TI Designs：TIDA-01375
符合 EMC 标准的汽车日间行车灯和位置灯参考设计

说明

该汽车参考设计详细展示了一个日间行车灯 (DRL) 和位置灯解决方案。汽车电池直接为该设计中使用的 TPS92830-Q1 线性发光二极管 (LED) 控制器供电，从而允许设计人员使用同一 LED 实现两种功能。该参考设计还 具有 良好的电磁兼容性 (EMC) 性能并提供全面的保护和诊断功能。

资源

TIDA-01375	设计文件夹
TPS92830-Q1	产品文件夹

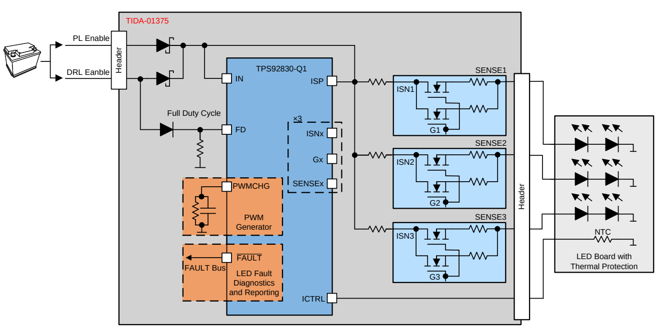
TI E2E™ Community 咨询我们的 E2E 专家

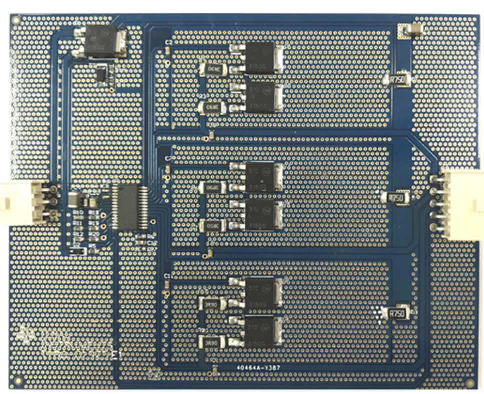
特性

- 汽车电池电源
- 符合 CISPR 25 传导和辐射发射标准并通过了 ISO11452-4 BCI 测试
- 可通过使用器件内部 PWM 发生器实现 DRL 和位置灯重复使用
- 具有自动恢复功能的 LED 灯串开路、接地短路和电池短路诊断
- 可配置为连带失效或仅失效的通道关闭的故障总线
- LED 过热保护

应用

- 汽车日间行车灯
- 汽车位置灯





该 TI 参考设计末尾的重要声明表述了授权使用、知识产权问题和其他重要的免责声明和信息。

1 System Description

Automotive DRLs and position lights often reuse the same LEDs with two levels of brightness. This reference design offers a dual-brightness solution for DRL and position light reuse applications using the integrated pulse-width modulation (PWM) generator of the TPS92830-Q1 controller. Using linear devices, this design has a satisfactory EMC performance that meets CISPR 25 Class-5 conducted emission and radiated emission standards and passes the ISO11452-4 bulk current injection (BCI) test.

This design provides protection to the LEDs and device from LED string short-to-ground and open-circuit faults with auto recovery. The LED open-circuit detection is disabled to avoid false diagnostics on an output channel resulting from a low supply voltage. By using different FAULT bus configurations, the designer can configure the system as one-fails–all-fail or only-failed-channel-off.

In the design, the LED strings are located on another board with a negative temperature coefficient (NTC) thermistor placed near the LEDs. The thermistor is used to protect the LEDs from overheating by reducing the output current when the detected temperature rises above the set point. Also, the LED current can be reduced when the input voltage is higher than 18 V to protect the MOSFETs from overheating.

1.1 Key System Specifications

表 **1. Key System Specifications**

PARAMETER	SPECIFICATION
Input voltage range	9 V to 16 V
Output current (DRL)	300 mA/CH
Output current (position light)	300 mA/CH with 10% duty cycle
LED number	2s3p
LED type	LUW H9GP, OSRAM

