

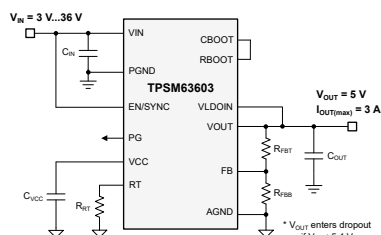
# TPSM63603 高密度、3V~36V 入力、1V~16V 出力、3A パワー・モジュール、Enhanced HotRod™ QFN パッケージ

## 1 特長

- 多用途な同期整流降圧 DC/DC モジュール
  - MOSFET、インダクタ、コントローラを内蔵
  - 広い入力電圧範囲: 3V~36V
  - 出力電圧を調整可能 1V~16V
  - 4mm × 6mm × 1.8mm の オーバーモールド・パッケージ
  - 接合部温度範囲: -40°C~125°C
  - RT ピンまたは外部 SYNC 信号を使用して 200kHz~2.2MHz の範囲で周波数を調整可能
  - 負電圧出力に対応可能
- 全負荷範囲にわたって極めて高い効率を実現
  - 93% のピーク効率 (12V<sub>IN</sub>, 5V<sub>OUT</sub>, 1MHz)
  - 外部バイアス・オプションによる効率向上
  - シャットダウン時静止電流: 0.6μA (標準値)
- 非常に小さい伝導および放射 EMI シグネチャ
  - デュアル入力バスと内蔵コンデンサを備えた低ノイズ・パッケージにより、スイッチのリングングが減少
  - スペクトラム拡散変調 (S サフィックス)
  - 抵抗により調整可能なスイッチ・ノードのスルーレート
  - 固定周波数 FPWM 動作モード
  - CISPR 11 および 32 Class B の放射規格に準拠
- スケーラブルな電源に好適
  - TPSM63602 (36V, 2A) とピン互換
- 本質的な保護機能による堅牢な設計
  - 高精度のイネーブル入力とオープン・ドレインの PGOOD インジケータによるシーケンシング、制御、V<sub>IN</sub> UVLO
  - 過電流およびサーマル・シャットダウン保護
- WEBENCH® Power Designer により、TPSM63603 を使用するカスタム設計を作成

## 2 アプリケーション

- 試験および測定、航空宇宙および防衛
- ファクトリ・オートメーション / 制御
- 降圧および反転型の昇降圧電源



代表的な回路図

## 3 概要

TPSM63603 同期整流降圧パワー・モジュールは、パワー MOSFET、シールド付きインダクタ、受動部品を Enhanced HotRod™ QFN パッケージに実装した、高集積 36V、3A DC/DC ソリューションです。このモジュールは、VIN と VOUT のピンをパッケージの角に配置し、入力および出力コンデンサのレイアウト配置を最適化しています。モジュールの下面には大きな 4 つのサーマル・パッドがあるため、単純なレイアウトが可能で、製造時の扱いも容易です。

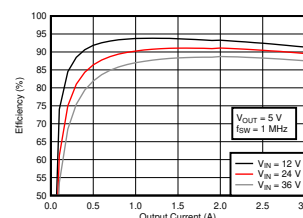
出力電圧が 1V~16V であるため、TPSM63603 は小さな PCB フットプリントで低 EMI の設計を迅速かつ容易に実装できるようになっています。このトータル・ソリューションを使用すると、外付け部品はわずか 4 個で済み、設計プロセスで磁気および補償のための部品選択も不要です。

TPSM63603 モジュールは、スペースが制約される用途での小型化と簡素化をめざして設計されているだけでなく、堅牢性の高い性能を実現するためのさまざまな機能を備えています。その例としては、可変入力電圧 UVLO 用のヒステリシス付き高精度イネーブル、抵抗を使ってプログラム可能なスイッチ・ノードのスルー・レートおよび拡散スペクトラム・オプションによる EMI 改善、内蔵 VCC ブーストラップおよび入力コンデンサによる信頼性向上と高密度化、全負荷電流範囲にわたって一定のスイッチング周波数、シーケンシング、障害保護、出力電圧監視用の PGOOD インジケータがあります。

### 製品情報

| 部品番号 <sup>(1)</sup> | パッケージ      | 本体サイズ (公称)    |
|---------------------|------------|---------------|
| TPSM63603           | B0QFN (30) | 4.0mm × 6.0mm |
| TPSM63603S          |            |               |

- (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。



代表的な効率 (V<sub>OUT</sub> = 5V、f<sub>SW</sub> = 1MHz)



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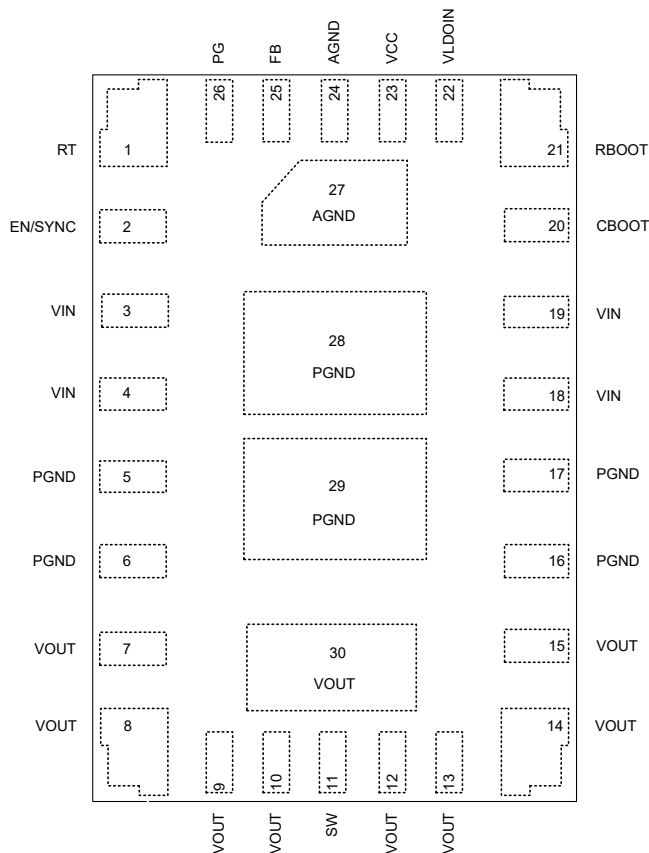
## 4 Revision History

| Changes from Revision * (March 2021) to Revision A (November 2021) | Page     |
|--------------------------------------------------------------------|----------|
| • ドキュメントのステータスを事前情報から量産データに変更.....                                 | <b>1</b> |

## Device Comparison Table

| DEVICE      | ORDERABLE PART NUMBER | MODE | SPREAD SPECTRUM | OUTPUT VOLTAGE | EXTERNAL SYNC | JUNCTION TEMPERATURE |
|-------------|-----------------------|------|-----------------|----------------|---------------|----------------------|
| TPSM63603   | TPSM63603RDHR         | FPWM | No              | Adjustable     | Yes           | –40°C to 125°C       |
| TPSM63603S  | TPSM63603SRDHR        | FPWM | Yes             | Adjustable     | Yes           | –40°C to 125°C       |
| TPSM63603V3 | TPSM63603V3RDHR       | FPWM | No              | Fixed 3.3 V    | Yes           | –40°C to 125°C       |
| TPSM63603V5 | TPSM63603V5RDHR       | FPWM | No              | Fixed 5 V      | Yes           | –40°C to 125°C       |

## 5 Pin Configuration and Functions



**5-1. 30-Pin QFN, RDH Package (Top View)**

表 5-1. Pin Functions

| PIN                  |         | TYPE <sup>(1)</sup> | DESCRIPTION                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|----------------------|---------|---------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| NO.                  | NAME    |                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| 1                    | RT      | I                   | Frequency setting pin. This analog pin is used to set the switching frequency between 200 kHz and 2.2 MHz by placing an external resistor from this pin to AGND. Do not leave open or connect to ground.                                                                                                                                                                                                                                                                                                                                                                                                                           |
| 2                    | EN/SYNC | I                   | Precision enable input pin. High = on, Low = off. Can be connected to VIN. Precision enable allows the pin to be used as an adjustable UVLO. It also functions as the synchronization input pin. Used to synchronize the device switching frequency to a system clock. Triggers on the rising edge of an external clock. A capacitor can be used to AC couple the synchronization signal to this pin. The module can be turned off by using an open-drain or collector device to connect this pin to AGND. An external voltage divider can be placed between this pin, AGND, and VIN to create an external UVLO.                   |
| 3, 4, 18, 19         | VIN     | P                   | Input supply voltage. Connect the input supply to these pins. Connect input capacitors between these pins and PGND in close proximity to the device. Refer to <a href="#">セクション 10.2</a> for input capacitor placement example.                                                                                                                                                                                                                                                                                                                                                                                                    |
| 5, 6, 16, 17, 28, 29 | PGND    | G                   | Power ground. This is the return current path for the power stage of the device. Connect this pad to the input supply return, the load return, and the capacitors associated with the VIN and VOUT pins. See <a href="#">セクション 10.2</a> for a recommended layout.                                                                                                                                                                                                                                                                                                                                                                  |
| 7-10, 12-15, 30      | VOUT    | P                   | Output voltage. These pins are connected to the internal output inductor. Connect these pins to the output load and connect external output capacitors between these pins and PGND.                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| 11                   | SW      | O                   | Switch node. Do not place any external component on this pin or connect to any signal. The amount of copper placed on these pins must be kept to a minimum to prevent issues with noise and EMI.                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| 20                   | CBOOT   | I/O                 | Bootstrap pin for internal high-side driver circuitry. A 100-nF bootstrap capacitor is internally connected from this pin to SW within the module to provide the bootstrap voltage. This pin is brought out to use in conjunction with RBOOT to effectively lower the value of the internal RBOOT resistor to adjust the SW node slew rate, if necessary.                                                                                                                                                                                                                                                                          |
| 21                   | RBOOT   | I/O                 | External bootstrap resistor connection. Internal to the device, a 100-Ω bootstrap resistor is connected between this pin and the CBOOT pin. This pin is brought out to use in conjunction with CBOOT to effectively lower the value of the internal RBOOT resistor to adjust the switch node slew rate, if necessary.                                                                                                                                                                                                                                                                                                              |
| 22                   | VLDOIN  | P                   | Input bias voltage. Supplies the control circuitry of the power module. Input to internal LDO. Connect to an output voltage point to improve efficiency. Connect an optional high quality 0.1-μF to 1-μF capacitor from this pin to ground for improved noise immunity. If the output voltage is above 12 V, connect this pin to ground.                                                                                                                                                                                                                                                                                           |
| 23                   | VCC     | O                   | Internal LDO output. Used as supply to internal control circuits. Do not connect to any external loads. Connect a high-quality 1-μF ceramic capacitor from this pin to PGND.                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| 24, 27               | AGND    | G                   | Analog ground. Zero voltage reference for internal references and logic. All electrical parameters are measured with respect to this pin. <b>This pin must be connected to PGND at a single point.</b> See <a href="#">セクション 10.2</a> for a recommended layout.                                                                                                                                                                                                                                                                                                                                                                    |
| 25                   | FB      | I                   | Feedback input. For the adjustable output version, connect the mid-point of the feedback resistor divider to this pin. Connect the upper resistor ( $R_{FBT}$ ) of the feedback divider to $V_{OUT}$ at the desired point of regulation. Connect the lower resistor ( $R_{FBB}$ ) of the feedback divider to AGND. When connecting with feedback resistor divider, keep this FB trace short and as small as possible to avoid noise coupling. See <a href="#">セクション 10.2</a> for a feedback resistor placement. For a fixed output version, connect this pin directly to output capacitor. Do not leave open or connect to ground. |
| 26                   | PG      | O                   | Power-good monitor. Open-drain output that asserts low if the feedback voltage is not within the specified window thresholds. A 10-kΩ to 100-kΩ pullup resistor is required to a suitable pullup voltage. If not used, this pin can be left open or connected to PGND.                                                                                                                                                                                                                                                                                                                                                             |

(1) P = Power, G = Ground, I = Input, O = Output

## 6 Specifications

### 6.1 Absolute Maximum Ratings

Limits apply over  $T_J = -40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$  (unless otherwise noted). <sup>(1)</sup>

|                                   |                                                        | MIN  | MAX  | UNIT               |
|-----------------------------------|--------------------------------------------------------|------|------|--------------------|
| Input voltage                     | VIN to AGND, PGND                                      | -0.3 | 40   | V                  |
|                                   | RBOOT to SW                                            | -0.3 | 5.5  | V                  |
|                                   | CBOOT to SW                                            | -0.3 | 5.5  | V                  |
|                                   | VLDOIN to AGND, PGND                                   | -0.3 | 16   | V                  |
|                                   | EN/SYNC to AGND, PGND                                  | -0.3 | 40   | V                  |
|                                   | RT to AGND, PGND                                       | -0.3 | 5.5  | V                  |
|                                   | FB to AGND, PGND                                       | -0.3 | 16   | V                  |
|                                   | PG to AGND, PGND                                       | 0    | 20   | V                  |
|                                   | PGND to AGND                                           | -1   | 2    | V                  |
| Output voltage                    | VCC to AGND, PGND                                      | -0.3 | 5.5  | V                  |
|                                   | SW to AGND, PGND <sup>(2)</sup>                        | -0.3 | 40   | V                  |
|                                   | VOOUT to AGND, PGND                                    | -0.3 | 16   | V                  |
| Input current                     | PG                                                     | -    | 10   | mA                 |
| $T_J$                             | Junction temperature                                   | -40  | 125  | $^{\circ}\text{C}$ |
| $T_A$                             | Ambient temperature                                    | -40  | 105  | $^{\circ}\text{C}$ |
| $T_{\text{stg}}$                  | Storage temperature                                    | -55  | 150  | $^{\circ}\text{C}$ |
| Peak reflow case temperature      |                                                        |      | 260  | $^{\circ}\text{C}$ |
| Maximum number of reflows allowed |                                                        |      | 3    |                    |
| Mechanical shock                  | Mil-STD-883D, Method 2002.3, 1 msec, 1/2 sine, mounted |      | 1500 | G                  |
| Mechanical vibration              | Mil-STD-883D, Method 2007.2, 20 to 2000 Hz             |      | 20   | G                  |

- (1) Operation outside the *Absolute Maximum Ratings* may cause permanent device damage. *Absolute Maximum Ratings* do not imply functional operation of the device at these or any other conditions beyond those listed under *Recommended Operating Conditions*. If used outside the *Recommended Operating Conditions* but within the *Absolute Maximum Ratings*, the device may not be fully functional, and this may affect device reliability, functionality, performance, and shorten the device lifetime.
- (2) A voltage of 2 V below PGND and 2 V above VIN can appear on this pin for  $\leq 200$  ns with a duty cycle of  $\leq 0.01\%$ .

### 6.2 ESD Ratings

|                    |                         |                                                                                | VALUE      | UNIT |
|--------------------|-------------------------|--------------------------------------------------------------------------------|------------|------|
| $V_{\text{(ESD)}}$ | Electrostatic discharge | Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 <sup>(1)</sup>              | $\pm 2500$ | V    |
|                    |                         | Charged-device model (CDM), per JEDEC specification JESD22-C101 <sup>(2)</sup> | $\pm 1500$ |      |

- (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.

### 6.3 Recommended Operating Conditions

Limits apply over  $T_J = -40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$  (unless otherwise noted).

|                |                                          | MIN | NOM         | MAX  | UNIT |
|----------------|------------------------------------------|-----|-------------|------|------|
| Input voltage  | VIN (Input voltage range after start-up) | 3   |             | 36   | V    |
| Input voltage  | VLDOIN                                   |     |             | 12.5 | V    |
| Output voltage | VOUT <sup>(1)</sup>                      | 1   |             | 16   | V    |
| Output voltage | VOUT <sup>(1)</sup>                      |     | TPSM63603V3 | 3.3  | V    |
| Output voltage | VOUT <sup>(1)</sup>                      |     | TPSM63603V5 | 5    | V    |
| Output current | IOUT <sup>(2)</sup>                      | 0   |             | 3    | A    |
| Frequency      | F <sub>SW</sub> set by RT or SYNC        | 200 |             | 2200 | kHz  |
| Input current  | PG                                       |     |             | 2    | mA   |
| Output voltage | PG                                       | 0   |             | 16   | V    |
| T <sub>J</sub> | Operating junction temperature           | -40 |             | 125  | °C   |
| T <sub>A</sub> | Operating ambient temperature            | -40 |             | 105  | °C   |

- (1) Under no conditions should the output voltage be allowed to fall below zero volts.  
 (2) Maximum continuous DC current may be derated when operating with high switching frequency and/or high ambient temperature. Refer to the *Typical Characteristics* section for details.

### 6.4 Thermal Information

| THERMAL METRIC <sup>(1)</sup> |                                                             | TPSM63603 | UNIT |
|-------------------------------|-------------------------------------------------------------|-----------|------|
|                               |                                                             | RDH (QFN) |      |
|                               |                                                             | 30 PINS   |      |
| R <sub>θJA</sub>              | Junction-to-ambient thermal resistance (TPSM63603 EVM)      | 29.1      | °C/W |
| R <sub>θJA</sub>              | Junction-to-ambient thermal resistance <sup>(2)</sup>       | 33.5      | °C/W |
| ψ <sub>JT</sub>               | Junction-to-top characterization parameter <sup>(3)</sup>   | 4.1       | °C/W |
| ψ <sub>JB</sub>               | Junction-to-board characterization parameter <sup>(4)</sup> | 21.5      | °C/W |

- (1) For more information about traditional and new thermal metrics, see the [Semiconductor and IC Package Thermal Metrics](#).  
 (2) The junction-to-ambient thermal resistance, R<sub>θJA</sub>, applies to devices soldered directly to a 64-mm x 83-mm four-layer PCB with 2 oz. copper and natural convection cooling. Additional airflow and PCB copper area reduces R<sub>θJA</sub>. For more information see the Layout section.  
 (3) The junction-to-top board characterization parameter, ψ<sub>JT</sub>, estimates the junction temperature, T<sub>J</sub>, of a device in a real system, using a procedure described in JESD51-2A (section 6 and 7).  $T_J = \psi_{JT} \times P_{dis} + T_T$ ; where P<sub>dis</sub> is the power dissipated in the device and T<sub>T</sub> is the temperature of the top of the device.  
 (4) The junction-to-board characterization parameter, ψ<sub>JB</sub>, estimates the junction temperature, T<sub>J</sub>, of a device in a real system, using a procedure described in JESD51-2A (sections 6 and 7).  $T_J = \psi_{JB} \times P_{dis} + T_B$ ; where P<sub>dis</sub> is the power dissipated in the device and T<sub>B</sub> is the temperature of the board 1mm from the device.

