Design Guide: TIDA-010958

Radiation-Hardened Dual-Phase Versal® FPGA Power Reference Design

Description

The TIDA-010958 is a radiation-hardened synchronous buck power reference design intended for the AMD® Versal® AI Core XQRVC1902 core rail. The design is optimized for a 12V input operation to generate a 0.8V output voltage and maximum 80A output current. This compact power design delivers high current while following the tight tolerance requirements of the FPGA. This power design, combined with the Versal® AI Core XQRVC1902, provides satellites with the accuracy, reliability, and efficiency needed to carry out different missions. TIDA-010958 has radiation-hardened devices and the passive components are compliant with MIL standard MIL-STD-55681 (or equivalent) where available. Otherwise, an equivalent value and component size was substituted.

Features

- Radiation performance - 100krad / 75MeV
- Nominal 12V DC input for space-based applications
- Load current up to 80A
- Switching frequency 278kHz
- Packaged GaN assembly
- Board dimensions: 126.7mm × 61.2mm
- Designed to power core rail voltage of the AMD® Versal® AI Core XQRVC1902

Applications

- Communications payload
- Radar imaging payload
- Optical imaging payload
- Satellite electric power system (EPS)

Resources

TIDA-010958	Design Folder
TPS7H6023-SP	Product Folder
TPS7H5004-SP	Product Folder

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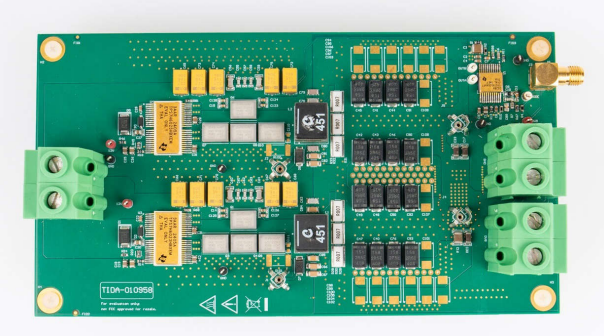

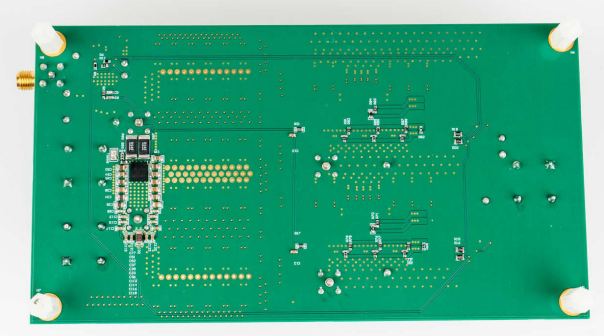

1 System Description

The TIDA-010958 reference design uses the TPS7H5004-SP, pulse-width modulation (PWM) controller, and TPS7H6023-SP gate driver, to create a synchronous buck converter. The design converts a 12V rail to a 0.8V rail intended for high-current FPGA designs and specifically to meet the regulation requirements of the AMD Versal™ AI Core XQRVC1902 core rail. A single TPS7H5004-SP provides a PWM output to two different TPS7H6023-SP devices which switch the FETs of the synchronous buck converter to provide voltage and current at the output. Each of the power stages delivers 40A for up to 80A total. Each gate driver drives one high-side FET and three low-side FETs. This reference design uses space-grade GaN FETs and a GaN gate driver.

