LMZ10501 最大入力電圧 5.5V の 1A Nano モジュール

1 特長

- 出力電流最大 1A
- 入力電圧範囲:2.7V ～ 5.5V
- 出力電圧範囲:0.6V ～ 3.6V
- 最大効率:95%
- インダクタ内蔵
- 8 ピンの microSiP フットプリント
- 接合部温度範囲:-40℃～125℃
- 可変出力電圧
- 2MHz の固定 PWM スイッチング周波数
- 補償機能を内蔵
- ソフトスタート機能
- 電流制限保護
- サーマル・シャットダウン保護
- 電源オン、電源オフ、およびブラウンアウト状況の入力電圧 UVLO
- 外付け部品はわずか 5 個 - 分圧抵抗と 3 個のセラミック・コンデンサ
- 小型デザイン・サイズ
- 低出力電圧リップル
- 簡単なコンポーネント選択とシンプルな PCB レイアウト
- 高い効率によりシステムの発熱が減少
- WEBENCH® Power Designer により、LMZ10501 を使用するカスタム設計を作成

2 アプリケーション

- 3.3V および 5V レールからのポイント・オブ・ロード (POL) 変換
- スペースの制約が厳しいアプリケーション
- 低出力ノイズのアプリケーション

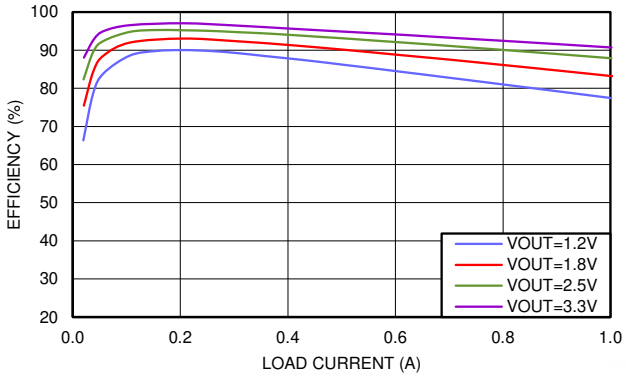
3 概要

LMZ10501 Nano モジュールは使いやすい降圧 DC/DC 設計であり、スペースに制約のあるアプリケーションで最大 1A の負荷を駆動できます。入力コンデンサ、出力コンデンサ、小さな V_{CON} フィルタ・コンデンサ、2 個の抵抗だけで、基本的な動作を実現できます。nano モジュールは 8 ピンの µSIP フットプリント・パッケージで供給され、インダクタが内蔵されています。内部の電流制限に基づくソフトスタート機能、電流過負荷保護、サーマル・シャットダウン機能も搭載されています。

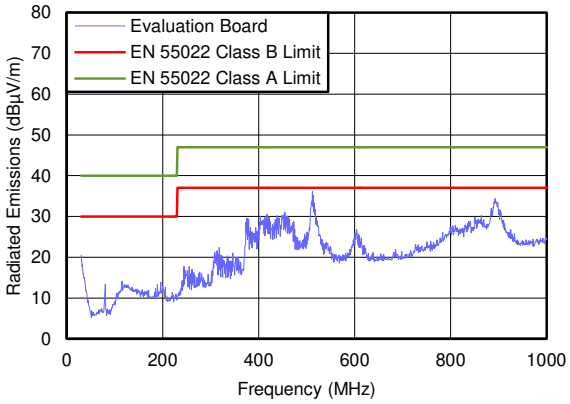
パッケージ情報

部品番号	パッケージ(1)	パッケージ・サイズ (2)
LMZ10501	SIL (µSIP、8)	3.00mm × 2.60mm

(1) 利用可能なすべてのパッケージについては、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。
(2) パッケージ・サイズ (長さ × 幅) は公称値であり、該当する場合はピンも含まれます。



V_{IN} = 3.6V での標準的な効率



放射 EMI (CISPR22) V_{IN} = 5V、V_{OUT} = 1.8V、I_{OUT} = 1A

このリソースの元の言語は英語です。翻訳は概要を便宜的に提供するもので、自動化ツール (機械翻訳) を使用していることがあり、TI では翻訳の正確性および妥当性につきましては一切保証いたしません。実際の設計などの前には、ti.com で必ず最新の英語版をご参照くださいますようお願いいたします。

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4 Revision History

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

Changes from Revision G (July 2018) to Revision H (October 2023) — **Page**

- ドキュメント全体にわたって表、図、相互参照の採番方法を更新 ... 1
- Updated trademark information ... 9

Changes from Revision F (November 2014) to Revision G (July 2018) — **Page**

- SEO を考慮した編集上の再ブランディング ... 1
- WEBENCH のリンクと、上端に TI リファレンス・デザインのナビゲーション・アイコンを追加 ... 1
- Move storage temperature spec to *Abs Max* table ... 4
- Changed "Handling" to "ESD" Ratings ... 4
- Added *セクション 9.1* ... 23
- Changed SIL package drawing to SIL0008G ... 24

Changes from Revision E (January 2014) to Revision F (November 2014) — **Page**

- 「ピン構成および機能」セクション、「取り扱いに関する定格」の表、「機能説明」セクション、「デバイスの機能モード」セクション、「アプリケーションと実装」セクション、「電源に関する推奨事項」セクション、「レイアウト」セクション、「デバイスおよびドキュメントのサポート」セクション、「メカニカル、パッケージ、および注文情報」セクションを追加 ... 1

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5 Pin Configuration and Functions

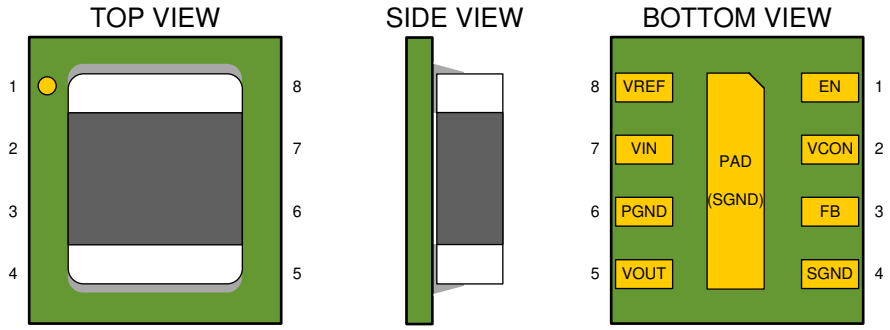


図 5-1. SIL Package, 8-Pin µSIP

表 5-1. Pin Functions

PIN		TYPE(1)	DESCRIPTION
NAME	NO.		
EN	1	I	Enable Input. Set this digital input higher than 1.2 V for normal operation. For shutdown, set low. Pin is internally pulled up to VIN and can be left floating for always-on operation.
VCON	2	I	Output voltage control pin. Connect to analog voltage from resisitve divider or DAC/controller to set the VOUT voltage. V_{OUT} = 2.5 x V_{CON}. Connect a small (470pF) capacitor from this pin to SGND to provide noise filtering.
FB	3	I	Feedback of the error amplifier. Connect directly to output capacitor to sense V_{OUT}.
SGND	4	I	Ground for analog and control circuitry. Connect to PGND at a single point.
VOUT	5	O	Output Voltage. Connected to one terminal of the integrated inductor. Connect output filter capacitor between VOUT and PGND.
PGND	6	I	Power ground for the power MOSFETs and gate-drive circuitry.
VIN	7	I	Voltage supply input. Connect ceramic capacitor between VIN and PGND as close as possible to these two pins. Typical capacitor values are between 4.7 µF and 22 µF.
VREF	8	O	2.35-V voltage reference output. Typically connected to VCON pin through a resistive divider to set the output voltage.
PAD		I	The center pad underneath the SIL0008A package is internally tied to SGND. Connect this pad to the ground plane for improved thermal performance.

(1) I = input, O = output

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6 Specifications

6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted) (1) (3) (2)

	MIN	MAX	UNIT
VIN, VREF to SGND	−0.2	+6.0	V
PGND to SGND	−0.2	+0.2	V
EN, FB, VCON	(SGND −0.2)	(VIN +0.2) w/6 max	V
VOUT	(PGND −0.2)	(VIN +0.2) w/6 max	V
Junction temperature (T_{J-MAX})	−40	125	°C
Maximum lead temperature		260	°C
Storage temperature, T_{stg}	–65	150	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *セクション 6.3*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) Absolute Maximum Ratings are limits beyond which damage to the device can occur. Operating Ratings are conditions under which operation of the device is intended to be functional. For the Electrical Characteristics table for specifications and test conditions.
(3) If Military/Aerospace specified devices are required, contact the Texas Instruments Sales Office/ Distributors for availability and specifications.

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001(1)	±1000	V
		Charged-device model (CDM), per JEDEC specification JESD22-C101(2)	±250	

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

6.3 Recommended Operating Conditions

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

	MIN	MAX	UNIT
Input voltage	2.7	5.5	V
Recommended load current	0	1000	mA
Junction temperature, T_J	−40	125	°C

6.4 Thermal Information

THERMAL METRIC(1)			LMZ10501 SIL (µSIP) 8 PINS	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance (2)	SIL0008G Package	45.8	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance		25	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance		9.2	°C/W
ψ_{JT}	Junction-to-top characterization parameter		1.5	°C/W
ψ_{JB}	Junction-to-board characterization parameter		9.1	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance		25	°C/W

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

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(2) Junction-to-ambient thermal resistance ($R_{\theta JA}$) is based on 4-layer board thermal measurements, performed under the conditions and guidelines set forth in the JEDEC standards JESD51-1 to JESD51-11. $R_{\theta JA}$ varies with PCB copper area, power dissipation, and airflow.