2 System Overview

2.1 Block Diagram

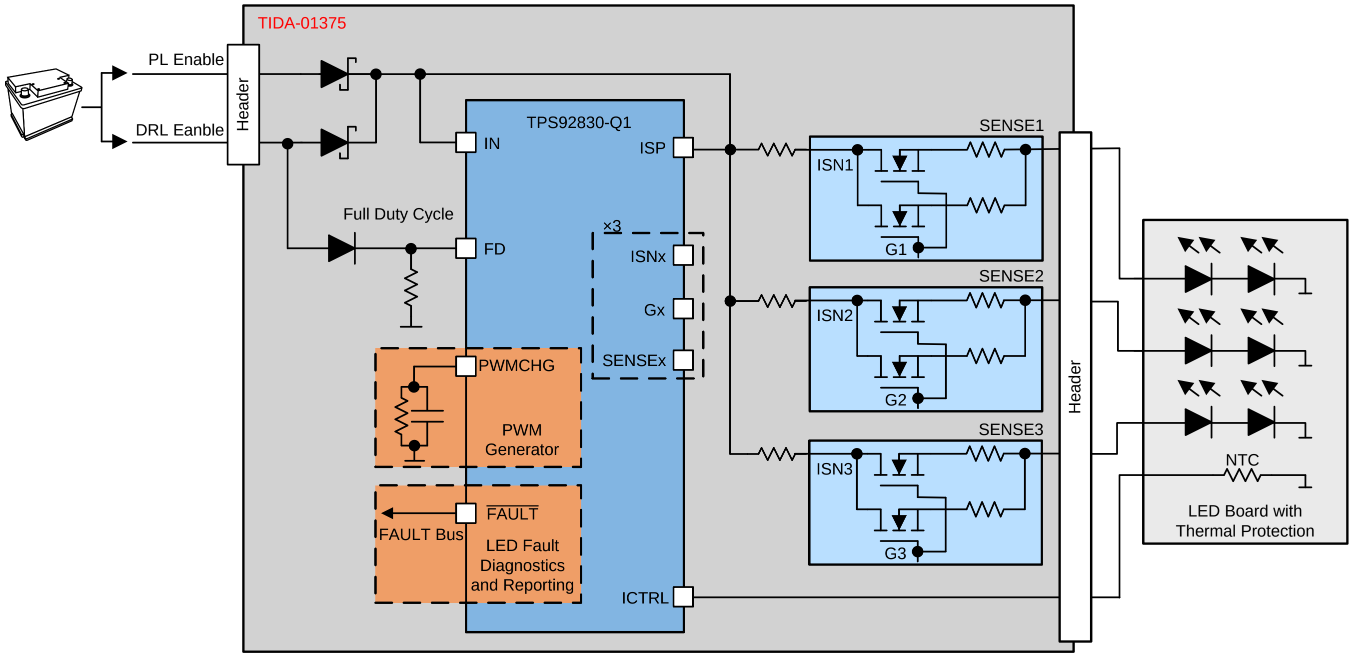


图 1. TIDA-01375 Block Diagram

2.2 Highlighted Products

2.2.1 TPS92830-Q1

The TPS92830-Q1 device is an advanced automotive-grade, high-side, constant-current linear LED controller for delivering high current using external N-channel MOSFETs. The device has a full set of features for automotive applications. Each channel of the TPS92830-Q1 device sets the channel current independently by the sense resistor value. An internal precision constant-current regulation loop senses the channel current by the voltage across the sense resistor and controls the gate voltage of the N-channel MOSFET accordingly. The device also integrates a two-stage charge pump for low-dropout operation. The charge-pump voltage is high enough to support a wide selection of N-channel MOSFETs. PWM dimming allows multiple sources for flexibility—internal PWM generator, external PWM inputs, or power-supply dimming. Various diagnostics and protection features specially designed for automotive applications help improve system robustness and ease of use. A one-fails–all-fail FAULT bus supports TPS92830-Q1 operation together with the TPS92630-Q1, TPS92638-Q1, and TPS9261x-Q1 family to fulfill various fault-handling requirements.

For more information on the TPS92830-Q1 device used in this reference design, refer to the product folder at www.ti.com.

2.3 System Design Theory

This reference design uses one TPS92830-Q1 linear LED controller to drive three white LED strings. The design offers a dual-brightness output for automotive DRL and position light applications. With a full set of features from TPS92830-Q1, the design can realize various functions with simple external circuits. 图 2 shows the schematic of the design. The following subsections provide details on the design process.

TIDUD55 — http://www-s.ti.com/sc/techlit/TIDUD55

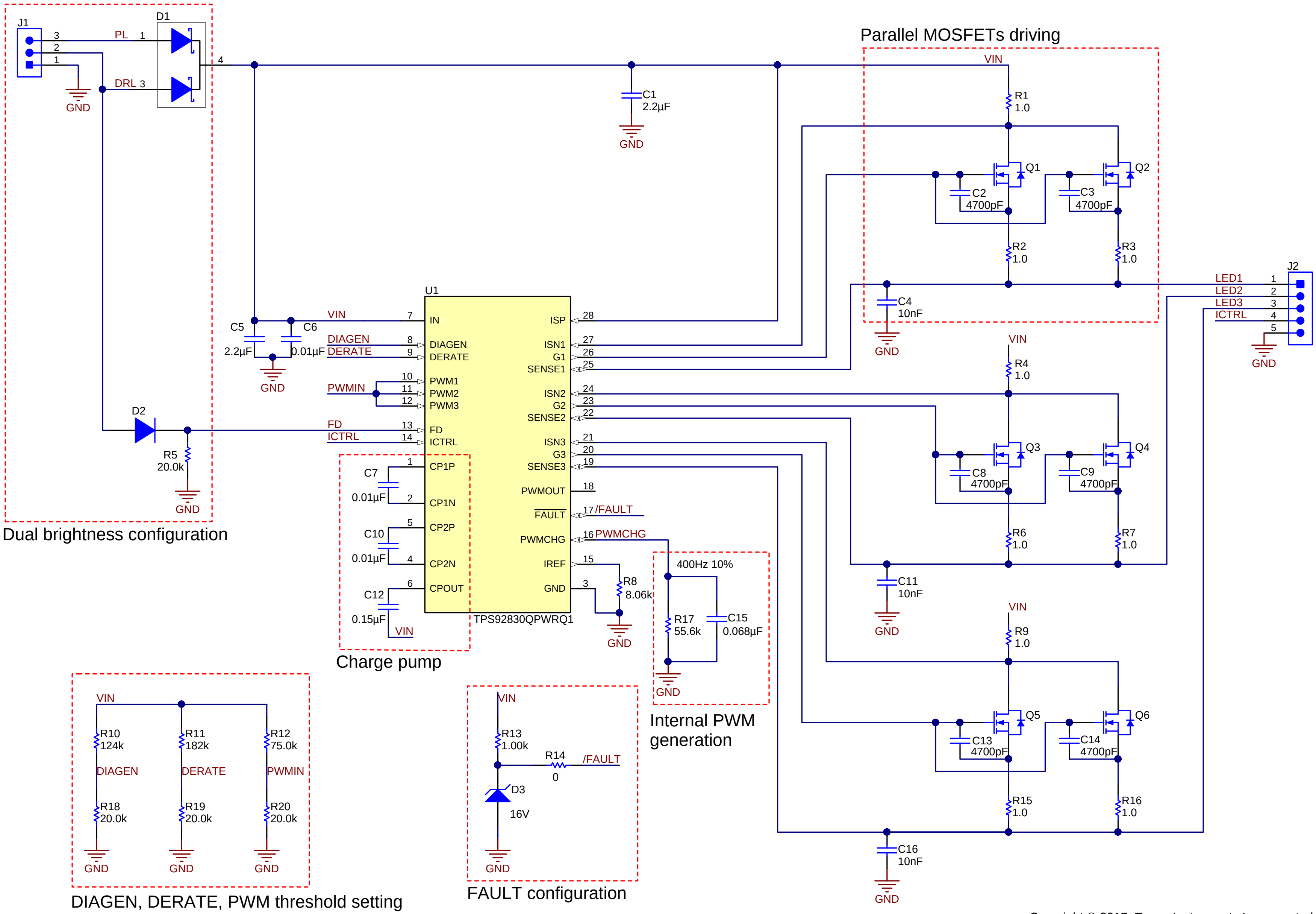


图 2. TIDA-01375 Schematic

2.3.1 Dual-Brightness Design

2.3.1.1 Dual-Brightness Concept

This design uses the same set of LEDs to illuminate both the DRL and position light. The LEDs can operate at two different brightness levels. One way to set the brightness level is through analog dimming, which means the LEDs always operate at a 100% duty cycle and the maximum current through the LEDs varies to the required level of brightness. However, note that differing levels of LED current may affect the LED color temperature. The other option is to use PWM dimming, which can achieve the desired dimming ratio with the same color temperature.