2 System Overview

2.1 Block Diagram

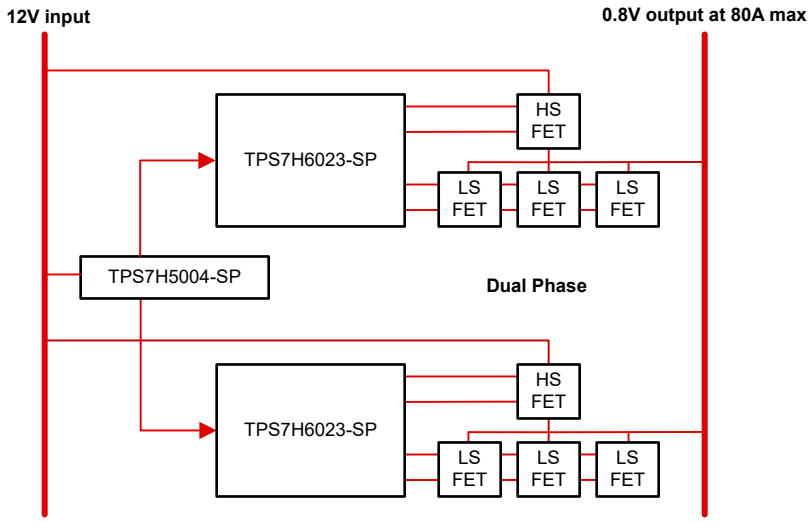

Figure 2-1. TIDA-010958 Block Diagram

2.2 Design Considerations

Table 2-1. Voltage and Current Requirements

PARAMETER	SPECIFICATIONS
Input Voltage	12V
Output Voltage	0.8V
Maximum Load Current	80A
Switching Frequency	278kHz

2.2.1 Switching Frequency

There are different tradeoffs between efficiency and bandwidth in regard to the switching frequency. Higher switching frequencies have larger bandwidths, but a lower efficiency than lower switching frequencies. Based on the requirements, the maximum switching frequency for the device is 381kHz. To make sure the maximum switching frequency of the device was not approached, the switching frequency of the device was set to 278kHz. The switching frequency is set with equations from the *TPS7H5004-SP Radiation-Hardness-Assured 1.3A, 2.5A, Half Bridge GaN FET Gate Drivers* data sheet. The switching frequency is 278kHz for each phase.

2.2.2 Design Size

Another key consideration in this design was creating a small design size while having a good efficiency. Generally, more compact designs have less space for cooling, causing heat dissipation problems, leading to reduced performance abilities. Additionally, placing components closely together can cause signal interference

and a need for higher routing accuracy. This design prioritized having a small and compact design size while maintaining a reasonable efficiency.

2.2.3 Gate Resistors

The gate resistors for the three low-side FETs in each phase were set to 0. This is intended to let the device switch as fast as possible and not allow efficiency to be affected by extra resistance in the current path.

2.2.4 Output Ripple

To optimize the output ripple of the device to fit with the tight restrictions of the Versal FPGA core rail requirements, tantalum capacitors with a low ESR of 5mOhms each were chosen. The design consists of 8 tantalum capacitors per phase, making a total of 16 output tantalum capacitors.

2.2.5 FET Placement

The recommended placement of the high side FET is directly centered between all the low side FETs. In this design there are three low-side FETs, so the high side FET is placed directly above the middle low side FET. The intention behind specific FET placement is to have balanced return paths with a single high side GaN FET to reduce potential switch node ringing.

2.3 Highlighted Products

The following sections describe key features of the PWM controller and gate driver ICs used in this reference design.

2.3.1 TPS7H5004-SP

The TPS7H500x-SP family of high speed radiation hardness-assured PWM controllers. The controllers provide a number of features that are beneficial for the design of DC-DC converter topologies intended for space applications. The controllers have a 0.613V +0.7%/–1% accurate internal reference and configurable switching frequency up to 2MHz. Each device offers programmable slope compensation and soft-start.

The TPS7H500x-SP series can be driven using an external clock through the SYNC pin or by using the internal oscillator at a frequency programmed by the user. The controller family offers the user various options for switching outputs, synchronous rectification capability, dead time (fixed or configurable), leading edge blank time (fixed or configurable), and duty cycle limit. Each device in the TPS7H500x-SP series is available in both a 22-pin CFP ceramic package and a 24-pin TSSOP plastic package.

2.3.2 TPS7H6023-SP

The TPS7H60x3-SP series of radiation-hardness assured (RHA) gallium nitride (GaN) field effect transistor (FET) gate drivers is designed for high frequency, high efficiency applications. The series consists of the TPS7H6003-SP (200V rating), TPS7H6013-SP (60V rating), and the TPS7H6023-SP (22V rating). The drivers feature adjustable dead time capability, small 30ns propagation delay, and 5.5ns high-side and low-side matching. These parts also include internal high-side and low-side LDOs which makes sure of a drive voltage of 5V regardless of supply voltage. The TPS7H60x3-SP drivers all have split gate outputs, providing flexibility to adjust the turn-on and turn-off strength of the outputs independently.

The TPS7H60x3-SP drivers feature two control input modes: independent input mode (IIM) and PWM mode. In IIM each of the outputs is controlled by a dedicated input. In PWM mode, two complementary output signals are generated from a single input and the user can adjust the dead time for each edge.

