

TPS2475x 電流モニタ搭載 12A eFuse 回路プロテクタ

1 特長

- バス動作電圧範囲：2.5V～18V
- 最大 12A の連続電流
- $R_{DS(on)}$ 3m Ω (標準値) の MOSFET を内蔵
- 電流制限をプログラム可能
- プログラム可能な FET SOA 保護
- 10mA～12A の高い I_{Limit} 精度
- プログラム可能なフォルト・タイマ
- 高速ブレーカによる短絡保護
- プログラム可能な VOUT スルーレート、UV、OV
- パワー・グッドおよびフォルト出力
- アナログ負荷電流モニタ
- サーマル・シャットダウン
- UL 2367 認定済み – ファイル番号 E339631

2 アプリケーション

- サーバー
- 大電流負荷スイッチ
- 通信機器
- プラグイン・モジュール
- RAID システム
- 基地局
- ファン制御

3 概要

TPS2475x は、2.5V～18V の機器向けに高度に統合された負荷保護機能を提供します。ホットスワップ・コントローラとパワー MOSFET を 1 つのパッケージに搭載しているため小型の機器に適しており、電源、負荷、内蔵 MOSFET を損傷に至る事象から守ることができます。起動時には、負荷電流および MOSFET の消費電力がユーザーの選択した値に制限されます。起動後は、設定したタイムアウトまで、ユーザーが選択した制限値を超える電流を流すこともできますが、極端な過負荷状態になると直ちに負荷が電源から切断されます。

プログラム可能な FET SOA 保護により、内蔵 MOSFET は常にその安全動作領域 (SOA) 内で動作し、負荷は定義されたランプ・レートで起動します。これにより、システムの信頼性を向上させながら、内蔵 MOSFET の性能を高めています。システム状態監視と下流負荷制御のために、パワー・グッド、フォルト、電流モニタの出力を提供します。

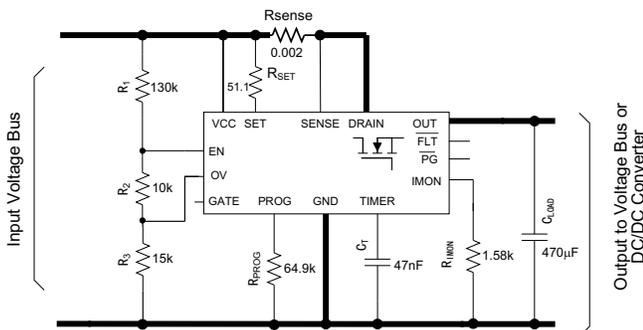
TPS2475x は 36 ピン、7mm × 3.5mm、QFN (RUV) パッケージで供給され、 -40°C ～ $+125^{\circ}\text{C}$ の接合部温度範囲で仕様が規定されています。

製品情報⁽¹⁾

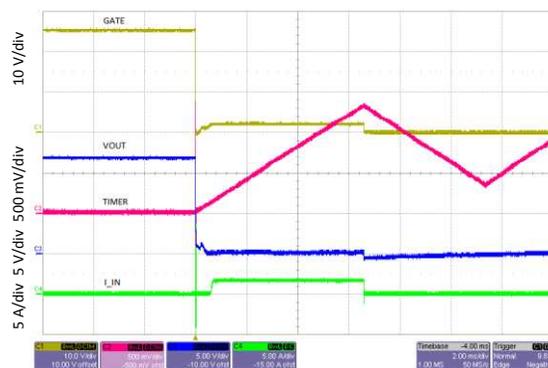
| 型番 | パッケージ | 本体サイズ(公称) |
|----------|-------|-----------------|
| TPS24750 | VQFN | 7.00mm × 3.50mm |
| TPS24751 | | |

(1) 利用可能なすべてのパッケージについては、このデータシートの末尾にある注文情報を参照してください。

アプリケーション回路図 (12V、10A)



過渡出力短絡応答



目次

| | | | | | |
|-----|-----------------------------------|----|------|--------------------------------|----|
| 1 | 特長 | 1 | 10 | Application and Implementation | 26 |
| 2 | アプリケーション | 1 | 10.1 | Application Information | 26 |
| 3 | 概要 | 1 | 10.2 | Typical Application | 26 |
| 4 | 改訂履歴 | 2 | 10.3 | System Examples | 33 |
| 5 | Device Comparison Table | 4 | 11 | Power Supply Recommendations | 35 |
| 6 | Pin Configuration and Functions | 4 | 11.1 | Transient Thermal Impedance | 35 |
| 7 | Specifications | 6 | 12 | Layout | 36 |
| 7.1 | Absolute Maximum Ratings | 6 | 12.1 | Layout Guidelines | 36 |
| 7.2 | ESD Ratings | 6 | 12.2 | Layout Example | 36 |
| 7.3 | Recommended Operating Conditions | 6 | 13 | デバイスおよびドキュメントのサポート | 38 |
| 7.4 | Thermal Information | 6 | 13.1 | ドキュメントのサポート | 38 |
| 7.5 | Electrical Characteristics | 7 | 13.2 | 関連リンク | 38 |
| 7.6 | Typical Characteristics | 9 | 13.3 | ドキュメントの更新通知を受け取る方法 | 38 |
| 8 | Parameter Measurement Information | 14 | 13.4 | コミュニティ・リソース | 38 |
| 9 | Detailed Descriptions | 15 | 13.5 | 商標 | 38 |
| 9.1 | Overview | 15 | 13.6 | 静電気放電に関する注意事項 | 38 |
| 9.2 | Functional Block Diagram | 15 | 13.7 | Export Control Notice | 38 |
| 9.3 | Feature Description | 16 | 13.8 | Glossary | 39 |
| 9.4 | Device Functional Modes | 19 | 14 | メカニカル、パッケージ、および注文情報 | 39 |

4 改訂履歴

資料番号末尾の英字は改訂を表しています。その改訂履歴は英語版に準じています。

| Revision B (November 2016) から Revision C に変更 | Page |
|--|------|
| • UL 2367 認定済み – ファイル番号E339631 を「特長」セクションに追加 | 1 |

| Revision A (September 2015) から Revision B に変更 | Page |
|--|------|
| • Added designator C1 to Figure 41 | 27 |
| • Updated STEP 5. Select R₁, R₂, and R₃ for UV and OV section | 30 |

| 2013年10月発行のものから更新 | Page |
|---|------|
| • 「ESD 定格」表、「詳細説明」、「機能説明」、「デバイスの機能モード」、「アプリケーションと実装」、「電源に関する推奨事項」、「デバイスおよびドキュメントのサポート」、「メカニカル、パッケージ、および注文情報」を追加 | 1 |
| • 「特長」の「FET 短絡検出 (TPS24752、TPS24753)」を削除 | 1 |
| • アプリケーション回路図を変更。C _{VIN} および D1 を削除 | 1 |
| • Deleted devices TPS24752 and TPS24753 from the data sheet | 4 |
| • Deleted list item from the Overview section: "Internal MOSFET short detection (TPS24752/3 only)" | 15 |
| • Removed notes for pin 30 and 31 from the Functional Block Diagram | 15 |
| • Deleted section Fault Detection of Internal Mosfet Short | 25 |
| • Changed Figure 40 . Deleted C _{VIN} and D1 | 26 |
| • Changed text in STEP 3. Choose Output Voltage Rising Time, t_{ON}, and Timing Capacitor C_T From: "maximum steady state junction temperature (T _{JDMAX} = T _{A(MAX)} + I _{LIM} ² × R _{(DS)ON)." To: "maximum steady state junction temperature (T_{JDMAX} = T_{A(MAX)} + I_{LIM}² × R_{(DS)ON} × R_{θJA)."}} | 29 |
| • Changed Figure 46 and Figure 47 . Deleted C _{VIN} and D1 | 33 |
| • Added text and Figure 48 to System Examples | 34 |
| • Changed Figure 51 | 36 |

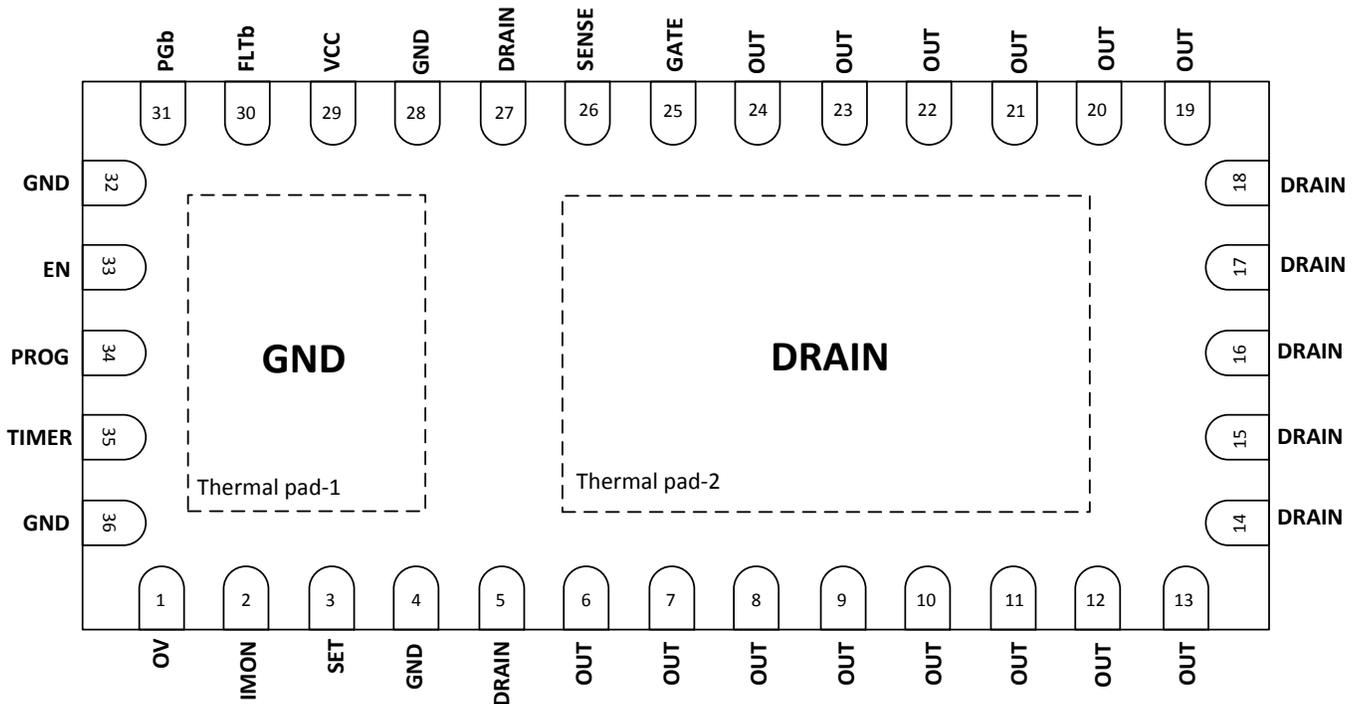
- Added [Figure 52](#) 37

5 Device Comparison Table

| Part Number | Operating Voltage Range | Function | Fault Response | Status |
|-------------|-------------------------|-------------------------------|----------------|--------|
| TPS24750RUV | 2.5 V-18 V | Integrated hot swap protector | Latch | Active |
| TPS24751RUV | 2.5 V-18 V | Integrated hot swap protector | Auto retry | Active |

6 Pin Configuration and Functions

TPS24750, TPS24751 RUV Package
36-Pin VQFN
Top View



Pin Functions

| PIN | | TYPE | DESCRIPTION |
|-------|---------------|------|--|
| NAME | NO. | | |
| DRAIN | 5, 14-18, 27 | I | The drain of the internal pass MOSFET. Connect to a terminal of current sense resistor in the power path |
| EN | 33 | I | Active high enable input. Logic input. Connects to resistor divider |
| FLTb | 30 | I | Active-low, open-drain output indicates overload fault timer has turned internal FET off |
| GATE | 25 | I/O | Gate driver output for the internal MOSFET |
| GND | 4, 28, 32, 36 | GND | Ground |
| IMON | 2 | O | Load current analog and current limit program point. Connect R_{IMON} to ground |
| OUT | 6-13, 19-24 | I/O | Internally connect to the source of internal pass MOSFET. Connect to output capacitors and load |
| OV | 1 | I | Overvoltage comparator input. Connects to resistor divider. GATE is pulled low when OV exceeds the threshold |
| Pad-1 | — | — | Tied to GND |
| Pad-2 | — | — | Tied to DRAIN |
| PGb | 31 | O | Active-low, open-drain power good indicator. Status is determined by the voltage across the MOSFET |

Pin Functions (continued)

| PIN | | TYPE | DESCRIPTION |
|-------|-----|------|---|
| NAME | NO. | | |
| PROG | 34 | I | Power-limiting programming pin. A resistor from this pin to GND sets the maximum power dissipation for the internal pass MOSFET |
| SENSE | 26 | I | Current sensing input for resistor shunt from VCC to SENSE. Connect to a terminal of current sense resistor |
| SET | 3 | I | Current limit programming set pin. A resistor is connected from this pin to VCC |
| TIMER | 35 | I/O | A capacitor connected from this pin to GND provides a fault timing function |
| VCC | 29 | I | Input voltage sense and power supply |

7 Specifications

7.1 Absolute Maximum Ratings

over operating free-air temperature range, all voltages referred to GND (unless otherwise noted) ⁽¹⁾

| | | MIN | MAX | UNIT |
|------------------|--|--------------------|-----|------|
| Input voltage | DRAIN, EN, FLTb ⁽²⁾ , GATE, OUT, PGb ⁽²⁾ , SENSE, SET ⁽²⁾ , VCC | -0.3 | 30 | V |
| | OV | -0.3 | 20 | |
| | PROG ⁽²⁾ | -0.3 | 3.6 | |
| | [SET, SENSE] to VCC | -0.3 | 0.3 | |
| | IMON, TIMER | -0.3 | 5 | |
| Sink current | FLTb, PGb | | 5 | mA |
| Source current | PROG | Internally limited | | |
| | IMON | | 5 | mA |
| T _J | Maximum junction temperature | 150 | | °C |
| T _{STG} | Storage temperature | -65 | 150 | °C |

- (1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
- (2) Do not apply voltage directly to these pins.

7.2 ESD Ratings

| | | VALUE | UNIT |
|--------------------|--|-------|------|
| V _(ESD) | Electrostatic discharge | | V |
| | Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 ⁽¹⁾ | ±500 | |
| | Charged-device model (CDM), per JEDEC specification JESD22-C101 ⁽²⁾ | ±500 | |

- (1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process
- (2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

7.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

| | | MIN | MAX | UNIT |
|----------------------|--|------|-----|------|
| Input voltage | OV | 0 | 16 | V |
| | SENSE, SET ⁽¹⁾ , VCC ⁽²⁾ | 2.5 | 18 | |
| | EN, FLTb, GATE ⁽²⁾ , PGb, OUT ⁽²⁾ , DRAIN ⁽²⁾ | 0 | 18 | |
| Sink current | FLTb, PGb | 0 | 2 | mA |
| Source current | IMON | 0 | 1 | mA |
| Resistance | PROG | 4.99 | 500 | kΩ |
| External capacitance | TIMER | 1 | | nF |
| | GATE ⁽³⁾ | | 1 | μF |
| T _J | Operating junction temperature | -40 | 125 | °C |

- (1) Do not apply voltage directly to these pins.
- (2) See the [Gate Clamp Diode](#) section for additional precaution to be taken for operating voltages >14 V.
- (3) External capacitance tied to GATE must be in series with a resistor no less than 1 kΩ.

7.4 Thermal Information

| THERMAL METRIC ⁽¹⁾ | | TPS2475x | UNIT |
|-------------------------------|--|------------|------|
| | | RUV (VQFN) | |
| | | 36 PINS | |
| R _{θJA} | Junction-to-ambient thermal resistance | 33.7 | °C/W |
| R _{θJC(top)} | Junction-to-case (top) thermal resistance | 28.2 | °C/W |
| R _{θJB} | Junction-to-board thermal resistance | 5.8 | °C/W |
| ψ _{JT} | Junction-to-top characterization parameter | 0.3 | °C/W |

- (1) For more information about traditional and new thermal metrics, see the [Semiconductor and IC Package Thermal Metrics](#) application report.

Thermal Information (continued)

| THERMAL METRIC ⁽¹⁾ | | TPS2475x | UNIT |
|-------------------------------|--|------------|------|
| | | RUV (VQFN) | |
| | | 36 PINS | |
| Ψ_{JB} | Junction-to-board characterization parameter | 5.7 | °C/W |
| $R_{\theta JC(bot)}$ | Junction-to-case (bottom) thermal resistance | 1.1 | °C/W |

7.5 Electrical Characteristics

–40°C ≤ T_J ≤ +125°C, V_{CC} = 12 V, V_{EN} = 3 V, R_{SET} = 191 Ω, R_{IMON} = 5 kΩ, and R_{PROG} = 50 kΩ to GND. All voltages referenced to GND, unless otherwise noted.

| PARAMETER | | CONDITIONS | MIN | NOM | MAX | UNIT |
|--------------------|--------------------------------|--|------|------|------|------|
| VCC | | | | | | |
| | UVLO threshold, rising | | 2.20 | 2.32 | 2.45 | V |
| | UVLO threshold, falling | | 2.10 | 2.22 | 2.35 | V |
| | UVLO hysteresis ⁽¹⁾ | | | 0.1 | | V |
| | Supply current | Enabled — I _{OUT} + I _{VCC} + I _{SENSE} | 0.5 | 1 | 1.4 | mA |
| | | Disabled ⁽¹⁾ — EN = 0 V, I _{OUT} + I _{VCC} + I _{SENSE} | | 0.45 | | mA |
| OUT | | | | | | |
| R _{ON} | On-resistance | 1 A ≤ I _{OUT} ≤ 10 A at T _J = 25°C | | 3 | 3.5 | mΩ |
| | | 1 A ≤ I _{OUT} ≤ 10 A at T _J = 125°C | | 5 | 6 | mΩ |
| | Input bias current | V _{OUT} = 12 V | 10 | 16 | 30 | μA |
| | Diode forward voltage | V _{EN} = 0 V, I _{OUT} = –100 mA, V _{OUT} > V _{SENSE} | | 0.8 | 1 | V |
| | Leakage current - DRAIN to OUT | V _{EN} = 0 V, V _{OUT} = 0 V, V _{DRAIN} = 18 V at 25°C | | 0 | 1 | μA |
| | | V _{EN} = 0 V, V _{OUT} = 0 V, V _{DRAIN} = 18 V at 125°C | | 2 | 5 | μA |
| C _{iss} | Input capacitance | | | 2710 | 3250 | pF |
| C _{oss} | Output capacitance | V _{GS} = 0 V, V _{DRAIN-OUT} = 15 V, f = 1 MHz | | 635 | 762 | pF |
| C _{rss} | Reverse transfer capacitance | | | 48 | 60 | pF |
| Q _g | Gate charge total (4.5 V) | | | 17.5 | 21.5 | nC |
| Q _{g(th)} | Gate charge at V _{th} | V _{DRAIN-OUT} = 15 V, I _{OUT} = 20 A | | 4.1 | | nC |
| EN | | | | | | |
| | Threshold voltage, falling | | 1.2 | 1.3 | 1.4 | V |
| | Hysteresis ⁽¹⁾ | | | 50 | | mV |
| | Input leakage current | 0 V ≤ V _{EN} ≤ 30 V | –1 | 0 | 1 | μA |
| | Turnoff time | EN ↓ to V _{GATE} < 1 V | 3 | 8 | 25 | μs |
| | Deglitch time | EN ↑ | 8 | 14 | 21 | μs |
| | Disable delay | EN ↓ to GATE ↓, C _{GATE} = 0, t _{pf50–90} , See Figure 28 | 0.1 | 0.4 | 1.8 | μs |
| | Turnon delay | C _{OUT} = 2.2 μF, V _{EN} ↑ to V _{OUT} ↑, V _{EN} : 0 V to 3 V, V _{OUT} : 90% V _{CC} | | 800 | | μs |
| OV | | | | | | |
| | Threshold voltage, rising | | 1.25 | 1.35 | 1.45 | V |
| | Hysteresis ⁽¹⁾ | | | 60 | | mV |
| | Input leakage current | 0 V ≤ V _{OV} ≤ 30 V | –1 | 0 | 1 | μA |
| | Deglitch time | OV rising | 0.5 | 1.2 | 1.5 | μs |
| FLTb | | | | | | |
| | Output low voltage | Sinking 2 mA | | 0.11 | 0.25 | V |
| | Input leakage current | V _{FLTb} = 0 V, 30 V | –1 | 0 | 1 | μA |
| PGb | | | | | | |
| | Threshold | V _(SENSE – OUT) rising, PGb going high | 140 | 220 | 340 | mV |
| | Hysteresis ⁽¹⁾ | Measured V _(SENSE – OUT) falling, PGb going low | | 70 | | mV |
| | Output low voltage | Sinking 2 mA | | 0.11 | 0.25 | V |
| | Input leakage current | V _{PGb} = 0 V, 30 V | –1 | 0 | 1 | μA |

(1) These parameters are provided for reference only and do not constitute part of TI's published device specifications for purposes of TI's product warranty.

