Design Guide: TIDA-050052

High Power Density 17-V, 3-A Buck Converter Reference Design

TEXAS INSTRUMENTS

Description

The TIDA-050052 reference design features the 3-V to 17-V VIN TPS62903 buck converter 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 inductor used in this design is 1-uH with about 48-mΩ DCR. The total solution size including all external components is 25-mm^2. This design provides highly efficient DC/DC conversion with the lowest operating quiescent current (IQ) in the industry, all with an incredibly small footprint.

Resources

TIDA-050052	Design Folder
TPS62903	Product Folder

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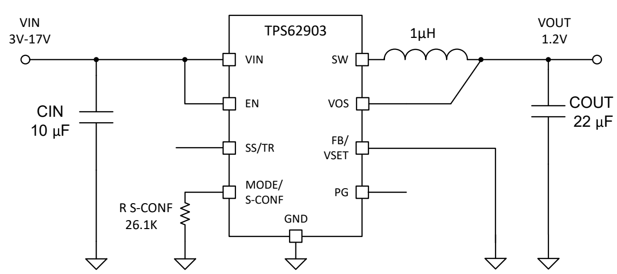
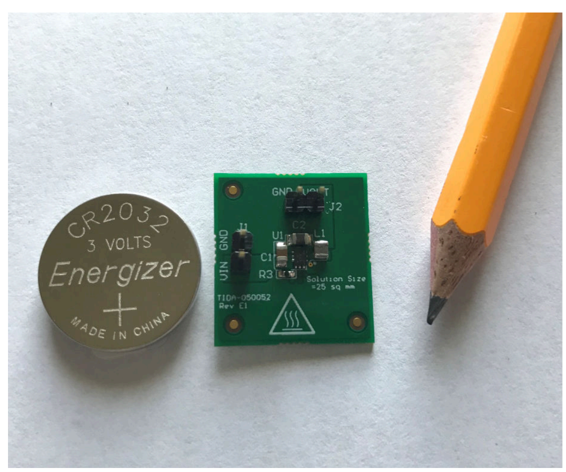
Features

- Small total solution size of 25-mm^2
- 120-mA/mm^2 power density
- 3-V to 17-V input voltage
- Up to 3-A continuous output current
- Low IQ: 4-uA typical
- Total system voltage accuracy of ±1.25% across temperature range (-40°C to 150°C)
- Operating junction temperature: -40C to 150C
- DCS-Control™ topology with 100% mode.

Applications

- Building Automation
- Factory Automation and Control
- Data Center and Enterprise Computing
- PC and Notebooks
- Power Delivery





1 System Description

The TIDA-050052 is designed by using the TPS62903 high efficiency and low IQ DC/DC Buck converter. 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 IQ are ideal for battery operated systems. The design allows to efficiently use the battery power and extend its life time.

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		150	C
Output Capacitor Discharge		Enabled		

2 System Overview

2.1 Block Diagram

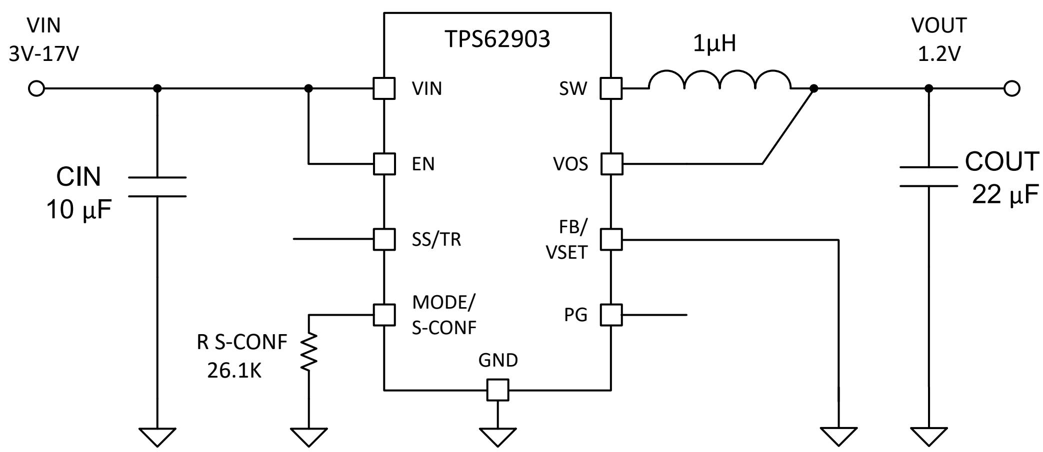


Figure 2-1. TIDA-050052 Block Diagram

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 TPS62903 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 TPS62903 has been enabled at least once since the supply voltage was applied.
- **Soft Start:** The SS/TR pin left floating for fastest start up time.

