

## LP8758-B0 4相DC/DC降圧型コンバータ

### 1 特長

- ・ 高効率の降圧型4相DC/DCコンバータ・コア
  - 最大出力電流: 16A
  - PWM-PFM自動切り換え動作と強制PWM動作
  - 自動位相追加/シェディングおよび強制マルチフェーズ動作
  - リモート差動帰還電圧センシング
  - 出力電圧スルー・レートを30mV/μs~0.5mV/μsの範囲でプログラム可能
  - $V_{OUT}$ 範囲 = 0.5V~3.36V (DVS付き)
- ・ プログラム可能なスタートアップおよびシャットダウン遅延 (イネーブル信号に同期)
- ・ I<sup>2</sup>C互換インターフェイスのStandard (100kHz)、Fast (400kHz)、Fast+ (1MHz)、High-Speed (3.4MHz)モードをサポート
- ・ マスクをプログラム可能な割り込み機能
- ・ 負荷電流測定
- ・ 出力短絡および過負荷保護
- ・ 拡散スペクトラム・モードおよび位相インターリーブによるEMIの低減
- ・ 過熱警告および保護
- ・ 低電圧誤動作防止(UVLO)

### 2 アプリケーション

- ・ スマートフォン、電子書籍、タブレット
- ・ ゲーム機

### 3 概要

LP8758は、携帯電話や同様の携帯機器アプリケーションに使用される、最先端のアプリケーション・プロセッサの電力管理要件を満たすように設計されています。このデバイスには、4つの降圧型DC/DCコンバータ・コアが内蔵され、互いに結合されて1つの4相降圧型コンバータを形成しています。このデバイスは、I<sup>2</sup>C互換のシリアル・インターフェイスにより制御されます。

PWM-PFMの自動切り換え(AUTOモード)動作と、自動位相追加/シェディングにより、広い出力電流範囲にわたって効率を最大化します。LP8758はリモート差動電圧検出をサポートしており、レギュレータ出力と負荷ポイントとの間のIR降下を補償することで、出力電圧の精度を向上させています。

LP8758は、イネーブル信号に同期したプログラム可能なスタートアップおよびシャットダウン遅延をサポートしています。

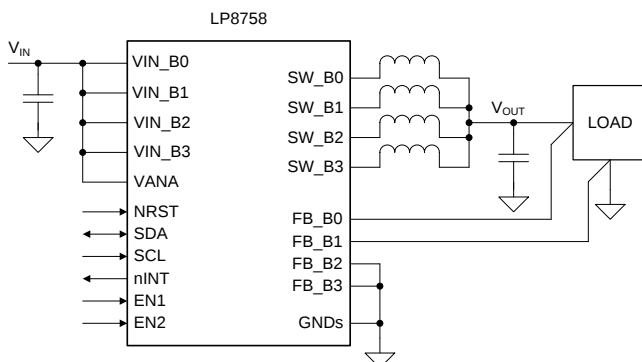
保護機能として、短絡保護、電流制限、入力電源UVLO、温度警告およびシャットダウン機能が搭載されています。デバイスのステータス情報のための複数のエラー・フラグが用意されています。さらに、LP8758デバイスは、外付けの電流検出抵抗を追加しないで負荷電流を測定できます。スタートアップ中と電圧変化時に、本デバイスは出力スルー・レートを制御し、出力電圧のオーバーシュートと突入電流を最小化します。

#### 製品情報<sup>(1)</sup>

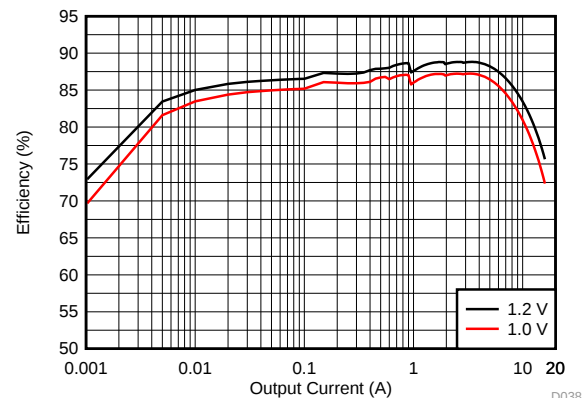
| 型番        | パッケージ      | 本体サイズ(公称)     |
|-----------|------------|---------------|
| LP8758-B0 | DSBGA (35) | 2.88mm×2.13mm |

(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。

### 4 概略回路図



#### 効率と出力電流との関係( $V_{IN} = 3.7V$ )



D038



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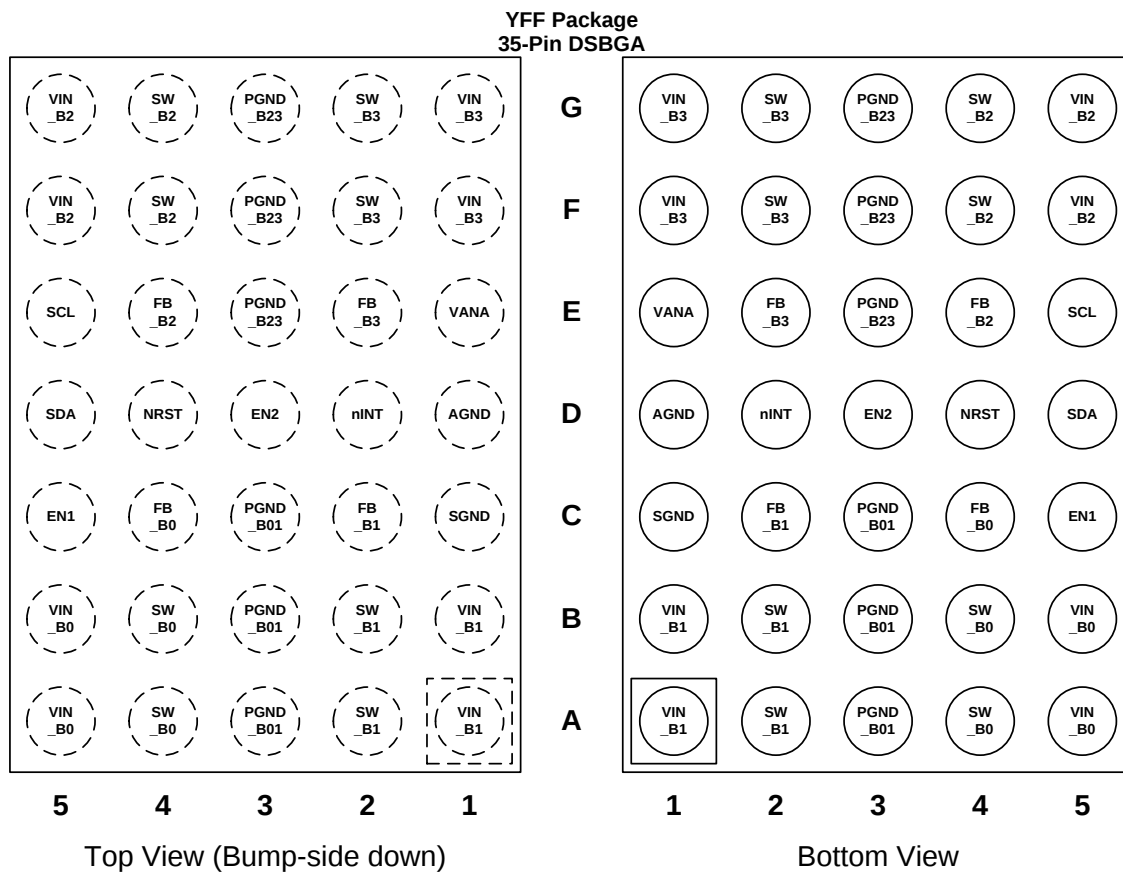
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## 5 改訂履歴

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|---------------------------------------------------------------------------|------|
| • Changed logic low level to 0 V and high level to VANA up to 3.6 V ..... | 5    |
| • Added support for I2C signals up to 3.3V .....                          | 5    |
| • Changed "700 μs" to "1.2 ms" .....                                      | 17   |

| Revision A (May 2015) から Revision B に変更 | Page |
|-----------------------------------------|------|
| 2015年3月発行のものから更新                        |      |
| • 最初のWebリリース .....                      | 1    |
| • 追加「コミュニティ・リソース」セクション .....            | 50   |

## 6 Pin Configuration and Functions



### Pin Functions

| PIN                                                                                     |          | TYPE  | DESCRIPTION                                                                                                                                                                 |
|-----------------------------------------------------------------------------------------|----------|-------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| NUMBER                                                                                  | NAME     |       |                                                                                                                                                                             |
| A1, B1                                                                                  | VIN_B1   | P     | Input for Buck 1. The separate power pins VIN_Bx are not connected together internally - VIN_Bx pins must be connected together in the application and be locally bypassed. |
| A2, B2                                                                                  | SW_B1    | A     | Buck 1 switch node.                                                                                                                                                         |
| A3, B3, C3                                                                              | PGND_B01 | G     | Power Ground for Buck 0 and Buck 1.                                                                                                                                         |
| A4, B4                                                                                  | SW_B0    | A     | Buck 0 switch node.                                                                                                                                                         |
| A5, B5                                                                                  | VIN_B0   | P     | Input for Buck 0. The separate power pins VIN_Bx are not connected together internally - VIN_Bx pins must be connected together in the application and be locally bypassed. |
| C1                                                                                      | SGND     | G     | Substrate Ground.                                                                                                                                                           |
| C2                                                                                      | FB_B1    | A     | Output ground feedback (negative) for Buck 0.                                                                                                                               |
| C4                                                                                      | FB_B0    | A     | Output voltage feedback (positive) for Buck 0.                                                                                                                              |
| C5                                                                                      | EN1      | D/I   | Programmable Enable signal for Buck regulator. Can be also configured to switch between two output voltage levels.                                                          |
| D1                                                                                      | AGND     | G     | Ground.                                                                                                                                                                     |
| D2                                                                                      | nINT     | D/O   | Open-drain interrupt output. Active LOW.                                                                                                                                    |
| D3                                                                                      | EN2      | D/I   | Programmable Enable signal for Buck regulator. Can be also configured to switch between two output voltage levels.                                                          |
| D4                                                                                      | NRST     | D/I   | Reset signal for the device.                                                                                                                                                |
| D5                                                                                      | SDA      | D/I/O | Serial interface data input and output for system access. Connect a pull-up resistor.                                                                                       |
| E1                                                                                      | VANA     | P     | Supply voltage for Analog and Digital blocks. VANA pin must be connected to same voltage as VIN_Bx pins.                                                                    |
| E2                                                                                      | FB_B3    | A     | Output voltage feedback (positive) for Buck 3 - Connect to ground in 4-phase configuration.                                                                                 |
| E4                                                                                      | FB_B2    | A     | Output voltage feedback (positive) for Buck 2. - Connect to ground in 4-phase configuration.                                                                                |
| E5                                                                                      | SCL      | D/I   | Serial interface clock input for system access. Connect a pull-up resistor.                                                                                                 |
| F1, G1                                                                                  | VIN_B3   | P     | Input for Buck 3. The separate power pins VIN_Bx are not connected together internally - VIN_Bx pins must be connected together in the application and be locally bypassed. |
| F2, G2                                                                                  | SW_B3    | A     | Buck 3 switch node.                                                                                                                                                         |
| E3, F3, G3                                                                              | PGND_B23 | G     | Power Ground for Buck 2 and Buck 3.                                                                                                                                         |
| F4, G4                                                                                  | SW_B2    | A     | Buck 2 switch node.                                                                                                                                                         |
| F5, G5                                                                                  | VIN_B2   | P     | Input for Buck 2. The separate power pins VIN_Bx are not connected together internally - VIN_Bx pins must be connected together in the application and be locally bypassed. |
| A: Analog Pin, D: Digital Pin, G: Ground Pin, P: Power Pin, I: Input Pin, O: Output Pin |          |       |                                                                                                                                                                             |

## 7 Specifications

### 7.1 Absolute Maximum Ratings

Over operating free-air temperature range (unless otherwise noted)<sup>(1)(2)</sup>

|                                                              |                                                                                         | MIN  | MAX                          | UNIT  |
|--------------------------------------------------------------|-----------------------------------------------------------------------------------------|------|------------------------------|-------|
| <b>INPUT VOLTAGE</b>                                         |                                                                                         |      |                              |       |
| VIN_Bx, VANA                                                 | Voltage on power connections                                                            | −0.3 | 6                            | V     |
| SW_Bx                                                        | Voltage on buck switch nodes                                                            | −0.3 | (VIN_Bx + 0.3 ) with 6 V max | V     |
| FB_Bx                                                        | Voltage on buck voltage sense nodes                                                     | −0.3 | (VANA + 0.3 ) with 6 V max   | V     |
| NRST                                                         | Voltage on NRST input                                                                   | −0.3 | 3.6                          | V     |
| ENx, SDA, SCL, nINT                                          | Voltage on logic pins (input or output pins)                                            | −0.3 | 3.6                          |       |
| <b>CURRENT</b>                                               |                                                                                         |      |                              |       |
| VIN_Bx, SW_Bx, PGND_Bx                                       | Current on power pins (average current over 100k hour lifetime, T <sub>J</sub> = 125°C) |      | 0.62                         | A/pin |
| <b>TEMPERATURE</b>                                           |                                                                                         |      |                              |       |
| Junction temperature, T <sub>J-MAX</sub>                     |                                                                                         | −40  | 150                          | °C    |
| Storage temperature, T <sub>stg</sub>                        |                                                                                         | −65  | 150                          | °C    |
| Maximum lead temperature (soldering, 10 sec.) <sup>(3)</sup> |                                                                                         |      | 260                          | °C    |

- (1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
- (2) All voltage values are with respect to network ground.
- (3) For detailed soldering specifications and information, refer to *AN-1112 DSBGA Wafer Level Chip Scale Package* ([SNVA009](#)).

### 7.2 ESD Ratings

|                    |                         | VALUE                                                                          | UNIT  |
|--------------------|-------------------------|--------------------------------------------------------------------------------|-------|
| V <sub>(ESD)</sub> | Electrostatic discharge | Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 <sup>(1)</sup>              | ±2000 |
|                    |                         | Charged-device model (CDM), per JEDEC specification JESD22-C101 <sup>(2)</sup> | ±500  |

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

### 7.3 Recommended Operating Conditions

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

|                                      |                                                                                                                          | MIN | MAX            | UNIT |
|--------------------------------------|--------------------------------------------------------------------------------------------------------------------------|-----|----------------|------|
| <b>INPUT VOLTAGE</b>                 |                                                                                                                          |     |                |      |
| VIN_Bx, VANA                         | Voltage on power connections                                                                                             | 2.5 | 5.5            | V    |
| NRST                                 | Voltage on NRST                                                                                                          | 0   | VANA up to 3.6 | V    |
| ENx, nINT                            | Voltage on logic pins (input or output pins)                                                                             | 0   | VANA up to 3.6 | V    |
| SCL, SDA                             | Voltage on I <sup>2</sup> C interface, standard (100 kHz), fast (400 kHz), fast+ (1 MHz), and high-speed (3.4 MHz) modes | 0   | 1.95           | V    |
|                                      | Voltage on I <sup>2</sup> C interface, standard (100 kHz), fast (400 kHz), and fast+ (1 MHz) modes                       | 0   | VANA up to 3.6 | V    |
| <b>TEMPERATURE</b>                   |                                                                                                                          |     |                |      |
| Junction temperature, T <sub>J</sub> |                                                                                                                          | −40 | 125            | °C   |
| Ambient temperature, T <sub>A</sub>  |                                                                                                                          | −40 | 85             | °C   |

## 7.4 Thermal Information

| THERMAL METRIC <sup>(1)</sup> |                                              | LP8758      | UNIT |
|-------------------------------|----------------------------------------------|-------------|------|
|                               |                                              | YFF (DSBGA) |      |
|                               |                                              | 35 PINS     |      |
| R <sub>θJA</sub>              | Junction-to-ambient thermal resistance       | 56.1        | °C/W |
| R <sub>θJCTop</sub>           | Junction-to-case (top) thermal resistance    | 0.2         | °C/W |
| R <sub>θJB</sub>              | Junction-to-board thermal resistance         | 8.5         | °C/W |
| ψ <sub>JT</sub>               | Junction-to-top characterization parameter   | 0.9         | °C/W |
| ψ <sub>JB</sub>               | Junction-to-board characterization parameter | 8.4         | °C/W |
| R <sub>θJCbott</sub>          | Junction-to-case (bottom) thermal resistance | N/A         | °C/W |

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report, [SPRA953](#).

## 7.5 Electrical Characteristics

Limits apply over the junction temperature range  $-40^{\circ}\text{C} \leq T_J \leq +125^{\circ}\text{C}$ , specified  $V_{(VANA)}$ ,  $V_{IN}$ ,  $V_{(NRST)}$ ,  $V_{OUT}$  and  $I_{OUT}$  range, unless otherwise noted. Typical values are at  $T_J = 25^{\circ}\text{C}$ ,  $f_{SW} = 3 \text{ MHz}$ ,  $V_{(VANA)} = V_{IN} = 3.7 \text{ V}$  and  $V_{OUT} = 1 \text{ V}$  unless otherwise noted.<sup>(1)(2)</sup>

| PARAMETER              |                                                                                                               | TEST CONDITIONS                                                                                                                                         | MIN               | TYP | MAX                    | UNIT |
|------------------------|---------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|-----|------------------------|------|
| EXTERNAL COMPONENTS    |                                                                                                               |                                                                                                                                                         |                   |     |                        |      |
| C <sub>IN</sub>        | Input filtering capacitance                                                                                   | Connected from VIN_Bx to PGND_Bx                                                                                                                        | 1.9               | 10  |                        | μF   |
| C <sub>OUT</sub>       | Output filtering capacitance, local                                                                           | Capacitance per phase                                                                                                                                   | 10                | 22  |                        | μF   |
| C <sub>OUT-TOTAL</sub> | Output capacitance, total (local and remote)                                                                  | Total output capacitance, 4-phase configuration                                                                                                         | 40                |     | 200                    | μF   |
| ESR <sub>C</sub>       | Input and output capacitor ESR                                                                                | [1-10] MHz                                                                                                                                              |                   | 2   | 10                     | mΩ   |
| L                      | Inductor                                                                                                      | Inductance of the inductor                                                                                                                              | 0.33 or 0.47      |     |                        | μH   |
|                        |                                                                                                               |                                                                                                                                                         | –30%              |     | 30%                    |      |
| DCR <sub>L</sub>       | Inductor DCR                                                                                                  | TOKO, DFE252010F-R33M                                                                                                                                   | 16                |     |                        | mΩ   |
| BUCK REGULATOR         |                                                                                                               |                                                                                                                                                         |                   |     |                        |      |
| V <sub>IN</sub>        | Input voltage range                                                                                           | Voltage between VIN_Bx and ground pins. VANA must be connected to the same supply as VIN_Bx.                                                            | 2.5               | 3.7 | 5.5                    | V    |
| V <sub>OUT</sub>       | Output voltage                                                                                                | Programmable voltage range                                                                                                                              | 0.5               | 1   | 3.36                   | V    |
|                        |                                                                                                               | Step size, 0.5 V ≤ V <sub>OUT</sub> < 0.73 V                                                                                                            |                   | 10  |                        | mV   |
|                        |                                                                                                               | Step size, 0.73 V ≤ V <sub>OUT</sub> < 1.4 V                                                                                                            |                   | 5   |                        |      |
|                        |                                                                                                               | Step size, 1.4 V ≤ V <sub>OUT</sub> ≤ 3.36 V                                                                                                            |                   | 20  |                        |      |
| I <sub>OUT</sub>       | Output current                                                                                                | Output current, 4-phase configuration                                                                                                                   |                   |     | 12 <sup>(3)</sup>      | A    |
|                        |                                                                                                               | Output current, 4-phase configuration, V <sub>IN</sub> > 3 V, V <sub>OUT</sub> < 2 V                                                                    |                   |     | 16 <sup>(3)</sup>      |      |
|                        | Dropout voltage                                                                                               | V <sub>IN</sub> – V <sub>OUT</sub>                                                                                                                      | 0.7               |     |                        | V    |
|                        | DC output voltage accuracy, includes voltage reference, DC load and line regulations, process and temperature | Forced PWM mode, 0.8 V ≤ V <sub>OUT</sub> ≤ 1.2 V, 2.5 V ≤ V <sub>IN</sub> ≤ 4.5 V, T <sub>J</sub> = 25°C, 0 ≤ I <sub>OUT</sub> ≤ I <sub>OUT(max)</sub> | –1%               |     | 1.5%                   |      |
|                        |                                                                                                               | PFM mode, the average output voltage level is increased by max. 20 mV                                                                                   | min (–2%, –15 mV) |     | max ( 2%, 15 mV) 20 mV |      |

- (1) All voltage values are with respect to network ground.
- (2) Minimum (MIN) and maximum (MAX) limits are specified by design, test, or statistical analysis. Typical (TYP) numbers are not verified, but do represent the most likely norm.
- (3) The maximum output current is also limited by the junction temperature and maximum average current over lifetime. The power dissipation inside the die increases the junction temperature and limits the maximum current depending of the length of the current pulse, efficiency, board and ambient temperature. The maximum average current/pin over lifetime is described in [Absolute Maximum Ratings](#).

## Electrical Characteristics (continued)

Limits apply over the junction temperature range  $-40^{\circ}\text{C} \leq T_J \leq +125^{\circ}\text{C}$ , specified  $V_{(VANA)}$ ,  $V_{IN}$ ,  $V_{(NRST)}$ ,  $V_{OUT}$  and  $I_{OUT}$  range, unless otherwise noted. Typical values are at  $T_J = 25^{\circ}\text{C}$ ,  $f_{SW} = 3 \text{ MHz}$ ,  $V_{(VANA)} = V_{IN} = 3.7 \text{ V}$  and  $V_{OUT} = 1 \text{ V}$  unless otherwise noted.<sup>(1)(2)</sup>

| PARAMETER                     |                                                                    | TEST CONDITIONS                                                                                                                                                                  | MIN  | TYP   | MAX | UNIT              |
|-------------------------------|--------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|-------|-----|-------------------|
| Ripple, 4-phase configuration |                                                                    | PWM mode, L = 0.33 μH                                                                                                                                                            |      | 10    |     | mV <sub>p-p</sub> |
|                               |                                                                    | PFM mode, L = 0.33 μH                                                                                                                                                            |      | 10    |     |                   |
| DC <sub>LNR</sub>             | DC line regulation                                                 | I <sub>OUT</sub> = I <sub>OUT(max)</sub>                                                                                                                                         |      | ±0.05 |     | %/V               |
| DC <sub>LDR</sub>             | DC load regulation in PWM mode                                     | I <sub>OUT</sub> from 0 to I <sub>OUT(max)</sub>                                                                                                                                 |      | 0.3%  |     |                   |
| T <sub>LDSR</sub>             | Undershoot for transient load step response, 4-phase configuration | I <sub>OUT</sub> = 1 A to 8 A, T <sub>R</sub> = 400 ns, PWM mode, C <sub>OUT</sub> = 100 μF, L = 0.33 μH                                                                         |      | -45   |     | mV                |
|                               |                                                                    | 2.5 V ≤ V <sub>IN</sub> ≤ 4.5 V, 0.8 V ≤ V <sub>OUT</sub> ≤ 1.2 V, I <sub>OUT</sub> = 0.1 A to 4.1 A, T <sub>R</sub> = 100 ns, AUTO mode, C <sub>OUT</sub> = 100 μF, L = 0.33 μH |      | -35   |     | mV                |
|                               |                                                                    | 3 V ≤ V <sub>IN</sub> ≤ 4.5 V, 0.8 V ≤ V <sub>OUT</sub> ≤ 1.2 V, I <sub>OUT</sub> from 1 A to 12 A, T <sub>R</sub> = 1000 ns, C <sub>OUT</sub> = 100 μF, L = 0.33 μH             |      | -45   |     | mV                |
|                               | Overshoot for transient load step response, 4-phase configuration  | I <sub>OUT</sub> = 8 A to 1 A, T <sub>F</sub> = 400 ns, PWM mode, C <sub>OUT</sub> = 100 μF, L = 0.33 μH                                                                         |      | 45    |     | mV                |
|                               |                                                                    | 2.5 V ≤ V <sub>IN</sub> ≤ 4.5 V, 0.8 V ≤ V <sub>OUT</sub> ≤ 1.2 V, I <sub>OUT</sub> = 4.1 A to 0.1 A, T <sub>F</sub> = 100 ns, AUTO mode, C <sub>OUT</sub> = 100 μF, L = 0.33 μH |      | 25    |     | mV                |
|                               |                                                                    | 3 V ≤ V <sub>IN</sub> ≤ 4.5 V, 0.8 V ≤ V <sub>OUT</sub> ≤ 1.2 V, I <sub>OUT</sub> from 12 A to 1 A, T <sub>F</sub> = 1000 ns, C <sub>OUT</sub> = 100 μF, L = 0.33 μH             |      | 50    |     | mV                |
| T <sub>LNSR</sub>             | Transient line response                                            | V <sub>IN</sub> stepping 2.5 V ↔ 3 V, T <sub>R</sub> = T <sub>F</sub> = 10 μs, I <sub>OUT</sub> = I <sub>OUT(max)</sub>                                                          |      | ±20   |     | mV                |
| I <sub>LIM FWD</sub>          | Forward current limit (peak for every switching cycle)             | Programmable range                                                                                                                                                               | 1.5  |       | 5   | A                 |
|                               |                                                                    | Step size                                                                                                                                                                        |      | 0.5   |     |                   |
|                               |                                                                    | Accuracy, 3 V ≤ V <sub>IN</sub> ≤ 5.5 V, I <sub>LIM</sub> = 5 A                                                                                                                  | -5%  | 7.5%  | 20% |                   |
|                               |                                                                    | Accuracy, 2.5 V ≤ V <sub>IN</sub> < 3 V, I <sub>LIM</sub> = 5 A                                                                                                                  | -20% | 7.5%  | 20% |                   |
| I <sub>LIM NEG</sub>          | Negative current limit                                             |                                                                                                                                                                                  | 1.6  | 2     | 2.4 | A                 |
| R <sub>DS(ON) HS FET</sub>    | On-resistance, high-side FET                                       | Each phase, between VIN_Bx and SW_Bx pins (I = 1 A)                                                                                                                              |      | 40    | 90  | mΩ                |
| R <sub>DS(ON) LS FET</sub>    | On-resistance, low-side FET                                        | Each phase, between SW_Bx and PGND_Bx pins (I = 1 A)                                                                                                                             |      | 33    | 50  | mΩ                |
|                               | Current balancing                                                  | Current mismatch between phases, I <sub>OUT</sub> > 1000 mA / phase, 0.8 V ≤ V <sub>OUT</sub> ≤ 1.2 V                                                                            |      |       | 10% |                   |
|                               | Overshoot during start-up                                          | V <sub>OUT</sub> = 1 V, Slew rate = 10 mV/μs                                                                                                                                     |      |       | 50  | mV                |
| I <sub>PFM-PWM</sub>          | PFM-to-PWM transition - current threshold <sup>(4)</sup>           |                                                                                                                                                                                  |      | 600   |     | mA                |
| I <sub>PWM-PFM</sub>          | PWM-to-PFM transition - current threshold <sup>(4)</sup>           |                                                                                                                                                                                  |      | 240   |     | mA                |
| I <sub>ADD</sub>              | Phase-adding level                                                 | From 1-phase to 2-phase                                                                                                                                                          |      | 1000  |     | mA                |
|                               |                                                                    | From 2-phase to 3-phase                                                                                                                                                          |      | 2000  |     |                   |
|                               |                                                                    | From 3-phase to 4-phase                                                                                                                                                          |      | 3000  |     |                   |
| I <sub>SHED</sub>             | Phase-shedding level                                               | From 2-phase to 1-phase                                                                                                                                                          |      | 750   |     | mA                |
|                               |                                                                    | From 3-phase to 2-phase                                                                                                                                                          |      | 1500  |     |                   |
|                               |                                                                    | From 4-phase to 3-phase                                                                                                                                                          |      | 2300  |     |                   |
|                               | Output pulldown resistance                                         | Regulator disabled                                                                                                                                                               | 150  | 250   | 350 | Ω                 |

(4) The final PFM-to-PWM and PWM-to-PFM transition current varies slightly and is dependant on the output voltage, input voltage, and the magnitude of inductor's ripple current.