The gate drivers also offer user configurable input interlock in independent input mode as anti-shoot through protection. Input interlock disallows turn-on of both outputs when both inputs are on simultaneously. The user has the option to enable or disable this protection in independent input mode, which allows the driver to be used in a number of different converter configurations. The drivers can also be utilized for both half-bridge and dual-low side converter applications.

The device is also offered in a plastic package as the TPS7H60x5-SEP and TPS7H60x5-SP.

3 Hardware, Testing Requirements, and Test Results

3.1 Hardware Requirements

- TIDA-010958 Reference Design Board
- DC Power Supply (12V and 10A)
- Electronic Load (80A)
- Multimeter
- Oscilloscope

3.2 Test Setup

Connect the power supply to the input terminal blocks and place the GND and 12V connections in the correct slots. Input current for this board is up to approximately 10A, therefore verify that the power supply is rated to handle 10A at 12V. Connect the electronic load to the output terminal blocks by placing the GND cables in the terminal labeled *GND* and the output cables in the terminal labeled *0V8*. Increase the load to 80A.

3.3 Test Results

3.3.1 Efficiency Graphs

Figure 3-1 and Figure 3-2 show the TIDA-010958 efficiency and power loss graphs, respectively.

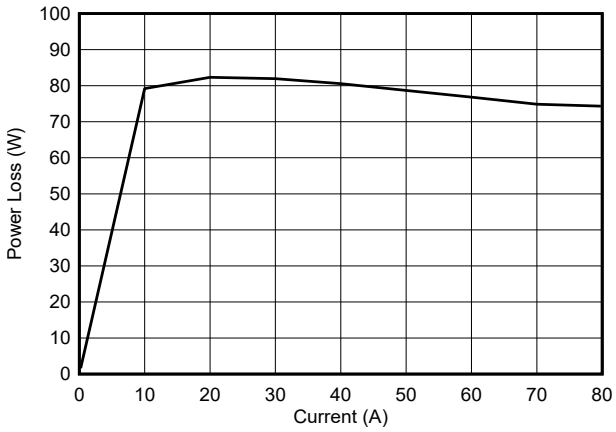

Figure 3-1. TIDA-010958 Efficiency, 12V Input, 0.8V Output

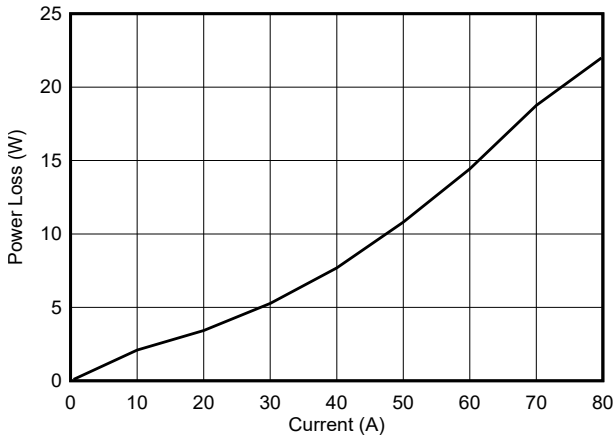

Figure 3-2. TIDA-010958 Power Loss, 12V Input, 0.8V Output

3.3.2 Bode Plot

Figure 3-3 shows the TIDA-010958 bode plot.

