EPC91109

High Power Density, Two-Phase Buck Converter Quick Start Guide

Featuring the EPC2057 eGaN® FET and LTC7890 Controller

May 30, 2025

Version 1.0

EFFICIENT POWER CONVERSION

DESCRIPTION

The EPC91109 evaluation board features a very compact and efficient 20–36 V to 12/16/20 V, two-phase synchronous buck converter. It uses four EPC2057, a 50 V-rated eGaN® FET, and the LTC7890, an analog two-phase step-down controller. The board can be configured as a two-phase interleaved converter with a single output, or as a dual-output buck converter. As the former, it can deliver up to 14.3 A into a 12 V load from a 36 V supply, equivalent to 180 W of input power, the maximum allowed by the USB-PD 3.1 specification for a 36 V bus [1]. The power stage area, including the inductors, measures 24 x 24 mm; it has a maximum component height of 3 mm; and it does not require a heatsink or forced air for cooling. A functional block diagram is provided in Figure 1.

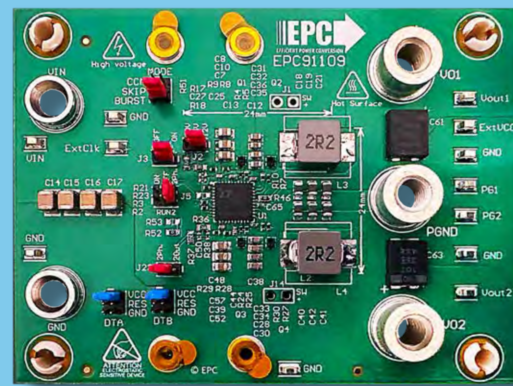
REGULATORY INFORMATION

This evaluation board is for evaluation purposes only. It is not a full-featured power supply and should not be used as a final product. No EMI test was conducted. It is not FCC approved.

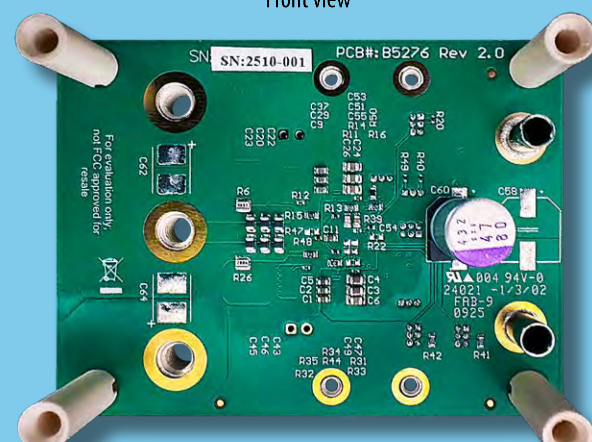
KEY FEATURES OF THE EPC91109 EVALUATION BOARD

- Uses four compact and efficient EPC2057 GaN FETs
- Features ADI's LTC7890 100 V two-phase synchronous buck controller for GaN FETs
- Configurable to operate in either two-phase or single phase, dual-output mode
- Utilizes a small inductor of just 6.95 x 6.60 mm and 3 mm thickness
- No heatsink or airflow required