## Electrical Characteristics (continued)

Limits apply over the junction temperature range  $-40^{\circ}\text{C} \leq T_J \leq +125^{\circ}\text{C}$ , specified  $V_{(VANA)}$ ,  $V_{IN}$ ,  $V_{(NRST)}$ ,  $V_{OUT}$  and  $I_{OUT}$  range, unless otherwise noted. Typical values are at  $T_J = 25^{\circ}\text{C}$ ,  $f_{SW} = 3\text{ MHz}$ ,  $V_{(VANA)} = V_{IN} = 3.7\text{ V}$  and  $V_{OUT} = 1\text{ V}$  unless otherwise noted.<sup>(1)(2)</sup>

| PARAMETER                |                                                                                             | TEST CONDITIONS                                                        | MIN   | TYP | MAX | UNIT |
|--------------------------|---------------------------------------------------------------------------------------------|------------------------------------------------------------------------|-------|-----|-----|------|
|                          | Powergood threshold for interrupt<br>BUCKx_INT(BUCKx_SC_INT), difference from final voltage | Rising ramp voltage, enable or voltage change                          | −23   | −17 | −10 | mV   |
|                          |                                                                                             | Falling ramp, voltage change                                           | 10    | 17  | 23  |      |
|                          | Powergood threshold for status signal<br>BUCKx_STAT(BUCKx_PG_STAT)                          | During operation, status signal is forced to '0' during voltage change | −23   | −17 | −10 | mV   |
| PROTECTION FEATURES      |                                                                                             |                                                                        |       |     |     |      |
| Thermal warning          |                                                                                             | Temperature rising, CONFIG(TDIE_WARN_LEVEL) = 0                        | 125   |     |     | °C   |
|                          |                                                                                             | Temperature rising, CONFIG(TDIE_WARN_LEVEL) = 1                        | 105   |     |     |      |
|                          |                                                                                             | Hysteresis                                                             | 15    |     |     |      |
| Thermal shutdown         |                                                                                             | Temperature rising                                                     | 150   |     |     | °C   |
|                          |                                                                                             | Hysteresis                                                             | 15    |     |     |      |
| VANA <sub>UVLO</sub>     | VANA undervoltage lockout                                                                   | Voltage falling                                                        | 2.3   | 2.4 | 2.5 | V    |
|                          |                                                                                             | Hysteresis                                                             | 50    |     |     | mV   |
| LOAD CURRENT MEASUREMENT |                                                                                             |                                                                        |       |     |     |      |
|                          | Current measurement range                                                                   | Maximum code                                                           | 20.46 |     |     | A    |
|                          | Resolution                                                                                  | LSB                                                                    | 20    |     |     | mA   |
|                          | Measurement accuracy                                                                        | I <sub>OUT</sub> ≥ 2 A                                                 | <10%  |     |     |      |
| CURRENT CONSUMPTION      |                                                                                             |                                                                        |       |     |     |      |
|                          | Shutdown current consumption                                                                | V <sub>(NRST)</sub> = 0 V                                              | 1     |     |     | μA   |
|                          | Standby current consumption, regulator disabled                                             | V <sub>(NRST)</sub> = 1.8 V                                            | 6     |     |     | μA   |
|                          | Active current consumption during PFM operation                                             | V <sub>(NRST)</sub> = 1.8 V, I <sub>OUT</sub> = 0 mA, not switching    | 71    |     |     | μA   |
|                          | Active current consumption during PWM operation                                             | V <sub>(NRST)</sub> = 1.8 V, I <sub>OUT</sub> = 0 mA                   | 18    |     |     | mA   |

## Electrical Characteristics (continued)

Limits apply over the junction temperature range  $-40^{\circ}\text{C} \leq T_J \leq +125^{\circ}\text{C}$ , specified  $V_{(VANA)}$ ,  $V_{IN}$ ,  $V_{(NRST)}$ ,  $V_{OUT}$  and  $I_{OUT}$  range, unless otherwise noted. Typical values are at  $T_J = 25^{\circ}\text{C}$ ,  $f_{SW} = 3\text{ MHz}$ ,  $V_{(VANA)} = V_{IN} = 3.7\text{ V}$  and  $V_{OUT} = 1\text{ V}$  unless otherwise noted.<sup>(1)(2)</sup>

| PARAMETER                                 |                                                 | TEST CONDITIONS                         | MIN | TYP  | MAX  | UNIT |
|-------------------------------------------|-------------------------------------------------|-----------------------------------------|-----|------|------|------|
| DIGITAL INPUT SIGNALS NRST, ENx, SCL, SDA |                                                 |                                         |     |      |      |      |
| V <sub>IL</sub>                           | Input low level                                 |                                         |     |      | 0.4  | V    |
| V <sub>IH</sub>                           | Input high level                                |                                         | 1.2 |      |      | V    |
| V <sub>HYS</sub>                          | Hysteresis of Schmitt trigger inputs (SCL, SDA) |                                         | 10  | 80   | 160  | mV   |
|                                           | ENx pulldown resistance                         | ENx_PD = 1                              |     | 500  |      | kΩ   |
|                                           | NRST pulldown resistance                        | Always present                          | 800 | 1200 | 1700 | kΩ   |
| DIGITAL OUTPUT SIGNALS nINT, SDA          |                                                 |                                         |     |      |      |      |
| V <sub>OL</sub>                           | Output low level                                | I <sub>SOURCE</sub> = 2 mA              |     |      | 0.4  | V    |
| R <sub>P</sub>                            | External pullup resistor for nINT               | To VIO Supply                           |     | 10   |      | kΩ   |
| ALL DIGITAL INPUTS                        |                                                 |                                         |     |      |      |      |
| I <sub>LEAK</sub>                         | Input current                                   | All logic inputs over pin voltage range | -1  |      | 1    | μA   |

## 7.6 I<sup>2</sup>C Serial Bus Timing Parameter

See<sup>(1)</sup> and [Figure 1](#).

|              |                        | MIN                                    | MAX  | UNIT          |
|--------------|------------------------|----------------------------------------|------|---------------|
| $f_{SCL}$    | Serial clock frequency | Standard mode                          | 100  | kHz           |
|              |                        | Fast mode                              | 400  | kHz           |
|              |                        | Fast mode +                            | 1    | MHz           |
|              |                        | High-speed mode, $C_b = 100\text{ pF}$ | 3.4  | MHz           |
|              |                        | High-speed mode, $C_b = 400\text{ pF}$ | 1.7  | MHz           |
| $t_{LOW}$    | SCL low time           | Standard mode                          | 4.7  | $\mu\text{s}$ |
|              |                        | Fast mode                              | 1.3  |               |
|              |                        | Fast mode +                            | 0.5  |               |
|              |                        | High-speed mode, $C_b = 100\text{ pF}$ | 160  | ns            |
|              |                        | High-speed mode, $C_b = 400\text{ pF}$ | 320  |               |
| $t_{HIGH}$   | SCL high time          | Standard mode                          | 4    | $\mu\text{s}$ |
|              |                        | Fast mode                              | 0.6  |               |
|              |                        | Fast mode +                            | 0.26 |               |
|              |                        | High-speed mode, $C_b = 100\text{ pF}$ | 60   | ns            |
|              |                        | High-speed mode, $C_b = 400\text{ pF}$ | 120  |               |
| $t_{SU;DAT}$ | Data setup time        | Standard mode                          | 250  | ns            |
|              |                        | Fast mode                              | 100  |               |
|              |                        | Fast mode +                            | 50   |               |
|              |                        | High-speed mode                        | 10   |               |
| $t_{HD;DAT}$ | Data hold time         | Standard mode                          | 0    | $\mu\text{s}$ |
|              |                        | Fast mode                              | 0    |               |
|              |                        | Fast mode +                            | 0    |               |
|              |                        | High-speed mode, $C_b = 100\text{ pF}$ | 0    | ns            |
|              |                        | High-speed mode, $C_b = 400\text{ pF}$ | 0    |               |

(1)  $C_b$  refers to the capacitance of one bus line.  $C_b$  is expressed in pF units.

## I<sup>2</sup>C Serial Bus Timing Parameter (continued)

 See<sup>(1)</sup> and [Figure 1](#).

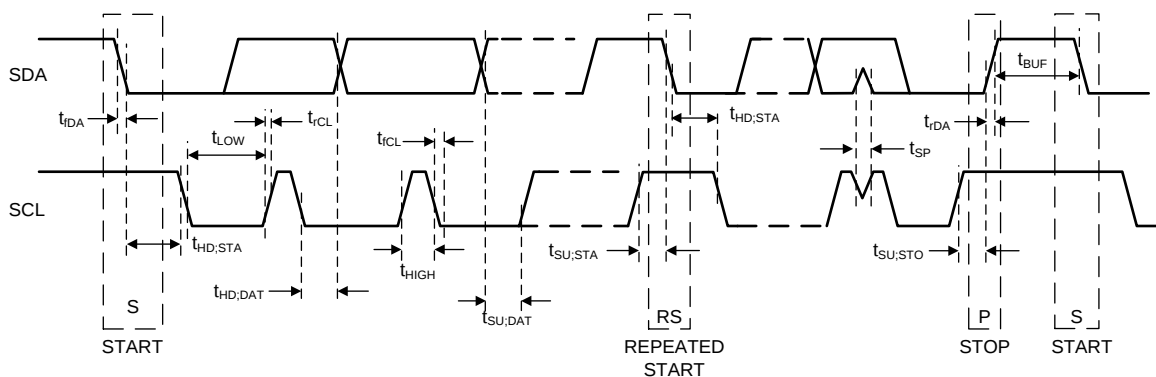
|              |                                                                                                                     | MIN                             | MAX  | UNIT    |
|--------------|---------------------------------------------------------------------------------------------------------------------|---------------------------------|------|---------|
| $t_{SU;STA}$ | Setup time for a start or a repeated start condition                                                                | Standard mode                   | 4.7  | $\mu s$ |
|              |                                                                                                                     | Fast mode                       | 0.6  |         |
|              |                                                                                                                     | Fast mode +                     | 0.26 |         |
|              |                                                                                                                     | High-speed mode                 | 160  | ns      |
| $t_{HD;STA}$ | Hold time for a start or a repeated start condition                                                                 | Standard mode                   | 4    | $\mu s$ |
|              |                                                                                                                     | Fast mode                       | 0.6  |         |
|              |                                                                                                                     | Fast mode +                     | 0.26 |         |
|              |                                                                                                                     | High-speed mode                 | 160  | ns      |
| $t_{BUF}$    | Bus free time between a stop and start condition                                                                    | Standard mode                   | 4.7  | $\mu s$ |
|              |                                                                                                                     | Fast mode                       | 1.3  |         |
|              |                                                                                                                     | Fast mode +                     | 0.5  |         |
| $t_{SU;STO}$ | Setup time for a stop condition                                                                                     | Standard mode                   | 4    | $\mu s$ |
|              |                                                                                                                     | Fast mode                       | 0.6  |         |
|              |                                                                                                                     | Fast mode +                     | 0.26 |         |
|              |                                                                                                                     | High-speed mode                 | 160  | ns      |
| $t_{rDA}$    | Rise time of SDA signal                                                                                             | Standard mode                   | 1000 | ns      |
|              |                                                                                                                     | Fast mode                       | 300  |         |
|              |                                                                                                                     | Fast mode +                     | 120  |         |
|              |                                                                                                                     | High-speed mode, $C_b = 100$ pF | 80   |         |
|              |                                                                                                                     | High-speed mode, $C_b = 400$ pF | 160  |         |
| $t_{fDA}$    | Fall time of SDA signal                                                                                             | Standard mode                   | 250  | ns      |
|              |                                                                                                                     | Fast mode                       | 250  |         |
|              |                                                                                                                     | Fast mode +                     | 120  |         |
|              |                                                                                                                     | High-speed mode, $C_b = 100$ pF | 80   |         |
|              |                                                                                                                     | High-speed mode, $C_b = 400$ pF | 160  |         |
| $t_{rCL}$    | Rise time of SCL signal                                                                                             | Standard mode                   | 1000 | ns      |
|              |                                                                                                                     | Fast mode                       | 300  |         |
|              |                                                                                                                     | Fast mode +                     | 120  |         |
|              |                                                                                                                     | High-speed Mode, $C_b = 100$ pF | 40   |         |
|              |                                                                                                                     | High-speed Mode, $C_b = 400$ pF | 80   |         |
| $t_{rCL1}$   | Rise time of SCL signal after a repeated start condition and after an acknowledge bit                               | Standard mode                   | 1000 | ns      |
|              |                                                                                                                     | Fast mode                       | 300  |         |
|              |                                                                                                                     | Fast mode +                     | 120  |         |
|              |                                                                                                                     | High-speed mode, $C_b = 100$ pF | 80   |         |
|              |                                                                                                                     | High-speed mode, $C_b = 400$ pF | 160  |         |
| $t_{fCL}$    | Fall time of a SCL signal                                                                                           | Standard mode                   | 300  | ns      |
|              |                                                                                                                     | Fast mode                       | 300  |         |
|              |                                                                                                                     | Fast mode +                     | 120  |         |
|              |                                                                                                                     | High-speed mode, $C_b = 100$ pF | 40   |         |
|              |                                                                                                                     | High-speed mode, $C_b = 400$ pF | 80   |         |
| $C_b$        | Capacitive load for each bus line (SCL and SDA)                                                                     |                                 | 400  | pF      |
| $t_{SP}$     | Pulse width of spike suppressed in SCL and SDA lines (spikes that are less than the indicated width are suppressed) | Fast mode, fast mode +          | 50   | ns      |
|              |                                                                                                                     | High-speed mode                 | 10   |         |

## 7.7 Switching Characteristics

Limits apply over the junction temperature range  $-40^{\circ}\text{C} \leq T_J \leq 125^{\circ}\text{C}$ , specified  $V_{(VANA)}$ ,  $V_{IN}$ ,  $V_{(NRST)}$ ,  $V_{OUT}$  and  $I_{OUT}$  range, unless otherwise noted. Typical values are at  $T_J = 25^{\circ}\text{C}$ ,  $f_{SW} = 3\text{ MHz}$ ,  $V_{(VANA)} = V_{IN} = 3.7\text{ V}$  and  $V_{OUT} = 1\text{ V}$  unless otherwise noted.<sup>(1)</sup>

| PARAMETER                               | TEST CONDITIONS                                                                                                       | MIN  | TYP  | MAX | UNIT              |
|-----------------------------------------|-----------------------------------------------------------------------------------------------------------------------|------|------|-----|-------------------|
| $f_{SW}$                                | Switching frequency, PWM mode                                                                                         | 2.7  | 3    | 3.3 | MHz               |
| $f_{SW-MAX}$                            | Maximum switching frequency, PWM mode                                                                                 | 2.7  | 3    | 3.3 | MHz               |
|                                         | Automatically limited to smaller of $f_{SW}$ and $f_{SW-MAX}$                                                         | 1.8  | 2    | 2.2 |                   |
| Regulator start-up time (soft start)    | From ENx to $V_{OUT} = 0.225\text{ V}$ (slew-rate control begins), $C_{OUT\_TOTAL} = 88\text{ }\mu\text{F}$ , no load |      | 90   |     | $\mu\text{s}$     |
| Output voltage slew-rate <sup>(2)</sup> | $SLEW\_RATEx[2:0] = 000$ , $V_{OUT} \geq 0.5\text{ V}$                                                                | -15% | 30   | 15% | mV/ $\mu\text{s}$ |
|                                         | $SLEW\_RATEx[2:0] = 001$ , $V_{OUT} \geq 0.5\text{ V}$                                                                | -15% | 15   | 15% |                   |
|                                         | $SLEW\_RATEx[2:0] = 010$ , $V_{OUT} \geq 0.5\text{ V}$                                                                | -15% | 10   | 15% |                   |
|                                         | $SLEW\_RATEx[2:0] = 011$ , $V_{OUT} \geq 0.5\text{ V}$                                                                | -15% | 7.5  | 15% |                   |
|                                         | $SLEW\_RATEx[2:0] = 100$ , $V_{OUT} \geq 0.5\text{ V}$                                                                | -15% | 3.8  | 15% |                   |
|                                         | $SLEW\_RATEx[2:0] = 101$ , $V_{OUT} \geq 0.5\text{ V}$                                                                | -15% | 1.9  | 15% |                   |
|                                         | $SLEW\_RATEx[2:0] = 110$ , $V_{OUT} \geq 0.5\text{ V}$                                                                | -15% | 0.94 | 15% |                   |
|                                         | $SLEW\_RATEx[2:0] = 111$ , $V_{OUT} \geq 0.5\text{ V}$                                                                | -15% | 0.4  | 15% |                   |
| Load current measurement time           | PFM mode (automatically changing to PWM mode for the measurement)                                                     |      | 50   |     | $\mu\text{s}$     |
|                                         | PWM mode                                                                                                              |      | 4    |     |                   |

- (1) Minimum (MIN) and maximum (MAX) limits are specified by design, test, or statistical analysis. Typical (TYP) numbers are not verified, but do represent the most likely norm.
- (2) The slew-rate can be limited by the current limit (forward or negative current limit), output capacitance and load current.



**Figure 1. I²C Timing**

## 7.8 Typical Characteristics

Unless otherwise specified:  $T_A = 25^\circ\text{C}$ ,  $V_{IN} = 3.7\text{ V}$ ,  $f_{SW} = 3\text{ MHz}$ .

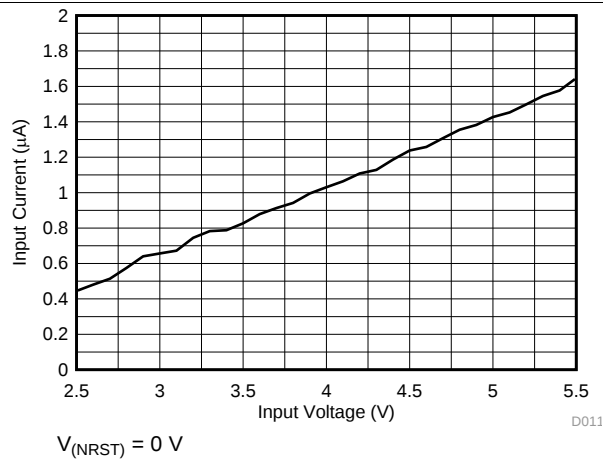


Figure 2. Shutdown Current Consumption vs Input Voltage

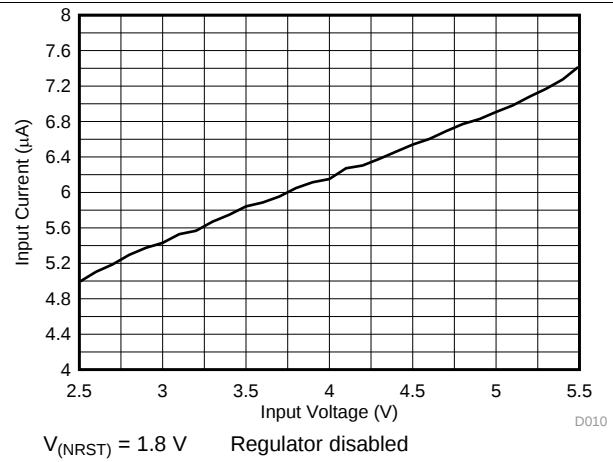


Figure 3. Standby Current Consumption vs Input Voltage

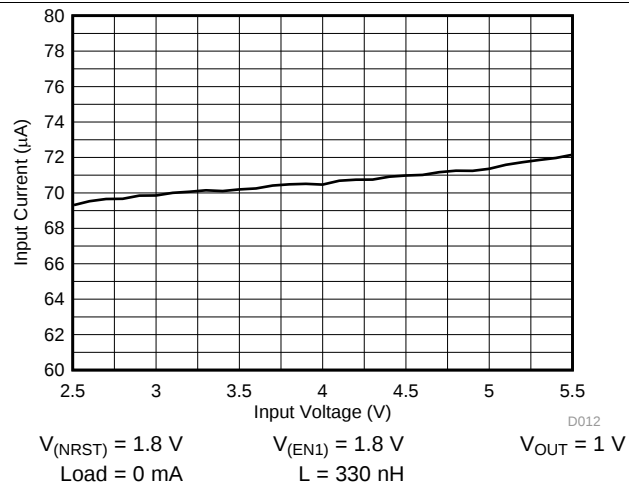


Figure 4. PFM Mode Current Consumption vs Input Voltage

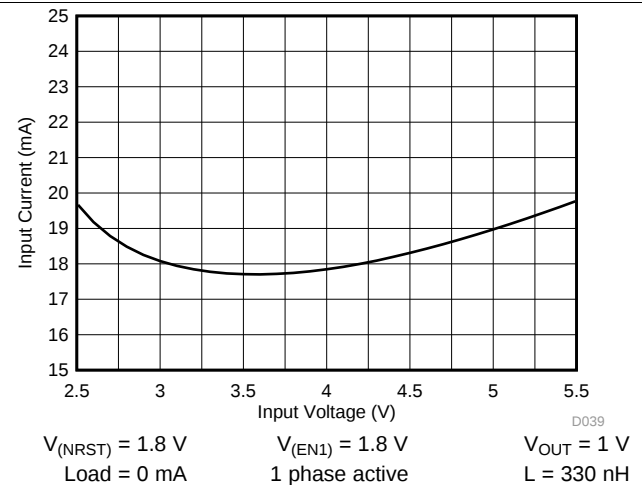


Figure 5. PWM Mode Current Consumption vs Input Voltage

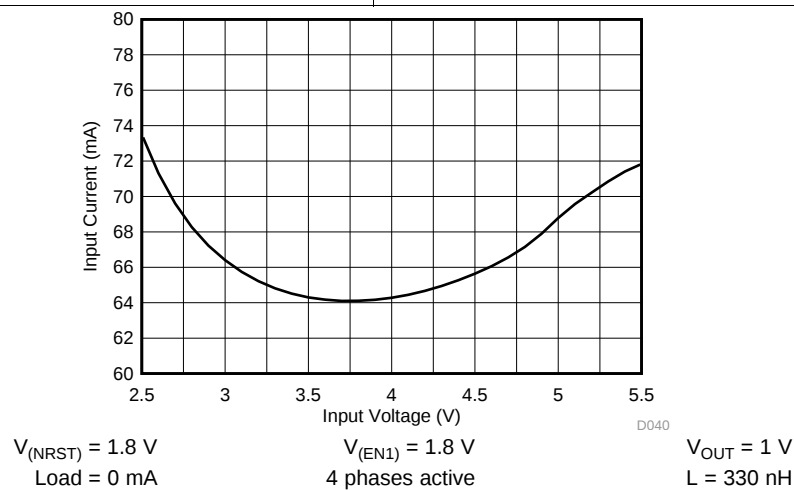


Figure 6. Forced Multi-Phase Current Consumption vs Input Voltage

## 8 Detailed Description

### 8.1 Overview

The LP8758 is a high-efficiency, high-performance power supply device with four step-down DC-DC converter cores. The cores are configured for a single 4-phase configuration. The device delivers 0.5-V to 3.36-V regulated voltage rail from 2.5-V to 5.5-V battery or supply voltage to portable devices such as cell phones, tablets, and PDAs.