2.3 Highlighted Products

The TPS62903 is a highly-efficient, small, and flexible synchronous step-down DC-DC converter that is easy to use. A selectable switching frequency of 2.5-MHz or 1.0-MHz allows the use of small inductors and provides fast transient response. The device supports high VOUT accuracy of ± 1.25% 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 TPS62903 can automatically enter power save mode (if auto PFM/PWM is selected) 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, if enabled, 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 small 9-pin VQFN package measuring 1.50-mm × 2.00-mm with 0.5-mm pitch.

2.4 System Design Theory

2.4.1 Buck Converter Circuit Design Using TPS62903

The TPS62903 is optimized to work within a range of external components. The LC output filters inductance and capacitance have to be considered together, creating a double pole, responsible for the corner frequency of the converter. See the TPS62903 data sheet for more details.

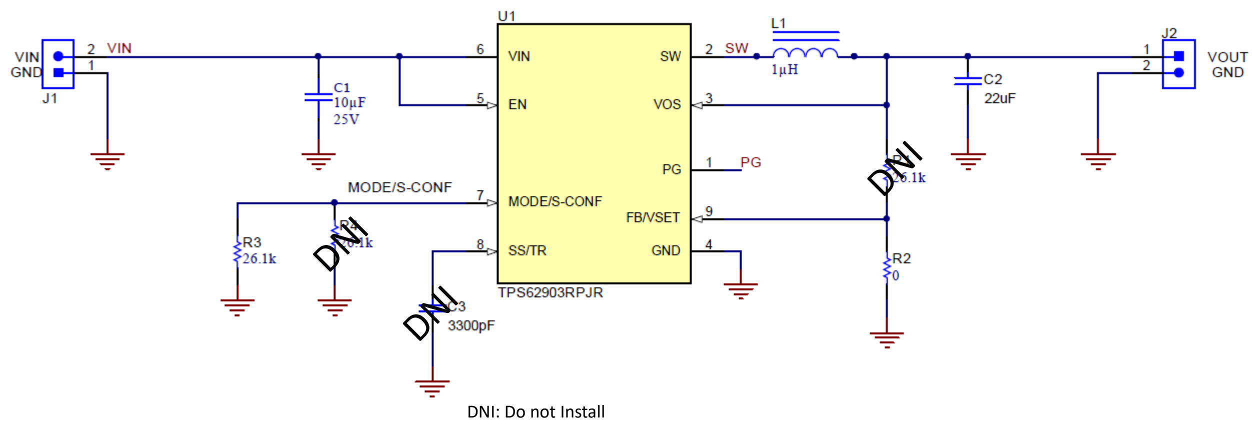


Figure 2-2. Buck Converter Circuit Design Using TPS62903

The TIDA-050052 is designed with a nominal 1-μH inductor to support 1.2-V output voltage. A shielded wire wound Inductor from Murata (DFE201612E-1R0M=P2) is used in this design. It has 4-A current saturation and 48-mΩ maximum DCR. 1-μH inductance is ideal for size and ripple given the VOUT of this design is only 1.2-V. Larger values can be used to achieve a lower inductor current ripple but they can have a negative impact on efficiency and transient response. Smaller values than 1-μH will cause a larger inductor current ripple which causes a larger negative inductor current in forced PWM mode at low or no output current.

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 Cal-Chip electronics (GMC21X7R106K25NT) is used as an input capacitor. It 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 (C2012X7S1A226M125AC) from TDK is chosen. Both the input and the output capacitors are X7R to cover the full temperature range of 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-050052 board 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-050052.

