参考資料

Design Guide: TIDA-050055

インダクタを内蔵した大電力密度、17V、3A、降圧コンバータ・モジュールのリファレンス・デザイン

概要

TIDA-050055 リファレンス・デザインは、インダクタを内蔵した VIN 3V～17V の TPSM82903 降圧コンバータを採用しており、設計空間が非常に限定されたアプリケーションのために開発されました。このリファレンス・デザインは、入力電圧を 1.2V の VOUT に降圧変換し、高効率かつ低静止電流で最大 3A を供給できます。すべての外部部品を含むソリューション全体のサイズは 20mm^2 です。このリファレンス・デザインは高効率 DC/DC 変換を、業界最小の動作時静止電流 (I_Q) で、しかも非常に小さいフットプリントで実現しています。

リソース

TIDA-050055	デザイン・フォルダ
TPSM82903	プロダクト・フォルダ

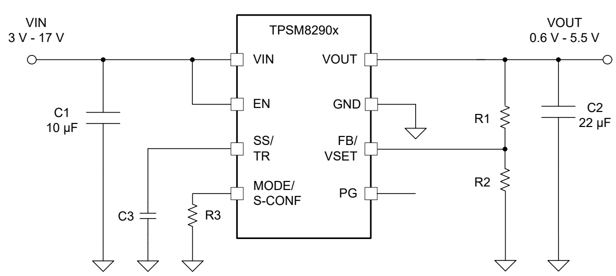
Ask our TI E2E™ support experts

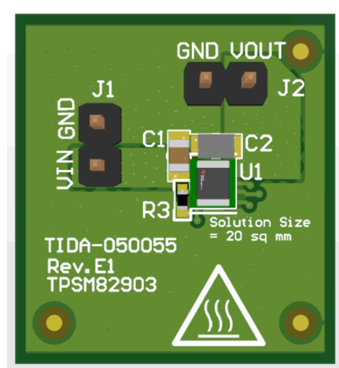
特長

- 20mm^2 の小型トータル・ソリューション・サイズ
- 150mA/mm^2 の電力密度
- 3V～17V の入力電圧
- 最大 3A の連続出力電流
- 低 I_Q:4μA (標準値)
- インダクタ内蔵
- 総合的なシステム電圧精度:±1.0% (-40℃～125℃の全温度範囲)
- 動作時接合部温度:-40℃～125℃
- 100% モードを備えた DCS-Control™ トポロジ

アプリケーション

- データ・センターおよびエンタープライズ・コンピューティング
- 有線ネットワーク
- ワイヤレス・インフラ
- ファクトリ・オートメーション / 制御
- 試験 / 測定機器





English Document: TIDUC99

1 System Description

The TIDA-050055 is designed by using the TPSM82903 high efficiency and low I_Q DC/DC Buck converter with integrated inductor. The design is optimized for small total solution size, low BOM count, high efficiency, best thermal performance, and lowest quiescent current possible. This design is ideal for applications where space is limited such as smart lock, wearable devices, and so on. The high efficiency and low I_Q are ideal for battery operated systems. The design allows for efficient battery usage and extended lifetime.

表 1-1. Key System Specifications

PARAMETER	MIN	Typical	MAX	UNIT
Input Voltage	3	12	17	V
Output Voltage	1.185	1.2	1.215	V
Output Current	0		3	A
Switching Frequency		2.5		MHz
Operating Quiescent Current (Power Save Mode)		4		uA
Junction Temperature	-40		125	C
Output Capacitor Discharge		Enabled		

