Design Guide: TIDA-050053

8-V to 16-V Input, 1.2-A, –12-V Inverting Power Supply Reference Design

TEXAS INSTRUMENTS

Description

This inverting power supply reference design supports a –12-V output voltage at up to 1.2 A of current from a 8-V to 16-V input. Such a negative voltage is required for many applications such as optical module biasing, line drivers, operational amplifier and other low-power applications. Using the TPS62933 power converter enables a very simple negative voltage inverter (inverting buck-boost) design to create a –12-V negative output voltage at 1.2-A currents.

Resources

TIDA-050053	Design Folder
TPS62933	Product Folder

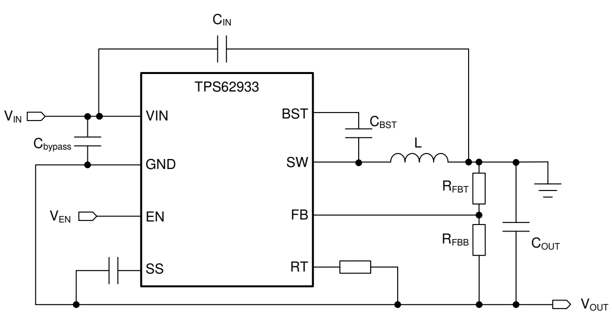
Ask our TI E2E™ support experts

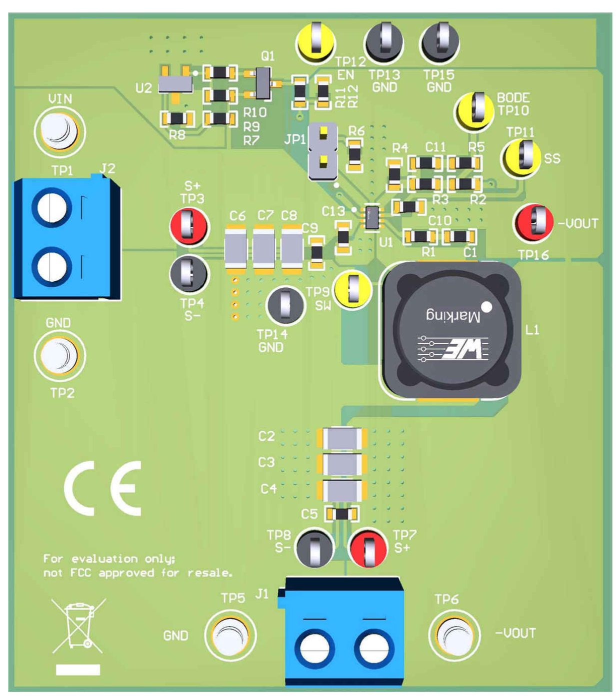
Features

- Simple inverting power supply design
- Wide input voltage range of 8 V to 16 V
- Up to 1.2-A continuous output current
- Low noise (less than 1% output ripple)
- Peak current control mode with internal compensation
- Operating junction temperature: –40°C to 150°C

Applications

- Optical module
- Macro remote radio unit (RRU)
- Baseband unit (BBU)
- Mobile smart TV





1 System Description

The TIDA-050053 enables a very simple inverting buck-boost design where the output voltage is inverted or negative with respect to ground by using the TPS62933 high efficiency and low-I_Q synchronous buck converter. This design demonstrates an inverting power supply to generate a –12-V rail at up to 1.2 A of current from 8-V to 16-V input voltage. The optimized internal loop compensation eliminates external compensation components. A negative voltage is required in low-current negative rails for an operational amplifier, optical module biasing, or line drives and other applications.