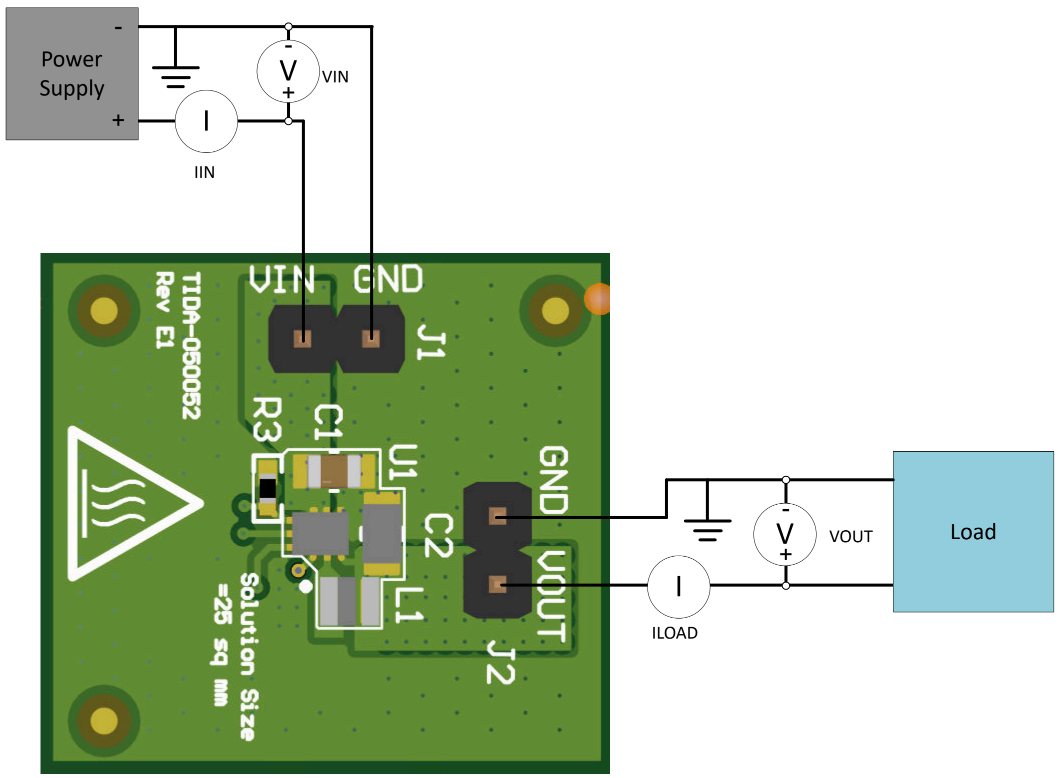


Figure 3-1. Test Setup

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.