6.5 Electrical Characteristics

over operating free-air temperature range (unless otherwise noted). Typical values represent the most likely parametric norm at T_J = 25°C, and are provided for reference purposes only. Unless otherwise stated the following conditions apply: V_{IN} = 3.6 V, V_{EN} = 1.2 V. (1)

PARAMETER		TEST CONDITIONS	MIN(1)	TYP(2)	MAX(1)	UNIT
SYSTEM PARAMETERS						
V_{REF} × GAIN	Reference voltage × VCON to FB bain	V_{IN} = V_{EN} = 5.5V, V_{CON} = 1.44V	5.7575	5.875	5.9925	V
GAIN	VCON to FB Gain	V_{IN} = 5.5V, V_{CON} = 1.44V	2.4375	2.5	2.5750	V/V
VIN_{UVLO}	VIN rising threshold		2.24	2.41	2.64	V
$VIN_{UVLO\ HYST}$	VIN UVLO hysteresis		120	165	200	mV
I_{SHDN}	Shutdown supply current	V_{IN} = 3.6V, V_{EN} = 0.5V(3)		11	18	µA
I_q	DC bias current into VIN	V_{IN} = 5.5V, V_{CON} = 1.6V, I_{OUT} = 0A		6.5	9.5	mA
$R_{DROPOUT}$	V_{IN} to V_{OUT}resistance	I_{OUT} = 200 mA		305	575	mΩ
I_{LIM}	DC output current limit	V_{CON} = 1.72V (4)	1025	1350		mA
F_{OSC}	Internal oscillator frequency		1.75	2.0	2.25	MHz
$V_{IH,ENABLE}$	Enable logic HIGH voltage		1.2			V
$V_{IL,ENABLE}$	Enable logic LOW voltage				0.5	V
T_{SD}	Thermal shutdown	Rising Threshold		150		°C
$T_{SD-HYST}$	Thermal shutdown hysteresis			20		°C
D_{MAX}	Maximum duty cycle			100%		
T_{ON-MIN}	Minimum on-time			50		ns
θ_{JA}	SIL0008A Package Thermal Resistance	20mm x 20mm board 2 layers, 2 oz copper, 0.5W, no airlow		77		°C/W
		15mm x 15mm board 2 layers, 2 oz copper, 0.5W, no airlow		88		
		10mm x 10mm board 2 layers, 2 oz copper, 0.5W, no airlow		107		

(1) Min and Max limits are 100% production tested at 25°C. Limits over the operating temperature range are specified through correlation using Statistical Quality Control (SQC) methods. Limits are used to calculate the Average Outgoing Quality Level (AOQL).
(2) Typical numbers are at 25°C and represent the most likely parametric norm.
(3) Shutdown current includes leakage current of the high side PFET.
(4) Current limit is built-in, fixed, and not adjustable.

6.6 System Characteristics

The following specifications are specified by design providing the component values in 図 8-1 are used (C_{IN} = C_{OUT} = 10 µF, 6.3 V, 0603, TDK C1608X5R0J106K). These parameters are not specified by production testing. Unless otherwise stated the following conditions apply: T_A = 25°C.

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$\Delta V_{OUT}/V_{OUT}$	Output voltage regulation over line voltage and load current	V_{OUT} = 0.6 V ΔV_{IN} = 2.7 V to 4.2 V ΔI_{OUT} = 0A to 1A		±1.75%		
$\Delta V_{OUT}/V_{OUT}$	Output voltage regulation over line voltage and load current	V_{OUT} = 1.5 V ΔV_{IN} = 2.7 V to 5.5 V ΔI_{OUT} = 0A to 1A		±0.92%		

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6.6 System Characteristics (続き)

The following specifications are specified by design providing the component values in 図 8-1 are used (C_{IN} = C_{OUT} = 10 µF, 6.3 V, 0603, TDK C1608X5R0J106K). These parameters are not specified by production testing. Unless otherwise stated the following conditions apply: T_A = 25°C.

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$\Delta V_{OUT}/V_{OUT}$	Output voltage regulation over line voltage and load current	V_{OUT} = 3.6 V ΔV_{IN} = 4.0 V to 5.5 V ΔI_{OUT} = 0A to 1A		±0.38%		
VREF T_{RISE}	Rise time of reference voltage	EN = Low to High, V_{IN} = 4.2 V V_{OUT} = 2.7 V, I_{OUT} = 1A		10		µs
η	Peak efficiency	V_{IN} = 5.0 V, V_{OUT} = 3.3 V I_{OUT} = 200 mA		95%		
	Full load efficiency	V_{IN} = 5.0 V, V_{OUT} = 3.6 V I_{OUT} = 1000 mA		91%		
V_{OUT} Ripple	Output voltage ripple	V_{IN} = 5.0 V, V_{OUT} = 1.8 V I_{OUT} = 1000 mA		10		mV pk-pk
Line Transient	Line transient response	VIN = 2.7 V to 5.5 V, T_R = T_F= 10 µs, VOUT = 1.8 V, I_{OUT} = 1000 mA		30		mV pk-pk
Load Transient	Load transient response	VIN = 5.0 V T_R = T_F = 40 µs, V_{OUT} = 1.8 V I_{OUT} = 100 mA to 1000 mA		30		mV pk-pk

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6.7 Typical Characteristics

Unless otherwise specified the following conditions apply: V_{IN} = 3.6 V, T_A = 25°C

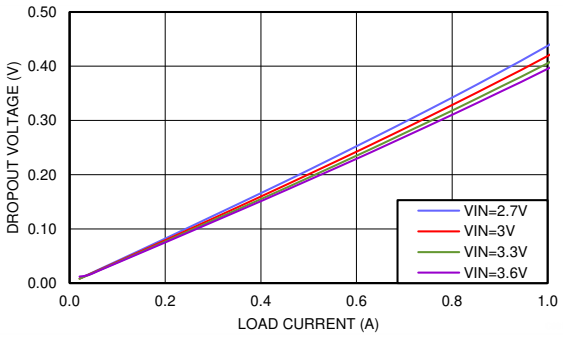


図 6-1. Dropout Voltage vs Load Current and Input Voltage, T_A = 85°C

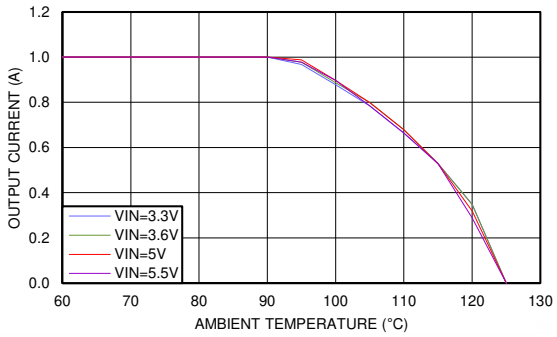


図 6-2. Thermal Derating V_{OUT} = 1.2 V, Θ_{JA} = 77°C/W

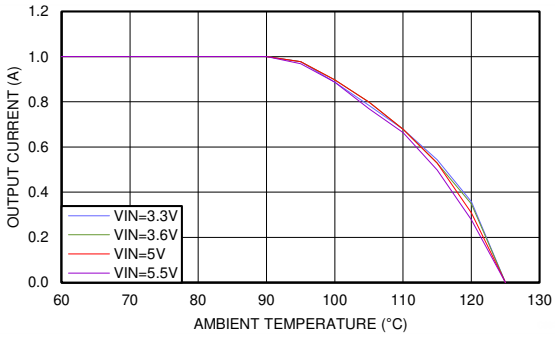


図 6-3. Thermal Derating V_{OUT} = 1.8 V, Θ_{JA} = 77°C/W

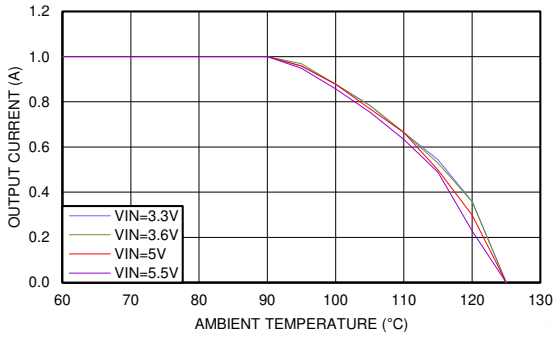


図 6-4. Thermal Derating V_{OUT} = 2.5 V, Θ_{JA} = 77°C/W

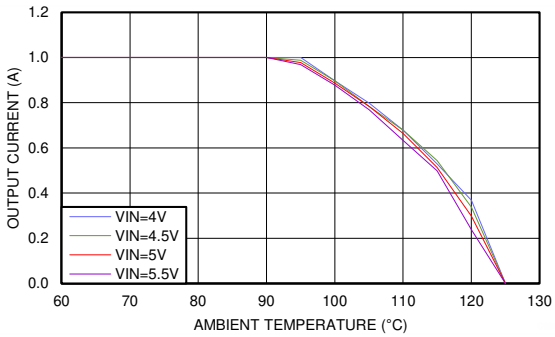


図 6-5. Thermal Derating V_{OUT} = 3.3 V, Θ_{JA} = 77°C/W

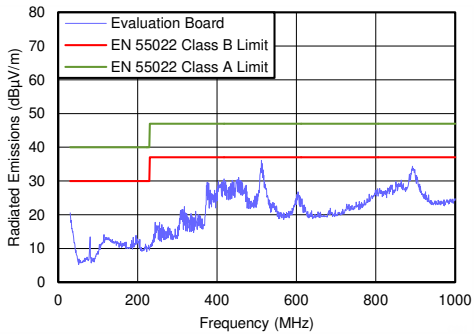


図 6-6. Radiated EMI (Cispr22) V_{IN} = 5 V, V_{OUT} = 1.8 V, I_{OUT} = 1-A Default Evaluation Board BOM

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6.7 Typical Characteristics (continued)

Unless otherwise specified the following conditions apply: V_{IN} = 3.6 V, T_A = 25°C

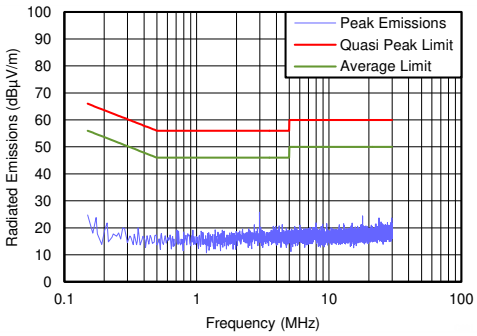


図 6-7. Conducted EMI V_{IN} = 5.0 V, V_{OUT} = 1.8 V, I_{OUT} = 1-A Default Evaluation Board BOM with Additional 2.2-µh 1-µf LC Input Filter