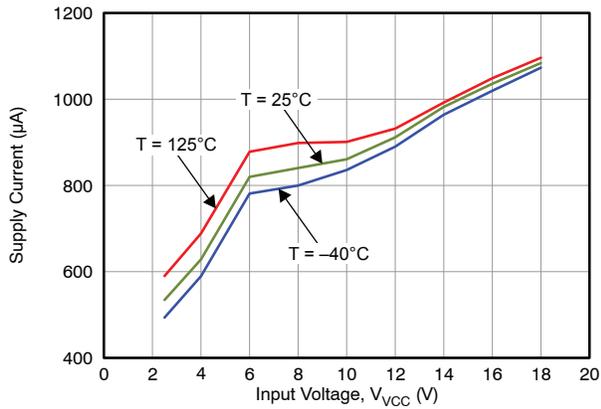
Electrical Characteristics (continued)

–40°C ≤ T_J ≤ +125°C, V_{CC} = 12 V, V_{EN} = 3 V, R_{SET} = 191 Ω, R_{IMON} = 5 kΩ, and R_{PROG} = 50 kΩ to GND. All voltages referenced to GND, unless otherwise noted.

| PARAMETER | CONDITIONS | MIN | NOM | MAX | UNIT |
|--|---|------|-------|------|------|
| Delay (deglitch) time | Rising or falling edge | 2 | 3.4 | 6 | ms |
| PROG | | | | | |
| Bias voltage | Sourcing 10 μA | 0.65 | 0.675 | 0.7 | V |
| Input leakage current | V _{PROG} = 1.5 V | –0.2 | 0 | 0.2 | μA |
| TIMER | | | | | |
| Sourcing current | V _{TIMER} = 0 V | 8 | 10 | 12 | μA |
| Sinking current | V _{TIMER} = 2 V | 8 | 10 | 12 | μA |
| | V _{EN} = 0 V, V _{TIMER} = 2 V | 2 | 4.5 | 7 | mA |
| Upper threshold voltage | | 1.3 | 1.35 | 1.4 | V |
| Lower threshold voltage | | 0.33 | 0.35 | 0.37 | V |
| Timer activation voltage | Raise GATE until I _{TIMER} sinking, measure V _(GATE – VCC) , V _{VCC} = 12 V | 5 | 5.8 | 7 | V |
| Retry duty cycle | During over current and short circuit conditions (TPS24751 only) | | 4% | | |
| IMON | | | | | |
| Circuit breaker threshold | | 650 | 675 | 696 | mV |
| Input referred offset of servo amplifier | At T _J = 25°C | –1 | 0 | 1 | mV |
| | T _J from –40°C to +125°C | –1.5 | 0 | 1.5 | mV |
| SET | | | | | |
| Input referred offset of servo amplifier | Measure SET to SENSE | –1.5 | 0 | 1.5 | mV |
| GATE | | | | | |
| Output voltage | V _{OUT} = 12 V | 23.5 | 25.7 | 28 | V |
| Clamp voltage | Inject 10 μA into GATE, measure V _(GATE – VCC) | 12 | 13.9 | 15.5 | V |
| Sourcing current | V _{GATE} = 12 V | 20 | 30 | 40 | μA |
| Sinking current | Fast turnoff, V _{GATE} = 14 V | 0.4 | 1 | 1.4 | A |
| | Sustained, V _{GATE} = 4 V to 23 V | 6 | 11 | 20 | mA |
| | In inrush current limit, V _{GATE} = 4 V to 23 V | 20 | 30 | 40 | μA |
| Pulldown resistance | Thermal shutdown or V _{EN} = 0 V | 14 | 20 | 26 | kΩ |
| Fast turnoff duration | | 8 | 13 | 18 | μs |
| Turnon delay | V _{VCC} rising to GATE sourcing, t _{prf50-50} , See Figure 29 | | 100 | 375 | μs |
| SENSE | | | | | |
| Input bias current | V _{SENSE} = 12 V, sinking current | | 30 | 40 | μA |
| Current limit threshold | V _{OUT} = 12 V | 22.5 | 25 | 27.5 | mV |
| Power limit threshold | V _{DRAIN-OUT} = 8 V, R _{PROG} = 100 kΩ | | 4 | | mV |
| | V _{DRAIN-OUT} = 8 V, R _{PROG} = 50 kΩ | 6.6 | 8 | 9.6 | |
| | V _{DRAIN-OUT} = 5.37 V, R _{PROG} = 50 kΩ | 10 | 12 | 14 | |
| | V _{DRAIN-OUT} = 10.3 V, R _{PROG} = 25 kΩ | 10 | 12.5 | 15 | |
| Fast-trip threshold | | 52 | 60 | 68 | mV |
| Fast-turnoff delay ⁽¹⁾ | V _(VCC – SENSE) = 80 mV, C _{GATE} = 0 pF, t _{prf50-50} , See Figure 30 | | 200 | | ns |
| OTSD | | | | | |
| Threshold, rising | Temperature referenced to PAD1 of the device. See ⁽²⁾ | 130 | 140 | | °C |
| Hysteresis ⁽¹⁾ | | | 10 | | °C |

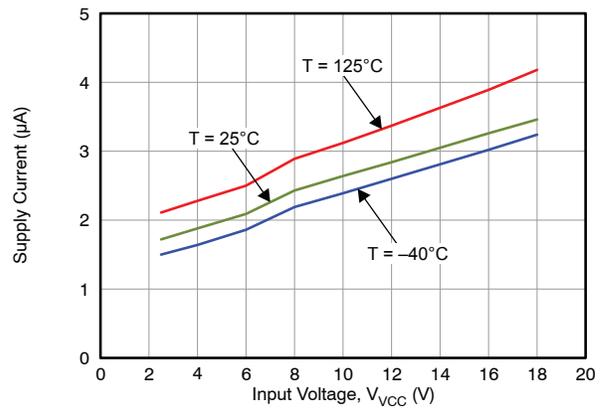
(2) The temperature difference between PAD1 and PAD2 must be minimized. See the SOA curve [Figure 27](#) and [Power-Limited Start-Up](#) section for temperature limited design.

7.6 Typical Characteristics



EN = High

Figure 1. Supply Current vs Input Voltage at Normal Operation



EN = 0 V

Figure 2. Supply Current vs Input Voltage at Shutdown

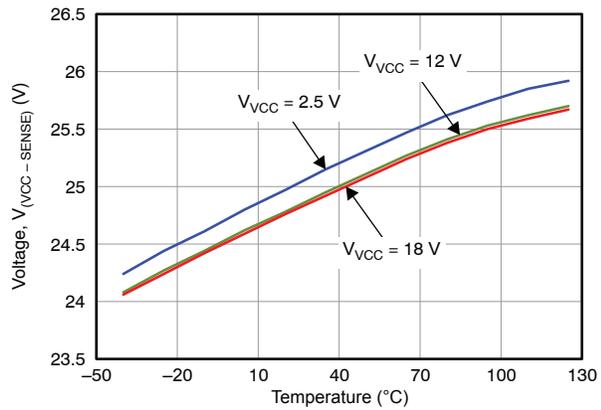


Figure 3. Voltage Across R_{SENSE} in Inrush Current Limiting vs Temperature

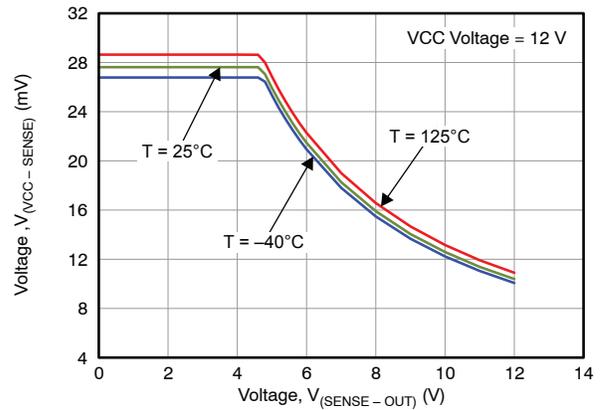


Figure 4. Voltage Across R_{SENSE} in Inrush Power Limiting vs V_{DS} of Internal FET

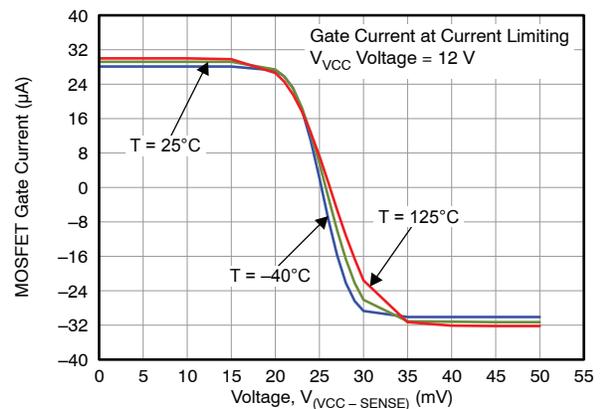


Figure 5. Internal FET Gate Current vs Voltage Across R_{SENSE} During Inrush Power Limiting

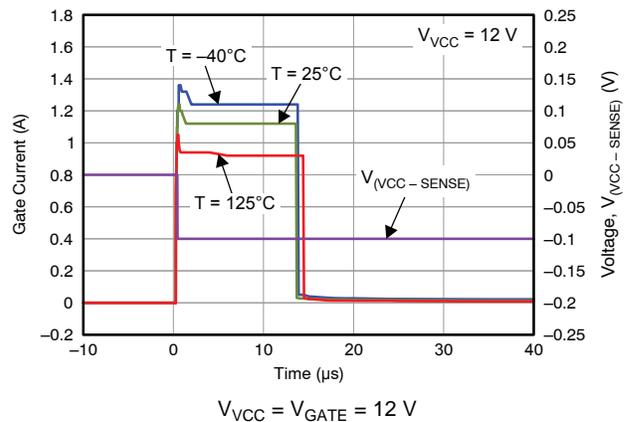
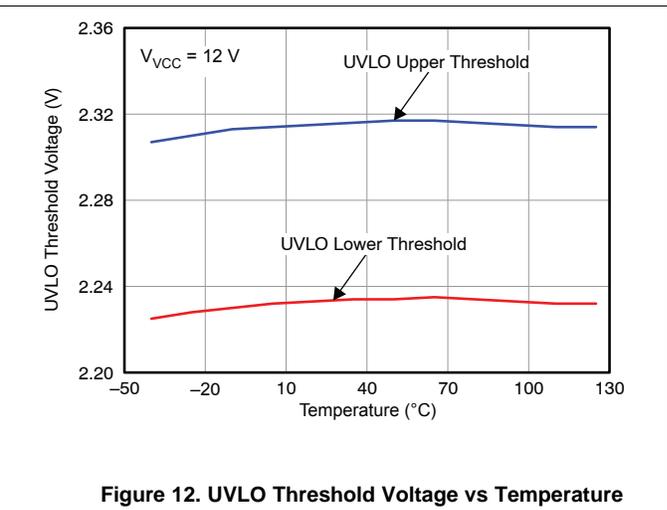
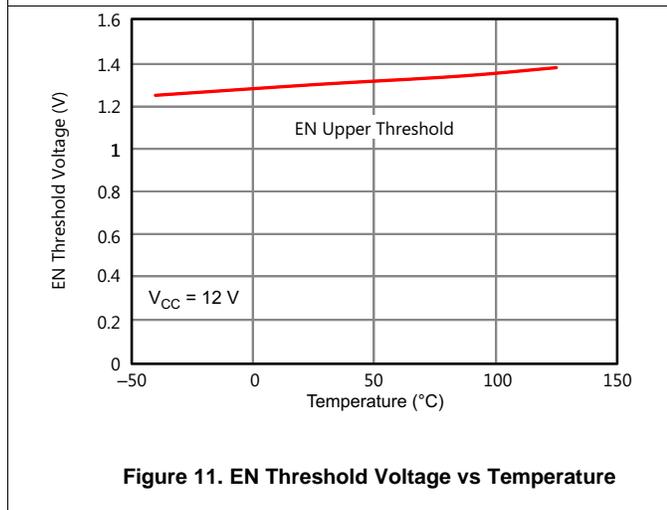
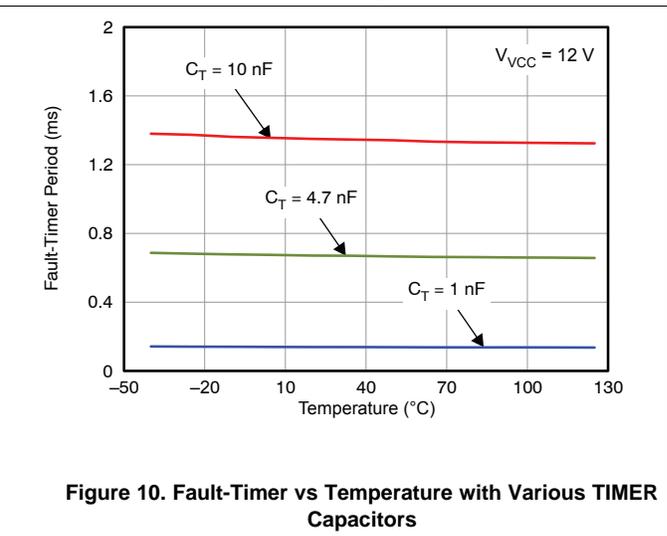
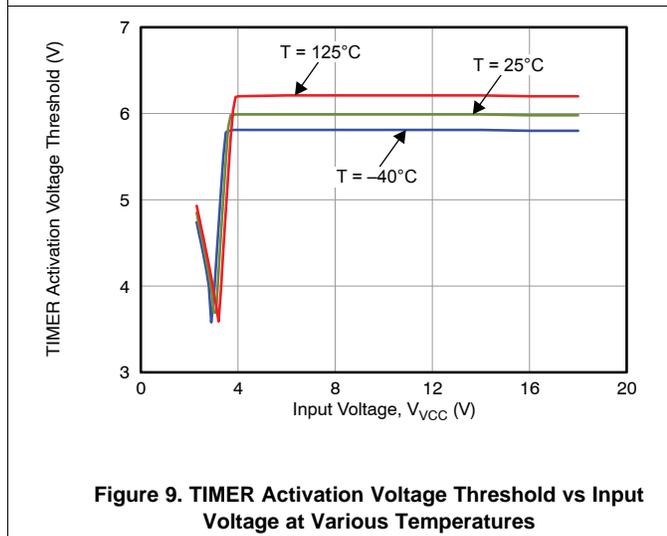
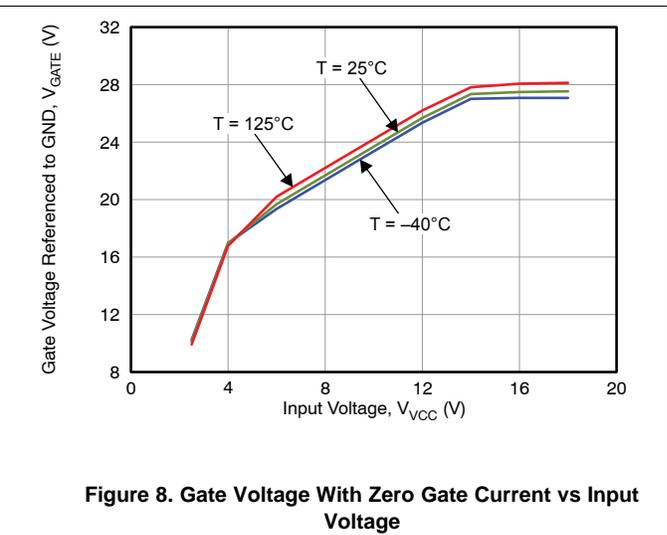
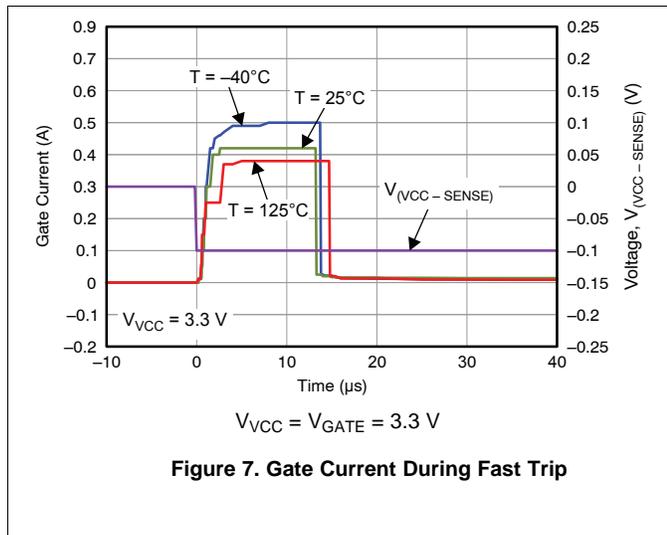


Figure 6. Gate Current During Fast Trip

Typical Characteristics (continued)



Typical Characteristics (continued)

