Design Guide: TIDA-050055

High-Power Density 17-V, 3-A Buck Converter Module with Integrated Inductor Reference Design

Description

The TIDA-050055 reference design features the 3-V to 17-V VIN TPSM82903 buck converter with integrated inductor and was developed for applications that have very limited design space. The reference design steps the input voltage down to 1.2-V VOUT and is capable of delivering up to 3-A of load with high efficiency and low quiescent current. The total solution size including all external components is 20-mm^2. This design provides highly efficient DC/DC conversion with the lowest operating quiescent current (I_Q) in the industry, all with an incredibly small footprint.

Resources

TIDA-050055	Design Folder
TPSM82903	Product Folder

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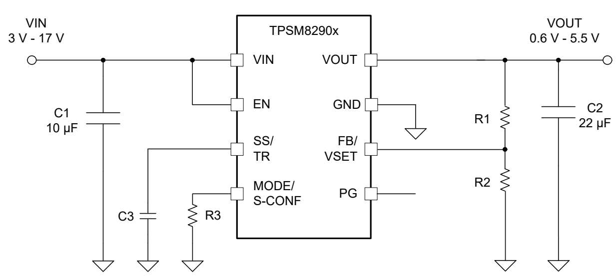
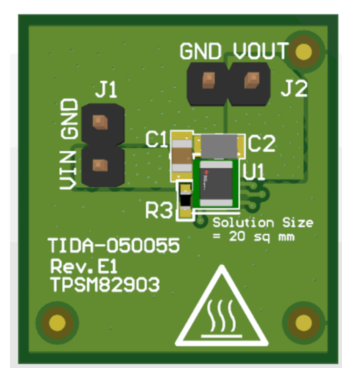
Features

- Small total solution size of 20-mm^2
- 150-mA/mm^2 power density
- 3-V to 17-V input voltage
- Up to 3-A continuous output current
- Low I_Q: 4-uA typical
- Integrated inductor
- Total system voltage accuracy of ±1.0% across temperature range (-40°C to 125°C)
- Operating junction temperature: -40°C to 125°C
- DCS-Control™ topology with 100% mode.

Applications

- Data Center and Enterprise Computing
- Wired Networking
- Wireless Infrastructure
- Factory Automation and Control
- Test and Measurement





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.

