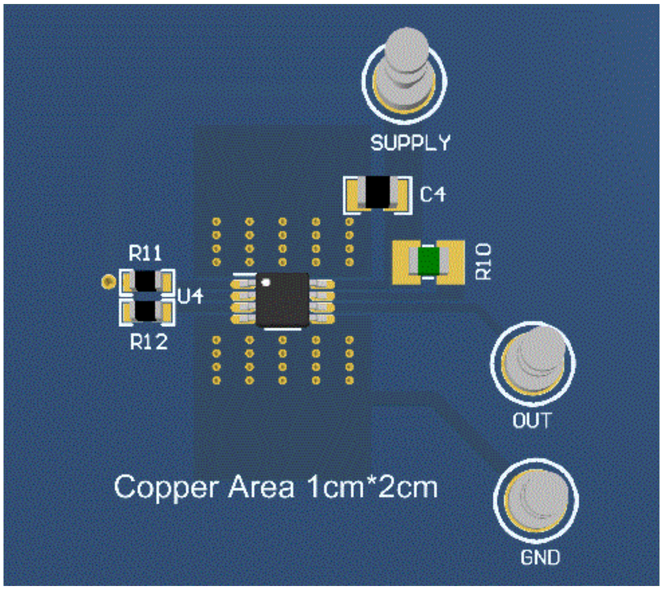

**Figure 3. 1cm*2cm Rectangle Layout**

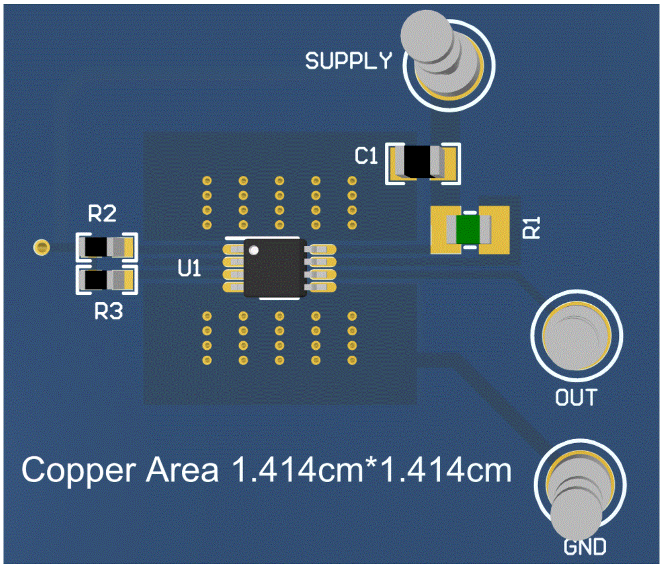

**Figure 4. 1.4cm*1.4cm Square Layout**

## 3 Design Example for Thermal Budget

This section provides a design example for calculating maximum output current using the TPS92611-Q1 device. Table 1 lists the design parameters.

**Table 1. Design Parameter**

| DESIGN PARAMETER | EXAMPLE VALUE |
|---|---|
| $V_{SUPPLY}$ | 9V ~ 16V |
| LED | 3s1p, OSRAM Red LED, VF = 2 V |
| Maximum ambient test temperature, $T_A$ | 85°C |

Calculation methods is shown as below:

$$V_{OUT} = 2 \times 3\ V = 6\ V \tag{2}$$

$$P_D = (150°C - T_A) / R_{\theta JA}$$

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 2 shows the design results based on the three different $R_{\theta JA}$ tested above. It shows the max output current based on different $R_{\theta JA}$. When using 1oz 1cm*1cm 40Vias board, the total max output current is 104mA. While using 1oz 2cm*3cm 40Vias board, the total max output current can be 174mA.

**Table 2. Design Results**

| DESIGN PARAMETER | 1cm*1cm | 1.4cm*1.4cm | 1cm*2cm | 1.7cm*1.7cm | 2cm*2cm | 2cm*3cm |
|---|---|---|---|---|---|---|
| $R_{\theta JA}$ | 62.3°C/W | 53.1°C/W | 46.3°C/W | 46.4°C/W | 44.3°C/W | 37.3°C/W |
| Maximum output current | 104mA | 122mA | 139mA | 140mA | 146mA | 174mA |
| Sense resistor | 0.94Ω | 0.8Ω | 0.7Ω | 0.7Ω | 0.67Ω | 0.56Ω |

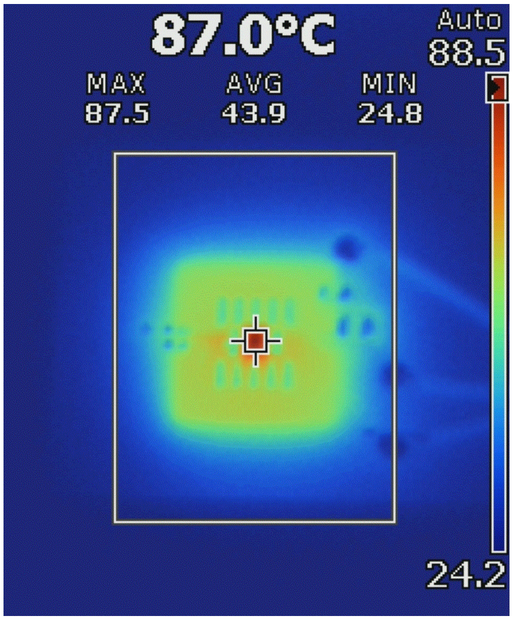

Figure 5. Thermal Distribution of 1.7cm*1.7cm Board Below Room Temperature

Figure 5 shows the thermal distribution under thermal imager. The test condition is the same as the design example of 1.7cm*1.7cm board version in Table 1 except the ambient temperature is 20°C instead of 85°C. The temperature rise of the junction is 87.5°C - 20°C = 67.5°C, which approaches the design parameter in Table 1 as 150°C - 85°C = 65°C.

In real application, recommend to leave some current margin for example 10% current less in order to avoid other factors' impact on the radiation.

## 4 Summary

This application report outlines the influences of different layout methods on TPS92611-Q1 thermal performance. Under our test PCB, for 2cm*3cm version, the thermal resistor is about 40 °C/W (room temperature). Always keep in mind that a different layout design can get a different thermal resistor and further different maximum output current. Layout designer needs not only give bigger area, but also take package into consideration so as to get better thermal heat radiation.

## 5 References

- Texas Instruments TPS92611-Q1 Automotive Single-Channel Linear LED Driver Data Sheet

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