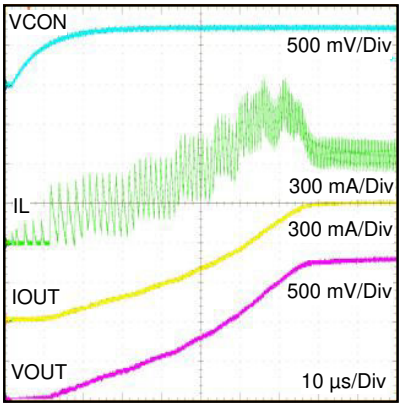


図 6-8. Startup

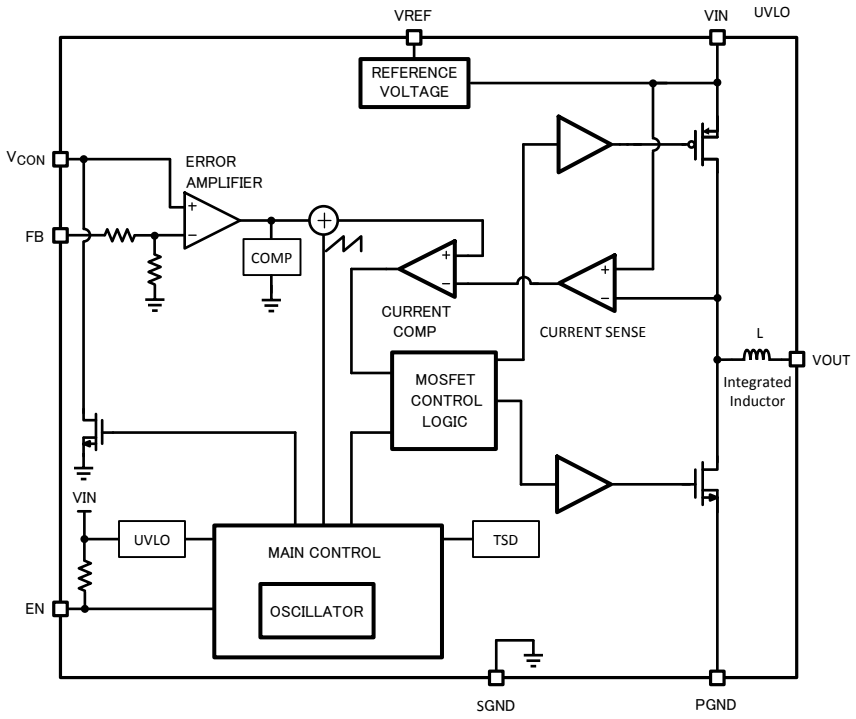
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7 Detailed Description

7.1 Overview

The LMZ10501 SIMPLE SWITCHER® power converter nano module is an easy-to-use step-down DC-DC solution capable of driving up to 1A load in space-constrained applications. Only an input capacitor, an output capacitor, a small V_{CON} filter capacitor, and two resistors are required for basic operation. The nano module comes in 8-pin LLP footprint package with an integrated inductor. The LMZ10501 operates in fixed 2.0-MHz PWM (Pulse Width Modulation) mode, and is designed to deliver power at maximum efficiency. The output voltage is typically set by using a resistive divider between the built-in reference voltage V_{REF} and the control pin V_{CON}. The V_{CON} pin is the positive input to the error amplifier. The output voltage of the LMZ10501 can also be dynamically adjusted between 0.6 V and 3.6 V by driving the V_{CON} pin externally. Internal current limit based soft-start function, current overload protection, and thermal shutdown are also provided.

7.2 Functional Block Diagram



7.3 Feature Description

7.3.1 Current Limit

The LMZ10501 current limit feature protects the module during an overload condition. The circuit employs positive peak current limit in the PFET and negative peak current limit in the NFET switch. The positive peak current through the PFET is limited to 1.7A (typ.). When the current reaches this limit threshold the PFET switch is immediately turned off until the next switching cycle. This behavior continues on a cycle-by-cycle basis until the overload condition is removed from the output. The typical negative peak current limit through the NFET switch is -0.6A (typ.).

The ripple of the inductor current depends on the input and output voltages. This means that the DC level of the output current when the peak current limiting occurs will also vary over the line voltage and the output voltage level. Refer to the DC Output Current Limit plots in the *Typical Characteristics* section for more information.

7.3.2 Startup Behavior and Soft Start

The LMZ10501 features a current limit based soft start circuit in order to prevent large in-rush current and output overshoot as V_{OUT} is ramping up. This is achieved by gradually increasing the PFET current limit threshold to

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the final operating value as the output voltage ramps during startup. The maximum allowed current in the inductor is stepped up in a staircase profile for a fixed number of switching periods in each step. Additionally, the switching frequency in the first step is set at 450kHz and is then increased for each of the following steps until it reaches 2MHz at the final step of current limiting. This current limiting behavior is illustrated in 図 7-1 and allows for a smooth V_{OUT} ramp up.

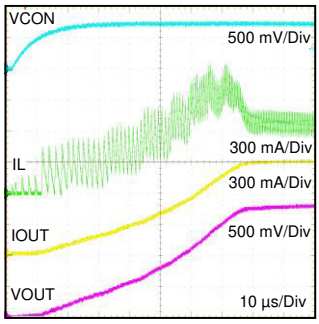


図 7-1. Startup Behavior of Current Limit Based Softstart.

The soft start rate is also limited by the V_{CON} ramp up rate. The V_{CON} pin is discharged internally through a pull down device before startup occurs. This is done to deplete any residual charge on the V_{CON} filter capacitor and allow the V_{CON} voltage to ramp up from 0V when the part is started. The events that cause V_{CON} discharge are thermal shutdown, UVLO, EN low, or output short circuit detection. The minimum recommended capacitance on V_{CON} is 220pF and the maximum is 1nF. The duration of startup current limiting sequence takes approximately 75µs. After the sequence is completed, the feedback voltage is monitored for output short circuit events.

7.3.3 Output Short Circuit Protection

In addition to cycle by cycle current limit, the LMZ10501 features a second level of short circuit protection. If the load pulls the output voltage down and the feedback voltage falls to 0.375 V, the output short circuit protection will engage. In this mode the internal PFET switch is turned OFF after the current limit comparator trips and the beginning of the next cycle is inhibited for approximately 230µs. This forces the inductor current to ramp down and limits excessive current draw from the input supply when the output of the regulator is shorted. The synchronous rectifier is always OFF in this mode. After 230 µs of non-switching a new startup sequence is initiated. During this new startup sequence the current limit is gradually stepped up to the nominal value as illustrated in the *セクション 7.3.2* section. After the startup sequence is completed again, the feedback voltage is monitored for output short circuit. If the short circuit is still persistent after the new startup sequence, switching will be stopped again and there will be another 230-µs off period. A persistent output short condition results in a hiccup behavior where the LMZ10501 goes through the normal startup sequence, then detects the output short at the end of startup, terminates switching for 230µs, and repeats this cycle until the output short is released. This behavior is illustrated in 図 7-2.

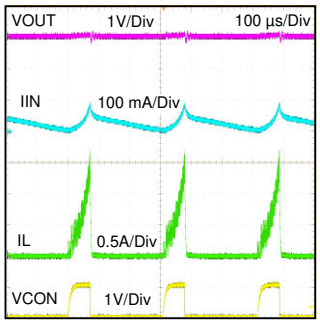


図 7-2. Hiccup Behavior with Persistent Output Short Circuit.

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Because the output current is limited during normal startup by the softstart function, the current charging the output capacitor is also limited. This results in a smooth V_{OUT} ramp up to nominal voltage. However, using excessively large output capacitance or V_{CON} capacitance under normal conditions can prevent the output voltage from reaching 0.375 V at the end of the startup sequence. In such cases the module will maintain the described above hiccup mode and the output voltage will not ramp up to final value. To cause this condition, one can have to use unnecessarily large output capacitance for 1A load applications. See the *セクション 8.2.2.5* section for guidance on maximum capacitances for different output voltage settings.

7.3.4 Thermal Overload Protection

The junction temperature of the LMZ10501 must not be allowed to exceed its maximum operating rating of 125°C. Thermal protection is implemented by an internal thermal shutdown circuit which activates at 150°C (typ). When this temperature is reached, the device enters a low power standby state. In this state switching remains off causing the output voltage to fall. Also, the V_{CON} capacitor is discharged to SGND. When the junction temperature falls back below 130°C (typ) normal startup occurs and V_{OUT} rises smoothly from 0V. Applications requiring maximum output current can require derating at elevated ambient temperature. See the *セクション 6.7* section for thermal derating plots for various output voltages.

7.4 Device Functional Modes

7.4.1 Circuit Operation

The LMZ10501 is a synchronous Buck power module using a PFET for the high side switch and an NFET for the synchronous rectifier switch. The output voltage is regulated by modulating the PFET switch on-time. The circuit generates a duty-cycle modulated rectangular signal. The rectangular signal is averaged using a low pass filter formed by the integrated inductor and an output capacitor. The output voltage is equal to the average of the duty-cycle modulated rectangular signal. In PWM mode, the switching frequency is constant. The energy per cycle to the load is controlled by modulating the PFET on-time, which controls the peak inductor current. In current mode control architecture, the inductor current is compared with the slope compensated output of the error amplifier. At the rising edge of the clock, the PFET is turned ON, ramping up the inductor current with a slope of $(V_{IN} - V_{OUT})/L$. The PFET is ON until the current signal equals the error signal. Then the PFET is turned OFF and NFET is turned ON, ramping down the inductor current with a slope of V_{OUT} /L. At the next rising edge of the clock, the cycle repeats. An increase of load pulls the output voltage down, resulting in an increase of the error signal. As the error signal goes up, the peak inductor current is increased, elevating the average inductor current and responding to the heavier load. To specify stability, a slope compensation ramp is subtracted from the error signal and internal loop compensation is provided.

7.4.2 Input Under Voltage Detection

The LMZ10501 implements an under voltage lock out (UVLO) circuit to specify proper operation during startup, shutdown and input supply brownout conditions. The circuit monitors the voltage at the V_{IN} pin to specify that sufficient voltage is present to bias the regulator. If the under voltage threshold is not met, all functions of the controller are disabled and the controller remains in a low power standby state.

7.4.3 Shutdown Mode

To shutdown the LMZ10501, pull the EN pin low (< 0.5 V). In the shutdown mode all internal circuits are turned OFF.

7.4.4 EN Pin Operation

The EN pin is internally pulled up to V_{IN} through a 790-kΩ (typical) resistor. This allows the nano module to be enabled by default when the EN pin is left floating. In such cases V_{IN} will set EN high when V_{IN} reaches 1.2 V. As the input voltage continues to rise, operation will start after V_{IN} exceeds the under-voltage lockout (UVLO) threshold. To set EN high externally, pull it up to 1.2 V or higher. Note that the voltage on EN must remain at less than VIN+ 0.2 V due to absolute maximum ratings of the device.

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7.4.5 Internal Synchronous Rectification

The LMZ10501 uses an internal NFET as a synchronous rectifier to minimize the switch voltage drop and increase efficiency. The NFET is designed to conduct through its intrinsic body diode during the built-in dead time between the PFET on-time and the NFET on-time. This eliminates the need for an external diode. The dead time between the PFET and NFET connection prevents shoot through current from V_{IN} to PGND during the switching transitions.