Table 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

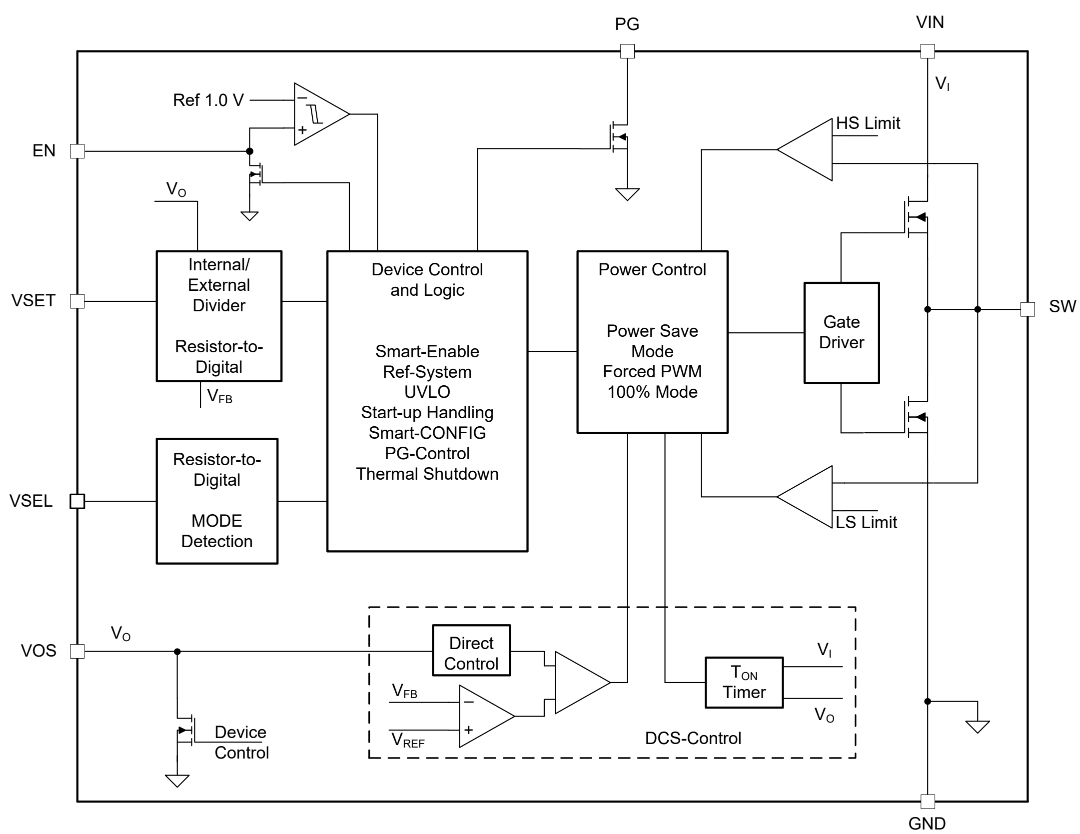


Figure 2-1. TIDA-050055 Block Diagram

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.