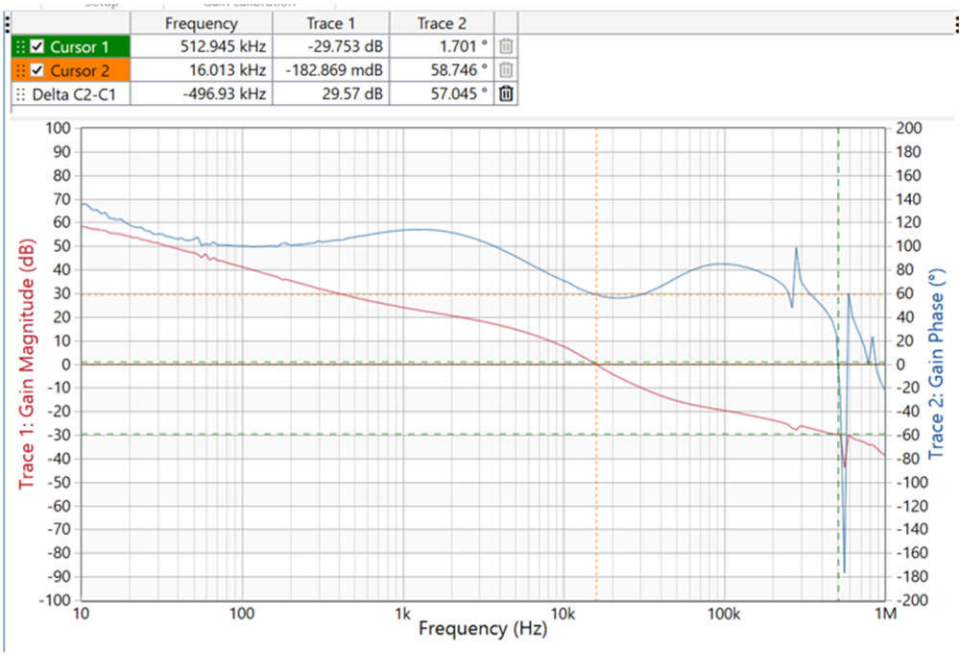

Figure 3-3. 12V Input, 0.8V Output; Bandwidth = 10Hz, Phase Margin = 58.7 Degrees

3.3.3 Switching

Figure 3-5 shows the switching behavior for TIDA-010958 measured with a test connector.

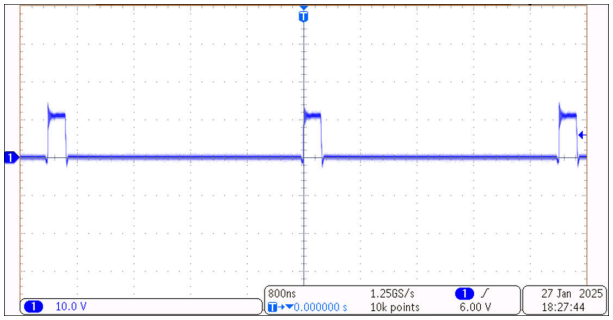

Figure 3-4. Switch Node Zoomed Out

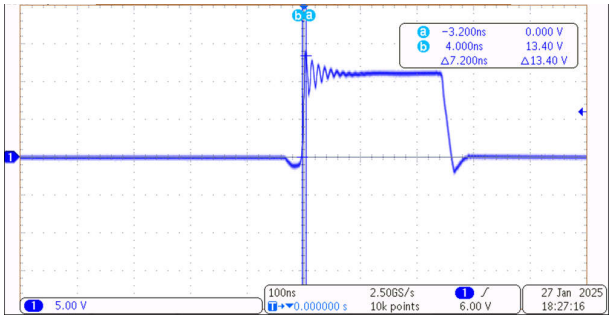

Figure 3-5. 278kHz Switching Frequency

3.3.4 Output Ripple

Figure 3-6 illustrates the TIDA-010958 output voltage ripple waveform. The output ripple is measured using a test connector.

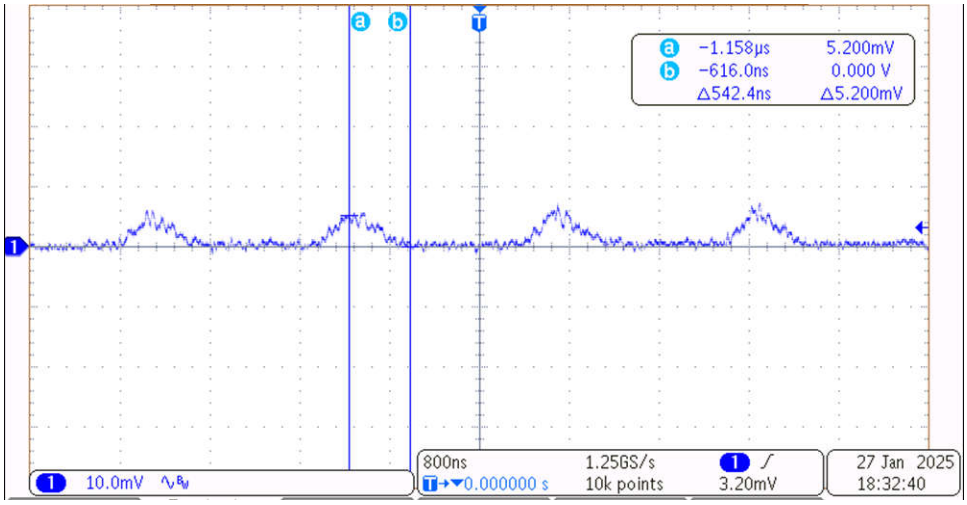

Figure 3-6. Output Voltage Ripple (AC Coupled) Measured 5.2mV Peak to Peak

3.3.5 Gate Signals

Figure 3-7 and Figure 3-8 illustrate the low-side gate rise time and high-side gate rise time, respectively.