7.4.6 High Duty Cycle Operation

The LMZ10501 features a transition mode designed to extend the output regulation range to the minimum possible input voltage. As the input voltage decreases closer and closer to V_{OUT}, the off-time of the PFET gets smaller and smaller and the duty cycle eventually must reach 100% to support the output voltage. The input voltage at which the duty cycle reaches 100% is the edge of regulation. When the LMZ10501 input voltage is lowered, such that the off-time of the PFET reduces to less than 35ns, the LMZ10501 doubles the switching period to extend the off-time for that V_{IN} and maintain regulation. If V_{IN} is lowered even more, the off-time of the PFET will reach the 35ns mark again. The LMZ10501 will then reduce the frequency again, achieving less than 100% duty cycle operation and maintaining regulation. As V_{IN} is lowered even more, the LMZ10501 will continue to scale down the frequency, aiming to maintain at least 35ns off time. Eventually, as the input voltage decreases further, 100% duty cycle is reached. This behavior of extending the V_{IN} regulation range is illustrated in 図 7-3.

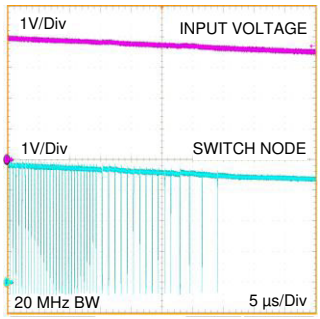


図 7-3. High Duty Cycle Operation and Switching Frequency Reduction

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8 Application and Implementation

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8.1 Application Information

This section describes a simple design procedure. Alternatively, WEBENCH® can be used to create and simulate a design using the LMZ10501. The WEBENCH® tool can be accessed from the LMZ10501 product folder at http://www.ti.com/product/lmz10501. For designs with typical output voltages (1.2 V, 1.8 V, 2.5 V, 3.3 V), jump to the *Application Curves* section for quick reference designs.

8.2 Typical Application

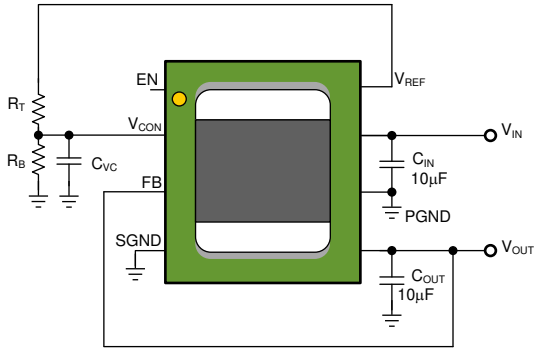


図 8-1. Typical Application Circuit

8.2.1 Design Requirements

The detailed design procedure is based on the required input and output voltage specifications for the design. The input voltage range of the LMZ10501 is 2.7V to 5.5V. The output voltage range is 0.6V to 3.6V. The output current capability is 1A.

8.2.2 Detailed Design Procedure

8.2.2.1 Custom Design With WEBENCH® Tools

Click here to create a custom design using the LMZ10501 device with the WEBENCH® Power Designer.

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

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

In most cases, these actions are available:

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

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8.2.2.2 Setting The Output Voltage

The LMZ10501 provides a fixed 2.35-V V_{REF} voltage output. As shown in 図 8-1 above, a resistive divider formed by R_T and R_B sets the V_{CON} pin voltage level. The V_{OUT} voltage tracks V_{CON} and is governed by the following relationship:

$$V_{OUT} = GAIN \times V_{CON} \quad (1)$$

where GAIN is 2.5 V/V from V_{CON} to V_{FB}

This equation is valid for output voltages between 0.6 V and 3.6 V and corresponds to V_{CON} voltage between 0.24 V and 1.44 V, respectively.

8.2.2.2.1 R_T And R_B Selection For Fixed V_{OUT}

The parameters affecting the output voltage setting are the R_T, R_B, and the product of the V_{REF} voltage × GAIN. The V_{REF} voltage is typically 2.35V. Because V_{CON} is derived from V_{REF} through R_T and R_B,

$$V_{CON} = V_{REF} \times R_B / (R_B + R_T) \quad (2)$$

After substitution,

$$V_{OUT} = V_{REF} \times GAIN \times R_B / (R_B + R_T) \quad (3)$$

$$R_T = (GAIN \times V_{REF} / V_{OUT} - 1) \times R_B \quad (4)$$

The ideal product of GAIN × V_{REF} = 5.875 V.

Choose R_T to be between 80kΩ and 300kΩ. Then, R_B can be calculated using 式 5 below.

$$R_B = (V_{OUT} / (5.875\ V - V_{OUT})) \times R_T \quad (5)$$

Note that the resistance of R_T must be ≥ 80kΩ. This ensures that the V_{REF} output current loading is not exceeded and the reference voltage is maintained. The current loading on V_{REF} must not be greater than 30 µA.

8.2.2.2.2 Output Voltage Accuracy Optimization

Each nano module is optimized to achieve high V_{OUT} accuracy. 式 1 shows that, by design, the output voltage is a function of the V_{CON} voltage and the gain from V_{CON} to V_{FB}. The voltage at V_{CON} is derived from V_{REF}. Therefore, as shown in 式 3, the accuracy of the output voltage is a function of the V_{REF} x GAIN product as well as the tolerance of the R_T and R_B resistors. The typical V_{REF} x GAIN product by design is 5.875 V. Each nano module's V_{REF} voltage is trimmed so that this product is as close to the ideal 5.875 V value as possible, achieving high V_{OUT} accuracy. See the *Features Description* section for the V_{REF} x GAIN product tolerance limits.

8.2.2.3 Dynamic Output Voltage Scaling

The V_{CON} pin on the LMZ10501 can be driven externally by a DAC to scale the output voltage dynamically. The output voltage V_{OUT} = 2.5 V/V x V_{CON}. When driving V_{CON} with a source different than V_{REF} place a 1.5kΩ resistor in series with the V_{CON} pin. Current limiting the external V_{CON} helps to protect this pin and allows the V_{CON} capacitor to be fully discharged to 0V after fault conditions.

8.2.2.4 Integrated Inductor

The LMZ10501 includes an inductor with over 1.2A DC current rating and soft saturation profile for up to 2A. This inductor allows for low package height and provides an easy to use, compact solution with reduced EMI.

8.2.2.5 Input And Output Capacitor Selection

The LMZ10501 is designed for use with low ESR multi-layer ceramic capacitors (MLCC) for its input and output filters. Using a 10 µF 0603 or 0805 with 6.3V or 10V rating ceramic input capacitor typically provides sufficient

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V_{IN} bypass. Use of multiple 4.7 µF or 2.2 µF capacitors can also be considered. Ceramic capacitors with X5R and X7R temperature characteristics are recommended for both input and output filters. These provide an optimal balance between small size, cost, reliability, and performance for space sensitive applications.

The DC voltage bias characteristics of the capacitors must be considered when selecting the DC voltage rating and case size of these components. The effective capacitance of an MLCC is typically reduced by the DC voltage bias applied across its terminals. For example, a typical 0805 case size X5R 6.3 V 10 µF ceramic capacitor can only have 4.8 µF left in it when a 5.0-V DC bias is applied. Similarly, a typical 0603 case size X5R 6.3V 10 µF ceramic capacitor can only have 2.4 µF at the same 5.0V DC. Smaller case size capacitors can have even larger percentage drop in value with DC bias.

The optimum output capacitance value is application dependent. Too small output capacitance can lead to instability due to lower loop phase margin. On the other hand, if the output capacitor is too large, it can prevent the output voltage from reaching the 0.375 V required voltage level at the end of the startup sequence. In such cases, the output short circuit protection can be engaged and the nano module will enter a hiccup mode as described in the *セクション 7.3.3* section. 表 8-1 sets the minimum output capacitance for stability and maximum output capacitance for proper startup for various output voltage settings. Note that the maximum C_{OUT} value in 表 8-1 assumes that the filter capacitance on V_{CON} is the maximum recommended value of 1nF and the R_T resistor value is less than 300kΩ. Lower V_{CON} capacitance can extend the maximum C_{OUT} range. There is no great performance benefit in using excessive C_{OUT} values.

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表 8-1. Output Capacitance Range

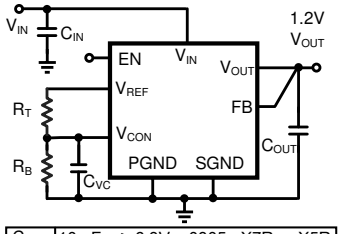
OUTPUT VOLTAGE	MINIMUM C_{OUT}	SUGGESTED C_{OUT}	MAXIMUM C_{OUT}
0.6 V	4.7 µF	10 µF	47 µF
1 V	3.3 µF	10 µF	47 µF
1.2 V	3.3 µF	10 µF	47 µF
1.8 V	3.3 µF	10 µF	68 µF
2.5 V	3.3 µF	10 µF	100 µF
3.3 V	3.3 µF	10 µF	100 µF

Use of multiple 4.7-µF or 2.2-µF output capacitors can be considered for reduced effective ESR and smaller output voltage ripple. In addition to the main output capacitor, small 0.1-µF – 0.01-µF parallel capacitors can be used to reduce high frequency noise.

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8.2.3 Application Curves

8.2.3.1 V_{OUT} = 1.2 V



C_{IN}	10 µF	≥ 6.3V	0805	X7R or X5R
C_{OUT}	10 µF	≥ 6.3V	0805	X7R or X5R
C_{VC}	470 pF	≥ 6.3V	0603	X7R or X5R
R_T	243 kΩ	1%	0603	
R_B	63.4 kΩ	1%	0603	