The TPS92830-Q1 device provides an integrated precision PWM generator for on-chip PWM dimming. An external RC circuit sets the duty cycle and frequency of the PWM signal, as the previous 图 2 shows. The device can flexibly switch between the internal PWM modulation mode and the 100% duty cycle mode by using the FD input. When the FD pin is high, the internal PWM generator is bypassed and the PWM inputs take complete control of the output.

In this design, when the DRL is connected to the battery, the FD is high. The LED strings work in DRL mode. The output is 300 mA per string at a 100% duty cycle. When the PL is connected to the battery, the FD is low. The LED strings work in position light mode. The output is at a 10% duty cycle and 400 Hz with an amplitude of 300 mA.

2.3.1.2 LED Current Design

The TPS92830-Q1 device has three independent constant-current-driving channels. Each channel sets the channel current with an external high-side current-sense resistor, $R_{(SNSx)}$. The channel current is set as $V_{(CS\_REG)}$ / $R_{(SNSx)}$. In this design, the current for each LED string is set at 300 mA, so the current-sense resistors can be calculated using 公式 1:

$$R1 = R4 = R9 = \frac{V_{(CS\_REG)}}{I_{(CH)}} = \frac{295}{300} = 0.983\ \Omega \tag{1}$$

where,

- $V_{(CH\_REG)}$ is the current-sense-resistor regulation voltage (typically 295 mV),
- $I_{(CH)}$ is the channel current.

Use three 1-Ω resistors for R1, R4 , and R9.

2.3.1.3 PWM Generator Design

As the previous 节 2.3.1.1 describes, the designer must generate a 10% duty cycle and 400-Hz PWM output to implement a functional position light. The PWM generator uses reference current 2 × $I_{(IREF)}$ as the internal charge current, $I_{(PWMCHG)}$. The recommended value of reference resistor R8 in 图 2 is 8 kΩ. Select an 8.06-kΩ resistor in this design.

Use external resistor R17 and C15 to set the PWM cycle time and duty cycle as required (see 公式 2 and 公式 3).

$$D_{(PL)} = \frac{\ln\left(\dfrac{V_{(PWMCHG\_th\_falling)} - I_{(PWMCHG)} \times R17}{V_{(PWMCHG\_th\_rising)} - I_{(PWMCHG)} \times R17}\right)}{\ln\left(\dfrac{V_{(PWMCHG\_th\_falling)} - I_{(PWMCHG)} \times R17}{V_{(PWMCHG\_th\_rising)} - I_{(PWMCHG)} \times R17}\right) + \ln\left(\dfrac{V_{(PWMCHG\_th\_rising)}}{V_{(PWMCHG\_th\_falling)}}\right)} \tag{2}$$

$$f_{(PL)} = \frac{1}{R17 \times C15 \times \left[\ln\left(\frac{V_{(PWMCHG\_th\_falling)} - I_{(PWMCHG)} \times R17}{V_{(PWMCHG\_th\_rising)} - I_{(PWMCHG)} \times R17} \right) + \ln\left(\frac{V_{(PWMCHG\_th\_rising)}}{V_{(PWMCHG\_th\_falling)}} \right) \right]} \quad (3)$$

R17 and C15 can be derived as follows in 公式 4 and 公式 5.

$$R17 = \frac{V_{(PWMCHG\_th\_falling)} \cdot \left(\frac{V_{(PWMCHG\_th\_falling)}}{V_{(PWMCHG\_th\_rising)}}\right)^{\frac{D_{(PL)}}{1-D_{(PL)}}} - V_{(PWMCHG\_th\_rising)}}{I_{(PWMCHG)}\left[\left(\frac{V_{(PWMCHG\_th\_falling)}}{V_{(PWMCHG\_th\_rising)}}\right)^{\frac{D_{(PL)}}{1-D_{(PL)}}} - 1\right]} \quad (4)$$

$$C15 = \frac{1-D_{(PL)}}{R17 \cdot f_{(PL)} \cdot \ln\left(\frac{V_{(PWMCHG\_th\_rising)}}{V_{(PWMCHG\_th\_falling)}}\right)} \quad (5)$$

where,

- $D_{(PL)}$ = 0.1,
- $f_{(PL)}$ = 400,
- $V_{(PWMCHG\_th\_rising)}$ is typically 1.48 V [(1)],
- $V_{(PWMCHG\_th\_falling)}$ is typically 0.8 V[(1)],
- $I_{(PWMCHG)}$ is typically 200 µA[(1)].

公式 2 shows that the duty cycle is only dependent on R17 and has nothing to do with C15, so the capacitance variation of C15 has no impact on the precision of the duty cycle.

According to the calculation, use R17 = 55.6 kΩ, C15 = 68 nF in the design.

2.3.2 Charge Pump

The TPS92830-Q1 device uses a two-stage charge pump to generate the high-side gate-drive voltage, as 图 2 shows. The charge pump is a voltage tripler which uses external flying capacitors C7 and C10 and storage capacitor C12. The charge-pump voltage is high enough to support a wide selection of N-channel MOSFETs. The recommended capacitance for C7, C10, and C12 is 10 nF, 10 nF, and 150 nF.

2.3.3 Parallel MOSFETs Driving

The TPS92830-Q1 device uses external MOSFETs rather than integrated power transistors to dissipate heat, so that high current can be delivered. In this design, the selected MOSFET is the NVD3055-150 in the DPAK package. This particular MOSFET is unable to support 300 mA of current for each channel. This case calls for connecting two MOSFETs in parallel within the same channel to balance the heat dissipation (see 图 2).

The MOSFET primarily operates in the saturation region as a current-control device; therefore, its current output strongly depends on its threshold. When the MOSFETs are in parallel, a small threshold mismatch can lead to an imbalance of current distribution. TI recommends using a ballast resistor for each MOSFET to balance the current distribution among parallel MOSFETs by introducing negative feedback. In this design, use ballast resistors R2 = R3 = R6 = R7 =R15 = R16 = 1 Ω.