## 6.5 Electrical Characteristics

Limits apply over  $T_J = -40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ,  $V_{IN} = 24\text{ V}$ ,  $V_{OUT} = 3.3\text{ V}$ ,  $V_{LDOIN} = 5\text{ V}$ ,  $F_{SW} = 800\text{ kHz}$  (unless otherwise noted). Minimum and maximum limits are specified through production test or by design. Typical values represent the most likely parametric norm and are provided for reference only.

| PARAMETER               |                                                                                                       | TEST CONDITIONS                                                                                      | MIN   | TYP   | MAX   | UNIT          |
|-------------------------|-------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|-------|-------|-------|---------------|
| <b>SUPPLY VOLTAGE</b>   |                                                                                                       |                                                                                                      |       |       |       |               |
| $V_{IN}$                | Input operating voltage range                                                                         | Needed to start up (over $I_{OUT}$ range)                                                            | 3.95  |       | 36    | V             |
|                         |                                                                                                       | Once operating (over $I_{OUT}$ range)                                                                | 3     |       | 36    | V             |
| $V_{IN\_HYS}$           | Hysteresis <sup>(1)</sup>                                                                             |                                                                                                      |       | 1.0   |       | V             |
| $I_{Q\_VIN}$            | Input operating quiescent current (non-switching)                                                     | $T_A = 25^{\circ}\text{C}$ , $V_{EN/SYNC} = 3.3\text{ V}$ , $V_{FB} = 1.5\text{ V}$                  |       | 4     |       | $\mu\text{A}$ |
| $I_{SDN\_VIN}$          | VIN shutdown quiescent current                                                                        | $V_{EN/SYNC} = 0\text{ V}$ , $T_A = 25^{\circ}\text{C}$                                              |       | 3     |       | $\mu\text{A}$ |
| <b>ENABLE</b>           |                                                                                                       |                                                                                                      |       |       |       |               |
| $V_{EN\_RISE}$          | EN voltage rising threshold                                                                           |                                                                                                      | 1.161 | 1.263 | 1.365 | V             |
| $V_{EN\_FALL}$          | EN voltage falling threshold                                                                          |                                                                                                      |       | 0.91  |       | V             |
| $V_{EN\_HYS}$           | EN voltage hysteresis                                                                                 |                                                                                                      | 0.275 | 0.353 | 0.404 | V             |
| $V_{EN\_WAKE}$          | EN wake-up threshold                                                                                  |                                                                                                      | 0.4   |       |       | V             |
| $I_{EN}$                | Input current into EN/SYNC (non-switching)                                                            | $V_{EN/SYNC} = 3.3\text{ V}$ , $V_{FB} = 1.5\text{ V}$                                               |       | 1.65  |       | $\mu\text{A}$ |
| $t_{EN}$                | EN HIGH to start of switching delay <sup>(1)</sup>                                                    |                                                                                                      |       | 0.7   |       | ms            |
| <b>INTERNAL LDO VCC</b> |                                                                                                       |                                                                                                      |       |       |       |               |
| $V_{CC}$                | Internal LDO VCC output voltage                                                                       | $3.4\text{ V} \leq V_{LDOIN} \leq 12.5\text{ V}$                                                     |       | 3.3   |       | V             |
|                         |                                                                                                       | $V_{LDOIN} = 3.1\text{ V}$ , Non-switching                                                           |       | 3.1   |       | V             |
| $V_{CC\_UVLO}$          | VCC UVLO rising threshold                                                                             | $V_{LDOIN} < 3.1\text{ V}$ <sup>(1)</sup>                                                            |       | 3.6   |       | V             |
|                         |                                                                                                       | $V_{IN} < 3.6\text{ V}$ <sup>(2)</sup>                                                               |       | 3.6   |       | V             |
| $V_{CC\_UVLO\_HYS}$     | VCC UVLO hysteresis <sup>(2)</sup>                                                                    | Hysteresis below $V_{CC\_UVLO}$                                                                      |       | 1.1   |       | V             |
| $I_{VLDOIN}$            | Input current into VLDOIN pin (non-switching, maximum at $T_A = 125^{\circ}\text{C}$ ) <sup>(3)</sup> | $V_{EN/SYNC} = 3.3\text{ V}$ , $V_{FB} = 1.5\text{ V}$                                               |       | 25    | 31.2  | $\mu\text{A}$ |
| <b>FEEDBACK</b>         |                                                                                                       |                                                                                                      |       |       |       |               |
| $V_{OUT}$               | Adjustable output voltage range (TPSM63603)                                                           | Over the $I_{OUT}$ range                                                                             | 1     |       | 16    | V             |
|                         | Fixed output voltage (TPSM63603V3)                                                                    |                                                                                                      |       | 3.3   |       | V             |
|                         | Fixed output voltage (TPSM63603V5)                                                                    |                                                                                                      |       | 5     |       | V             |
| $V_{FB}$                | Feedback voltage                                                                                      | $T_A = 25^{\circ}\text{C}$ , $I_{OUT} = 0\text{ A}$                                                  |       | 1.0   |       | V             |
| $V_{FB\_ACC}$           | Feedback voltage accuracy                                                                             | Over the $V_{IN}$ range, $V_{OUT} = 1\text{ V}$ , $I_{OUT} = 0\text{ A}$ , $F_{SW} = 200\text{ kHz}$ | -1    |       | +1    | %             |
| $V_{FB}$                | Load Regulation                                                                                       | $T_A = 25^{\circ}\text{C}$ , $0\text{ A} \leq I_{OUT} \leq 3\text{ A}$                               |       | 0.1   |       | %             |
| $V_{FB}$                | Line Regulation                                                                                       | $T_A = 25^{\circ}\text{C}$ , $I_{OUT} = 0\text{ A}$ , $4.0\text{ V} \leq V_{IN} \leq 36\text{ V}$    |       | 0.1   |       | %             |
| $I_{FB}$                | Input current into FB pin                                                                             | $V_{FB} = 1.0\text{ V}$                                                                              |       | 10    |       | nA            |
| <b>CURRENT</b>          |                                                                                                       |                                                                                                      |       |       |       |               |
| $I_{OUT}$               | Output current                                                                                        | $T_A = 25^{\circ}\text{C}$                                                                           | 0     |       | 3.0   | A             |
| $I_{OCL}$               | Output over-current (DC) limit threshold                                                              |                                                                                                      |       | 4.9   |       | A             |
| $I_{L\_HS}$             | High-side switch current limit                                                                        | Duty cycle approaches 0%                                                                             | 5.6   | 6.2   | 6.8   | A             |
| $I_{L\_LS}$             | Low-side switch current limit                                                                         |                                                                                                      | 2.9   | 3.4   | 3.8   | A             |
| $I_{L\_NEG}$            | Negative current limit                                                                                |                                                                                                      |       | -3    |       | A             |
| $V_{HICCUP}$            | Ratio of FB voltage to in-regulation FB voltage to enter hiccup                                       | Not during soft start                                                                                |       | 40    |       | %             |
| $t_W$                   | Short circuit wait time ("hiccup" time before soft start) <sup>(1)</sup>                              |                                                                                                      |       | 80    |       | ms            |
| <b>SOFT-START</b>       |                                                                                                       |                                                                                                      |       |       |       |               |
| $t_{SS}$                | Time from first SW pulse to $V_{REF}$ at 90%                                                          | $V_{IN} \geq 4.2\text{ V}$                                                                           | 3.5   | 5     | 7     | ms            |
| $t_{SS2}$               | Time from first SW pulse to release of FPWM lockout if output not in regulation <sup>(1)</sup>        | $V_{IN} \geq 4.2\text{ V}$                                                                           | 9.5   | 13    | 17    | ms            |

## 6.5 Electrical Characteristics (continued)

Limits apply over  $T_J = -40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ,  $V_{IN} = 24\text{ V}$ ,  $V_{OUT} = 3.3\text{ V}$ ,  $V_{LDOIN} = 5\text{ V}$ ,  $F_{SW} = 800\text{ kHz}$  (unless otherwise noted). Minimum and maximum limits are specified through production test or by design. Typical values represent the most likely parametric norm and are provided for reference only.

| PARAMETER                  |                                                                                       | TEST CONDITIONS                                                          | MIN  | TYP  | MAX   | UNIT               |
|----------------------------|---------------------------------------------------------------------------------------|--------------------------------------------------------------------------|------|------|-------|--------------------|
| <b>POWER GOOD</b>          |                                                                                       |                                                                          |      |      |       |                    |
| PG <sub>OV</sub>           | PG upper threshold - rising                                                           | % of $V_{OUT}$ setting                                                   | 105% | 107% | 110%  |                    |
| PG <sub>UV</sub>           | PG lower threshold - falling                                                          | % of $V_{OUT}$ setting                                                   | 92%  | 94%  | 96.5% |                    |
| PG <sub>HYS</sub>          | PG upper threshold hysteresis (rising & falling)                                      | % of $V_{OUT}$ setting                                                   |      | 1.3% |       |                    |
| V <sub>IN_PG_VALID</sub>   | Input voltage for valid PG output                                                     | 46 $\mu\text{A}$ pull-up, $V_{EN/SYNC} = 0\text{ V}$                     | 1.0  |      |       | V                  |
| V <sub>PG_LOW</sub>        | Low level PG function output voltage                                                  | 2 mA pullup to PG pin, $V_{EN/SYNC} = 3.3\text{ V}$                      |      |      | 0.4   | V                  |
| I <sub>PG</sub>            | Input current into PG pin when open drain output is high                              | $V_{PG} = 3.3\text{ V}$                                                  |      | 10   |       | nA                 |
| I <sub>OV</sub>            | Pull down current at the SW node under over voltage condition                         |                                                                          |      | 0.5  |       | mA                 |
| t <sub>PG_FLT_RISE</sub>   | Delay time to PG high signal                                                          |                                                                          | 1.5  | 2.0  | 2.5   | ms                 |
| t <sub>PG_FLT_FALL</sub>   | Glitch filter time constant for PG function                                           |                                                                          |      | 120  |       | $\mu\text{s}$      |
| <b>SWITCHING FREQUENCY</b> |                                                                                       |                                                                          |      |      |       |                    |
| f <sub>SW_RANGE</sub>      | Switching frequency range by $R_T$ or SYNC                                            |                                                                          | 200  |      | 2200  | kHz                |
| f <sub>SW_RT1</sub>        | Default switching frequency by $R_T$                                                  | $R_{RT} = 66.5\text{ k}\Omega$                                           | 180  | 200  | 220   | kHz                |
| f <sub>SW_RT2</sub>        | Default switching frequency by $R_T$                                                  | $V_{IN} = 12\text{ V}$ , $R_{RT} = 5.76\text{ k}\Omega$                  | 1980 | 2200 | 2420  | kHz                |
| f <sub>S_SS</sub>          | Frequency span of spread spectrum operation – largest deviation from center frequency | Spread spectrum active (TPSM63603S)                                      |      | 2%   |       |                    |
| f <sub>PSS</sub>           | Spread spectrum pattern frequency <sup>(1)</sup>                                      | Spread spectrum active, $f_{SW} = 2.1\text{ MHz}$                        |      |      | 1.5   | Hz                 |
| <b>SYNCHRONIZATION</b>     |                                                                                       |                                                                          |      |      |       |                    |
| V <sub>EN_SYNC</sub>       | Edge amplitude necessary to sync using EN/SYNC                                        | Rise/fall time < 30 ns                                                   | 2.4  |      |       | V                  |
| t <sub>B</sub>             | Blanking of EN after rising or falling edges <sup>(1)</sup>                           |                                                                          | 4    |      | 28    | $\mu\text{s}$      |
| t <sub>SYNC_EDGE</sub>     | Enable sync signal hold time after edge for edge recognition <sup>(1)</sup>           |                                                                          | 100  |      |       | ns                 |
| <b>POWER STAGE</b>         |                                                                                       |                                                                          |      |      |       |                    |
| V <sub>BOOT_UVLO</sub>     | Voltage on CBOOT pin compared to SW which will turn off high-side switch              |                                                                          |      | 2.1  |       | V                  |
| t <sub>ON_MIN</sub>        | Minimum ON pulse width <sup>(1)</sup>                                                 | $V_{OUT} = 1\text{ V}$ , $I_{OUT} = 1\text{ A}$ , RBOOT shorted to CBOOT |      | 55   | 70    | ns                 |
| t <sub>ON_MAX</sub>        | Maximum ON pulse width <sup>(1)</sup>                                                 |                                                                          |      | 9    |       | $\mu\text{s}$      |
| t <sub>OFF_MIN</sub>       | Minimum OFF pulse width                                                               | $V_{IN} = 4\text{ V}$ , $I_{OUT} = 1\text{ A}$ , RBOOT shorted to CBOOT  |      | 65   | 85    | ns                 |
| <b>THERMAL SHUTDOWN</b>    |                                                                                       |                                                                          |      |      |       |                    |
| T <sub>SDN</sub>           | Thermal shutdown threshold <sup>(1)</sup>                                             | Temperature rising                                                       | 158  | 168  | 180   | $^{\circ}\text{C}$ |
| T <sub>HYST</sub>          | Thermal shutdown hysteresis <sup>(1)</sup>                                            |                                                                          |      | 10   |       | $^{\circ}\text{C}$ |

(1) Parameter specified by design, statistical analysis and production testing of correlated parameters. Not production tested.

(2) Production Tested with  $V_{IN} = 3\text{ V}$ .

(3) This is the current used by the device while not switching, open loop, with FB pulled to +5% of nominal. It does not represent the total input current to the system while regulating. For additional information, reference the Systems Characteristics Table and the Input Supply Current Section.

## 6.6 System Characteristics

The following specifications apply only to the typical applications circuit, with nominal component values. Specifications in the typical (TYP) column apply to  $T_J = 25^\circ\text{C}$  only. These specifications are not ensured by production testing.

| PARAMETER        |                                         | TEST CONDITIONS                                                                                                                                                                       | MIN | TYP  | MAX | UNIT |
|------------------|-----------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|------|-----|------|
| SUPPLY           |                                         |                                                                                                                                                                                       |     |      |     |      |
| I <sub>IN</sub>  | Input supply current when in regulation | V <sub>IN</sub> = 24 V, V <sub>OUT</sub> = 3.3 V, V <sub>EN/SYNC</sub> = V <sub>IN</sub> , V <sub>VLDOIN</sub> = V <sub>OUT</sub> , F <sub>SW</sub> = 800 kHz, I <sub>OUT</sub> = 0 A |     | 10   |     | mA   |
| OUTPUT VOLTAGE   |                                         |                                                                                                                                                                                       |     |      |     |      |
| V <sub>FB</sub>  | Load regulation                         | V <sub>OUT</sub> = 3.3 V, V <sub>IN</sub> = 24 V, I <sub>OUT</sub> = 0.1 A to full load                                                                                               |     | 1    |     | mV   |
| V <sub>FB</sub>  | Line regulation                         | V <sub>OUT</sub> = 3.3 V, V <sub>IN</sub> = 4 V to 36 V, I <sub>OUT</sub> = 3 A                                                                                                       |     | 6    |     | mV   |
| V <sub>OUT</sub> | Load transient                          | V <sub>OUT</sub> = 3.3 V, V <sub>IN</sub> = 24 V, I <sub>OUT</sub> = 1 A to 2.5 A @ 2 A/μs, C <sub>OUT(derated)</sub> = 49 uF                                                         |     | 50   |     | mV   |
| EFFICIENCY       |                                         |                                                                                                                                                                                       |     |      |     |      |
| η                | Efficiency                              | V <sub>OUT</sub> = 3.3 V, V <sub>IN</sub> = 12 V, I <sub>OUT</sub> = 2.5 A, V <sub>LDOIN</sub> = V <sub>OUT</sub> , F <sub>SW</sub> = 800 kHz                                         |     | 89.5 |     | %    |
|                  |                                         | V <sub>OUT</sub> = 3.3 V, V <sub>IN</sub> = 24 V, I <sub>OUT</sub> = 2.5 A, V <sub>LDOIN</sub> = V <sub>OUT</sub> , F <sub>SW</sub> = 800 kHz                                         |     | 87.5 |     | %    |
|                  |                                         | V <sub>OUT</sub> = 5 V, V <sub>IN</sub> = 24 V, I <sub>OUT</sub> = 2.5 A, V <sub>LDOIN</sub> = V <sub>OUT</sub> , F <sub>SW</sub> = 1 MHz                                             |     | 91   |     | %    |
|                  |                                         | V <sub>OUT</sub> = 5 V, V <sub>IN</sub> = 36 V, I <sub>OUT</sub> = 2.5 A, V <sub>LDOIN</sub> = V <sub>OUT</sub> , F <sub>SW</sub> = 1 MHz                                             |     | 88.1 |     | %    |
|                  |                                         | V <sub>OUT</sub> = 12 V, V <sub>IN</sub> = 24 V, I <sub>OUT</sub> = 1.5 A, V <sub>LDOIN</sub> = V <sub>OUT</sub> , F <sub>SW</sub> = 2 MHz                                            |     | 94.1 |     | %    |
| CAPACITANCE      |                                         |                                                                                                                                                                                       |     |      |     |      |

## 6.7 Typical Characteristics

$V_{IN} = 24\text{ V}$ , unless otherwise specified.

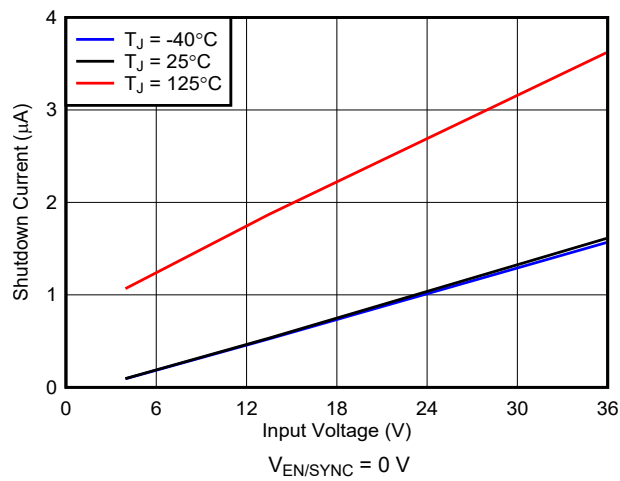


Figure 6-1. Shutdown Supply Current

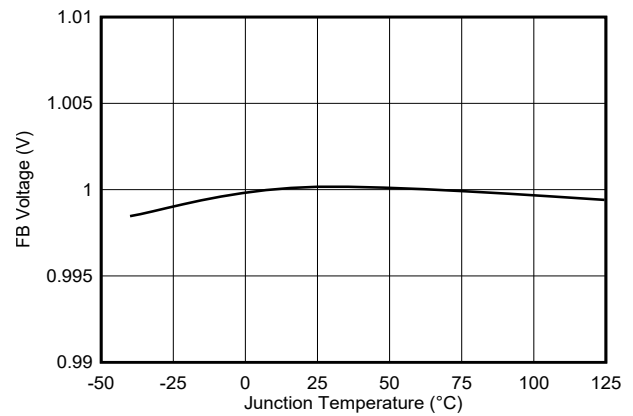


Figure 6-2. Feedback Voltage

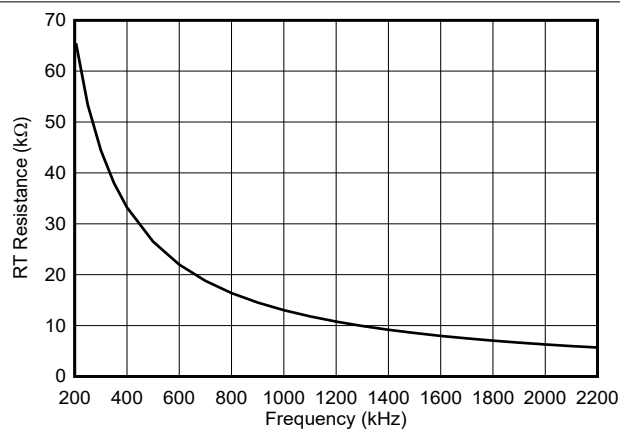


Figure 6-3. Switching Frequency Set by RT Resistor

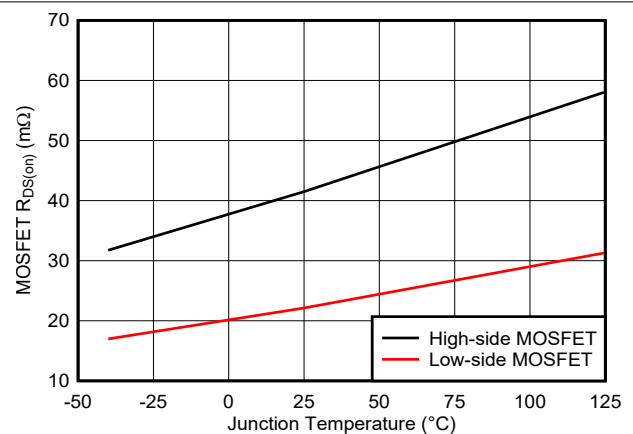


Figure 6-4. High-Side and Low-Side MOSFET  $R_{DS(on)}$

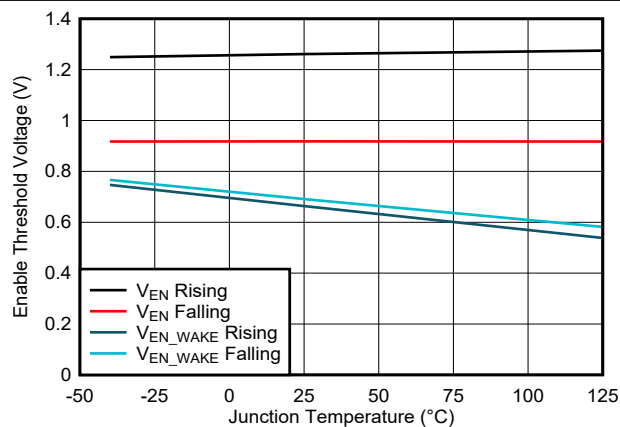


Figure 6-5. Enable Thresholds

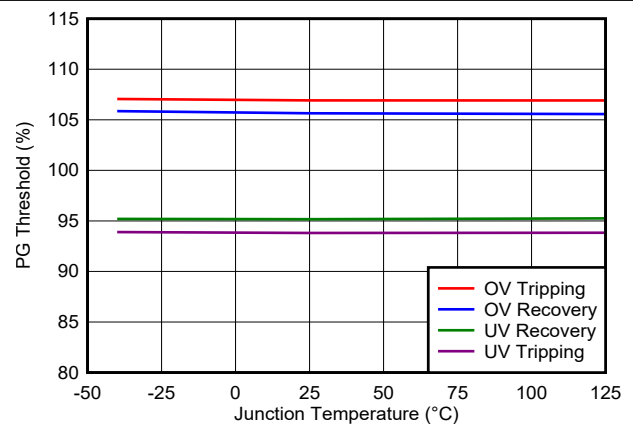


Figure 6-6. Power-Good (PG) Thresholds

## 6.8 Typical Characteristics: $V_{IN} = 12\text{ V}$

Refer to セクション 8.2 for circuit designs.