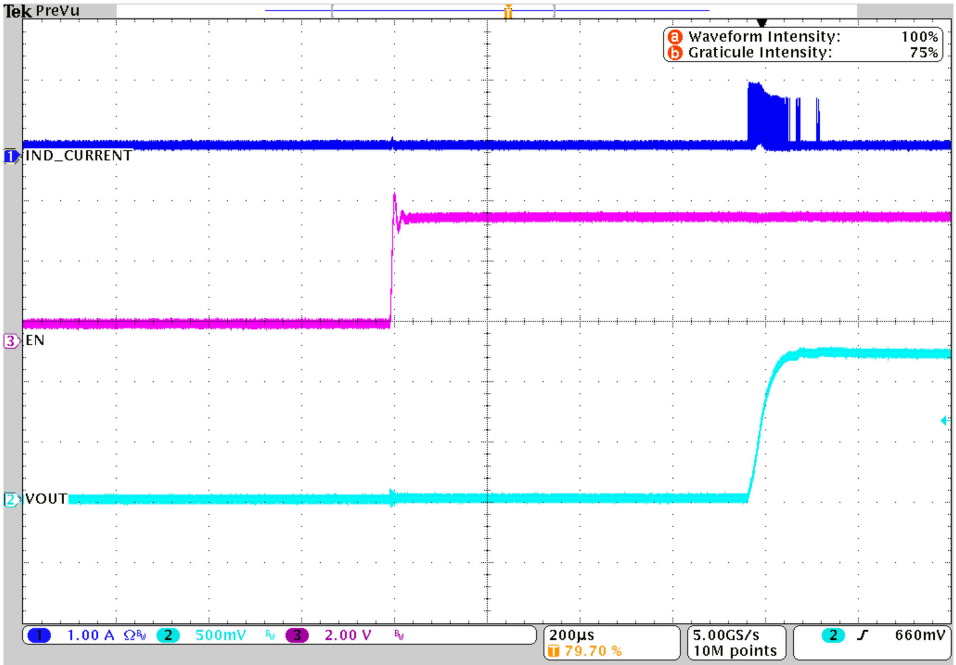


Figure 3-2. Startup Behavior

3.3.2 Load Transient

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

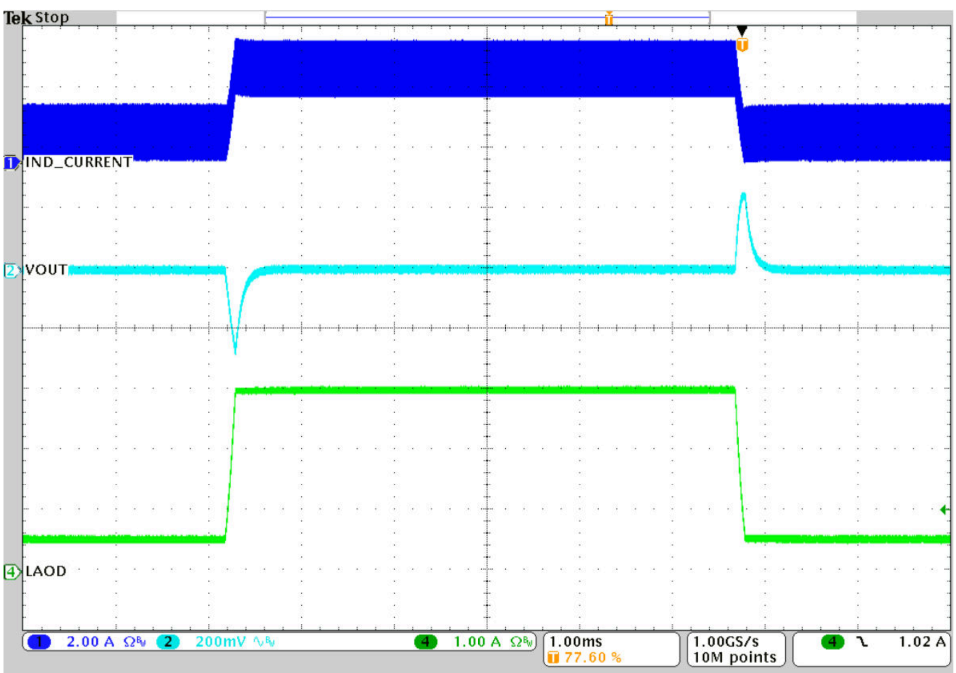


Figure 3-3. Load Transient 500-mA to 3-A with 12-Vin

Figure 3-4 shows the transient response from 1-A to 3-A with 12-V input.