2 System Overview

2.1 Block Diagram

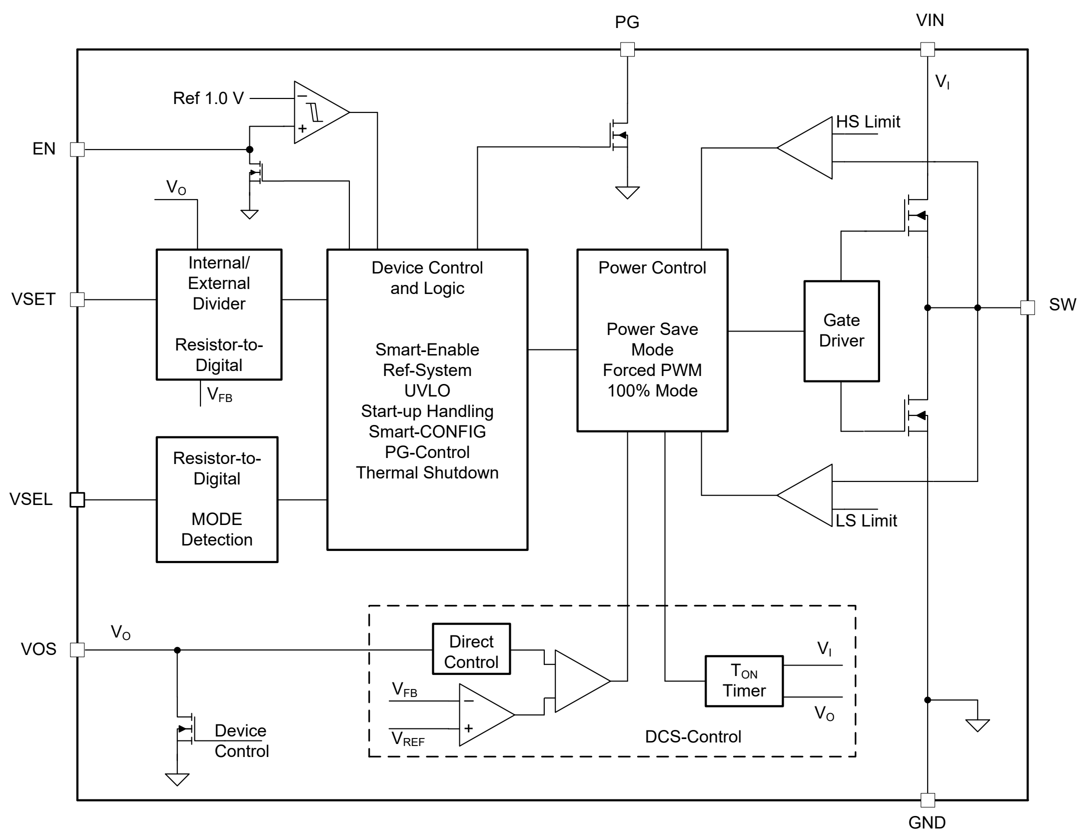


図 2-1. TIDA-050055 Block Diagram

2.2 Design Considerations

By connecting 26.1-kΩ resistor on Mode/S-CONF pin, the device is configured to:

- **VSET-operation**: VOUT is sensed only through the VOS pin by an internal resistor divider. The target Vout is programmed by an external resistor connected between the VSET pin and GND. In this design, FB/VSET is connected to GND and thus the VOUT is programmed to 1.2-V.
- **2.5-MHz Switching Frequency with AEE (Automatic Efficiency Enhancement)**: The MODE/S-CONF pin is configured for AEE mode; the TPSM82903 provides the highest efficiency over the entire input voltage and output voltage range by automatically adjusting the switching frequency of the converter. The efficiency decreases if VOUT decreases, VIN increases, or both. To keep the efficiency high over the entire duty cycle range (VOUT/VIN ratio), the switching frequency is adjusted while maintaining the ripple current. The AEE feature provides an efficiency enhancement for various duty cycles, especially for lower VOUT values where fixed frequency converters suffer from a significant efficiency drop. Furthermore, this feature compensates for the very small duty cycles of high VIN to low VOUT conversion, which limits the control range in other topologies.
- **Power Save Mode Operation (Auto PFM/PWM):** The MODE/S-CONF pin is configured for power save mode (auto PFM/PWM). The device operates in PWM mode as long the output current is higher than half of the ripple current of the inductor. To maintain high efficiency at light loads, the device enters power save mode at the boundary to discontinuous conduction mode (DCM). This happens if the output current becomes smaller than half of the ripple current of the inductor. The power save mode is entered seamlessly when the load current decreases. This ensures a high efficiency in light load operation. The device remains in power save mode as long as the inductor current is discontinuous. In power save mode, the switching frequency decreases linearly with the load current maintaining high efficiency. The transition in and out of power save mode is seamless in both directions.
- **Output Discharge Function Enabled:** The discharge function is enabled to ensure a defined down-ramp of the output voltage when the device is being disabled but also to keep the output voltage close to 0-V when the device is off. The output discharge feature is only active once TPSM82903 has been enabled at least once since the supply voltage was applied.
- **Soft Start:** The SS/TR pin should be left floating for fastest start up time.

2.3 Highlighted Products

The TPSM82903 is a highly-efficient, small, and flexible synchronous step-down DC-DC converter that is easy to use. The device supports high VOUT accuracy of ± 1.0% using VSET with the DCS-Control topology. The wide input voltage range of 3-V to 17-V supports a variety of nominal inputs, like 12-V supply rails, single-cell or multi-cell Li-Ion, and 5-V or 3.3-V rails.