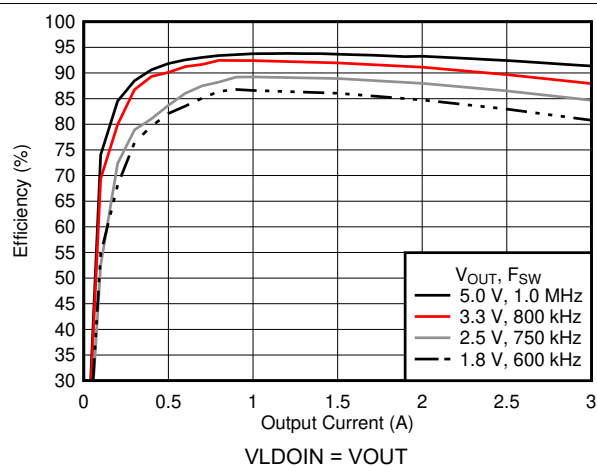


図 6-7. Efficiency

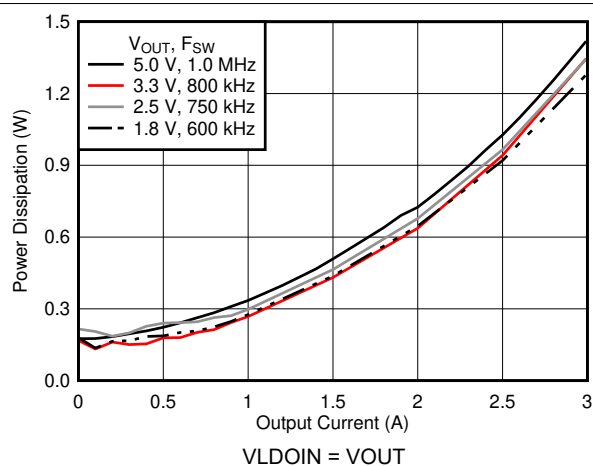


図 6-8. Power Dissipation

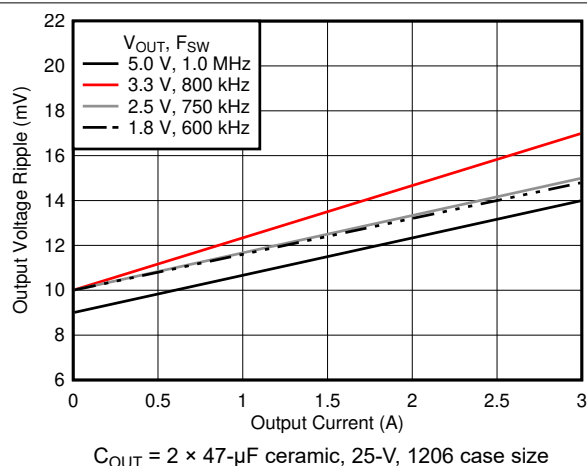


図 6-9. Output Voltage Ripple

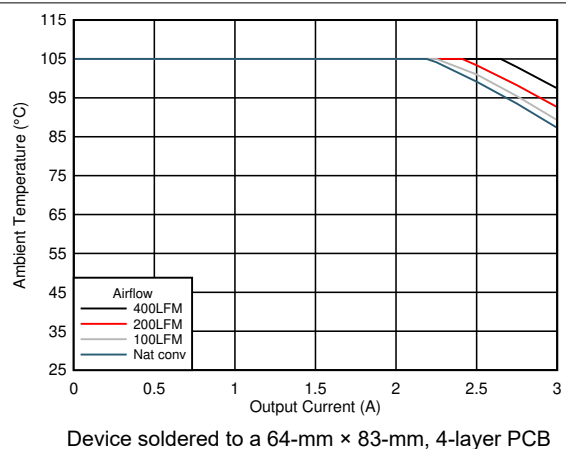


図 6-10. Safe Operating Area  
 $V_{OUT} = 1.8\text{ V}$ ,  $F_{SW} = 600\text{ kHz}$

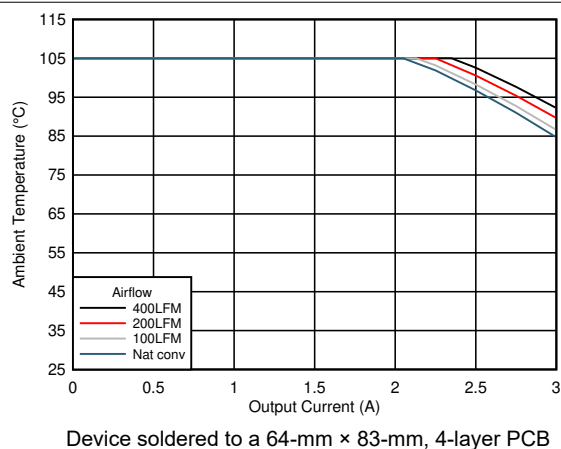


図 6-11. Safe Operating Area  
 $V_{OUT} = 3.3\text{ V}$ ,  $F_{SW} = 800\text{ kHz}$

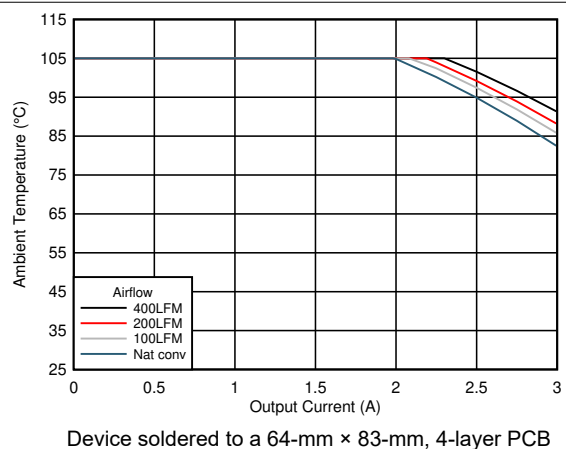


図 6-12. Safe Operating Area  
 $V_{OUT} = 5.0\text{ V}$ ,  $F_{SW} = 1\text{ MHz}$

## 6.9 Typical Characteristics: $V_{IN} = 24\text{ V}$

Refer to セクション 8.2 for circuit designs.

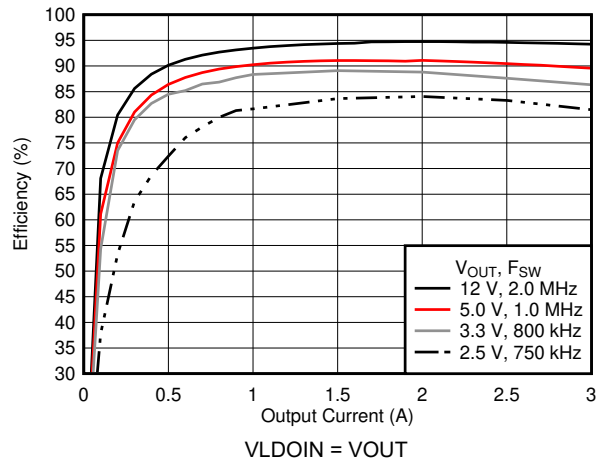


Figure 6-13. Efficiency

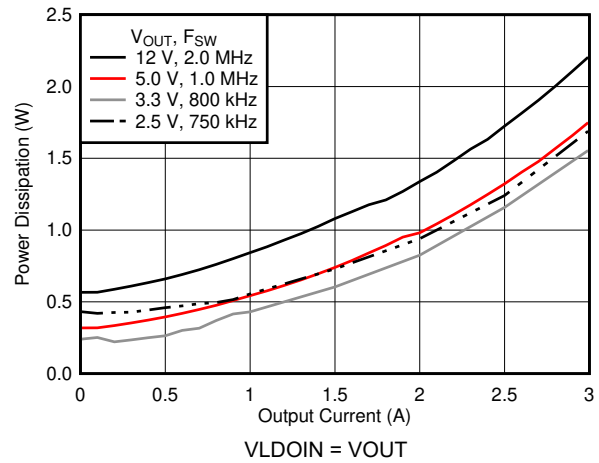


Figure 6-14. Power Dissipation

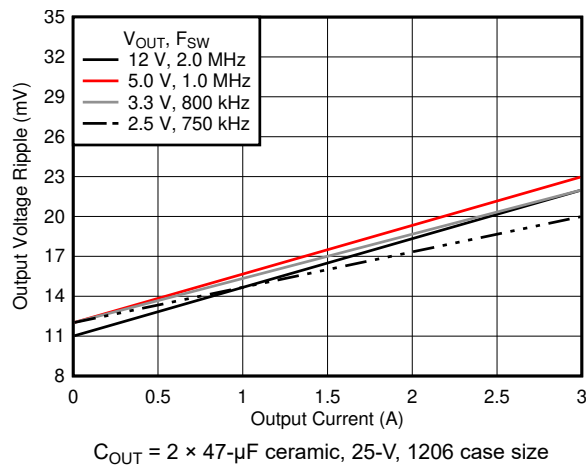


Figure 6-15. Output Voltage Ripple

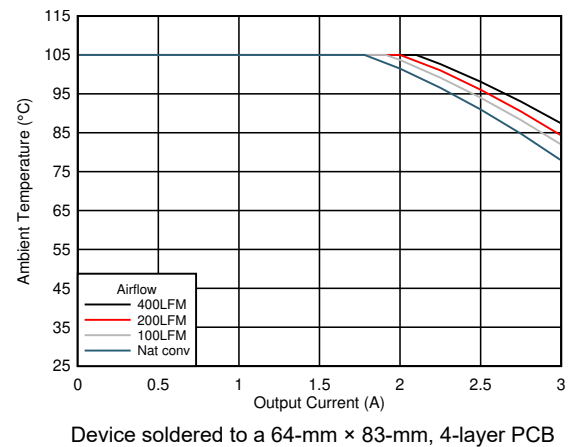


Figure 6-16. Safe Operating Area  
 $V_{OUT} = 3.3\text{ V}$ ,  $F_{SW} = 800\text{ kHz}$

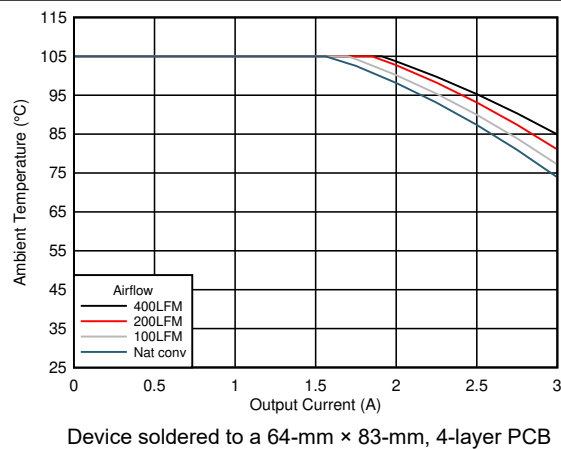


Figure 6-17. Safe Operating Area  
 $V_{OUT} = 5.0\text{ V}$ ,  $F_{SW} = 1\text{ MHz}$

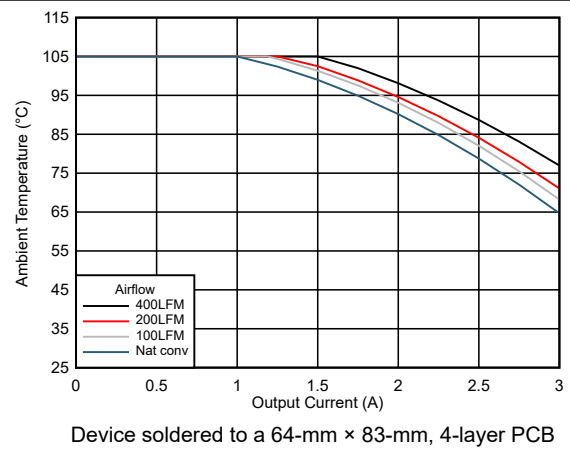


Figure 6-18. Safe Operating Area  
 $V_{OUT} = 12\text{ V}$ ,  $F_{SW} = 2\text{ MHz}$

## 6.10 Typical Characteristics: $V_{IN} = 36\text{ V}$

Refer to セクション 8.2 for circuit designs.

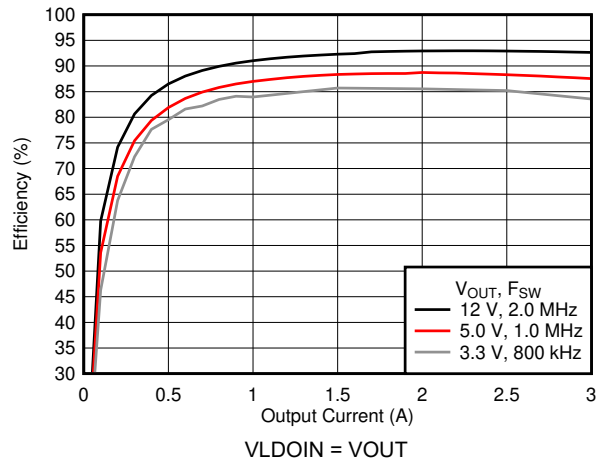


Figure 6-19. Efficiency

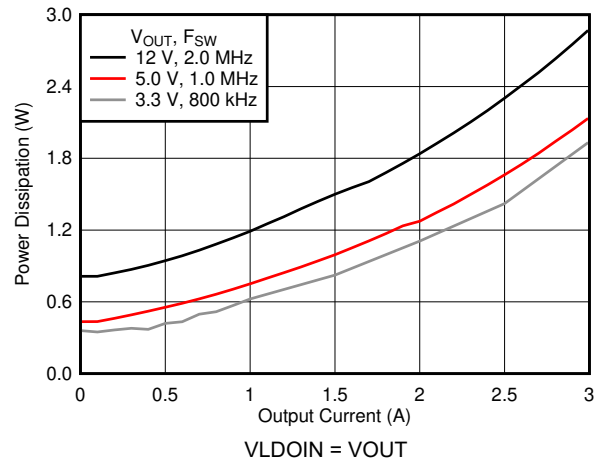


Figure 6-20. Power Dissipation

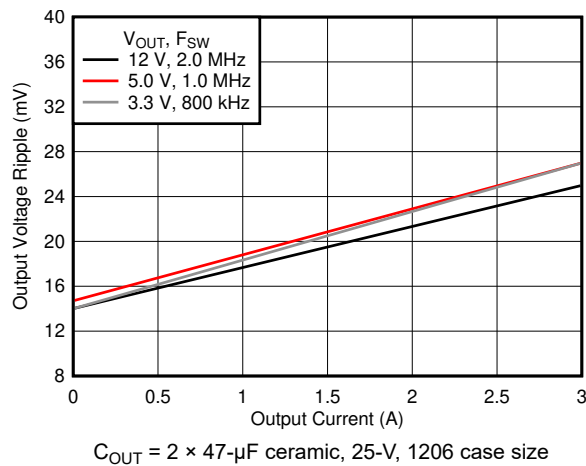


Figure 6-21. Output Voltage Ripple

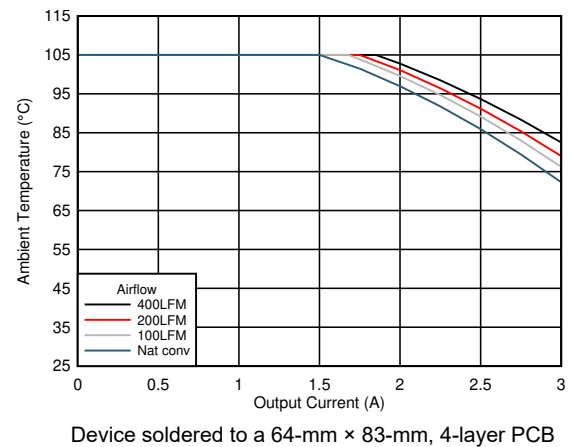


Figure 6-22. Safe Operating Area  
 $V_{OUT} = 3.3\text{ V}, F_{SW} = 800\text{ kHz}$

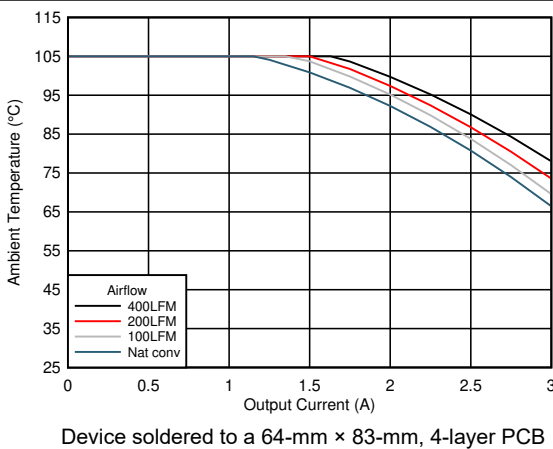


Figure 6-23. Safe Operating Area  
 $V_{OUT} = 5.0\text{ V}, F_{SW} = 1\text{ MHz}$

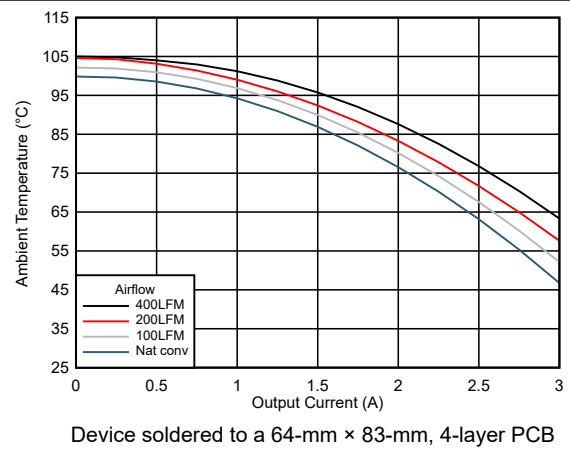


Figure 6-24. Safe Operating Area  
 $V_{OUT} = 12\text{ V}, F_{SW} = 2\text{ MHz}$

## 7 Detailed Description

### 7.1 Overview

The TPSM63603 is an easy-to-use, synchronous buck, DC-DC power module that operates from a 3-V to 36-V supply voltage. The device is intended for step-down conversions from 5-V, 12-V, and 24-V supply rails. With an integrated power controller, inductor, and MOSFETs, the TPSM63603 delivers up to 3-A DC load current, with high efficiency and ultra-low input quiescent current, in a very small solution size. Although designed for simple implementation, this device offers flexibility to optimize its usage according to the target application. Control-loop compensation is not required, reducing design time and external component count.