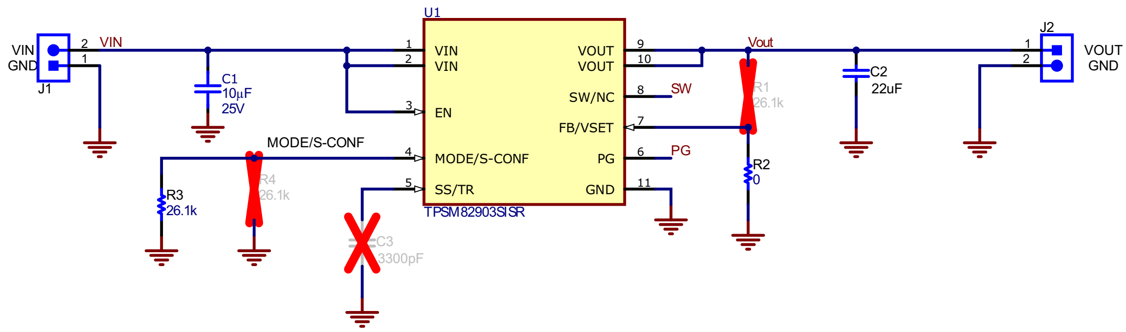


Figure 2-2. Buck Converter Circuit Design Using TPSM82903

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

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

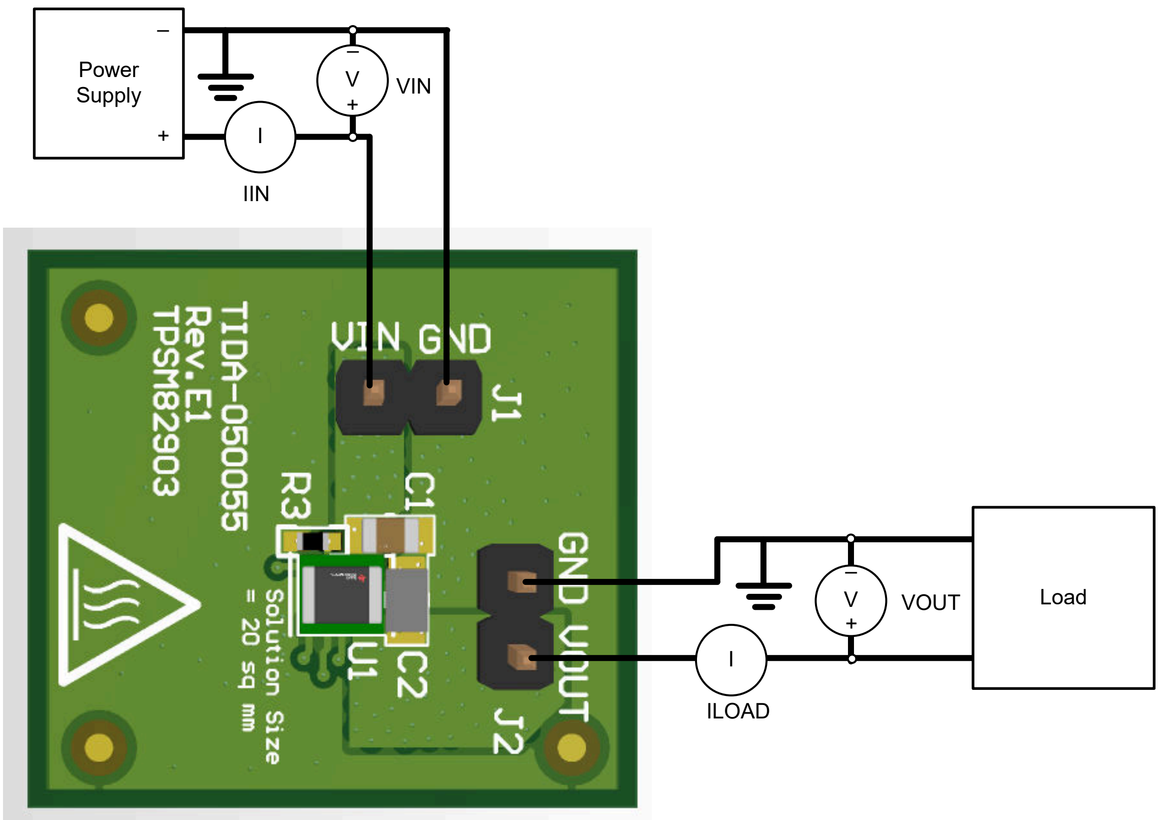


Figure 3-1. Test Setup

3.3 Test Results

3.3.1 Startup

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

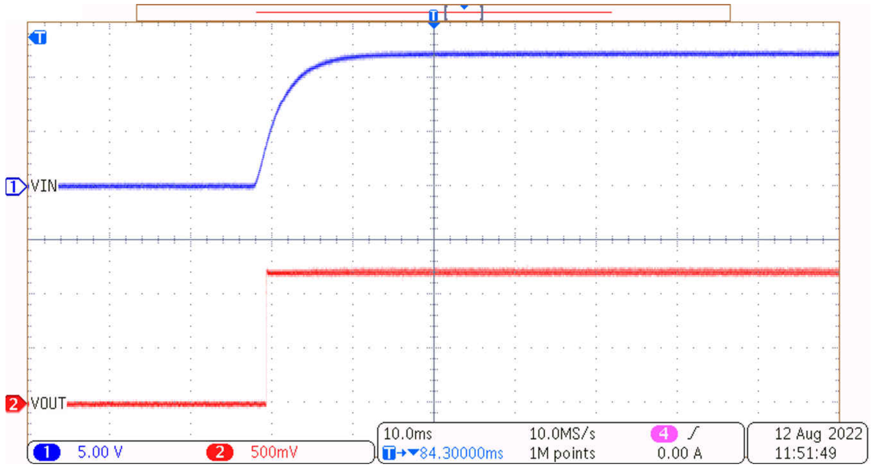


Figure 3-2. Startup Behavior

3.3.2 Shutdown

Figure 3-3 shows the shutdown behavior.