(1) Data sheet value; refer to the data sheet for a detailed calculation description.

To ensure control loop stability, the drive circuit requires sufficient gate-to-source capacitance (C_{GS}) on the MOSFETs. The recommended minimum total gate-to-source capacitance on the MOSFETs is 4 nF. For the NVD3055-150 MOSFET, TI recommends placing additional capacitors across the gate and source terminals because C_{GS} is smaller than 1 nF. Use C2 = C3 = C8 = C9 = C13 = C14 = 4.7 nF.

2.3.4 Fault Bus Configuration

The TPS92830-Q1 device provides advanced diagnostics and fault protection methods for this design. The device is able to detect and protect the system from LED output short-to-GND, LED output open-circuit, and device overtemperature scenarios.

The device also supports a FAULT bus for diagnostics output. The designer can configure the FAULT bus as one-fails–all-fail or only-failed-channel-off based on requirements and application conditions. Setting resistor R14 enables and disables the one-fails–all-fail function.

When R14 in 图 3 is removed, $\overline{\text{FAULT}}$ is floating. During normal operation, an internal pullup current source weakly pulls up the $\overline{\text{FAULT}}$ pin. If any fault scenario occurs, an internal pulldown current source strongly pulls the $\overline{\text{FAULT}}$ pin low. All outputs shut down for protection, which effectively realizes the one-fails–all-fail function. The faulty channel continually retries until the fault condition is removed. The designer can also connect the FAULT bus to an MCU for fault reporting.

If R14 is mounted, $\overline{\text{FAULT}}$ is externally pulled up. The one-fails–all-fail function is disabled and only the faulty channel is turned off. A 16-V Zener diode (D3) is used to prevent the $\overline{\text{FAULT}}$ pin from overvoltage because the recommended maximum operating voltage for the $\overline{\text{FAULT}}$ pin is 20 V.

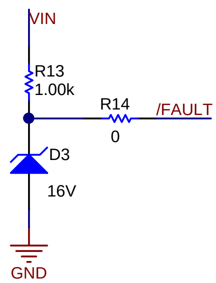


图 **3. FAULT Bus Configuration**

2.3.5 DIAGEN, DERATE, and PWM Threshold Setting

图 4 shows a schematic of the DIAGEN, DERATE, and PWM threshold setting.

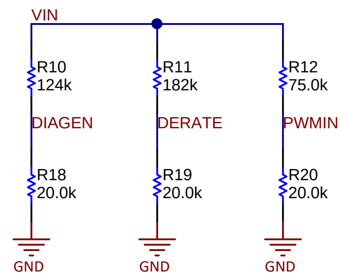


图 **4. DIAGEN, DERATE, and PWM Threshold Setting**

2.3.5.1 DIAGEN Setting

When the input voltage is not high enough to keep the external N-channel MOSFET in the constant-current saturation region, the TPS92830-Q1 device works in low-dropout mode. In low-dropout mode, the LED open-circuit detection must be disabled through the DIAGEN input; if not, the dropout mode is treated as an LED open-circuit fault.

In this design, the LED open detection is enabled when V_{IN} > 9 V. Set the resistor divider R10 and R18 using 公式 6:

$$K_{(RES\_DIAGEN)} = \frac{R18}{R10 + R18} = \frac{V_{IH(DIAGEN,\ max)}}{9} \tag{6}$$

where,

- $V_{IH(DIAGEN,\ max)}$ is the maximum input logic-high voltage for the DIAGEN pin in the data sheet (1.255 V).

Set R10 = 124 kΩ and R18 = 20 kΩ.

2.3.5.2 DERATE Setting

The TPS92830-Q1 device has an integrated output-current derating function. The voltage across the sense resistor is reduced if the DERATE pin voltage ($V_{(DERATE)}$) increases, which also reduces the output current. 图 5 shows a representation of the output-current derating profile.

The current reduces when V_{IN} rises above the set level due to the connection of the external resistor divider R11 and R19, which is connected from V_{IN} to set the $V_{(DERATE)}$ voltage (see previous 图 4). Therefore, use the current derating function to limit power dissipation in external MOSFETs and prevent thermal damage at a high input voltage.

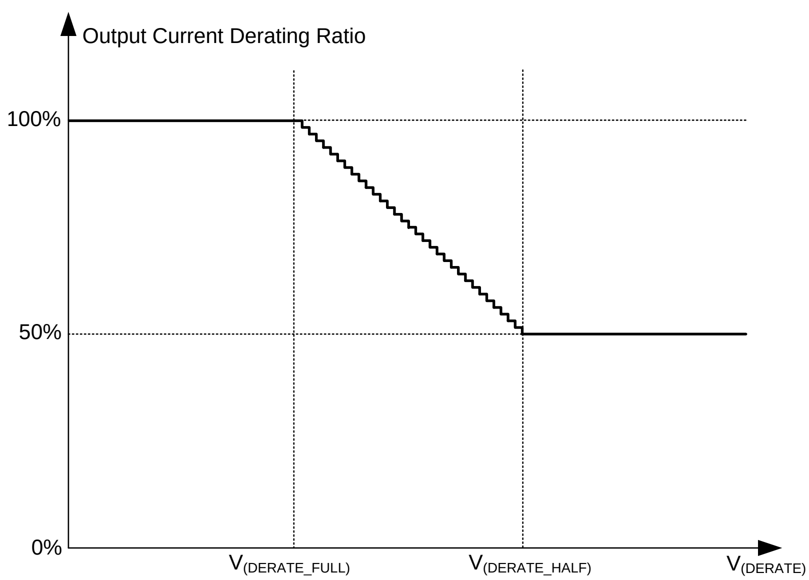


图 5. Output-Current Derating Profile

In this design, the output current is configured to be reduced when V_{IN} > 18 V with the output-current derating feature. The designer can set the resistor divider ratio using 公式 7:

$$K_{(RES\_DERATE)} = \frac{R19}{R11 + R19} = \frac{V_{(DERATE\_FULL)}}{18} \tag{7}$$

where,

- $V_{(DERATE\_FULL)}$ is the full-range DERATE voltage in the data sheet (1.83 V).

Set R11 = 182 kΩ and R19 = 20 kΩ.