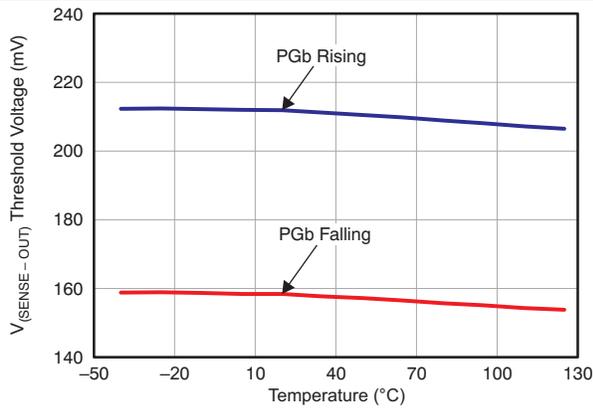


Figure 13. Threshold Voltage of V_{DS} vs Temperature, PGB Rising and Falling

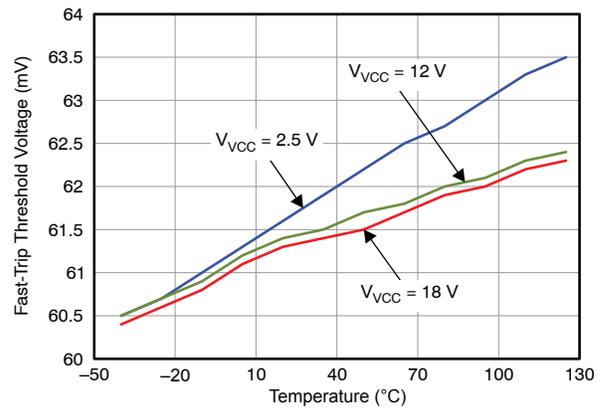


Figure 14. Fast-Trip Threshold Voltage vs Temperature

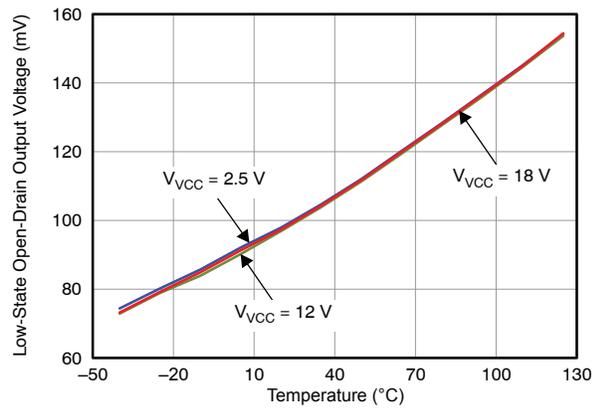


Figure 15. PGB Open-Drain Output Voltage in Low State

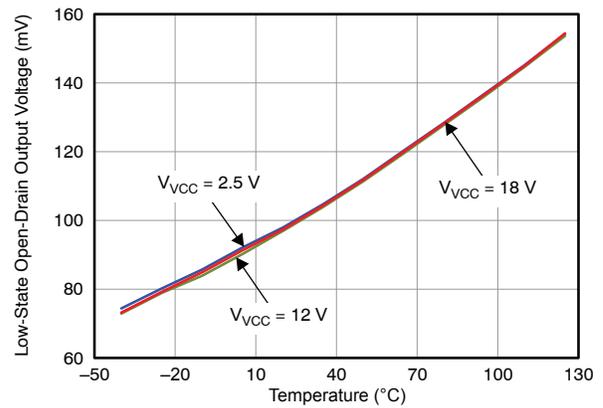


Figure 16. FLTb Open-Drain Output Voltage in Low State

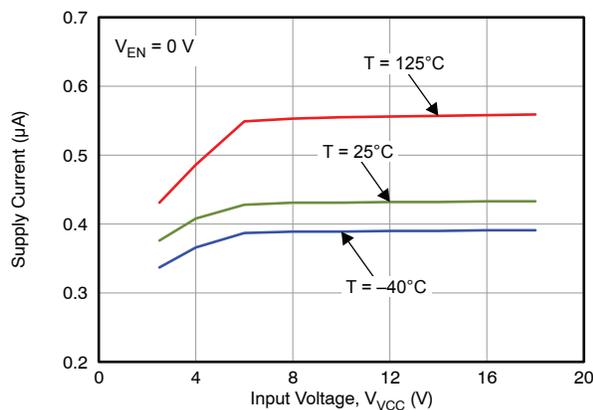


Figure 17. Supply Current vs Input Voltage at Various Temperatures when EN Pulled Low

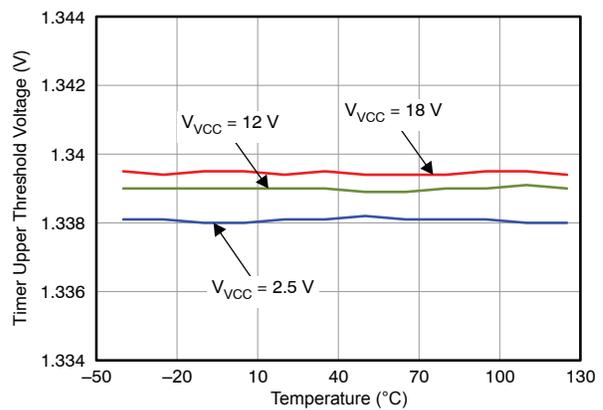


Figure 18. Timer Upper Threshold Voltage vs Temperature at Various Input Voltages

Typical Characteristics (continued)

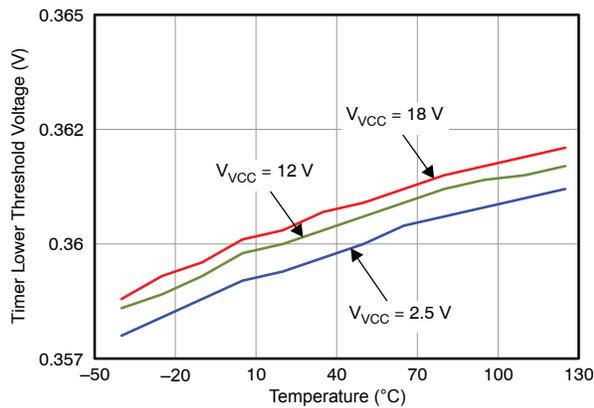


Figure 19. Timer Lower Threshold Voltage vs Temperature at Various Input Voltages

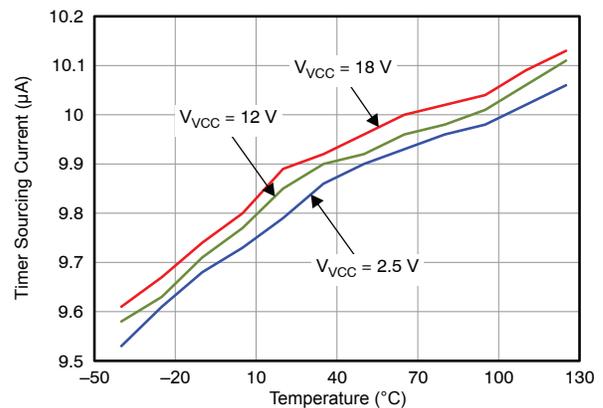


Figure 20. Timer Sourcing Current vs Temperature at Various Input Voltages

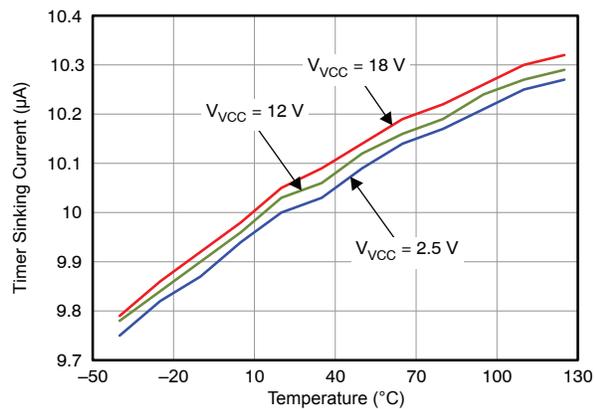


Figure 21. Timer Sinking Current vs Temperature at Various Input Voltages

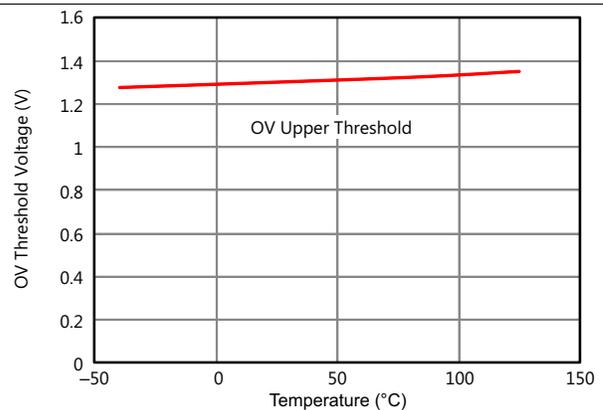


Figure 22. OV Threshold Voltage vs Temperature

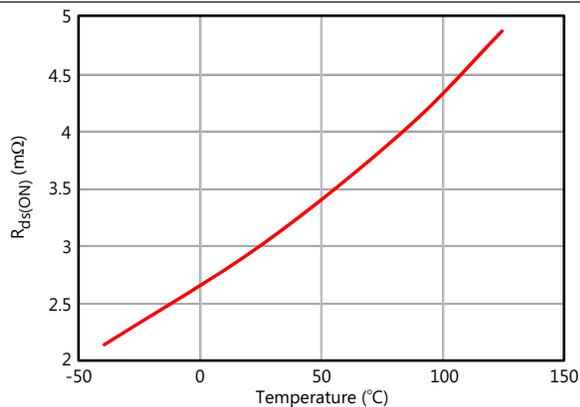


Figure 23. $R_{DS(ON)}$ vs Temperature

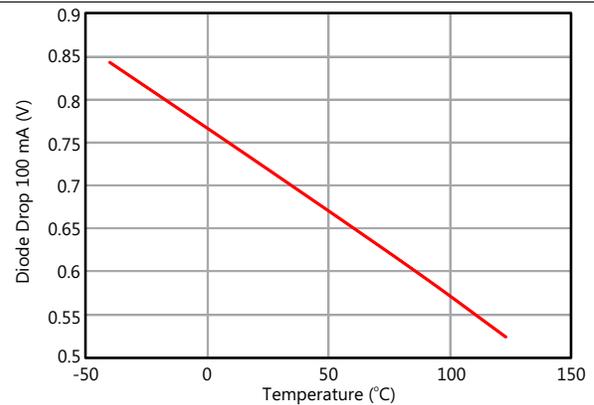


Figure 24. Diode Drop vs Temperature

Typical Characteristics (continued)

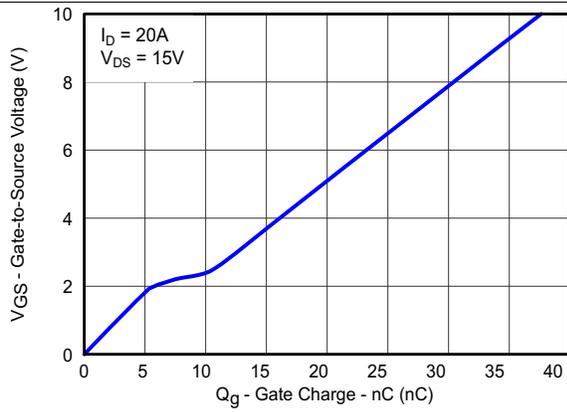


Figure 25. Gate Charge – Internal MOSFET

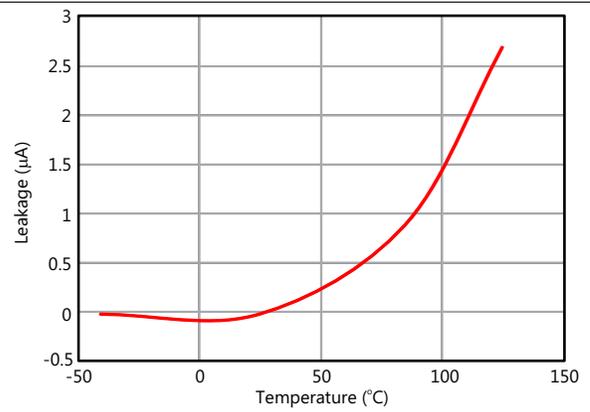


Figure 26. Leakage Current vs Temperature

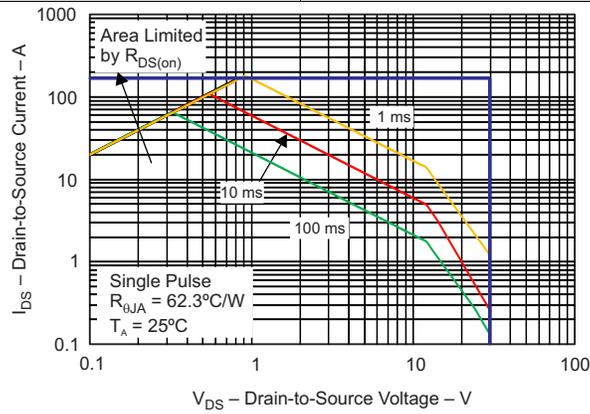


Figure 27. TPS2475x Maximum Safe Operating Area (SOA)

8 Parameter Measurement Information

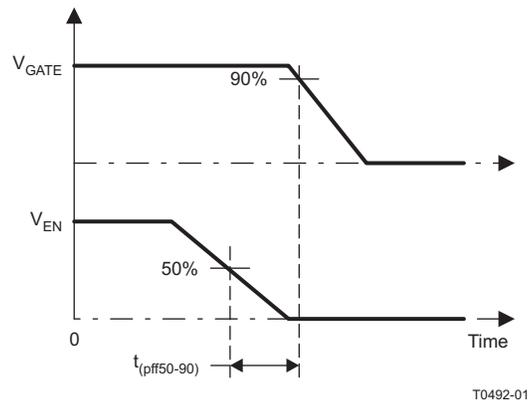


Figure 28. $t_{pff50-90}$ Timing Definition

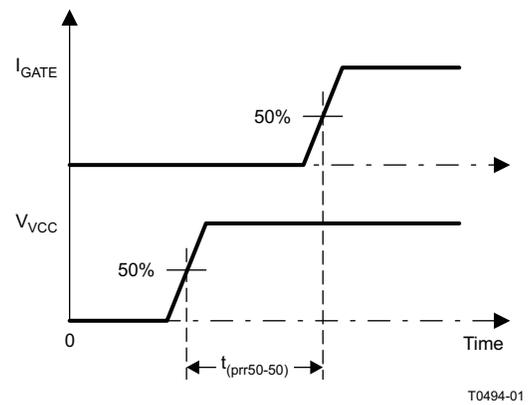


Figure 29. $t_{pr50-50}$ Timing Definition

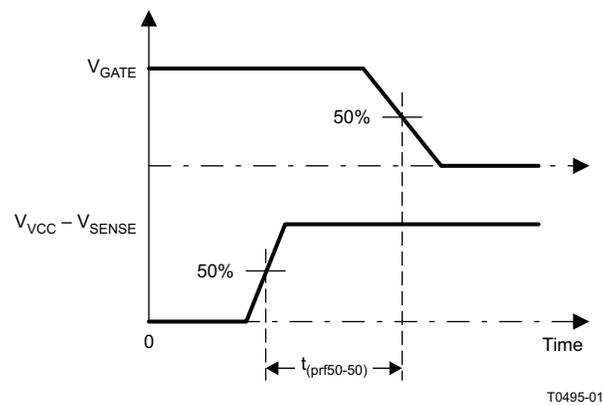


Figure 30. $t_{prf50-50}$ Timing Definition

9 Detailed Descriptions

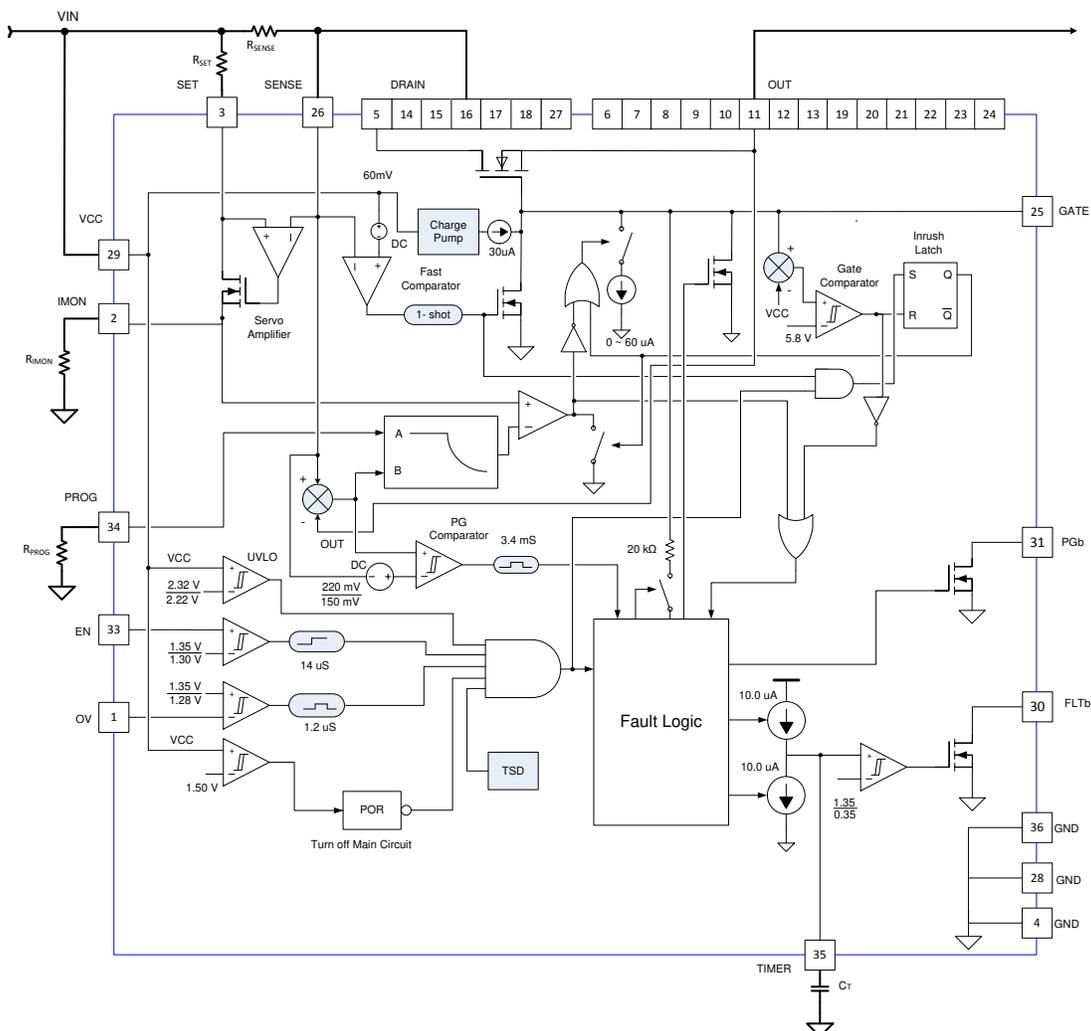
9.1 Overview

The TPS2475x provides all the features needed for a positive hot-swap protector. These features include:

- Undervoltage lockout
- Adjustable (system-level) enable
- Turnon inrush limiting
- Integrated N-channel MOSFET
- MOSFET protection by power limiting
- Electronic circuit breaker operation with adjustable overload timeout
- Charge-complete indicator for downstream converter coordination
- A choice of latch or automatic restart mode
- Load overvoltage protection
- Precise current monitor output

The typical application diagram, shown on the front page of this data sheet, and oscilloscope plots, shown in [Figure 31](#) through [Figure 33](#) and [Figure 35](#) through [Figure 39](#), demonstrate many of the functions of the device.

9.2 Functional Block Diagram



9.3 Feature Description

9.3.1 DRAIN

The drain of the internal pass MOSFET. Connect to a terminal of current sense resistor in the power path.

9.3.2 EN

Applying a voltage of 1.3 V or more to this pin enables the gate driver. The addition of an external resistor divider allows the EN pin to serve as an undervoltage monitor. Cycling EN low and then back high resets the TPS24750 that has latched off due to a fault condition. This pin must not be left floating.

9.3.3 FLTb

This active-low open-drain output pulls low when the TPS2475x has remained in current limit long enough for the fault timer to expire. The TPS24750 operates in latch mode while the TPS24751 operates in retry mode. In latch mode, a fault timeout disables the internal MOSFET and holds FLTb low. The fault is reset when EN is pulled low or VCC falls under UVLO. In retry mode, a fault timeout first disables the internal MOSFET, next waits sixteen cycles of TIMER charging and discharging, and finally attempts a restart. This process repeats as long as the fault persists. In retry mode, the FLTb pin is pulled low whenever the internal MOSFET is disabled by the fault timer. In a sustained fault, the FLTb waveform becomes a train of pulses. The FLTb pin does not assert if the internal MOSFET is disabled by EN, OV, overtemperature shutdown, or UVLO. This pin can be left floating when not used.