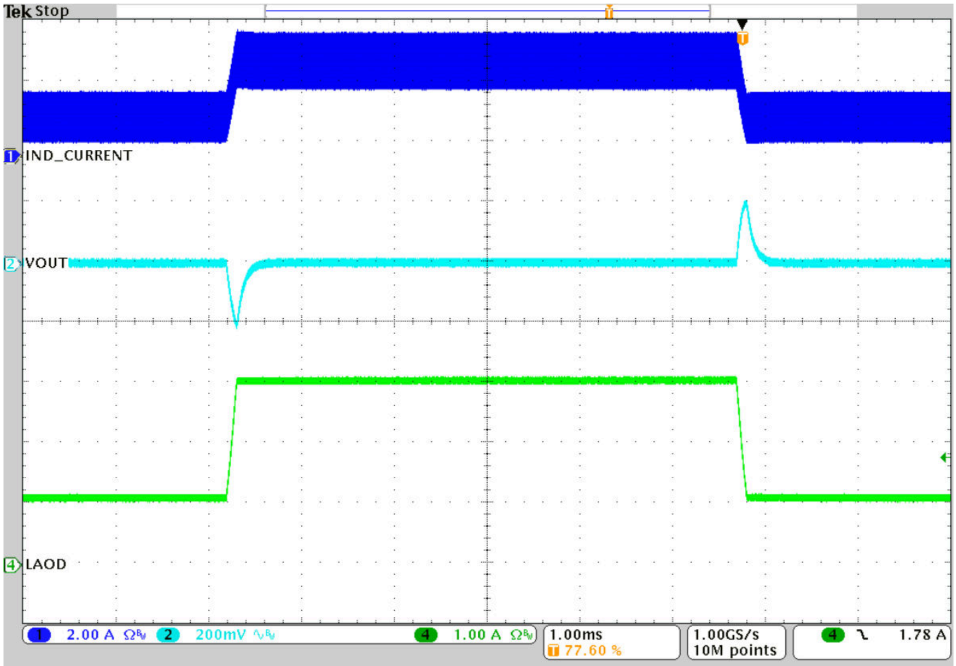


Figure 3-4. Load Transient 1-A to 3-A with 12-Vin

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

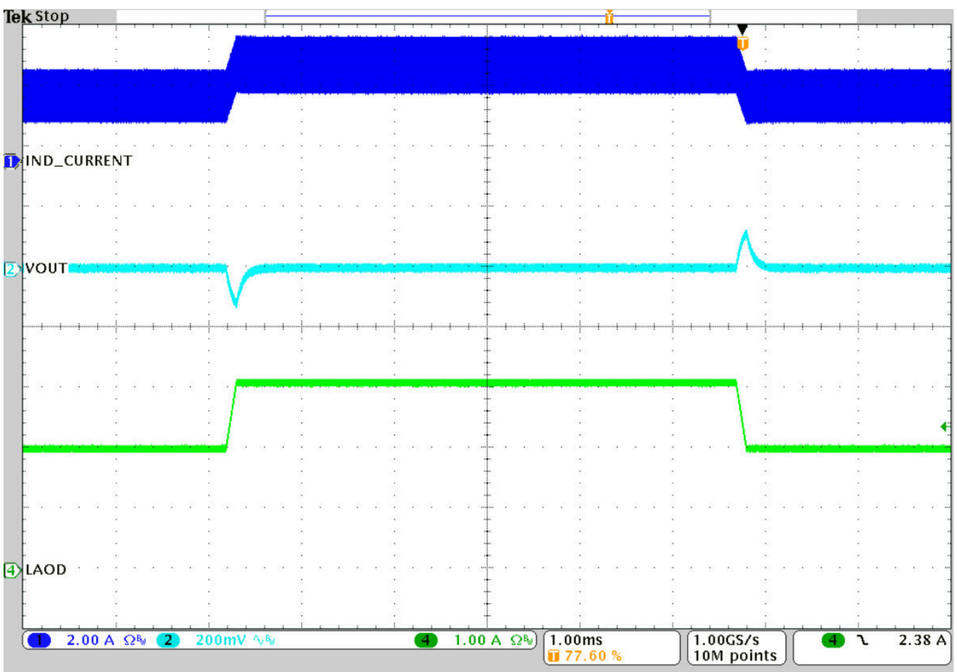


Figure 3-5. Load Transient 2-A to 3-A with 12-Vin

A sinusoidal load is applied with 5-Vin. Figure 3-6 shows the transition between Power Save Mode (PSM) during light load to Pulse Width Modulation (PWM) mode at heavy load.