Table 1-1. Key System Specifications

Design Parameter	Example Value
Input voltage range	12-V nominal 8 V to 16 V
Output voltage range	–12 V
Transient response, 50% load step	ΔV_O = ±5%
Output ripple voltage	1%
Output current rating	1.2 A

2 System Overview

2.1 Block Diagram

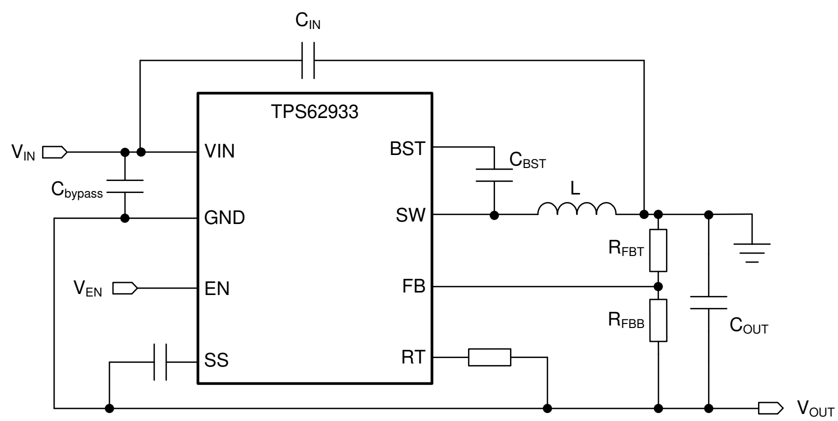


Figure 2-1. TIDA-050053 Block Diagram

2.2 Design Considerations

Details of the main differences for when the buck converter is configured as an inverting buck boost follow:

- The input voltage that can be applied to an inverting buck-boost converter IC is less than the input voltage that can be applied to the same buck converter IC. This is because the ground pin of the IC is connected to the (negative) output voltage. Therefore, the input voltage across the device is V_{IN} to V_{OUT}, not V_{IN} to ground. Thus, the input voltage range of the TPS62933 device is 3.8 V to 30 V – V_{OUT}, where V_{OUT} is a positive value.
- The output voltage is the same as when configured as a buck converter, but negative. So, set the output voltage for the inverting buck-boost topology from –0.8 V to –22 V. The output voltage is set the same way as in the buck configuration, with two resistors connected to the FB pin.
- In the buck configuration, the average inductor current equals the average output current because the inductor always supplies current to the load during both the on and off times of the control MOSFET. However, in the inverting buck-boost configuration, the load is supplied with current only from the output capacitor and is completely disconnected from the inductor during the on time of the control MOSFET. During the off time, the inductor connects to both the output capacitor and the load. Thus, the output current that the device can hold in the buck-boost application is lower than in the buck application. The output current will vary with the value of inductor, input voltage, and output voltage.

- The TPS62933 device is enabled when the voltage at the EN pin trips its threshold, and the input voltage is above the UVLO threshold. The device stops operation when the voltage on the EN pin falls below its threshold, or the input voltage falls below the UVLO threshold. However, when configured as a buck-boost application, the GND pin of the TPS62933 device is tied to the negative output voltage and not the zero voltage (system ground), which can cause difficulties enabling or disabling the device. So, level-shifting circuitry is needed to solve the problem.

2.3 Highlighted Products

The TPS62933 is a high-efficiency, easy-to-use synchronous buck converter with a wide input voltage range of 3.8 V to 30 V, and supports up to 3-A continuous output current and 0.8-V to 22-V output voltage.

The device employs fixed-frequency *Peak Current Control* mode for fast transient response and good line and load regulation. The optimized internal loop compensation eliminates external compensation components over a wide range of output voltage and operation frequency. *Pulse Frequency Modulation* (PFM) mode maximizes the light load efficiency. The *Ultra Low Quiescent* (ULQ) feature is extremely beneficial for long battery lifetime in low-power operation. The switching frequency can be set by the configuration of the RT pin in the range of 200 kHz to 2.2 MHz, which allows the user to optimize system efficiency, filtering size, and bandwidth. The soft-start time can be adjusted by the external capacitor at the SS pin, which can minimize the inrush current when driving large capacitive load. This device also has the frequency spread spectrum feature, which helps in lowering EMI noise.