There are two modes of operation for the converter, depending on the output current required: pulse-width modulation (PWM) and pulse-frequency modulation (PFM). The converter operates in PWM mode at high load currents of approximately 400 mA or higher. When operating in PWM mode the phases are automatically added/shedded based on the load current level. Lighter output current loads will cause the converter to automatically switch into PFM mode for reduced current consumption and a longer battery life when forced PWM mode is disabled. The forced multi-phase mode can be enabled for highest transient performance.

Additional features include soft-start, undervoltage lockout, overload protection, thermal warning, and thermal shutdown.

#### 8.1.1 Buck Information

The LP8758 has four integrated high-efficiency buck converter cores. The cores are designed for flexibility; most of the functions are programmable, thus giving a possibility to optimize the regulator operation for each application.

##### 8.1.1.1 Operating Modes

- OFF: Output is isolated from the input voltage rail in this mode. Output has an optional pulldown resistor.
- PWM: Converter operates in buck configuration with fixed switching frequency.
- PFM: Converter switches only when output voltage decreases below programmed threshold. Inductor current is discontinuous.

##### 8.1.1.2 Features

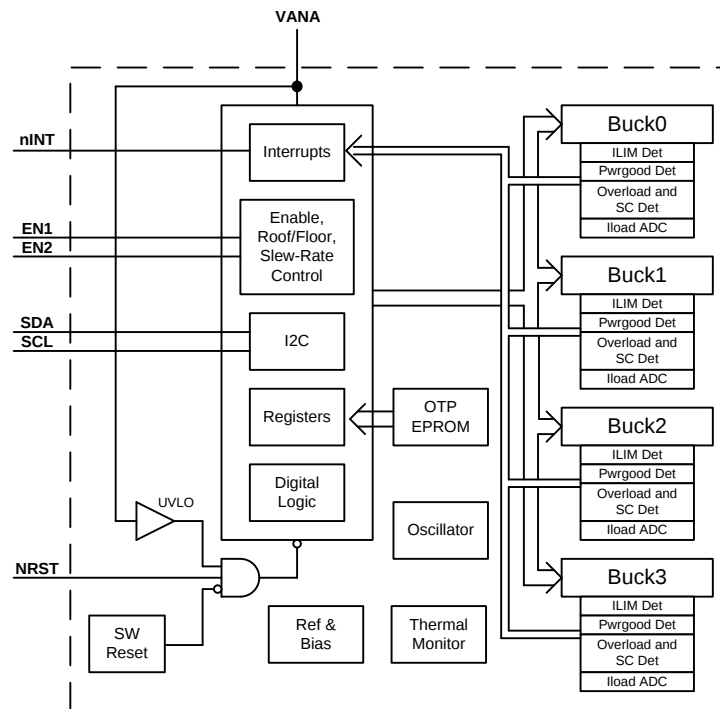
- Output voltage
- Forced PWM operation
- Forced multi-phase operation (forces also the PWM operation)
- Switch current limit
- Output voltage slew rate
- Enable and disable delays

##### 8.1.1.3 Programmability

The following parameters can be programmed via registers:

- DVS support with programmable slew-rate
- Automatic mode control based on the loading
- Synchronous rectification
- Current mode loop with PI compensator
- Optional spread spectrum technique to reduce EMI
- Soft start
- Power good flag with maskable interrupt
- Phase control for optimized EMI
- Average output current sensing (for PFM entry, phase shedding/adding, and load current measurement)
- Current balancing between the phases of the converter
- Differential voltage sensing from point of the load
- Dynamic phase shedding/adding, each output being phase shifted

## 8.2 Functional Block Diagram



## 8.3 Feature Description

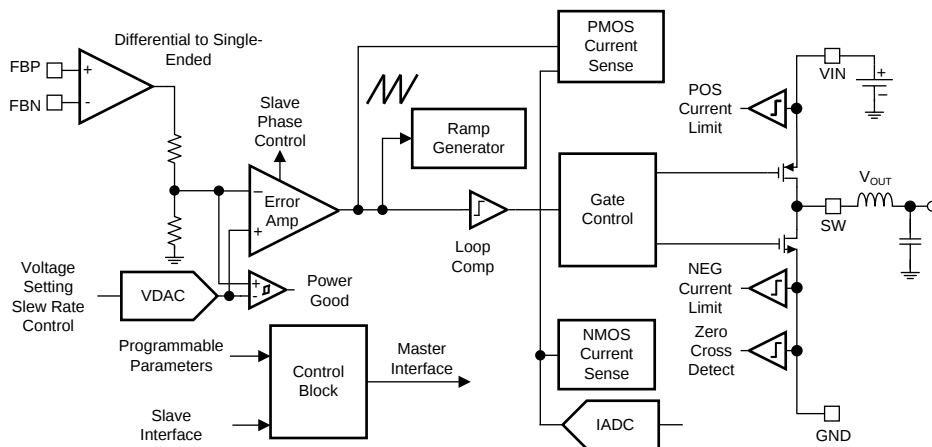
### 8.3.1 Multi-Phase DC-DC Converters

#### 8.3.1.1 Overview

A multi-phase synchronous buck converter offers several advantages over a single power stage converter. For application processor power delivery, lower ripple on the input and output currents and faster transient response to load steps are the most significant advantages. Also, since the load current is evenly shared among multiple channels, the heat generated is greatly reduced for each channel due to the fact that power loss is proportional to square of current. Physical size of the output inductor shrinks significantly due to this heat reduction. A block diagram of a single core is shown in [Figure 7](#).

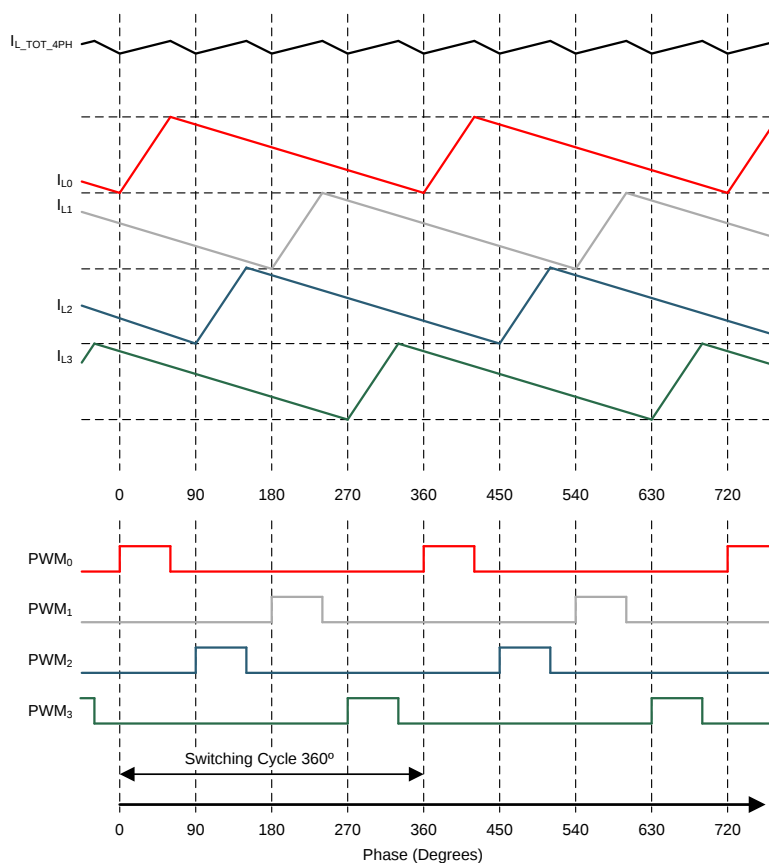
Interleaving switching action of the converters and channels in a four-phase configuration is illustrated in [Figure 8](#).

## Feature Description (continued)



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**Figure 7. Detailed Block Diagram Showing One Core**



**Figure 8. PWM Timings and Inductor Current Waveforms in 4-phase Configuration <sup>(1)</sup>**

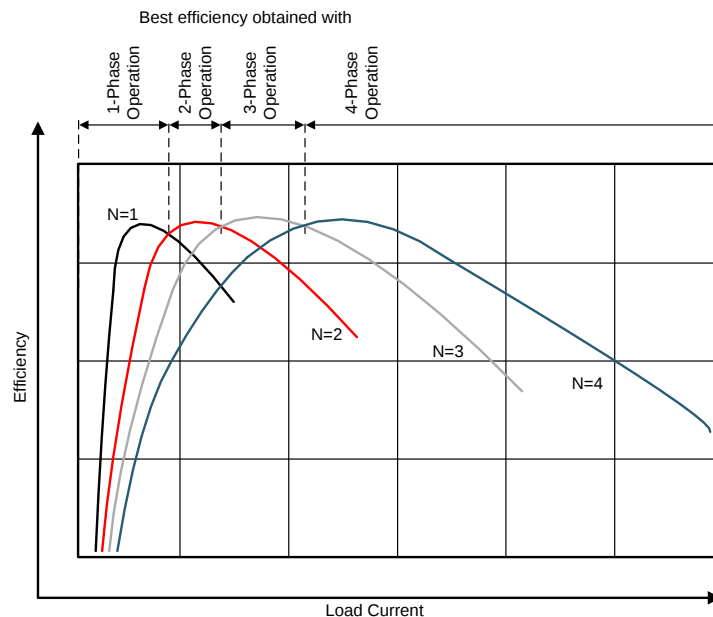
<sup>(1)</sup> Graph is not in scale and is for illustrative purposes only.

## Feature Description (continued)

### 8.3.1.2 Multi-Phase Operation and Phase Adding/Shedding

Under heavy load conditions, the 4-phase converter switches each channel 90° apart. As a result, the 4-phase converter has an effective ripple frequency four times greater than the switching frequency of any one phase. However, the parallel operation decreases the efficiency at light load conditions. In order to overcome this operational inefficiency, the LP8758 can change the number of active phases to optimize efficiency for the variations of the load. This is called phase adding/shedding. The concept is illustrated below in [Figure 9](#).

The converter can be forced to multi-phase operation by the BUCK0\_CTRL1.BUCK0\_FPWM\_MP bit. If the regulator operates in forced multi-phase mode the forced PWM operation is automatically used. If the multi-phase operation is not forced, the number of phases are added and shedded automatically to follow the required output current.



**Figure 9. Multi-Phase Buck Converter Efficiency vs Number of Phases - All Converters in PWM Mode <sup>(2)</sup>**

### 8.3.1.3 Transition Between PWM and PFM Modes

Normal PWM mode operation with phase-adding or phase-shedding optimizes efficiency at mid-to-full load at the expense of light-load efficiency. The LP8758 converter operates in PWM mode at load current of about 400 mA or higher. At lighter load current levels the device automatically switches into PFM mode for reduced current consumption when Forced PWM mode is disabled (AUTO mode operation). By combining the PFM and the PWM modes a high efficiency is achieved over a wide output-load current range.

### 8.3.1.4 Multi-Phase Switcher Configurations

In the multi-phase configuration the control of the multi-phase regulator settings is done using the control registers of the master buck. The following slave registers are ignored:

- BUCKx\_CTRL1
- BUCKx\_CTRL2, except ILIMx[2:0] bits
- interrupt bits related to the slave buck, except BUCKx\_ILIM\_INT

<sup>(2)</sup> Graph is not in scale and is for illustrative purposes only.

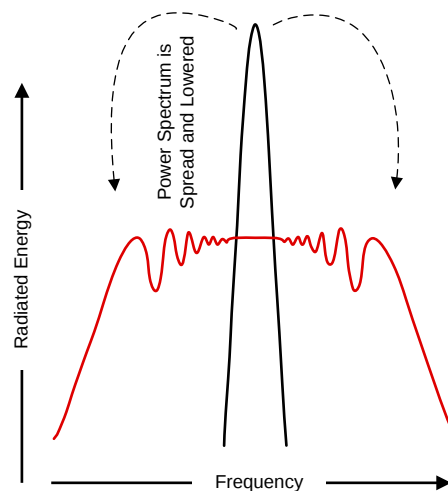
## Feature Description (continued)

### 8.3.1.5 Buck Converter Load Current Measurement

Buck load current can be monitored via I<sup>2</sup>C registers. The monitored buck converter is selected with the SEL\_I\_LOAD.LOAD\_CURRENT\_BUCK\_SELECT[1:0] register bits. A write to this selection register starts a current measurement sequence. The measurement sequence is typically 50  $\mu$ s long. The LP8758 device can be configured to give out an interrupt INT\_TOP.I\_LOAD\_READY after the load current measurement sequence is finished. Load current measurement interrupt can be masked with TOP\_MASK.I\_LOAD\_READY\_MASK bit. The measurement result can be read from registers I\_LOAD\_1 and I\_LOAD\_2. Register I\_LOAD\_1 bits BUCK\_LOAD\_CURRENT[7:0] give out the LSB bits and register I\_LOAD\_2 bits BUCK\_LOAD\_CURRENT[9:8] the MSB bits. The measurement result BUCK\_LOAD\_CURRENT[9:0] LSB is 20 mA, and maximum value of the measurement is 20.46 A. The measured current is the total value of the master and slave phases.

### 8.3.1.6 Spread-Spectrum Mode

Systems with periodic switching signals may generate a large amount of switching noise in a set of narrowband frequencies (the switching frequency and its harmonics). The usual solution to reduce noise coupling is to add EMI-filters and shields to the boards. The LP8758's register selectable spread-spectrum mode minimizes the need for output filters, ferrite beads, or chokes. In spread spectrum mode, the switching frequency varies randomly by  $\pm 5\%$  (depending on selected switching frequency) about the center frequency, reducing the EMI emissions radiated by the converter and associated passive components and PCB traces (see Figure 10). This feature is enabled with the CONFIG.EN\_SPREAD\_SPEC bit, and it affects all the buck cores.



Where a fixed frequency converter exhibits large amounts of spectral energy at the switching frequency, the spread spectrum architecture of the LP8758 spreads that energy over a large bandwidth.

**Figure 10. Spread-Spectrum Modulation**

### 8.3.2 Power-Up

The power-up sequence for the LP8758 is as follows:

- VANA (and VIN\_Bx) reach min recommended levels ( $V_{(VANA)} > V_{ANA_{UVLO}}$ ).
- NRST is set to high level. This initiates power-on-reset (POR), OTP reading and enables the system I/O interface. The I<sup>2</sup>C host allows at least 1.2 ms before writing or reading data to the LP8758.
- Device enters STANDBY mode.
- The host can change the default register setting by I<sup>2</sup>C if needed.
- The regulator can be enabled/disabled by ENx pin(s) and by I<sup>2</sup>C interface.

## Feature Description (continued)

### 8.3.3 Regulator Control

#### 8.3.3.1 Enabling and Disabling Regulator

The regulator can be enabled when the device is in STANDBY state. There are two ways for enable and disable the regulator:

- Using BUCK0\_CTRL1.EN\_BUCK0 register bit (BUCK0\_CTRL1.EN\_PIN\_CTRL0 register bit is '0').
- Using EN1/2 control pins (BUCK0\_CTRL1.EN\_BUCK0 register bit is '1' AND BUCK0\_CTRL1.EN\_PIN\_CTRL0 register bit is '1').

If the EN1/2 control pins are used for enable and disable then the delay from the control signal rising edge to startup is set by BUCK0\_DELAY.BUCK0\_STARTUP\_DELAY[3:0] bits and the delay from control signal falling edge to shutdown is set by BUCK0\_DELAY.BUCK0\_SHUTDOWN\_DELAY[3:0] bits. The delays are valid only for EN1/2 signal and not for control with BUCK0\_CTRL1.EN\_BUCK0 bit. The delay time implemented by EN1/2 has overall +/-10% timing accuracy.

The control of the regulator (with 0 ms delays) is shown in [Table 1](#). The multi-phase regulator is controlled with registers of the master phase.

**Table 1. Regulator Control**

| CONTROL METHOD                           | ROW | EN_BUCKx0 | BUCK0_CTRL1<br>EN_PIN_CTRL0 | BUCK0_CTRL1<br>EN_PIN_SELECT0 | BUCK0_CTRL1<br>EN_ROOF_FLOOR0 | EN1 PIN    | EN2 PIN    | BUCK0<br>OUTPUT VOLTAGE                |
|------------------------------------------|-----|-----------|-----------------------------|-------------------------------|-------------------------------|------------|------------|----------------------------------------|
| Enable/disable control with EN_BUCK0 bit | 1   | 0         | Don't Care                  | Don't Care                    | Don't Care                    | Don't Care | Don't Care | Disabled                               |
|                                          | 2   | 1         | 0                           | Don't Care                    | Don't Care                    | Don't Care | Don't Care | BUCK0_VOUT.BUCK0_VSET[7:0]             |
| Enable/disable control with EN1 pin      | 3   | 1         | 1                           | 0                             | 0                             | Low        | Don't Care | Disabled                               |
|                                          | 4   | 1         | 1                           | 0                             | 0                             | High       | Don't Care | BUCK0_VOUT.BUCK0_VSET[7:0]             |
| Enable/disable control with EN2 pin      | 5   | 1         | 1                           | 1                             | 0                             | Don't Care | Low        | Disabled                               |
|                                          | 6   | 1         | 1                           | 1                             | 0                             | Don't Care | High       | BUCK0_VOUT.BUCK0_VSET[7:0]             |
| Roof/floor control with EN1 pin          | 7   | 1         | 1                           | 0                             | 1                             | Low        | Don't Care | BUCK0_FLOOR_VOUT.BUCK0_FLOOR_VSET[7:0] |
|                                          | 8   | 1         | 1                           | 0                             | 1                             | High       | Don't Care | BUCK0_VOUT.BUCK0_VSET[7:0]             |
| Roof/floor control with EN2 pin          | 9   | 1         | 1                           | 1                             | 1                             | Don't Care | Low        | BUCK0_FLOOR_VOUT.BUCK0_FLOOR_VSET[7:0] |
|                                          | 10  | 1         | 1                           | 1                             | 1                             | Don't Care | High       | BUCK0_VOUT.BUCK0_VSET[7:0]             |

The following configuration allows the enable/disable control using ENx pin:

- BUCK0\_CTRL1.EN\_BUCK0 = 1
- BUCK0\_CTRL1.EN\_PIN\_CTRL0 = 1
- BUCK0\_CTRL1.EN\_ROOF\_FLOOR0 = 0
- BUCK0\_VOUT.BUCK0\_VSET[7:0] = Required voltage when ENx is high
- The enable pin for control is selected with BUCK0\_CTRL1.EN\_PIN\_SELECT0

When the ENx pin is low, [Table 1](#) row 3 (or 5) is valid, and the regulator is disabled. By setting ENx pin high, [Table 1](#) row 4 (or 6) is valid, and the regulator is enabled with required voltage.

If the regulator is enabled all the time, and the ENx pin controls selection between two voltage level, the following configuration is used:

- BUCK0\_CTRL1.EN\_BUCK0 = 1
- BUCK0\_CTRL1.EN\_PIN\_CTRL0 = 1
- BUCK0\_CTRL1.EN\_ROOF\_FLOOR0 = 1
- BUCK0\_VOUT.BUCK0\_VSET[7:0] = Required voltage when ENx is high
- The enable pin for control is selected with BUCK0\_CTRL1.EN\_PIN\_SELECT0

When the ENx pin is low, [Table 1](#) row 7(or 9) is valid, and the regulator is enabled with a voltage defined by BUCK0\_FLOOR\_VOUT.BUCK0\_FLOOR\_VSET[7:0] bits. Setting the ENx pin high, [Table 1](#) row 8 (or 10) is valid, and the regulator is enabled with a voltage defined by BUCK0\_VOUT.BUCK0\_VSET[7:0] bits.

If the regulator is controlled by I<sup>2</sup>C writings, the BUCK0\_CTRL1.EN\_PIN\_CTRL0 bit is set to 0. The enable/disable is controlled by the BUCK0\_CTRL1.EN\_BUCK0 bit, and when the regulator is enabled, the output voltage is defined by the BUCK0\_VOUT.BUCK0\_VSET[7:0] bits. The Table 1 rows 1 and 2 are valid for I<sup>2</sup>C controlled operation (ENx pins are ignored).

The regulator is enabled by the ENx pin or by I<sup>2</sup>C writing as shown in Figure 11. The soft-start circuit limits the in-rush current during start-up. Output voltage increase rate is around 30 mV/μsec during soft-start. When the output voltage rises to approximately 0.3 V, the output voltage becomes slew-rate controlled. If there is a short circuit at the output, and the output voltage does not increase above a 0.35-V level in 1 ms, the regulator is disabled, and interrupt is set. When the output voltage reaches the powergood threshold level the INT\_BUCK\_0\_1.BUCK0\_PG\_INT interrupt flag is set. The powergood interrupt flag can be masked using BUCK\_0\_1\_MASK.BUCK0\_PG\_MASK bit.

The ENx input pins have integrated pull-down resistors. The pull-down resistors are enabled by default and host can disable those with CONFIG.ENx\_PD bits.