9.3.4 GATE

This pin provides gate drive to the internal MOSFET. A charge pump sources 30 μ A to enhance the internal MOSFET. A 13.9 V clamp between GATE and VCC limits the gate-to-source voltage since V_{VCC} is close to V_{OUT} in normal operation. During start up, a transconductance amplifier regulates the gate voltage of the internal FET to provide inrush current limiting. The TIMER pin charges timer capacitor C_T during the inrush. Inrush current limiting continues until the $V_{(GATE - VCC)}$ exceeds the Timer Activation Voltage 5.8 V for $V_{VCC} = 12$ V. Then the TPS2475x enters into circuit breaker mode. In the circuit breaker mode, the current flowing in R_{SENSE} is compared with the current limit threshold derived from the MOSFET power limit scheme (see the [PROG](#) definition). If the current flowing in R_{SENSE} exceeds the current limit threshold, then the internal pass MOSFET will be turned off. The GATE pin is disabled by the following three mechanisms:

1. GATE is pulled down by an 11-mA current source when
 - The fault timer expires during an overload current fault ($V_{IMON} > 675$ mV)
 - V_{EN} is below its falling threshold
 - V_{VCC} drops below the UVLO threshold
 - V_{OV} is above its rising threshold
2. GATE is pulled down by a 1-A current source for 13.5 μ s when a hard output short circuit occurs and $V_{(VCC - SENSE)}$ is greater than 60 mV, that is, the fast-trip shutdown threshold. After fast-trip shutdown is complete, an 11-mA sustaining current ensures that the internal FET remains off.
3. GATE is discharged by a 20-k Ω resistor to GND if the chip die temperature exceeds the OTSD rising threshold.

GATE remains low in latch mode (TPS24750) and attempts a restart periodically in retry mode (TPS24751).

Connect a capacitor from this pin to GND to control the slew rate of the output voltage at power-on. This pin can be left floating to obtain a predetermined slew rate on the output.

If used, any capacitor connecting GATE and GND must not exceed 1 μ F and it must be connected in series with a resistor of no less than 1 k Ω . No external resistor must be directly connected from GATE to GND or from GATE to OUT.

9.3.5 GND

This pin is connected to system ground.

Feature Description (continued)

9.3.6 IMON

A resistor connected from this pin to GND scales the current-limit and power-limit settings, as illustrated in the [Functional Block Diagram](#). The voltage present at this pin is proportional to the current flowing through sense resistor R_{SENSE} . This voltage can be used as a means of monitoring current flow through the system. The value of R_{IMON} can be calculated from [Equation 3](#). This pin must not have a bypass capacitor or any other load except for R_{IMON} .

9.3.7 OUT

This pin is connected to the source of the internal MOSFET inside the chip. It allows the device to measure the drain-to-source voltage across the internal MOSFET. The power good indicator (PGb) relies upon this information, as does the power limiting engine. The OUT pin must be bypassed to GND with a low-impedance ceramic capacitor in the range of 10 nF to 1 μ F. Connect all the OUT pins to output capacitors and load. In the presence of cable inductance, the OUT pin must be protected from negative voltage transients by using a clamping/Schottky diode.

9.3.8 OV

This pin is used to program the device overvoltage level. A voltage of more than 1.35 V on this pin turns off the internal FET. A resistor divider connected from VCC to this pin provides overvoltage protection for the downstream load. This pin must be tied to GND when not used.

9.3.9 PGb

This active low, open-drain output is intended to interface to downstream dc/dc converters or monitoring circuits. PGb pulls low after the drain-to-source voltage of the internal FET has fallen below 150 mV and a 3.4 ms deglitch delay has elapsed. It goes open drain when V_{DS} exceeds 220 mV. PGb assumes high impedance status after a 3.4 ms deglitch delay once V_{DS} of internal FET rises up, resulting from GATE being pulled to GND at the following conditions:

- An overload current fault occurs ($V_{IMON} > 675$ mV) and the fault timer times out.
- A hard output short circuit occurs, leading to $V_{(VCC - SENSE)}$ greater than 60 mV, that is, the fast-trip shutdown threshold has been exceeded.
- V_{EN} is below its falling threshold.
- V_{VCC} drops below the UVLO threshold.
- V_{OV} is above its rising threshold.
- Die temperature exceeds the OTSD threshold.

This pin can be left floating when not used.

9.3.10 PROG

A resistor from this pin to GND sets the maximum power permitted in the internal MOSFET during inrush. Do not apply a voltage to this pin. If the constant power limit is not desired, use a PROG resistor of 4.99 k Ω . To set the maximum power, use [Equation 1](#).

$$P_{LIM} = \frac{84375 \times R_{SET}}{R_{PROG} \times R_{SENSE} \times R_{IMON}} \quad (1)$$

where P_{LIM} is the allowed power limit of the internal MOSFET. R_{SENSE} is the load current monitoring resistor connected between the VCC pin and the SENSE pin. R_{PROG} is the resistor connected from the PROG pin to GND. Both R_{PROG} and R_{SENSE} are in ohms and P_{LIM} is in watts. P_{LIM} is determined by the maximum allowed thermal stress of internal MOSFET, given by [Equation 2](#).

$$P_{LIM} < \frac{T_{J(MAX)} - T_{C(MAX)}}{R_{\theta JC(MAX)}} \quad (2)$$

where $T_{J(MAX)}$ is the maximum desired transient junction temperature and $T_{C(MAX)}$ is the maximum case temperature prior to a start or restart. $R_{\theta JC(MAX)}$ is the junction-to-case thermal impedance of the internal pass FET in units of $^{\circ}\text{C}/\text{W}$. Both $T_{J(MAX)}$ and $T_{C(MAX)}$ are in $^{\circ}\text{C}$.

Feature Description (continued)

9.3.11 SENSE

This pin connects to the negative terminal of R_{SENSE} . It provides a means of sensing the voltage across this resistor, as well as a way to monitor the drain-to-source voltage across the internal FET. The current limit I_{LIM} is set by [Equation 3](#).

$$I_{LIM} = \frac{0.675 \text{ V} \times R_{SET}}{R_{IMON} \times R_{SENSE}} \quad (3)$$

A fast-trip shutdown occurs when $V_{(VCC - V_{SENSE})}$ exceeds 60 mV.

SET: A resistor R_{SET} is connected from this pin to the positive terminal of R_{SENSE} . This resistor scales the current limit and power limit settings. It coordinates with R_{IMON} and R_{SENSE} to determine the current limit value. The value of R_{SET} can be calculated from [Equation 3](#) (see the [SENSE](#) definition).

9.3.12 TIMER

A capacitor C_T connected from the TIMER pin to GND determines the overload fault timing. TIMER sources 10 μA when an overload is present, and discharges C_T at 10 μA otherwise. Internal FET is turned off when V_{TIMER} reaches 1.35 V. In an application implementing auto-retry after a fault, this capacitor also determines the period before the internal FET is re-enabled. A minimum timing capacitance of 1 nF is recommended to ensure proper operation of the fault timer. The value of C_T can be calculated from the desired fault time t_{FLT} , using [Equation 4](#).

$$C_T = \frac{10 \mu\text{A}}{1.35 \text{ V}} \times t_{FLT} \quad (4)$$

Either latch mode (TPS24750) or retry mode (TPS24751) occurs if the load current exceeds the current limit threshold or the fast trip shutdown threshold. While in latch mode, the TIMER pin continues to periodically charge and discharge the attached capacitor. In retry mode, the internal MOSFET is disabled for sixteen cycles of TIMER charging and discharging. The TIMER pin is pulled to GND by a 2 mA current source at the end of the 16th cycle of charging and discharging. The internal MOSFET is then re-enabled. The TIMER pin capacitor, C_T , can also be discharged to GND during latch mode or retry mode in the following way:

- A 2-mA current sinks TIMER whenever any of the following occurs:
 - V_{EN} is below its falling threshold.
 - V_{VCC} drops below the UVLO threshold.
 - V_{OV} is above its rising threshold.

TIMER is not affected when the die temperature exceeds the OTSD threshold.

9.3.13 VCC

This pin performs three functions. First, it provides biasing power to the integrated circuit. Second, it serves as an input to the power-on reset (POR) and undervoltage lockout (UVLO) functions. Bypass capacitor C_1 , shown in the typical application diagram on the front page, must be connected to the positive terminal of V_{VCC} . A capacitance of at least 10 nF is recommended.

9.4 Device Functional Modes

9.4.1 Board Plug-In

Figure 31 and Figure 32 illustrate the inrush current that flows when a hot swap board under the control of the TPS2475x is plugged into a system bus. Only the bypass capacitor charge current and small bias currents are evident when a board is first plugged in. The TPS2475x is held inactive for a short period while internal voltages stabilize. In this short period, GATE, PROG, and TIMER are held low and PGB, and FLTb, are held open-drain. When the voltage on the internal VCC rail exceeds approximately 1.5 V, the power-on reset (POR) circuit initializes the TPS2475x and a start-up cycle is ready to take place.

GATE, PROG, TIMER, PGB, and FLTb are released after the internal voltages have stabilized and the external EN (enable) thresholds have been exceeded. The part begins sourcing current from the GATE pin to turn on internal FET. The TPS2475x monitors both the drain-to-source voltage across internal MOSFET and the drain current passing through it. Based on these measurements, the TPS2475x limits the drain current by controlling the gate voltage so that the power dissipation of the internal FET does not exceed the power limit programmed by the user. The current increases as the voltage across the FET decreases until finally the current reaches the current limit I_{LIM} .

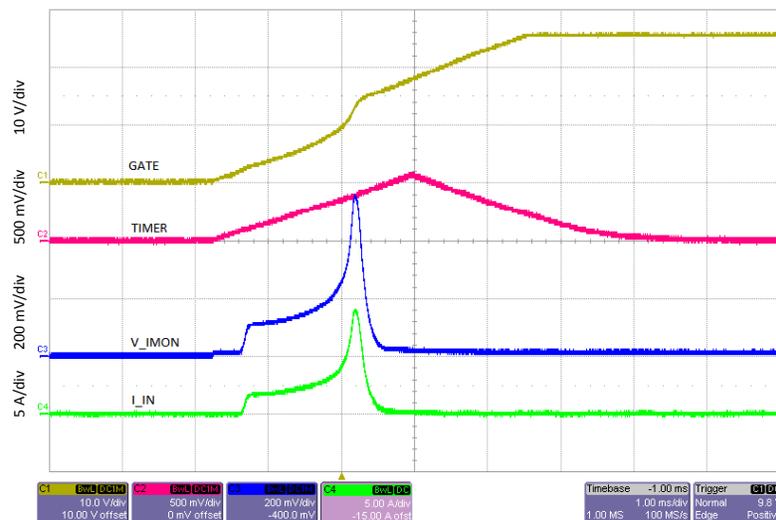


Figure 31. Inrush Mode at Hot-Swap Circuit Insertion

9.4.2 Inrush Operation

After the TPS2475x initialization is complete (as described in the [Board Plug-in section](#)) and EN is active, GATE is enabled (V_{GATE} starts increasing), when V_{GATE} reaches the internal FET gate threshold, a current flows into the downstream bulk storage capacitors. When this current exceeds the limit set by the power-limit engine, the gate of the internal FET is regulated by a feedback loop to make the internal FET current rise in a controlled manner. This not only limits the capacitor-charging inrush current but it also limits the power dissipation of the internal FET to safe levels. A more complete explanation of the power-limiting scheme is given in the [Action of the Constant-Power Engine](#) section. When the GATE is enabled, the TIMER pin begins to charge the timing capacitor C_T with a current of approximately 10 μ A. The TIMER pin continues to charge C_T until $V_{(GATE-VCC)}$ reaches the timer activation voltage (5.8 V for $V_{VCC} = 12V$). The TIMER then begins to discharge C_T with a current of approximately 10 μ A. This indicates that the inrush mode is finished. If the TIMER exceeds its upper threshold of 1.35 V before $V_{(GATE - VCC)}$ reaches the timer activation voltage, the GATE pin is pulled to GND and the hot-swap circuit enters either latch mode (TPS24750) or auto-retry mode (TPS24751).

The power limit feature is disabled once the inrush operation is finished and the hotswap circuit becomes a circuit breaker. The TPS2475x turns off the internal FET after a fault timer period once the load exceeds the current limit threshold.

Device Functional Modes (continued)

9.4.3 Action of the Constant-Power Engine

Figure 32 illustrates the operation of the constant-power engine during start-up. The circuit used to generate the waveforms of Figure 32 was programmed to a power limit of 21 W by means of the resistor connected between PROG and GND. At the moment current begins to flow through the internal FET, a voltage of 12 V appears across it (input voltage $V_{VCC} = 12$ V), and the constant-power engine therefore allows a current of 1.75 A (equal to 21 W divided by 12 V) to flow. This current increases in inverse ratio as the drain-to-source voltage diminishes, so as to maintain a constant dissipation of 21 W. The constant-power engine adjusts the current by altering the reference signal fed to the current limit amplifier. The lower part of Figure 32 shows the measured power dissipated in the internal FET, labeled FET_PWR, remaining substantially constant during this period of operation, which ends when the current through the FET reaches the current limit I_{LIM} . This behavior can be considered a form of foldback limiting, but unlike the standard linear form of foldback limiting, it allows the power device to operate near its maximum capability, thus reducing the start-up time.

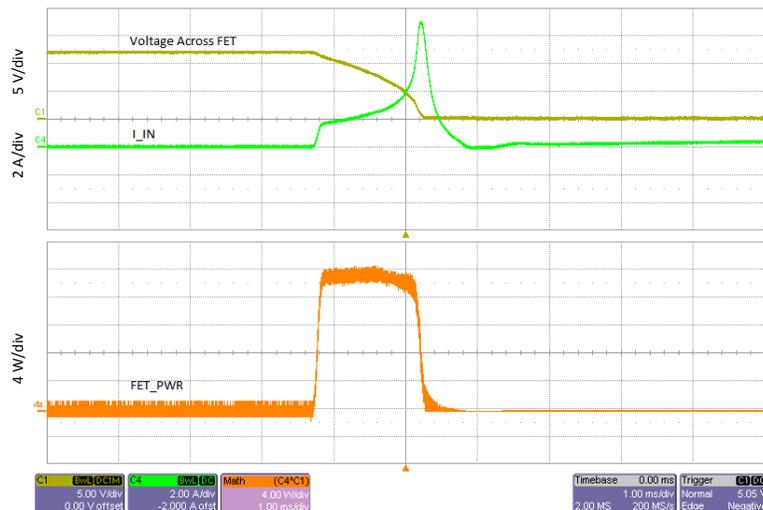


Figure 32. Computation of Power Stress During Startup

9.4.4 Circuit Breaker and Fast Trip

The TPS2475x monitors load current by sensing the voltage across R_{SENSE} . The TPS2475x incorporates two distinct thresholds: a current-limit threshold and a fast-trip threshold.

The functions of circuit breaker and fast-trip turnoff are shown in Figure 33 through Figure 36.

Figure 33 shows the behavior of the TPS2475x when a fault in the output load causes the current passing through R_{SENSE} to increase to a value above the current limit but less than the fast-trip threshold. When the current exceeds the current-limit threshold, a current of approximately 10 μ A begins to charge timing capacitor C_T . If the voltage on C_T reaches 1.35 V, then the internal FET is turned off. The TPS24750 version latches off, while as the TPS24751 version commences a restart cycle. In either event, fault pin FLTb pulls low to signal a fault condition. Overload between the current limit and the fast-trip threshold is permitted for this period. This shutdown scheme is sometimes called an electronic circuit breaker.

The fast-trip threshold protects the system against a severe overload or a dead short circuit. When the voltage across the sense resistor R_{SENSE} exceeds the 60-mV fast-trip threshold, the GATE pin immediately pulls the internal FET gate to ground with approximately 1 A of current. The fast-trip circuit holds the internal FET off for only a few microseconds, after which the TPS2475x turns back on slowly, allowing the current-limit feedback loop to take over the gate control of the internal FET. Then the hot-swap circuit goes into latch mode (TPS24750) or auto-retry mode (TPS24751). Figure 35 and Figure 36 illustrate the behavior of the system when the current exceeds the fast-trip threshold.

Device Functional Modes (continued)

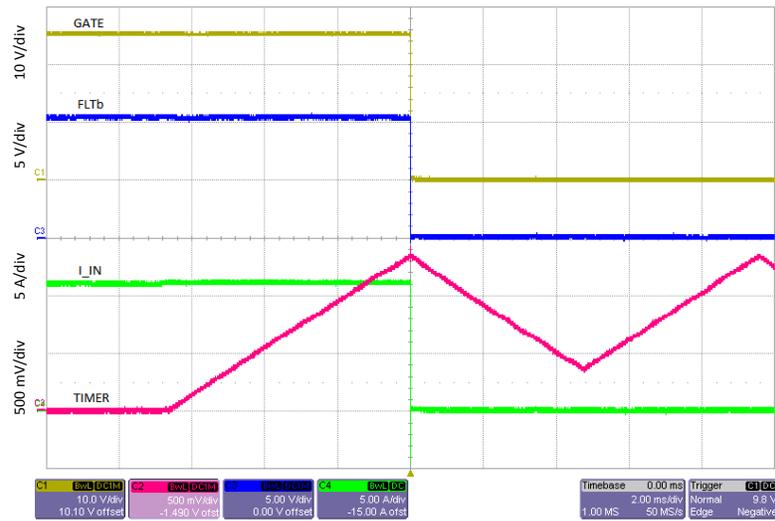


Figure 33. Circuit-Breaker Mode During Overload Condition

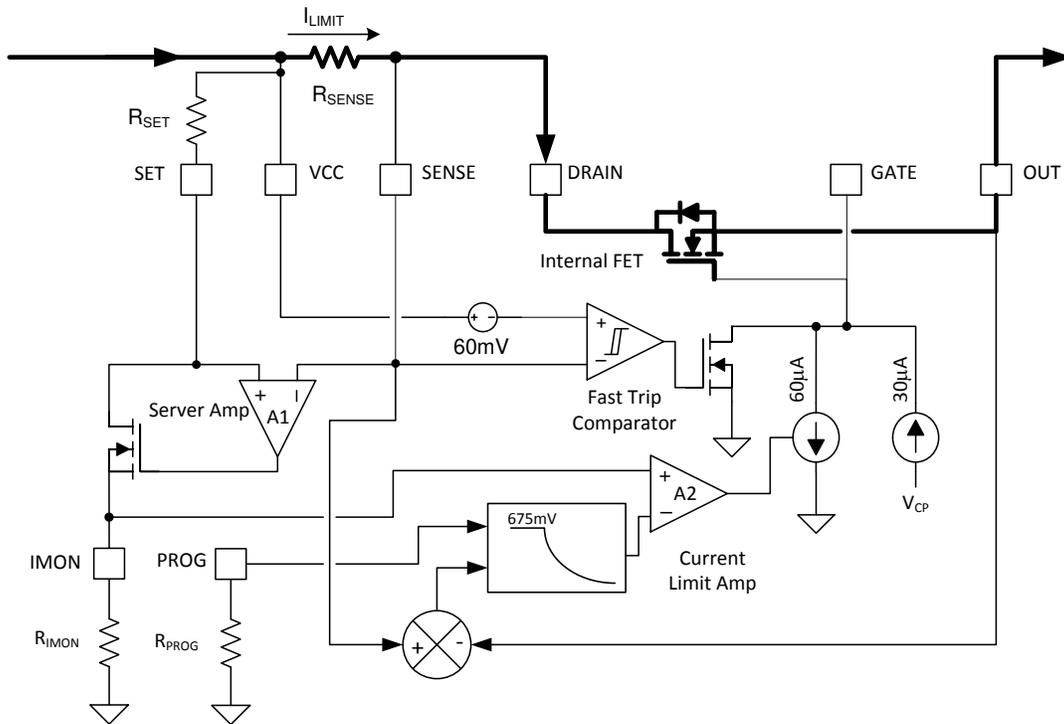
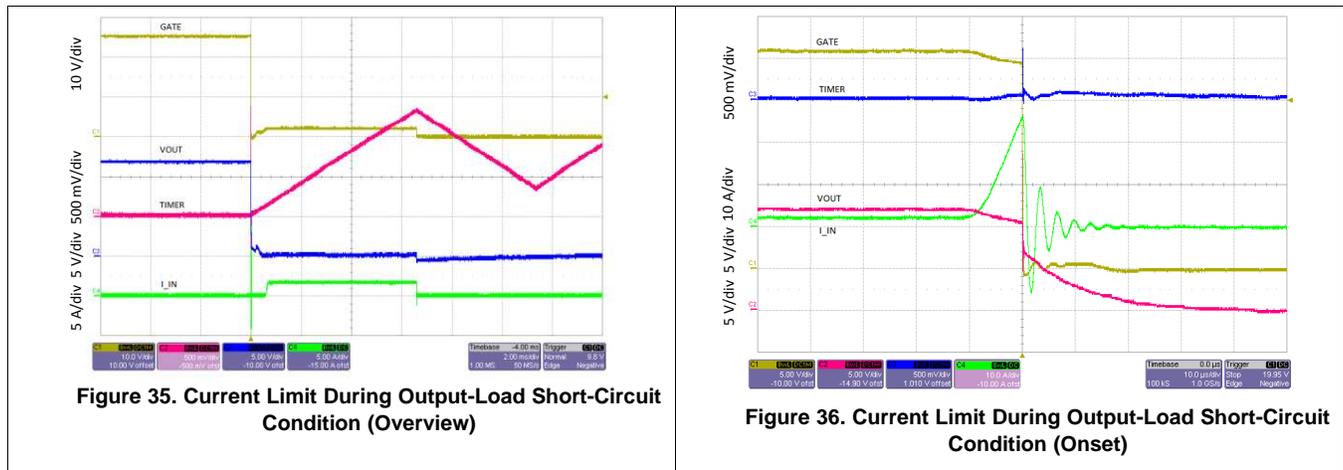