2.3.5.3 PWM Threshold Setting

With the wide range of battery voltages in modern automotive systems, one common requirement among car original equipment manufacturers (OEMs) is to turn off the LEDs when the battery voltage is below the minimal voltage threshold. In this design, the three channels are designed to be enabled when V_{IN} > 6 V. PWM1 – PWM3 are connected together with a resistor divider R12 and R20. The designer can set the resistor-divider ratio using 公式 8:

$$K_{(RES\_PWM)} = \frac{R20}{R12 + R20} = \frac{V_{IH(PWMx,\ max)}}{6} \quad (8)$$

where,

- $V_{IH(PWMx,\ max)}$ is the maximum input logic-high voltage for PWM in the data sheet (1.248 V).

Set R12 = 75 kΩ and R20 = 20 kΩ.

2.3.6 LED Thermal Protection

Thermal is a concern when driving the DRL LEDs at high currents in an automotive environment. Take care at high temperatures so as to not exceed the LED operating temperature requirements. To prevent such an occurrence, the current going through the LEDs must be decreased when the LED temperature exceeds a thermal threshold to cool down the LEDs before they take any damage. Use the analog dimming function of the TPS92830-Q1 device to accomplish this task.

The TPS92830-Q1 device has a linear analog input pin ICTRL with an internal pullup current $I_{(ICTRL\_pullup)}$, which is typically 0.985 mA from the data sheet. The voltage across the sense resistor and the output current is linearly reduced if the ICTRL voltage ($V_{(ICTRL)}$) decreases. 图 6 shows the analog dimming ratio versus the $V_{(ICTRL)}$ voltage.

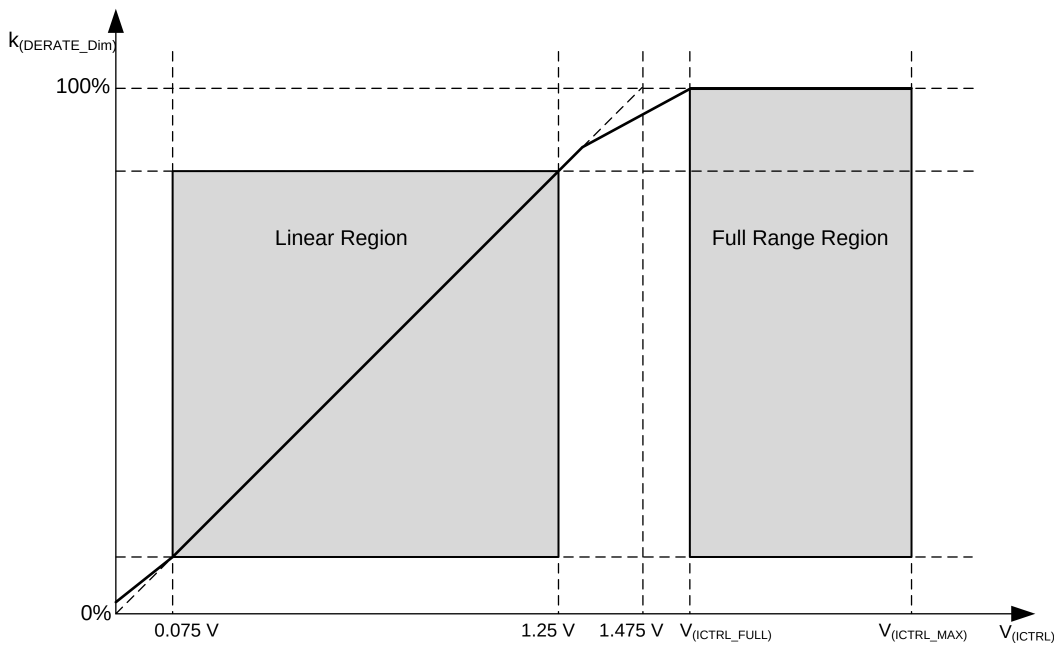
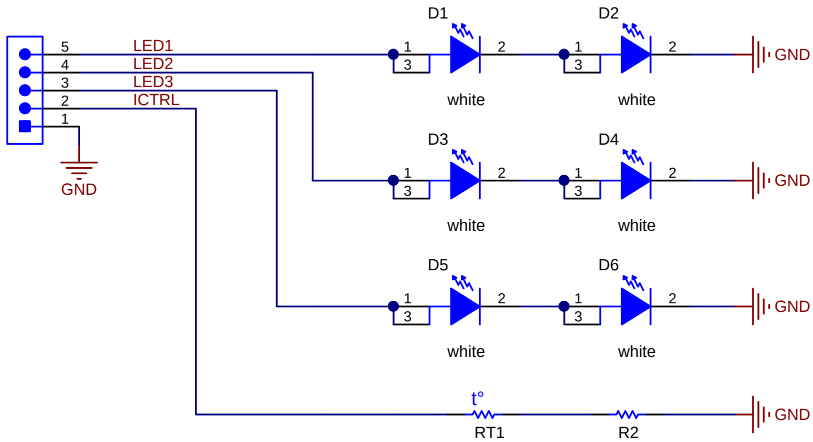


图 6. Analog Dimming Ratio

ICTRL supports off-board thermistor connection. Place an NTC thermistor RT1 near the LED to monitor the temperature of the LED and connect it to the ICTRL pin (see 图 7). With the resistance of the NTC thermistor decreasing as the temperature rises, $V_{(ICTRL)}$ decreases accordingly. When the temperature exceeds a desired point and $V_{(ICTRL)}$ decreases below the full-range ICTRL voltage, $V_{(ICTRL\_FULL)}$, the output current will be reduced, after which it protects the LEDs from overheating and enhances LED reliability.



Copyright © 2017, Texas Instruments Incorporated

图 7. LED Board With NTC Thermistor

Selection of the thermistor depends on the required relationship of LED current versus temperature and the relationship between the LED junction temperature and the NTC thermistor temperature for a specific board. These factors are all application-specific, so the designer should select the thermistor based on the real application. Users can also disable the thermal protection feature by leaving the ICTRL pin floating.

3 Getting Started Hardware

The following steps outline the hardware setup:

1. Connect the LED board to the TIDA-01375 board with a five-wire cable assembly, as 图 8 shows.
2. Connect a 12-V DC power supply across terminals PL and GND to enable the position light function.
3. Connect a 12-V DC power supply across terminals DRL and GND to enable the DRL function.