The TPSM82903 can automatically enter power save mode at light loads to maintain high efficiency. Additionally, to provide high efficiency at very small loads, the device has a low typical quiescent current of 4-µA. AEE provides high efficiency across VIN, VOUT, and load current. The device includes a MODE/Smart-CONF input to set the internal/external divider, switching frequency, output voltage discharge, and automatic power save mode or forced PWM operation. The device is available in a small 11-pin MicroSiP package measuring 3.00-mm × 2.80-mm with 1.60-mm pitch with an integrated 1-µH inductor.

2.4 System Design Theory

2.4.1 Buck Converter Circuit Design Using TPSM82903

The TPSM82903 is optimized to work within a range of external components. A 1-μH inductor has been integrated to reduce solution size. Output capacitor selection can influence circuit stability; the recommended value for the output capacitor is 22 μF. SeeTPSM82903 data sheet for more details.

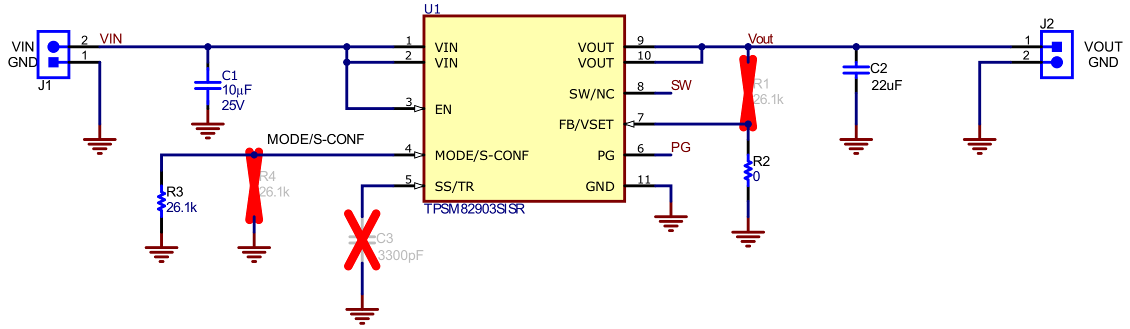


図 2-2. Buck Converter Circuit Design Using TPSM82903

A small low equivalent series resistance (ESR) multilayer ceramic capacitor (MLCC) is recommended to obtain the best filtering. For this design, a 10-μF/25V multilayer ceramic chip capacitor from TDK (C2012X7S1E106K125AC) is used as an input capacitor. The capacitor is designed to withstand up to 25-V which is enough for the input voltage range that we want to cover in this design.

For the output capacitor, the voltage rating is much smaller than the input, only 6-V to 10-V capacitor rating is needed. A 22-μF/10V multilayer ceramic chip capacitor (GRM21BD71A226ME44K) from Murata Manufacturing is chosen. The input and the output capacitors are X7S and X7T respectively; both of these cover the full temperature range needed for this design.

The MODE/S-CONF requires an E96 Resistor Series, 1% Accuracy, Temperature Coefficient better or equal than ±200- ppm/°C. A small size CRCW040226K1FKED from Vishay is used in this design.

3 Hardware, Software, Testing Requirements, and Test Results

3.1 Hardware Requirements

For testing purposes, this reference design requires the following equipment:

- A power supply that is capable of supplying at least 2-A of load and up to 20-V.
- Current and Voltage Multimeters to measure the currents and voltages during the related tests.
- The TIDA-050055 board which is a printed circuit board (PCB) with all the devices in this design.
- Resistive load or electronic load that is capable at least 3-A.
- Thermal camera used to measure the thermal rise of the board during operation.
- Oscilloscope to capture voltages and a current.

3.2 Test Setup

図 3-1 shows the set up used to test the TIDA-050055.