EPC91109 Evaluation Board



Front view



Back view

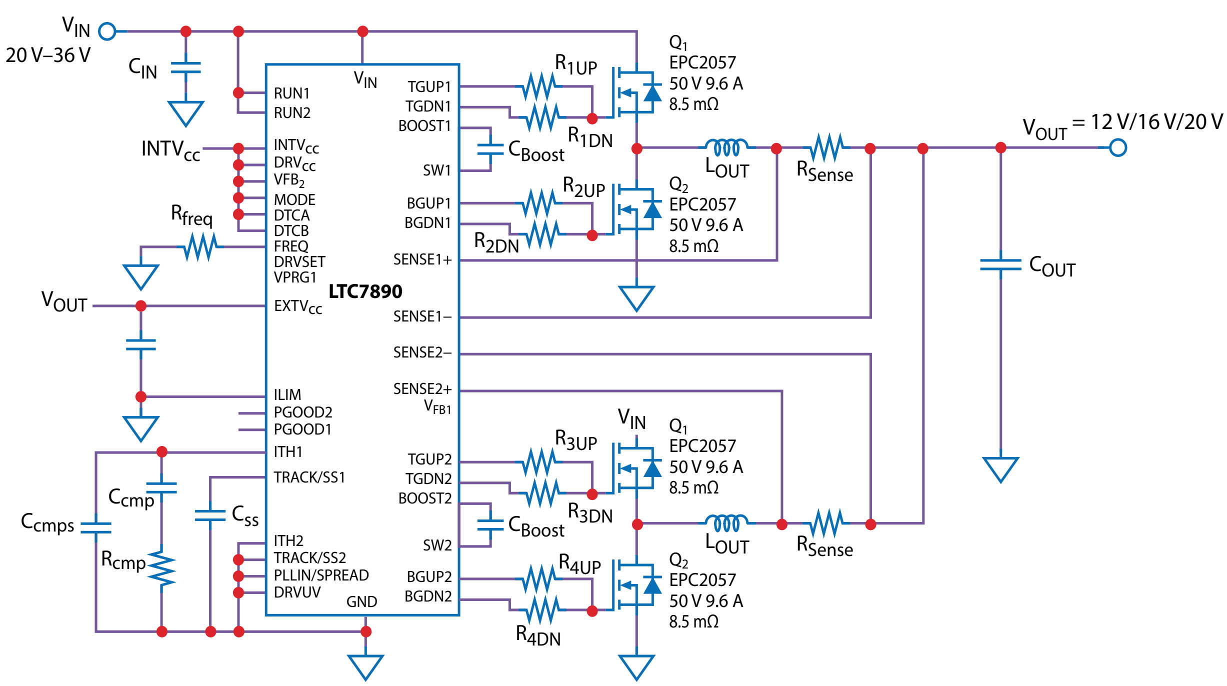


Figure 1: Block diagram overview of the EPC91109 evaluation board

FEATURED GaN FET

The EPC91109 evaluation board features the 50 V rated, 8.5 mΩ $R_{DS(on)}$ EPC2057 GaN FETs. The symbol of GaN FET and photo with pin assignment are shown in figure 2.

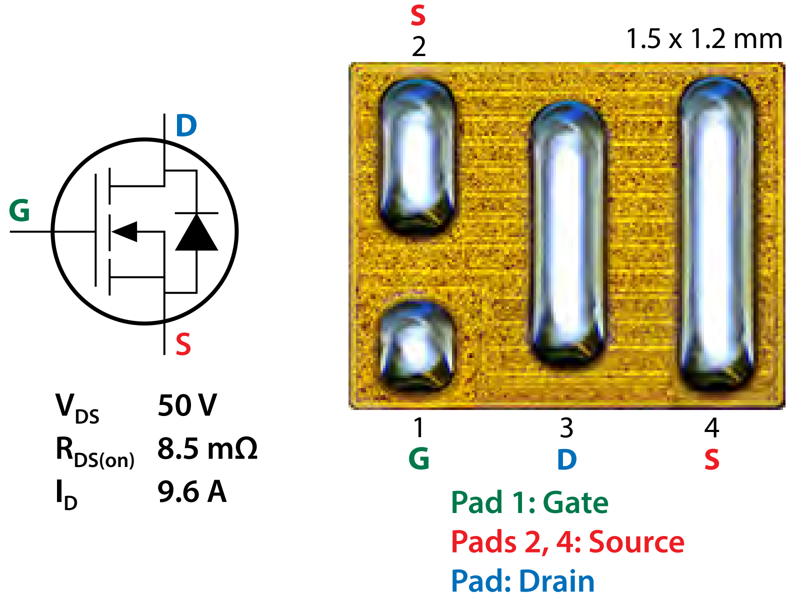


Figure 2: Symbol and photo with pin assignment of the EPC2057

For additional details, refer to the **EPC2057 datasheet available at www.epc-co.com**. The datasheet should be read in conjunction with this quick start guide.

OVERVIEW OF THE EPC91109 EVALUATION BOARD

Figure 3 shows an image of both sides of the EPC91109 evaluation board with the location of the various functional circuits highlighted.