The device provides complete protections including OTP, OVP, UVLO, cycle-by-cycle OC limit, and UVP with Hiccup mode. This device is in a small SOT583 (1.6 mm × 2.1 mm) package with 0.5-mm pin pitch, and has an optimized pin-out for easy PCB layout and promotes good EMI performance.

2.4 System Design Theory

2.4.1 Inverting Power Supply Design Using TPS62933

The inverting buck-boost topology is similar to the buck topology. In the buck configuration, shown in Figure 2-2, the positive connection (V_{OUT}) is connected to the inductor, and the return connection is connected to the integrated circuit (IC) ground (GND). However, in Figure 2-1 illustrating the inverting buck-boost configuration, the IC GND is used as the negative output voltage pin. What was the positive output in the buck configuration is used as the GND. This inverting topology allows the output voltage to be inverted and always lower than the GND.

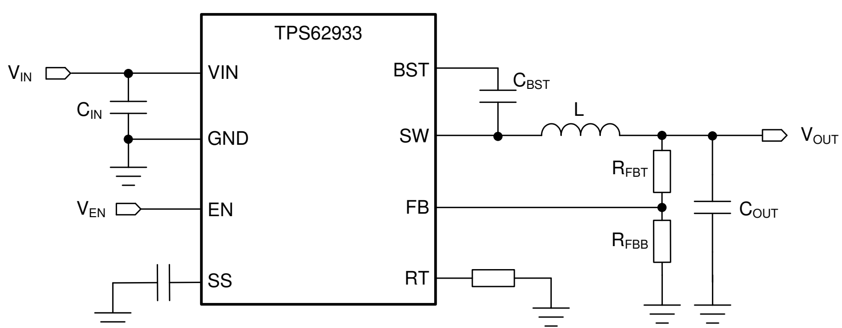


Figure 2-2. Buck Converter Application

The circuit operation in the inverting buck-boost topology is different from the buck topology. During the on time of the control MOSFET, the inductor is charged with current while the output capacitor supplies the load current. The inductor does not provide current to the load during that time. During the off time of the control MOSFET and the on time of the synchronous MOSFET, the inductor provides current to the load and the output capacitor.

Figure 2-3 shows the inverting power supply design using the TPS62933.

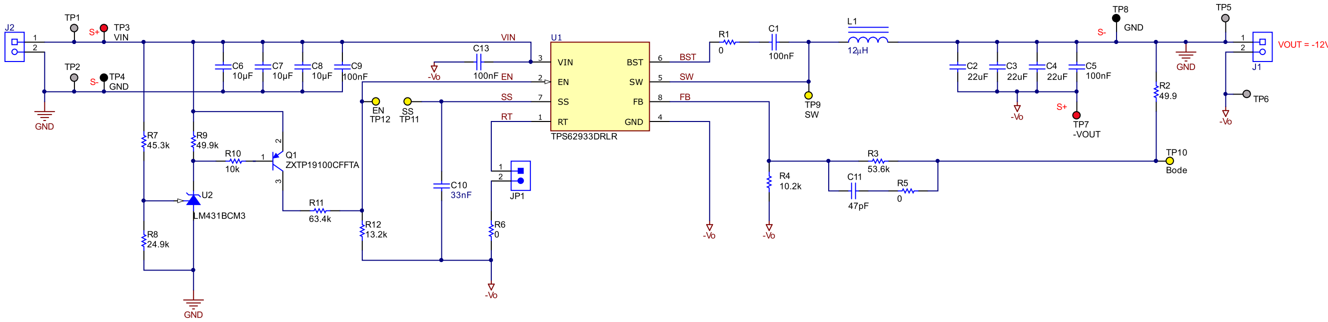


Figure 2-3. Inverting Power Supply Using TPS62933

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.
- Oscilloscope to capture voltages and a current.
- The TIDA-050053 board is a printed circuit board (PCB) with all the devices in this design.
- Resistive load or electronic load that is capable at least 2-A.
- Thermal camera used to measure the thermal rise of the board during operation.