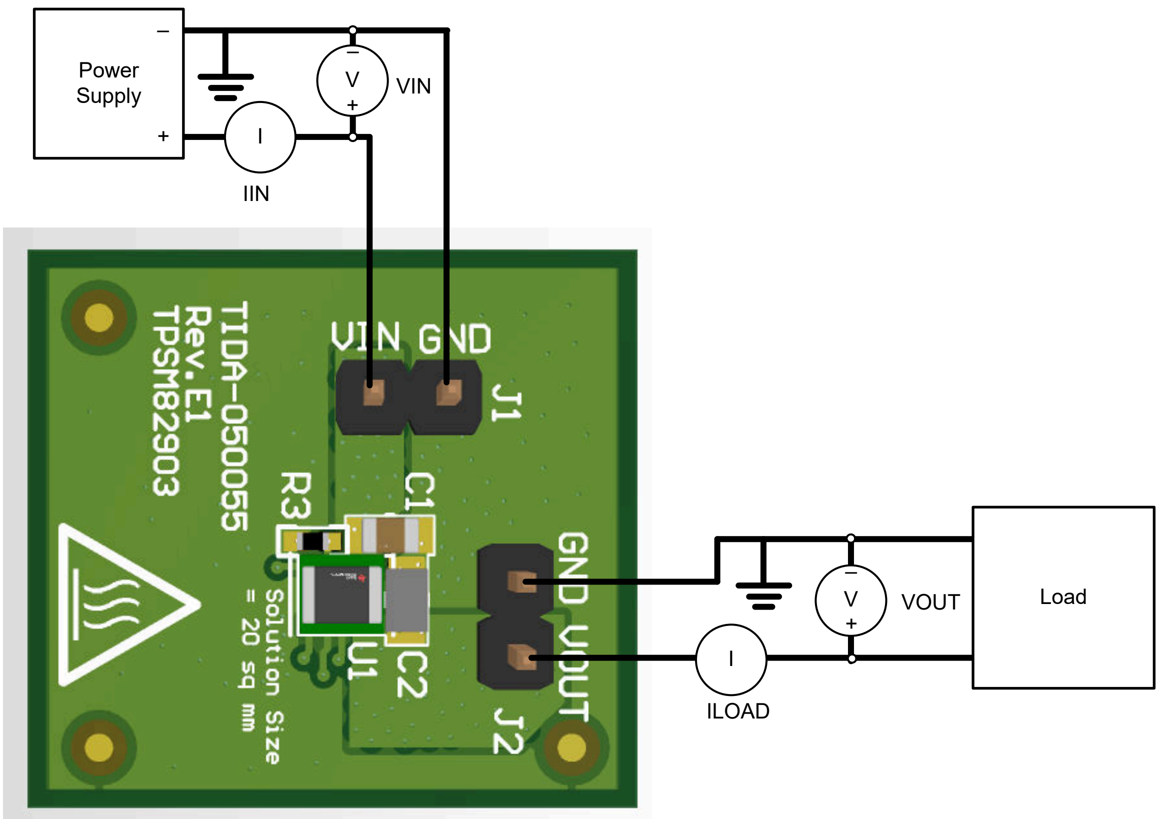


図 3-1. Test Setup

3.3 Test Results

3.3.1 Startup

図 3-2 shows the startup behavior. With no soft start capacitor, it defaults to pre-programmed start up time.

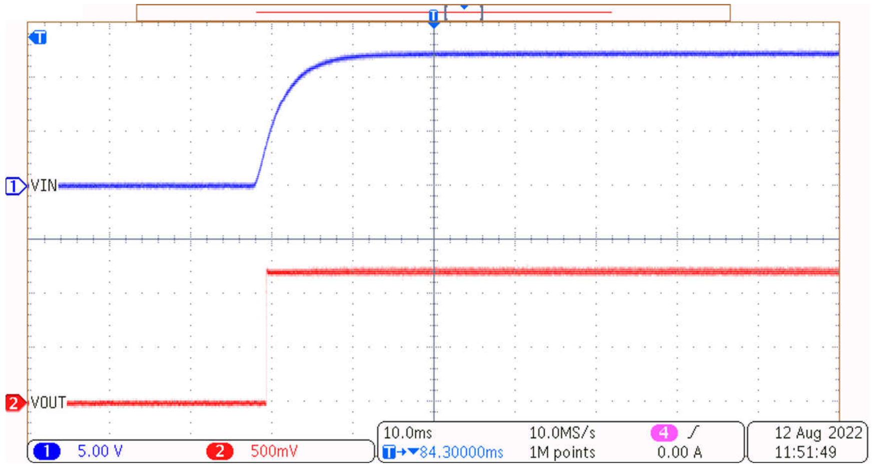


図 3-2. Startup Behavior

3.3.2 Shutdown

図 3-3 shows the shutdown behavior.