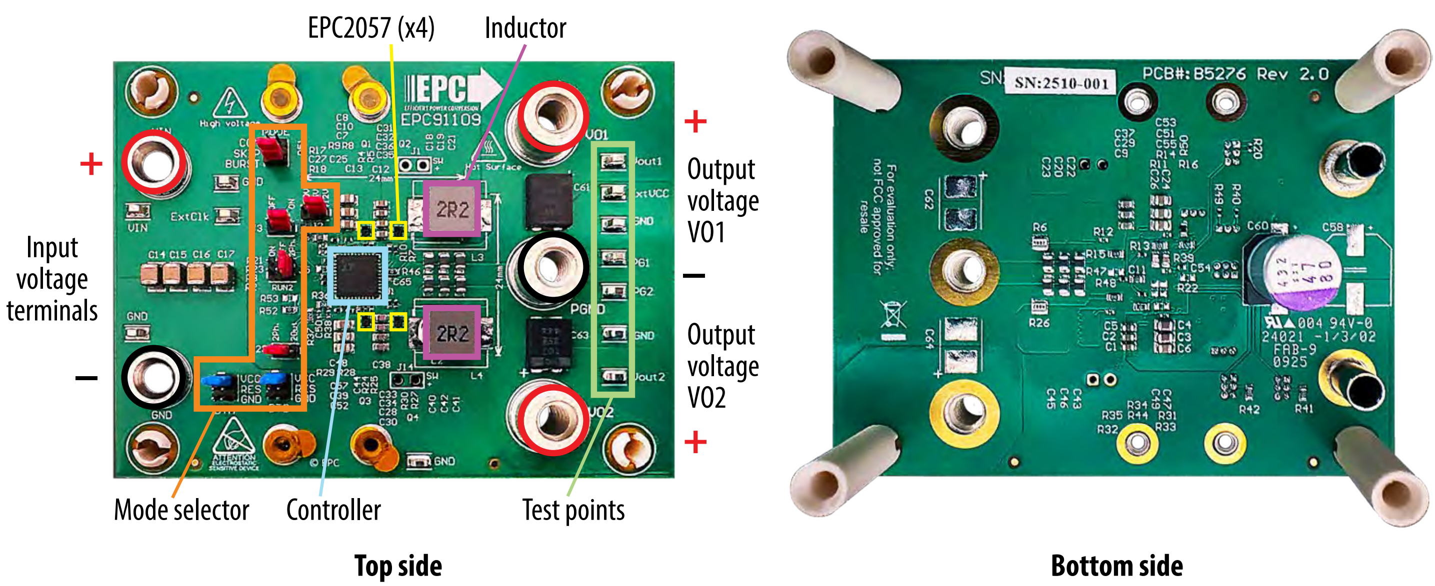


Figure 3: Photo overview of the EPC91109 evaluation board with various functional blocks highlighted

Figure 4 shows a zoomed-in photo of the power stage area on both sides of the board.

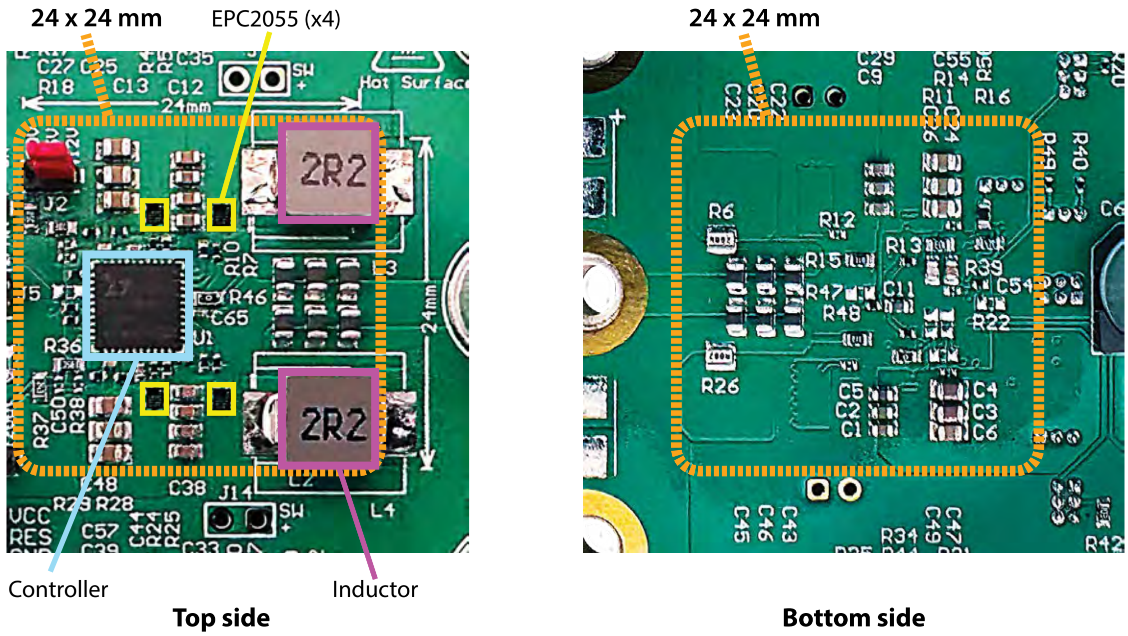


Figure 4: Zoomed-in photo details of the EPC91109 evaluation board with power circuit highlighted