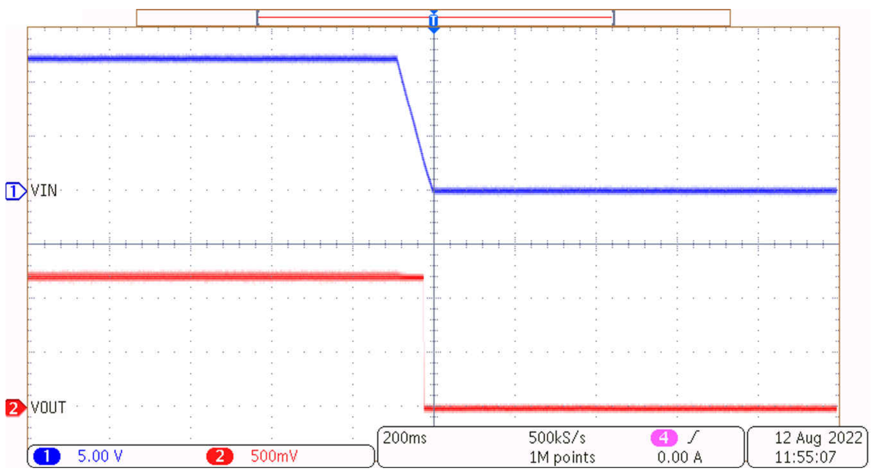


Figure 3-3. Shutdown Waveform

3.3.3 Load Transient

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

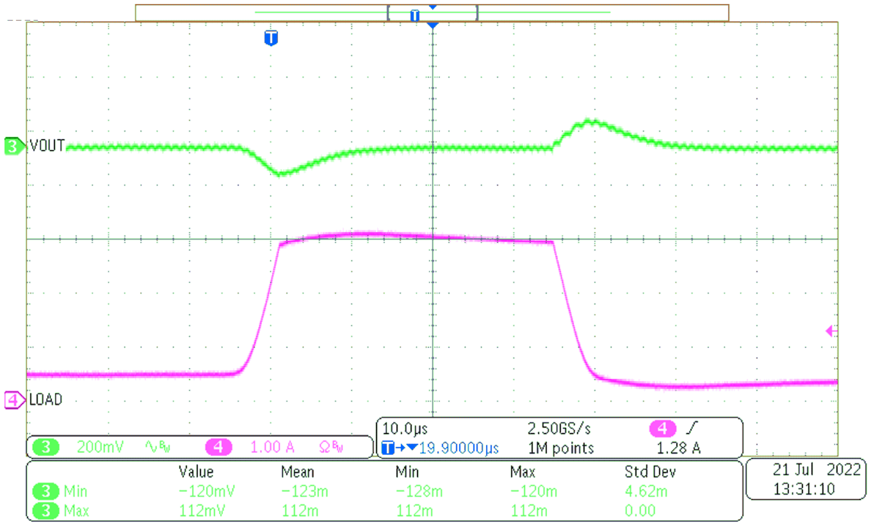


Figure 3-4. Load Transient 500-mA to 3-A with 12-Vin

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

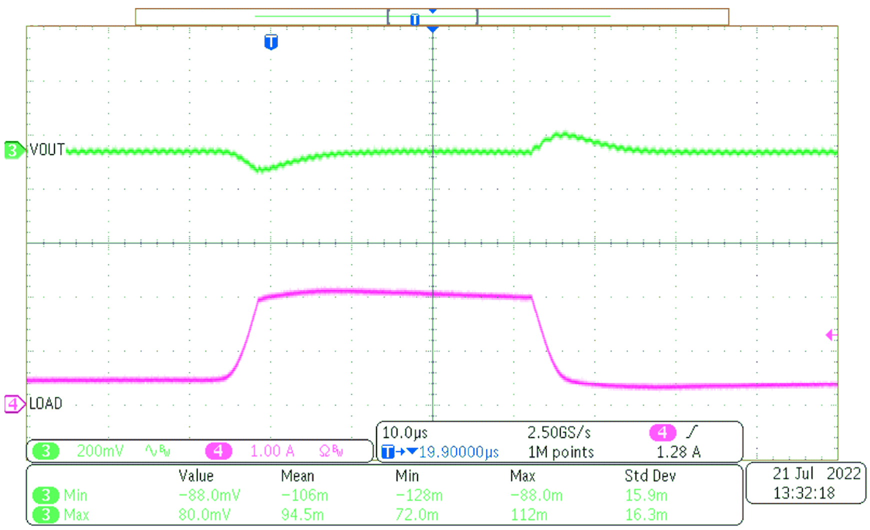