With a programmable switching frequency from 200 kHz to 2.2 MHz using its RT pin or an external clock signal, the TPSM63603 incorporates specific features to improve EMI performance in noise-sensitive applications:

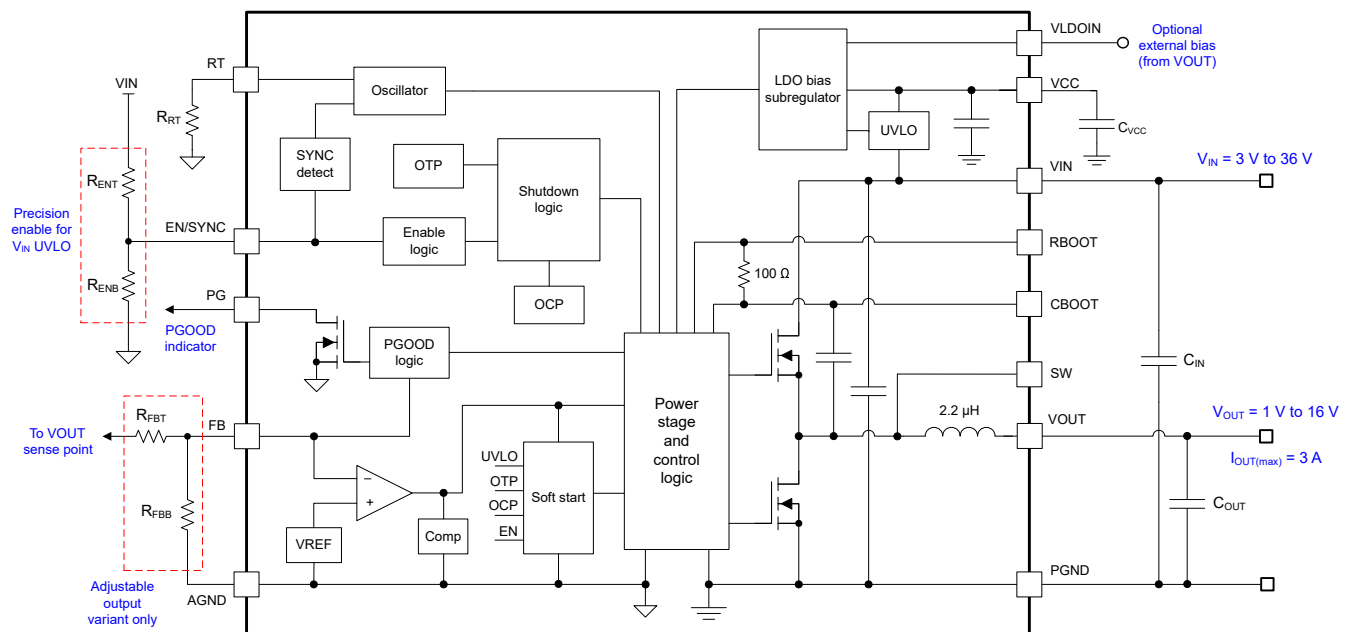
- An optimized package and pinout design enables a shielded switch-node layout that mitigates radiated EMI
- Parallel input and output paths with symmetrical capacitor layouts minimize parasitic inductance, switch-voltage ringing, and radiated field coupling
- **Pseudo-random spread spectrum (PRSS)** modulation in the TPSM63603S reduces peak emissions
- Clock synchronization and FPWM mode enable constant switching frequency across the load current range
- Integrated power MOSFETs with enhanced gate drive control enable low-noise PWM switching
- Adjustable switch-node slew rate, which allows optimization of EMI at higher frequency harmonics

The TPSM63603 module also includes inherent protection features for robust system requirements:

- An open-drain PGOOD indicator for power-rail sequencing and fault reporting
- Precision enable input with hysteresis, providing
  - Programmable line undervoltage lockout (UVLO)
  - Remote ON/OFF capability
- Internally fixed output-voltage soft start with monotonic startup into prebiased loads
- Hiccup-mode overcurrent protection with cycle-by-cycle peak and valley current limits
- Thermal shutdown with automatic recovery.

These features enable a flexible and easy-to-use platform for a wide range of applications. The pin arrangement is designed for simple layout, requiring few external components. See [セクション 10](#) for layout example.

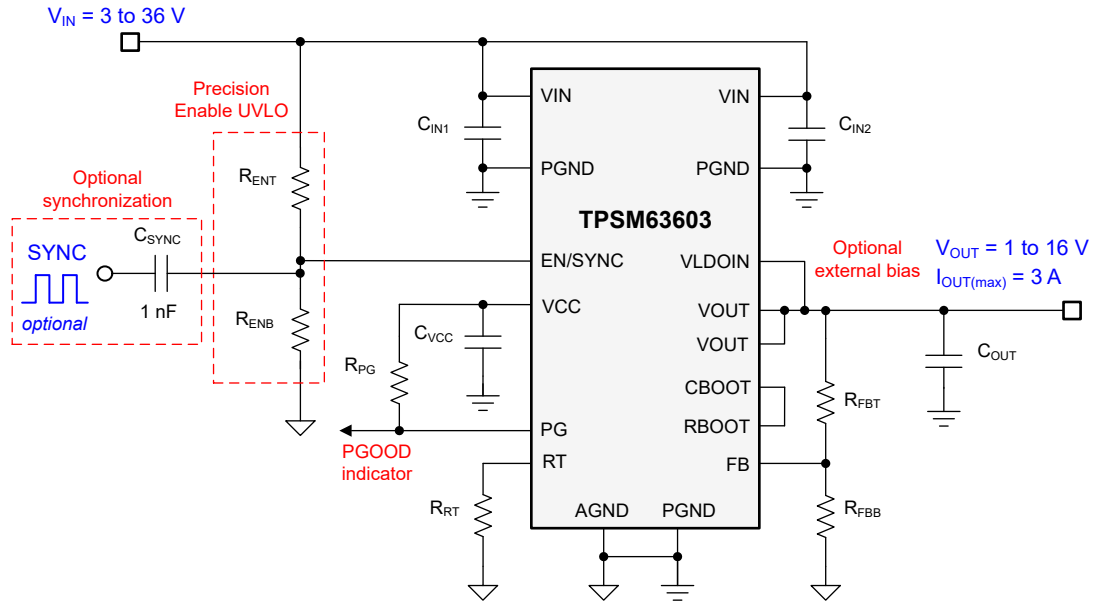
### 7.2 Functional Block Diagram



## 7.3 Feature Description

### 7.3.1 Input Voltage Range

With a steady-state input voltage range from 3 V to 36 V, the TPSM63603 module is intended for step-down conversions from typical 12-V, 24-V, and 28-V input supply rails. The schematic circuit in [Figure 7-1](#) shows all the necessary components to implement a TPSM63603-based buck regulator using a single input supply.



**Figure 7-1. TPSM63603 Schematic Diagram with Input Voltage Operating Range of 3 V to 36 V**

Take extra care to make sure that the voltage at the VIN pins of the module does not exceed the absolute maximum voltage rating of 40 V during line or load transient events. Voltage ringing at the VIN pins that exceeds the absolute maximum ratings can damage the IC.

### 7.3.2 Adjustable Output Voltage (FB)

The TPSM63603 has an adjustable output voltage range of 1 V to 16 V. Setting the output voltage requires two resistors,  $R_{FBT}$  and  $R_{FBB}$  (see [Figure 7-2](#)). Connect  $R_{FBT}$  between VOUT, at the regulation point, and the FB pin. Connect  $R_{FBB}$  between the FB pin and AGND (pin 10). The recommended value of  $R_{FBB}$  is 10 k $\Omega$ . The value for  $R_{FBT}$  can be calculated using [Equation 1](#). [Table 7-1](#) lists the standard resistor values for several output voltages and the recommended switching frequency. The minimum required output capacitance for each output voltage is also included in [Table 7-1](#). The capacitance values listed represent the effective capacitance, taking into account the effects of DC bias and temperature variation.

$$R_{FBT} [\text{k}\Omega] = R_{FBB} [\text{k}\Omega] \cdot \left( \frac{V_{OUT} [\text{V}]}{1\text{V}} - 1 \right) \quad (1)$$

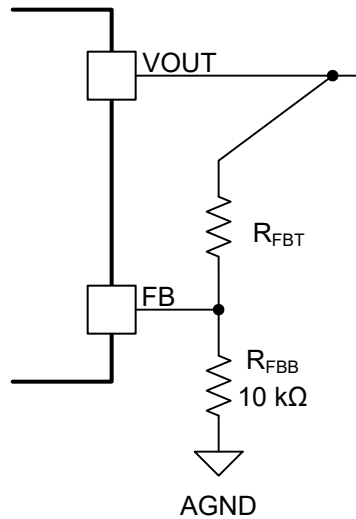


図 7-2. FB Resistor Divider

表 7-1. Standard  $R_{FBT}$  Values, Recommended  $F_{SW}$  and Minimum  $C_{OUT}$ 

| $V_{OUT}$ (V) | $R_{FBT}$ (kΩ) <sup>(1)</sup> | RECOMMENDED $F_{SW}$ (kHz) | $C_{OUT(MIN)}$ (μF) (EFFECTIVE) | $V_{OUT}$ (V) | $R_{FBT}$ (kΩ) <sup>(1)</sup> | RECOMMENDED $F_{SW}$ (kHz) | $C_{OUT(MIN)}$ (μF) (EFFECTIVE) |
|---------------|-------------------------------|----------------------------|---------------------------------|---------------|-------------------------------|----------------------------|---------------------------------|
| 1.0           | Short                         | 400                        | 300                             | 3.3           | 23.2                          | 800                        | 40                              |
| 1.2           | 2                             | 500                        | 200                             | 5.0           | 40.2                          | 1000                       | 25                              |
| 1.5           | 4.99                          | 500                        | 160                             | 7.5           | 64.9                          | 1300                       | 20                              |
| 1.8           | 8.06                          | 600                        | 120                             | 10            | 90.9                          | 1500                       | 15                              |
| 2.0           | 10                            | 600                        | 100                             | 12            | 110                           | 2000                       | 5                               |
| 2.5           | 15                            | 750                        | 65                              | 15            | 140                           | 2200                       | 4                               |
| 3.0           | 20                            | 750                        | 50                              | 16            | 150                           | 2200                       | 3                               |

(1)  $R_{FBB} = 10 \text{ k}\Omega$ .

Note that higher feedback resistances consume less DC current, which is mandatory if light-load efficiency is critical. However,  $R_{FBT}$  larger than 1 MΩ is not recommended as the feedback path becomes more susceptible to noise. High feedback resistance generally requires more careful layout of the feedback path. It is important to keep the feedback trace as short as possible while keeping the feedback trace away from the noisy area of the PCB. For more layout recommendations, see [セクション 10](#).

### Fixed Output Voltage Variants

The TPSM63603V3 and TPSM63603V5 are the fixed output voltage variants of the module with 3.3-V and 5-V fixed output voltages, respectively. In these variants, the resistor feedback dividers are located internal to the module. Therefore, the FB pin can be connected directly to output voltage regulation point.

### 7.3.3 Input Capacitors

Input capacitors are necessary to limit the input ripple voltage to the module due to switching-frequency AC currents. TI recommends using ceramic capacitors to provide low impedance and high RMS current rating over a wide temperature range. 式 2 gives the input capacitor RMS current. The highest input capacitor RMS current occurs at  $D = 0.5$ , at which point the RMS current rating of the capacitors should be greater than half the output current.

$$I_{CIN,rms} = \sqrt{D \cdot \left( I_{OUT}^2 \cdot (1-D) + \frac{\Delta I_L^2}{12} \right)} \quad (2)$$

where

- $D = V_{OUT} / V_{IN}$  = the module duty cycle

Ideally, the DC and AC components of input current to the buck stage are provided by the input voltage source and the input capacitors, respectively. Neglecting inductor ripple current, the input capacitors source current of amplitude  $(I_{OUT} - I_{IN})$  during the  $D$  interval and sink  $I_{IN}$  during the  $1 - D$  interval. Thus, the input capacitors conduct a square-wave current of peak-to-peak amplitude equal to the output current. The resultant capacitive component of AC ripple voltage is a triangular waveform. Together with the ESR-related ripple component, 式 3 gives the peak-to-peak ripple voltage amplitude:

$$\Delta V_{IN} = \frac{I_{OUT} \cdot D \cdot (1-D)}{F_{SW} \cdot C_{IN}} + I_{OUT} \cdot R_{ESR} \quad (3)$$

式 4 gives the input capacitance required for a particular load current:

$$C_{IN} \geq \frac{D \cdot (1-D) \cdot I_{OUT}}{F_{SW} \cdot (\Delta V_{IN} - R_{ESR} \cdot I_{OUT})} \quad (4)$$

where

- $\Delta V_{IN}$  is the input voltage ripple specification.

The TPSM63603 requires a minimum of  $2 \times 4.7 \mu F$  of ceramic type input capacitance. Only use high-quality ceramic type capacitors with sufficient voltage and temperature rating. The ceramic input capacitors provide a low impedance source to the converter in addition to supplying the ripple current and isolating switching noise from other circuits. Additional capacitance can be required for applications with transient load requirements. The voltage rating of input capacitors must be greater than the maximum input voltage. To compensate for the derating of ceramic capacitors, TI recommends a voltage rating of twice the maximum input voltage or placing multiple capacitors in parallel. 表 7-2 includes a preferred list of capacitors by vendor.

**表 7-2. Recommended Input Capacitors**

| VENDOR <sup>(1)</sup> | DIELECTRIC | PART NUMBER          | CASE SIZE | CAPACITOR CHARACTERISTICS |                                 |
|-----------------------|------------|----------------------|-----------|---------------------------|---------------------------------|
|                       |            |                      |           | VOLTAGE RATING (V)        | CAPACITANCE <sup>(2)</sup> (μF) |
| TDK                   | X7R        | C3216X7R1H475K160AC  | 1206      | 50                        | 4.7                             |
| Murata                | X7R        | GRM31CR71H475KA12L   | 1206      | 50                        | 4.7                             |
| TDK                   | X7R        | CGA6P3X7R1H475K250AB | 1210      | 50                        | 4.7                             |
| Murata                | X7S        | GCM31CC71H475KA03L   | 1206      | 50                        | 4.7                             |

(1) Consult capacitor suppliers regarding availability, material composition, RoHS and lead-free status, and manufacturing process requirements for any capacitors identified in this table. See the [Third-Party Products Disclaimer](#).

(2) Nameplate capacitance values (the effective values are lower based on the applied DC voltage and temperature).

### 7.3.4 Output Capacitors

表 7-1 lists the TPSM63603 minimum amount of required output capacitance. The effects of DC bias and temperature variation must be considered when using ceramic capacitance. For ceramic capacitors, the package size, voltage rating, and dielectric material contribute to differences between the standard rated value and the actual effective value of the capacitance.

When adding additional capacitance above  $C_{OUT(MIN)}$ , the capacitance can be ceramic type, low-ESR polymer type, or a combination of the two. See 表 7-3 for a preferred list of output capacitors by vendor.

**表 7-3. Recommended Output Capacitors**

| VENDOR <sup>(1)</sup> | TEMPERATURE COEFFICIENT | PART NUMBER          | CASE SIZE | CAPACITOR CHARACTERISTICS |                                 |
|-----------------------|-------------------------|----------------------|-----------|---------------------------|---------------------------------|
|                       |                         |                      |           | VOLTAGE (V)               | CAPACITANCE <sup>(2)</sup> (μF) |
| TDK                   | X7R                     | CGA5L1X7R1C106K160AC | 1206      | 16                        | 10                              |

**表 7-3. Recommended Output Capacitors (continued)**

| VENDOR <sup>(1)</sup> | TEMPERATURE COEFFICIENT | PART NUMBER         | CASE SIZE | CAPACITOR CHARACTERISTICS |                                 |
|-----------------------|-------------------------|---------------------|-----------|---------------------------|---------------------------------|
|                       |                         |                     |           | VOLTAGE (V)               | CAPACITANCE <sup>(2)</sup> (μF) |
| Murata                | X7R                     | GCM31CR71C106KA64L  | 1206      | 16                        | 10                              |
| TDK                   | X7R                     | C3216X7R1E106K160AB | 1206      | 25                        | 10                              |
| Murata                | X7S                     | GCJ31CC71E106KA15L  | 1206      | 25                        | 10                              |
| Murata                | X6S                     | GRM31CC81E226K      | 1206      | 25                        | 22                              |
| Murata                | X7R                     | GRM32ER71E226M      | 1210      | 25                        | 22                              |

- (1) Consult capacitor suppliers regarding availability, material composition, RoHS and lead-free status, and manufacturing process requirements for any capacitors identified in this table. See the [Third-Party Products Disclaimer](#).
- (2) Nameplate capacitance values (the effective values are lower based on the applied DC voltage and temperature).

**7.3.5 Switching Frequency (RT)**

The switching frequency range of the TPSM63603 is 200 kHz to 2.2 MHz. The switching frequency can easily be set by connecting a resistor ( $R_{RT}$ ) between the RT pin and AGND. Use 式 5 to calculate the  $R_{RT}$  value for a desired frequency or simply select from 表 7-4. Note that a resistor value outside of the recommended range can cause the device to shut down. This prevents unintended operation if RT pin is shorted to ground or left open. Do not apply a pulsed signal to this pin to force synchronization. If synchronization is needed, refer to セクション 7.3.7.

The switching frequency must be selected based on the output voltage setting of the device. See 表 7-4 for  $R_{RT}$  resistor values and the allowable output voltage range for a given switching frequency for common input voltages.

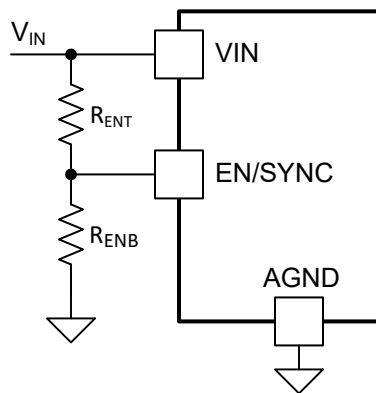
$$R_{RT} [k\Omega] = \frac{13.46}{F_{SW} [MHz]} - 0.44 \quad (5)$$

**表 7-4. Switching Frequency Versus Output Voltage ( $I_{OUT} = 3 A$ )**

| $F_{SW}$ (kHz) | $R_{RT}$ (kΩ) | $V_{IN} = 5 V$      |     | $V_{IN} = 12 V$     |     | $V_{IN} = 24 V$     |      | $V_{IN} = 36 V$     |      |
|----------------|---------------|---------------------|-----|---------------------|-----|---------------------|------|---------------------|------|
|                |               | $V_{OUT}$ RANGE (V) |     | $V_{OUT}$ RANGE (V) |     | $V_{OUT}$ RANGE (V) |      | $V_{OUT}$ RANGE (V) |      |
|                |               | MIN                 | MAX | MIN                 | MAX | MIN                 | MAX  | MIN                 | MAX  |
| 200            | 66.5          | 1.0                 | 2.0 | 1.0                 | 2.0 | 1.0                 | 1.5  | 1.0                 | 1.5  |
| 400            | 33.2          | 1.0                 | 3.0 | 1.0                 | 4.0 | 1.0                 | 3.3  | 1.2                 | 3.0  |
| 600            | 22.1          | 1.0                 | 3.5 | 1.0                 | 6.0 | 1.5                 | 6.0  | 1.8                 | 5.0  |
| 800            | 16.5          | 1.0                 | 3.5 | 1.0                 | 7.0 | 1.5                 | 9.0  | 2.5                 | 7.0  |
| 1000           | 13.0          | 1.0                 | 3.0 | 1.0                 | 8.0 | 2.0                 | 12.0 | 3.0                 | 10.0 |
| 1200           | 10.7          | 1.0                 | 3.0 | 1.5                 | 9.0 | 2.5                 | 13.0 | 3.5                 | 14.0 |
| 1400           | 9.09          | 1.0                 | 3.0 | 1.5                 | 9.5 | 3.0                 | 14.0 | 4.0                 | 16.0 |
| 1600           | 8.06          | 1.0                 | 3.0 | 1.5                 | 9.0 | 3.0                 | 15.0 | 4.5                 | 16.0 |
| 1800           | 6.98          | 1.0                 | 3.0 | 2.0                 | 9.0 | 3.5                 | 16.0 | 5.0                 | 16.0 |
| 2000           | 6.34          | 1.2                 | 2.5 | 2.0                 | 9.0 | 4.0                 | 16.0 | 5.5                 | 16.0 |
| 2200           | 5.626         | 1.2                 | 2.5 | 2.0                 | 9.0 | 4.5                 | 16.0 | 6.0                 | 16.0 |

### 7.3.6 Output ON/OFF Enable (EN/SYNC) and $V_{IN}$ UVLO

The EN/SYNC pin provides precision ON and OFF control for the TPSM63603. Once the EN/SYNC pin voltage exceeds the threshold voltage and  $V_{IN}$  is above the minimum turn-on threshold, the device starts operation. The simplest way to enable the TPSM63603 is to connect EN/SYNC directly to  $V_{IN}$ . This allows the TPSM63603 to start up when  $V_{IN}$  is within its valid operating range. However, many applications benefit from the employment of an enable divider network as shown in [Figure 7-3](#), which establishes a precision input undervoltage lockout (UVLO). This can be used for sequencing, to prevent re-triggering the device when used with long input cables, or to reduce the occurrence of deep discharge of a battery power source. An external logic signal can also be used to drive the enable input to toggle the output on and off and for system sequencing or protection.