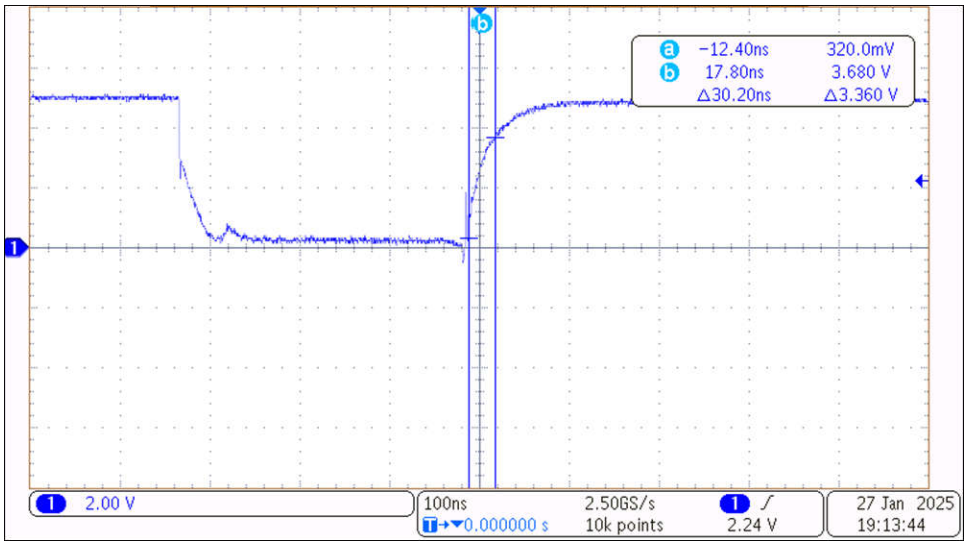

Figure 3-7. Low-Side Gate Rise Time

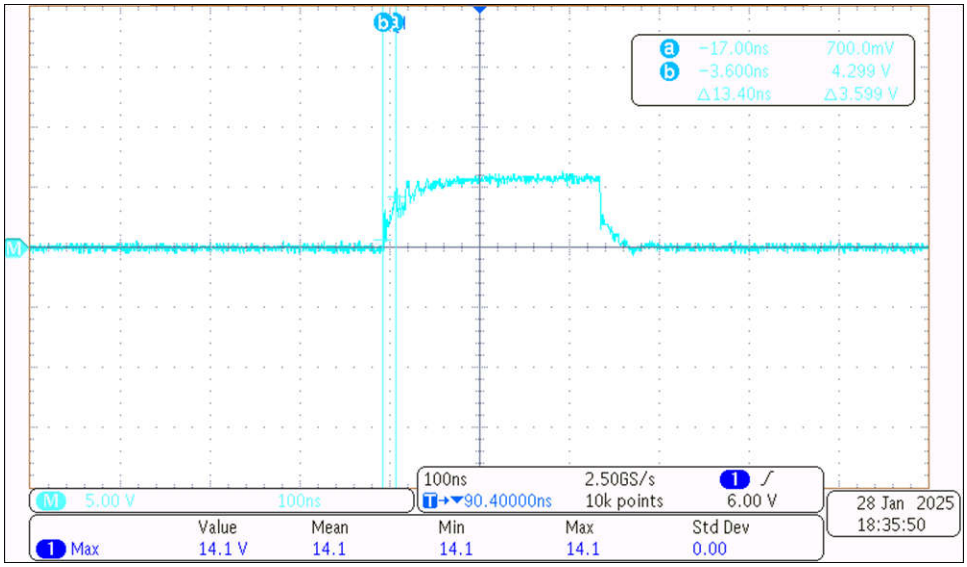

Figure 3-8. High-Side Gate Rise Time

3.3.6 Start-Up Sequence

Figure 3-9 shows start-up behavior of TIDA-010958.