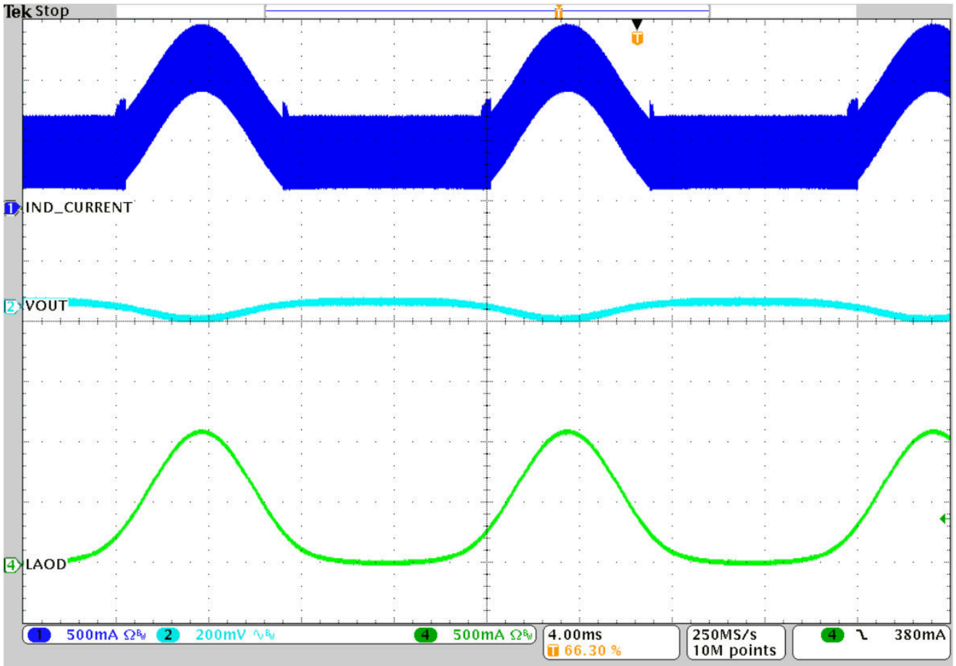


Figure 3-6. PSM to PWM Transition with 5-Vin

3.3.3 Output Ripple

Figure 3-7 shows the output voltage ripple at 3-A

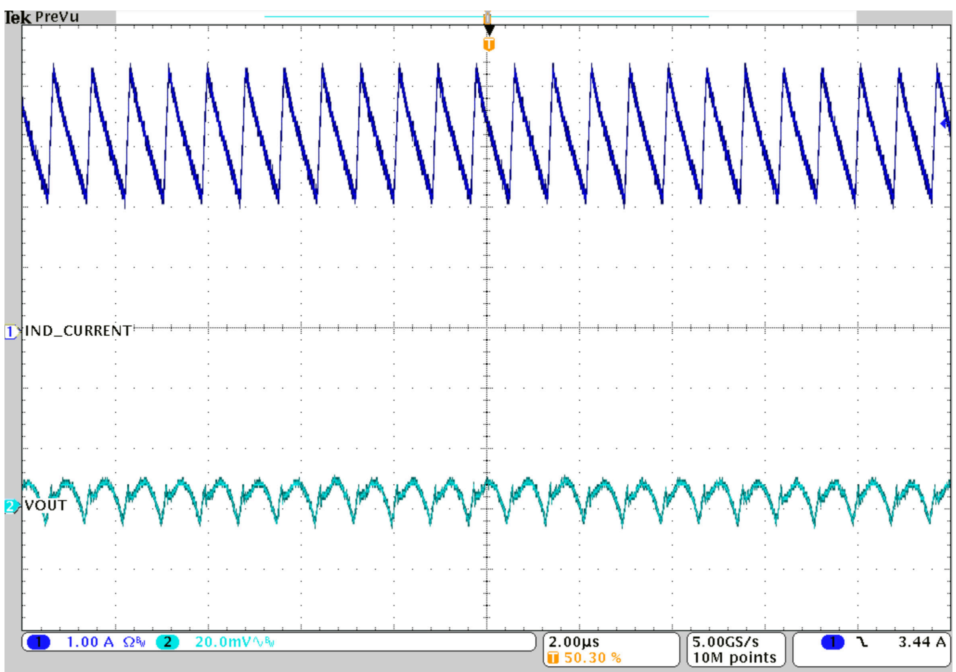


Figure 3-7. Vout ripple at 3-A

3.3.4 Efficiency

Figure 3-8 shows the efficiency data with 12-V input.