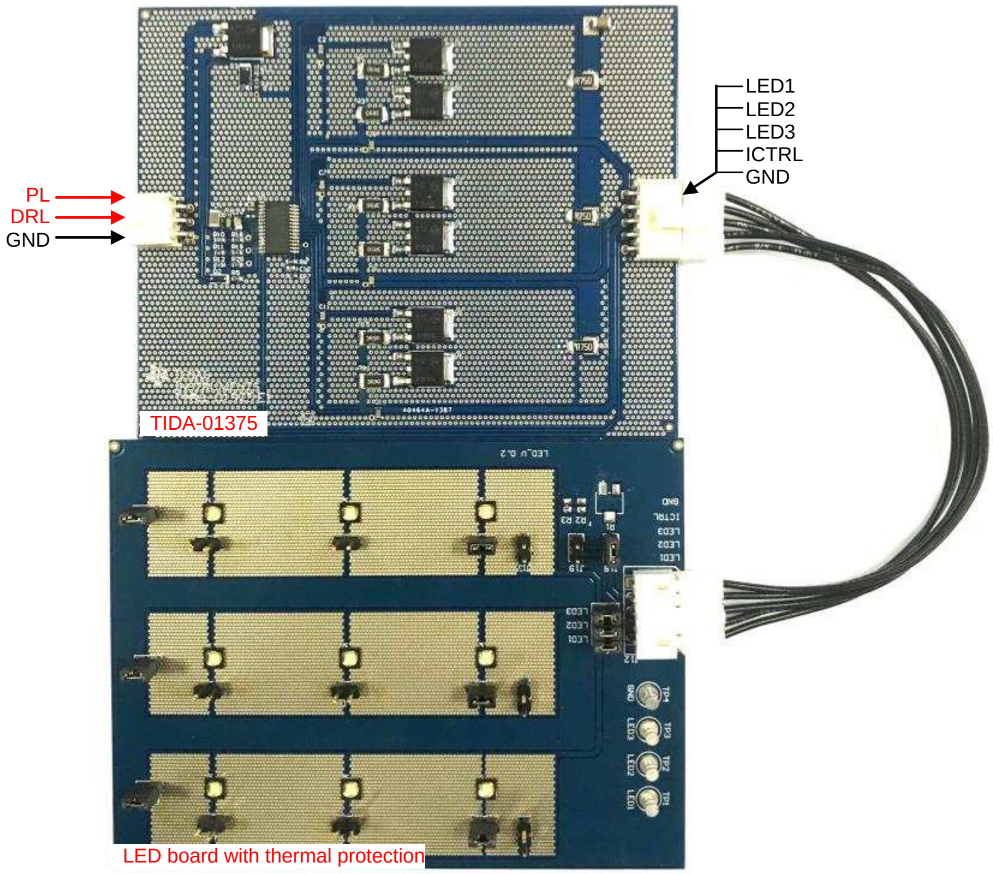


图 8. TIDA-01375 With LED Daughter Board

4 Testing and Results

4.1 Operating Waveforms

With the supply voltage applied to the DRL input and position light input, the design operates at a 100% duty cycle and 10% duty cycle, respectively, and achieves two levels of brightness. 表 2 lists the system input currents tested under two different brightness levels. 图 9 and 图 10 show the input voltage and input current waveforms for DRL and position light function, respectively.

表 2. System Input Current

FUNCTION	BRIGHTNESS	INPUT VOLTAGE	INPUT AVERAGE CURRENT
DRL	100%	9 V	887 mA
		12 V	887 mA
		16 V	888 mA
Position light	10%	9 V	91 mA
		12 V	91 mA
		16 V	91 mA