図 8-2. Schematic V_{OUT} = 1.2 V

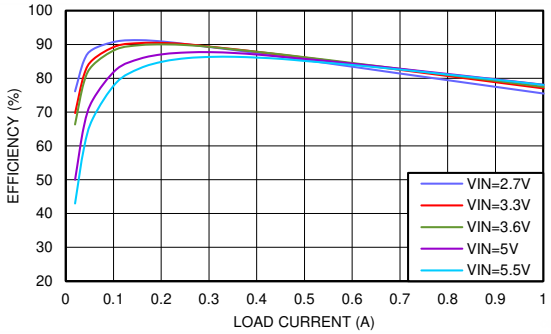


図 8-3. Efficiency V_{OUT} = 1.2 V

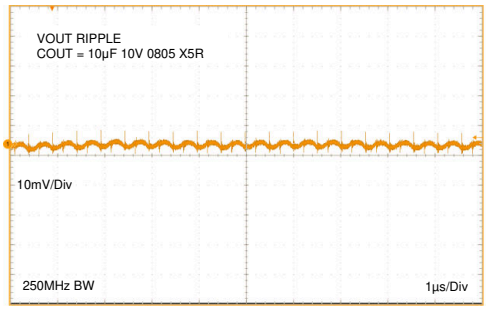


図 8-4. Output Ripple V_{OUT} = 1.2 V

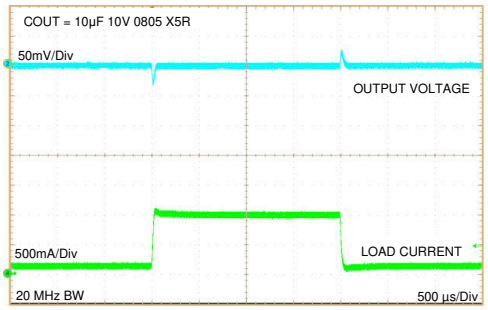


図 8-5. Load Transient V_{OUT} = 1.2 V

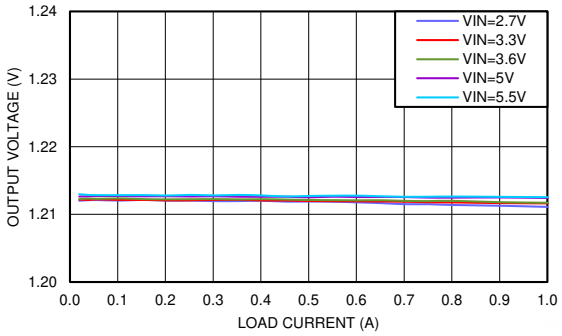


図 8-6. Line and Load Regulation V_{OUT} = 1.2 V

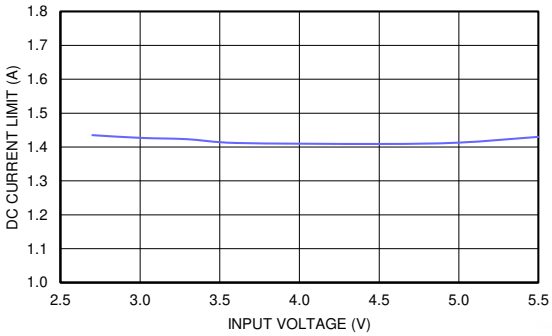
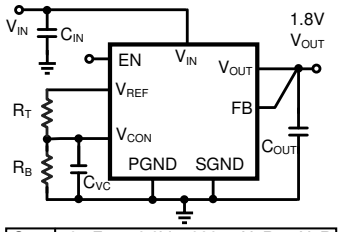


図 8-7. DC Current Limit V_{OUT} = 1.2 V, T_A=85°C

8.2.3.2 V_{OUT} = 1.8 V



C_{IN}	10 µF	≥ 6.3V	0805	X7R or X5R
C_{OUT}	10 µF	≥ 6.3V	0805	X7R or X5R
C_{VC}	470 pF	≥ 6.3V	0603	X7R or X5R
R_T	187 kΩ	1%	0603	
R_B	82.5 kΩ	1%	0603	

図 8-8. Schematic V_{OUT} = 1.8 V

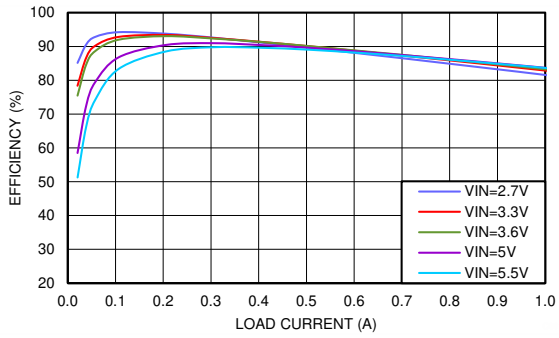


図 8-9. Efficiency V_{OUT} = 1.8 V

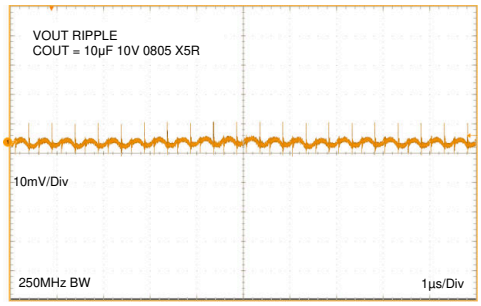


図 8-10. Output Ripple V_{OUT} = 1.8 V

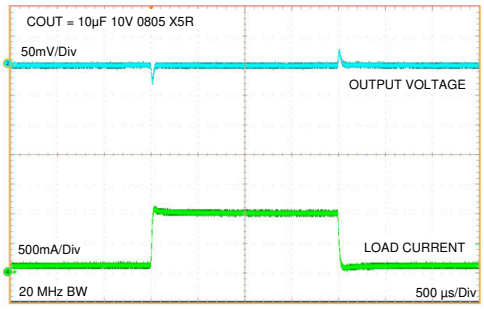


図 8-11. Load Transient V_{OUT} = 1.8 V

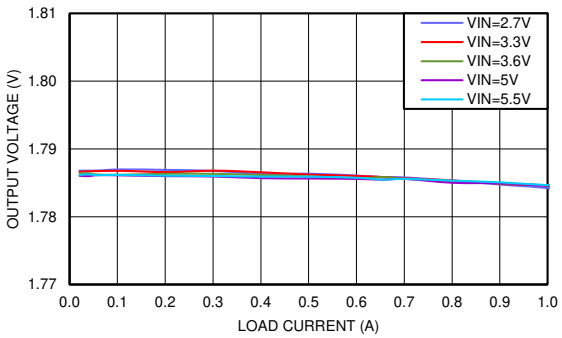


図 8-12. Line and Load Regulation V_{OUT} = 1.8 V

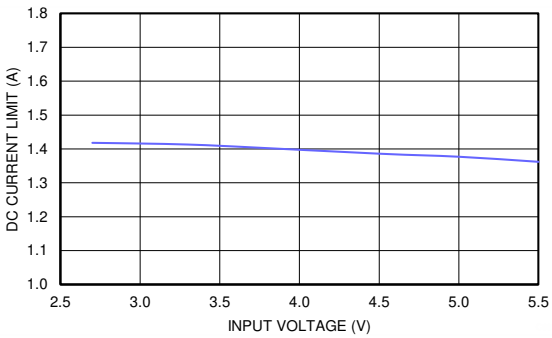
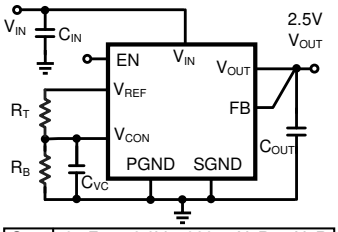


図 8-13. DC Current Limit V_{OUT} = 1.8 V, T_A= 85°C

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8.2.3.3 V_{OUT} = 2.5 V



C_{IN}	10 µF	≥ 6.3V	0805	X7R or X5R
C_{OUT}	10 µF	≥ 6.3V	0805	X7R or X5R
C_{VC}	470 pF	≥ 6.3V	0603	X7R or X5R
R_T	150 kΩ	1%	0603	
R_B	118 kΩ	1%	0603	

図 8-14. Schematic V_{OUT} = 2.5 V

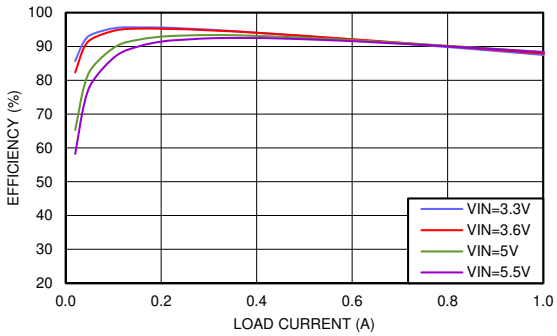


図 8-15. Efficiency V_{OUT} = 2.5 V

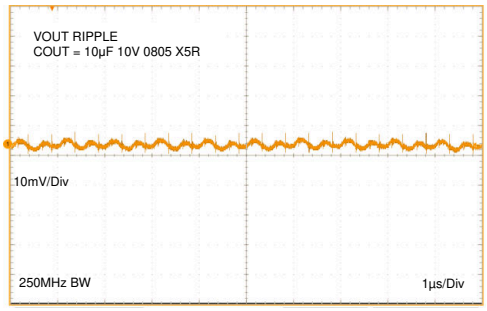


図 8-16. Output Ripple V_{OUT} = 2.5 V

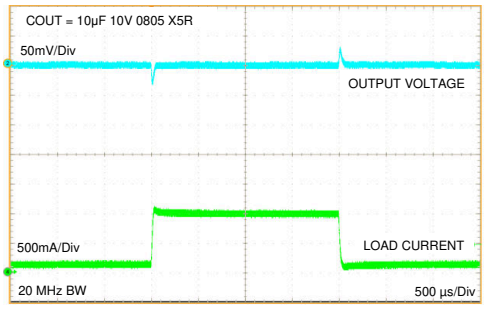


図 8-17. Load Transient V_{OUT} = 2.5 V

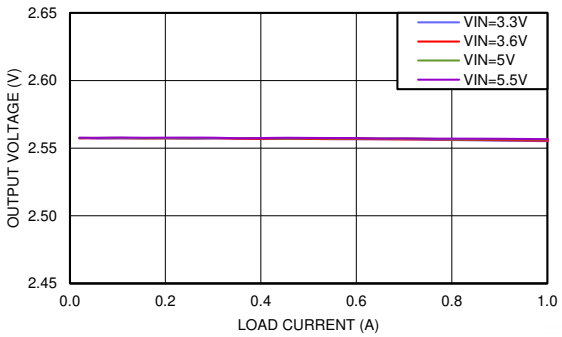


図 8-18. Line and Load Regulation V_{OUT} = 2.5 V

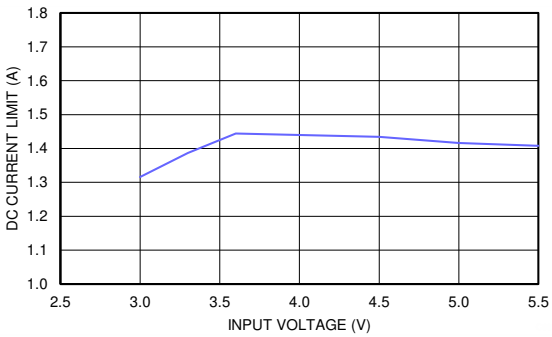
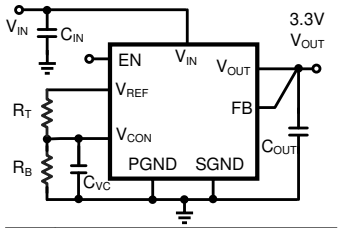


図 8-19. DC Current Limit V_{OUT} = 2.5 V, T_A= 85°C

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8.2.3.4 V_{OUT} = 3.3 V



C_{IN}	10 µF	≥ 6.3V	0805	X7R or X5R
C_{OUT}	10 µF	≥ 6.3V	0805	X7R or X5R
C_{VC}	470 pF	≥ 6.3V	0603	X7R or X5R
R_T	118 kΩ	1%	0603	
R_B	150 kΩ	1%	0603	