**Figure 7-3. VIN UVLO Using the EN/SYNC Pin**

$R_{ENB}$  can be calculated using [Equation 6](#).

$$R_{ENB} [k\Omega] = R_{ENT} [k\Omega] \cdot \left( \frac{V_{EN\_RISE} [V]}{V_{IN(on)} [V] - V_{EN\_RISE} [V]} \right) \quad (6)$$

where

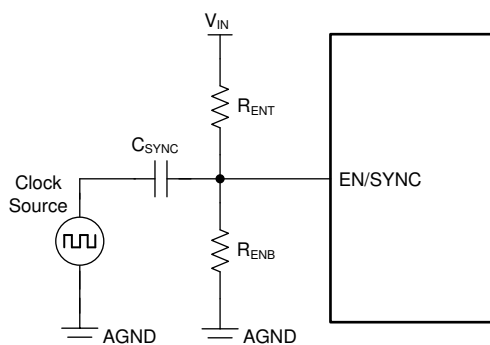
- A typical value for  $R_{ENT}$  is 100 k $\Omega$ .
- $V_{EN}$  is 1.263 V (typical).
- $V_{IN(ON)}$  is the desired start-up input voltage.

#### Note

The EN/SYNC pin can also be used as an external synchronization clock input. See [Section 7.3.7](#) for additional information. A blanking time of 4  $\mu$ s to 28  $\mu$ s is applied to the enable logic after a clock edge is detected. To effectively disable the output, the EN/SYNC input must stay low for longer than 28  $\mu$ s. Any logic change within the blanking time is ignored. Blanking time is not applied when the device is in shutdown mode.

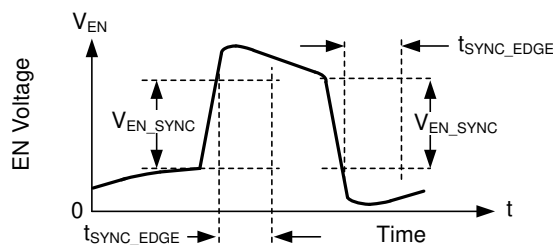
### 7.3.7 Frequency Synchronization (EN/SYNC)

The TPSM63603 can be synchronized to an external clock using the EN/SYNC pin. The synchronization frequency range is 200 kHz to 2.2 MHz. The internal oscillator can be synchronized by AC coupling a positive clock edge into the EN/SYNC pin, as shown in [Figure 7-4](#). It is recommended to keep the parallel combination value of  $R_{ENT}$  and  $R_{ENB}$  in the 100-k $\Omega$  range.  $R_{ENT}$  is required for synchronization, but  $R_{ENB}$  can be left open. The external clock must be off before start-up to allow proper start-up sequencing. After a valid synchronization signal is applied for 2048 cycles, the clock frequency changes to that of the applied signal.



**Figure 7-4. Typical Synchronization Using the EN/SYNC Pin**

Referring to [Figure 7-5](#), the AC-coupled voltage edge at the EN/SYNC pin must exceed the SYNC amplitude threshold,  $V_{EN\_SYNC}$ , of 2.4 V to trip the internal synchronization pulse detector. In addition, the minimum EN/SYNC rising pulse and falling pulse durations must be longer than the SYNC signal hold time,  $t_{SYNC\_EDGE}$ , of 100 ns and shorter than the minimum blanking time,  $t_B$ . A 3.3-V or higher amplitude pulse signal coupled through a 1-nF capacitor,  $C_{SYNC}$ , is suggested.



**Figure 7-5. Typical SYNC Waveform**

### 7.3.8 Spread Spectrum

Spread spectrum is a factory option included in part number TPSM63603S. The purpose of spread spectrum is to eliminate peak emissions at specific frequencies by spreading these peaks across a wider range of frequencies than a part with fixed frequency operation. In most systems with the TPSM63603S, low-frequency conducted emissions from the first few harmonics of the switching frequency can be easily filtered. A more difficult design criterion is reduction of emissions at higher harmonics that fall in the FM band. These harmonics often couple to the environment through electric fields around the switch node and inductor. The TPSM63603S uses a  $\pm 2\%$  spread of frequencies that can spread energy smoothly across the FM and TV bands but is small enough to limit sub-harmonic emissions below the device switching frequency. Peak emissions at the module switching frequency are only reduced slightly, by less than 1 dB, while peaks in the FM band are typically reduced by more than 6 dB.

The TPSM63603S uses a cycle-to-cycle frequency hopping method based on a linear feedback shift register (LFSR). This intelligent pseudo-random generator limits cycle to cycle frequency changes to limit output ripple. The pseudo-random pattern repeats at less than 1.5 Hz, which is below the audio band.

The spread spectrum is only available while the clock of TPSM63603S device are free running at their natural frequency. Any of the following conditions overrides spread spectrum, turning it off:

- The clock is slowed during dropout.
- Spread spectrum is active even if there is no load.
- At a high input voltage/low output voltage ratio when the device operates at minimum on-time, the internal clock is slowed, disabling spread spectrum.
- The clock is synchronized with an external clock.

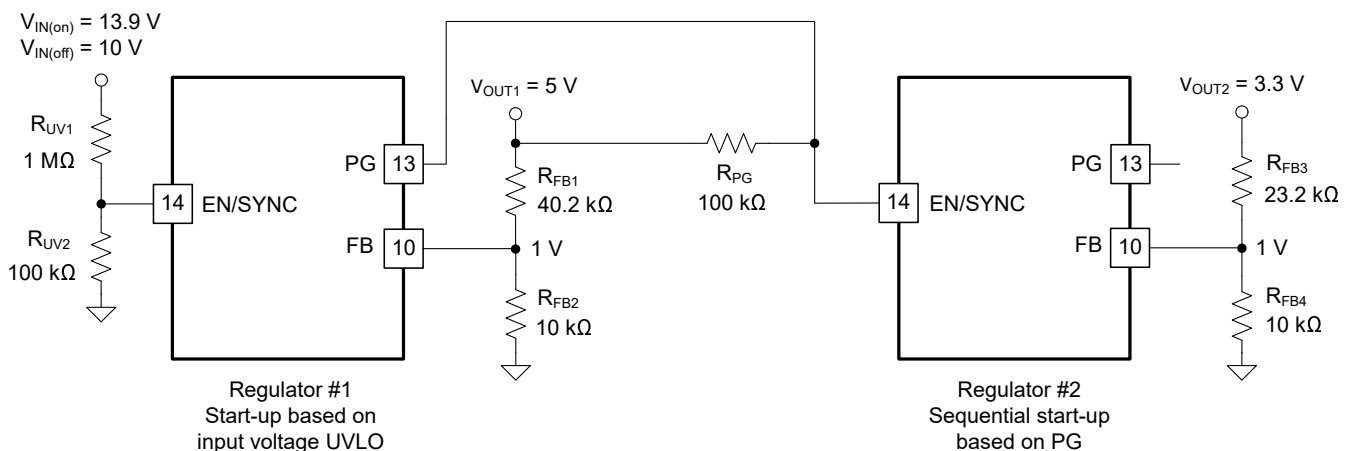
### 7.3.9 Power Good Monitor (PG)

The TPSM63603 provides a PGOOD signal to indicate when the output voltage is within regulation. Use the PGOOD signal for output monitoring, fault protection, or start-up sequencing of downstream converters. The PGOOD pin voltage goes low when the feedback voltage is outside of the PGOOD thresholds. This occurs during the following:

- While the device is disabled
- In current limit
- In thermal shutdown
- During normal start-up, when the output voltage has not reach its regulation value

A glitch filter prevents false flag operation for short excursions (<120  $\mu$ s typical) of the output voltage, such as during line and load transients.

PGOOD is an open-drain output that requires a pullup resistor to a DC supply not greater than 20 V. The typical range of pullup resistance is 10 k $\Omega$  to 100 k $\Omega$ . When EN is pulled low, the flag output is also forced low. With EN low, power good remains valid as long as the input voltage is above 1 V (typical). Use the PG signal for start-up sequencing of downstream regulators, as shown in [Figure 7-6](#), or for fault protection and output monitoring.



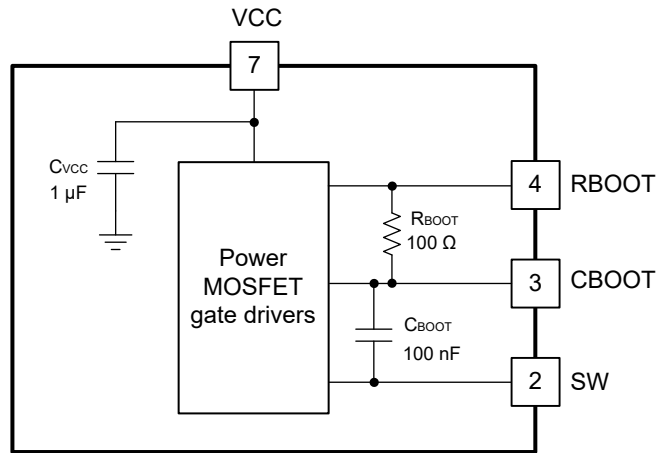
**Figure 7-6. TPSM63603 Sequencing Implementation Using PG and EN/SYNC**

### 7.3.10 Adjustable Switch-Node Slew Rate (RBOOT/CBOOT)

Adjust the switch-node slew rate of the TPSM63603 to slow the switch-node voltage rise time and improve EMI performance at high frequencies. However, slowing the rise time decreases efficiency. Care must be taken to balance the improved EMI versus the decreased efficiency.

Internal to the device, a bootstrap resistor of 100  $\Omega$  is connected between the RBOOT and CBOOT pins as shown in [Figure 7-7](#). Leaving these pins open incorporates the 100- $\Omega$  resistor in the BOOT circuit, slowing the SW voltage slew rate and optimizing EMI. However, if improved EMI is not required, connecting RBOOT to CBOOT

shorts the internal resistor, resulting in higher efficiency. Placing a resistor across RBOOT and CBOOT allows adjustment of the internal resistor to balance EMI and efficiency.



7-7. Internal BOOT Resistor

### 7.3.11 Internal LDO, VCC Output, and VLDOIN Input

The TPSM63603 has an internal LDO to power internal circuitry. The VCC pin is the output of the internal LDO. This pin must not be used to power external circuitry. Connect a high-quality, 1-µF capacitor from this pin to AGND, close to the device pins. Do not load the VCC pin or short it to ground.

The VLDOIN pin is an optional input to the internal LDO. Connect an optional high quality 0.1-µF to 1-µF capacitor from this pin to ground for improved noise immunity.

The LDO generates the VCC voltage from one of the two inputs:  $V_{IN}$  or the VLDOIN input. When VLDOIN is tied to ground or below 3.1 V, the LDO is powered from  $V_{IN}$ . When VLDOIN is tied to a voltage higher than 3.1 V, the LDO input is powered from VLDOIN. VLDOIN voltage must be lower than both  $V_{IN}$  and 12.5 V.

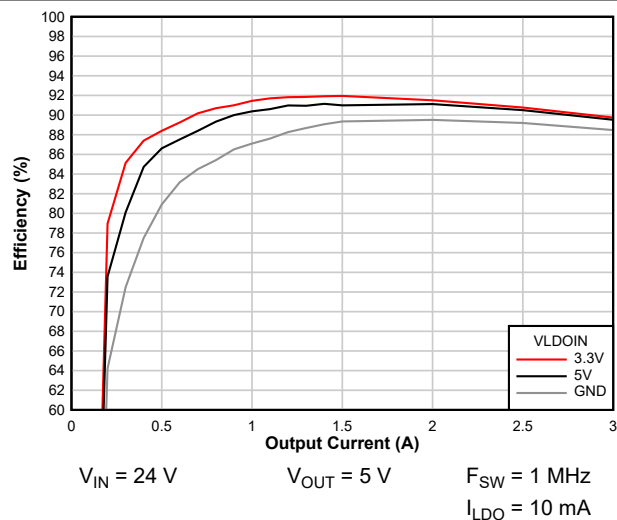
The VLDOIN input is designed to reduce the LDO power loss. The LDO power loss is:

$$P_{LDO-LOSS} = I_{LDO} \times (V_{IN\_LDO} - V_{VCC}) \quad (7)$$

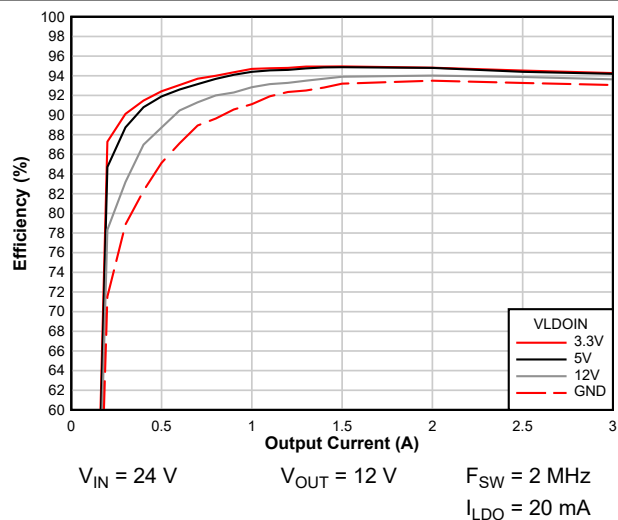
The higher the difference between the input and output voltages of the LDO, the more loss occurs to supply the same LDO output current. The VLDOIN input provides an option to supply the LDO with a lower voltage than  $V_{IN}$ , to reduce the difference of the input and output voltages of the LDO and reduce power loss. For example, if the LDO current is 10 mA at a certain frequency with  $V_{IN} = 24$  V and  $V_{OUT} = 5$  V. The LDO loss with VLDOIN tied to ground is equal to  $10 \text{ mA} \times (24 \text{ V} - 3.3 \text{ V}) = 207 \text{ mW}$ , while the loss with VLDOIN tied to  $V_{OUT}$  (5 V) is equal to  $10 \text{ mA} \times (5 \text{ V} - 3.3 \text{ V}) = 17 \text{ mW}$ .

The efficiency improvement is more significant at light and mid loads because the LDO loss is a higher percentage of the total loss. The improvement is more significant with higher switching frequency because the LDO current is higher at higher switching frequency. The improvement is more significant when  $V_{IN} \gg V_{OUT}$  because the voltage difference is higher.

7-8 and 7-9 show typical efficiency waveforms with VLDOIN powered by different input voltages.



7-8. Efficiency improvements with VLDOIN  
( $V_{OUT} = 5\text{ V}$ )



7-9. Efficiency improvements with VLDOIN  
( $V_{OUT} = 12\text{ V}$ )

### 7.3.12 Overcurrent Protection (OCP)

The TPSM63603 is protected from overcurrent conditions using cycle-by-cycle current limiting of the peak inductor current. The current is compared every switching cycle to the current limit threshold. During an overcurrent condition, the output voltage decreases.

The TPSM63603 employs hiccup overcurrent protection if there is an extreme overload. In hiccup mode, the regulator is shut down and kept off for 80 ms (typical) before the TPSM63603 tries to start again. If an overcurrent or short-circuit fault condition still exists, hiccup repeats until the fault condition is removed. Hiccup mode reduces power dissipation under severe overcurrent conditions, and prevents overheating and potential damage to the device. Once the fault is removed, the module automatically recovers and returns to normal operation.

### 7.3.13 Thermal Shutdown

Thermal shutdown is an integrated self-protection used to limit junction temperature and prevent damage related to overheating. Thermal shutdown turns off the device when the junction temperature exceeds 168°C (typical) to prevent further power dissipation and temperature rise. Junction temperature decreases after shutdown, and the TPSM63603 attempts to restart when the junction temperature falls to 158°C (typical).

## 7.4 Device Functional Modes

### 7.4.1 Shutdown Mode

The EN/SYNC pin provides ON and OFF control for the TPSM63603. When  $V_{\text{EN/SYNC}}$  is below approximately 0.4 V, the device is in shutdown mode. Both the internal LDO and the switching regulator are off. The input quiescent current in shutdown mode drops to 0.6  $\mu\text{A}$  (typical). The TPSM63603 also employs internal undervoltage protection. If the input voltage is below its UV threshold, the regulator remains off.

### 7.4.2 Standby Mode

The internal LDO has a lower enable threshold than the regulator itself. When  $V_{\text{EN/SYNC}}$  is above 1.1 V (maximum) and below the precision enable threshold of 1.263 V (typical), the internal LDO is on and regulating. The precision enable circuitry is turned on once the internal  $V_{\text{CC}}$  is above its UVLO threshold. The switching action and voltage regulation are not enabled until  $V_{\text{EN/SYNC}}$  rises above the precision enable threshold.

### 7.4.3 Active Mode

The TPSM63603 is in active mode when  $V_{\text{IN}}$  and  $V_{\text{EN/SYNC}}$  are above their relevant thresholds and no fault conditions are present. The simplest way to enable the operation is to connect the EN/SYNC pin to  $V_{\text{IN}}$ , which allows self start-up when the applied input voltage exceeds the minimum start-up voltage.

## 8 Applications and Implementation

### Note

以下のアプリケーション情報は、TI の製品仕様に含まれるものではなく、TI ではその正確性または完全性を保証いたしません。個々の目的に対する製品の適合性については、お客様の責任で判断していただくことになります。お客様は自身の設計実装を検証しテストすることで、システムの機能を確認する必要があります。

### 8.1 Application Information

The TPSM63603 only requires a few external components to convert from a wide range of supply voltages to a fixed output voltage. The following section describes the design procedure to configure the TPSM63603 power module. To expedite and streamline the design process, WEBENCH® online software is available to generate complete designs, leveraging iterative design procedures and access to comprehensive component databases. To expedite and streamline the process of designing of a TPSM63603-based regulator, a comprehensive TPSM63603 [quickstart calculator](#).

As mentioned previously, the TPSM63603 also integrates several optional features to meet system design requirements, including the following:

- Precision enable with hysteresis
- External adjustable UVLO
- Adjustable SW node slew rate
- Power-good indicator

The following application circuit detailed shows the TPSM63603 configuration options suitable for several application use cases. Refer to the [TPSM63603EVM User's Guide](#) for more detail.

### 8.2 Typical Applications

The following are sample typical applications along with design procedure for the implementation of TPSM63603.

#### 8.2.1 Design 1: 3-A Synchronous Buck Regulator for Industrial Applications

Figure 8-1 shows the schematic diagram of a 5-V, 3-A buck regulator with a switching frequency of 1 MHz. The nominal input voltage for the sample design is 24 V. A resistor  $R_{RT}$  of 13 k $\Omega$  sets the free-running switching frequency at 1 MHz. An optional SYNC input signal allows adjustment of the switching frequency for this specific application.

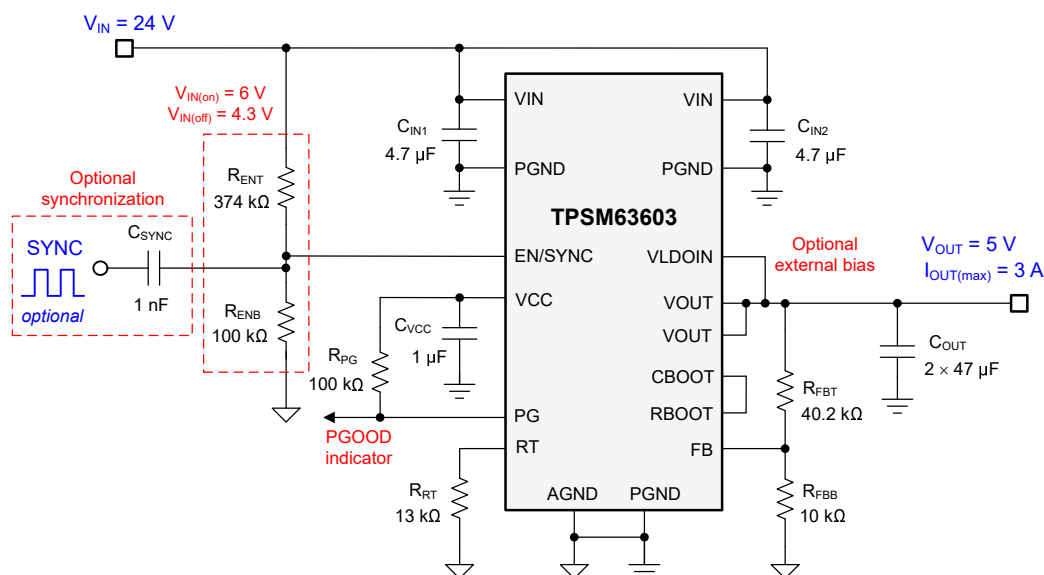


Figure 8-1. Circuit Schematic

### 8.2.1.1 Design Requirements

For this design example, use the parameters listed in 表 8-1 as the input parameters and follow the design procedures in セクション 8.2.1.2.