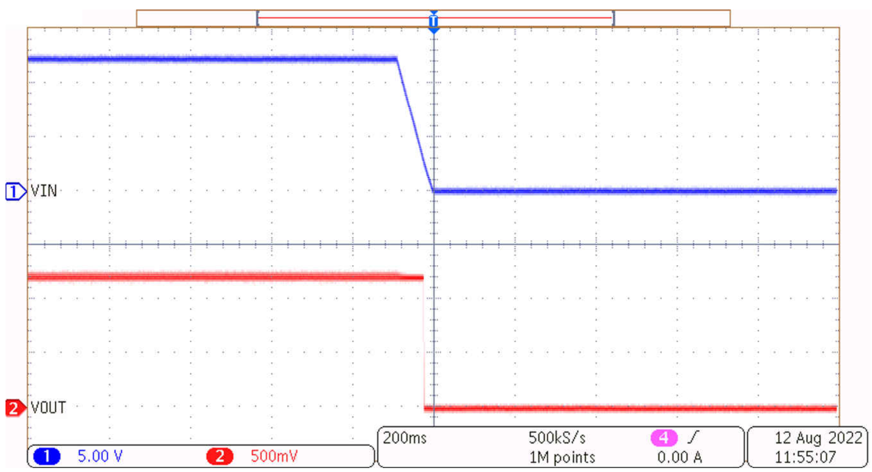


図 3-3. Shutdown Waveform

3.3.3 Load Transient

図 3-4 shows the transient response from 0.5-A to 3-A with 12-V input.

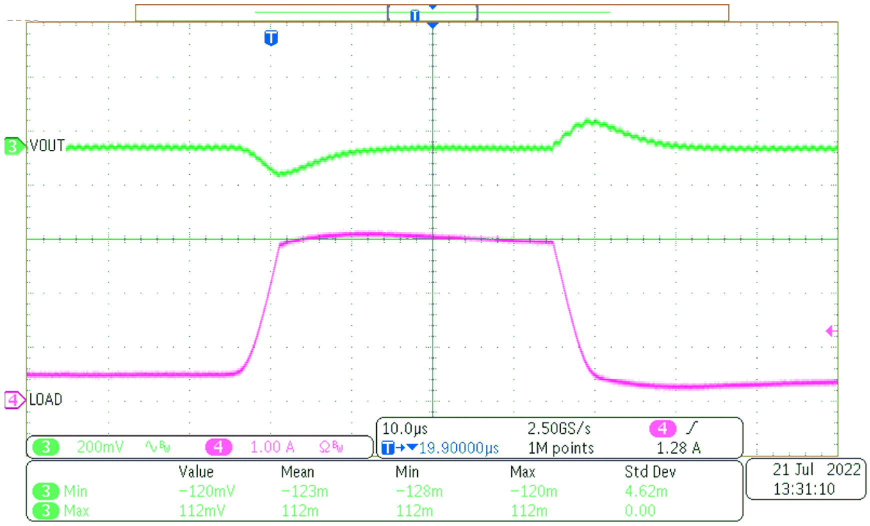


図 3-4. Load Transient 500-mA to 3-A with 12-Vin

図 3-5 shows the transient response from 0.5-A to 2-A with 12-V input.

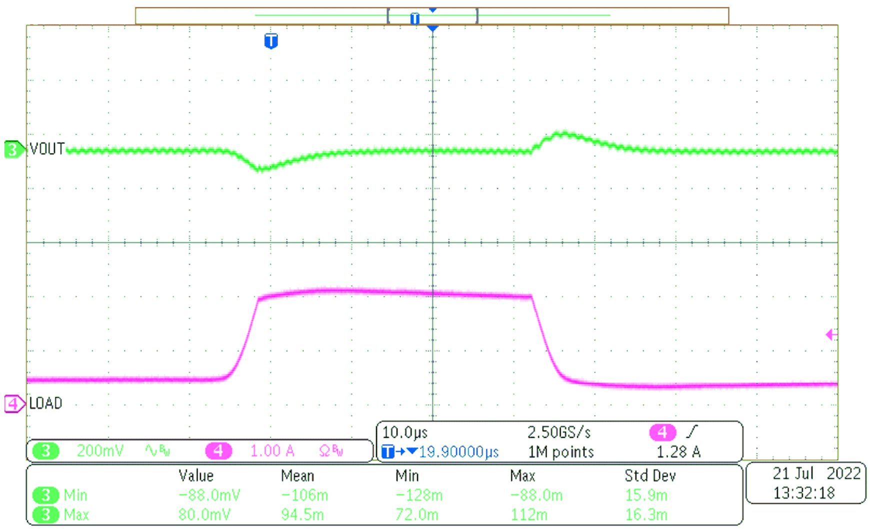


図 3-5. Load Transient 500-mA to 2-A with 12-Vin

図 3-6 shows the transient response from 0.5-A to 1-A with 12-V input.