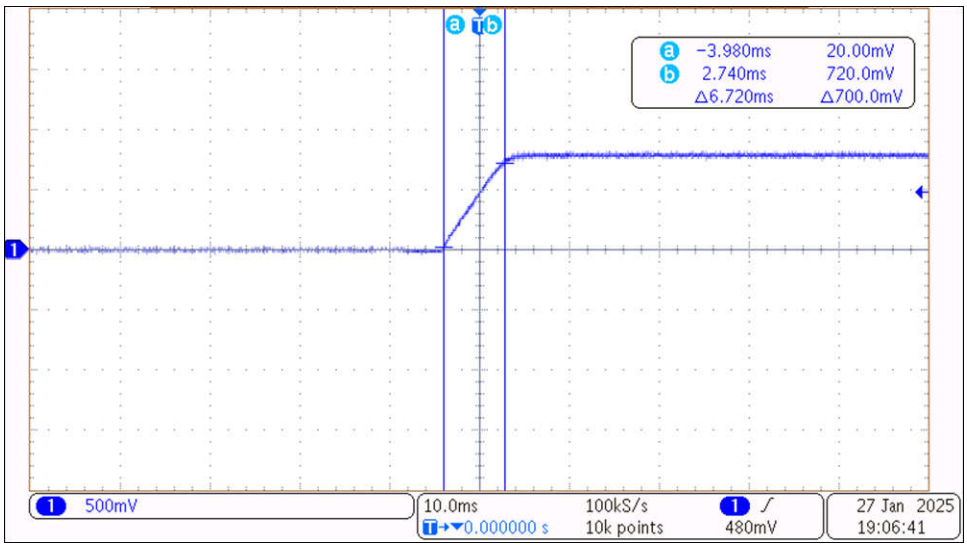

Figure 3-9. 12V Input, 0V Output, No Load

3.3.7 Load Transient

Figure 3-12 shows the behavior of the TIDA-0109458 during a load transient at 0.8V, 10A to 30A, and 30A to 10A load steps.

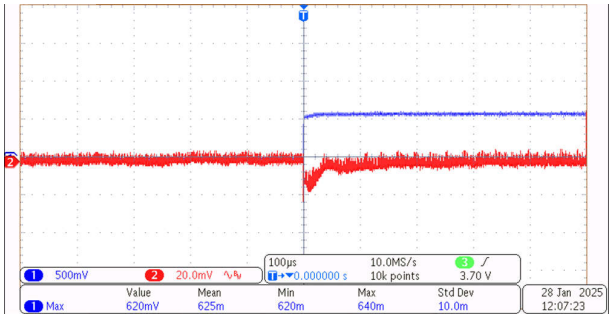

Figure 3-10. 10A to 30A Load Step

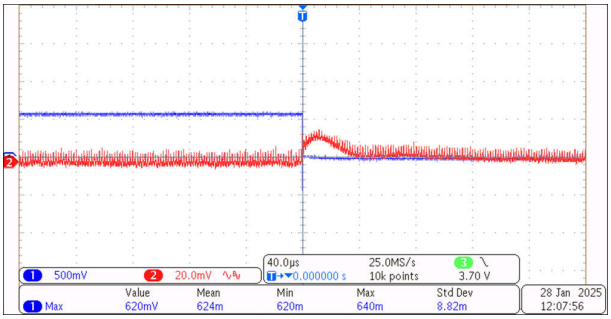

Figure 3-11. 30A to 10A Load Step

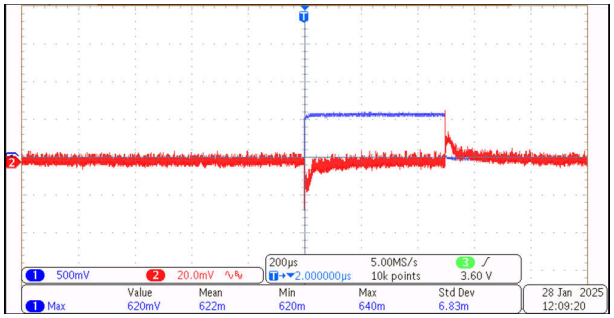

Figure 3-12. 12V input; CH1: Output voltage, AC coupled 20mV/div; CH2: Output Current

3.3.8 Thermal Images

Figure 3-13, Figure 3-14, and Figure 3-15 show the thermal performance of the top side of the TIDA-010958 board at different load currents after one minute at each current.