**表 8-1. Design Example Parameters**

| DESIGN PARAMETER    | VALUE      |
|---------------------|------------|
| Input voltage       | 24 V       |
| Output voltage      | 5 V        |
| Output current      | 0 A to 3 A |
| Switching Frequency | 1 MHz      |

表 8-2 gives the selected buck module power-stage components with availability from multiple vendors. This design uses an all-ceramic output capacitor implementation.

**表 8-2. List of Materials for Application Circuit 1**

| REFERENCE DESIGNATOR                  | QTY | SPECIFICATION                               | MANUFACTURER <sup>(1)</sup> | PART NUMBER          |
|---------------------------------------|-----|---------------------------------------------|-----------------------------|----------------------|
| C <sub>IN1</sub> , C <sub>IN2</sub>   | 2   | 4.7 $\mu$ F, 50 V, X7R, 1210, ceramic       | Taiyo Yuden                 | UMK325B7475KN-TR     |
|                                       |     |                                             | TDK                         | CGA6P3X7R1H475K250AB |
|                                       |     | 4.7 $\mu$ F, 100 V, X7S, 1206, ceramic      | Murata                      | GRM31CC72A475KE11L   |
| C <sub>OUT1</sub> , C <sub>OUT2</sub> | 2   | 47 $\mu$ F, 10 V, X7R, 1210, ceramic        | Murata                      | GRM32ER71A476ME15L   |
|                                       |     |                                             | AVX                         | 1210ZC476MAT2A       |
| C <sub>VCC</sub>                      | 1   | 1 $\mu$ F, 16 V, X7R, 0603, ceramic         | Murata                      | GCM188R71C105KA64J   |
|                                       |     | 1 $\mu$ F, 16 V, X5R, 0402, ceramic         | Taiyo Yuden                 | EMK105BJ105KVHF      |
| U <sub>1</sub>                        | 1   | TPSM63603 36-V, 3-A synchronous buck module | Texas Instruments           | TPSM63603RDLR        |

(1) See the [Third-Party Products Disclaimer](#).

More generally, the TPSM63603 module is designed to operate with a wide range of external components and system parameters. However, the integrated loop compensation is optimized for a certain range of output capacitance.

### 8.2.1.2 Detailed Design Procedure

#### 8.2.1.2.1 Custom Design With WEBENCH® Tools

[Click here](#) to create a custom design using the TPSM63603 device with the WEBENCH® Power Designer.

1. Start by entering the input voltage ( $V_{IN}$ ), output voltage ( $V_{OUT}$ ), and output current ( $I_{OUT}$ ) requirements.
2. Optimize the design for key parameters such as efficiency, footprint, and cost using the optimizer dial.
3. Compare the generated design with other possible solutions from Texas Instruments.

The WEBENCH Power Designer provides a customized schematic along with a list of materials with real-time pricing and component availability.

In most cases, these actions are available:

- Run electrical simulations to see important waveforms and circuit performance.
- Run thermal simulations to understand board thermal performance.
- Export customized schematic and layout into popular CAD formats.
- Print PDF reports for the design, and share the design with colleagues.

Get more information about WEBENCH tools at [www.ti.com/WEBENCH](http://www.ti.com/WEBENCH).

#### 8.2.1.2.2 Output Voltage Setpoint

The output voltage of the TPSM63603 device is externally adjustable using a resistor divider. The recommended value of  $R_{FBB}$  is 10 k $\Omega$ . The value for  $R_{FBB}$  can be selected from 表 7-1 or calculated using 式 8:

$$R_{FBT} [k\Omega] = R_{FBB} [k\Omega] \cdot \left( \frac{V_{OUT} [V]}{1V} - 1 \right) \quad (8)$$

For the desired output voltage of 5 V, the formula yields a value of 40.2 kΩ. Choose the closest available standard value of 40.2 kΩ for  $R_{FBT}$ . Alternatively, if using TPSM63603V5, which is the fixed 5-V output variant of the module, the user can connect the FB pin directly to the output capacitor.

#### 8.2.1.2.3 Switching Frequency Selection

The recommended switching frequency for standard output voltages can be found in [表 7-1](#). For a 5-V output, the recommended switching frequency is 1 MHz. To set the switching frequency to 1 MHz, connect a 13.0-kΩ resistor between the RT pin and AGND.

#### 8.2.1.2.4 Input Capacitor Selection

The TPSM63603 requires a minimum input capacitance of  $2 \times 4.7\text{-}\mu\text{F}$  ceramic type. High-quality ceramic type capacitors with sufficient voltage and temperature rating are required. The voltage rating of input capacitors must be greater than the maximum input voltage.

For this design, select two 4.7-μF, 50-V, 1210 case size, ceramic capacitors.

#### 8.2.1.2.5 Output Capacitor Selection

For a 5-V output, the TPSM63603 requires a minimum of 25 μF of effective output capacitance for proper operation (see [表 7-1](#)). High-quality ceramic type capacitors with sufficient voltage and temperature rating are required. Additional output capacitance can be added to reduce ripple voltage or for applications with transient load requirements.

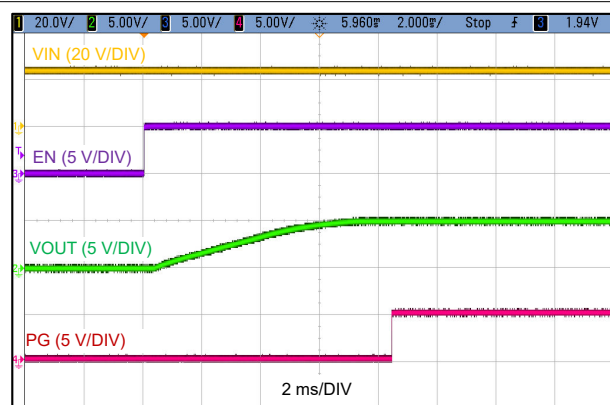
For this design example, select two 47-μF, 10-V, 1210 case size, ceramic capacitors, which have a total effective capacitance of approximately 48 μF at 5 V.

#### 8.2.1.2.6 Other Connections

- Short RBOOT to CBOOT for best efficiency.
- Connect VLDOIN to VOUT to improve efficiency.
- Place a 1-μF capacitor between the VCC pin and PGND, located near to the device.

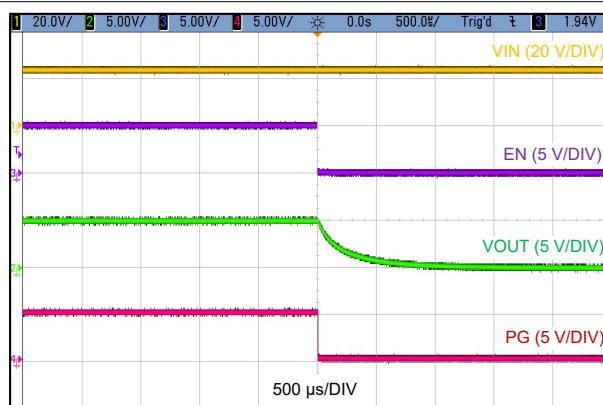
### 8.2.1.3 Application Curves

Unless otherwise indicated,  $V_{IN} = 24\text{ V}$ ,  $V_{OUT} = 5\text{ V}$ ,  $I_{OUT} = 3\text{ A}$ , and  $F_{SW} = 1\text{ MHz}$ .



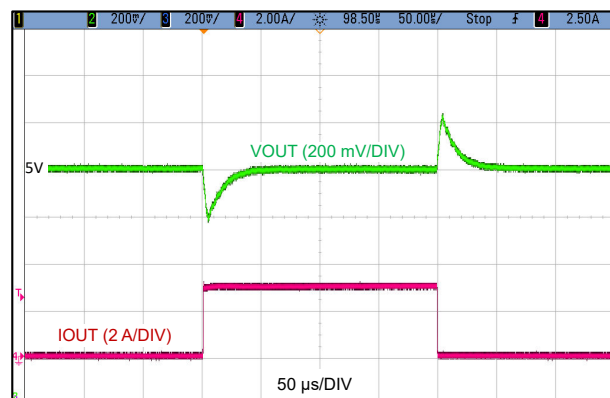
$V_{IN} = 24\text{ V}$   $V_{OUT} = 5\text{ V}$

**8-2. Start-Up Waveforms**



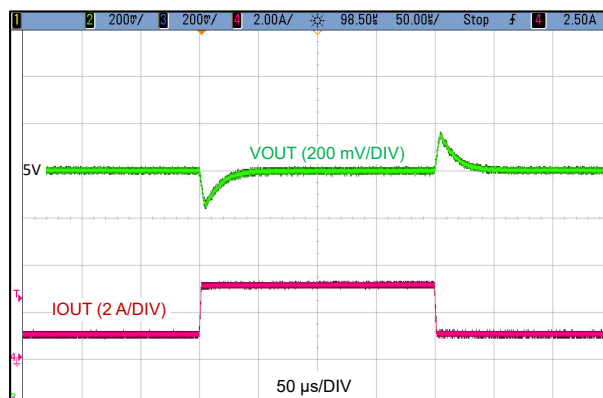
$V_{IN} = 24\text{ V}$   $V_{OUT} = 5\text{ V}$

**8-3. Shutdown Waveforms**



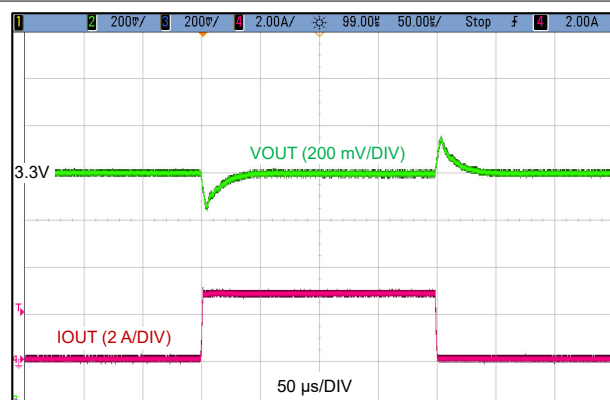
$V_{IN} = 24\text{ V}$   $V_{OUT} = 5\text{ V}$   $F_{SW} = 1\text{ MHz}$   
 $C_{OUT} = 2 \times 47\mu\text{F}$

**8-4. Load Transient 0 A to 3 A, 1 A/μs**



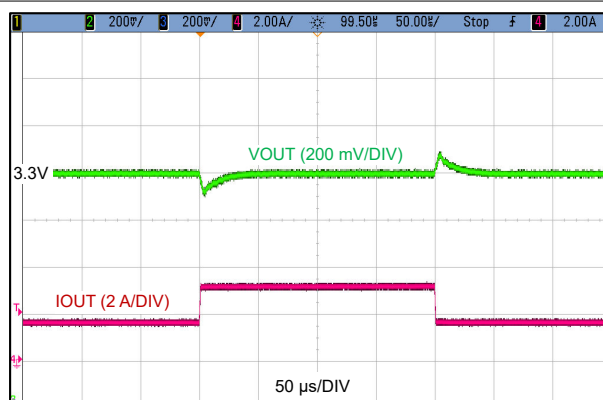
$V_{IN} = 24\text{ V}$   $V_{OUT} = 5\text{ V}$   $F_{SW} = 1\text{ MHz}$   
 $C_{OUT} = 2 \times 47\mu\text{F}$

**8-5. Load Transient 1.5 A to 3 A, 1 A/μs**



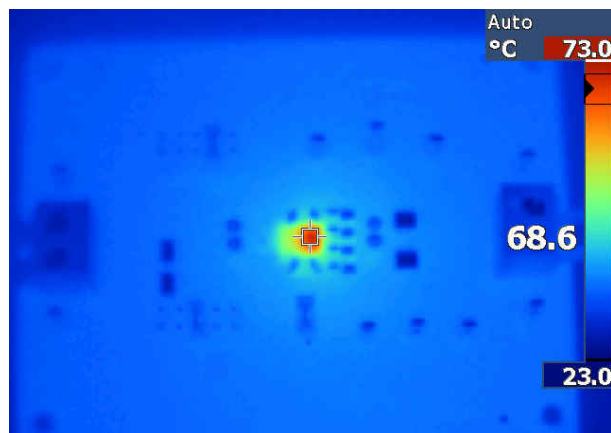
$V_{IN} = 24\text{ V}$   $V_{OUT} = 3.3\text{ V}$   $F_{SW} = 1\text{ MHz}$   
 $C_{OUT} = 2 \times 47\mu\text{F}$

**8-6. Load Transient 0 A to 3 A, 1 A/μs**

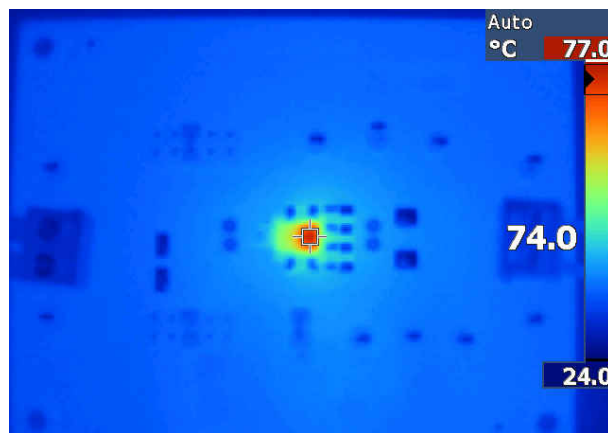


$V_{IN} = 24\text{ V}$   $V_{OUT} = 3.3\text{ V}$   $F_{SW} = 1\text{ MHz}$   
 $C_{OUT} = 2 \times 47\mu\text{F}$

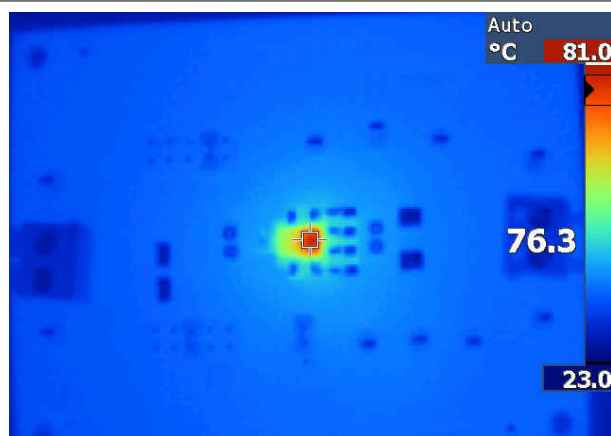
**8-7. Load Transient 1.5 A to 3 A, 1 A/μs**



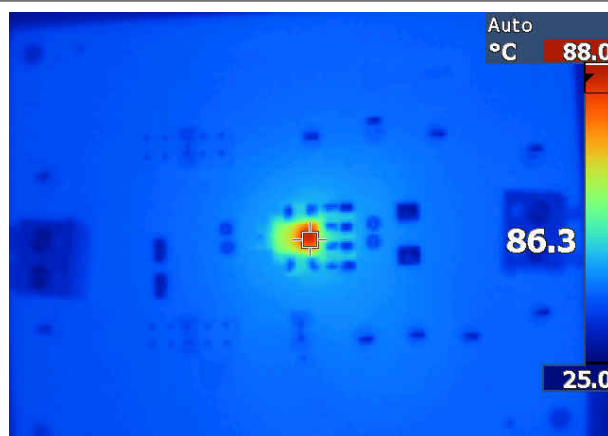
8-8. Thermal Image  $V_{IN} = 12\text{ V}$ ,  $V_{OUT} = 3.3\text{ V}$ ,  $F_{SW} = 1\text{ MHz}$ ,  $I_{OUT} = 3\text{ A}$



8-9. Thermal Image  $V_{IN} = 12\text{ V}$ ,  $V_{OUT} = 5\text{ V}$ ,  $F_{SW} = 1\text{ MHz}$ ,  $I_{OUT} = 3\text{ A}$



8-10. Thermal Image  $V_{IN} = 24\text{ V}$ ,  $V_{OUT} = 3.3\text{ V}$ ,  $F_{SW} = 1\text{ MHz}$ ,  $I_{OUT} = 3\text{ A}$



8-11. Thermal Image  $V_{IN} = 24\text{ V}$ ,  $V_{OUT} = 5\text{ V}$ ,  $F_{SW} = 1\text{ MHz}$ ,  $I_{OUT} = 3\text{ A}$

## 8.2.2 Design 2: Inverting Buck-Boost Regulator with a –5-V Output

Figure 8-12 shows the schematic diagram of a –5-V inverting buck-boost regulator with a switching frequency of 1 MHz. The input voltage range for the sample design is 12 V to 24 V.

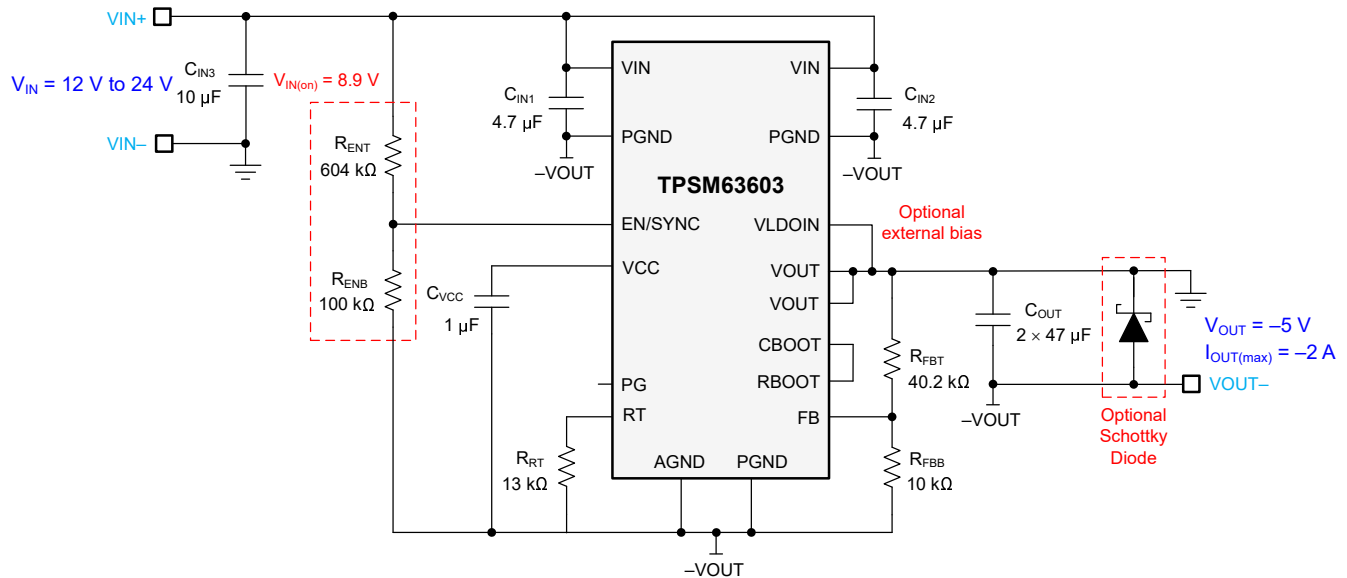


Figure 8-12. Circuit Schematic

### 8.2.2.1 Design Requirements

For this design example, use the parameters listed in Table 8-3 as the input parameters and follow the design procedures in Section 8.2.2.2.

Table 8-3. Design Example Parameters

| DESIGN PARAMETER    | VALUE      |
|---------------------|------------|
| Input voltage       | 12 to 24 V |
| Output voltage      | –5 V       |
| Output current      | 0 A to 2 A |
| Switching frequency | 1 MHz      |

Table 8-4 gives the selected module power-stage components with availability from multiple vendors. This design uses an all-ceramic output capacitor implementation.