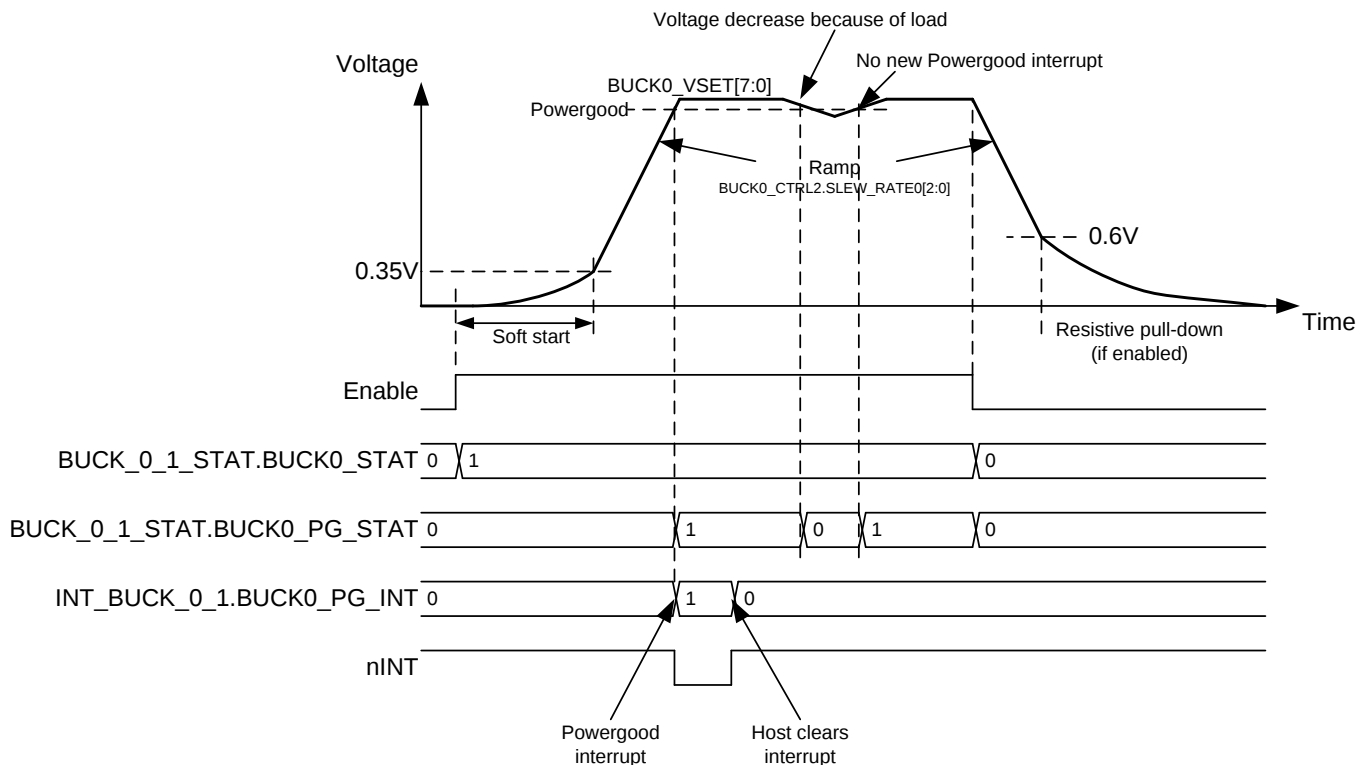
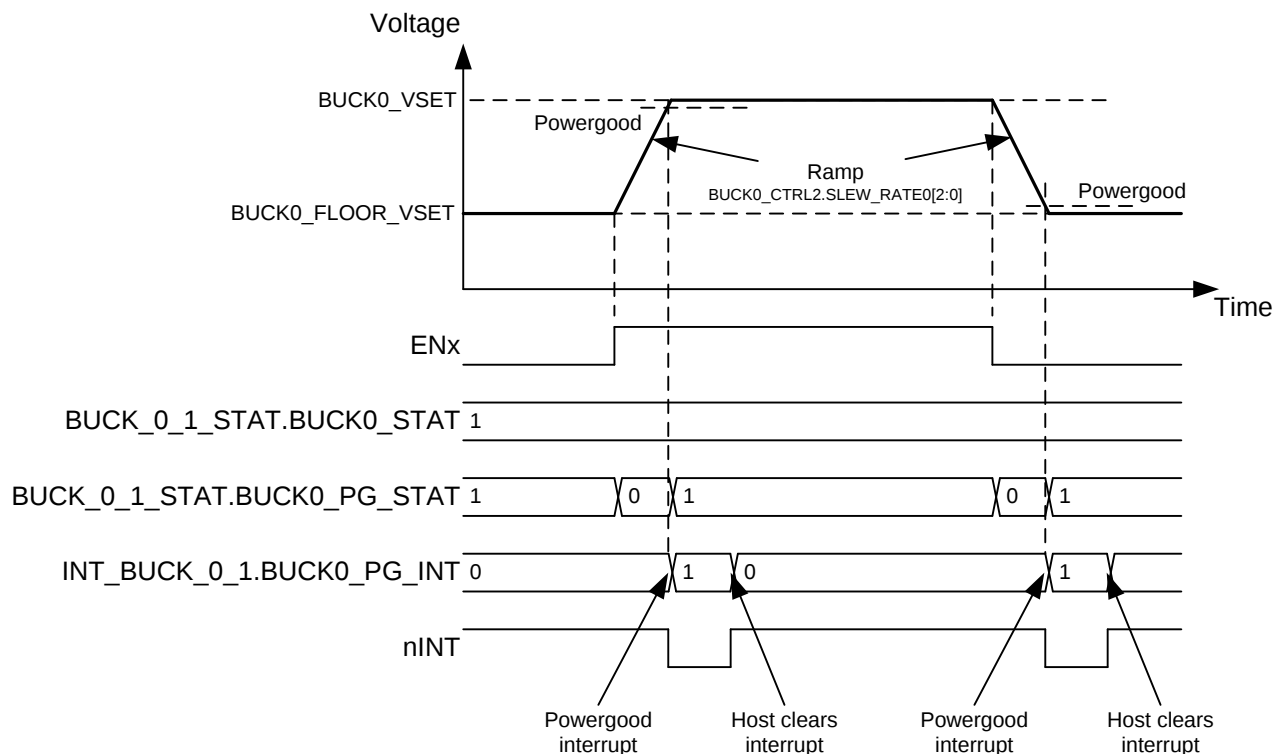


Figure 11. Regulator Enable and Disable

### 8.3.3.2 Changing Output Voltage

The regulator's output voltage can be changed by the ENx pin (voltage levels defined by the BUCK0\_VOUT and BUCK0\_FLOOR\_VOUT registers) or by writing to the BUCK0\_VOUT and BUCK0\_FLOOR\_VOUT registers. The voltage change is always slew-rate controlled, and the slew-rate is defined by the BUCKx\_CTRL2.SLEW\_RATE[2:0] bits. During voltage change the Forced PWM mode is used automatically. If the multi-phase operation is forced by the BUCK0\_CTRL1.BUCK0\_FPWM\_MP bit, the regulator operates in multi-phase mode (four phases active). If the multi-phase operation is not forced, the number of phases are added and shedded automatically to follow the required slew rate. When the programmed output voltage is achieved, the mode becomes the one defined by load current, and the BUCK0\_CTRL1.BUCK0\_FPWM and BUCK0\_CTRL1.BUCK0\_FPWM\_MP bits.



**Figure 12. Regulator Output Voltage Change**

### 8.3.4 Device Reset Scenarios

There are three reset methods implemented on the LP8758:

- Software reset with RESET.SW\_RESET register bit
- Reset from low logic level of NRST signal
- Undervoltage lockout (UVLO) reset from VANA supply

An SW reset occurs when RESET.SW\_RESET bit is written '1'. The bit is automatically cleared after writing. This event disables the regulator immediately, resets all the register bits to the default values and OTP bits are loaded (see [Figure 14](#)). I<sup>2</sup>C interface is not reset during software reset.

If VANA supply voltage falls below UVLO threshold level or NRST signal is set low, then the regulator is disabled immediately, and all the register bits are reset to the default values. When the VANA supply voltage is above UVLO threshold level and NRST signal rises above threshold level an internal power-on reset (POR) occurs. OTP bits are loaded to the registers, and a start-up is initiated according to the register settings.

### 8.3.5 Diagnosis and Protection Features

The LP8758 is capable of providing three levels of protection features:

- Warnings for diagnosis which sets interrupt;
- Protection events which are disabling the regulator; and
- Faults which are causing the device to shutdown.

When the device detects warning/protection condition(s), the LP8758 sets the flag bits indicating what protection or warning conditions have occurred, and the nINT pin will be pulled low. nINT will be released again after a clear of flags is complete. The nINT signal stays low until all the pending interrupts are cleared.

When a fault is detected, it is indicated by a INT\_TOP.RESET\_REG interrupt flag after next start-up.

**Table 2. Summary of Interrupt Signals**

| EVENT                                                                                                                                    | RESULT                                                                    | INTERRUPT REGISTER AND BIT                             | INTERRUPT MASK              | STATUS BIT                  | RECOVERY / INTERRUPT CLEAR                                                                                 |
|------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------|--------------------------------------------------------|-----------------------------|-----------------------------|------------------------------------------------------------------------------------------------------------|
| Current limit triggered (20 $\mu$ s debounce)                                                                                            | No effect                                                                 | INT_TOP.INT_BUCKx = 1<br>INT_BUCKx.BUCKx_ILIM_INT = 1  | BUCKx_MASK.BUCKx_ILIM_MASK  | BUCKx_STAT.BUCKx_ILIM_STAT  | Write 1 to INT_BUCKx.BUCKx_ILIM_INT bit<br>Interrupt is not cleared if current limit is active             |
| Short circuit ( $V_{OUT} < 0.35$ V at 1 ms after enable) or Overload ( $V_{OUT}$ decreasing below 0.35V during operation, 1 ms debounce) | Regulator disable                                                         | INT_TOP.INT_BUCK0 = 1<br>INT_BUCK_0_1.BUCK0_SC_INT = 1 | N/A                         | N/A                         | Write 1 to INT_BUCK_0_1.BUCK0_SC_INT bit                                                                   |
| Thermal Warning                                                                                                                          | No effect                                                                 | INT_TOP.TDIE_WARN = 1                                  | TOP_MASK.TDIE_WARN_MASK     | TOP_STAT.TDIE_WARN_STAT     | Write 1 to INT_TOP.TDIE_WARN bit<br>Interrupt is not cleared if temperature is above thermal warning level |
| Thermal Shutdown                                                                                                                         | Regulator disabled                                                        | INT_TOP.TDIE_SD = 1                                    | N/A                         | TOP_STAT.TDIE_SD_STAT       | Write 1 to INT_TOP.TDIE_SD bit<br>Interrupt is not cleared if temperature is above thermal shutdown level  |
| Powergood, output voltage reaches the programmed value                                                                                   | No effect                                                                 | INT_TOP.INT_BUCK0 = 1<br>INT_BUCK_0_1.BUCK0_PG_INT = 1 | BUCK_0_1_MASK.BUCK0_PG_MASK | BUCK_0_1_STAT.BUCK0_PG_STAT | Write 1 to INT_BUCK_0_1.BUCK0_PG_INT bit                                                                   |
| Load current measurement ready                                                                                                           | No effect                                                                 | INT_TOP.I_LOAD_READY = 1                               | TOP_MASK.I_LOAD_READY_MASK  | N/A                         | Write 1 to INT_TOP.I_LOAD_READY bit                                                                        |
| Start-up (NRST rising edge)                                                                                                              | Device ready for operation, registers reset to default values             | INT_TOP.RESET_REG = 1                                  | TOP_MASK.RESET_REG_MASK     | N/A                         | Write 1 to INT_TOP.RESET_REG bit                                                                           |
| Glitch on supply voltage and UVLO triggered (VANA falling and rising)                                                                    | Immediate shutdown followed by powerup, registers reset to default values | INT_TOP.RESET_REG = 1                                  | TOP_MASK.RESET_REG_MASK     | N/A                         | Write 1 to INT_TOP.RESET_REG bit                                                                           |
| Software requested reset                                                                                                                 | Immediate shutdown followed by powerup, registers reset to default values | INT_TOP.RESET_REG = 1                                  | TOP_MASK.RESET_REG_MASK     | N/A                         | Write 1 to INT_TOP.RESET_REG bit                                                                           |

### 8.3.5.1 Warnings for Diagnosis (Interrupt)

#### 8.3.5.1.1 Output Current Limit

The buck regulators have programmable output peak current limits. The limits are individually programmed for all buck regulators with BUCKx\_CTRL2.ILIMx[2:0] bits. The current limit settings of master and slave regulators used for the same output voltage rail must be identical. If the load current is increased so that the current limit is triggered, the regulator continues to regulate to the limit current level (current peak regulation). The voltage may decrease if the load current is higher than limit current. If the current regulation continues for 20  $\mu$ s, the LP8758 device sets the INT\_BUCKx.BUCKx\_ILIM\_INT bit and pulls the nINT pin low. The host processor can read BUCKx\_STAT.BUCKx\_ILIM\_STAT bits to see if the regulator is still in peak current regulation mode.

If the load is so high that the output voltage decreases below a 350-mV level, the LP8758 device disables the regulator and sets the INT\_BUCK\_0\_1.BUCK0\_SC\_INT bit. In addition the BUCK\_0\_1\_STAT.BUCK0\_STAT bit is set to 0. The interrupt is cleared when the host processor writes 1 to INT\_BUCK\_0\_1.BUCK0\_SC\_INT bit. The overload situation is shown in [Figure 13](#).

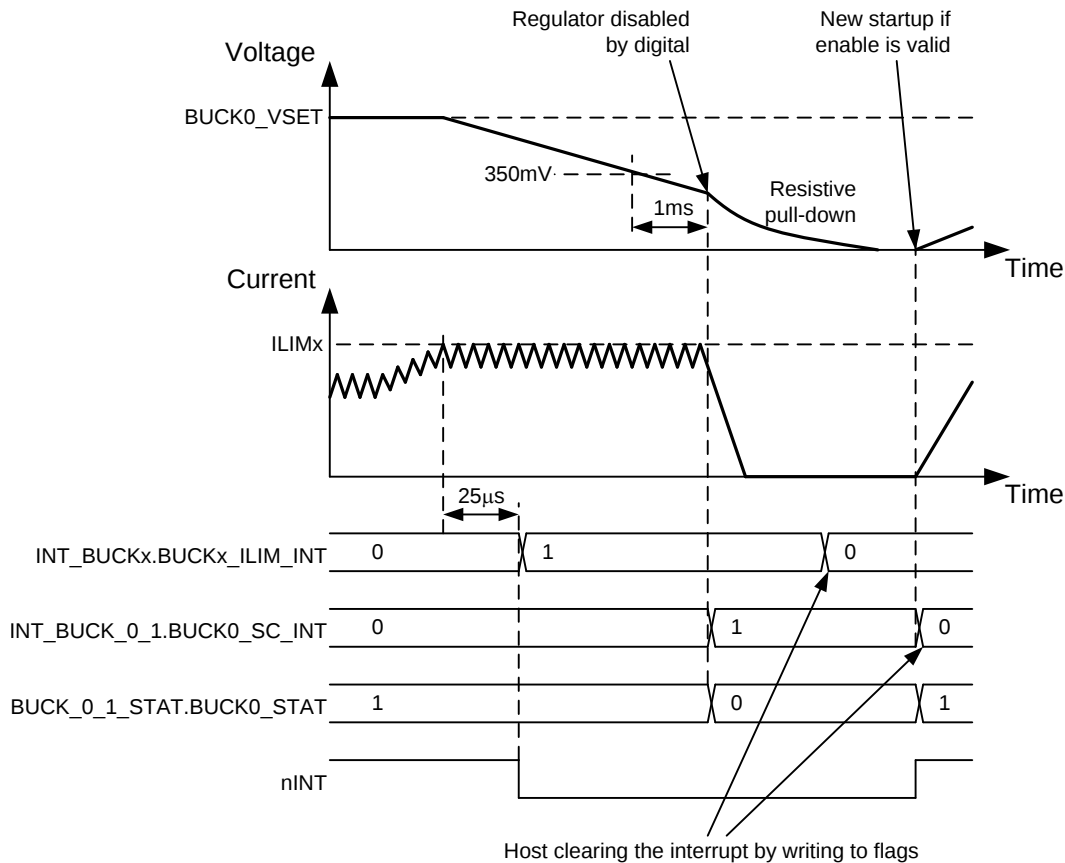


Figure 13. Overload Situation

#### 8.3.5.1.2 Thermal Warning

The LP8758 device includes protection feature against over-temperature by setting an interrupt for host processor. The threshold level of the thermal warning is selected with CONFIG.TDIE\_WARN\_LEVEL bit.

If the LP8758 device temperature increases above thermal warning level the device sets INT\_TOP.TDIE\_WARN bit and pulls nINT pin low. The status of the thermal warning can be read from TOP\_STAT.TDIE\_WARN\_STAT bit and the interrupt is cleared by writing 1 to INT\_TOP.TDIE\_WARN bit.

#### 8.3.5.2 Protection (Regulator Disable)

If the regulator is disabled because of protection or fault (short-circuit protection, overload protection, thermal shutdown, or undervoltage lockout), the output power FETs are set to high-impedance mode, and the output pull-down resistor is enabled (if enabled with BUCKx\_CTRL1.EN\_RDISx bits). The turn-off time of the output voltage is defined by the output capacitance, load current, and the resistance of the integrated pulldown resistor.

##### 8.3.5.2.1 Short-Circuit and Overload Protection

A short-circuit protection feature allows the LP8758 to protect itself and external components against short circuit at the output or against overload during start-up. The fault threshold is 350 mV, and the protection is triggered, and the regulator disabled, if the output voltage is below the threshold level 1 ms after the regulator is enabled.

In a similar way the overload situation is protected during normal operation. If the regulator's feedback-pin voltage falls below 0.35 V, and remains below the threshold level for 1 ms, the regulator is disabled.

In the short-circuit and overload situations the INT\_BUCK\_0\_1.BUCK0\_SC\_INT and the INT\_TOP.INT\_BUCK0 bits are set to 1, the BUCK\_0\_1\_STAT.BUCK0\_STAT bit is set to 0 and the nINT signal is pulled low. The host processor clears the interrupt by writing 1 to the INT\_BUCK\_0\_1.BUCK0\_SC\_INT bit. Upon clearing the interrupt the regulator makes a new start-up attempt if the enable register bits and/or ENx control signal is valid.

### 8.3.5.2.2 Thermal Shutdown

The LP8758 has an overtemperature protection function that operates to protect itself from short-term misuse and overload conditions. When the junction temperature exceeds around 150°C, the regulator is disabled, the INT\_TOP.TDIE\_SD bit is set to 1, the nINT signal is pulled low, and the device enters STANDBY. nINT will be cleared by writing 1 to the INT\_TOP.TDIE\_SD bit. If the temperature is above thermal shutdown level the interrupt is not cleared. The host can read the status of the thermal shutdown from the TOP\_STAT.TDIE\_SD\_STAT bit. Regulator cannot be enabled as long as the junction temperature is above thermal shutdown level or the thermal shutdown interrupt is pending.

### 8.3.5.3 Fault (Power Down)

#### 8.3.5.3.1 Undervoltage Lockout

When the input voltage falls below  $VANA_{UVLO}$  at the VANA pin, the buck converters are disabled immediately, and the output capacitor is discharged using the pulldown resistor and the LP8758 device enters SHUTDOWN. When VANA voltage is above UVLO threshold level and NRST signal is high, the device powers up to STANDBY state.

If the reset interrupt is unmasked by default (TOP\_MASK.RESET\_REG\_MASK = 0) the INT\_TOP.RESET\_REG interrupt indicates that the device has been in SHUTDOWN. The host processor must clear the interrupt by writing 1 to the INT\_TOP.RESET\_REG bit. If the host processor reads the INT\_TOP.RESET\_REG flag after detecting an nINT low signal, it knows that the input supply voltage has been below UVLO level (or the host has requested reset), and the registers are reset to default values.

### 8.3.6 Digital Signal Filtering

The digital signals have a debounce filtering. The signal/supply is sampled with a clock signal and a counter. This results as an accuracy of one clock period for the debounce window.

**Table 3. Digital Signal Filtering**

| EVENT                                   | SIGNAL / SUPPLY              | RISING EDGE LENGTH | FALLING EDGE LENGTH |
|-----------------------------------------|------------------------------|--------------------|---------------------|
| Enable/Disable/Voltage Select for BUCK0 | EN1                          | 3μs <sup>(1)</sup> | 3μs <sup>(1)</sup>  |
| Enable/Disable/Voltage Select for BUCK0 | EN2                          | 3μs <sup>(1)</sup> | 3μs <sup>(1)</sup>  |
| VANA undervoltage lockout               | VANA                         | Immediate          | Immediate           |
| Thermal warning                         | TDIE_WARN                    | 20 μs              | 20 μs               |
| Thermal shutdown                        | TDIE_SD                      | 20 μs              | 20 μs               |
| Current limit                           | VOUTx_ILIM                   | 20 μs              | 20 μs               |
| Overload                                | FB_B0 - FB_B1, FB_B2 - FB_F3 | 1 ms               | 1 ms                |
| Powergood                               | FB_B0 - FB_B1, FB_B2 - FB_F3 | 20 μs              | 20 μs               |

(1) No glitch filtering, only synchronization.

## 8.4 Device Functional Modes

### 8.4.1 Modes of Operation

**SHUTDOWN:** The  $V_{(NRST)}$  voltage is below threshold level. All switch, reference, control and bias circuitry of the LP8758 device are turned off.

**WAIT-ON:** The  $V_{(NRST)}$  voltage is above threshold level. The reference and bias circuitry are enabled. The regulator of the LP8758 device is turned off.

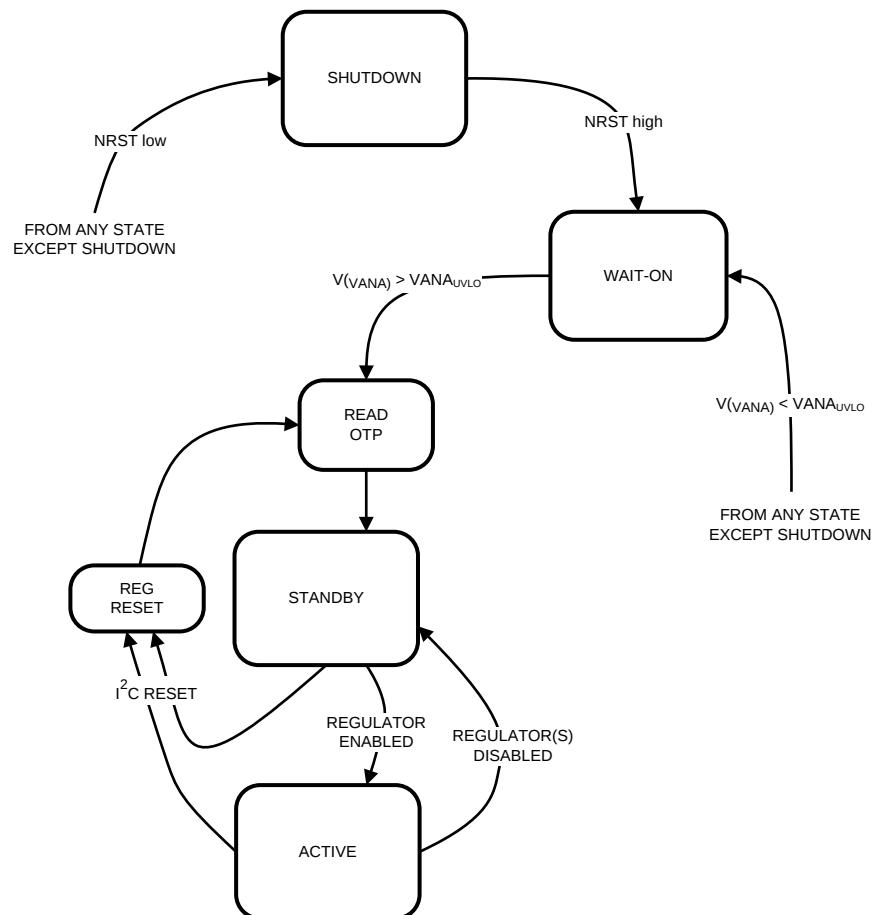
**READ OTP:** The main supply voltage  $V_{(VANA)}$  is above  $VANA_{UVLO}$  level and  $V_{(NRST)}$  voltage is above threshold level. The regulator is disabled and the reference and bias circuitry of the LP8758 are enabled. The OTP bits are loaded to registers.

**STANDBY:** The main supply voltage  $V_{(VANA)}$  is above  $VANA_{UVLO}$  level and  $V_{(NRST)}$  voltage is above threshold level. The regulator is disabled and the reference, control and bias circuitry of the LP8758 are enabled. All registers can be read or written by the host processor via the system serial interface. The regulator can be enabled if needed.

**ACTIVE:** The main supply voltage  $V_{(VANA)}$  is above  $VANA_{UVLO}$  level and  $V_{(NRST)}$  voltage is above threshold level. At least one regulated DC-DC converter is enabled. All registers can be read or written by the host processor via the system serial interface.

The operating modes and transitions between the modes are shown in [Figure 14](#).

## Device Functional Modes (continued)



**Figure 14. Device Operation Modes**

## 8.5 Programming

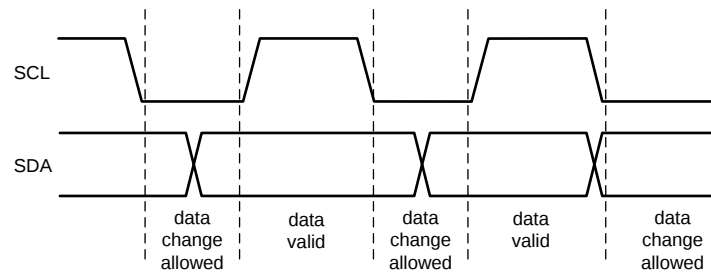
### 8.5.1 I<sup>2</sup>C-Compatible Interface

The I<sup>2</sup>C-compatible synchronous serial interface provides access to the programmable functions and registers on the device. This protocol uses a two-wire interface for bidirectional communications between the devices connected to the bus. The two interface lines are the Serial Data Line (SDA), and the Serial Clock Line (SCL). Every device on the bus is assigned a unique address and acts as either a Master or a Slave depending on whether it generates or receives the serial clock SCL. The SCL and SDA lines should each have a pullup resistor placed somewhere on the line and remain HIGH even when the bus is idle. The LP8758 supports standard mode (100 kHz), fast mode (400 kHz), fast mode plus (1 MHz), and high-speed mode (3.4 MHz).

#### 8.5.1.1 Data Validity

The data on the SDA line must be stable during the HIGH period of the clock signal (SCL). In other words, the state of the data line can only be changed when clock signal is LOW.