3.2 Test Setup

Figure 3-1 shows the set up used to test the TIDA-050053.

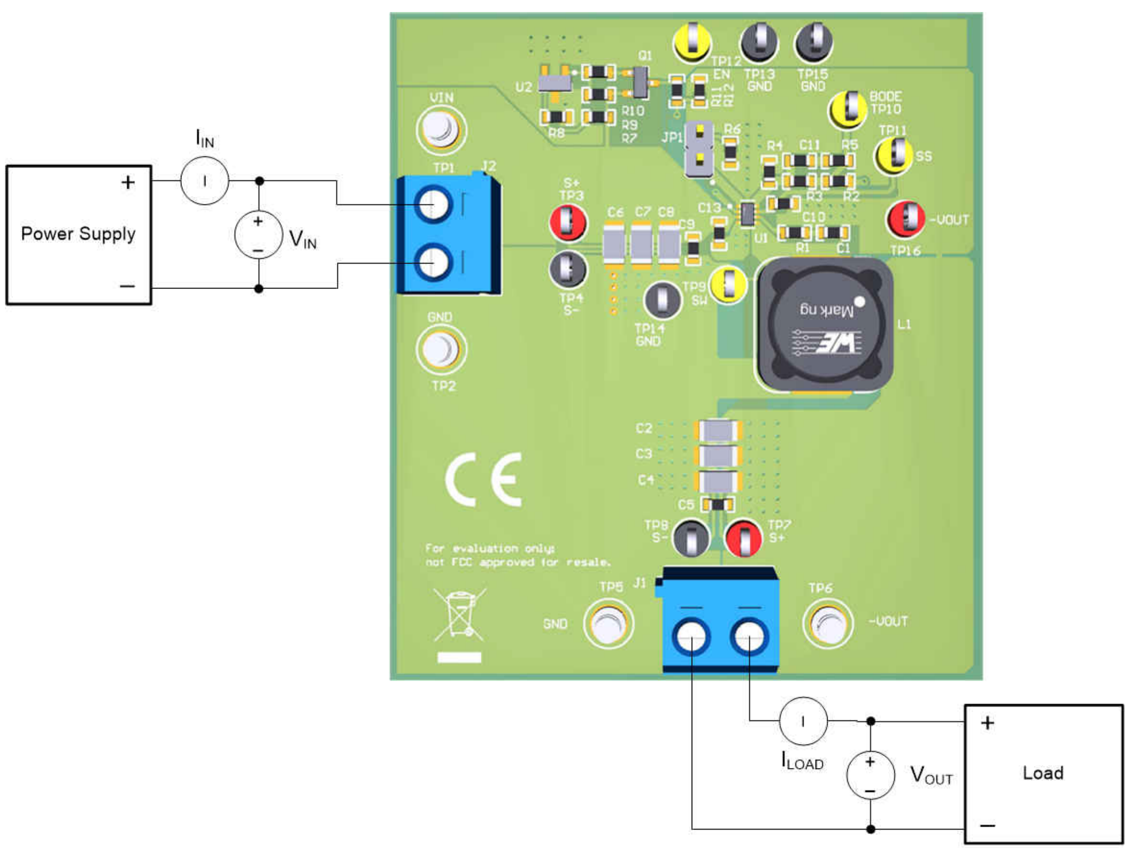


Figure 3-1. Test Setup

3.3 Test Results

3.3.1 Start-up

Figure 3-2 shows the start-up behavior.