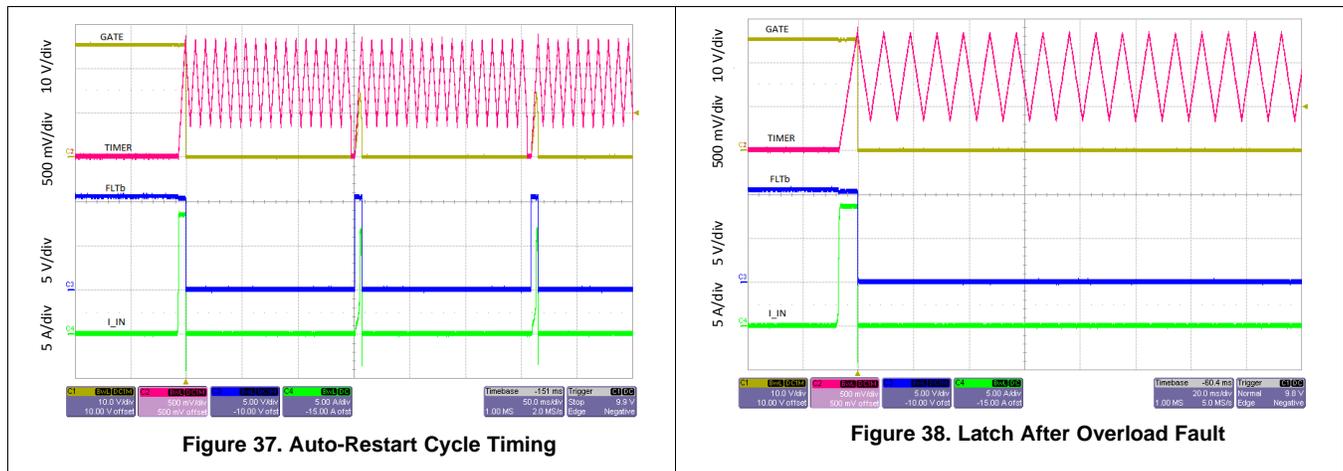
Figure 34. Partial Diagram of the TPS2475x with Selected External Components

Device Functional Modes (continued)



9.4.5 Automatic Restart

In Auto-retry versions (TPS24751), device automatically initiates a restart after a fault has caused it to turnoff the internal FET. Internal control circuits use C_T to count 16 cycles before re-enabling the FET as shown in [Figure 37](#). This sequence repeats if the fault persists. The timer has a 1:1 charge-to-discharge current ratio. For the very first cycle, the TIMER pin starts from 0 V and rises to the upper threshold of 1.35 V and subsequently falls to 0.35 V before restarting. For the following 16 cycles, 0.35 V is used as the lower threshold. This small duty cycle often reduces the average short-circuit power dissipation to levels associated with normal operation and eliminates special thermal considerations for surviving a prolonged output short.



Device Functional Modes (continued)

9.4.6 Start-Up with Short on Output

The TPS2475x has ability of detecting the short at the output during start-up and ensure shutdown of the hot-swap circuit/system with fault indication. During start-up, after the initialization process is complete and the GATE is enabled, the device limits the power as explained in the *Action of the Constant-Power Engine* section and the TIMER pin begins to charge the timing capacitor CT with approximately 10 μ A constant current source. If the voltage on CT reaches its upper limit threshold of 1.35V, during start-up cycle itself, then the internal FET is turned off and fault pin FLTb is pulled low to signal the fault condition. After this, the hot-swap circuit enters either in latch mode (TPS24750) or auto-retry mode (TPS24751). Figure 39 shows the behavior of the TPS2475x for start-up with short on the output.

This feature help to ensure early detection of fault and quick isolation of the subsystem to ensure stability of the other units connected on the DC bus.

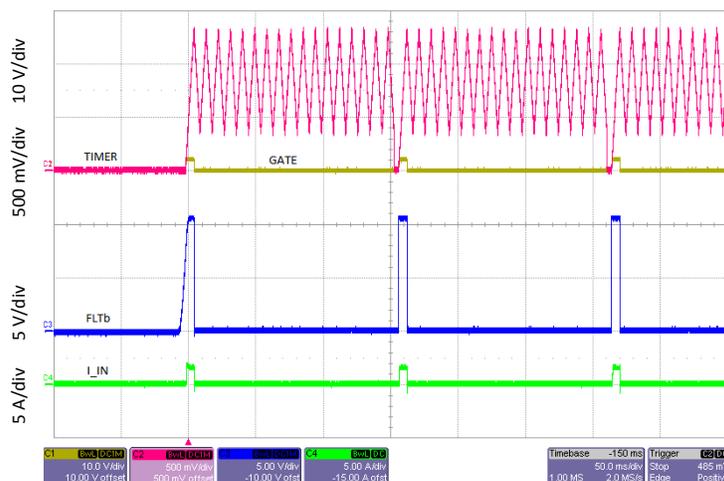


Figure 39. Start-Up with Short on Output

Device Functional Modes (continued)

9.4.7 PGb, FLTb, and Timer Operations

The open-drain PGb output provides a deglitched end-of-inrush indication based on the voltage across internal FET. PGb is useful for preventing a downstream dc/dc converter from starting while its input capacitor C_{OUT} is still charging. PGb goes active-low about 3.4 ms after C_{OUT} is charged. This delay allows the internal FET to fully turn on and any transients in the power circuits to end before the converter starts up. This type of sequencing prevents the downstream converter from demanding full current before the power-limiting engine allows the internal FET to conduct the full current set by the current limit I_{LIM} . Failure to observe this precaution may prevent the system from starting. The pullup resistor shown on the PGb pin in the typical system block diagram application diagram [Figure 41](#) is illustrative only; the actual connection to the converter depends on the application. The PGb pin may indicate that inrush has ended before the MOSFET is fully enhanced, but the downstream capacitor will have been charged to substantially its full operating voltage. After the hot-swap circuit successfully starts up, the PGb pin can return to a high-impedance status whenever the drain-to-source voltage of internal FET exceeds its upper threshold of 340 mV, which presents the downstream converters a warning flag. This flag may occur as a result of overload fault, output short fault, input overvoltage, higher die temperature, or the GATE shutdown by UVLO, EN.

FLTb is an indicator that the allowed fault-timer period during which the load current can exceed the programmed current limit (but not the fast-trip threshold) expires. The fault timer starts when a current of approximately 10 μ A begins to flow into the external capacitor C_T , and ends when the voltage of C_T reaches TIMER upper threshold, that is, 1.35 V. FLTb pulls low at the end of the fault timer. Otherwise, FLTb assumes a high-impedance state.

The fault-timer state requires an external capacitor C_T connected between the TIMER pin and GND pin. The duration of the fault timer is the charging time of C_T from 0 V to its upper threshold of 1.35 V. The fault timer begins to count under any of the following three conditions:

1. In the inrush mode, TIMER begins to source current to the timer capacitor, C_T , when device is enabled. TIMER begins to sink current from the timer capacitor, C_T when $V_{(GATE - VCC)}$ exceeds the timer activation voltage (see the *Inrush Operation* section). If $V_{(GATE - VCC)}$ does not reach the timer activation voltage before TIMER reaches 1.35 V, then the TPS2475x disables the internal FET. After the MOSFET turns off, the timer goes into either latch mode (TPS24750) or retry mode (TPS24751).
2. In an overload fault, TIMER begins to source current to the timer capacitor, C_T , when the load current exceeds the programmed current limits. When the timer capacitor voltage reaches its upper threshold of 1.35 V, TIMER begins to sink current from the timer capacitor, C_T , and the GATE pin is pulled to ground. After the fault timer period, TIMER may go into latch mode (TPS24750) or retry mode (TPS24751).
3. In output short-circuit fault, TIMER begins to source current to the timer capacitor, C_T , when the load current exceeds the programmed current limits following a fast-trip shutdown of internal FET. When the timer capacitor voltage reaches its upper threshold of 1.35 V, TIMER begins to sink current from the timer capacitor, C_T , and the GATE pin is pulled to ground. After the fault timer period, TIMER may go into latch mode (TPS24750) or retry mode (TPS24751).

If the fault current drops below the programmed current limit within the fault timer period, V_{TIMER} decreases and the internal pass MOSFET remains enabled.

The behaviors of TIMER are different in the latch mode and retry mode. If the timer capacitor reaches the upper threshold of 1.35 V, then:

- In latch mode (TPS24750), the TIMER pin continues to charge and discharge the attached capacitor periodically until device is disabled by UVLO, EN, or OV, as shown in [Figure 38](#).
- In retry mode (TPS24751), TIMER charges and discharges C_T between the lower threshold of 0.35 V and the upper threshold of 1.35 V for sixteen cycles before the device attempts to re-start. The TIMER pin is pulled to GND at the end of the 16th cycle of charging and discharging and then ramps from 0 V to 1.35 V for the initial half-cycle in which the GATE pin sources current. This periodic pattern is stopped once the overload fault is removed or the TPS2475x is disabled by UVLO, EN or OV.

Device Functional Modes (continued)

9.4.7.1 Overtemperature Shutdown

The TPS2475x includes a built-in overtemperature shutdown circuit designed to disable the gate driver and hence turnoff the internal FET if the die temperature exceeds approximately 140°C. An overtemperature condition also causes the FLTb and PGb pins to go to high-impedance states. Normal operation resumes once the die temperature has fallen approximately 10°C.

9.4.7.2 Start-Up of Hot-Swap Circuit by VCC or EN

The connection and disconnection between a load and the input power bus are controlled by turning on and turning off the internal FET.

The TPS2475x has two ways to turn on the internal FET:

- Increasing V_{VCC} above UVLO upper threshold while EN is already higher than its upper threshold sources current to the gate of internal FET. After an inrush period, the TPS2475x fully turns on internal FET.
- Increasing EN above its upper threshold while V_{VCC} is already higher than the UVLO upper threshold sources current to the gate of internal FET. After an inrush period, the TPS2475x fully turns on internal FET.

The EN pin can be used to start up the TPS2475x at a selected input voltage V_{VCC} .

To isolate the load from the input power bus, the internal FET can be disabled by any of the following conditions: UVLO, EN, load current above the current-limit threshold, hard short at load, OV, or OTSD. Three separate mechanisms disable the internal FET by pulling down the GATE as described below:

1. GATE is pulled down by an 11-mA current source when any of the following occurs.
 - The fault timer expires during an overload current fault ($V_{IMON} > 675$ mV).
 - V_{EN} is below its falling threshold.
 - V_{VCC} drops below the UVLO threshold.
 - V_{OV} is above its rising threshold.
2. GATE is pulled down by a 1-A current source for 13.5 μ s when a hard output short circuit occurs and $V_{(VCC - SENSE)}$ is greater than 60 mV, that is, the fast-trip shutdown threshold. After fast-trip shutdown is complete, an 11-mA sustaining current ensures that the internal FET remains off.
3. GATE is discharged by a 20-k Ω resistor to GND if the chip die temperature exceeds the OTSD rising threshold.

10 Application and Implementation

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

10.1 Application Information

The TPS2475x provide highly integrated load protection for 2.5 V to 18 V applications. The devices integrate a hot swap controller and a power MOSFET in a single package for small form factor applications. These devices protect source, load and internal MOSFET from potentially damaging events in applications such as Servers, Plug-In Modules, RAID systems, Base stations and Fan Control.

The following design procedure can be used to select component values for the device.

Additionally, a spreadsheet design tool [TPS2475x Design Calculator Tool \(SLVC545\)](#) is available on web folder.

10.2 Typical Application

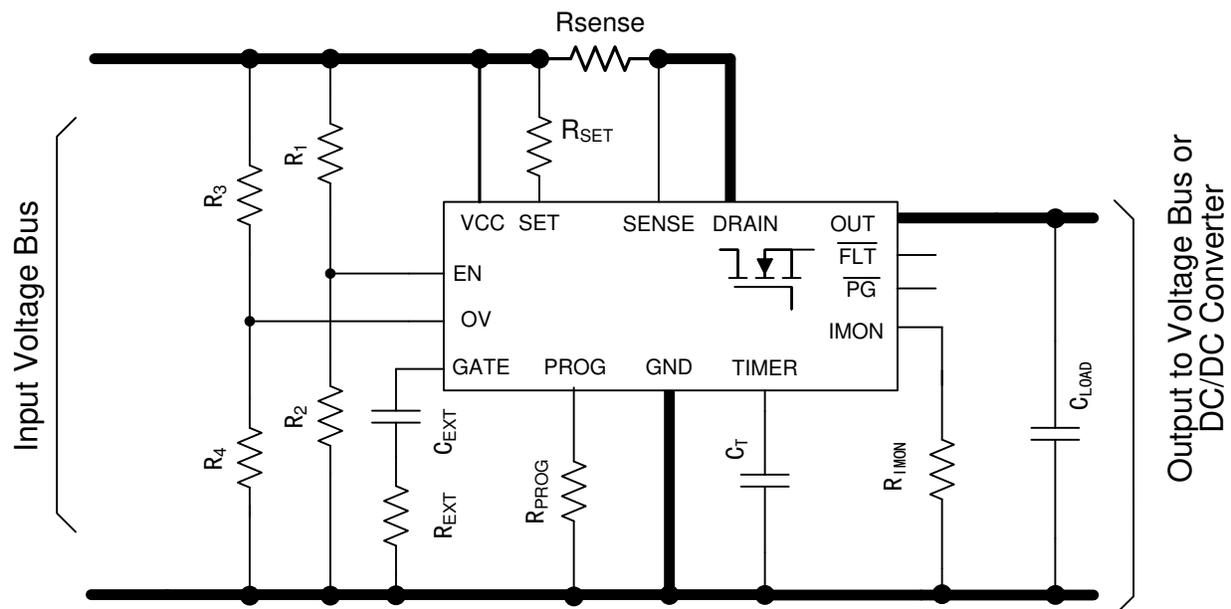


Figure 40. Gate Capacitor (dV/dt) Control Inrush Mode

10.2.1 Design Requirements

For this design example, use the parameters shown in [Table 1](#).

Table 1. Design Parameters

| Parameter | Value |
|--|--------------|
| Input voltage $V_{(VCC)}$ | 12 V |
| Undervoltage lockout set point, V_{UV} | 8.4 V |
| Overvoltage protection set point, V_{OV} | 14 V |
| Load after PG asserted, R_{LOAD} | 1.2 Ω |
| Current limit, I_{LIM} | 11 A |
| Load capacitance, C_{OUT} | 470 μ F |
| Maximum ambient temperatures, T_A | 60°C |

$$I_{LIM} = \frac{0.675 \text{ V} \times R_{SET}}{R_{IMON} \times R_{SENSE}}$$

therefore,

$$R_{IMON} = \frac{0.675 \text{ V} \times 51.1}{11 \times 0.002} = 1567.8 \quad (5)$$

10.2.2.1.2 STEP 2. Choose Power-Limit Value, P_{LIM} , and R_{PROG}

The internal MOSFET dissipates large amounts of power during inrush. The power limit P_{LIM} of the TPS2475x must be set to prevent the internal FET die temperature from exceeding a short-term maximum temperature, $T_{J(MAX)2}$. The short-term $T_{J(MAX)2}$ could be set $\leq 125^\circ\text{C}$ to have sufficient margin to the internal maximum FET junction temperature. Equation 6 is an expression for calculating P_{LIM} .

$$P_{LIM} \leq 0.8 \times \frac{T_{J(MAX)2} - \left[(I_{MAX}^2 \times R_{DS(on)} \times R_{\theta CA}) + T_{A(MAX)} \right]}{R_{\theta JC}}$$

therefore,

$$P_{LIM} \leq 0.8 \times \frac{125^\circ\text{C} - \left[((11 \text{ A})^2 \times 5 \text{ m}\Omega \times (33.7^\circ\text{C/W} - 1.1^\circ\text{C/W})) + 60^\circ\text{C} \right]}{1.1^\circ\text{C/W}} = 32.93 \text{ W} \quad (6)$$

In the above equation, $R_{\theta CA} = R_{\theta JA} - R_{\theta JC}$

Where, $R_{\theta CA}$ is the case-to-ambient thermal resistance ($R_{\theta CA}$ is a strong function of the user defined PCB layout and heat sinking provided on Pad-2 of the device and can vary accordingly), $R_{\theta JA}$ is the junction-to-ambient thermal resistance and $R_{\theta JC}$ is the junction-to-case thermal resistance of the device, (In Equation 6, the values are used from the TPS2475x [Thermal Information](#) table), $r_{DS(on)}$ is internal FET on-resistance at the maximum operating temperature, and the factor of 0.8 represents the tolerance of the constant-power engine. For an ambient temperature of 60°C , the calculated maximum P_{LIM} is 33 W. Power limit selected must be lower than value obtained in Equation 6, to have substantial safe margin considering the tolerance of components and extended system temperatures. Power limit (P_{LIM}) of 21 W is considered for this design. From Equation 1, a 64.9-k Ω , 1% resistor is selected for R_{PROG} (see Equation 7).

$$R_{PROG} = \frac{84375 \times R_{SET}}{P_{LIM} \times R_{SENSE} \times R_{IMON}}$$

therefore,

$$R_{PROG} = \frac{84375 \times 51.1}{21 \times 0.002 \Omega \times 1580 \Omega} = 64.97 \text{ k}\Omega \quad (7)$$

Power Limit fold back (P_{LIM-FB}) is the ratio of operating current (I_{LIM}) and minimum power limited (regulated) current (when $V_{OUT} = 0\text{V}$). Degradation of programmed power limit (P_{LIM}) accuracy and start up issues may occur if P_{LIM-FB} is too large. Equation 8 calculates V_{SNS-PL_MIN} (minimum sense voltage during power limit) and P_{LIM-FB} . To ensure reliable operation, verify that $P_{LIM-FB} < 12$ and $V_{SNS-PL_MIN} \geq 3\text{mV}$.

$$V_{SNS-PL_MIN} = \frac{P_{LIM} \times R_{SENSE}}{V_{CC(MAX)}} = \frac{21\text{W} \times 2 \text{ m}\Omega}{14 \text{ V}} = 3 \text{ mV} (\geq 3 \text{ mV})$$

$$P_{LIM-FB} = \frac{I_{LIM} \times V_{CC(MAX)}}{P_{LIM}} = \frac{11 \text{ A} \times 14 \text{ V}}{21 \text{ W}} = 7.33 (< 12) \quad (8)$$

If the above conditions are not met, please adjust and align R_{SENSE} , P_{LIM} set, and $T_{A(MAX)}$ appropriately to satisfy the above conditions.