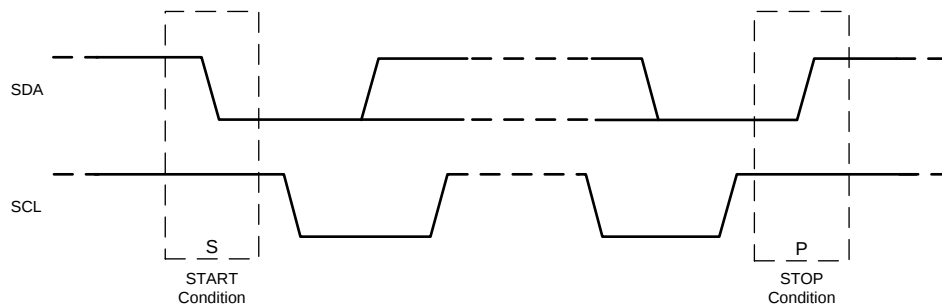
## Programming (continued)



**Figure 15. Data Validity Diagram**

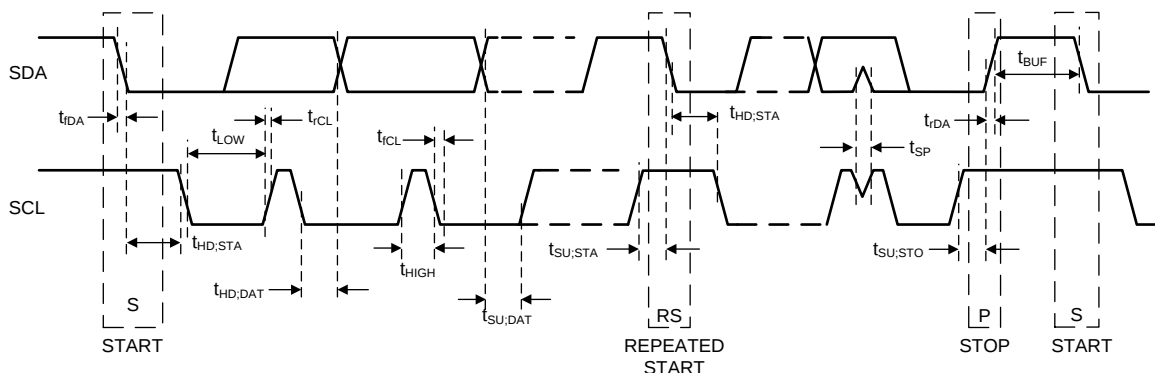
### 8.5.1.2 Start and Stop Conditions

The LP8758 is controlled via an I<sup>2</sup>C-compatible interface. START and STOP conditions classify the beginning and end of the I<sup>2</sup>C session. A START condition is defined as SDA transitions from HIGH to LOW while SCL is HIGH. A STOP condition is defined as SDA transition from LOW to HIGH while SCL is HIGH. The I<sup>2</sup>C master always generates the START and STOP conditions.



**Figure 16. Start and Stop Sequences**

The I<sup>2</sup>C bus is considered busy after a START condition and free after a STOP condition. During data transmission the I<sup>2</sup>C master can generate repeated START conditions. A START and a repeated START condition are equivalent function-wise. The data on SDA must be stable during the HIGH period of the clock signal (SCL). In other words, the state of SDA can only be changed when SCL is LOW. [Figure 17](#) shows the SDA and SCL signal timing for the I<sup>2</sup>C-Compatible Bus. See the [I<sup>2</sup>C Serial Bus Timing Parameter](#) for timing values.



**Figure 17. I<sup>2</sup>C-Compatible Timing**

## Programming (continued)

### 8.5.1.3 Transferring Data

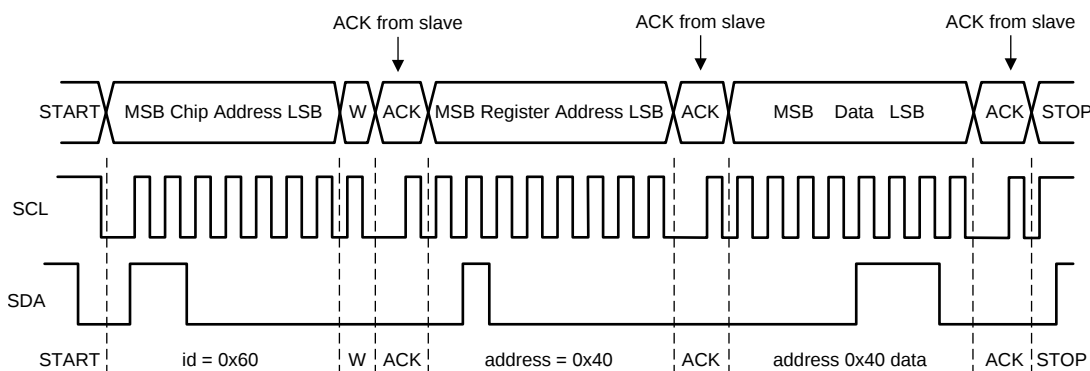
Every byte put on the SDA line must be eight bits long, with the most significant bit (MSB) being transferred first. Each byte of data has to be followed by an acknowledge bit. The acknowledge related clock pulse is generated by the master. The master releases the SDA line (HIGH) during the acknowledge clock pulse. The LP8758 pulls down the SDA line during the 9th clock pulse, signifying an acknowledge. The LP8758 generates an acknowledge after each byte has been received.

There is one exception to the “acknowledge after every byte” rule. When the master is the receiver, it must indicate to the transmitter an end of data by not-acknowledging (“negative acknowledge”) the last byte clocked out of the slave. This “negative acknowledge” still includes the acknowledge clock pulse (generated by the master), but the SDA line is not pulled down.

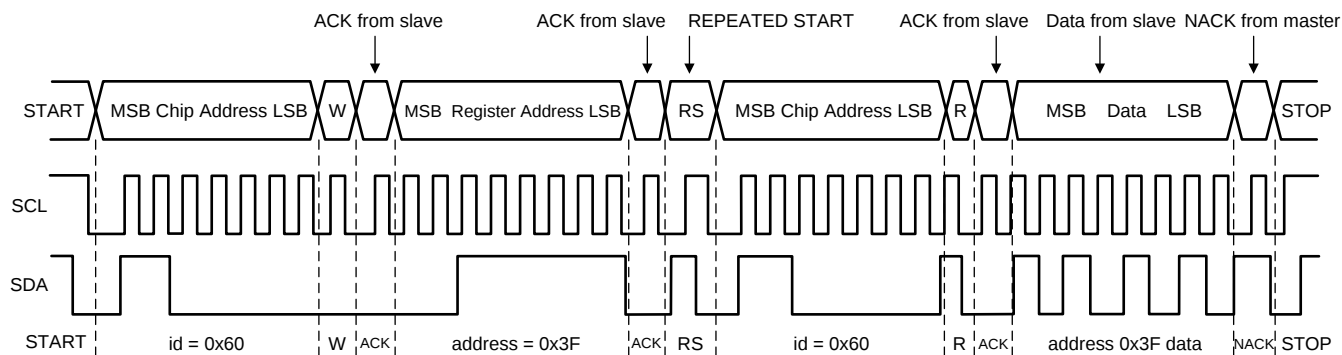
#### NOTE

If the NRST signal is low during I<sup>2</sup>C communication the LP8758 device does not drive SDA line. The ACK signal and data transfer to the master is disabled at that time.

After the START condition, the bus master sends a chip address. This address is seven bits long followed by an eighth bit which is a data direction bit (READ or WRITE). For the eighth bit, a “0” indicates a WRITE and a “1” indicates a READ. The second byte selects the register to which the data will be written. The third byte contains data to write to the selected register.



**Figure 18. Write Cycle (w = write; SDA = '0'), id = Device Address = 60Hex for LP8758**



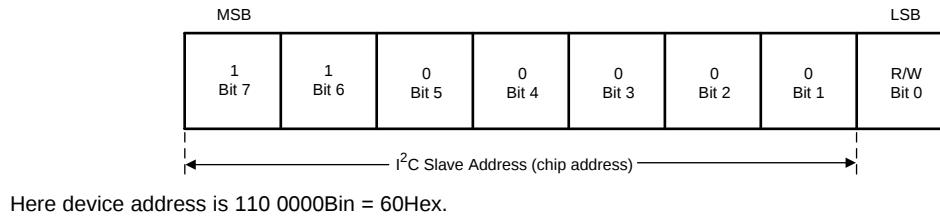
When READ function is to be accomplished, a WRITE function must precede the READ function as shown above.

**Figure 19. Read Cycle ( r = read; SDA = '1'), id = Device Address = 60Hex for LP8758**

## Programming (continued)

### 8.5.1.4 I<sup>2</sup>C-Compatible Chip Address

The device address for the LP8758 is 0x60. After the START condition, the I<sup>2</sup>C master sends the 7-bit address followed by an eighth bit, read or write (R/W). R/W = 0 indicates a WRITE and R/W = 1 indicates a READ. The second byte following the device address selects the register address to which the data will be written. The third byte contains the data for the selected register.



**Figure 20. Device Address**

### 8.5.1.5 Auto Increment Feature

The auto-increment feature allows writing several consecutive registers within one transmission. Every time an 8-bit word is sent to the LP8758, the internal address index counter will be incremented by one and the next register will be written. [Table 4](#) below shows writing sequence to two consecutive registers. Note that the auto-increment feature does not work for read.

**Table 4. Auto-Increment Example**

| Master Action | Start | Device Address = 60H | Write |     | Register Address |     | Data |     | Data |     | Stop |
|---------------|-------|----------------------|-------|-----|------------------|-----|------|-----|------|-----|------|
| LP8758 Action |       |                      |       | ACK |                  | ACK |      | ACK |      | ACK |      |

## 8.6 Register Maps

### 8.6.1 Register Descriptions

The LP8758 is controlled by a set of registers through the system serial interface port. The device registers, their addresses and their abbreviations are listed in [Table 5](#). A more detailed description is given in sections [DEV\\_REV](#) to [I\\_LOAD\\_1](#).

**Table 5. Summary of LP8758 Control Registers**

| Addr | Register         | Read / Write | D7                        | D6           | D5             | D4              | D3                       | D2              | D1                            | D0                |          |
|------|------------------|--------------|---------------------------|--------------|----------------|-----------------|--------------------------|-----------------|-------------------------------|-------------------|----------|
| 0x01 | OTP_REV          | R            | OTP_ID[7:0]               |              |                |                 |                          |                 |                               |                   |          |
| 0x02 | BUCK0_CTRL1      | R/W          | EN_BUCK0                  | EN_PIN_CTRL0 | EN_PIN_SELECT0 | EN_ROOF_FLOOR0  | EN_RDIS0                 | Reserved        | BUCK0_FPWM                    | BUCK0_FPWM_MP     |          |
| 0x03 | BUCK0_CTRL2      | R/W          | Reserved                  |              | ILIM0[2:0]     |                 |                          | SLEW_RATE0[2:0] |                               |                   |          |
| 0x05 | BUCK1_CTRL2      | R/W          | Reserved                  |              | ILIM1[2:0]     |                 |                          | Reserved        |                               |                   |          |
| 0x07 | BUCK2_CTRL2      | R/W          | Reserved                  |              | ILIM2[2:0]     |                 |                          | Reserved        |                               |                   |          |
| 0x09 | BUCK3_CTRL2      | R/W          | Reserved                  |              | ILIM3[2:0]     |                 |                          | Reserved        |                               |                   |          |
| 0x0A | BUCK0_VOUT       | R/W          | BUCK0_VSET[7:0]           |              |                |                 |                          |                 |                               |                   |          |
| 0x0B | BUCK0_FLOOR_VOUT | R/W          | BUCK0_FLOOR_VSET[7:0]     |              |                |                 |                          |                 |                               |                   |          |
| 0x12 | BUCK0_DELAY      | R/W          | BUCK0_SHUTDOWN_DELAY[3:0] |              |                |                 | BUCK0_STARTUP_DELAY[3:0] |                 |                               |                   |          |
| 0x16 | RESET            | R/W          | Reserved                  |              |                |                 |                          |                 |                               |                   | SW_RESET |
| 0x17 | CONFIG           | R/W          | Reserved                  |              |                |                 | TDIE_WARN_LEVEL          | EN2_PD          | EN1_PD                        | EN_SPREAD_SPEC    |          |
| 0x18 | INT_TOP          | R/W          | INT_BUCK3                 | INT_BUCK2    | INT_BUCK1      | INT_BUCK0       | TDIE_SD                  | TDIE_WARN       | RESET_REG                     | I_LOAD_READY      |          |
| 0x19 | INT_BUCK_0_1     | R/W          | Reserved                  |              |                | BUCK1_ILIM_INT  | Reserved                 | BUCK0_PG_INT    | BUCK0_SC_INT                  | BUCK0_ILIM_INT    |          |
| 0x1A | INT_BUCK_2_3     | R/W          | Reserved                  |              |                | BUCK3_ILIM_INT  | Reserved                 |                 |                               | BUCK2_ILIM_INT    |          |
| 0x1B | TOP_STAT         | R            | Reserved                  |              |                |                 | TDIE_SD_STAT             | TDIE_WARN_STAT  | Reserved                      |                   |          |
| 0x1C | BUCK_0_1_STAT    | R            | Reserved                  |              |                | BUCK1_ILIM_STAT | BUCK0_STAT               | BUCK0_PG_STAT   | Reserved                      | BUCK0_ILIM_STAT   |          |
| 0x1D | BUCK_2_3_STAT    | R            | Reserved                  |              |                | BUCK3_ILIM_STAT | Reserved                 |                 |                               | BUCK2_ILIM_STAT   |          |
| 0x1E | TOP_MASK         | R/W          | Reserved                  |              |                |                 |                          | TDIE_WARN_MASK  | RESET_REG_MASK                | I_LOAD_READY_MASK |          |
| 0x1F | BUCK_0_1_MASK    | R/W          | Reserved                  |              |                | BUCK1_ILIM_MASK | Reserved                 | BUCK0_PG_MASK   | Reserved                      | BUCK0_ILIM_MASK   |          |
| 0x20 | BUCK_2_3_MASK    | R/W          | Reserved                  |              |                | BUCK3_ILIM_MASK | Reserved                 |                 |                               | BUCK2_ILIM_MASK   |          |
| 0x21 | SEL_I_LOAD       | R/W          | Reserved                  |              |                |                 |                          |                 | LOAD_CURRENT_BUCK_SELECT[1:0] |                   |          |
| 0x22 | I_LOAD_2         | R/W          | Reserved                  |              |                |                 |                          |                 | BUCK_LOAD_CURRENT[9:8]        |                   |          |
| 0x23 | I_LOAD_1         | R/W          | BUCK_LOAD_CURRENT[7:0]    |              |                |                 |                          |                 |                               |                   |          |

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**8.6.1.1 DEV\_REV**

Address: 0x00

| D7             | D6                | D5             | D4      | D3                                                                                                                                                                           | D2 | D1 | D0 |
|----------------|-------------------|----------------|---------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|----|----|
| DEVICE_ID[1:0] |                   | ALL_LAYER[1:0] |         | METAL_LAYER[3:0]                                                                                                                                                             |    |    |    |
| Bits           | Field             | Type           | Default | Description                                                                                                                                                                  |    |    |    |
| 7:6            | DEVICE_ID[1:0]    | R              | 00      | Device specific ID code.                                                                                                                                                     |    |    |    |
| 5:4            | ALL_LAYER[1:0]    | R              | 00      | Shows the all layer version of the device:<br>00 - First all layer version<br>01 - Second all layer version<br>10 - Third all layer version<br>11 - Fourth all layer version |    |    |    |
| 3:0            | METAL_LAYER [3:0] | R              | 0001    | Shows the metal layer version of the device:<br>0000 - All layer version<br>0001 - First metal layer spin<br>...<br>1111 - 15 <sup>th</sup> metal layer spin                 |    |    |    |

**8.6.1.2 OTP\_REV**

Address: 0x01

| D7          | D6          | D5   | D4        | D3                                            | D2 | D1 | D0 |
|-------------|-------------|------|-----------|-----------------------------------------------|----|----|----|
| OTP_ID[7:0] |             |      |           |                                               |    |    |    |
| Bits        | Field       | Type | Default   | Description                                   |    |    |    |
| 7:0         | OTP_ID[7:0] | R    | 1011 0000 | Identification Code of the OTP EPROM Version. |    |    |    |

**8.6.1.3 BUCK0\_CTRL1**

Address: 0x02

| D7       | D6             | D5             | D4             | D3                                                                                                                                                                                                                                                                                                     | D2       | D1         | D0            |
|----------|----------------|----------------|----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|------------|---------------|
| EN_BUCK0 | EN_PIN_CTRL0   | EN_PIN_SELECT0 | EN_ROOF_FLOOR0 | EN_RDIS0                                                                                                                                                                                                                                                                                               | Reserved | BUCK0_FPWM | BUCK0_FPWM_MP |
| Bits     | Field          | Type           | Default        | Description                                                                                                                                                                                                                                                                                            |          |            |               |
| 7        | EN_BUCK0       | R/W            | 1              | Enable BUCK0 regulator:<br>0 - BUCK0 regulator is disabled<br>1 - BUCK0 regulator is enabled.                                                                                                                                                                                                          |          |            |               |
| 6        | EN_PIN_CTRL0   | R/W            | 1              | Enable EN1/2 pin control for BUCK0:<br>0 - only EN_BUCK0 bit controls BUCK0<br>1 - EN_BUCK0 bit AND EN1/2 pin control BUCK0.                                                                                                                                                                           |          |            |               |
| 5        | EN_PIN_SELECT0 | R/W            | 0              | Select which ENx pin controls BUCK0 if EN_PIN_CTRL0 = 1:<br>0 - EN1 pin<br>1 - EN2 pin.                                                                                                                                                                                                                |          |            |               |
| 4        | EN_ROOF_FLOOR0 | R/W            | 0              | Enable Roof/Floor control of EN1/2 pin if EN_PIN_CTRL0 = 1:<br>0 - Enable/Disable (1/0) control<br>1 - Roof/Floor (1/0) control.                                                                                                                                                                       |          |            |               |
| 3        | EN_RDIS0       | R/W            | 1              | Enable output discharge resistor when BUCK0 is disabled:<br>0 - Discharge resistor disabled<br>1 - Discharge resistor enabled.                                                                                                                                                                         |          |            |               |
| 2        | Reserved       | R/W            | 0              |                                                                                                                                                                                                                                                                                                        |          |            |               |
| 1        | BUCK0_FPWM     | R/W            | 0              | Forces the BUCK0 regulator to operate in PWM mode:<br>0 - Automatic transitions between PFM and PWM modes (AUTO mode).<br>1 - Forced to PWM operation.                                                                                                                                                 |          |            |               |
| 0        | BUCK0_FPWM_MP  | R/W            | 0              | Forces the BUCK0 regulator to operate always in multi-phase and forced PWM operation mode:<br>0 - Automatic phase adding and shedding.<br>1 - Forced to multi-phase operation, 2 phases in the 2-phase configuration, 3 phases in the 3-phase configuration and 4 phases in the 4-phase configuration. |          |            |               |

### 8.6.1.4 BUCK0\_CTRL2

Address: 0x03

| D7       |                 | D6   |         | D5                                                                                                                                                                                                                                                |  | D4 |  | D3 |  | D2              |  | D1 |  | D0 |  |
|----------|-----------------|------|---------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|----|--|----|--|-----------------|--|----|--|----|--|
| Reserved |                 |      |         | ILIM0[2:0]                                                                                                                                                                                                                                        |  |    |  |    |  | SLEW_RATE0[2:0] |  |    |  |    |  |
| Bits     | Field           | Type | Default | Description                                                                                                                                                                                                                                       |  |    |  |    |  |                 |  |    |  |    |  |
| 7:6      | Reserved        | R/W  | 00      |                                                                                                                                                                                                                                                   |  |    |  |    |  |                 |  |    |  |    |  |
| 5:3      | ILIM0[2:0]      | R/W  | 111     | Sets the switch current limit of BUCK0. Can be programmed at any time during operation:<br>000 - 1.5 A<br>001 - 2.0 A<br>010 - 2.5 A<br>011 - 3.0 A<br>100 - 3.5 A<br>101 - 4.0 A<br>110 - 4.5 A<br>111 - 5.0 A (Default)                         |  |    |  |    |  |                 |  |    |  |    |  |
| 2:0      | SLEW_RATE0[2:0] | R/W  | 010     | Sets the output voltage slew rate for BUCK0 regulator (rising and falling edges):<br>000 - 30 mV/μs<br>001 - 15 mV/μs<br>010 - 10 mV/μs (Default)<br>011 - 7.5 mV/μs<br>100 - 3.8 mV/μs<br>101 - 1.9 mV/μs<br>110 - 0.94 mV/μs<br>111 - 0.4 mV/μs |  |    |  |    |  |                 |  |    |  |    |  |

### 8.6.1.5 BUCK1\_CTRL2

Address: 0x05

| D7       |            | D6   |         | D5                                                                                                                                                                                                                        |  | D4 |  | D3 |  | D2       |  | D1 |  | D0 |  |
|----------|------------|------|---------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|----|--|----|--|----------|--|----|--|----|--|
| Reserved |            |      |         | ILIM1[2:0]                                                                                                                                                                                                                |  |    |  |    |  | Reserved |  |    |  |    |  |
|          |            |      |         |                                                                                                                                                                                                                           |  |    |  |    |  |          |  |    |  |    |  |
| Bits     | Field      | Type | Default | Description                                                                                                                                                                                                               |  |    |  |    |  |          |  |    |  |    |  |
| 7:6      | Reserved   | R/W  | 00      |                                                                                                                                                                                                                           |  |    |  |    |  |          |  |    |  |    |  |
| 5:3      | ILIM1[2:0] | R/W  | 111     | Sets the switch current limit of BUCK1. Can be programmed at any time during operation:<br>000 - 1.5 A<br>001 - 2.0 A<br>010 - 2.5 A<br>011 - 3.0 A<br>100 - 3.5 A<br>101 - 4.0 A<br>110 - 4.5 A<br>111 - 5.0 A (Default) |  |    |  |    |  |          |  |    |  |    |  |
| 2:0      | Reserved   | R/W  | 010     |                                                                                                                                                                                                                           |  |    |  |    |  |          |  |    |  |    |  |

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**8.6.1.6 BUCK2\_CTRL2**

Address: 0x07

| D7       |            | D6   |         | D5                                                                                                                                                                                                                        |  | D4 |  | D3 |  | D2       |  | D1 |  | D0 |  |
|----------|------------|------|---------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|----|--|----|--|----------|--|----|--|----|--|
| Reserved |            |      |         | ILIM2[2:0]                                                                                                                                                                                                                |  |    |  |    |  | Reserved |  |    |  |    |  |
| Bits     | Field      | Type | Default | Description                                                                                                                                                                                                               |  |    |  |    |  |          |  |    |  |    |  |
| 7:6      | Reserved   | R/W  | 00      |                                                                                                                                                                                                                           |  |    |  |    |  |          |  |    |  |    |  |
| 5:3      | ILIM2[2:0] | R/W  | 111     | Sets the switch current limit of BUCK2. Can be programmed at any time during operation:<br>000 - 1.5 A<br>001 - 2.0 A<br>010 - 2.5 A<br>011 - 3.0 A<br>100 - 3.5 A<br>101 - 4.0 A<br>110 - 4.5 A<br>111 - 5.0 A (Default) |  |    |  |    |  |          |  |    |  |    |  |
| 2:0      | Reserved   | R/W  | 010     |                                                                                                                                                                                                                           |  |    |  |    |  |          |  |    |  |    |  |

**8.6.1.7 BUCK3\_CTRL2**

Address: 0x09

| D7       |            | D6 |      | D5         |                                                                                                                                                                                                                           | D4 |  | D3 |  | D2       |  | D1 |  | D0 |  |
|----------|------------|----|------|------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|--|----|--|----------|--|----|--|----|--|
| Reserved |            |    |      | ILIM3[2:0] |                                                                                                                                                                                                                           |    |  |    |  | Reserved |  |    |  |    |  |
|          |            |    |      |            |                                                                                                                                                                                                                           |    |  |    |  |          |  |    |  |    |  |
| Bits     | Field      |    | Type | Default    | Description                                                                                                                                                                                                               |    |  |    |  |          |  |    |  |    |  |
| 7:6      | Reserved   |    | R/W  | 00         |                                                                                                                                                                                                                           |    |  |    |  |          |  |    |  |    |  |
| 5:3      | ILIM3[2:0] |    | R/W  | 111        | Sets the switch current limit of BUCK3. Can be programmed at any time during operation:<br>000 - 1.5 A<br>001 - 2.0 A<br>010 - 2.5 A<br>011 - 3.0 A<br>100 - 3.5 A<br>101 - 4.0 A<br>110 - 4.5 A<br>111 - 5.0 A (Default) |    |  |    |  |          |  |    |  |    |  |
| 2:0      | Reserved   |    | R/W  | 010        |                                                                                                                                                                                                                           |    |  |    |  |          |  |    |  |    |  |

**8.6.1.8 BUCK0\_VOUT**

Address: 0x0A

| D7              | D6              | D5   | D4        | D3                                                                                                                                                                                                                                                                                                                 | D2 | D1 | D0 |
|-----------------|-----------------|------|-----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|----|----|
| BUCK0_VSET[7:0] |                 |      |           |                                                                                                                                                                                                                                                                                                                    |    |    |    |
| Bits            | Field           | Type | Default   | Description                                                                                                                                                                                                                                                                                                        |    |    |    |
| 7:0             | BUCK0_VSET[7:0] | R/W  | 0110 0001 | Sets the output voltage of BUCK0 regulator<br><b>0.5 V - 0.73 V, 10 mV steps</b><br>0000 0000 - 0.5V<br>...<br>0001 0111 - 0.73 V<br><b>0.73 V - 1.4 V, 5 mV steps</b><br>0001 1000 - 0.735 V<br>...<br>1001 1101 - 1.4 V<br><b>1.4 V - 3.36 V, 20 mV steps</b><br>1001 1110 - 1.42 V<br>...<br>1111 1111 - 3.36 V |    |    |    |