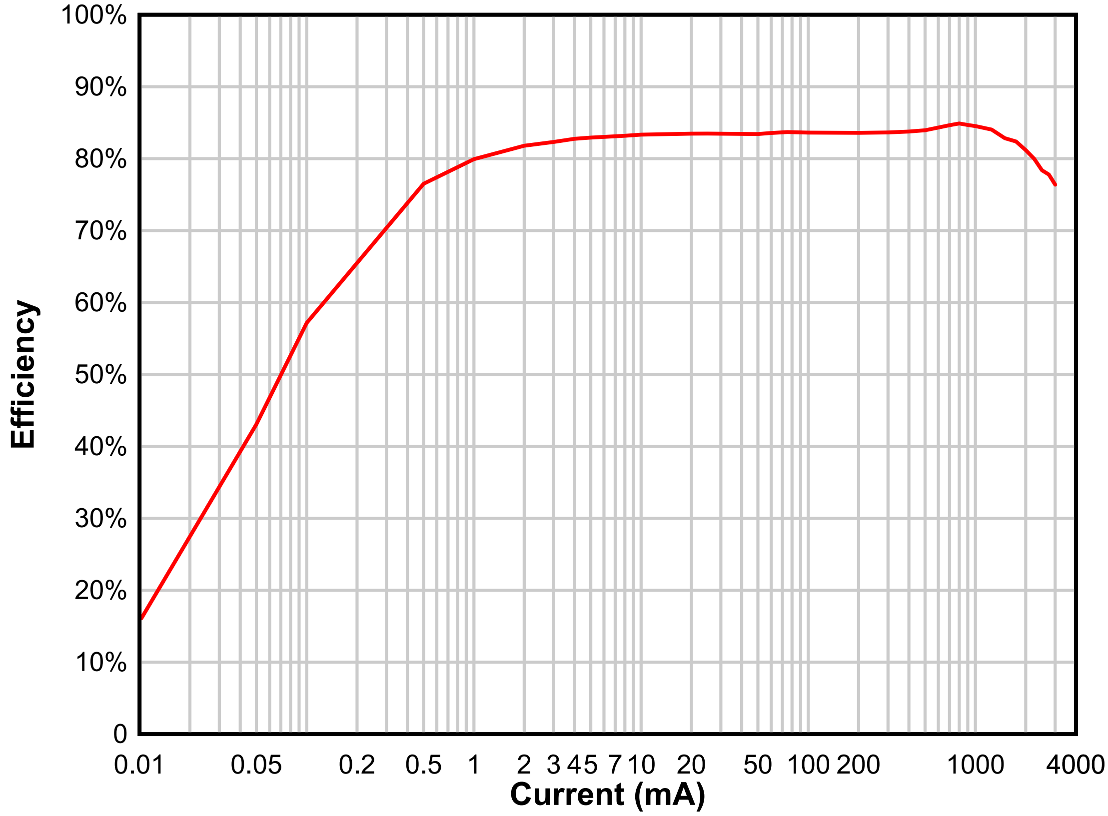


Figure 3-8. Efficiency Data with 12-Vin, 1.2-Vo, up to 3-A Load.

3.3.5 Thermal Performance

Thermal Performance at 3-A, 2-A, and 1-A Load. The images are taken under room temperature of about 27C. No air flow and the thermal camera placed horizontal 5-inches from the camera. The peak temperature measured right at the center of the board where the inductor and the converter are located. The TPS62903 is designed for maximum junction temperature of 150C.

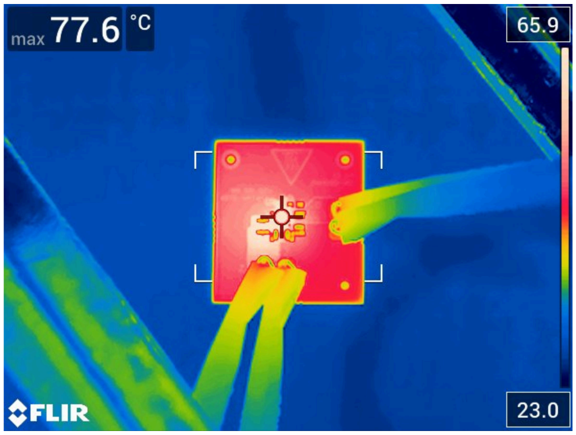


Figure 3-9. Thermal Image at Room Temperature with 12-Vin, 1.2-Vo, 3-A

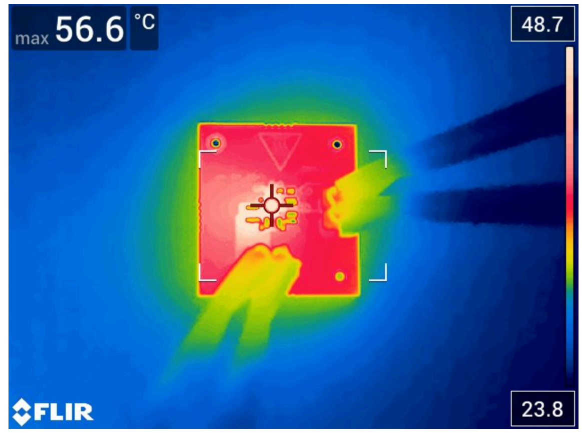


Figure 3-10. Thermal Image at Room Temperature with 12-Vin, 1.2-Vo, 2-A

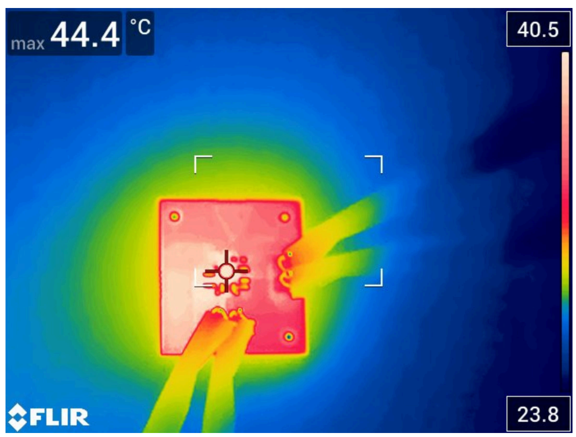


Figure 3-11. Thermal Image at Room Temperature with 12-Vin, 1.2-Vo, 1-A.