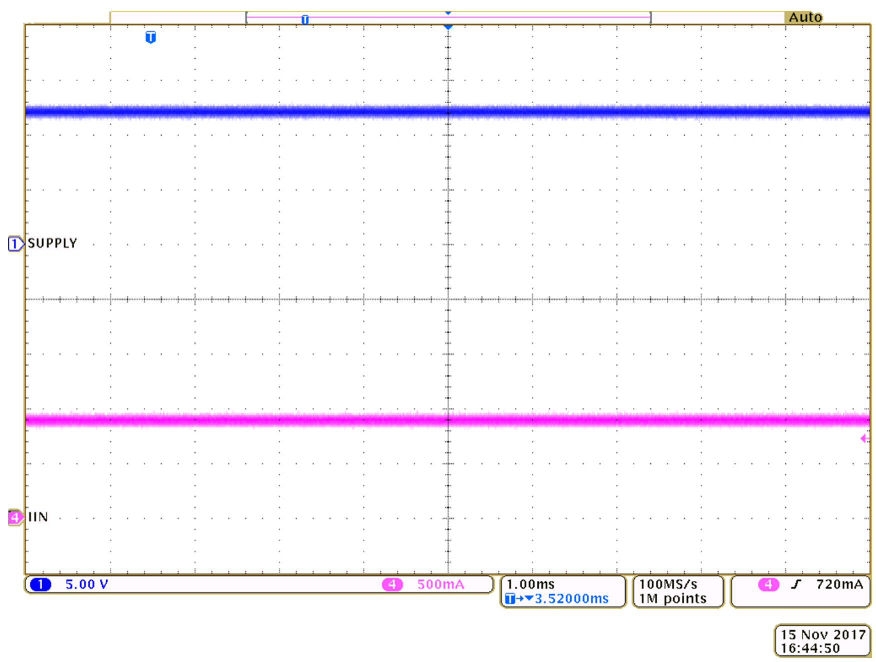


图 9. DRL Function Waveform—CH1: Supply Voltage, CH4: Input Current

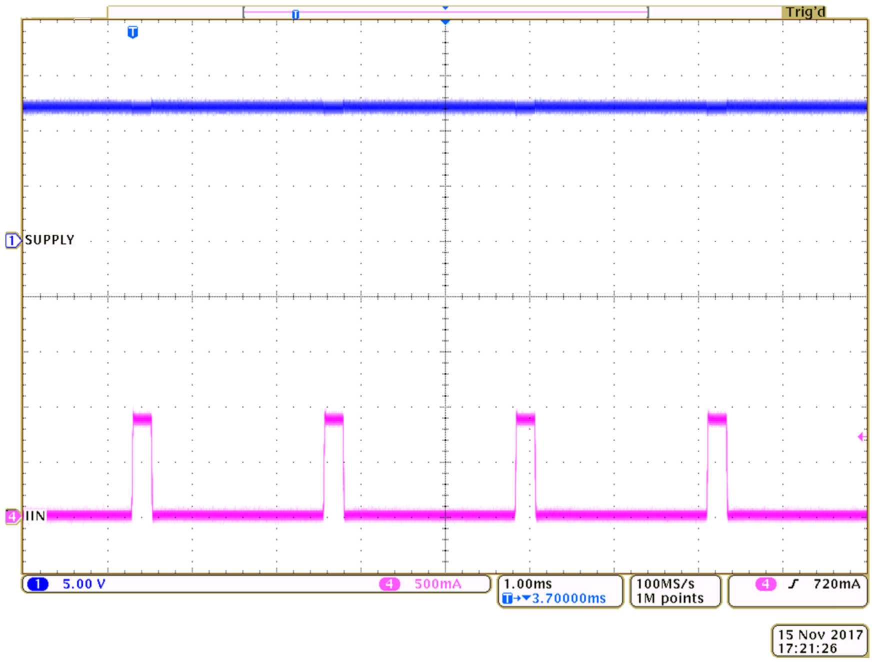


图 **10. Position Light Function Waveform—CH1: Supply Voltage, CH4: Input Current**

4.2 Thermal Results

图 11 and 图 12 show the infrared thermal images of the design when operating as a DRL and position light, respectively. The input voltage is 12 V. The ambient temperature is 25°C.

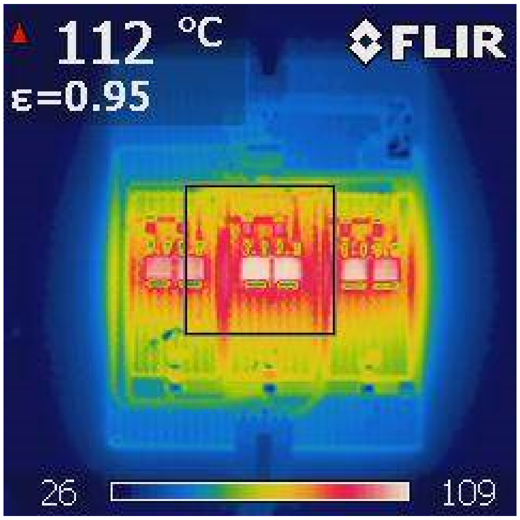


图 **11. Thermal Image of DRL Function at 25°C, 12-V Input Voltage**

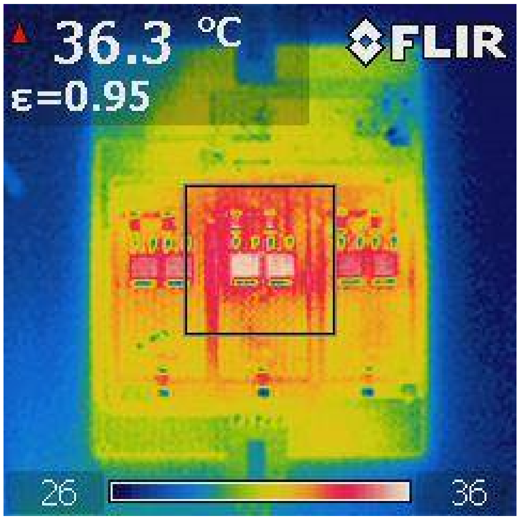


图 **12. Thermal Image of Position Light Function at 25°C, 12-V Input Voltage**

4.3 EMC Test Results

This reference design is compliant with several EMC standards that are important for automotive applications. The design has been tested against the CISPR 25 conducted and radiated emissions standard and ISO11452-4 bulk current injection (BCI) standard at a qualified third-party facility. The following subsections provide the test results.

4.3.1 Conducted and Radiated Emissions Test

CISPR 25 is the automotive EMI standard that most OEMs reference for requirements. Both conducted and radiated emissions tests for this design were completed against CISPR 25 standards. The test was conducted at a 13.5-V input when operating in DRL function mode.

表 3 shows the summarized results of both the conducted and radiated portions of the tests across different operating points and test conditions. For the test setup, test equipment, limits, and detailed test results, see the official test report at TIDA-01375.

表 3. Conducted and Radiated Emissions Test Results Summary

RADIATED EMISSION (ALSE METHOD)-CISPR25: 2008					
FREQUENCY BAND (MHz)	**ANTENNA POLARIZATION**	**MEASUREMENT SYSTEM BANDWIDTH**	**DETECTION SCHEME**	**TEST LIMIT**	**TEST RESULTS DESCRIPTION**
0.15 – 30	V	9 kHz	PK/QP/AV	CISPR25: 2008 Class 5	Meets requirement
30 – 200	V	120 kHz	PK/QP/AV		Meets requirement
	H	120 kHz	PK/QP/AV		Meets requirement
200 – 1000	V	120 kHz	PK/QP/AV		Meets requirement
	H	120 kHz	PK/QP/AV		Meets requirement
1000 – 2500	V	9/120 kHz	PK/AV		Meets requirement
	H	9/120 kHz	PK/AV		Meets requirement
CONDUCTED EMISSION (VOLTAGE MODE)-CISPR25: 2008					
FREQUENCY BAND (MHz)	**SUPPLY LINE POLARITY**	**MEASUREMENT SYSTEM BANDWIDTH**	**DETECTION SCHEME**	**TEST LIMIT**	**TEST RESULTS DESCRIPTION**
0.15 ≈ 108	Positive	9/120 kHz	PK/QP/AV	CISPR25: 2008 Class 5	Meets requirement
	Negative	9/120 kHz	PK/QP/AV		Meets requirement

4.3.2 BCI Test

The BCI test for this design was conducted against the ISO11452-4 standard and at a 13.5-V input when operating in DRL mode. 表 4 and 表 5 list the test requirement and acceptance criteria of the BCI test. 表 6 summarizes the test results. For the test setup, test equipment, limits, and detailed test results, see the official test report at TIDA-01375.