### 8.6.1.9 BUCK0\_FLOOR\_VOUT

Address: 0x0B

| D7                    | D6                    | D5   | D4        | D3                                                                                                                                                                                                                                                                                                                                          | D2 | D1 | D0 |
|-----------------------|-----------------------|------|-----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|----|----|
| BUCK0_FLOOR_VSET[7:0] |                       |      |           |                                                                                                                                                                                                                                                                                                                                             |    |    |    |
| Bits                  | Field                 | Type | Default   | Description                                                                                                                                                                                                                                                                                                                                 |    |    |    |
| 7:0                   | BUCK0_FLOOR_VSET[7:0] | R/W  | 0000 0000 | Sets the output voltage of BUCK0 regulator when Floor state is used<br><b>0.5 V - 0.73 V, 10 mV steps</b><br>0000 0000 - 0.5V<br>...<br>0001 0111 - 0.73 V<br><b>0.73 V - 1.4 V, 5 mV steps</b><br>0001 1000 - 0.735 V<br>...<br>1001 1101 - 1.4 V<br><b>1.4 V - 3.36 V, 20 mV steps</b><br>1001 1110 - 1.42 V<br>...<br>1111 1111 - 3.36 V |    |    |    |

### 8.6.1.10 BUCK0\_DELAY

Address: 0x12

| D7                        | D6                        | D5   | D4      | D3                                                                                                            | D2 | D1 | D0 |
|---------------------------|---------------------------|------|---------|---------------------------------------------------------------------------------------------------------------|----|----|----|
| BUCK0_SHUTDOWN_DELAY[3:0] |                           |      |         | BUCK0_STARTUP_DELAY[3:0]                                                                                      |    |    |    |
| Bits                      | Field                     | Type | Default | Description                                                                                                   |    |    |    |
| 7:4                       | BUCK0_SHUTDOWN_DELAY[3:0] | R/W  | 0000    | Shutdown delay of BUCK0 from falling edge of ENx signal:<br>0000 - 0 ms<br>0001 - 1 ms<br>...<br>1111 - 15 ms |    |    |    |
| 3:0                       | BUCK0_STARTUP_DELAY[3:0]  | R/W  | 0000    | Start-up delay of BUCK0 from rising edge of ENx signal:<br>0000 - 0 ms<br>0001 - 1 ms<br>...<br>1111 - 15 ms  |    |    |    |

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**8.6.1.11 RESET**

Address: 0x16

| D7       | D6       | D5   | D4       | D3                                                                                                                                                                                             | D2 | D1 | D0       |
|----------|----------|------|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|----|----------|
| Reserved |          |      |          |                                                                                                                                                                                                |    |    | SW_RESET |
| Bits     | Field    | Type | Default  | Description                                                                                                                                                                                    |    |    |          |
| 7:1      | Reserved | R/W  | 000 0000 |                                                                                                                                                                                                |    |    |          |
| 0        | SW_RESET | R/W  | 0        | Software commanded reset. When written to 1, the registers will be reset to default values, OTP memory is read, and the I <sup>2</sup> C interface is reset. The bit is automatically cleared. |    |    |          |

**8.6.1.12 CONFIG**

Address: 0x17

| D7       | D6              | D5   | D4      | D3                                                                                                                                | D2     | D1     | D0             |
|----------|-----------------|------|---------|-----------------------------------------------------------------------------------------------------------------------------------|--------|--------|----------------|
| Reserved |                 |      |         | TDIE_WARN_LEVEL                                                                                                                   | EN2_PD | EN1_PD | EN_SPREAD_SPEC |
| Bits     | Field           | Type | Default | Description                                                                                                                       |        |        |                |
| 7:4      | Reserved        | R/W  | 0000    |                                                                                                                                   |        |        |                |
| 3        | TDIE_WARN_LEVEL | R/W  | 0       | Thermal warning threshold level.<br>0 - 125°C<br>1 - 105°C.                                                                       |        |        |                |
| 2        | EN2_PD          | R/W  | 1       | Selects the pull down resistor on the EN2 input pin.<br>0 - Pull-down resistor is disabled.<br>1 - Pull-down resistor is enabled. |        |        |                |
| 1        | EN1_PD          | R/W  | 1       | Selects the pull down resistor on the EN1 input pin.<br>0 - Pull-down resistor is disabled.<br>1 - Pull-down resistor is enabled. |        |        |                |
| 0        | EN_SPREAD_SPEC  | R/W  | 0       | Enable spread spectrum feature:<br>0 - Disabled<br>1 - Enabled                                                                    |        |        |                |

**8.6.1.13 INT\_TOP**

Address: 0x18

| D7        | D6        | D5        | D4        | D3                                                                                                                                                                                                                                                                                                                                 | D2        | D1        | D0           |
|-----------|-----------|-----------|-----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|-----------|--------------|
| INT_BUCK3 | INT_BUCK2 | INT_BUCK1 | INT_BUCK0 | TDIE_SD                                                                                                                                                                                                                                                                                                                            | TDIE_WARN | RESET_REG | I_LOAD_READY |
| Bits      | Field     | Type      | Default   | Description                                                                                                                                                                                                                                                                                                                        |           |           |              |
| 7         | INT_BUCK3 | R         | 0         | Interrupt indicating that output BUCK3 has a pending interrupt. The reason for the interrupt is indicated in INT_BUCK3 register. This bit is cleared automatically when INT_BUCK3 register is cleared to 0x00.                                                                                                                     |           |           |              |
| 6         | INT_BUCK2 | R         | 0         | Interrupt indicating that output BUCK2 has a pending interrupt. The reason for the interrupt is indicated in INT_BUCK2 register. This bit is cleared automatically when INT_BUCK2 register is cleared to 0x00.                                                                                                                     |           |           |              |
| 5         | INT_BUCK1 | R         | 0         | Interrupt indicating that output BUCK1 has a pending interrupt. The reason for the interrupt is indicated in INT_BUCK1 register. This bit is cleared automatically when INT_BUCK1 register is cleared to 0x00.                                                                                                                     |           |           |              |
| 4         | INT_BUCK0 | R         | 0         | Interrupt indicating that output BUCK0 has a pending interrupt. The reason for the interrupt is indicated in INT_BUCK0 register. This bit is cleared automatically when INT_BUCK0 register is cleared to 0x00.                                                                                                                     |           |           |              |
| 3         | TDIE_SD   | R/W       | 0         | Latched status bit indicating that the die junction temperature has exceeded the thermal shutdown level. The regulator has been disabled if it was enabled. The regulator cannot be enabled if this bit is active. The actual status of the thermal warning is indicated by TOP_STAT.TDIE_SD_STAT bit. Write 1 to clear interrupt. |           |           |              |

| Bits | Field        | Type | Default | Description                                                                                                                                                                                                                                                                                                                                            |
|------|--------------|------|---------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2    | TDIE_WARN    | R/W  | 0       | Latched status bit indicating that the die junction temperature has exceeded the thermal warning level. The actual status of the thermal warning is indicated by TOP_STAT.TDIE_WARN_STAT bit.<br>Write 1 to clear interrupt.                                                                                                                           |
| 1    | RESET_REG    | R/W  | 0       | Latched status bit indicating that either startup (NRST rising edge) has done, VANA supply voltage has been below undervoltage threshold level or the host has requested a reset (RESET.SW_RESET). The regulator has been disabled, and registers are reset to default values and the normal startup procedure is done.<br>Write 1 to clear interrupt. |
| 0    | I_LOAD_READY | R/W  | 0       | Latched status bit indicating that the load current measurement result is available in I_LOAD_1 and I_LOAD_2 registers.<br>Write 1 to clear interrupt.                                                                                                                                                                                                 |

#### 8.6.1.14 INT\_BUCK\_0\_1

Address: 0x19

|          |    |    |                |          |              |              |                |
|----------|----|----|----------------|----------|--------------|--------------|----------------|
| D7       | D6 | D5 | D4             | D3       | D2           | D1           | D0             |
| Reserved |    |    | BUCK1_ILIM_INT | Reserved | BUCK0_PG_INT | BUCK0_SC_INT | BUCK0_ILIM_INT |

| Bits | Field          | Type | Default | Description                                                                                                                                                                                   |
|------|----------------|------|---------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7:5  | Reserved       | R/W  | 000     |                                                                                                                                                                                               |
| 4    | BUCK1_ILIM_INT | R/W  | 0       | Latched status bit indicating that output current limit has been active.<br>Write 1 to clear.                                                                                                 |
| 3    | Reserved       | R/W  | 0       |                                                                                                                                                                                               |
| 2    | BUCK0_PG_INT   | R/W  | 0       | Latched status bit indicating that BUCK0 output voltage has reached powergood threshold level.<br>Write 1 to clear.                                                                           |
| 1    | BUCK0_SC_INT   | R/W  | 0       | Latched status bit indicating that the BUCK0 output voltage has fallen below 0.35V level during operation or BUCK0 output didn't reach 0.35 V level in 1 ms from enable.<br>Write 1 to clear. |
| 0    | BUCK0_ILIM_INT | R/W  | 0       | Latched status bit indicating that output current limit has been active.<br>Write 1 to clear.                                                                                                 |

#### 8.6.1.15 INT\_BUCK\_2\_3

Address: 0x1A

|          |    |    |                |          |    |                |    |
|----------|----|----|----------------|----------|----|----------------|----|
| D7       | D6 | D5 | D4             | D3       | D2 | D1             | D0 |
| Reserved |    |    | BUCK3_ILIM_INT | Reserved |    | BUCK2_ILIM_INT |    |

| Bits | Field          | Type | Default | Description                                                                                   |
|------|----------------|------|---------|-----------------------------------------------------------------------------------------------|
| 7:5  | Reserved       | R/W  | 000     |                                                                                               |
| 4    | BUCK3_ILIM_INT | R/W  | 0       | Latched status bit indicating that output current limit has been active.<br>Write 1 to clear. |
| 3:1  | Reserved       | R/W  | 000     |                                                                                               |
| 0    | BUCK2_ILIM_INT | R/W  | 0       | Latched status bit indicating that output current limit has been active.<br>Write 1 to clear. |

### 8.6.1.16 TOP\_STAT

Address: 0x1B

| D7       | D6 | D5 | D4 | D3           | D2             | D1       | D0 |
|----------|----|----|----|--------------|----------------|----------|----|
| Reserved |    |    |    | TDIE_SD_STAT | TDIE_WARN_STAT | Reserved |    |

| Bits | Field          | Type | Default | Description                                                                                                                                                    |
|------|----------------|------|---------|----------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7:4  | Reserved       | R    | 0000    |                                                                                                                                                                |
| 3    | TDIE_SD_STAT   | R    | 0       | Status bit indicating the status of thermal shutdown:<br>0 - Die temperature below thermal shutdown level<br>1 - Die temperature above thermal shutdown level. |
| 2    | TDIE_WARN_STAT | R    | 0       | Status bit indicating the status of thermal warning:<br>0 - Die temperature below thermal warning level<br>1 - Die temperature above thermal warning level.    |
| 1:0  | Reserved       | R    | 00      |                                                                                                                                                                |

### 8.6.1.17 BUCK\_0\_1\_STAT

Address: 0x1C

| D7       | D6 | D5 | D4              | D3         | D2            | D1       | D0              |
|----------|----|----|-----------------|------------|---------------|----------|-----------------|
| Reserved |    |    | BUCK1_ILIM_STAT | BUCK0_STAT | BUCK0_PG_STAT | Reserved | BUCK0_ILIM_STAT |

| Bits | Field           | Type | Default | Description                                                                                                                                                                     |
|------|-----------------|------|---------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7:5  | Reserved        | R    | 000     |                                                                                                                                                                                 |
| 4    | BUCK1_ILIM_STAT | R    | 0       | Status bit indicating BUCK1 current limit status (raw status)<br>0 - BUCK1 output current is below current limit level<br>1 - BUCK1 output current limit is active.             |
| 3    | BUCK0_STAT      | R    | 0       | Status bit indicating the enable/disable status of BUCK0:<br>0 - BUCK0 regulator is disabled<br>1 - BUCK0 regulator is enabled.                                                 |
| 2    | BUCK0_PG_STAT   | R    | 0       | Status bit indicating BUCK0 output voltage validity (raw status)<br>0 - BUCK0 output is above powergood threshold level<br>1 - BUCK0 output is below powergood threshold level. |
| 1    | Reserved        | R    | 0       |                                                                                                                                                                                 |
| 0    | BUCK0_ILIM_STAT | R    | 0       | Status bit indicating BUCK0 current limit status (raw status)<br>0 - BUCK0 output current is below current limit level<br>1 - BUCK0 output current limit is active.             |

### 8.6.1.18 BUCK\_2\_3\_STAT

Address: 0x1D

| D7       | D6 | D5 | D4              | D3       | D2 | D1              | D0 |
|----------|----|----|-----------------|----------|----|-----------------|----|
| Reserved |    |    | BUCK3_ILIM_STAT | Reserved |    | BUCK2_ILIM_STAT |    |

| Bits | Field           | Type | Default | Description                                                                                                                                                         |
|------|-----------------|------|---------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7:5  | Reserved        | R    | 000     |                                                                                                                                                                     |
| 4    | BUCK3_ILIM_STAT | R    | 0       | Status bit indicating BUCK3 current limit status (raw status)<br>0 - BUCK3 output current is below current limit level<br>1 - BUCK3 output current limit is active. |
| 3:1  | Reserved        | R    | 000     |                                                                                                                                                                     |
| 0    | BUCK2_ILIM_STAT | R    | 0       | Status bit indicating BUCK2 current limit status (raw status)<br>0 - BUCK2 output current is below current limit level<br>1 - BUCK2 output current limit is active. |

### 8.6.1.19 TOP\_MASK

Address: 0x1E

| D7       | D6                | D5   | D4      | D3                                                                                                                                                                                  | D2             | D1             | D0                |
|----------|-------------------|------|---------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|----------------|-------------------|
| Reserved |                   |      |         |                                                                                                                                                                                     | TDIE_WARN_MASK | RESET_REG_MASK | I_LOAD_READY_MASK |
| Bits     | Field             | Type | Default | Description                                                                                                                                                                         |                |                |                   |
| 7:3      | Reserved          | R/W  | 0 0000  |                                                                                                                                                                                     |                |                |                   |
| 2        | TDIE_WARN_MASK    | R/W  | 0       | Masking for thermal warning interrupt INT_TOP.TDIE_WARN:<br>0 - Interrupt generated<br>1 - Interrupt not generated.<br>This bit does not affect TOP_STAT.TDIE_WARN_STAT status bit. |                |                |                   |
| 1        | RESET_REG_MASK    | R/W  | 1       | Masking for register reset interrupt INT_TOP.RESET_REG:<br>0 - Interrupt generated<br>1 - Interrupt not generated.                                                                  |                |                |                   |
| 0        | I_LOAD_READY_MASK | R/W  | 0       | Masking for load current measurement ready interrupt INT_TOP.I_LOAD_READY.<br>0 - Interrupt generated<br>1 - Interrupt not generated.                                               |                |                |                   |

### 8.6.1.20 BUCK\_0\_1\_MASK

Address: 0x1F

| D7       | D6              | D5   | D4              | D3                                                                                                                                                                                                                | D2            | D1       | D0              |
|----------|-----------------|------|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|----------|-----------------|
| Reserved |                 |      | BUCK1_ILIM_MASK | Reserved                                                                                                                                                                                                          | BUCK0_PG_MASK | Reserved | BUCK0_ILIM_MASK |
| Bits     | Field           | Type | Default         | Description                                                                                                                                                                                                       |               |          |                 |
| 7:5      | Reserved        | R/W  | 000             |                                                                                                                                                                                                                   |               |          |                 |
| 4        | BUCK1_ILIM_MASK | R/W  | 1               | Masking for BUCK1 current limit detection interrupt INT_BUCK_0_1.BUCK1_ILIM_INT:<br>0 - Interrupt generated<br>1 - Interrupt not generated.<br>This bit does not affect BUCK_0_1_STAT.BUCK1_ILIM_STAT status bit. |               |          |                 |
| 3        | Reserved        | R/W  | 0               |                                                                                                                                                                                                                   |               |          |                 |
| 2        | BUCK0_PG_MASK   | R/W  | 0               | Masking for BUCK0 power good interrupt INT_BUCK_0_1.BUCK0_PG_INT:<br>0 - Interrupt generated<br>1 - Interrupt not generated.<br>This bit does not affect BUCK_0_1_STAT.BUCK1_PG_STAT status bit.                  |               |          |                 |
| 1        | Reserved        | R    | 0               |                                                                                                                                                                                                                   |               |          |                 |
| 0        | BUCK0_ILIM_MASK | R/W  | 0               | Masking for BUCK0 current limit detection interrupt INT_BUCK_0_1.BUCK0_ILIM_INT:<br>0 - Interrupt generated<br>1 - Interrupt not generated.<br>This bit does not affect BUCK_0_1_STAT.BUCK1_ILIM_STAT status bit. |               |          |                 |

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[www.ti.com](http://www.ti.com)
**8.6.1.21 BUCK\_2\_3\_MASK**

Address: 0x20

| D7       | D6 | D5 | D4              | D3 | D2       | D1 | D0              |
|----------|----|----|-----------------|----|----------|----|-----------------|
| Reserved |    |    | BUCK3_ILIM_MASK |    | Reserved |    | BUCK2_ILIM_MASK |

| Bits | Field           | Type | Default | Description                                                                                                                                                                                                       |
|------|-----------------|------|---------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7:5  | Reserved        | R/W  | 000     |                                                                                                                                                                                                                   |
| 4    | BUCK3_ILIM_MASK | R/W  | 1       | Masking for BUCK3 current limit detection interrupt INT_BUCK_2_3.BUCK3_ILIM_INT:<br>0 - Interrupt generated<br>1 - Interrupt not generated.<br>This bit does not affect BUCK_2_3_STAT.BUCK3_ILIM_STAT status bit. |
| 3:1  | Reserved        | R/W  | 000     |                                                                                                                                                                                                                   |
| 0    | BUCK2_ILIM_MASK | R/W  | 1       | Masking for BUCK2 current limit detection interrupt INT_BUCK_2_3.BUCK2_ILIM_INT:<br>0 - Interrupt generated<br>1 - Interrupt not generated.<br>This bit does not affect BUCK_2_3_STAT.BUCK1_ILIM_STAT status bit. |

**8.6.1.22 SEL\_I\_LOAD**

Address: 0x21

| D7       | D6 | D5 | D4 | D3 | D2 | D1                            | D0 |
|----------|----|----|----|----|----|-------------------------------|----|
| Reserved |    |    |    |    |    | LOAD_CURRENT_BUCK_SELECT[1:0] |    |

| Bits | Field                         | Type | Default | Description                                                                                                                                                                                                                                                                                                                                                                       |
|------|-------------------------------|------|---------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7:2  | Reserved                      | R/W  | 00 0000 |                                                                                                                                                                                                                                                                                                                                                                                   |
| 1:0  | LOAD_CURRENT_BUCK_SELECT[1:0] | R/W  | 00      | Start the current measurement on the selected regulator:<br>00 - BUCK0<br>01 - BUCK1<br>10 - BUCK2<br>11 - BUCK3<br>The measurement is started when register is written.<br>If the selected buck is master, the measurement result is a sum current of master and slave bucks.<br>If the selected buck is slave, the measurement result is a current of the selected slave bucks. |

**8.6.1.23 I\_LOAD\_2**

Address: 0x22

| D7       | D6 | D5 | D4 | D3 | D2 | D1                     | D0 |
|----------|----|----|----|----|----|------------------------|----|
| Reserved |    |    |    |    |    | BUCK_LOAD_CURRENT[9:8] |    |

| Bits | Field                  | Type | Default | Description                                                                                                                                   |
|------|------------------------|------|---------|-----------------------------------------------------------------------------------------------------------------------------------------------|
| 7:2  | Reserved               | R    | 00 0000 |                                                                                                                                               |
| 1:0  | BUCK_LOAD_CURRENT[9:8] | R    | 00      | This register describes 3 MSB bits of the average load current on selected regulator with a resolution of 20 mA per LSB and max 20 A current. |

**8.6.1.24 I\_LOAD\_1**

Address: 0x23

| D7                     | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
|------------------------|----|----|----|----|----|----|----|
| BUCK_LOAD_CURRENT[7:0] |    |    |    |    |    |    |    |

| Bits | Field                  | Type | Default   | Description                                                                                                                                   |
|------|------------------------|------|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------|
| 7:0  | BUCK_LOAD_CURRENT[7:0] | R    | 0000 0000 | This register describes 8 LSB bits of the average load current on selected regulator with a resolution of 10 mA per LSB and max 20 A current. |

## 9 Application and Implementation

### NOTE

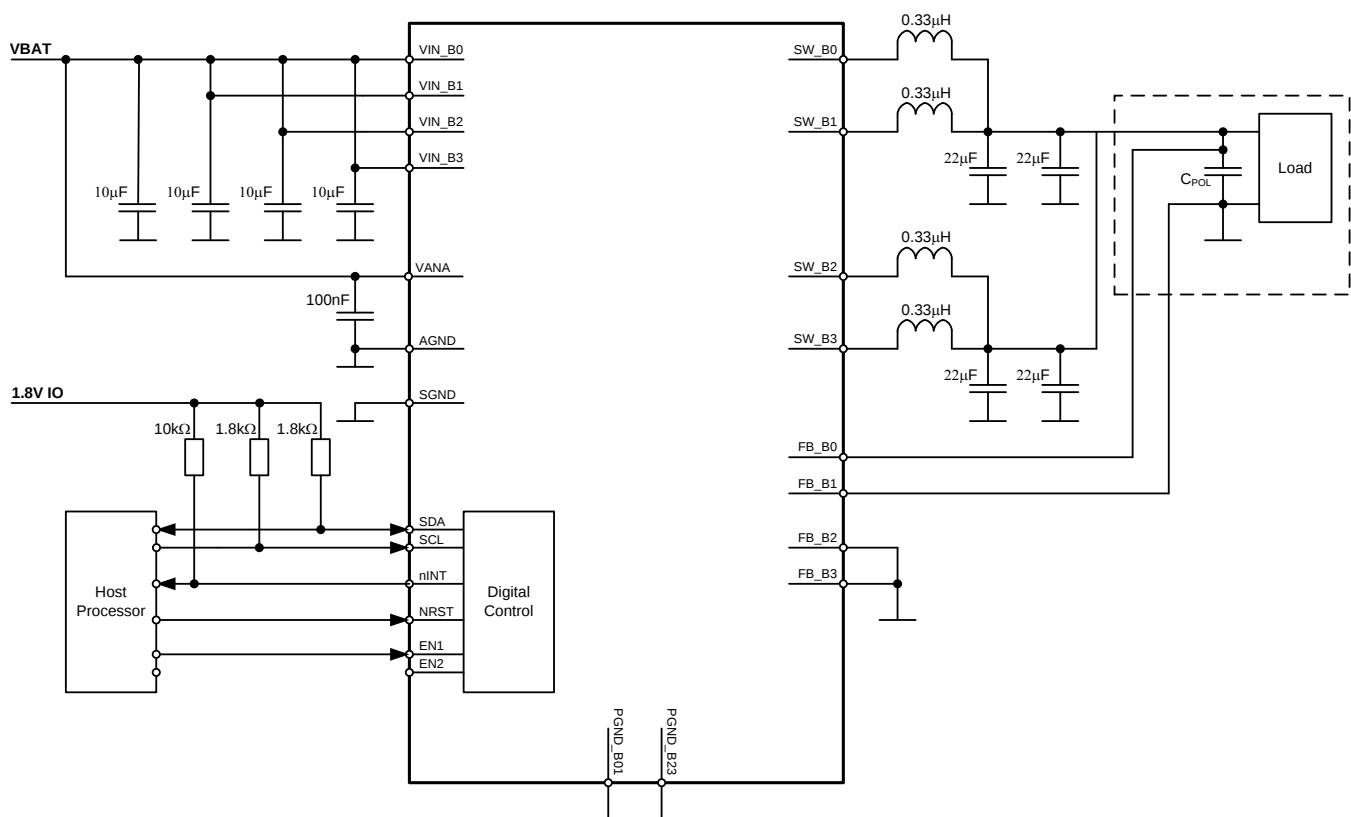
Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation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

### 9.1 Application Information

The LP8758 is a multi-phase step-down converter with four switcher cores bundled together.

### 9.2 Typical Application

#### 4-Phase configuration



**Figure 21. LP8758 Typical Application Circuit**

#### 9.2.1 Design Requirements

**Table 6. Design Parameters**

| DESIGN PARAMETER         | EXAMPLE VALUE       |
|--------------------------|---------------------|
| Input voltage range      | 2.5 V to 5.5 V      |
| Output voltage           | 1.1 V               |
| Converter operation mode | Auto mode (PWM-PFM) |
| Maximum load current     | 16 A                |
| Inductor current limit   | 5 A                 |

## 9.2.2 Detailed Design Procedure

The performance of the LP8758 device depends greatly on the care taken in designing the printed circuit board (PCB). The use of low-inductance and low serial-resistance ceramic capacitors is strongly recommended, while proper grounding is crucial. Attention must be given to decoupling the power supplies. Decoupling capacitors must be connected close to the device and between the power and ground pins to support high peak currents being drawn from system power rail during turn-on of the switching MOSFETs. Keep input and output traces as short as possible, because trace inductance, resistance, and capacitance can easily become the performance limiting items. The separate power pins VIN\_Bx are not connected together internally. The VIN\_Bx power connections shall be connected together outside the package using power plane construction.