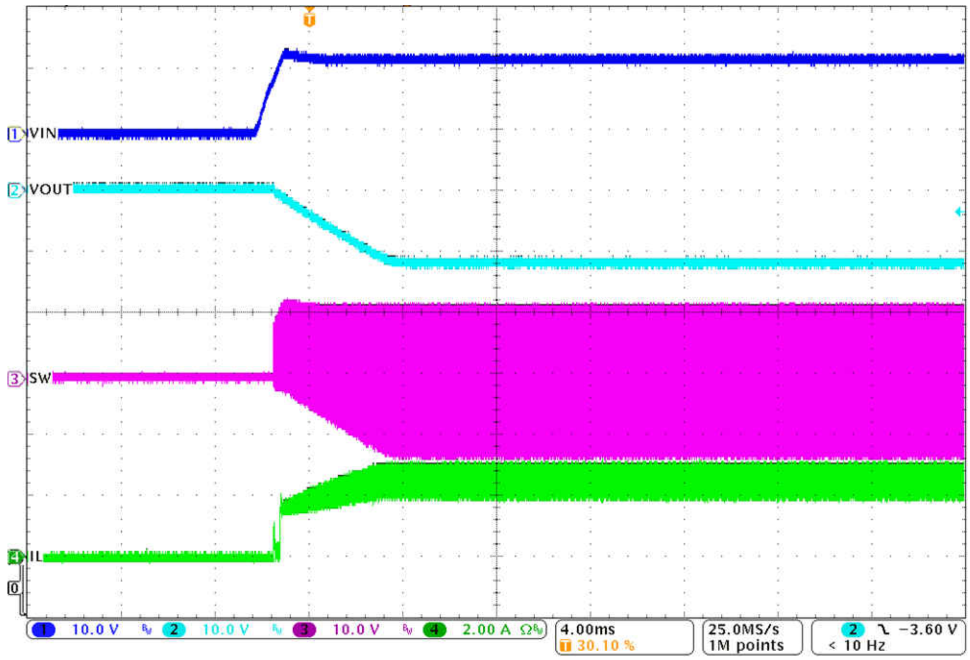


Figure 3-2. Start-up Behavior

3.3.2 Load Transient

Figure 3-3 shows the transient response from 0.4 A to 1.2 A with 12-V input.

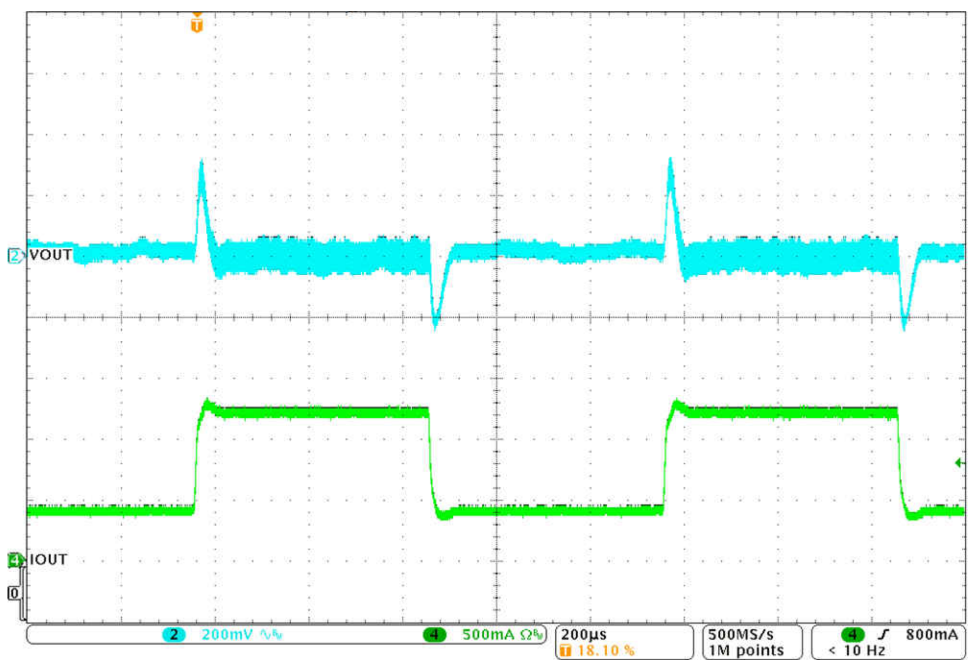


Figure 3-3. Load Transient 0.4 A to 1.2 A With 12 V_{IN}

Figure 3-4 shows the transient response from 0.8 A to 1.2 A with 12-V input.