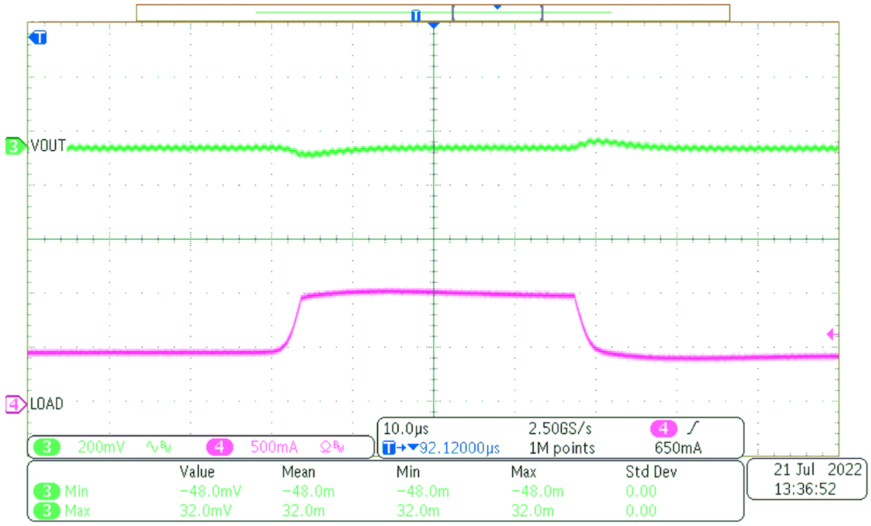


図 3-6. Load Transient 500-mA to 1-A with 12-Vin

A sinusoidal load is applied with 12-Vin. 図 3-7 shows the transition between Power Save Mode (PSM) during light load to Pulse Width Modulation (PWM) mode at heavy load.

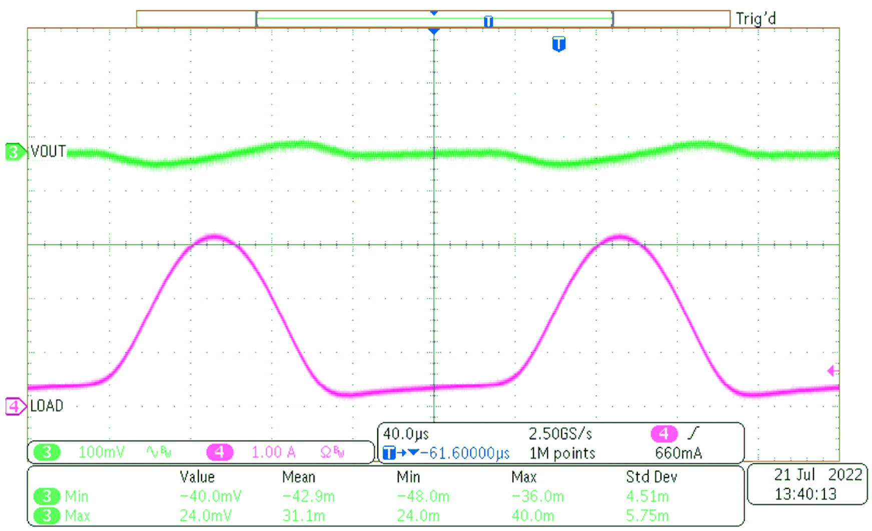


図 3-7. PSM to PWM Transition with 12-Vin

3.3.4 Output Ripple

図 3-8 shows the output voltage ripple at 3-A

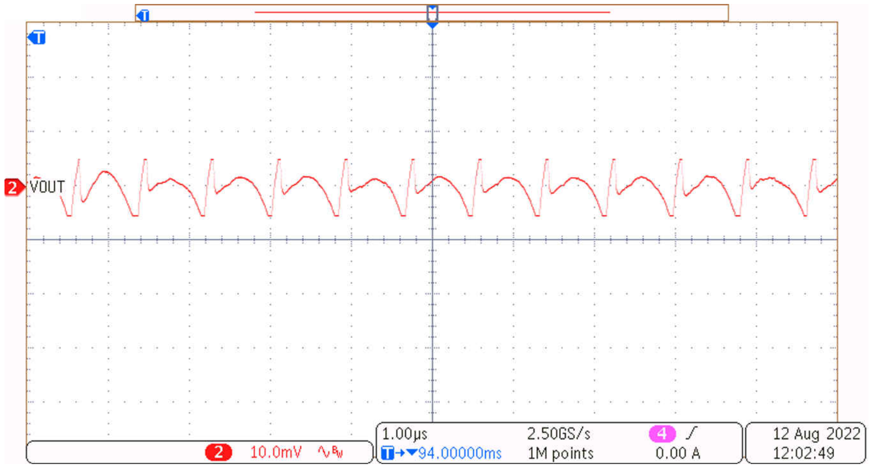


図 3-8. Vout Ripple at 3-A

3.3.5 Efficiency

図 3-9 shows the efficiency data with 12-V input.