図 8-20. Schematic V_{OUT} = 3.3 V

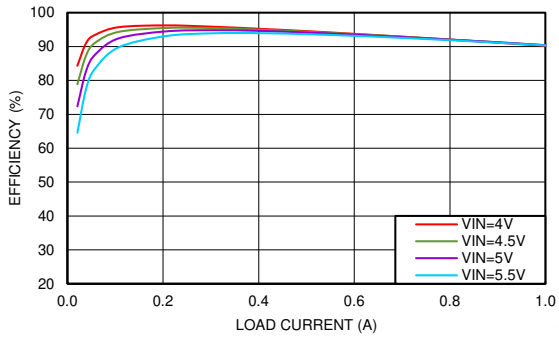


図 8-21. Efficiency V_{OUT} = 3.3 V

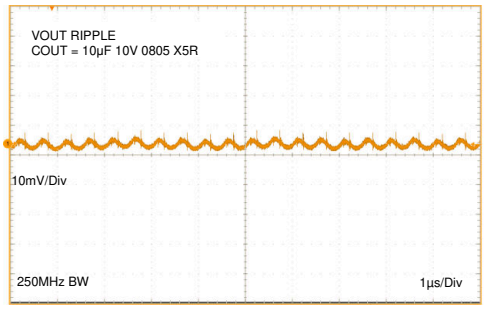


図 8-22. Output Ripple V_{OUT} = 3.3 V

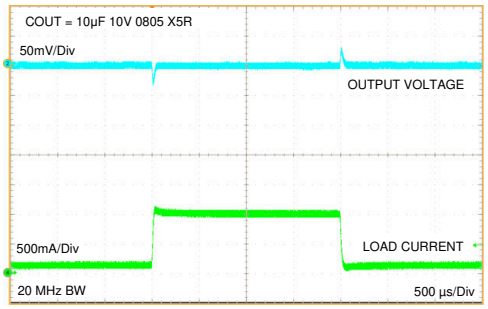


図 8-23. Load Transient V_{OUT} = 3.3 V

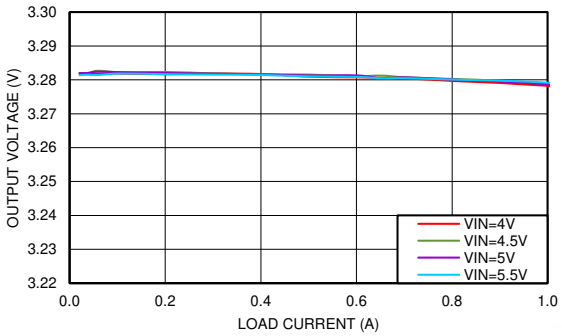


図 8-24. Line and Load Regulation V_{OUT} = 3.3 V

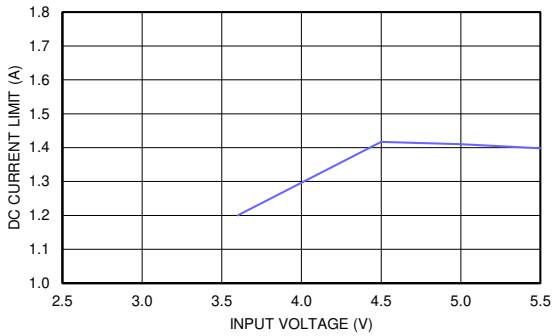


図 8-25. DC Current Limit V_{OUT} = 3.3 V, T_A= 85°C

8.3 Power Supply Recommendations

8.3.1 Voltage Range

The voltage of the input supply must not exceed the *セクション 6.1* and the *セクション 6.3* of the LMZ10501.

8.3.2 Current Capability

The input supply must be able to supply the required input current to the LMZ10501 converter. The required input current depends on the application's minimum required input voltage (V_{IN-MIN}), the required output power (V_{OUT} × $I_{OUT-MAX}$), and the converter efficiency (η).

$$I_{IN} = V_{OUT} \times I_{OUT-MAX} / (V_{IN-MIN} \times \eta) \quad (6)$$

For example, for a design with 5-V minimum input voltage,1.8-V output, and 1-A maximum load, considering 82% conversion efficiency, the required input current at steady state is 0.439 A.

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8.3.3 Input Connection

Long input connection cables can cause issues with the normal operation of any buck converter.

8.3.3.1 Voltage Drops

Using long input wires to connect the supply to the input of any converter adds impedance in series with the input supply. This impedance can cause a voltage drop at the VIN pin of the converter when the output of the converter is loaded. If the input voltage is near the minimum operating voltage, this added voltage drop can cause the converter to drop out or reset. If long wires are used during testing, it is recommended to add some bulk (i.e. electrolytic) capacitance at the input of the converter.

8.3.3.2 Stability

The added inductance of long input cables together with the ceramic (and low ESR) input capacitor can result in an under damped RLC network at the input of the Buck converter. This can cause oscillations on the input and instability. If long wires are used, it is recommended to add some electrolytic capacitance in parallel with the ceramic input capacitor. The electrolytic capacitor's ESR will improve the damping.

Use an electrolytic capacitor with $C_{ELECTROLYTIC} \geq 4 \times C_{CERAMIC}$ and $ESR_{ELECTROLYTIC} \approx \sqrt{(L_{CABLE} / C_{CERAMIC})}$

For example, two cables (one for VIN and one for GND), each 1 meter (~3 ft) long with ~1 mm diameter (18AWG), placed 1cm (~0.4 in) apart will form a rectangular loop resulting in about 1.2µH of inductance. The inductance in this example can be decreased to almost half if the input wires are twisted. Based on a 10µF ceramic input capacitor, the recommended parallel $C_{ELECTROLYTIC}$ is ≥ 40 µF. Using a 47-µF capacitor will be sufficient. The recommended $ESR_{ELECTROLYTIC} \approx 0.35\Omega$ or larger, based on about 1.2 µH of inductance and 10 µF of ceramic input capacitance.

See application note SNVA489 for more details on input filter design.

8.4 Layout

8.4.1 Layout Guidelines

The board layout of any DC/DC switching converter is critical for the optimal performance of the design. Bad PCB layout design can disrupt the operation of an otherwise good schematic design. Even if the regulator still converts the voltage properly, the board layout can mean the difference between passing or failing EMI regulations. In a Buck converter, the most critical board layout path is between the input capacitor ground terminal and the synchronous rectifier ground. The loop formed by the input capacitor and the power FETs is a path for the high di/dt switching current during each switching period. This loop must always be kept as short as possible when laying out a board for any buck converter.

The LMZ10501 integrates the inductor and simplifies the DC/DC converter board layout. Refer to the example layout in 図 8-26. There are a few basic requirements to achieve a good LMZ10501 layout.

1. Place the input capacitor C_{IN} as close as possible to the V_{IN} and PGND pins. V_{IN} (pin 7) and PGND (pin 6) on the LMZ10501 are next to each other which makes the input capacitor placement simple.

2. Place the V_{CON} filter capacitor C_{VC} and the R_B R_T resistive divider as close as possible to the V_{CON} and SGND pins. The C_{VC} capacitor (not R_B) must be the component closer to the V_{CON} pin, as shown in 図 8-26. This allows for better bypass of the control voltage set at V_{CON}.

3. Run the feedback trace (from V_{OUT} to FB) away from noise sources.

4. Connect SGND to a quiet GND plane.

5. Provide enough PCB area for proper heat sinking. Refer to the *Electrical Characteristics* table for example θ_{JA} values for different board areas. Also, refer to AN-2020 for additional thermal design hints.

Refer to the evaluation board user's guide *LMZ10501SIL and LMZ10500SIL SIMPLE SWITCHER® Nano Module Evaluation Board* for a complete board layout example.

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8.4.2 Layout Example

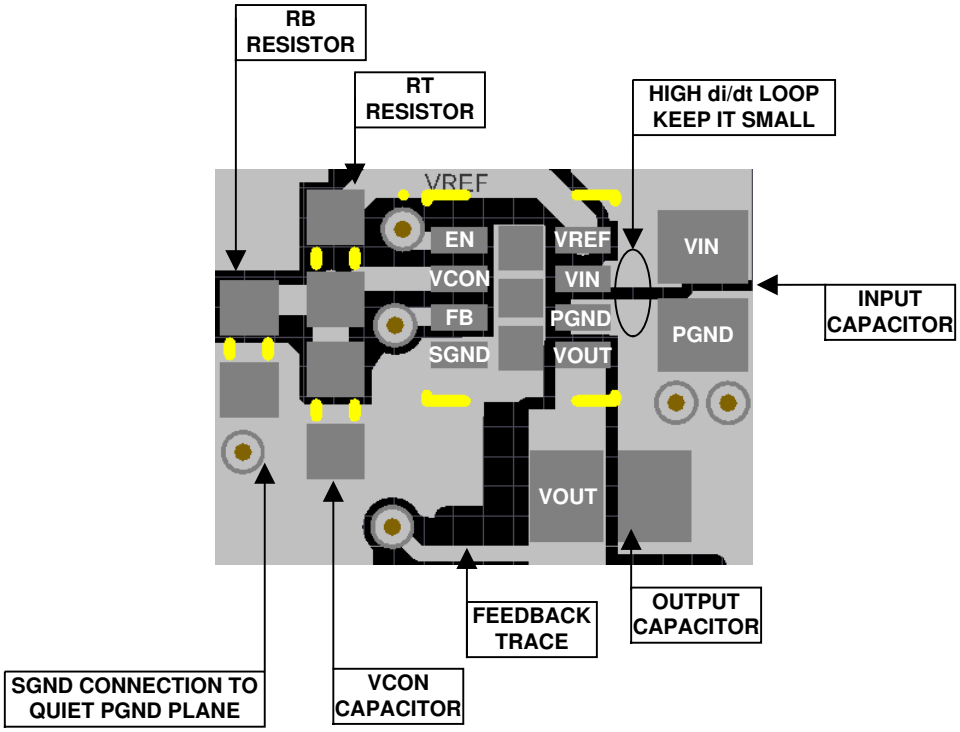


図 8-26. Example Top Layer Board Layout

8.4.3 Package Considerations

Use the following recommendations when using machine placement :

- Use 1.06 mm (42mil) or smaller nozzle size. The pick up area is the top of the inductor which is 1.6 mm × 2 mm.
- Soft tip pick and place nozzle is recommended.
- Add 0.05 mm to the component thickness so that the device will be released 0.05 mm (2 mil) into the solder paste without putting pressure or splashing the solder paste.
- Slow the pick arm when picking the part from the tape and reel carrier and when depositing the IC on the board.
- If the machine releases the component by force, use minimum force or no more than 3 Newtons.

For manual placement:

- Use a vacuum pick up hand tool with soft tip head.
- If vacuum pick up tool is not available, use non-metal tweezers and hold the part by sides.
- Use minimal force when picking and placing the module on the board.
- Using hot air station provides better temperature control and better controlled air flow than a heat gun.
- Go to the video section at www.ti.com/product/lmz10501 for a quick video on how to solder rework the LMZ10501.