### 9.2.2.1 Application Components

#### 9.2.2.1.1 Inductor Selection

DC bias current characteristics of inductors must be considered. Different manufacturers follow different saturation current rating specifications, so attention must be given to details. DC bias curves should be requested from them as part of the inductor selection process. Minimum effective value of inductance to ensure good performance is 0.22  $\mu\text{H}$  at 4-A bias current over the inductor's operating temperature range. The inductor's DC resistance should be less than 0.05  $\Omega$  for good efficiency at high current condition. The inductor AC loss (resistance) also affects conversion efficiency. Higher Q factor at switching frequency usually gives better efficiency at light load to middle load. See [Table 7](#). Shielded inductors are preferred as they radiate less noise.

**Table 7. Recommended Inductors**

| MANUFACTURER | PART NUMBER       | VALUE              | DIMENSIONS L×W×H (mm) | DCR (m $\Omega$ )  |
|--------------|-------------------|--------------------|-----------------------|--------------------|
| TOKO         | DFE252010F-R33M   | 0.33 $\mu\text{H}$ | 2.5 × 2.0 × 1.0       | 16 (typ), 21 (max) |
| TDK          | VLS252010HBX-R33M | 0.33 $\mu\text{H}$ | 2.5 × 2.0 × 1.0       | 25 (typ), 31 (max) |
| TDK          | VLS252010HBX-R47M | 0.47 $\mu\text{H}$ | 2.5 × 2.0 × 1.0       | 29 (typ), 35 (max) |
| TDK          | TFM2016GHM-0R47M  | 0.47 $\mu\text{H}$ | 2.0 × 1.6 × 1.0       | 46 (max)           |
| TOKO         | DFE322512C R47    | 0.47 $\mu\text{H}$ | 3.2 × 2.5 × 1.2       | 21 (typ), 31 (max) |

#### 9.2.2.1.2 Input Capacitor Selection

A ceramic input capacitor of 10  $\mu\text{F}$ , 6.3 V is sufficient for most applications. Place the power input capacitor as close as possible to the VIN\_Bx pin and PGND\_Bx pin of the device. A larger value or higher voltage rating may be used to improve input voltage filtering. Use X7R or X5R types, do not use Y5V or F. DC bias characteristics of ceramic capacitors must be considered when selecting case sizes like 0402. Minimum effective input capacitance to ensure good performance is 1.9  $\mu\text{F}$  per buck input at maximum input voltage DC bias including tolerances and over ambient temp range, assuming that there are at least 22  $\mu\text{F}$  of additional capacitance common for all the power input pins on the system power rail. See [Table 8](#).

The input filter capacitor supplies current to the high-side FET switch in the first half of each cycle and reduces voltage ripple imposed on the input power source. A ceramic capacitor's low equivalent series resistance (ESR) provides the best noise filtering of the input voltage spikes due to this rapidly changing current. Select an input filter capacitor with sufficient ripple current rating.

The VANA input is used to supply analog and digital circuits in the device. See recommended components from [Table 9](#) for VANA input supply filtering.

**Table 8. Recommended Power Input Capacitors (X5R Dielectric)**

| MANUFACTURER | PART NUMBER       | VALUE                  | CASE SIZE | DIMENSIONS L×W×H (mm) | VOLTAGE RATING |
|--------------|-------------------|------------------------|-----------|-----------------------|----------------|
| Murata       | GRM188R60J106ME47 | 10 $\mu\text{F}$ (20%) | 0603      | 1.6 × 0.8 × 0.8       | 6.3 V          |

**Table 9. Recommended VANA Supply Filtering Components**

| MANUFACTURER | PART NUMBER       | VALUE        | CASE SIZE | DIMENSIONS L×W×H (mm) | VOLTAGE RATING |
|--------------|-------------------|--------------|-----------|-----------------------|----------------|
| Samsung      | CL03A104KP3NNNC   | 100 nF (10%) | 0201      | 0.6 × 0.3 × 0.3       | 10 V           |
| Murata       | GRM033R61A104KE84 | 100 nF (10%) | 0201      | 0.6 × 0.3 × 0.3       | 6.3 V          |

### 9.2.2.1.3 Output Capacitor Selection

Use ceramic capacitors, X7R or X5R types; do not use Y5V or F. DC bias voltage characteristics of ceramic capacitors must be considered. DC bias characteristics vary from manufacturer to manufacturer, and DC bias curves should be requested from them as part of the capacitor selection process. The output filter capacitor smooths out current flow from the inductor to the load, helps maintain a steady output voltage during transient load changes and reduces output voltage ripple. These capacitors must be selected with sufficient capacitance and sufficiently low ESR and ESL to perform these functions. Minimum effective output capacitance to ensure good performance is 10  $\mu$ F per phase at the output voltage DC bias including tolerances and over ambient temp range.

The output voltage ripple is caused by the charging and discharging of the output capacitor and also due to its  $R_{ESR}$ . The  $R_{ESR}$  is frequency dependent (as well as temperature dependent); make sure the value used for selection process is at the switching frequency of the part. See [Table 10](#).

A higher output capacitance improves the load step behavior and reduces the output voltage ripple as well as decreases the PFM switching frequency. For most 4-phase applications 4 × 22  $\mu$ F 0603 capacitors for  $C_{OUT}$  are suitable. A point-of-load (POL) capacitance  $C_{POL}$  can be added with remove feedback as shown in [Figure 21](#). Although a converter's loop compensation can be programmed to adapt to virtually several hundreds of microfarads  $C_{OUT}$ , it is preferable for  $C_{OUT}$  to be < 200  $\mu$ F (4-phase configuration). Choosing higher than that is not necessarily of any benefit. Note that the output capacitor may be the limiting factor in the output voltage ramp, especially for very large (> 100  $\mu$ F) output capacitors. For large output capacitors, the output voltage might be slower than the programmed ramp rate at voltage transitions, because of the higher energy stored on the output capacitance. Also at start-up, the time required to charge the output capacitor to target value might be longer. At shutdown, if the output capacitor is discharged by the internal discharge resistor, more time is required to settle  $V_{OUT}$  down as a consequence of the increased time constant.

**Table 10. Recommended Output Capacitors (X5R Dielectric)**

| MANUFACTURER | PART NUMBER       | VALUE            | CASE SIZE | DIMENSIONS L×W×H (mm) | VOLTAGE RATING |
|--------------|-------------------|------------------|-----------|-----------------------|----------------|
| Samsung      | CL10A226MP8NUNE   | 22 $\mu$ F (20%) | 0603      | 1.6 × 0.8 × 0.8       | 10 V           |
| Murata       | GRM188R60J226MEA0 | 22 $\mu$ F (20%) | 0603      | 1.6 × 0.8 × 0.8       | 6.3 V          |

## 9.2.3 Application Curves

Unless otherwise specified:  $V_{IN} = 3.7\text{ V}$ ,  $V_{OUT} = 1\text{ V}$ ,  $V_{(NRST)} = 1.8\text{ V}$ ,  $T_A = 25\text{ }^{\circ}\text{C}$ ,  $f_{SW} = 3\text{ MHz}$ ,  $L = 330\text{ nH}$  (TOKO DFE252010F-R33M),  $C_{POL} = 22\text{ }\mu\text{F}$ . Measurements done with connections in [Figure 21](#).

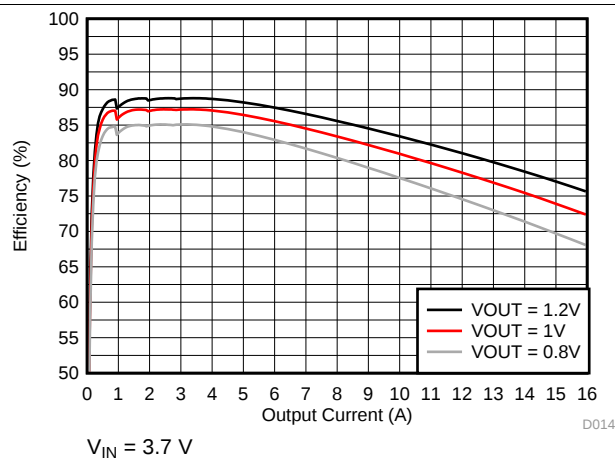


Figure 22. Efficiency in Forced PWM Mode

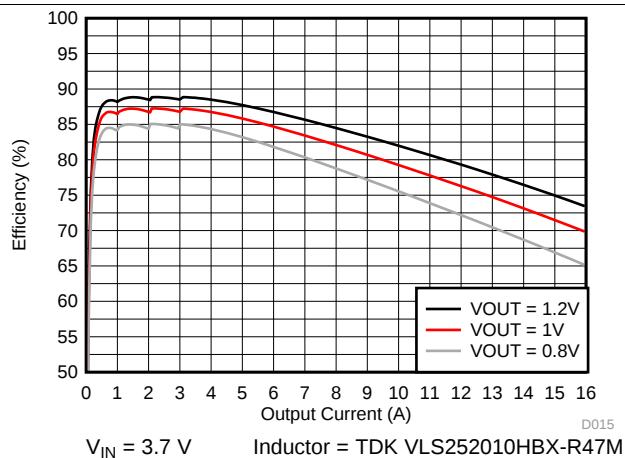


Figure 23. Efficiency in Forced PWM Mode

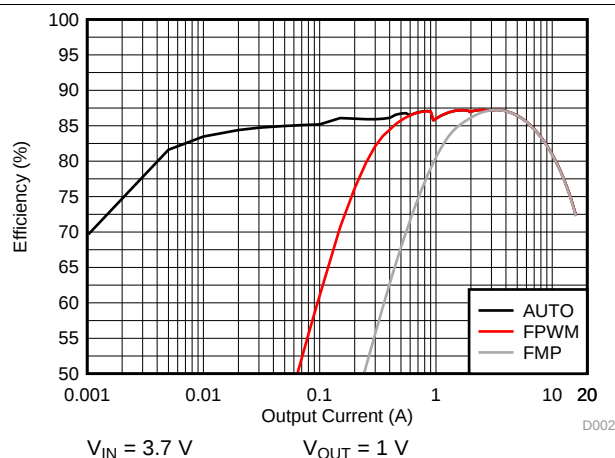


Figure 24. Efficiency in PFM, PWM and Forced Multi-Phase Mode

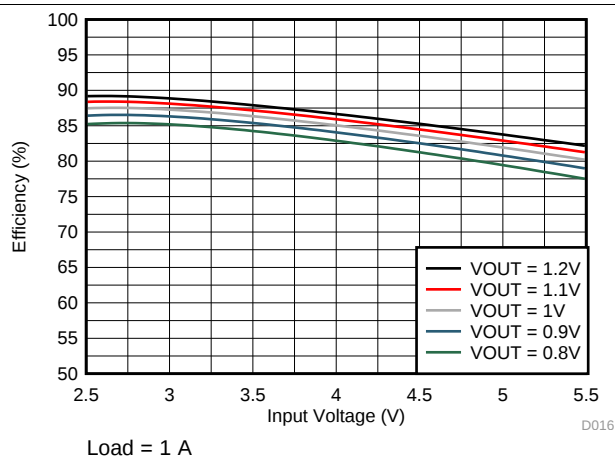


Figure 25. Efficiency vs Input Voltage

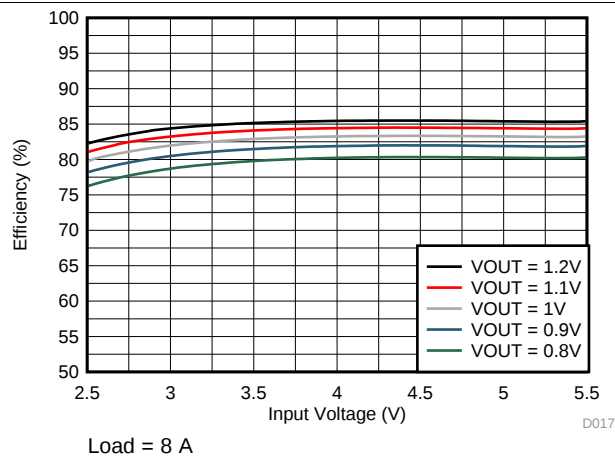


Figure 26. Efficiency vs Input Voltage

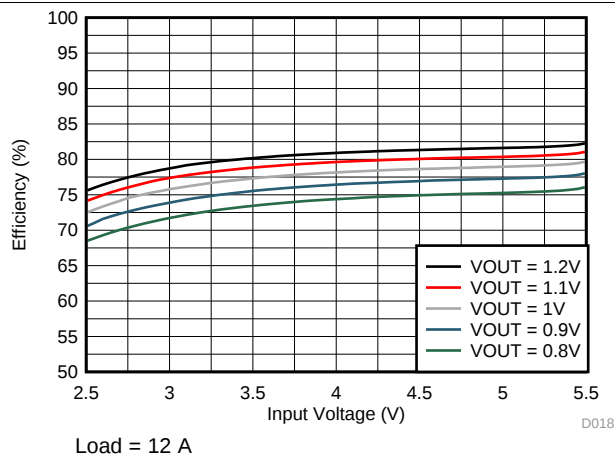


Figure 27. Efficiency vs Input Voltage

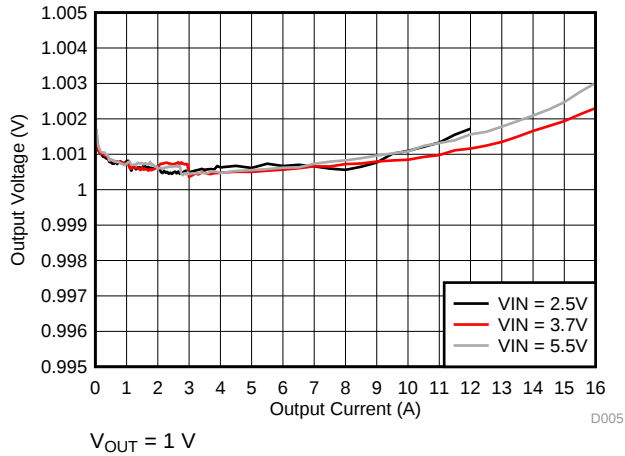


Figure 28. Output Voltage vs Load Current in Forced PWM Mode

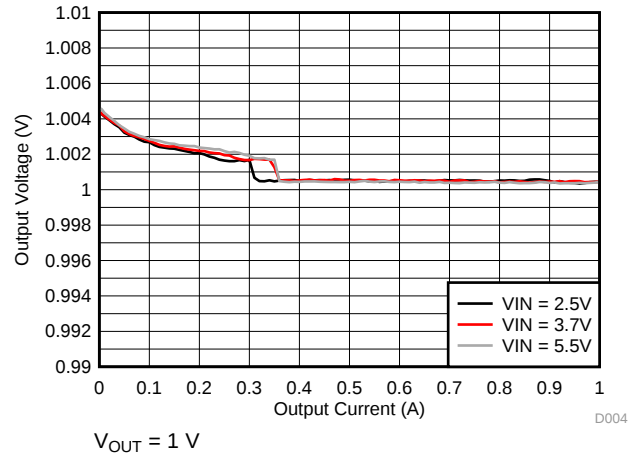


Figure 29. Output Voltage vs Load Current in PWM-PFM Mode

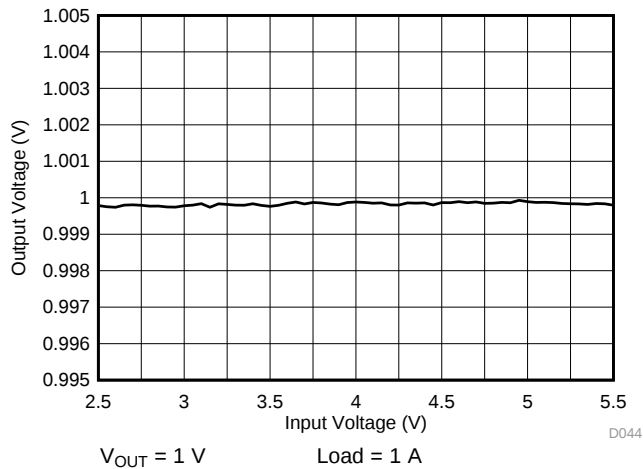


Figure 30. Output Voltage vs Input Voltage in PWM Mode

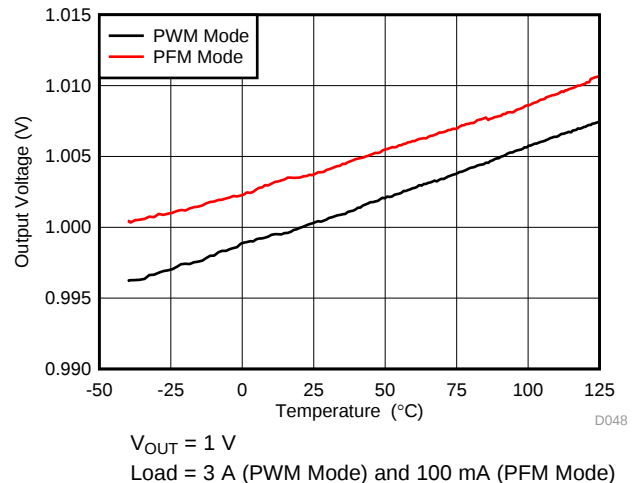


Figure 31. Output Voltage vs Temperature

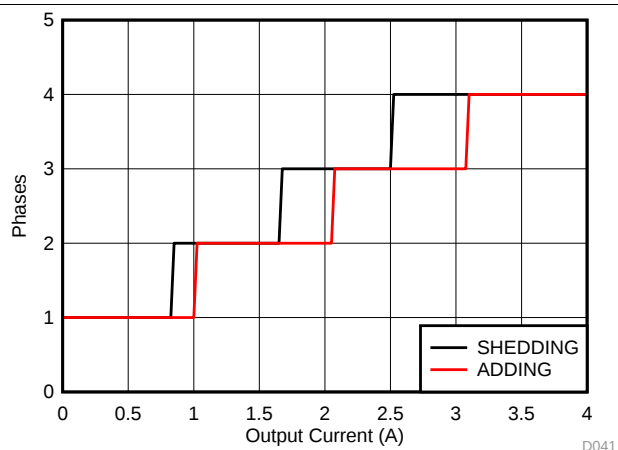


Figure 32. Phase Adding and Shedding vs Load Current

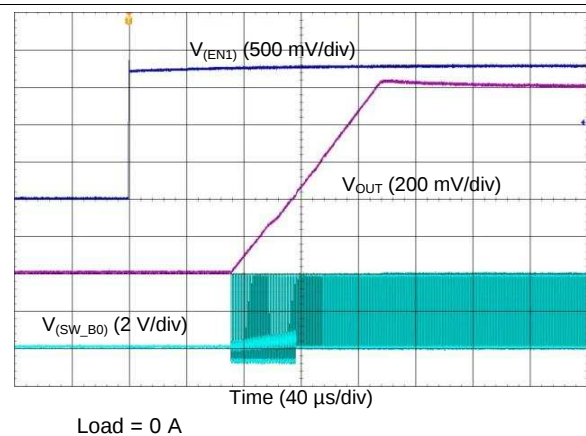
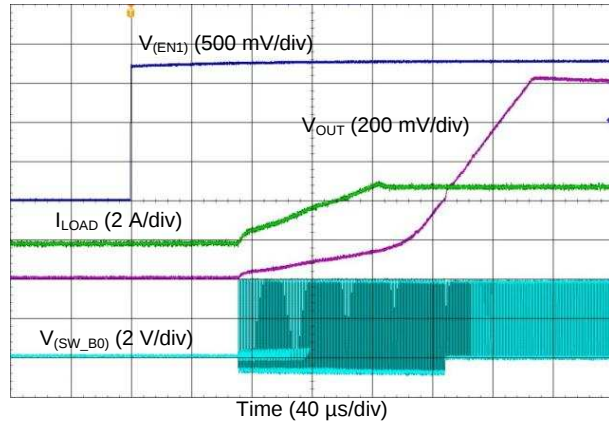
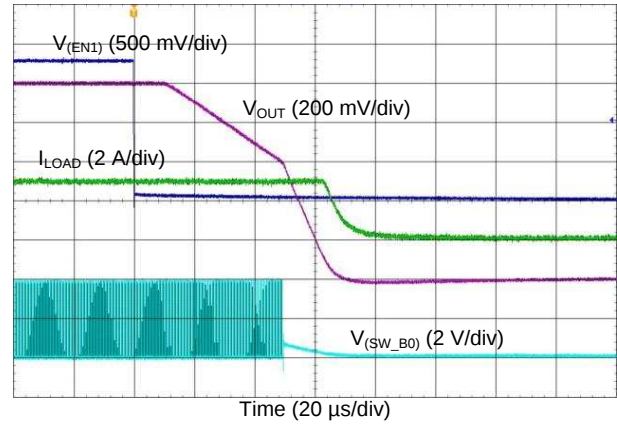