10.2.2.1.3 STEP 3. Choose Output Voltage Rising Time, t_{ON} , and Timing Capacitor C_T

The maximum output voltage rise time, t_{ON} , set by timer capacitor C_T must suffice to fully charge the load capacitance C_{OUT} without triggering the fault circuitry. Equation 9 defines t_{ON} for two possible inrush cases. Assuming that only the load capacitance draws current during startup,

$$t_{ON} = \begin{cases} \frac{C_{OUT} \times P_{LIM}}{2 \times I_{LIM}^2} + \frac{C_{OUT} \times V_{VCC(MAX)}^2}{2 \times P_{LIM}} & \text{if } P_{LIM} < I_{LIM} \times V_{VCC(MAX)} \\ \frac{C_{OUT} \times V_{VCC(MAX)}}{I_{LIM}} & \text{if } P_{LIM} > I_{LIM} \times V_{VCC(MAX)} \end{cases}$$

therefore,

$$t_{ON} = \frac{470 \mu\text{F} \times 21 \text{ W}}{2 \times (11 \times 11)} + \frac{470 \mu\text{F} \times 14 \times 14}{2 \times 21} = 2.234 \text{ ms} \quad (9)$$

The next step is to determine the minimum fault-timer period. In Equation 9, the output rise time is t_{ON} . This is the amount of time it takes to charge the output capacitor up to the final output voltage. However, the fault timer uses the difference between the input voltage and the gate voltage to determine if the TPS2475x is still in inrush limit. The fault timer continues to run until V_{GS} rises 5.8 V (for $V_{VCC} = 12 \text{ V}$) above the input voltage. Some additional time must be added to the charge time to account for this additional gate voltage rise. The minimum fault time can be calculated using Equation 10.

$$t_{FLT} = t_{ON} + \frac{Q_{GINT} + Q_{GBLK}}{I_G}$$

therefore,

$$t_{FLT} = t_{ON} + \frac{22 \text{ nC} + 17 \text{ nC}}{20 \mu\text{A}} = t_{ON} + 1.95 \text{ ms} = 4.184 \text{ ms} \quad (10)$$

where Q_{GINT} is the Gate charge of the internal FET to reach the 5.8 V gate voltage (see Figure 25), Q_{GBLK} is the Gate charge of blocking FET (for this design, it is considered that CSD17501Q5A SLPS303 blocking FET is used, take this as '0' if blocking FET is not used) and I_{GATE} is the minimum gate sourcing current of the TPS2475x, or 20 μA . Overall, Equation 10 leads to a minimum fault time of 4.184 ms. Considering the tolerances of C_{OUT} , C_T , I_{LIM} , I_{TIMER} and P_{LIM} , the fault timer must be set to a value ≥ 1.4 times of t_{FLT} obtained, to avoid turning off during start-up, but need to be lower than any maximum fault time limit determined by the device SOA curve (see Figure 27).

For this example, we select 6.3 ms ($1.5 \times T_{FLT}$) to allow for variation of system parameters such as temperature, load, component tolerance, and input voltage. As per SOA curve ($T_A = 25^\circ\text{C}$), for approximately 6.5 ms, the power handled by the device is approximately 70 W at 12 V (value obtained from extrapolation). This need to be scaled (derated) by a factor of $(150 - T_{JDCMAX}) / (150 - T_A)$, where T_{JDCMAX} is the maximum steady state junction temperature ($T_{JDCMAX} = T_{A(MAX)} + I_{LIM}^2 \times R_{(DS)ON} \times R_{\theta JA}$). The scaled power is approximately 34 W. So the power limit of 21 W considered has safe margin of 38% over the derated SOA. This can be depicted through the Figure 42. Also, from Figure 42, from the blue dotted line shown, it can be analyzed that the device at $T_A = 25^\circ\text{C}$, can tolerate 12 V and 10 A for approximately time 1 ms and can take power of 21 W for duration of approximately 70 to 75 ms.

The timing capacitor is calculated in Equation 11 as 46.67 nF. Selecting the next-highest standard value, 47 nF, yields a 6.35 ms fault time.

$$C_T = \frac{10 \mu\text{A} \times t_{\text{FLT}}}{1.35}$$

therefore,

$$C_T = \frac{10 \mu\text{A} \times 6.3 \text{ ms}}{1.35} = 46.67 \text{ nF} \tag{11}$$

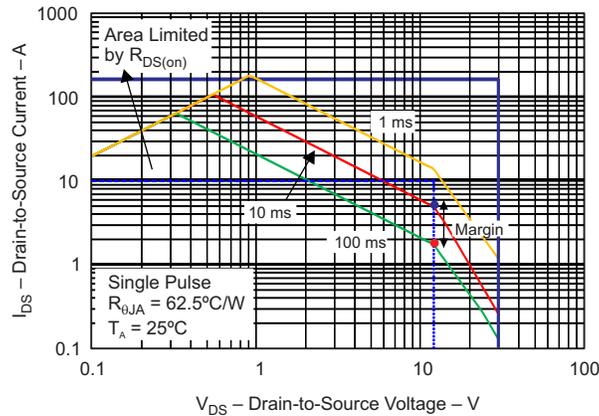


Figure 42. Design Example SOA

10.2.2.1.4 STEP 4. Calculate the Retry-Mode Duty Ratio

In retry mode, the TPS24751 is on for one charging cycle and off for 16 charge-discharge cycles, as can be seen in Figure 37. The first C_T charging cycle is from 0 V to 1.35 V, which gives 6.35 ms. The first C_T discharging cycle is from 1.35 V to 0.35 V, which gives 4.7 ms. Therefore, the total time is 6.35 ms + 33 × 4.7 ms = 161.45 ms. As a result, the retry mode duty ratio is 6.35 ms/161.45 ms = 3.93%. So effective steady state power dissipation in device during continuous short conditions is 4% of P_{LIM} .

10.2.2.1.5 STEP 5. Select R_1 , R_2 , and R_3 for UV and OV

Next, select the values of the OV and UV resistors, R_1 , R_2 , and R_3 , as shown in the typical system application diagram Figure 41. From the TPS2475x electrical specifications, $V_{\text{OVTHRESH}} = 1.35 \text{ V}$ and $V_{\text{ENTHRESH}} = 1.35 \text{ V}$. V_{OV} is the overvoltage trip voltage, which in this case is 14 V. V_{UV} is the undervoltage trip voltage, which for this example equals 8.4 V.

$$V_{\text{OVTHRESH}} = \frac{R_3}{R_1 + R_2 + R_3} \times V_{\text{OV}} \tag{12}$$

$$V_{\text{ENTHRESH}} = \frac{R_2 + R_3}{R_1 + R_2 + R_3} \times V_{\text{UV}} \tag{13}$$

Assume R_3 is 1.5 kΩ and use Equation 12 to solve for $(R_1 + R_2)$. Use Equation 13 and the $(R_1 + R_2)$ from Equation 12 to solve for R_2 and finally for R_1 . From Equation 12, $(R_1 + R_2) = 14.05 \text{ k}\Omega$. From Equation 13, $R_2 = 1 \text{ k}\Omega$ and $R_1 = 13.05 \text{ k}\Omega$. Scaling all three resistors by a factor of ten to use less supply current for these voltage references and using standard 1% resistor values gives $R_1 = 130 \text{ k}\Omega$, $R_2 = 10 \text{ k}\Omega$, and $R_3 = 15 \text{ k}\Omega$.

10.2.2.1.6 STEP 6. Choose R_4 , R_5 , and C_1

As per the typical application diagram on the front page, R_4 , and R_5 are required only if PGb, and FLTb are used; these resistors serve as pull-ups for the open-drain output drivers. The current sunk by each of these pins must not exceed 2 mA (refer to the Recommended Operating Conditions table). C_1 is a bypass capacitor to help control transient voltages, unit emissions, and local supply noise while in the disabled state. Where acceptable, a value in the range of 0.001 μF to 0.1 μF is recommended.

10.2.2.2 Alternative Design Example: Gate Capacitor (dv/dt) Control in Inrush Mode

The TPS2475x can be used in applications that expect a constant inrush current. This current is controlled by a capacitor connected from the GATE terminal to GND. A resistor of 1 kΩ placed in series with this capacitor prevents it from slowing a fast-turnoff event. In this mode of operation, the internal FET operates as a source follower, and the slew rate of the output voltage approximately equals the slew rate of the gate voltage (see Figure 43).

To implement a constant-inrush-current circuit, choose the time to charge, Δt, using Equation 14.

$$\Delta t = \frac{C_{OUT} \times V_{VCC}}{I_{CHG}} \quad (14)$$

where C_{OUT} is the output capacitance, V_{VCC} is the input voltage, and I_{CHG} is the desired charge current. Choose I_{CHG} < P_{LIM} / V_{VCC} to prevent power limiting from affecting the desired current.

To select the gate capacitance use Equation 15. where, I_{GATE} is the nominal gate current and C_{INTRS}, the effective capacitance contributed by the internal FET (approximately 175 pF). In addition, the effect of other capacitances like the capacitance offered by the usage of the Blocking FET (C_{BLK}) and other component capacitances C_{PR} (due to external gate protection diodes, such as Zener diode and board parasitic) to be accounted for arriving at exact value of C_{GATE}. The TIMER capacitor, C_T, must be programmed for timing greater than the total turnon time (t_{ON}), to ensure and avoid fault detection during start-up.

Typical application circuit with Gate Capacitor (dV/dt) Control Inrush Mode is shown in Figure 43. The turnon waveform with C_{GATE} of 4.7 nF and series resistor of 1 kΩ is shown in Figure 44.

$$C_{GATE} = \left(I_{GATE} \times \frac{\Delta t}{V_{VCC}} \right) - C_{INTRS} \quad (15)$$

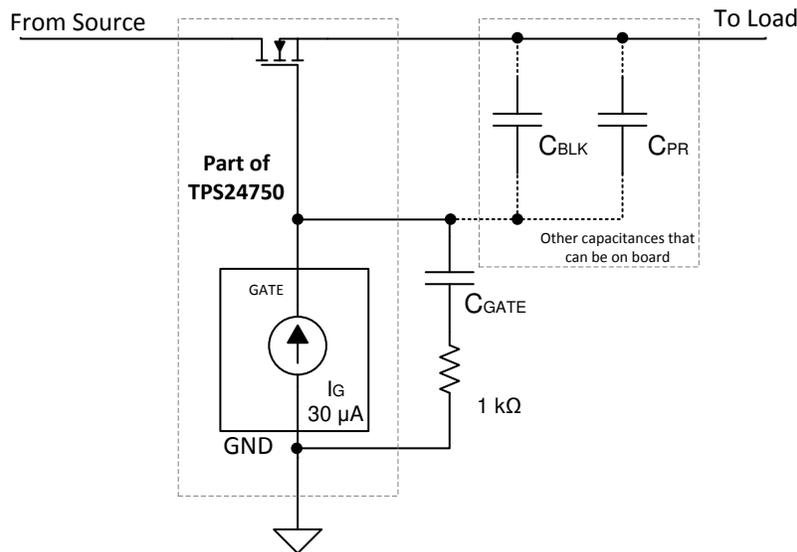


Figure 43. Gate Capacitor (dV/dt) Control Inrush Mode.

10.2.2.3 Additional Design Considerations

10.2.2.3.1 Use of PGb

Use the PGb pin to control and coordinate a downstream dc/dc converter. If this is not done, then a long time delay is needed to allow C_{OUT} to fully charge before the converter starts. An undesirable latch-up condition can be created between the TPS2475x output characteristic and the dc/dc converter input characteristic if the converter starts while C_{OUT} is still charging; using the PGb pin is one way to avoid this.

10.2.2.3.2 Output Clamp Diode

Inductive loads on the output may drive the OUT pin below GND when the circuit is unplugged or during a current-limit event. The OUT pin ratings can be satisfied by connecting a diode from OUT to GND. The diode must be selected to control the negative voltage at the full short-circuit current. Schottky diodes are generally recommended for this application.

10.2.2.3.3 Gate Clamp Diode

The TPS2475x has a relatively well-regulated gate voltage of 12 V-15.5 V with a supply voltage V_{VCC} higher than 4 V. For the applications with operating voltage greater than 14 V, a negative gate clamp (of ≤ 15.5 V) is needed as shown in Figure 47. In addition, a series resistance of several hundred ohms or a series silicon diode is recommended to prevent the output capacitance from discharging through the gate driver to ground. For applications with Blocking FET, a small clamp Zener from gate to OUT is recommended if V_{GS} of external blocking FET is rated below 12 V.

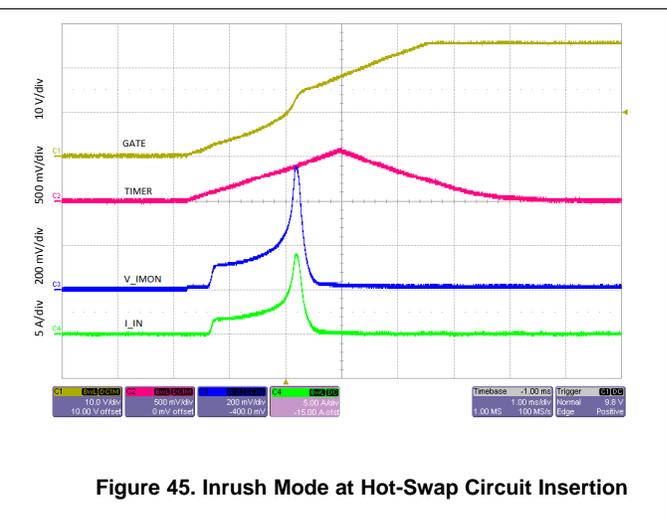
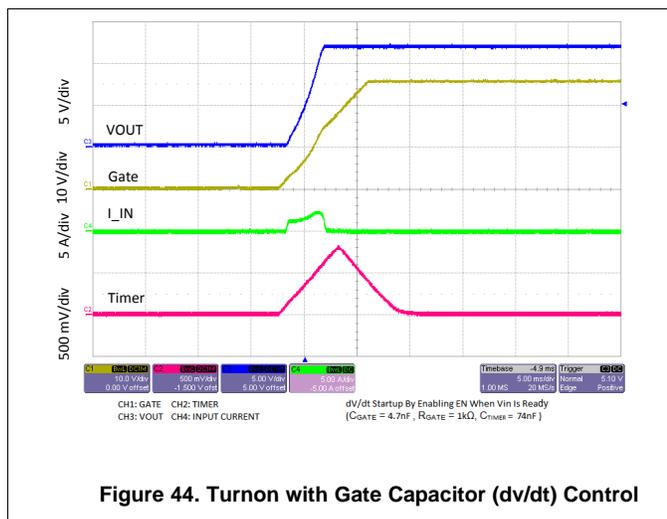
10.2.2.3.4 Bypass Capacitors

It is a good practice to provide low-impedance ceramic capacitor bypassing of the VCC and OUT pins. Values in the range of 10 nF to 1 μ F are recommended. Some system topologies are insensitive to the values of these capacitors; however, some are not and require minimization of the value of the bypass capacitor. Input capacitance on a plug-in board may cause a large inrush current as the capacitor charges through the low-impedance power bus when inserted. This stresses the connector contacts and causes a short voltage sag on the input bus. Small amounts of capacitance (that is, 10 nF to 0.1 μ F) are often tolerable in these systems.

10.2.2.3.5 Output Short-Circuit Measurements

Repeatable short-circuit testing results are difficult to obtain. The many details of source bypassing, input leads, circuit layout and component selection, output shorting method, relative location of the short, and instrumentation all contribute to variation in results. The actual short itself exhibits a certain degree of randomness as it microscopically bounces and arcs. Care in configuration and methods must be used to obtain realistic results. Do not expect to see waveforms exactly like those in the data sheet; every setup differs.

10.2.3 Application Curves



10.3 System Examples

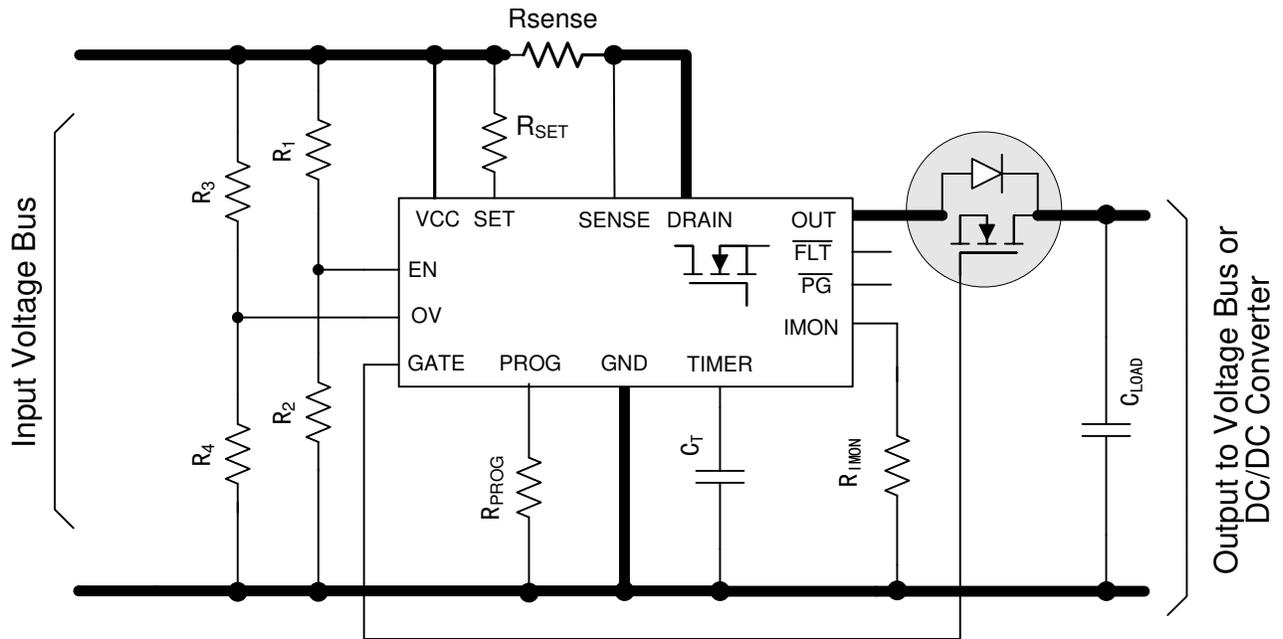


Figure 46. Reverse Blocking Implementation

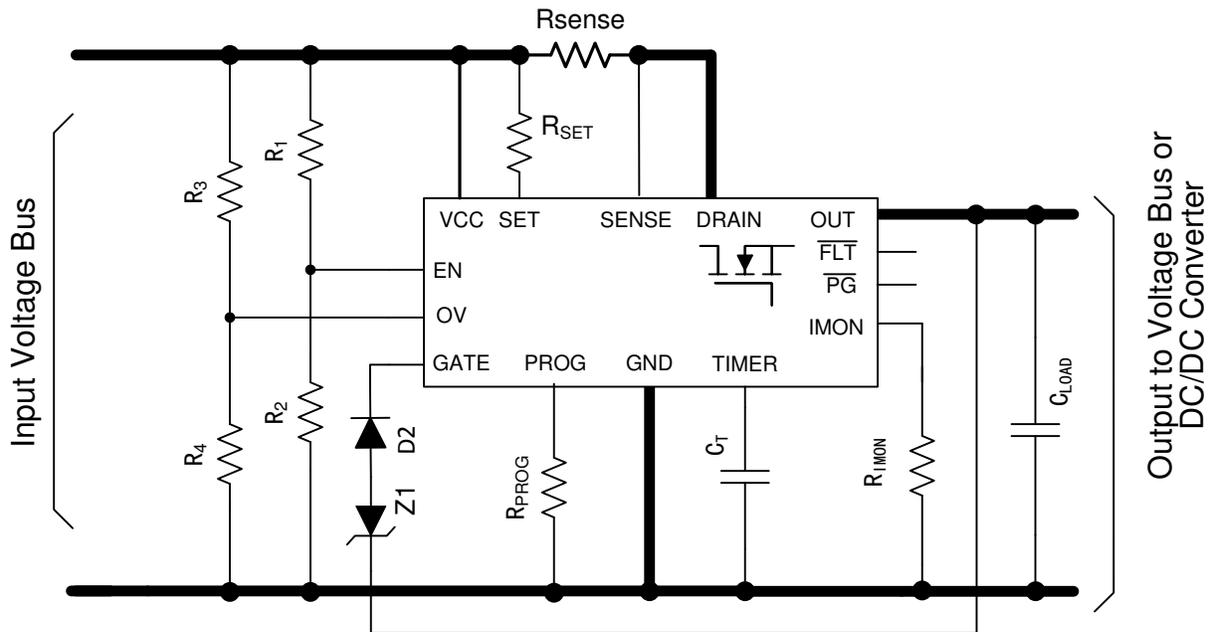


Figure 47. Negative Voltage Gate Protection

System Examples (continued)

The TPS2475x can be configured as a high current load switch with low external part count. The schematic diagram of load switch configuration is shown in [Figure 48](#). The output voltage ramp rate is controlled with RC circuit (R_{gate} and C_{gate}) at the Gate pin of the device. For detailed design process refer to the application note [12-A Integrated Load Switch Using TPS24750/51](#).