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9 Device and Documentation Support

9.1 Device Support

9.1.1 Custom Design With WEBENCH® Tools

Click here to create a custom design using the LMZ10501 device with the WEBENCH® Power Designer.

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

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

In most cases, these actions are available:

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

Get more information about WEBENCH tools at www.ti.com/WEBENCH.

9.2 Documentation Support

9.2.1 Related Documentation

- Texas Instruments, *AN-2162 Simple Success With Conducted EMI From DC- DC Converters* application report
- Texas Instruments, *LMZ10501SIL and LMZ10500SIL SIMPLE SWITCHER® Nano Module Evaluation Board* user's guide

9.3 ドキュメントの更新通知を受け取る方法

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ESD による破損は、わずかな性能低下からデバイスの完全な故障まで多岐にわたります。精密な IC の場合、パラメータがわずかに変化するだけで公表されている仕様から外れる可能性があるため、破損が発生しやすくなっています。

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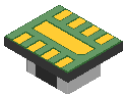
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10 Mechanical, Packaging, and Orderable Information

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

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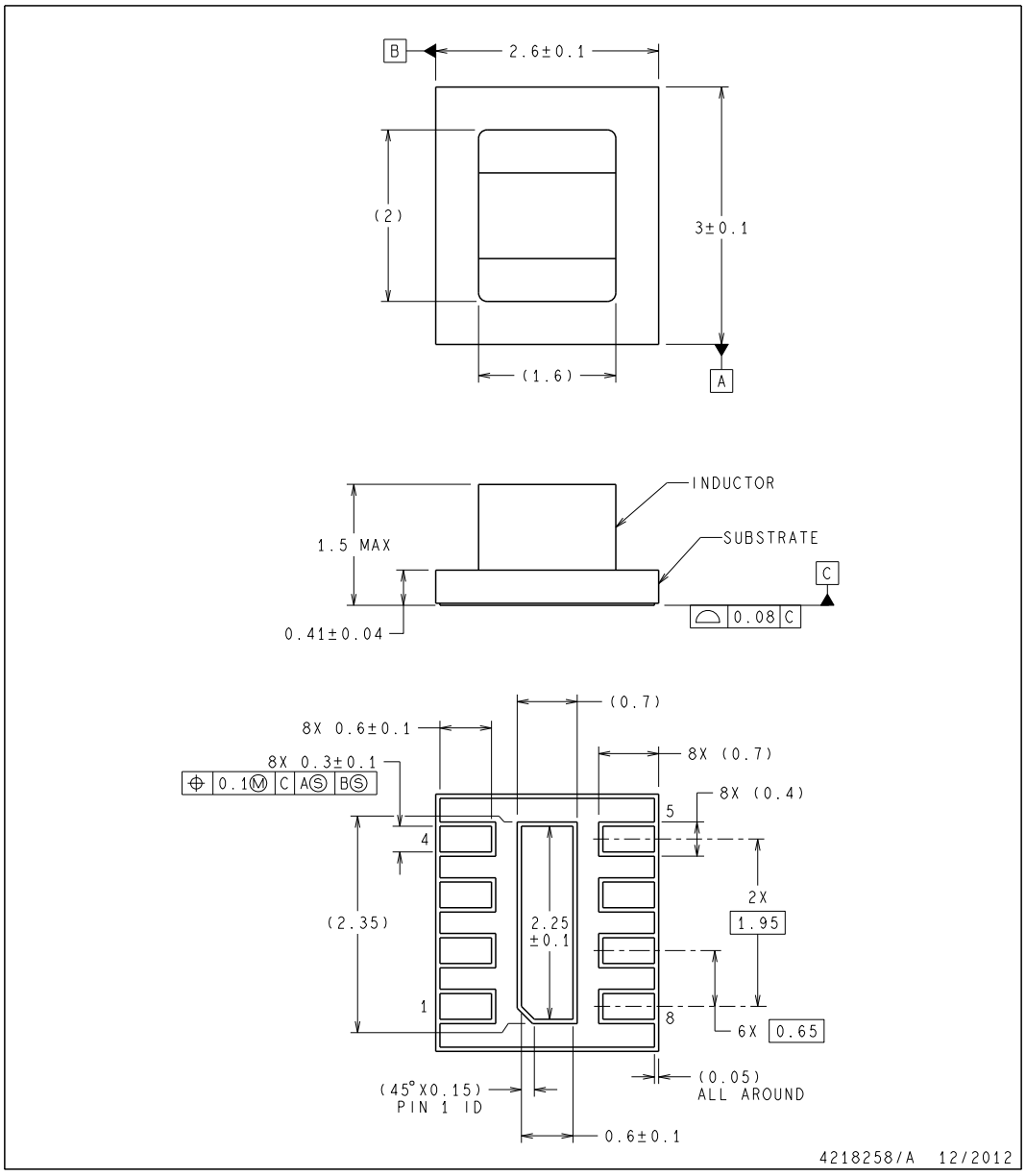
MECHANICAL DATA



SIL0008A

MicroSiP - 1.5mm max height

SYSTEM IN PACKAGE



NOTES:
1. DIMENSIONS ARE IN MILLIMETERS. DIMENSIONS IN PARENTHESIS ARE FOR REFERENCE ONLY.
2. THIS DRAWING IS SUBJECT TO CHANGE WITHOUT NOTICE.
3. NO JEDEC REFERENCE AS OF NOVEMBER 2012.
4. R-uSiP-N8.

TEXAS INSTRUMENTS
www.ti.com

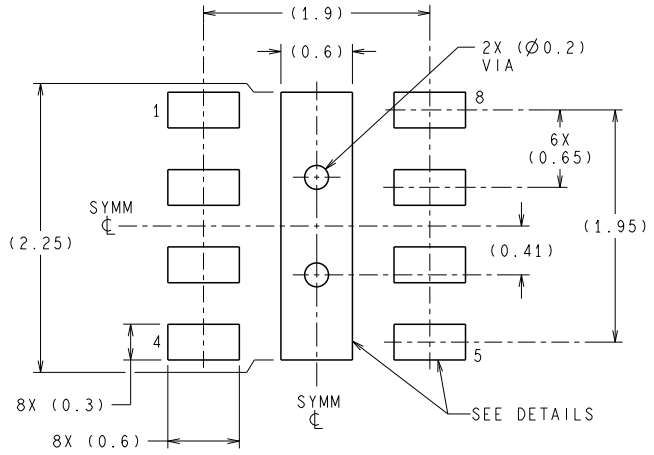
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MECHANICAL DATA

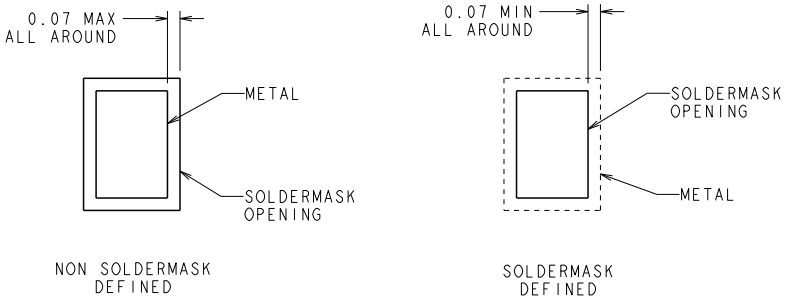
SIL0008A

MicroSiP - 1.5mm max height

SYSTEM IN PACKAGE



RECOMMENDED LAND PATTERN
1:1 RATIO WITH PACKAGE SOLDER PADS



SOLDERMASK DETAILS
NOT TO SCALE

4218258/A 12/2012

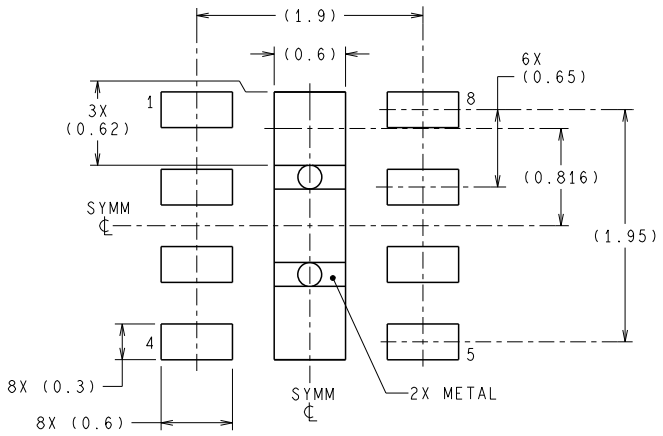
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MECHANICAL DATA