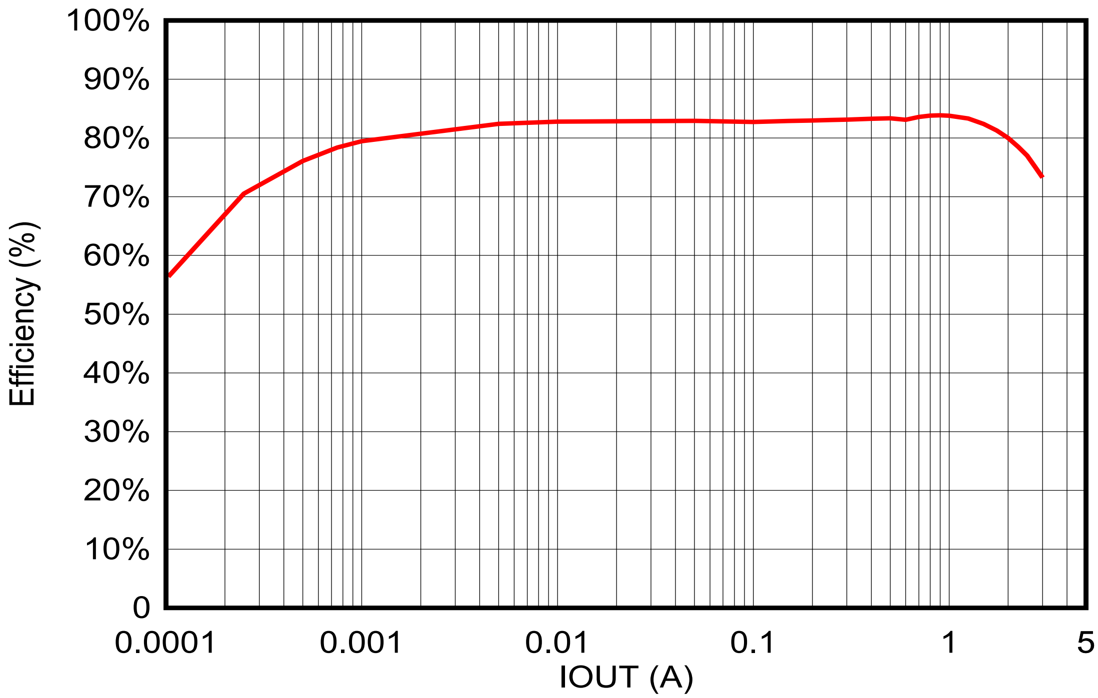


図 3-9. Efficiency Data with 12-Vin, 1.2-Vo, up to 3-A Load

3.3.6 Thermal Performance

Thermal performances measured at 2.5-A and 2-A loads. The TPSM82903 is designed for maximum junction temperature of 125°C. These images were captured under room temperature, which is approximately 27°C. The measurements were taken with no air flow present and the thermal camera placed horizontally at a distance of 5-inches from the camera. The peak temperature typically occurs at the center of the board where the inductor and the converter are located.

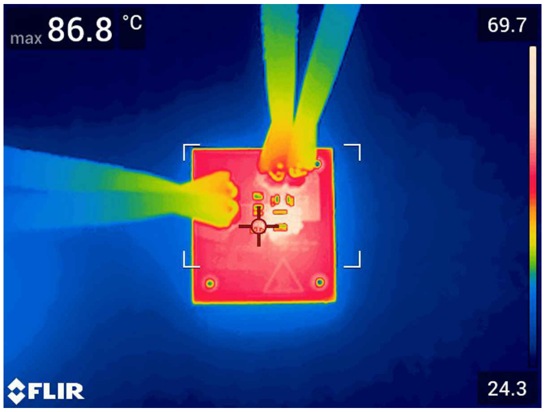


図 3-10. Thermal Image at Room Temperature with 12-Vin, 1.2-Vo, 2.5-A

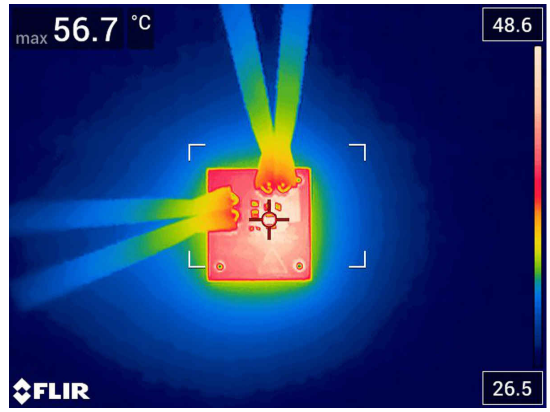


図 3-11. Thermal Image at Room Temperature with 12-Vin, 1.2-Vo, 2-A

3.3.7 Output Voltage vs. Output Current

図 3-12 shows the output voltage at room temperature at different VIN and across IOUT.