3.3.6 Output Voltage vs. Output Current

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

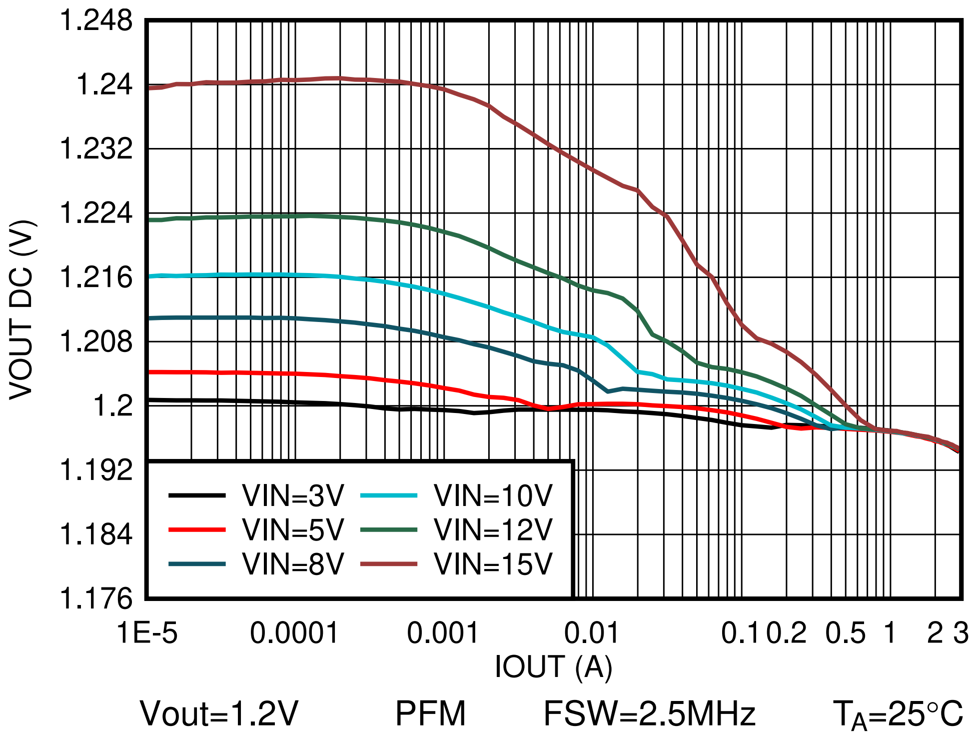


Figure 3-12. Output Voltage vs. Output Current at Room Temperature

4 Design and Documentation Support

4.1 Design Files

4.1.1 Schematics

To download the schematics, see the design files at TIDA-050052.

4.1.2 BOM

To download the bill of materials (BOM), see the design files at TIDA-050052.

4.1.3 PCB Layout Recommendations

4.1.3.1 Layout Prints

To download the layer plots, see the design files at TIDA-050052.

4.1.4 Altium Project

To download the Altium Designer® project files, see the design files at TIDA-050052.

4.1.5 Gerber Files

To download the Gerber files, see the design files at TIDA-050052.

4.1.6 Assembly Drawings

To download the assembly drawings, see the design files at TIDA-050052.

4.2 Documentation Support

1. Texas Instruments, 3-V to 17-V, High Efficiency and Low IQ Buck Converter in 1.5mm x 2-mm QFN Package data sheet.
2. Texas Instruments, TPS62902 3-V to 17-V, Synchronous Buck Converters in 1.5 mm × 2 mm QFN Package data sheet.
3. Texas Instruments, TPS62901, 3-V to 17-V, High Efficiency and Low IQ Buck Converter data sheet.
4. Texas Instruments, Comparison of TPS6290x vs. TPS621x0 application note.

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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5 About the Author

Tahar Allag is Systems Engineer at Texas Instruments for over a decade responsible for defining new products and technology platforms based on our marketing strategy and business opportunities. Tahar also provides application support, and system design for customers to understand their overall product ecosystem and how best to use mid-voltage buck converters.