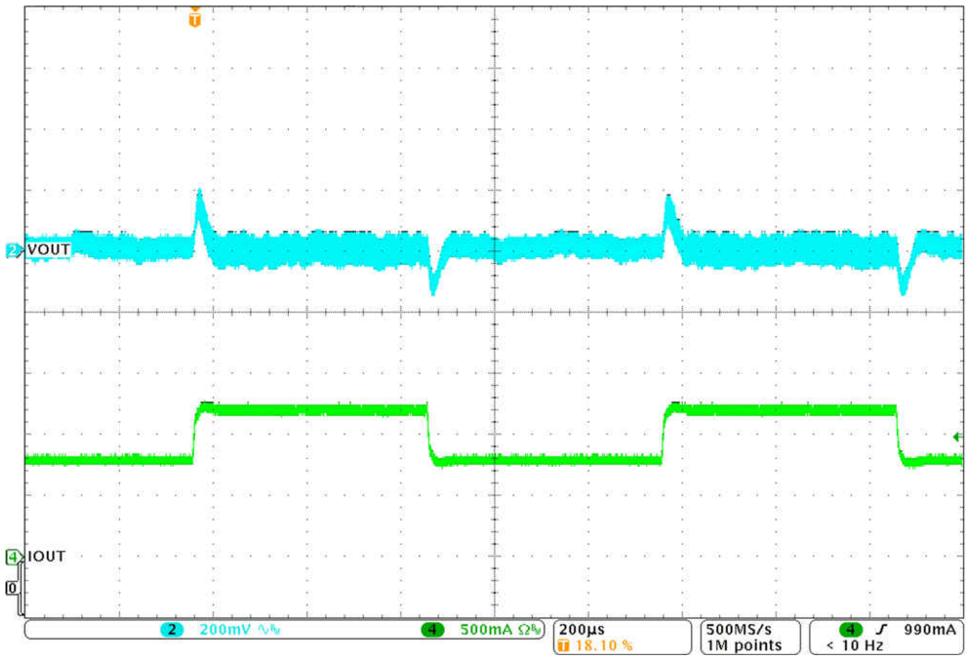


Figure 3-4. Load Transient 0.8 A to 1.2 A With 12 V_{IN}

3.3.3 Output Ripple

Figure 3-5 shows the output voltage ripple at 1.2 A.