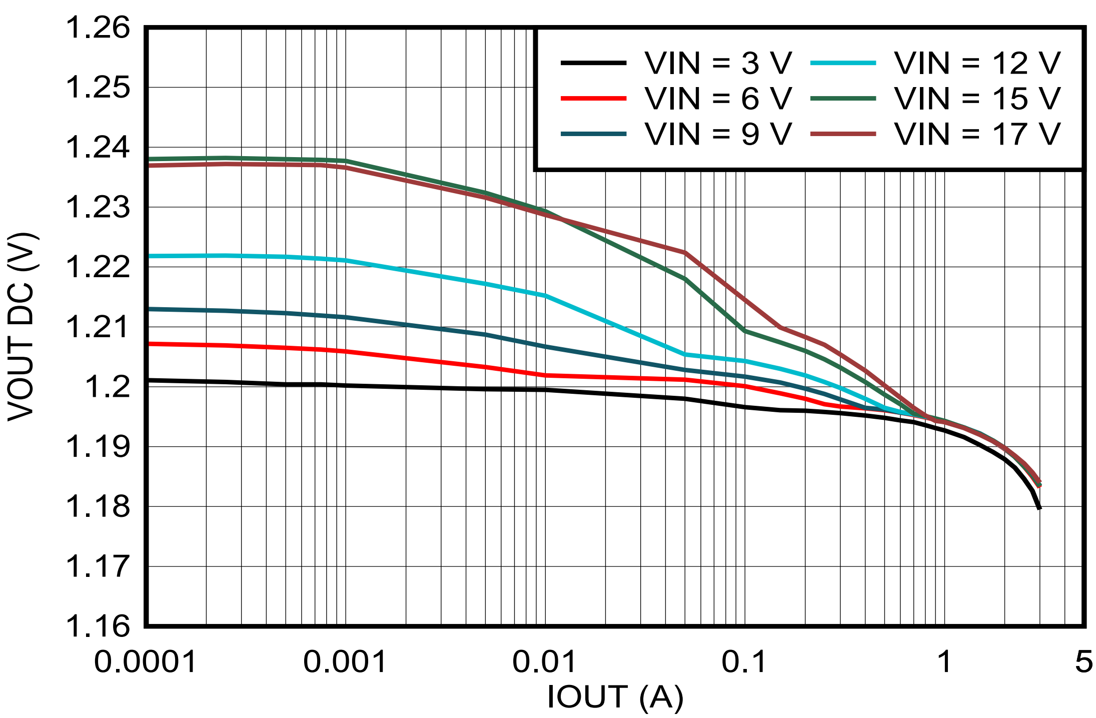


図 3-12. Output Voltage vs. Output Current at Room Temperature

4 Design and Documentation Support

4.1 Design Files

4.1.1 Schematics

To download the schematics, see the design files at TIDA-050055.

4.1.2 BOM

To download the bill of materials (BOM), see the design files at TIDA-050055.

4.1.3 PCB Layout Recommendations

4.1.3.1 Layout Prints

To download the layer plots, see the design files at TIDA-050055.

4.1.4 Altium Project

To download the Altium Designer® project files, see the design files at TIDA-050055.

4.1.5 Gerber Files

To download the Gerber files, see the design files at TIDA-050055.

4.1.6 Assembly Drawings

To download the assembly drawings, see the design files at TIDA-050055.

4.2 Documentation Support

1. Texas Instruments, *3-V to 17-V, High Efficiency and Low IQ Buck Converter Module with an Integrated Inductor* data sheet.
2. Texas Instruments, *Detailed Comparison Between TPSM82903 and TPS82130* application note.
3. Texas Instruments, *TPSM8290x Step-Down Converter Evaluation Module* user's guide.

4.3 サポート・リソース

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

リンクされているコンテンツは、該当する貢献者により、現状のまま提供されるものです。これらは TI の仕様を構成するものではなく、必ずしも TI の見解を反映したものではありません。TI の使用条件を参照してください。

4.4 Trademarks

TI E2E™ and DCS-Control™, and are trademarks of Texas Instruments.
Altium Designer® is a registered trademark of Texas Instruments.
すべての商標は、それぞれの所有者に帰属します。

重要なお知らせと免責事項

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

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

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

TI の製品は、TI の販売条件、または ti.com やかかる TI 製品の関連資料などのいずれかを通じて提供する適用可能な条項の下で提供されています。TI がこれらのリソースを提供することは、適用される TI の保証または他の保証の放棄の拡大や変更を意味するものではありません。

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

郵送先住所：Texas Instruments, Post Office Box 655303, Dallas, Texas 75265