SIL0008A

MicroSiP - 1.5mm max height

SYSTEM IN PACKAGE



RECOMMENDED SOLDERPASTE
EXPOSED PAD
82% PRINTED SOLDER COVERAGE BY AREA

4218258/A 12/2012

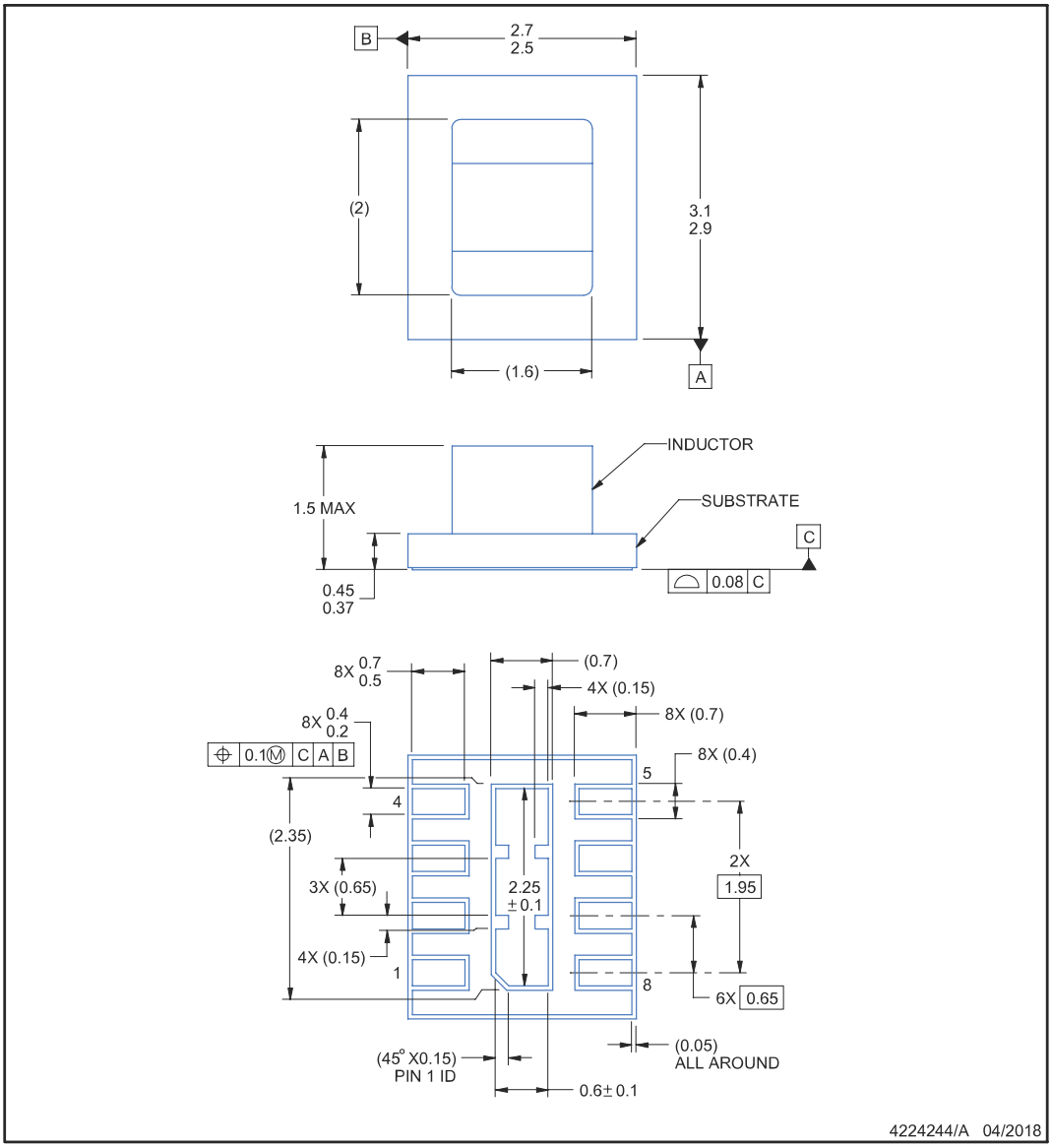
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PACKAGE OUTLINE

SIL0008G — **uSiP - 1.5mm max height**

MICRO SYSTEM IN PACKAGE



NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Pick and place nozzle ∅ 1.3 mm or smaller recommended.

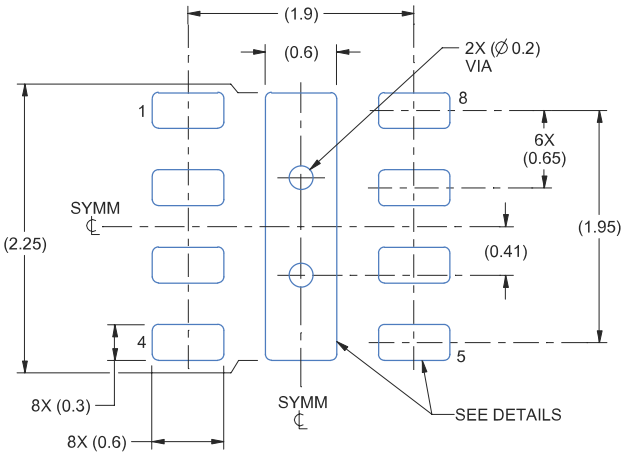
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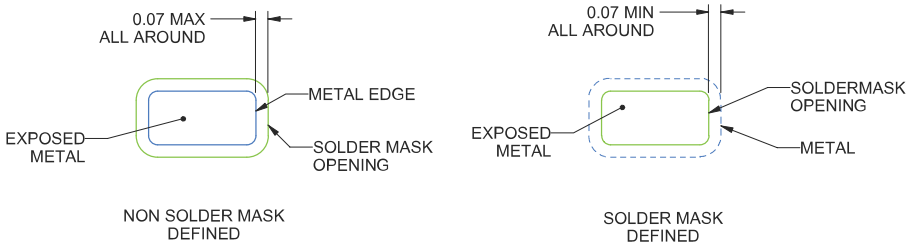
EXAMPLE BOARD LAYOUT

SIL0008G — **uSiP - 1.5mm max height**

MICRO SYSTEM IN PACKAGE



LAND PATTERN EXAMPLE
1:1 RATIO WITH PACKAGE SOLDER PADS
SCALE: 20X



SOLDER MASK DETAILS
NOT TO SCALE

4224244/A 04/2018

NOTES: (continued)

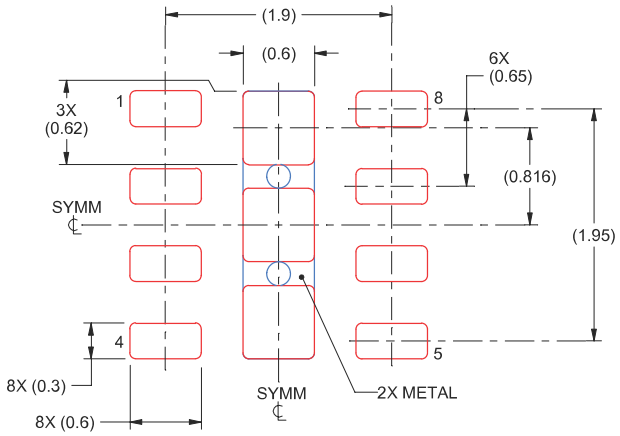
4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/slua271).

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EXAMPLE STENCIL DESIGN

SIL0008G — **uSiP - 1.5mm max height**

MICRO SYSTEM IN PACKAGE



SOLDER PASTE EXAMPLE
BASED ON 0.125 MM THICK STENCIL

82% PRINTED SOLDER COVERAGE BY AREA
SCALE: 20X

4224244/A 04/2018

NOTES: (continued)

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

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PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package | Pins	Package qty | Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
LMZ10501SILR	Active	Production	uSiP (SIL) | 8	3000 | LARGE T&R	Yes	Call TI	Level-3-260C-168 HR	-40 to 125	501 0501 421A DG
LMZ10501SILR.A	Active	Production	uSiP (SIL) | 8	3000 | LARGE T&R	Yes	Call TI	Level-3-260C-168 HR	-40 to 125	501 0501 421A DG
LMZ10501SILT	Active	Production	uSiP (SIL) | 8	250 | SMALL T&R	Yes	Call TI	Level-3-260C-168 HR	-40 to 125	501 0501 421A DG
LMZ10501SILT.A	Active	Production	uSiP (SIL) | 8	250 | SMALL T&R	Yes	Call TI	Level-3-260C-168 HR	-40 to 125	501 0501 421A DG

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

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

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

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

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

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

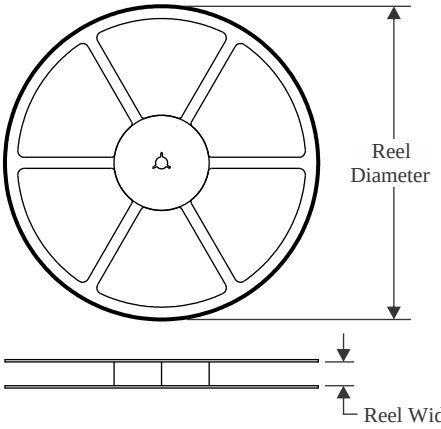
Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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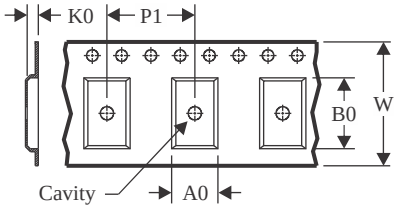
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TAPE AND REEL INFORMATION

REEL DIMENSIONS

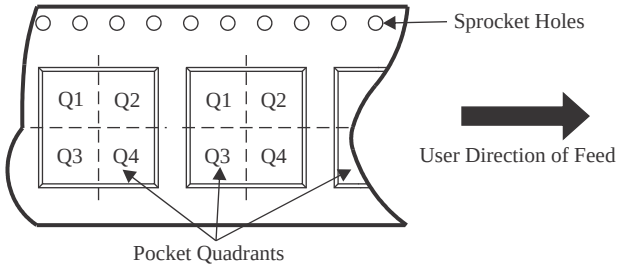


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

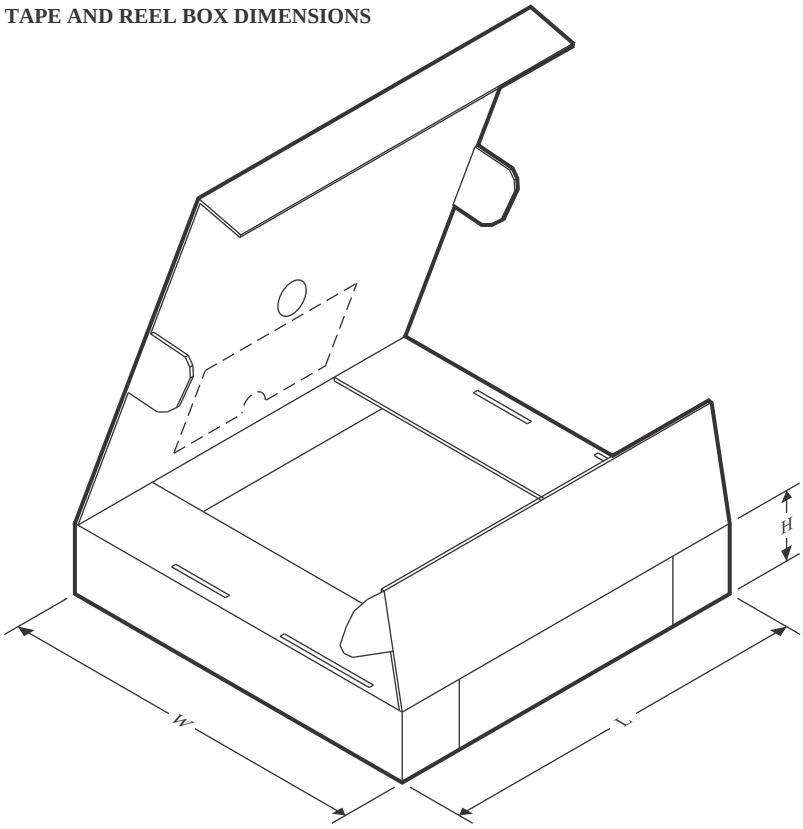
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
LMZ10501SILR	uSiP	SIL	8	3000	330.0	12.4	2.85	3.25	1.7	4.0	12.0	Q1
LMZ10501SILT	uSiP	SIL	8	250	178.0	13.2	2.85	3.25	1.7	4.0	12.0	Q1

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LMZ10501SILR	uSiP	SIL	8	3000	383.0	353.0	58.0
LMZ10501SILT	uSiP	SIL	8	250	223.0	194.0	35.0

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