表 4. BCI Test Requirement

BULK CURRENT INJECTION-ISO11452-4: 2011			
FREQUENCY (MHz)	**FREQUENCY STEP SIZE (MHz)**	**DWELL TIME (sec)**	**TEST LEVEL (mA)**
1 – 10	1	2	200
10 – 200	5	2	200
200 – 400	10	2	200

表 5. BCI Test Acceptance Criteria

WORKING MODE	MONITORING PARAMETERS	ACCEPTANCE	TEST LEVEL	STATUS
Mode 1	The brightness of light	No obvious phenomenon	200 mA	Class A

表 6. BCI Test Results Summary

FREQUENCY BAND (MHz)	INJECTION MODE	POSITION (mm)	MODULATION	TEST LEVEL	TEST RESULTS DESCRIPTION
1 – 400	CBCI	150	CW	200 mA	No obvious phenomenon
			AM		No obvious phenomenon
		450	CW		No obvious phenomenon
			AM		No obvious phenomenon
		750	CW		No obvious phenomenon
			AM		No obvious phenomenon

5 Design Files

5.1 *Schematics*

To download the schematics, see the design files at TIDA-01375.

5.2 *Bill of Materials*

To download the bill of materials (BOM), see the design files at TIDA-01375.

5.3 *PCB Layout Recommendations*

This design relies on external MOSFETs to dissipate heat. The thermal performance of the design is highly dependent on the cooling conditions of the MOSFETs and LEDs. A good printed-circuit board (PCB) design can optimize heat transfer, which is essential for long-term reliability. Consider the following PCB layout recommendations:

- Increase copper thickness or use metal-based boards if possible. Maximize the copper coverage on the PCB to increase the thermal conductivity of the board. Place thermal vias on the thermal dissipation area to further improve the thermal dissipation capability.
- The current path starts from IN through the sense-resistors, MOSFETs, and LEDs to GND. Wide traces are helpful to reduce parasitic resistance along the current path.
- Place capacitors, especially charge pump capacitors, close to the device to make the current path as short as possible.

5.3.1 Layout Prints

To download the layer plots, see the design files at TIDA-01375.

5.4 *Altium Project*

To download the Altium project files, see the design files at TIDA-01375.

5.5 *Gerber Files*

To download the Gerber files, see the design files at TIDA-01375.

5.6 *Assembly Drawings*

To download the assembly drawings, see the design files at TIDA-01375.

6 Related Documentation

1. CISPR 25, Edition 3.0, 2008-03, *Vehicles, Boats and Internal Combustion Engines – Radio Disturbance Characteristics – Limits and Methods of Measurement for the Protection of On-Board Receivers*
2. ISO11452-4, Edition 4, 2011-12, *Road vehicles — Component test methods for electrical disturbances from narrowband radiated electromagnetic energy — Part 4: Harness excitation methods*
3. Texas Instruments, *TPS92830-Q1 3-Channel High-Current Linear LED Controller*

6.1 *商标*

有关 TI 设计信息和资源的重要通知

德州仪器 (TI) 公司提供的技术、应用或其他设计建议、服务或信息，包括但不限于与评估模块有关的参考设计和材料（总称"TI 资源"），旨在帮助设计人员开发整合了 TI 产品的 应用； 如果您（个人，或如果是代表贵公司，则为贵公司）以任何方式下载、访问或使用了任何特定的 TI 资源，即表示贵方同意仅为该等目标，按照本通知的条款进行使用。

TI 所提供的 TI 资源，并未扩大或以其他方式修改 TI 对 TI 产品的公开适用的质保及质保免责声明；也未导致 TI 承担任何额外的义务或责任。TI 有权对其 TI 资源进行纠正、增强、改进和其他修改。

您理解并同意，在设计应用时应自行实施独立的分析、评价和 判断， 且应全权负责并确保 应用的安全性， 以及您的 应用 （包括应用中使用的所有 TI 产品））应符合所有适用的法律法规及其他相关要求。你就您的 应用声明，您具备制订和实施下列保障措施所需的一切必要专业知识，能够 (1) 预见故障的危险后果，(2) 监视故障及其后果，以及 (3) 降低可能导致危险的故障几率并采取适当措施。您同意，在使用或分发包含 TI 产品的任何 应用前， 您将彻底测试该等 应用 和该等应用所用 TI 产品的 功能。除特定 TI 资源的公开文档中明确列出的测试外，TI 未进行任何其他测试。

您只有在为开发包含该等 TI 资源所列 TI 产品的 应用时， 才被授权使用、复制和修改任何相关单项 TI 资源。但并未依据禁止反言原则或其他法理授予您任何TI知识产权的任何其他明示或默示的许可，也未授予您 TI 或第三方的任何技术或知识产权的许可，该等产权包括但不限于任何专利权、版权、屏蔽作品权或与使用TI产品或服务的任何整合、机器制作、流程相关的其他知识产权。涉及或参考了第三方产品或服务的信息不构成使用此类产品或服务的许可或与其相关的保证或认可。使用 TI 资源可能需要您向第三方获得对该等第三方专利或其他知识产权的许可。

TI 资源系"按原样"提供。TI 兹免除对 TI 资源及其使用作出所有其他明确或默认的保证或陈述，包括但不限于对准确性或完整性、产权保证、无屡发故障保证，以及适销性、适合特定用途和不侵犯任何第三方知识产权的任何默认保证。

TI 不负责任何申索，包括但不限于因组合产品所致或与之有关的申索，也不为您辩护或赔偿，即使该等产品组合已列于 TI 资源或其他地方。对因 TI 资源或其使用引起或与之有关的任何实际的、直接的、特殊的、附带的、间接的、惩罚性的、偶发的、从属或惩戒性损害赔偿，不管 TI 是否获悉可能会产生上述损害赔偿，TI 概不负责。

您同意向 TI 及其代表全额赔偿因您不遵守本通知条款和条件而引起的任何损害、费用、损失和/或责任。

本通知适用于 TI 资源。另有其他条款适用于某些类型的材料、TI 产品和服务的使用和采购。这些条款包括但不限于适用于 TI 的半导体产品 (http://www.ti.com/sc/docs/stdterms.htm)、评估模块和样品 (http://www.ti.com/sc/docs/sampterms.htm) 的标准条款。

邮寄地址：上海市浦东新区世纪大道 1568 号中建大厦 32 楼，邮政编码：200122