Table 8-4. List of Materials for Application Circuit 2

| REFERENCE DESIGNATOR                                   | QTY | SPECIFICATION                               | MANUFACTURER <sup>(1)</sup> | PART NUMBER          |
|--------------------------------------------------------|-----|---------------------------------------------|-----------------------------|----------------------|
| C <sub>IN1</sub> , C <sub>IN2</sub> , C <sub>IN3</sub> | 3   | 4.7 µF, 50 V, X7R, 1210, ceramic            | Taiyo Yuden                 | UMK325B7475KN-TR     |
|                                                        |     | 4.7 µF, 50 V, X7S, 1206, ceramic            | TDK                         | CGA6P3X7R1H475K250AB |
|                                                        |     | 4.7 µF, 50 V, X7S, 1206, ceramic            | Murata                      | GCM31CC71H475KA03K   |
| C <sub>OUT1</sub> , C <sub>OUT2</sub>                  | 2   | 47 µF, 10 V, X7R, 1210, ceramic             | Murata                      | GRM32ER71A476ME15L   |
|                                                        |     | 47 µF, 10 V, X7R, 1210, ceramic             | AVX                         | 1210ZC476MAT2A       |
| C <sub>VCC</sub>                                       | 1   | 1 µF, 16 V, X7R, 0603, ceramic              | Murata                      | GCM188R71C105KA64J   |
| U <sub>1</sub>                                         | 1   | TPSM63603 36-V, 3-A synchronous buck module | Texas Instruments           | TPSM63603RDLR        |

More generally, the TPSM63603 module is designed to operate with a wide range of external components and system parameters. However, the integrated loop compensation is optimized for a certain range of output capacitance.

## 8.2.2.2 Detailed Design Procedure

### 8.2.2.2.1 Output Voltage Setpoint

The output voltage of the TPSM63603 device is externally adjustable using a resistor divider. The recommended value of  $R_{FBB}$  is 10 k $\Omega$ . Calculate the value for  $R_{FBT}$  using 式 9:

$$R_{FBT} [k\Omega] = R_{FBB} [k\Omega] \cdot \left( \frac{V_{OUT} [V]}{1V} - 1 \right) \quad (9)$$

For the desired output voltage of –5 V, enter the absolute value of 5 V for the  $V_{OUT}$  in 式 9. The formula yields a value of 40.2 k $\Omega$ . Choose the closest available standard value of 40.2 k $\Omega$  for  $R_{FBT}$ .

### 8.2.2.2.2 IBB Maximum Output Current

The achievable output current with an *IBB topology* using the TPSM63603 is  $I_{OUT(max)} = I_{LDC(max)} \times (1 - D)$ , where  $I_{LDC(max)} = 3$  A is the rated current of the module and  $D = |V_{OUT}| / (V_{IN} + |V_{OUT}|)$  is the module duty cycle. Therefore in the case of  $V_{IN} = 12$  V and the  $V_{OUT} = -5$  V, the maximum output current is 2.1 A.

### 8.2.2.2.3 Switching Frequency Selection

To set the switching frequency to 1 MHz, connect a 13.0-k $\Omega$  resistor between the RT pin and AGND pins of the module based on 式 5.

### 8.2.2.2.4 Input Capacitor Selection

The TPSM63603 requires a minimum input capacitance of  $2 \times 4.7$ - $\mu$ F ceramic type between the VIN pins and PGND pins as close as possible to the module. High-quality ceramic type capacitors with sufficient voltage and temperature rating are required. In the inverting buck-boost configuration the maximum voltage between VIN and PGND pin of the module is equal to  $V_{IN} + |V_{OUT}|$ .

For this design, two 4.7- $\mu$ F, 50-V, 1210 case size, ceramic capacitors are selected.

### 8.2.2.2.5 Output Capacitor Selection

The TPSM63603 requires a minimum of 25  $\mu$ F of effective output capacitance for proper operation. High-quality ceramic type capacitors with sufficient voltage and temperature rating are required. Additional output capacitance can be added to reduce ripple voltage or for applications with transient load requirements.

For this design example, a two 47- $\mu$ F, 10-V, 1210 case size, ceramic capacitors are used which have a total effective capacitance of approximately 48  $\mu$ F at 5 V.

### 8.2.2.2.6 Other Connections

Short RBOOT to CBOOT and connect VLDOIN to VOUT for best efficiency.

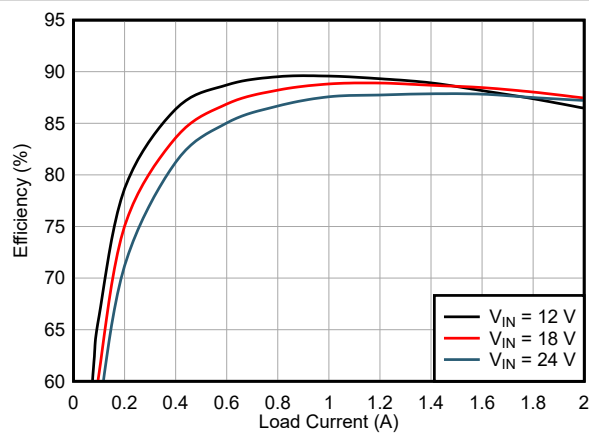
Place a 1- $\mu$ F capacitor between the VCC pin and PGND, located near to the device.

The right-half-plane zero of an IBB topology is at its lowest frequency at minimum input voltage. However, it does not appear at low frequency for a –5 V output and thus has minimal effect on the loop response for this application.

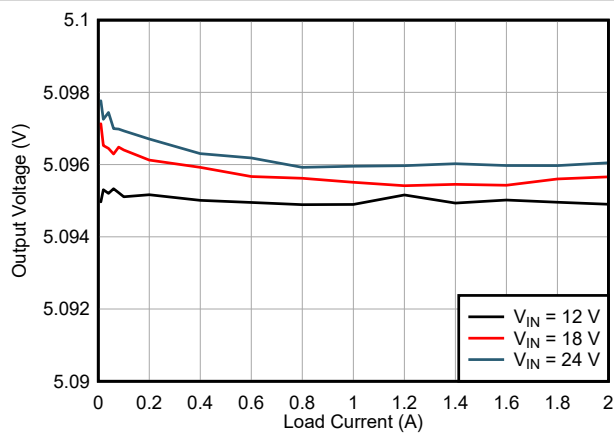
In the inverting buck-boost configuration, the input capacitor  $C_{IN}$  and output capacitor  $C_{OUT}$  can formed an AC capacitive divider during a fast  $V_{IN}$  transient or hot-plugged event at the input. This event will resulted in a positive voltage spike at the output that may disturb the load. In this case, an optional Schottky diode may be installed between –VOUT and GND as shown in 图 8-12 to clamp the output spike.

### 8.2.2.3 Application Curves

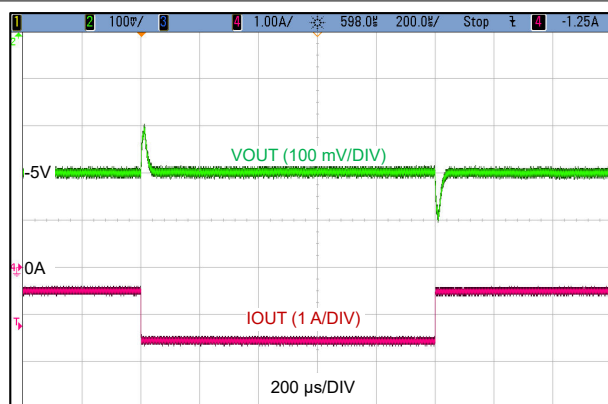
Unless otherwise indicated,  $V_{IN} = 12\text{ V}$ ,  $V_{OUT} = -5\text{ V}$ , and  $F_{SW} = 1\text{ MHz}$ .



8-13. Efficiency Curves

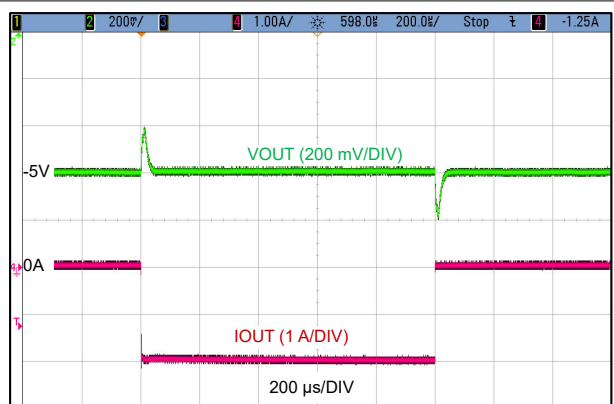


8-14. Load Regulation



$V_{IN} = 12\text{ V}$        $V_{OUT} = -5\text{ V}$        $F_{SW} = 1\text{ MHz}$   
 $C_{OUT} = 2 \times 47\text{ }\mu\text{F}$

8-15. Load Transient  $-0.5\text{ A}$  to  $-1.5\text{ A}$ ,  $1\text{ A}/\mu\text{s}$



$V_{IN} = 12\text{ V}$        $V_{OUT} = -5\text{ V}$        $F_{SW} = 1\text{ MHz}$   
 $C_{OUT} = 2 \times 47\text{ }\mu\text{F}$

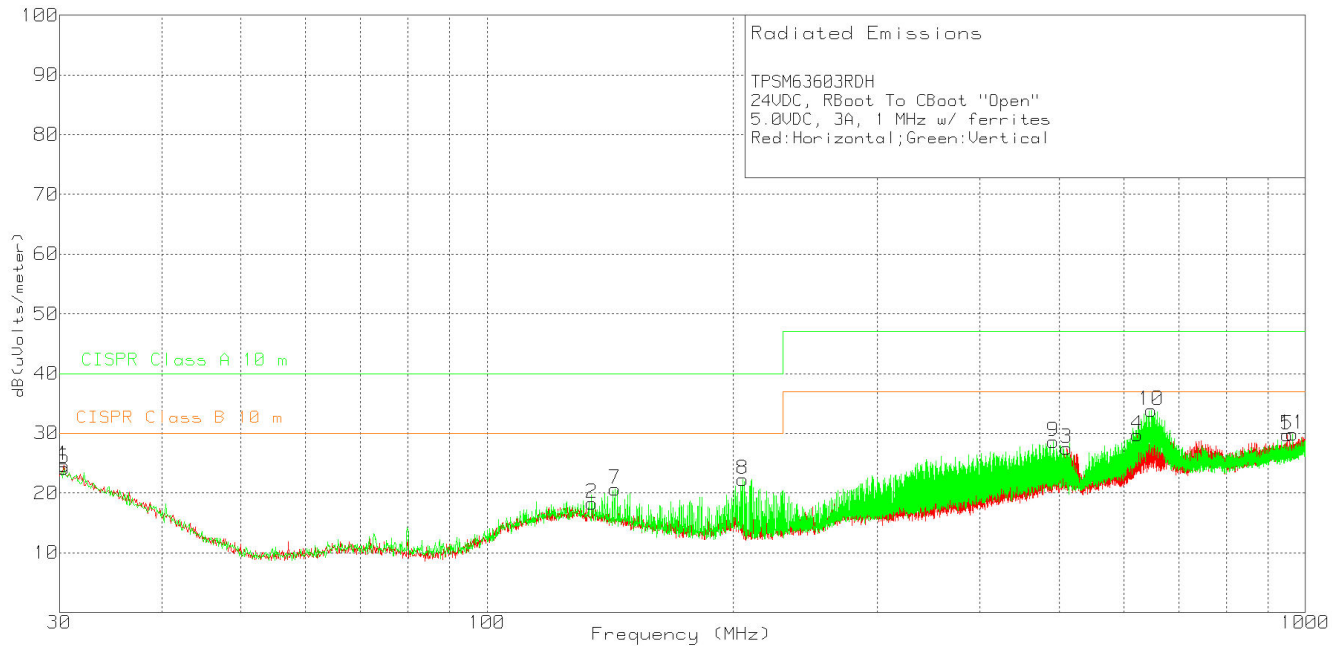
8-16. Load Transient  $0\text{ A}$  to  $-2\text{ A}$ ,  $1\text{ A}/\mu\text{s}$

### 8.2.2.4 EMI

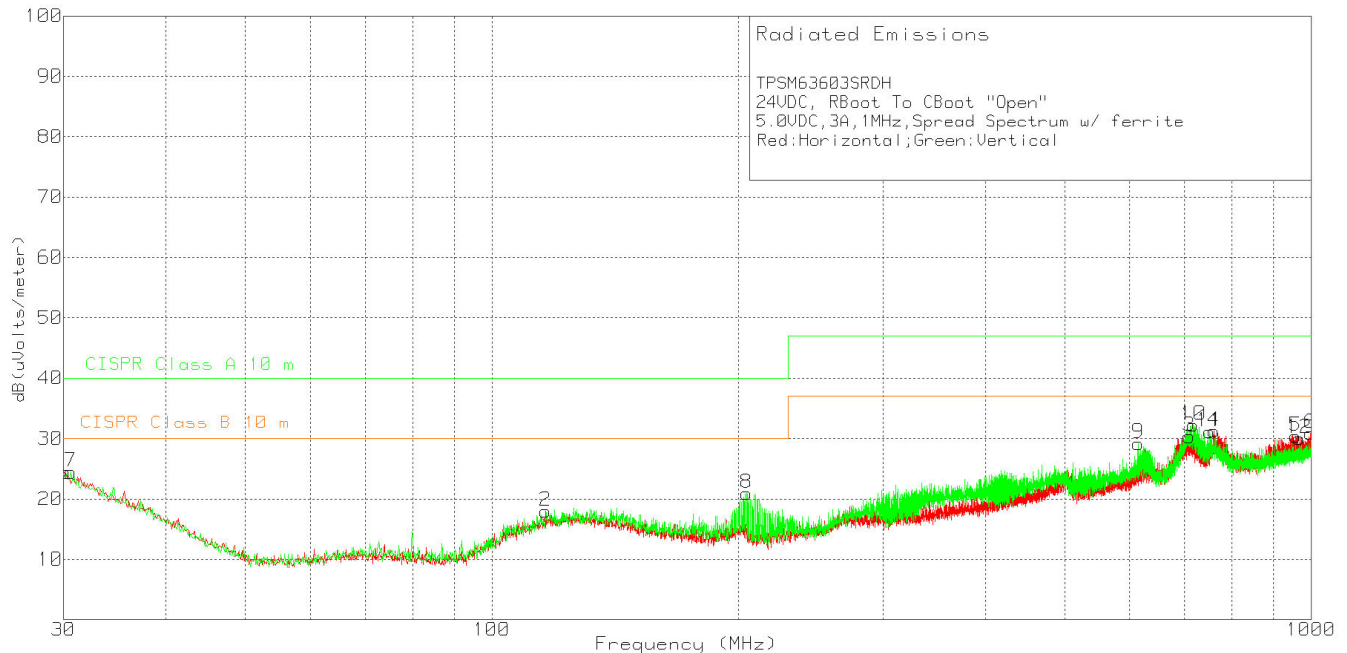
The TPSM63603 is compliant with EN55011 radiated emissions. [Figure 8-17](#), [Figure 8-18](#), and [Figure 8-19](#) show typical examples of radiated emission plots for the TPSM63603. The graphs include the plots of the antenna in the horizontal and vertical positions.

#### 8.2.2.4.1 EMI Plots

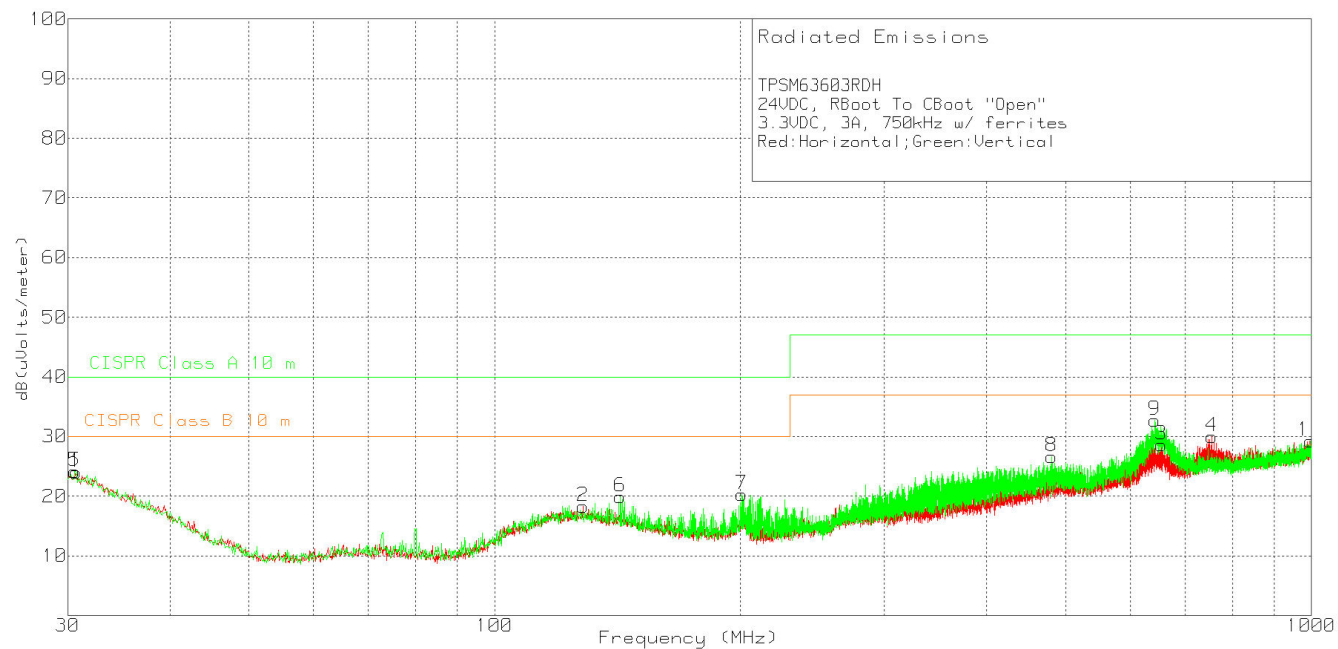
EMI plots were measured using the standard TPSM63603EVM.



**Figure 8-17. Radiated Emissions 24-V Input, 5-V Output, 3-A Load**



**Figure 8-18. Radiated Emissions 24-V Input, 5-V Output, 3-A Load, Spread Spectrum**



**8-19. Radiated Emissions 24-V Input, 3.3-V Output, 3-A Load**

## 9 Power Supply Recommendations

The TPSM63603 buck module is designed to operate over a wide input voltage range of 3 V to 36 V. The characteristics of the input supply must be compatible with the [Absolute Maximum Ratings](#) and [Recommended Operating Conditions](#) in this data sheet. In addition, the input supply must be capable of delivering the required input current to the loaded regulator circuit. Estimate the average input current with 式 10.

$$I_{IN} = \frac{V_{OUT} \cdot I_{OUT}}{V_{IN} \cdot \eta} \quad (10)$$

where

- $\eta$  = efficiency

If the module is connected to an input supply through long wires or PCB traces with a large impedance, take special care to achieve stable performance. The parasitic inductance and resistance of the input cables can have an adverse affect on module operation. More specifically, the parasitic inductance in combination with the low-ESR ceramic input capacitors form an underdamped resonant circuit, possibly resulting in instability, voltage transients, or both, each time the input supply is cycled ON and OFF. The parasitic resistance causes the input voltage to dip during a load transient. If the module is operating close to the minimum input voltage, this dip can cause false UVLO triggering and a system reset.

The best way to solve such issues is to reduce the distance from the input supply to the module and use an electrolytic input capacitor in parallel with the ceramics. The moderate ESR of the electrolytic capacitor helps damp the input resonant circuit and reduce any overshoot or undershoot at the input. A capacitance in the range of 47  $\mu$ F to 100  $\mu$ F is usually sufficient to provide input parallel damping and helps hold the input voltage steady during large load transients. A typical ESR of 0.1  $\Omega$  to 0.4  $\Omega$  provides enough damping for most input circuit configurations.

## 10 Layout

The performance of any switching power supply depends as much upon the layout of the PCB as the component selection. Use the following guidelines to design a PCB with the best power conversion performance, optimal thermal performance, and minimal generation of unwanted EMI.