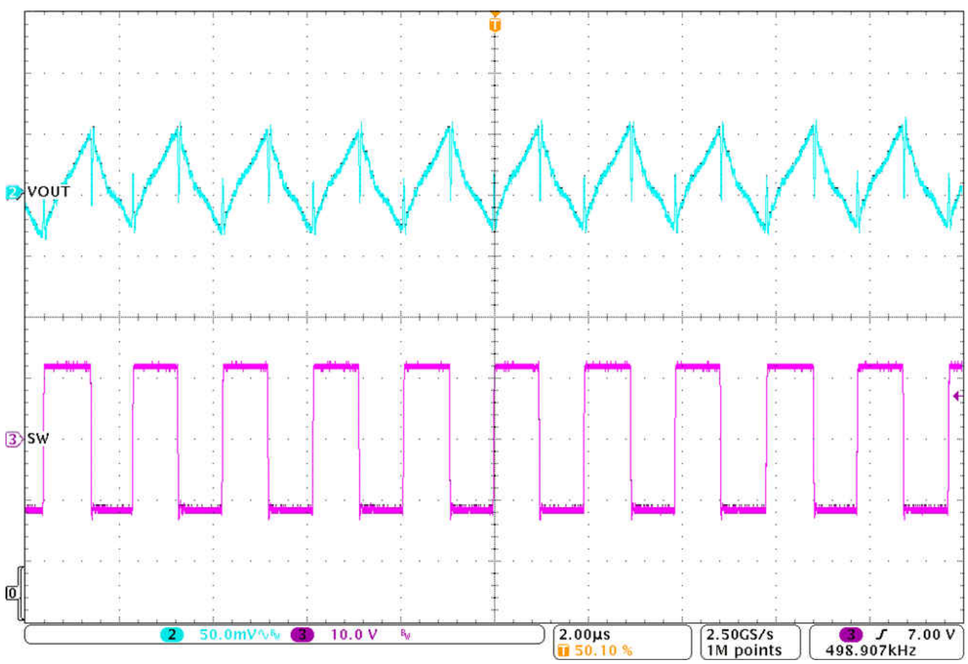


Figure 3-5. V_{OUT} Ripple at 1.2 A

3.3.4 Thermal Performance

Figure 3-6 shows the thermal performance at 1.2-A load. The image is taken under room temperature of about 27°C.

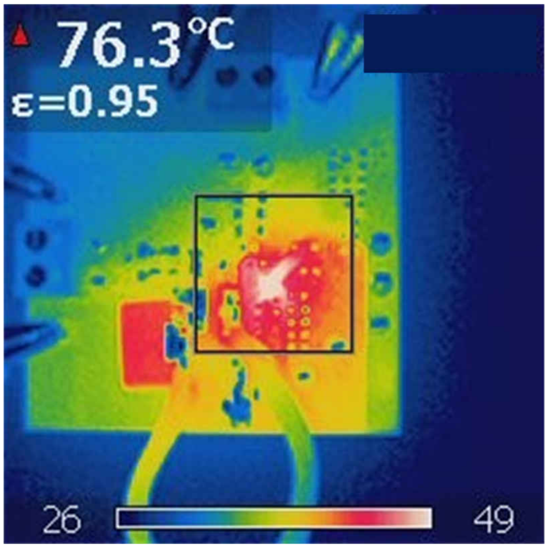


Figure 3-6. Thermal Image at Room Temperature With 12-V_{IN}, –12-Vo, 1.2 A

4 Design and Documentation Support

4.1 Design Files

4.1.1 Schematics

To download the schematics, see the design files at TIDA-050053.

4.1.2 BOM

To download the bill of materials (BOM), see the design files at TIDA-050053.

4.1.3 PCB Layout Recommendations

To download the layer plots, see the design files at TIDA-050053.

4.1.4 Altium Project

To download the Altium Designer® project files, see the design files at TIDA-050053.

4.1.5 Gerber Files

To download the Gerber files, see the design files at TIDA-050053.

4.1.6 Assembly Drawings

To download the assembly drawings, see the design files at TIDA-050053.

4.2 Documentation Support

1. Texas Instruments, *TPS62933 3.8-V to 30-V, 3-A Synchronous Buck Converter in SOT583 Package* data sheet
2. Texas Instruments, *Create an Inverting Power Supply Using a TPS54202 Buck Converter With Internal Compensation* 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.

Linked content is provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

4.4 Trademarks

TI E2E™ are trademarks of Texas Instruments.
Altium Designer® is a registered trademark of Altium LLC.
All trademarks are the property of their respective owners.

5 About the Author

LUCIA GAO is an Applications Engineer at Texas Instruments responsible for providing application support and solving technical challenges of customers. Lucia also helps to understand customers needs and create innovative solutions.

ZHAO MA has been a Systems and Application Engineer at Texas Instruments for 5 years responsible for defining new products based on our marketing strategy and business opportunities. Zhao also provides technical support to help customers understand how best to use mid-voltage buck converters.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265