Figure 33. Start-up with EN1, Forced PWM



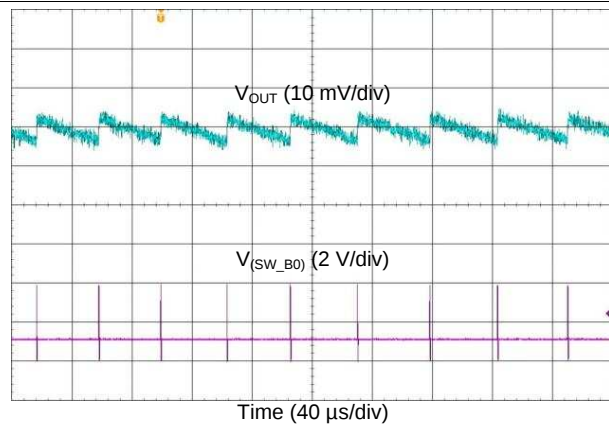
Load = 3 A

**Figure 34. Start-up with EN1, Forced PWM**



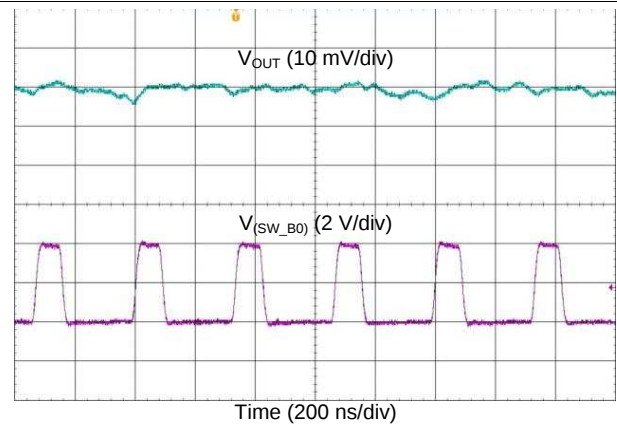
Load = 3 A

**Figure 35. Shutdown with EN1, Forced PWM**



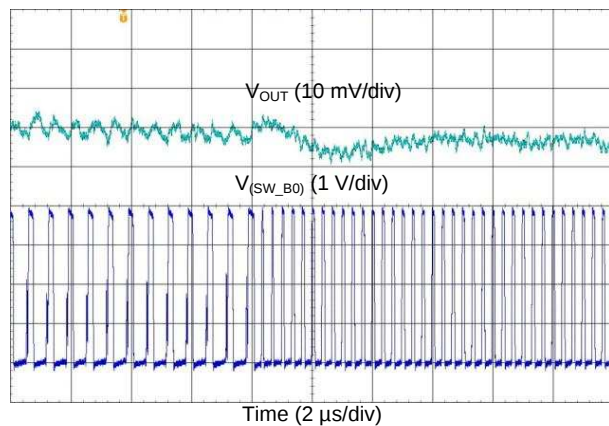
Load = 10 mA

**Figure 36. Output Voltage Ripple, PFM Mode**

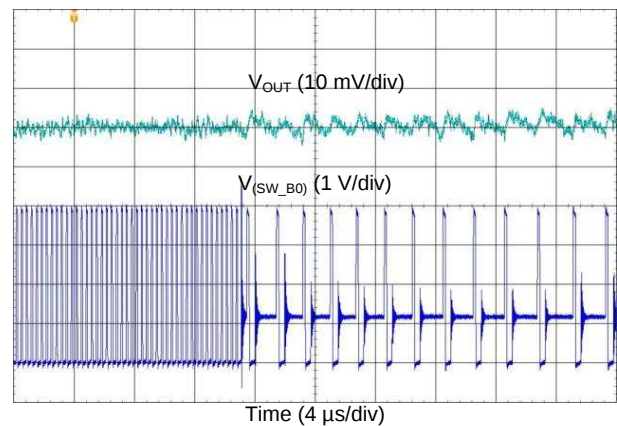


Load = 200 mA

**Figure 37. Output Voltage Ripple, Forced PWM Mode**



**Figure 38. Transient from PFM-to-PWM Mode**



**Figure 39. Transient from PWM-to-PFM Mode**

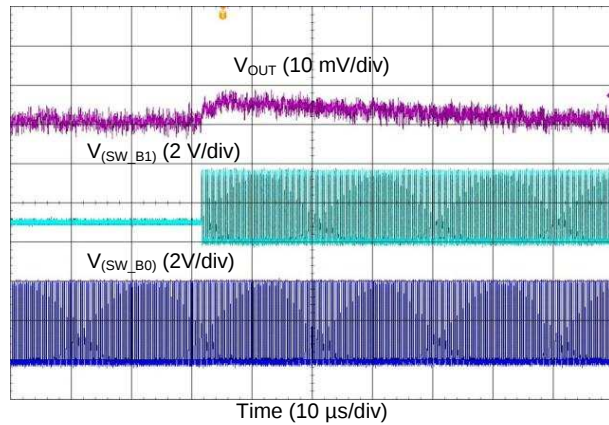


Figure 40. Transient from 1-Phase to 2-Phase Operation

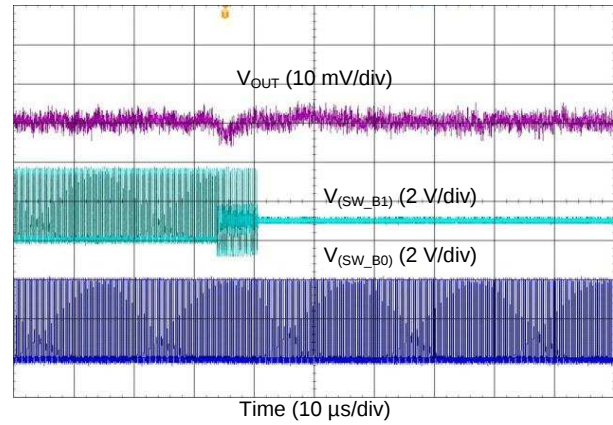


Figure 41. Transient from 2-Phase to 1-Phase Operation

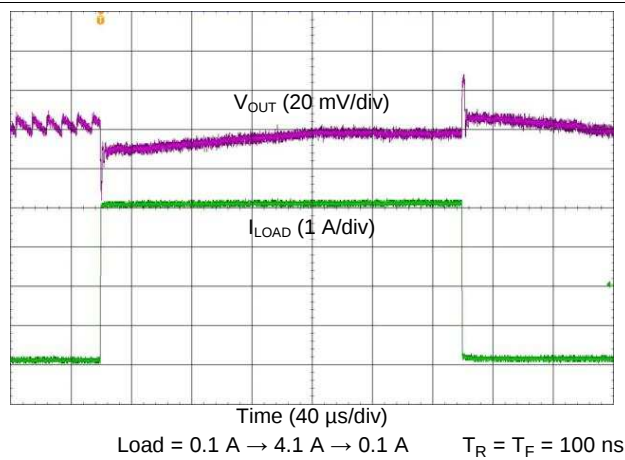


Figure 42. Transient Load Step Response, AUTO Mode

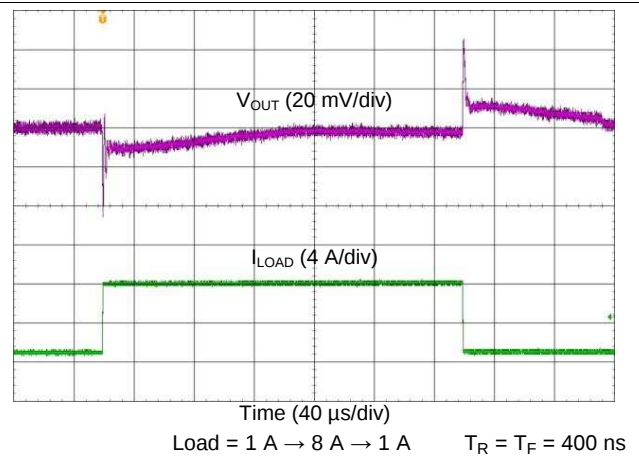


Figure 43. Transient Load Step Response, FPWM Mode

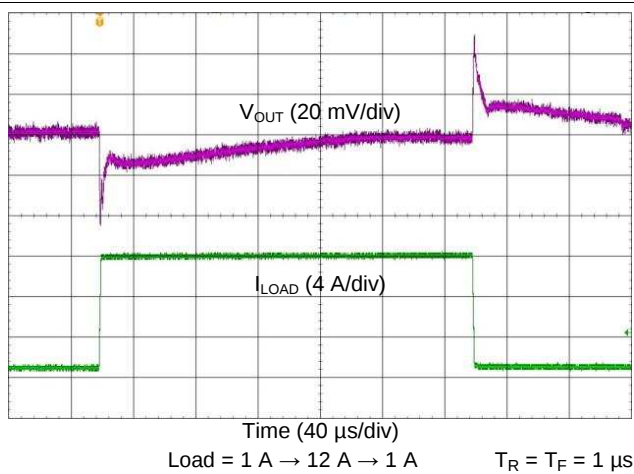


Figure 44. Transient Load Step Response, FPWM Mode

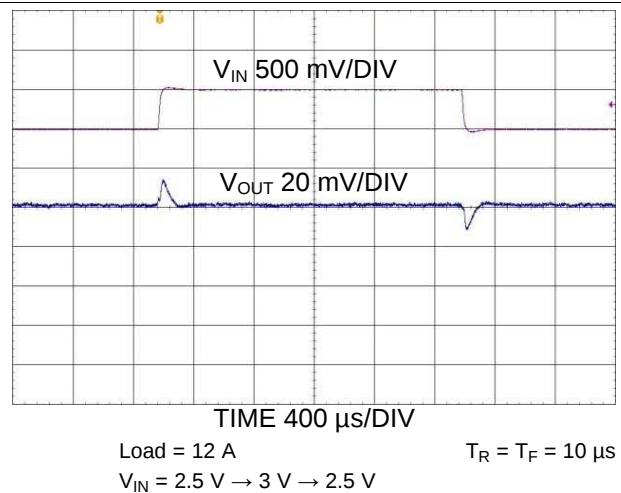
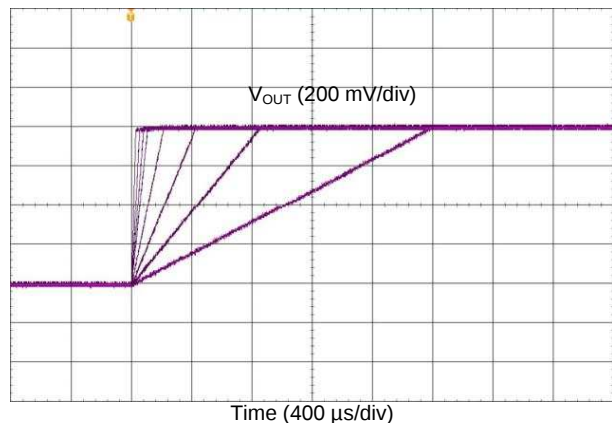
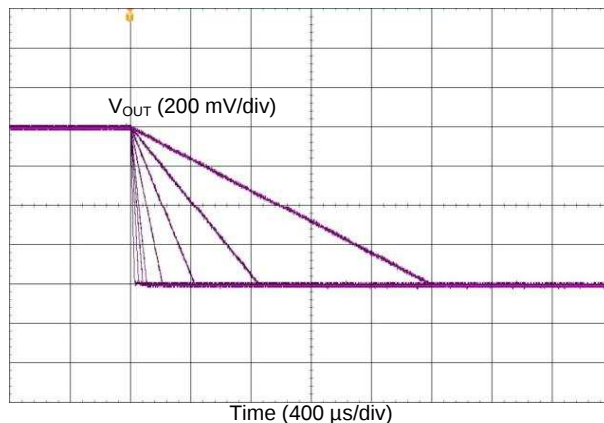


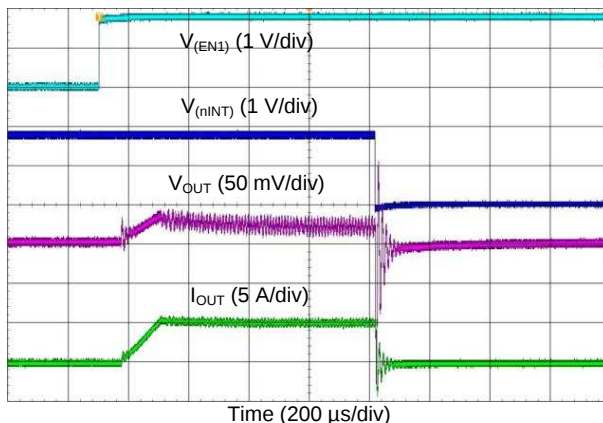
Figure 45. Transient Line Response



**Figure 46.  $V_{OUT}$  Transition from 0.6 V to 1.4 V with Different Slew Rate Settings**



**Figure 47.  $V_{OUT}$  Transition from 1.4 V to 0.6 V with Different Slew Rate Settings**



**Figure 48. Start-up with Short on Output**

## 10 Power Supply Recommendations

The device is designed to operate from an input voltage supply range between 2.5 V and 5.5 V. This input supply should be well-regulated and able to withstand maximum input current and maintain stable voltage without voltage drop even at load transition condition. The resistance of the input supply rail should be low enough that the input current transient does not cause too high drop in the LP8758 supply voltage that can cause false UVLO fault triggering. If the input supply is located more than a few inches from the LP8758 additional bulk capacitance may be required in addition to the ceramic bypass capacitors.

## 11 Layout

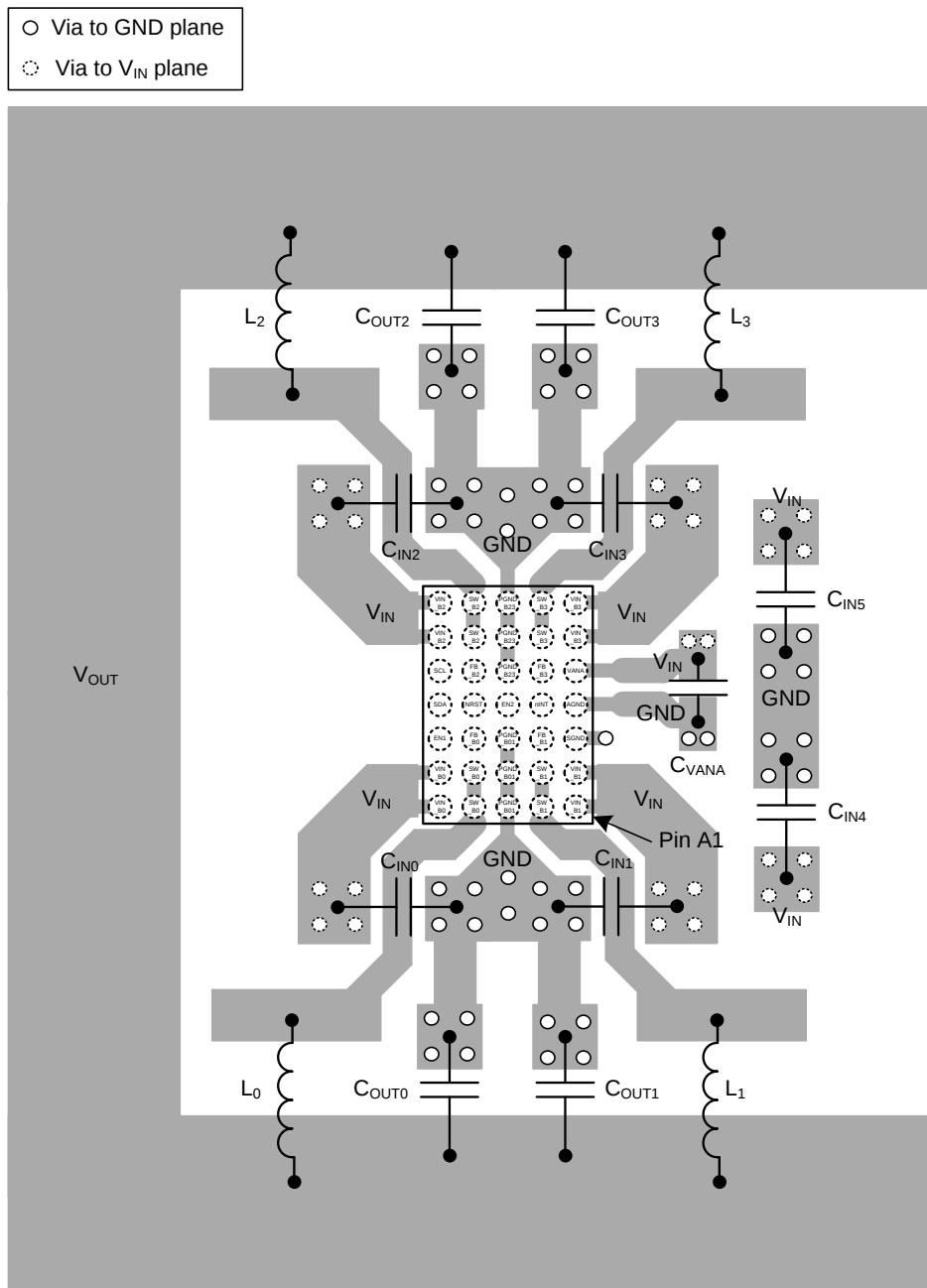
### 11.1 Layout Guidelines

The high frequency and large switching currents of the LP8758 make the choice of layout important. Good power supply results only occur when care is given to proper design and layout. Layout affects noise pickup and generation and can cause a good design to perform with less-than-expected results. With a range of output currents from milliamps to 10 A and over, good power supply layout is much more difficult than most general PCB design. Use the following steps as a reference to ensure the device is stable and maintains proper voltage and current regulation across its intended operating voltage and current range.

1. Place  $C_{IN}$  as close to the VIN\_Bx pin and the PGND\_Bxx pin as possible. Route the  $V_{IN}$  trace wide and thick to avoid IR drops. The trace between the input capacitor's positive node and LP8758's VIN\_Bx pin(s) as well as the trace between the input capacitor's negative node and power PGND\_Bxx pin(s) must be kept as short as possible. The input capacitance provides a low-impedance voltage source for the switching converter. The inductance of the connection is the most important parameter of a local decoupling capacitor — parasitic inductance on these traces must be kept as tiny as possible for proper device operation.
2. The output filter, consisting of  $L_x$  and  $C_{OUTx}$ , converts the switching signal at SW\_Bx to the noiseless output voltage. Place the output filter as close to the device as possible, keeping the switch node small, for best EMI behavior. Route the traces between the LP8758's output capacitors and the load's input capacitors direct and wide to avoid losses due to the IR drop.
3. Input for analog blocks (VANA and AGND) must be isolated from noisy signals. Connect VANA directly to a quiet system voltage node and AGND to a quiet ground point where no IR drop occurs. Place the decoupling capacitor as close to the VANA pin as possible. VANA must be connected to the same power node as VIN\_Bx pins.
4. If the processor load supports remote voltage sensing, connect the LP8758's feedback pins FB\_Bx to the respective sense pins on the processor. The sense lines are susceptible to noise. They must be kept away from noisy signals such as PGND\_Bxx, VIN\_Bx, and SW\_Bx, as well as high bandwidth signals such as the  $I^2C$ . Avoid both capacitive as well as inductive coupling by keeping the sense lines short, direct and close to each other. Run the lines in a quiet layer. Isolate them from noisy signals by a voltage or ground plane if possible. TI recommends running the signal as a differential pair.
5. Route PGND\_Bxx, VIN\_Bx and SW\_Bx on thick layers. They must not surround inner signal layers which are not able to withstand interference from noisy PGND\_Bxx, VIN\_Bx and SW\_Bx.

Due to the small package of this converter and the overall small solution size, the thermal performance of the PCB layout is important. Many system-dependent issues such as thermal coupling, airflow, added heat sinks and convection surfaces, and the presence of other heat-generating components affect the power dissipation limits of a given component. Proper PCB layout, focusing on thermal performance, results in lower die temperatures. Wide power traces come with the ability to sink dissipated heat. This can be improved further on multi-layer PCB designs with vias to different planes. This results in reduced junction-to-ambient ( $R_{\theta JA}$ ) and junction-to-board ( $R_{\theta JB}$ ) thermal resistances, thereby reducing the device junction temperature,  $T_J$ . Performing a careful system-level 2D or full 3D dynamic thermal analysis at the beginning product design process is strongly recommended, using a thermal modeling analysis software.

## 11.2 Layout Example



**Figure 49. LP8758 Board Layout**

## 12 デバイスおよびドキュメントのサポート

### 12.1 デバイス・サポート

#### 12.1.1 デベロッパー・ネットワークの製品に関する免責事項

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### 12.2 ドキュメントのサポート

#### 12.2.1 関連資料

関連資料については、以下を参照してください。

『AN-1112 DSBGAウェハー・レベル・チップ・スケール・パッケージ』

### 12.3 ドキュメントの更新通知を受け取る方法

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### 12.4 コミュニティ・リソース

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

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### 12.7 Glossary

[SLYZ022](#) — TI Glossary.

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

## 13 メカニカル、パッケージ、および注文情報

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

## PACKAGING INFORMATION

| Orderable part number          | Status<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="#">LP8758A1B0YFFR</a> | Active        | Production           | DSBGA (YFF)   35 | 3000   LARGE T&R      | Yes         | SNAGCU                               | Level-1-260C-UNLIM                | -40 to 85    | 8758A1B0            |
| LP8758A1B0YFFR.A               | Active        | Production           | DSBGA (YFF)   35 | 3000   LARGE T&R      | Yes         | SNAGCU                               | Level-1-260C-UNLIM                | -40 to 85    | 8758A1B0            |

<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.

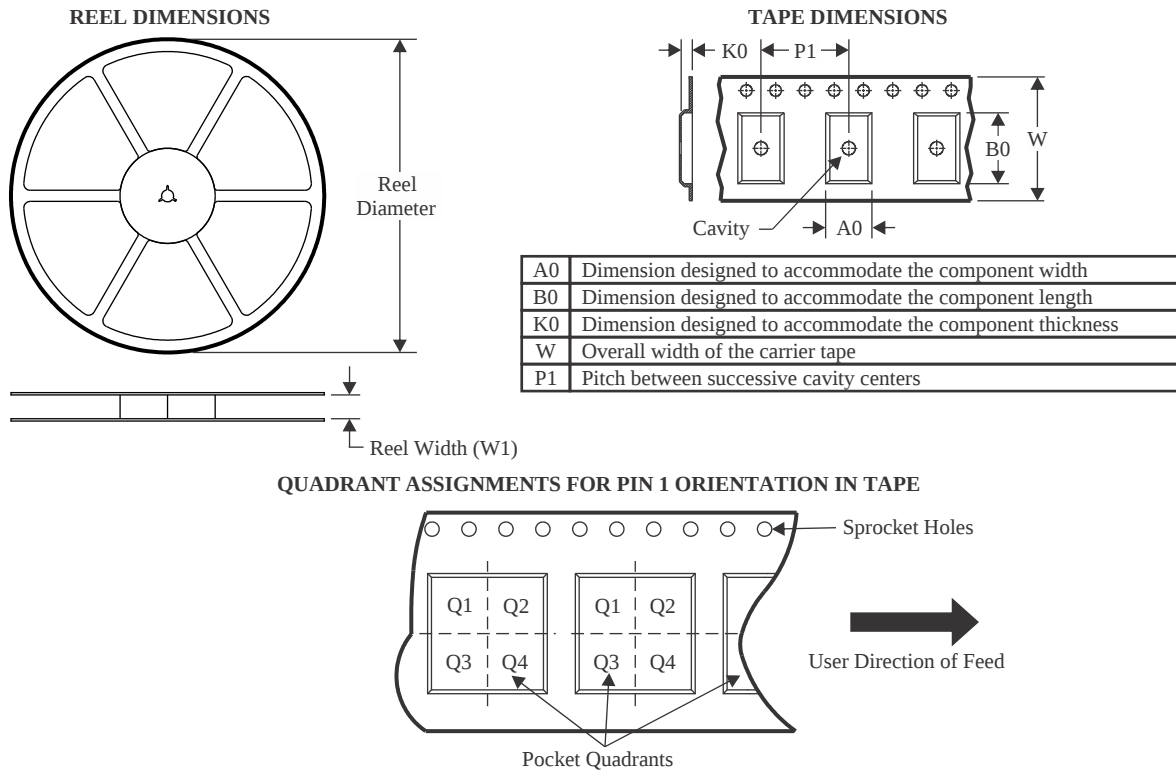
<sup>(6)</sup> **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

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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## TAPE AND REEL INFORMATION



\*All dimensions are nominal

| Device         | Package Type | Package Drawing | Pins | SPQ  | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|----------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| LP8758A1B0YFFR | DSBGA        | YFF             | 35   | 3000 | 180.0              | 8.4                | 2.28    | 3.03    | 0.74    | 4.0     | 8.0    | Q1            |

## TAPE AND REEL BOX DIMENSIONS

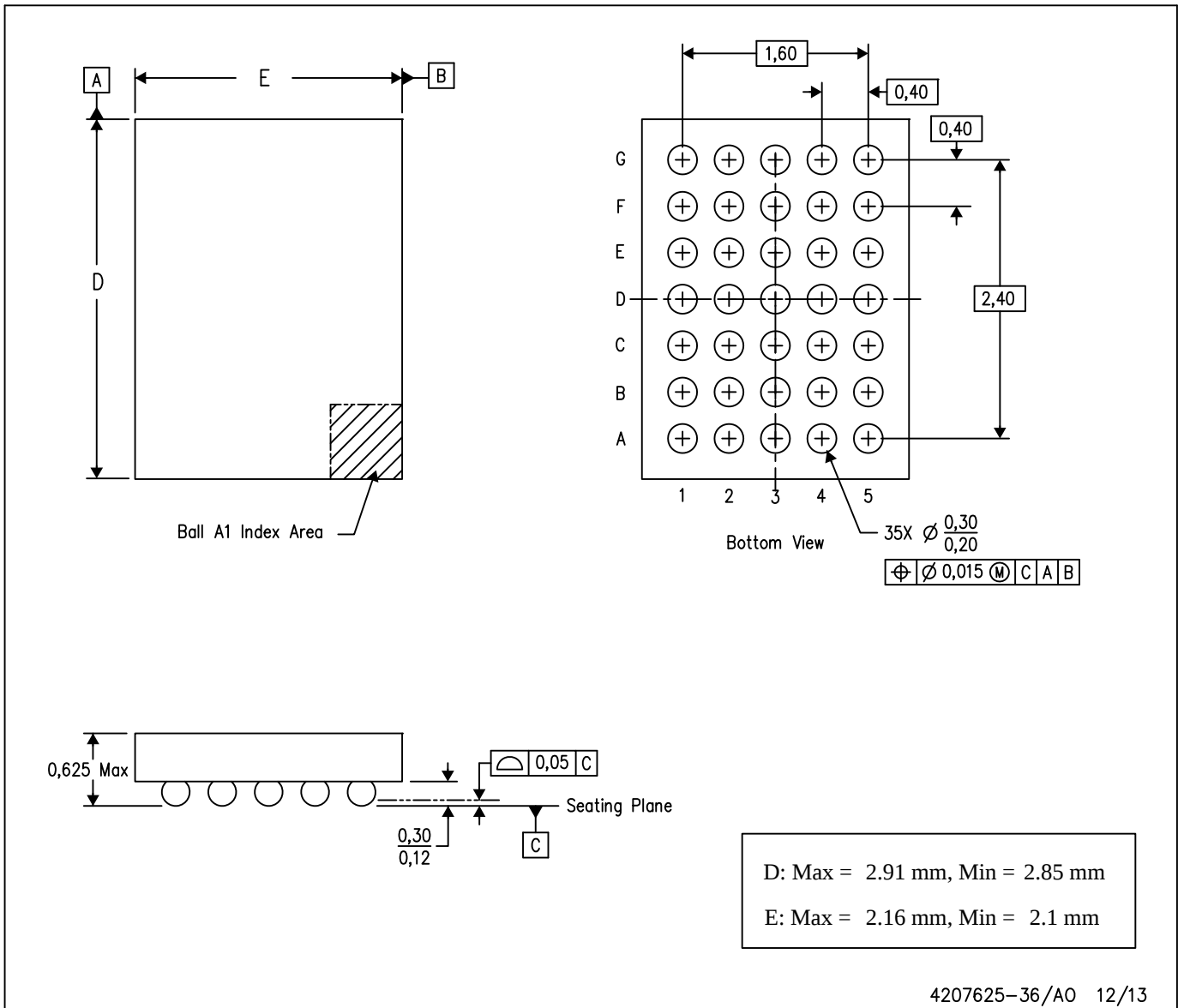


\*All dimensions are nominal

| Device         | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|----------------|--------------|-----------------|------|------|-------------|------------|-------------|
| LP8758A1B0YFFR | DSBGA        | YFF             | 35   | 3000 | 182.0       | 182.0      | 20.0        |

YFF (R-XBGA-N35)

DIE-SIZE BALL GRID ARRAY



- NOTES: A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.  
 B. This drawing is subject to change without notice.  
 C. NanoFree™ package configuration.

NanoFree is a trademark of Texas Instruments.

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