### 10.1 Layout Guidelines

To achieve optimal electrical and thermal performance, an optimized PCB layout is required. [Figure 10-1](#) and [Figure 10-2](#) show a typical PCB layout. Some considerations for an optimized layout are:

- Use large copper areas for power planes (VIN, VOUT, and PGND) to minimize conduction loss and thermal stress.
- Place ceramic input and output capacitors close to the device pins to minimize high-frequency noise.
- Locate additional output capacitors between the ceramic capacitors and the load.
- Connect AGND to PGND at a single point.
- Place  $R_{FBT}$  and  $R_{FBB}$  as close as possible to the FB pin.
- Use multiple vias to connect the power planes to internal layers.

### 10.2 Layout Example

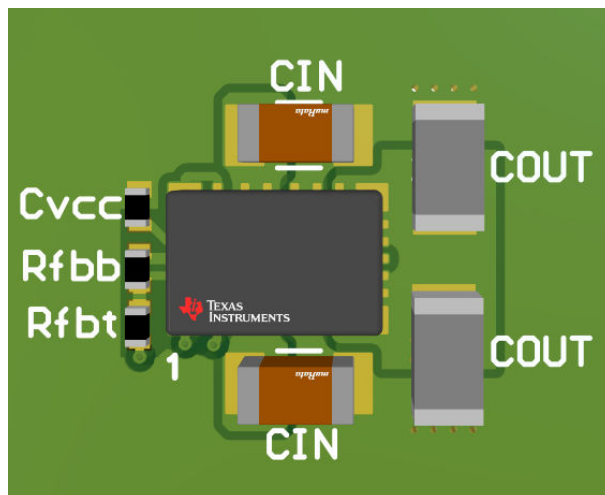


Figure 10-1. Typical Top-Layer Layout

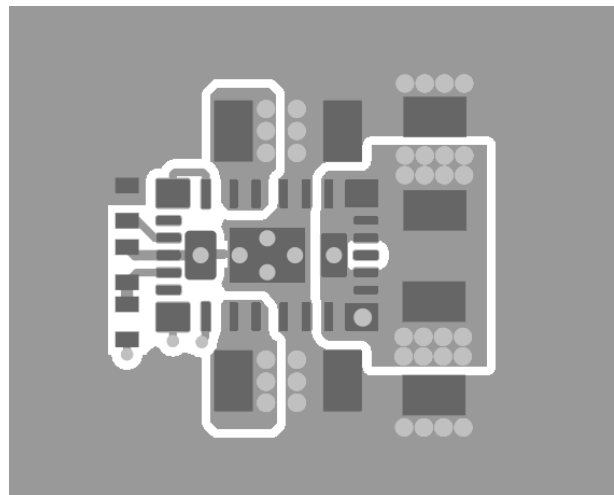


Figure 10-2. Typical Top-Layer

#### 10.2.1 Package Specifications

Table 10-1. Package Specifications Table

| TPSM63603                   |                                                                           | VALUE | UNIT |
|-----------------------------|---------------------------------------------------------------------------|-------|------|
| Weight                      |                                                                           | 123   | mg   |
| Flammability                | Meets UL 94 V-0                                                           |       |      |
| MTBF calculated reliability | Per Bellcore TR-332, 50% stress, $T_A = 40^\circ\text{C}$ , ground benign | 84    | MHrs |

## 11 Device and Documentation Support

### 11.1 Device Support

#### 11.1.1 Third-Party Products Disclaimer

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#### 11.1.2 Development Support

With an input operating voltage from 3 V to 36 V and rated output current from 2 A to 6 A, the TPSM63602/3/4/6 family of synchronous buck power modules specified in 表 11-1 provides flexibility, scalability and optimized solution size for a range of applications. These modules enable DC/DC solutions with high density, low EMI and increased flexibility. Available EMI mitigation features include pseudo-random spread spectrum (PRSS), RBOOT-configured switch-node slew rate control, and integrated input bypass capacitors. All modules are rated for an ambient temperature up to 105°C.

**表 11-1. Synchronous Buck DC/DC Power Module Family**

| DC/DC MODULE              | RATED I <sub>OUT</sub> | PACKAGE    | DIMENSIONS         | FEATURES                                                    | EMI MITIGATION                                         |
|---------------------------|------------------------|------------|--------------------|-------------------------------------------------------------|--------------------------------------------------------|
| <a href="#">TPSM63602</a> | 2 A                    | B0QFN (30) | 4.0 × 6.0 × 1.8 mm | RT adjustable F <sub>SW</sub> ,<br>external synchronization | PRSS, RBOOT, integrated input and BOOT capacitors      |
| <a href="#">TPSM63603</a> | 3 A                    |            |                    |                                                             |                                                        |
| <a href="#">TPSM63604</a> | 4 A                    | B3QFN (20) | 5.0 × 5.5 × 4.0 mm |                                                             | PRSS, RBOOT, integrated input, VCC and BOOT capacitors |
| <a href="#">TPSM63606</a> | 6 A                    |            |                    |                                                             |                                                        |

For development support see the following:

- [TPSM63603 Quickstart Calculator](#)
- [TPSM63603 Simulation Models](#)
- [TPSM63603 and TPSM63603S EVM User's Guide](#)
- [TPSM63603 Altium Layout Design Files](#)
- For TI's reference design library, visit the [TI Reference Design library](#).
- For TI's WEBENCH Design Environment, visit the [WEBENCH® Design Center](#).
- To design a low-EMI power supply, review TI's comprehensive [EMI Training Series](#).
- To design an inverting buck-boost (IBB) regulator, visit [DC/DC inverting buck-boost modules](#).
- TI Reference Designs:
  - [Multiple Output Power Solution For Kintex 7 Application](#)
  - [Arria V Power Reference Design](#)
  - [Altera Cyclone V SoC Power Supply Reference Design](#)
  - [Space-optimized DC/DC Inverting Power Module Reference Design With Minimal BOM Count](#)
  - [3- To 11.5-V<sub>IN</sub>, -5-V<sub>OUT</sub>, 1.5-A Inverting Power Module Reference Design For Small, Low-noise Systems](#)
- Technical Articles:
  - [Powering Medical Imaging Applications With DC/DC Buck Converters](#)
  - [How To Create A Programmable Output Inverting Buck-boost Regulator](#)
- To view a related device of this product, see the [LM61460 36-V, 6-A synchronous buck converter](#).

##### 11.1.2.1 Custom Design With WEBENCH® Tools

[Click here](#) to create a custom design using the TPSM63603 device with WEBENCH® Power Designer.

1. Start by entering the input voltage (V<sub>IN</sub>), output voltage (V<sub>OUT</sub>), and output current (I<sub>OUT</sub>) requirements.
2. Optimize the design for key parameters such as efficiency, footprint, and cost using the optimizer dial.
3. Compare the generated design with other possible solutions from Texas Instruments.

The WEBENCH Power Designer provides a customized schematic along with a list of materials with real-time pricing and component availability.

In most cases, these actions are available:

- Run electrical simulations to see important waveforms and circuit performance.
- Run thermal simulations to understand board thermal performance.
- Export customized schematic and layout into popular CAD formats.
- Print PDF reports for the design, and share the design with colleagues.

Get more information about WEBENCH tools at [www.ti.com/WEBENCH](http://www.ti.com/WEBENCH).

## 11.2 Documentation Support

### 11.2.1 Related Documentation

For related documentation, see the following:

- Texas Instruments, [Innovative DC/DC Power Modules](#) selection guide
- Texas Instruments, [Enabling Small, Cool and Quiet Power Modules with Enhanced HotRod™ QFN Package Technology](#) white paper
- Texas Instruments, [Benefits and Trade-offs of Various Power-Module Package Options](#) white paper
- Texas Instruments, [Simplify Low EMI Design with Power Modules](#) white paper
- Texas Instruments, [Power Modules for Lab Instrumentation](#) white paper
- Texas Instruments, [An Engineer's Guide To EMI In DC/DC Regulators](#) e-book
- Texas Instruments, [Soldering Considerations for Power Modules](#) application report
- Texas Instruments, [Practical Thermal Design With DC/DC Power Modules](#) application report
- Texas Instruments, [Using New Thermal Metrics](#) application report
- Texas Instruments, [AN-2020 Thermal Design By Insight, Not Hindsight](#) application report
- Texas Instruments, [Using the TPSM53602/3/4 for Negative Output Inverting Buck-Boost Applications](#) application report

### 11.3 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on [ti.com](http://ti.com). Click on *Subscribe to updates* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

### 11.4 サポート・リソース

**TI E2E™ サポート・フォーラム**は、エンジニアが検証済みの回答と設計に関するヒントをエキスパートから迅速かつ直接得ることができる場所です。既存の回答を検索したり、独自の質問をしたりすることで、設計に必要な支援を迅速に得ることができます。

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is a registered trademark of Texas Instruments.

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### 11.6 Electrostatic Discharge Caution



This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

### 11.7 Glossary

[TI Glossary](#) This glossary lists and explains terms, acronyms, and definitions.

## 12 Mechanical, Packaging, and Orderable Information

The following pages include mechanical packaging and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

## PACKAGING INFORMATION

| Orderable part number           | Status<br>(1) | Material type<br>(2) | Package   Pins   | Package qty   Carrier | RoHS<br>(3) | Lead finish/<br>Ball material<br>(4) | MSL rating/<br>Peak reflow<br>(5) | Op temp (°C) | Part marking<br>(6) |
|---------------------------------|---------------|----------------------|------------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| <a href="#">TPSM63603RDHR</a>   | Active        | Production           | B0QFN (RDH)   30 | 3000   LARGE T&R      | -           |                                      |                                   | -40 to 125   | 63603               |
| TPSM63603RDHR.A                 | Active        | Production           | B0QFN (RDH)   30 | 3000   LARGE T&R      | -           | Call TI                              | Call TI                           | -40 to 125   | 63603               |
| <a href="#">TPSM63603SRDHR</a>  | Active        | Production           | B0QFN (RDH)   30 | 3000   LARGE T&R      | -           |                                      |                                   | -40 to 125   | 63603S              |
| TPSM63603SRDHR.A                | Active        | Production           | B0QFN (RDH)   30 | 3000   LARGE T&R      | -           | Call TI                              | Call TI                           | -40 to 125   | 63603S              |
| TPSM63603SRDHRG4                | Active        | Production           | B0QFN (RDH)   30 | 3000   LARGE T&R      | -           | Call TI                              | Call TI                           | -40 to 125   | 63603S              |
| TPSM63603SRDHRG4.A              | Active        | Production           | B0QFN (RDH)   30 | 3000   LARGE T&R      | -           | Call TI                              | Call TI                           | -40 to 125   | 63603S              |
| <a href="#">TPSM63603V3RDHR</a> | Active        | Production           | B0QFN (RDH)   30 | 3000   LARGE T&R      | -           |                                      |                                   | -40 to 125   | 63603V3             |
| TPSM63603V3RDHR.A               | Active        | Production           | B0QFN (RDH)   30 | 3000   LARGE T&R      | -           | Call TI                              | Call TI                           | -40 to 125   | 63603V3             |
| <a href="#">TPSM63603V5RDHR</a> | Active        | Production           | B0QFN (RDH)   30 | 3000   LARGE T&R      | -           |                                      |                                   | -40 to 125   | 63603V5             |
| TPSM63603V5RDHR.A               | Active        | Production           | B0QFN (RDH)   30 | 3000   LARGE T&R      | -           | Call TI                              | Call TI                           | -40 to 125   | 63603V5             |

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

<sup>(2)</sup> **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.

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

<sup>(4)</sup> **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.

<sup>(5)</sup> **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.

<sup>(6)</sup> **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.

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## B0QFN - 1.9 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



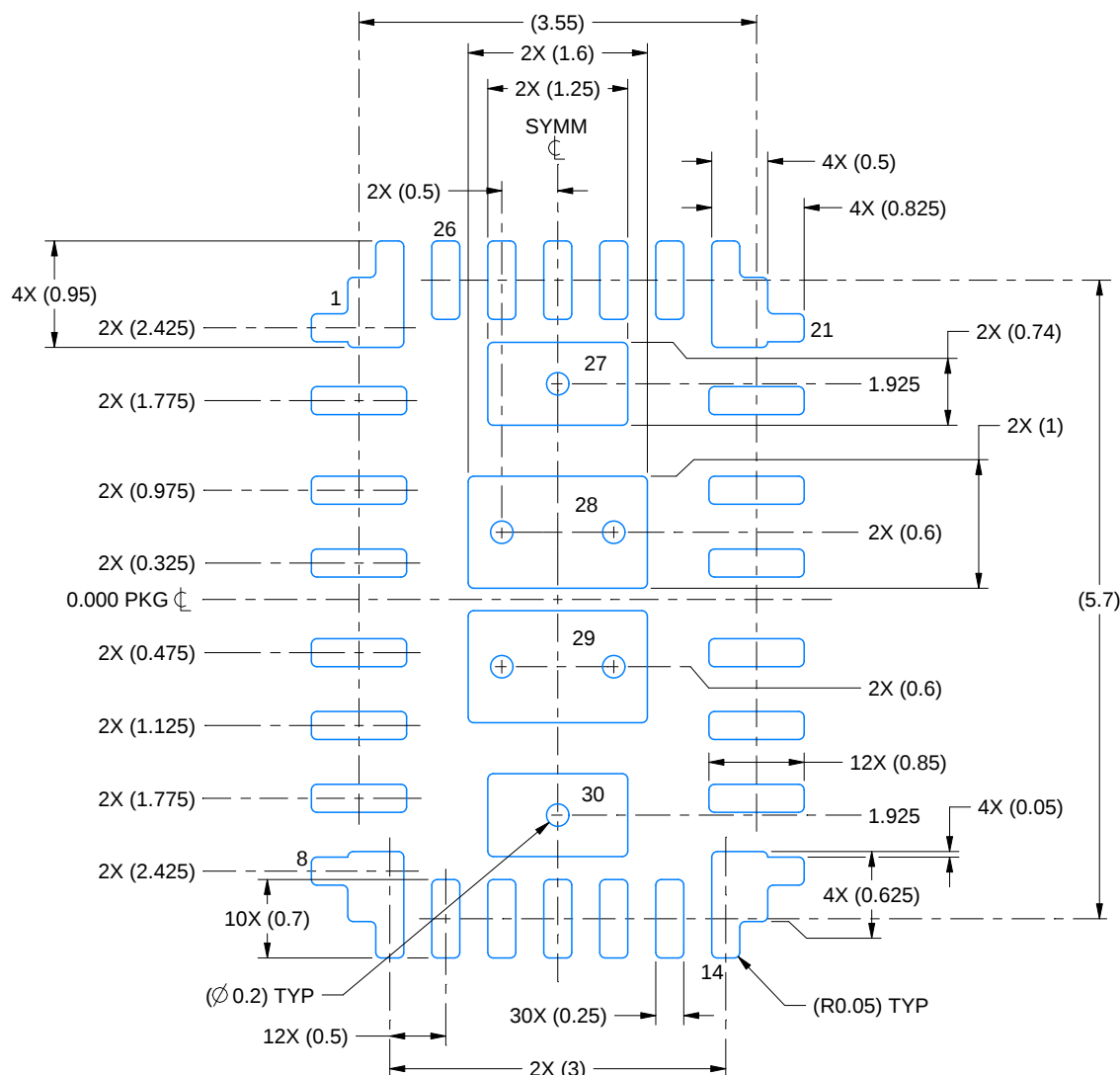
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.

# EXAMPLE BOARD LAYOUT

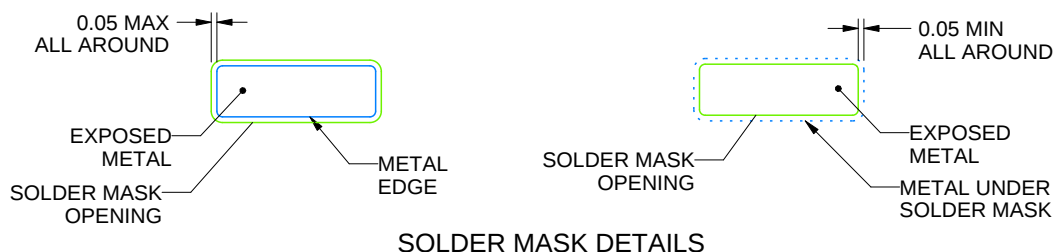
RDH0030A

B0QFN - 1.9 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE:15X



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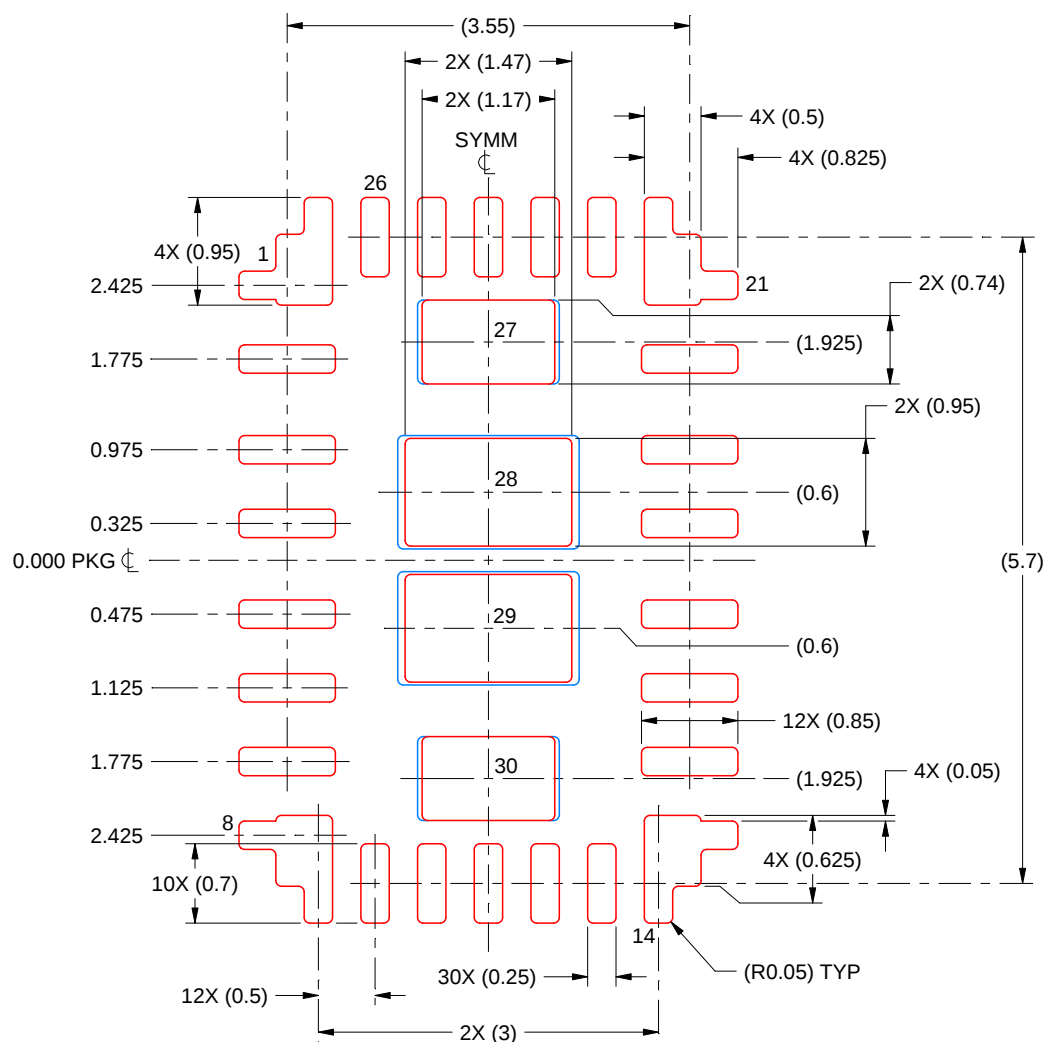
NOTES: (continued)

4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 ([www.ti.com/lit/sluea271](http://www.ti.com/lit/sluea271)).
5. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.

**RDH0030A**

## B0QFN - 1.9 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



## SOLDER PASTE EXAMPLE BASED ON 0.125 mm THICK STENCIL

EXPOSED PAD 27 & 30:  
94% PRINTED SOLDER COVERAGE BY AREA

EXPOSED PAD 28 & 29  
87% PRINTED SOLDER COVERAGE BY AREA

SCALE:15X

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NOTES: (continued)

6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.

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