Figure 3-5. Load Transient 500-mA to 2-A with 12-Vin

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

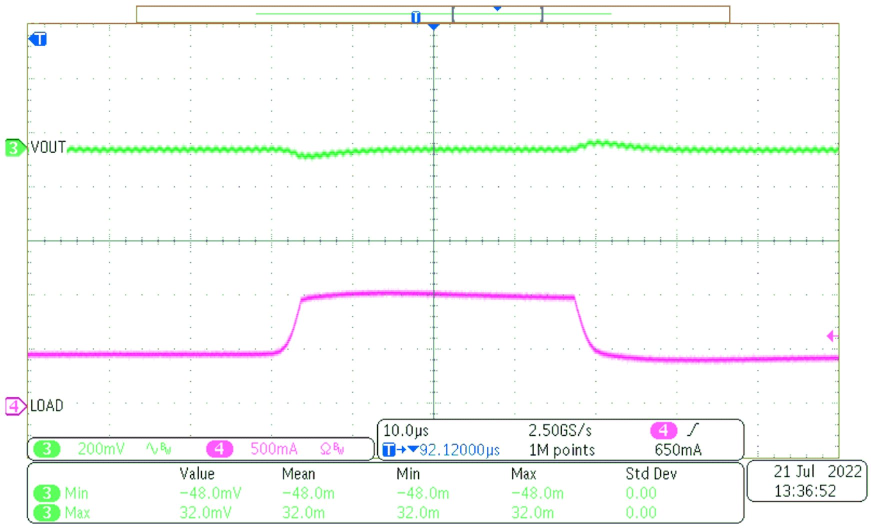


Figure 3-6. Load Transient 500-mA to 1-A with 12-Vin

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

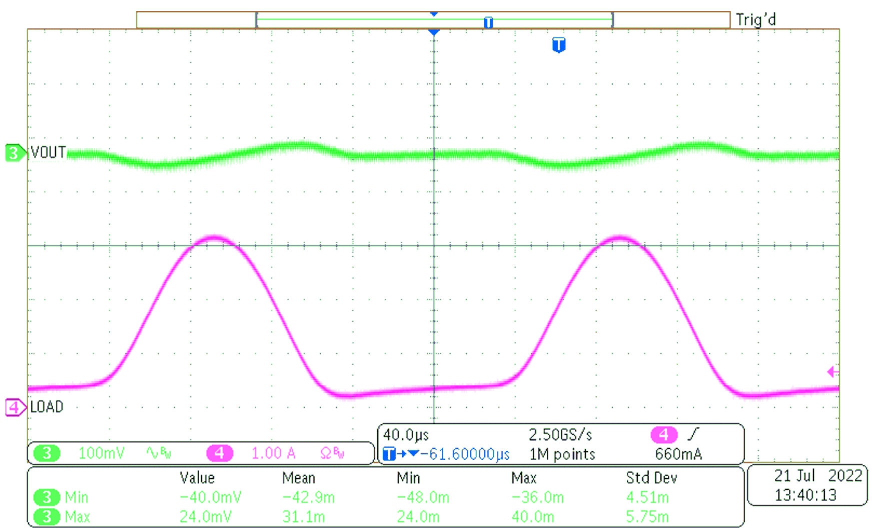


Figure 3-7. PSM to PWM Transition with 12-Vin

3.3.4 Output Ripple