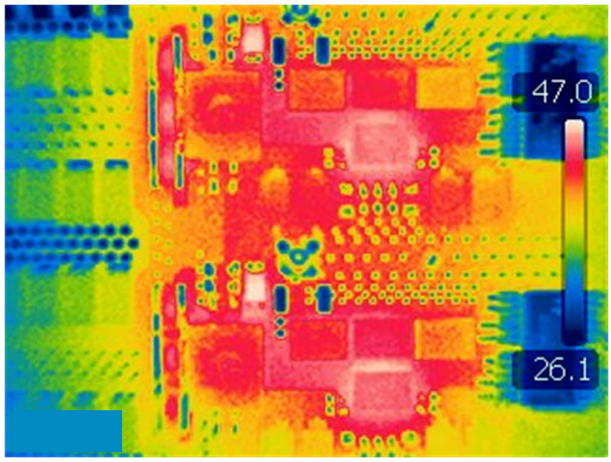

Figure 3-13. Top View, 12V Input, 0.8V Output at 30A

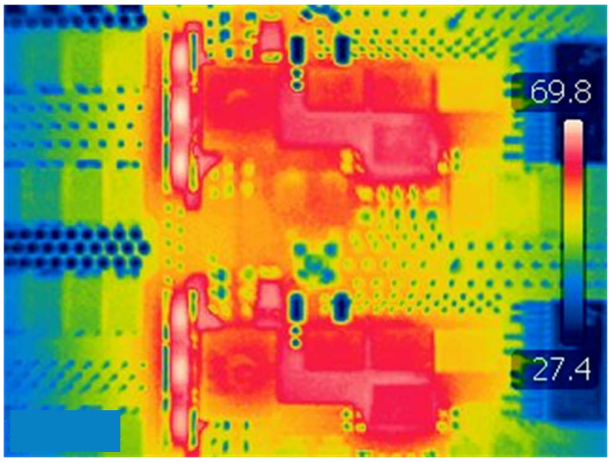

Figure 3-14. Top View, 12V Input, 0.8V Output at 60A

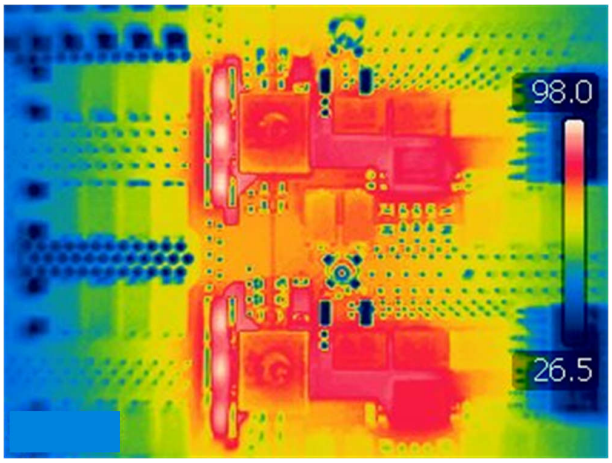

Figure 3-15. Top View, 12V Input, 0.8V Output at 80A

4 Design and Documentation Support

4.1 Design Files

4.1.1 Schematics

To download the schematics, see the design files at TIDA-010958.

4.1.2 BOM

To download the bill of materials (BOM), see the design files at TIDA-010958.

4.2 Tools

Tools

POWERSTAGE-DESIGNER	Power Stage Designer™ software tool of most commonly used switch-mode power supplies.

4.3 Documentation Support

1. Texas Instruments, *TPS7H500x-SP Radiation-Hardness-Assured 2MHz Current Mode PWM Controllers Data Sheet*

2. Texas Instruments, *TPS7H60x3-SP Radiation-Hardness-Assured 1.3A, 2.5A, Half Bridge GaN FET Gate Drivers Data Sheet*

4.4 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

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6 Revision History

Changes from Revision * (February 2025) to Revision A (March 2025)	Page
• Updated the numbering format for tables, figures, and cross-references throughout the document	1
• Changed Figure 3-14 and Figure 3-15 by switching the images	9

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