Due to their robust protection features along with low $R_{DS(on)}$ of 3 m Ω integrated MOSFET and precise current-limiting, the TPS2475x eFuses finds usage in power supply modules for Position Encoder Interfaces in applications such as Servo Drives and Position Control. Refer to the following TI Designs for system usage examples of the TPS2475x in these applications.

[Power Supply with Programmable Output Voltage and Protection for Position Encoder Interfaces](#)

[Interface to a 5-V BiSS® Position Encoder](#)

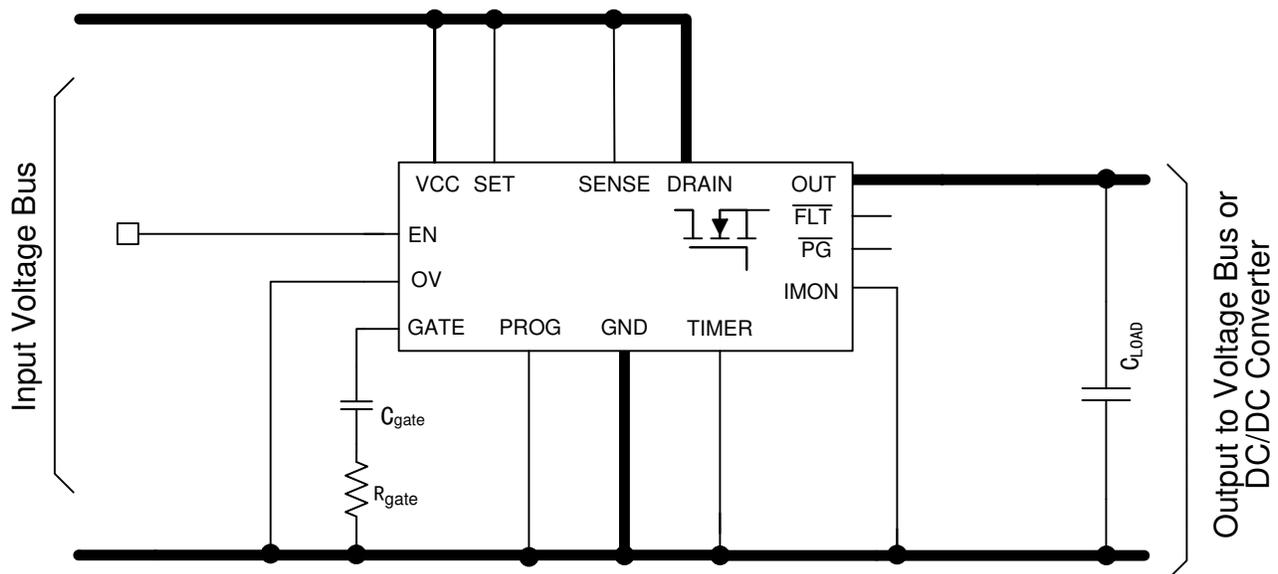


Figure 48. TPS2475x Configured as Simple 12-A Load Switch

11 Power Supply Recommendations

The device is designed for supply voltage range of $2.5\text{ V} \leq V_{(VCC)} \leq 18\text{ V}$. If the input supply is located more than a few inches from the device an input ceramic bypass capacitor higher than $0.1\text{ }\mu\text{F}$ is recommended. Power supply must be rated higher than the current limit set to avoid voltage droops during over current and short-circuit conditions.

11.1 Transient Thermal Impedance

$T_A = 25^\circ\text{C}$ (unless otherwise stated)

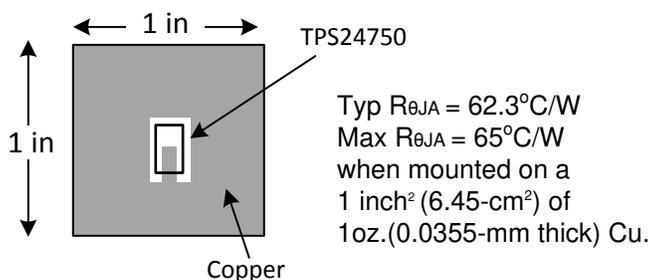


Figure 49. Board Details - Thermal Impedance Characteristic

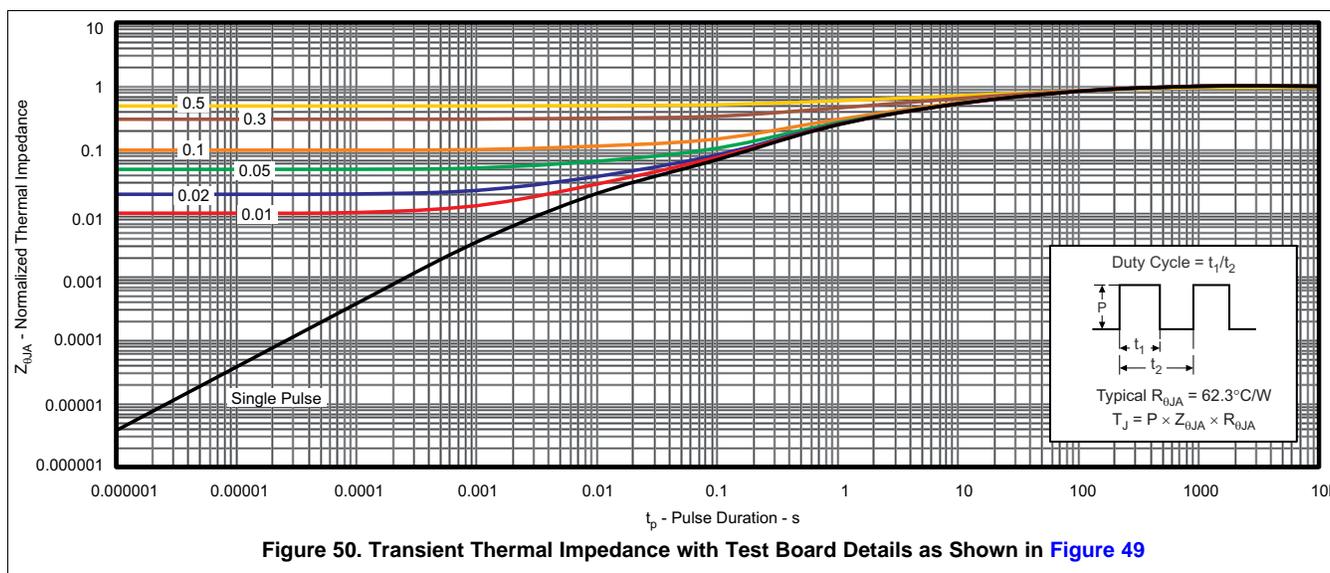


Figure 50. Transient Thermal Impedance with Test Board Details as Shown in Figure 49

12 Layout

12.1 Layout Guidelines

The TPS2475x applications require careful attention to layout to ensure proper performance and to minimize susceptibility to transients and noise. In general, all traces must be as short as possible, but the following list deserves first consideration:

- Decoupling capacitors on VCC pin must have minimal trace lengths to the pin and to GND.
- Traces to SET and SENSE must be short and run side-by-side to maximize common-mode rejection. Kelvin connections must be used at the points of contact with R_{SENSE} . See [Figure 51](#) and [Figure 52](#) for a PCB layout example.
- SET runs must be short on both sides of R_{SET} .
- High current carrying Power path connections must be as short as possible and sized to carry at least twice the full-load current, more if possible.
- Connections to IMON pin must be minimized after the previously described connections have been placed.
- The reference must be a copper plane or island. Use via holes if necessary for direct connections of components to their appropriate return ground plane or island.
- Thermal Considerations: When properly mounted the PowerPAD package provides significantly greater cooling ability than an ordinary package. To operate at rated power, PowerPAD-2 must be soldered directly to the PC board DRAIN plane directly under the device. The PowerPAD-2 is at the DRAIN potential and can be connected using multiple vias to the inner and bottom layers of the DRAIN. The bottom side of the circuit board is highly recommended to be used for DRAIN plane to increase heat sinking in higher current applications. Refer to Technical Briefs: PowerPAD™ Thermally Enhanced Package, [SLMA002](#)) and PowerPAD™ Made Easy, [SLMA004](#)) for more information on using this PowerPad package.
- The thermal via land pattern specific to the TPS2475x can be downloaded from the [device webpage](#).
- Protection devices such as snubbers, TVS, capacitors, or diodes must be placed physically close to the device they are intended to protect, and routed with short traces to reduce inductance. For example, the protection Schottky diode suggested to address transients due to heavy inductive loads, must be physically close to the OUT pins.

12.2 Layout Example

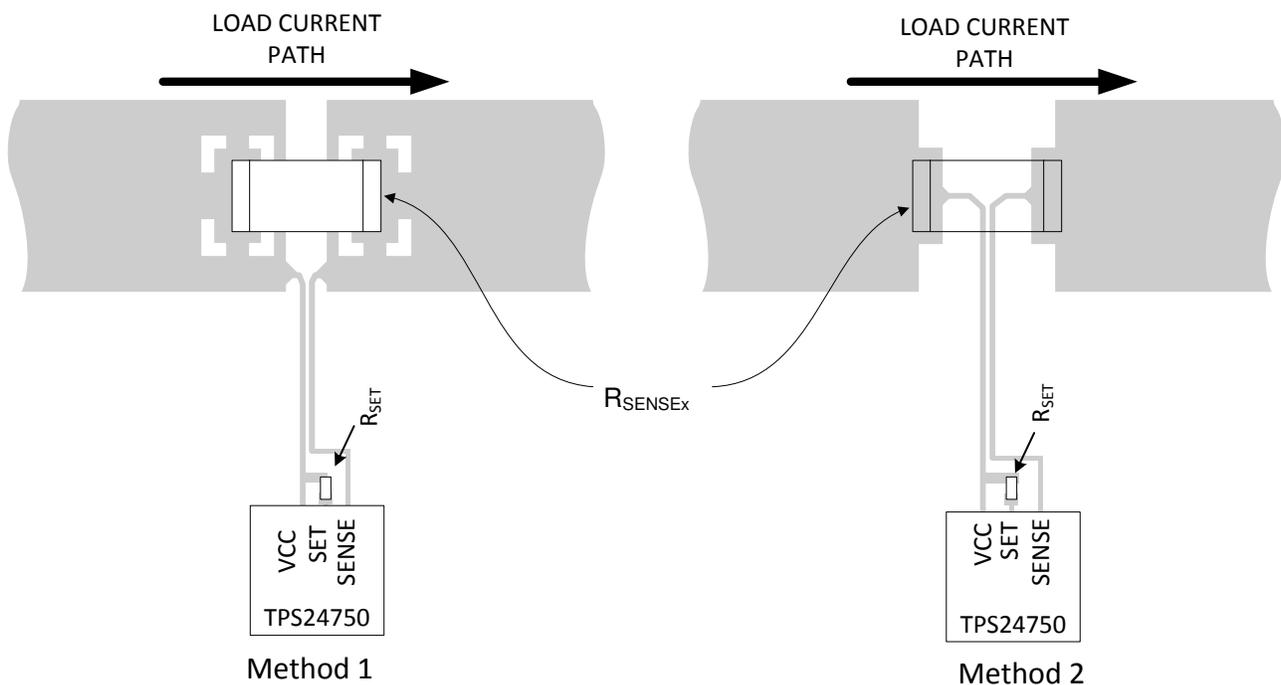
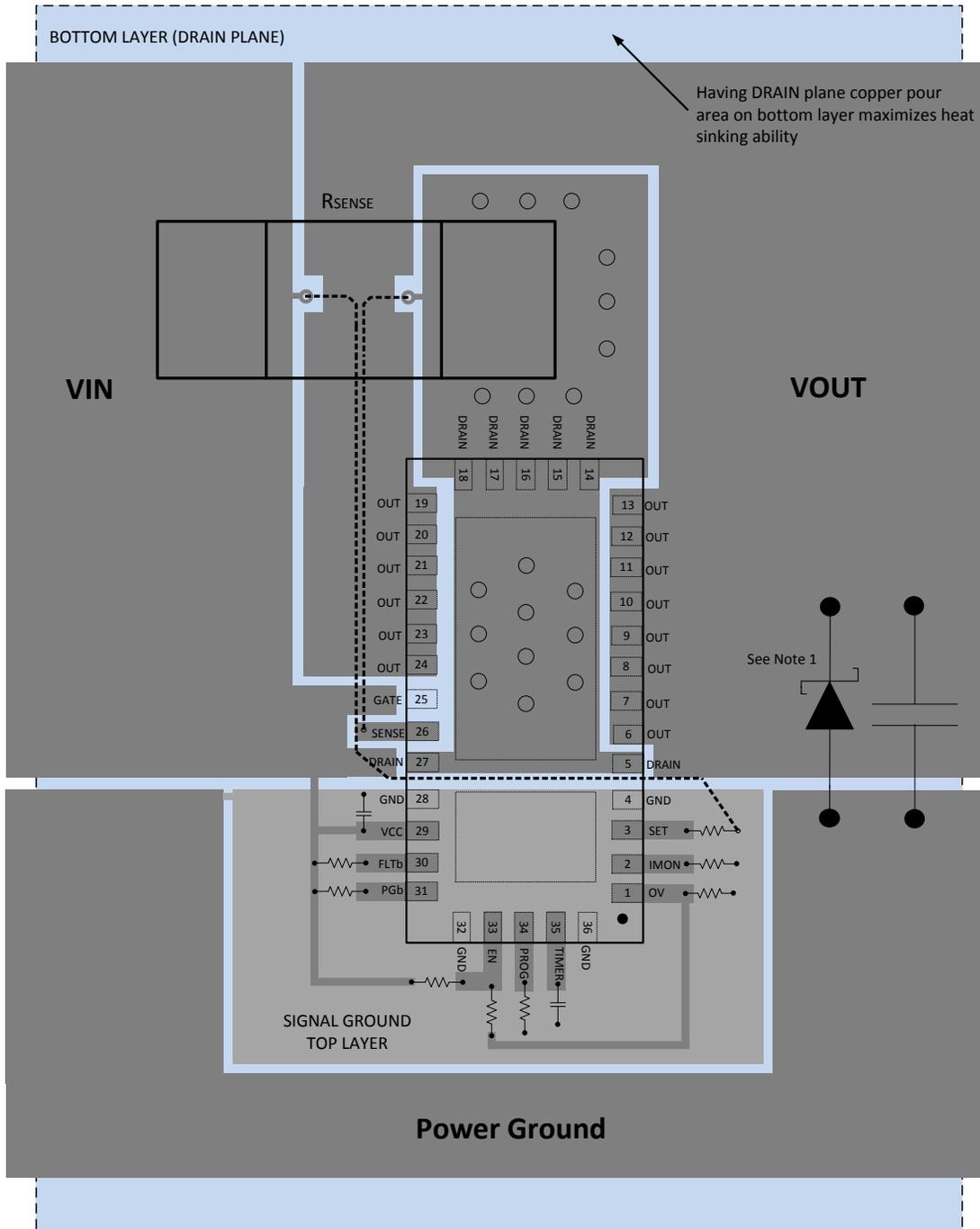


Figure 51. Recommended R_{SENSE} Layout

Layout Example (continued)

- Top Layer
- Top Layer Signal Ground Plane
- Bottom Layer Drain plane
- Via to Bottom Layer
- Track in bottom or internal layer



(1) Optional: Needed only to suppress the transients caused by inductive load switching.

Figure 52. Layout Example

13 デバイスおよびドキュメントのサポート

13.1 ドキュメントのサポート

13.1.1 関連資料

関連資料については、以下を参照してください。

- 『熱特性強化型パッケージ PowerPAD™』(TI 文書番号)
- 『PowerPAD™の簡単な使用法』
- ポジション・エンコーダ・インターフェイス向けプログラマブル出力電圧 / 保護付き電源
- 『5V BiSS® 位置エンコードへのインターフェイス』
- 『TPS24750/51 を使用した 12A 統合負荷スイッチ』
- 『TPS2475X EVM ユーザー・ガイド』

13.2 関連リンク

次の表に、クイック・アクセス・リンクを示します。カテゴリには、技術資料、サポートおよびコミュニティ・リソース、ツールとソフトウェア、およびサンプル注文またはご購入へのクイック・アクセスが含まれます。

表 2. 関連リンク

| 製品 | プロダクト・フォルダ | サンプルとご購入 | 技術資料 | ツールとソフトウェア | サポートとコミュニティ |
|----------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|
| TPS24750 | ここをクリック |
| TPS24751 | ここをクリック |

13.3 ドキュメントの更新通知を受け取る方法

ドキュメントの更新についての通知を受け取るには、[ti.com](#)のデバイス製品フォルダを開いてください。右上の「アラートを受け取る」をクリックして登録すると、変更されたすべての製品情報に関するダイジェストを毎週受け取れます。変更の詳細については、修正されたドキュメントに含まれている改訂履歴をご覧ください。

13.4 コミュニティ・リソース

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's [Terms of Use](#).

TI E2E™オンライン・コミュニティ TIのE2E (*Engineer-to-Engineer*) コミュニティ。エンジニア間の共同作業を促進するために開設されたものです。e2e.ti.comでは、他のエンジニアに質問し、知識を共有し、アイデアを検討して、問題解決に役立てることができます。

設計サポート TIの設計サポート役に立つE2Eフォーラムや、設計サポート・ツールをすばやく見つけることができます。技術サポート用の連絡先情報も参照できます。

13.5 商標

E2E is a trademark of Texas Instruments.

All other trademarks are the property of their respective owners.

13.6 静電気放電に関する注意事項



すべての集積回路は、適切なESD保護方法を用いて、取扱いと保存を行うようにして下さい。

静電気放電はわずかな性能の低下から完全なデバイスの故障に至るまで、様々な損傷を与えます。高精度の集積回路は、損傷に対して敏感であり、極めてわずかなパラメータの変化により、デバイスに規定された仕様に適合しなくなる場合があります。

13.7 Export Control Notice

Recipient agrees to not knowingly export or re-export, directly or indirectly, any product or technical data (as defined by the U.S., EU, and other Export Administration Regulations) including software, or any controlled product restricted by other applicable national regulations, received from disclosing party under nondisclosure obligations (if any), or any direct product of such technology, to any destination to which such export or re-export is restricted or prohibited by U.S. or other applicable laws, without obtaining prior authorization from U.S. Department of Commerce and other competent Government authorities to the extent required by those laws.