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

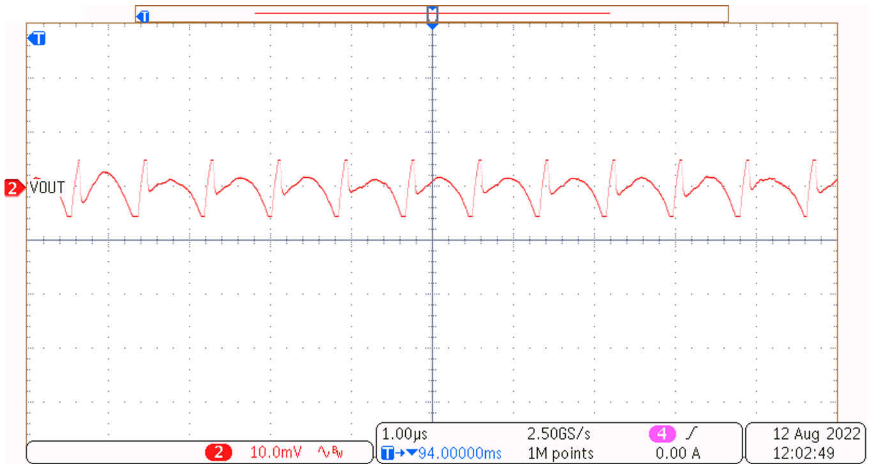


Figure 3-8. Vout Ripple at 3-A

3.3.5 Efficiency

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

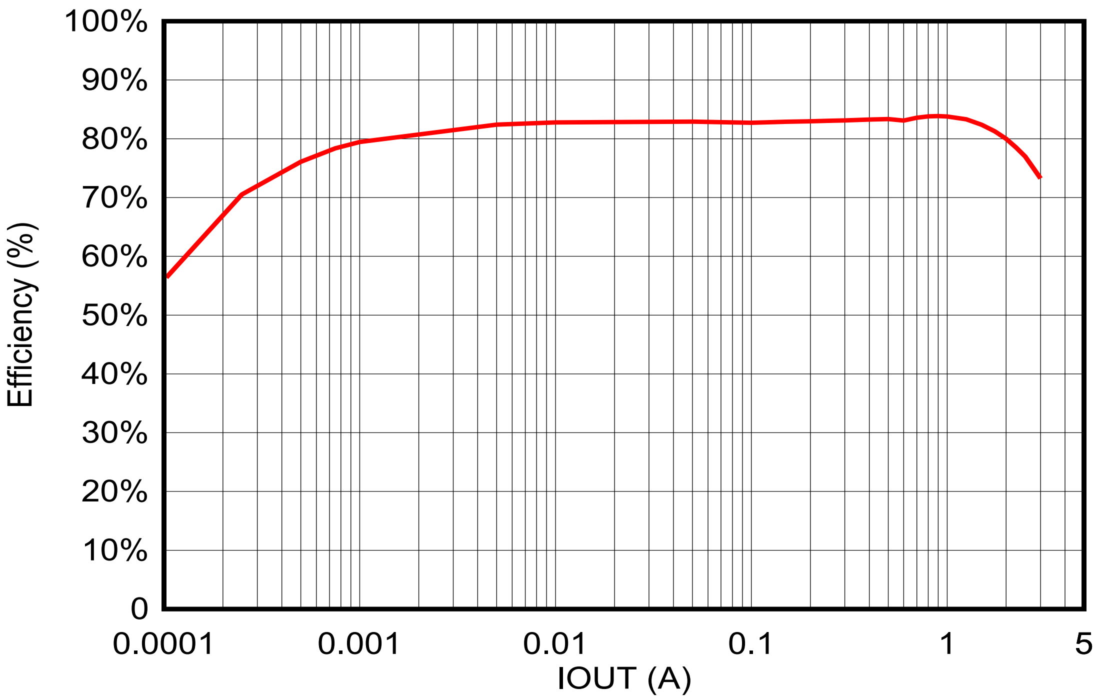


Figure 3-9. Efficiency Data with 12-Vin, 1.2-Vo, up to 3-A Load

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.

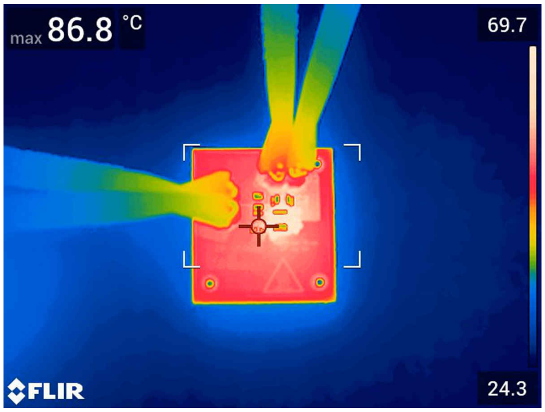


Figure 3-10. Thermal Image at Room Temperature with 12-Vin, 1.2-Vo, 2.5-A

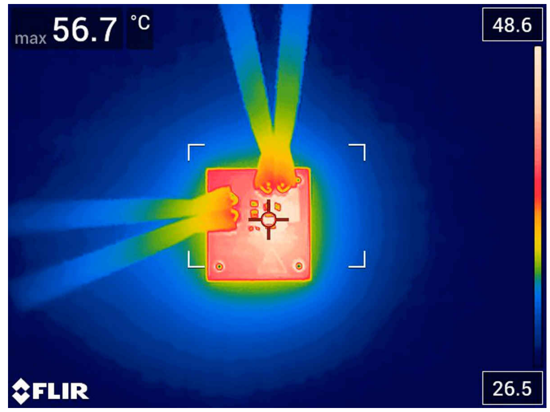


Figure 3-11. Thermal Image at Room Temperature with 12-Vin, 1.2-Vo, 2-A

3.3.7 Output Voltage vs. Output Current

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

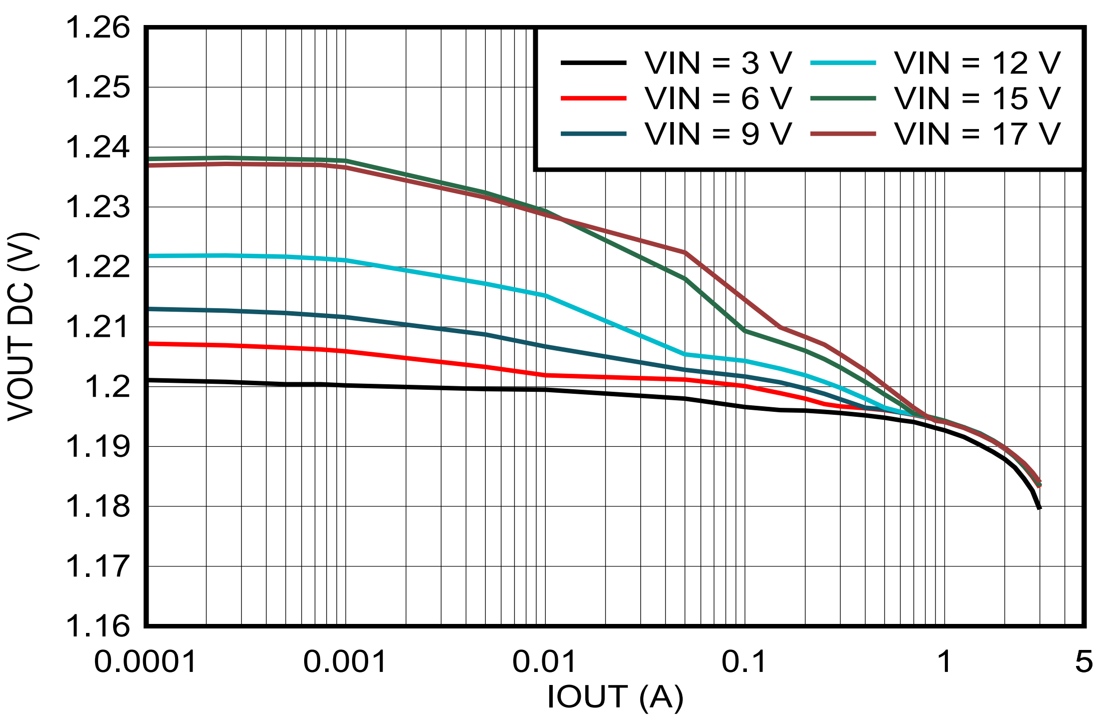


Figure 3-12. Output Voltage vs. Output Current at Room Temperature

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 Support Resources

TI E2E™ support forums are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

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