13.8 Glossary

[SLYZ022](#) — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

14 メカニカル、パッケージ、および注文情報

以降のページには、メカニカル、パッケージ、および注文に関する情報が記載されています。これらの情報は、指定のデバイスに対して提供されている最新のデータです。このデータは予告なく変更されることがあり、ドキュメントが改訂される場合もあります。本データシートのブラウザ版を使用されている場合は、画面左側の説明をご覧ください。

PACKAGING INFORMATION

| Orderable part number | Status (1) | Material type (2) | Package Pins | Package qty Carrier | RoHS (3) | Lead finish/ Ball material (4) | MSL rating/ Peak reflow (5) | Op temp (°C) | Part marking (6) |
|------------------------------|---------------|----------------------|-----------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| TPS24750RUVR | Active | Production | VQFN (RUV) 36 | 3000 LARGE T&R | Yes | NIPDAU | Level-2-260C-1 YEAR | -40 to 85 | TPS24750 |
| TPS24750RUVR.A | Active | Production | VQFN (RUV) 36 | 3000 LARGE T&R | Yes | NIPDAU | Level-2-260C-1 YEAR | -40 to 85 | TPS24750 |
| TPS24750RUVT | Active | Production | VQFN (RUV) 36 | 250 SMALL T&R | Yes | NIPDAU | Level-2-260C-1 YEAR | -40 to 85 | TPS24750 |
| TPS24750RUVT.A | Active | Production | VQFN (RUV) 36 | 250 SMALL T&R | Yes | NIPDAU | Level-2-260C-1 YEAR | -40 to 85 | TPS24750 |
| TPS24750RUVTG4 | Active | Production | VQFN (RUV) 36 | 250 SMALL T&R | Yes | NIPDAU | Level-2-260C-1 YEAR | -40 to 85 | TPS24750 |
| TPS24750RUVTG4.A | Active | Production | VQFN (RUV) 36 | 250 SMALL T&R | Yes | NIPDAU | Level-2-260C-1 YEAR | -40 to 85 | TPS24750 |
| TPS24751RUVR | Active | Production | VQFN (RUV) 36 | 3000 LARGE T&R | Yes | NIPDAU | Level-2-260C-1 YEAR | -40 to 85 | TPS24751 |
| TPS24751RUVR.A | Active | Production | VQFN (RUV) 36 | 3000 LARGE T&R | Yes | NIPDAU | Level-2-260C-1 YEAR | -40 to 85 | TPS24751 |
| TPS24751RUVT | Active | Production | VQFN (RUV) 36 | 250 SMALL T&R | Yes | NIPDAU | Level-2-260C-1 YEAR | -40 to 85 | TPS24751 |
| TPS24751RUVT.A | Active | Production | VQFN (RUV) 36 | 250 SMALL T&R | Yes | NIPDAU | Level-2-260C-1 YEAR | -40 to 85 | TPS24751 |
| TPS24751RUVTG4 | Active | Production | VQFN (RUV) 36 | 250 SMALL T&R | Yes | NIPDAU | Level-2-260C-1 YEAR | -40 to 85 | TPS24751 |
| TPS24751RUVTG4.A | Active | Production | VQFN (RUV) 36 | 250 SMALL T&R | Yes | NIPDAU | Level-2-260C-1 YEAR | -40 to 85 | TPS24751 |

(1) **Status:** For more details on status, see our [product life cycle](#).

(2) **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

(3) **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

(4) **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

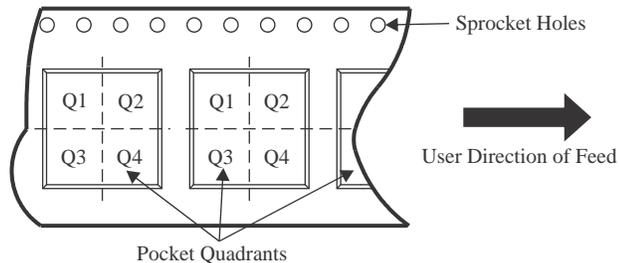
(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "-" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

Important Information and Disclaimer: The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

TAPE AND REEL INFORMATION

QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE


*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|----------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| TPS24750RUVR | VQFN | RUV | 36 | 3000 | 330.0 | 16.4 | 3.85 | 7.35 | 1.2 | 8.0 | 16.0 | Q1 |
| TPS24750RUVT | VQFN | RUV | 36 | 250 | 180.0 | 16.4 | 3.85 | 7.35 | 1.2 | 8.0 | 16.0 | Q1 |
| TPS24750RUVTG4 | VQFN | RUV | 36 | 250 | 180.0 | 16.4 | 3.85 | 7.35 | 1.2 | 8.0 | 16.0 | Q1 |
| TPS24751RUVR | VQFN | RUV | 36 | 3000 | 330.0 | 16.4 | 3.85 | 7.35 | 1.2 | 8.0 | 16.0 | Q1 |
| TPS24751RUVT | VQFN | RUV | 36 | 250 | 180.0 | 16.4 | 3.85 | 7.35 | 1.2 | 8.0 | 16.0 | Q1 |
| TPS24751RUVTG4 | VQFN | RUV | 36 | 250 | 180.0 | 16.4 | 3.85 | 7.35 | 1.2 | 8.0 | 16.0 | Q1 |

TAPE AND REEL BOX DIMENSIONS

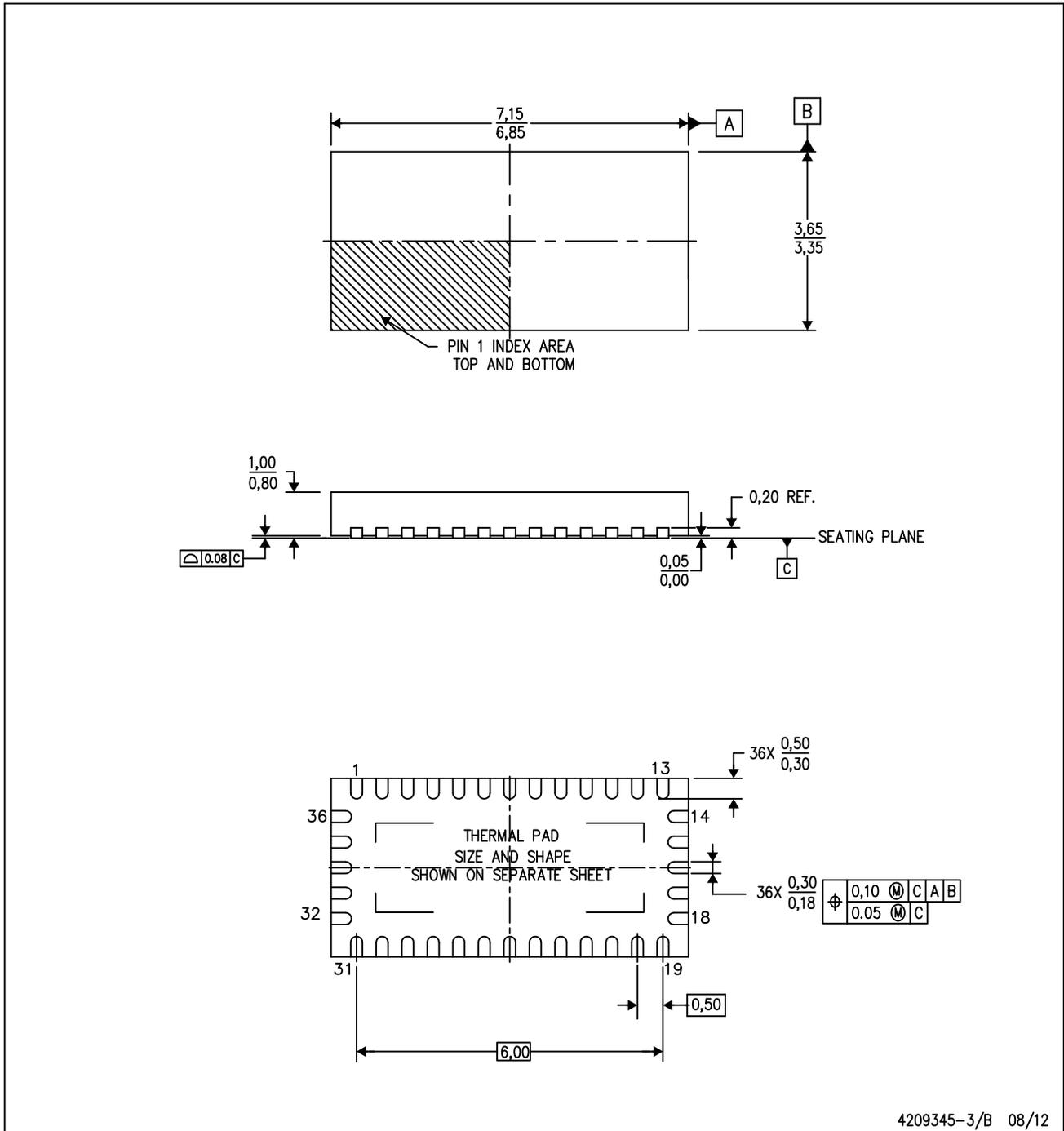


*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|----------------|--------------|-----------------|------|------|-------------|------------|-------------|
| TPS24750RUVR | VQFN | RUV | 36 | 3000 | 367.0 | 367.0 | 38.0 |
| TPS24750RUVT | VQFN | RUV | 36 | 250 | 210.0 | 185.0 | 35.0 |
| TPS24750RUVTG4 | VQFN | RUV | 36 | 250 | 210.0 | 185.0 | 35.0 |
| TPS24751RUVR | VQFN | RUV | 36 | 3000 | 367.0 | 367.0 | 38.0 |
| TPS24751RUVT | VQFN | RUV | 36 | 250 | 210.0 | 185.0 | 35.0 |
| TPS24751RUVTG4 | VQFN | RUV | 36 | 250 | 210.0 | 185.0 | 35.0 |

RUV (R-PVQFN-N36)

PLASTIC QUAD FLATPACK NO-LEAD



- NOTES:
- All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
 - This drawing is subject to change without notice.
 - Quad Flatpack, No-leads (QFN) package configuration.
 - The package thermal pad must be soldered to the board for thermal and mechanical performance.
 - See the additional figure in the Product Data Sheet for details regarding the exposed thermal pad features and dimensions.
 - Falls within JEDEC MO-220.

THERMAL PAD MECHANICAL DATA

RUV (S-PVQFN-N36)

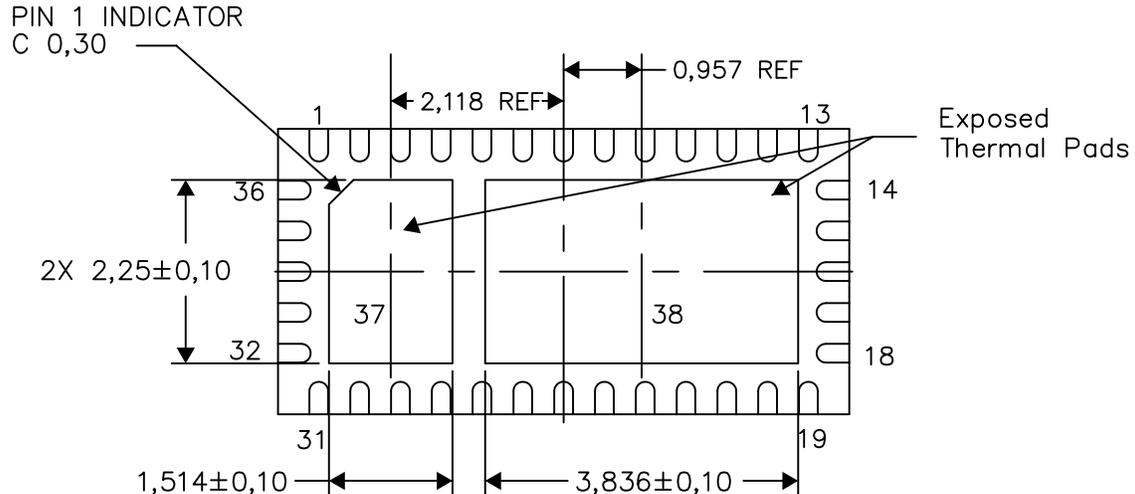
PLASTIC QUAD FLATPACK NO-LEAD

THERMAL INFORMATION

This package incorporates an exposed thermal pad that is designed to be attached directly to an external heatsink. The thermal pad must be soldered directly to the printed circuit board (PCB). After soldering, the PCB can be used as a heatsink. In addition, through the use of thermal vias, the thermal pad can be attached directly to the appropriate copper plane shown in the electrical schematic for the device, or alternatively, can be attached to a special heatsink structure designed into the PCB. This design optimizes the heat transfer from the integrated circuit (IC).

For information on the Quad Flatpack No-Lead (QFN) package and its advantages, refer to Application Report, QFN/SON PCB Attachment, Texas Instruments Literature No. SLUA271. This document is available at www.ti.com.

The exposed thermal pad dimensions for this package are shown in the following illustration.



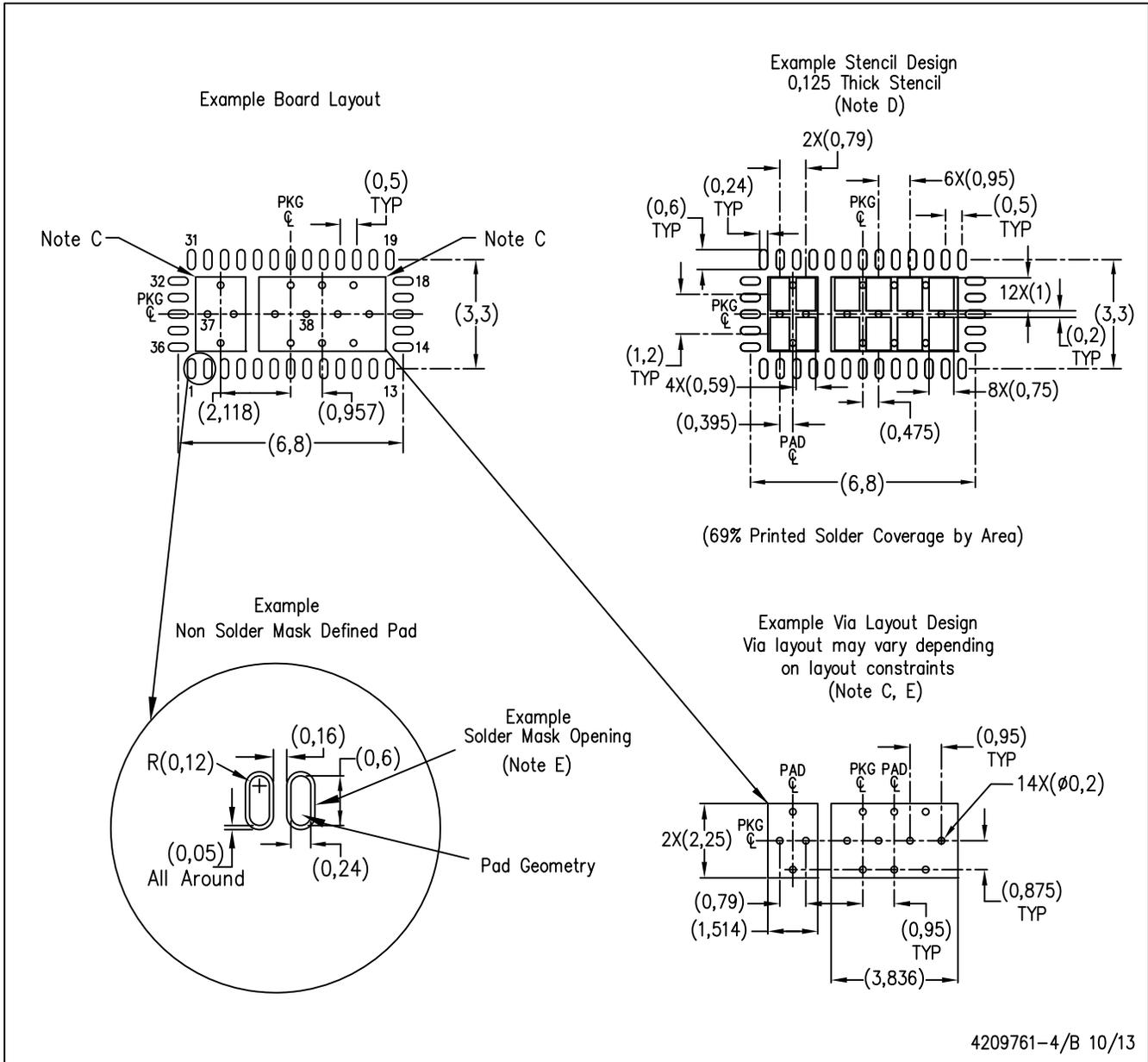
Exposed Thermal Pad Dimensions

4209552-4/E 06/13

NOTE: All linear dimensions are in millimeters

RUV (R-PVQFN-N36)

PLASTIC QUAD FLATPACK NO-LEAD



- NOTES:
- All linear dimensions are in millimeters.
 - This drawing is subject to change without notice.
 - This package is designed to be soldered to a thermal pad on the board. Refer to Application Note, Quad Flat-Pack Packages, Texas Instruments Literature No. SLUA271, and also the Product Data Sheets for specific thermal information, via requirements, and recommended board layout. These documents are available at www.ti.com <<http://www.ti.com>>.
 - Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC 7525 for stencil design considerations.
 - Customers should contact their board fabrication site for recommended solder mask tolerances and via tenting recommendations for vias placed in the thermal pad.

重要なお知らせと免責事項

TI は、技術データと信頼性データ (データシートを含みます)、設計リソース (リファレンス デザインを含みます)、アプリケーションや設計に関する各種アドバイス、Web ツール、安全性情報、その他のリソースを、欠陥が存在する可能性のある「現状のまま」提供しており、商品性および特定目的に対する適合性の黙示保証、第三者の知的財産権の非侵害保証を含むいかなる保証も、明示的または黙示的にかかわらず拒否します。

これらのリソースは、TI 製品を使用する設計の経験を積んだ開発者への提供を意図したものです。(1) お客様のアプリケーションに適した TI 製品の選定、(2) お客様のアプリケーションの設計、検証、試験、(3) お客様のアプリケーションに該当する各種規格や、その他のあらゆる安全性、セキュリティ、規制、または他の要件への確実な適合に関する責任を、お客様のみが単独で負うものとし、

上記の各種リソースは、予告なく変更される可能性があります。これらのリソースは、リソースで説明されている TI 製品を使用するアプリケーションの開発の目的でのみ、TI はその使用をお客様に許諾します。これらのリソースに関して、他の目的で複製することや掲載することは禁止されています。TI や第三者の知的財産権のライセンスが付与されている訳ではありません。お客様は、これらのリソースを自身で使用した結果発生するあらゆる申し立て、損害、費用、損失、責任について、TI およびその代理人を完全に補償するものとし、TI は一切の責任を拒否します。

TI の製品は、[TI の販売条件](#)、[TI の総合的な品質ガイドライン](#)、[ti.com](#) または TI 製品などに関連して提供される他の適用条件に従い提供されます。TI がこれらのリソースを提供することは、適用される TI の保証または他の保証の放棄の拡大や変更を意味するものではありません。TI がカスタム、またはカスタマー仕様として明示的に指定していない限り、TI の製品は標準的なカタログに掲載される汎用機器です。

お客様がいかなる追加条項または代替条項を提案する場合も、TI はそれらに異議を唱え、拒否します。

Copyright © 2026, Texas Instruments Incorporated

最終更新日 : 2025 年 10 月