It can be seen from figure 4 that the circuit is compact and can fit in a small area of approximately 24 x 24 mm excluding the input and output bulk capacitors.

RECOMMENDED OPERATING CONDITIONS

Table 1: Performance Summary (T_A = 25°C) EPC91109

Symbol	Parameter	Conditions	Min	Nominal	Max	Units
V_{IN}	Input Voltage Port (V_{IN})	V_{OUT} = 12 V or 16 V	20		36 [1]	V
		V_{OUT} = 20 V	22			
V_{OUT}	Output Voltage Port (V_{OUT}) Configured with pin header J2	J2 position 1-2		12		
		J2 – no jumper		16		
		J2 position 2-3		20		
I_{OUT}	Total Output Current (two-phase configuration)	No heatsink, no airflow needed			14.3 [2]	A
f_{SW}	Nominal Switching frequency			970 [3]		kHz
ExtClk	External clock		-0.3 [4]		6	V
PG	Power Good logic output	Low		0.2 [5]	0.4	

[1] *Maximum voltage limited by an input capacitor derated to 40 V with 80% derating. In addition, the board was not tested in closed loop beyond 36 V input voltage.*

[2] *Maximum current capability is lower than stated in EPC2057 datasheet as it is dependent on thermal conditions and die temperature, and on component choice and ILIM pin setting of LTC7890 (see datasheet for more details). Actual maximum current is affected by switching frequency, bus voltage, inductor current and thermal limits, and thermal cooling. Refer to thermal performance section in this guide and to EPC2057 datasheet for details. 14.3 A corresponds to a maximum input current of 5 A when V_{IN} = 36 V and V_{OUT} = 12 V.*

[3] *LTC7890 controller can operate from 100 kHz through 3 MHz switching frequency. EPC91109 is set to operate at a fixed switching frequency of 970 kHz.*

[4] *Minimum input high logic is 2.2 V and maximum input low logic is 0.5 V.*

[5] *Power good logic output is low when the output voltage is not within +/- 10% of a regulated output voltage.*

HIGHLIGHTED PARTS OF THE EPC91109 CIRCUIT

Refer to figures 1 and 4 for the main blocks and components that comprise the EPC91109 evaluation board.

Power Stage

The power stage within EPC91109 consists of a single controller with integrated gate drivers, four GaN FETs configured in two half-bridges, two inductors and some high-frequency input/output ceramic capacitors. By default, the power stage is configured to operate as a two-phase interleaved buck converter. It can also be reconfigured to function as two buck converters with independent outputs. To configure it as either a two-phase or a two-output, please refer to the “Configuration Setting” subsection under the “Jumper Setting” section.

Current and Voltage Sense

The EPC91109 evaluation board relies on voltage and current measurements for feedback. Voltages are measured using simple resistor divider networks. Inductor current for each phase / output is measured using a 2 mΩ shunt resistor (**R6** and **R26**).

Controller

The EPC91109 evaluation board is controlled using the LTC7890, a dual output/two-phase synchronous step-down controller from Analog Devices. The controller uses a fixed frequency of 970 kHz (set with resistor **R21**) and peak current mode control. By default, the peak current for each phase is set to approximately 12.5 A, preventing saturation of the inductor. This is achieved by tying the ILIM pin of the controller to GND with resistor **R52**. In two-phase configuration, the two controller channels operate at 180° phase shift, which reduces the required input and output capacitance. Additional functions of the LTC7890 controller can be adjusted using the appropriate jumper-settings. For more information, please refer to the jumper settings section.

CONNECTIONS, MEASUREMENT TEST POINTS, and JUMPERS

Power Connections

To operate the EPC91109, connect the input supply and the load as shown in figure 5. Note that V01 and V02 are not connected together on the board.

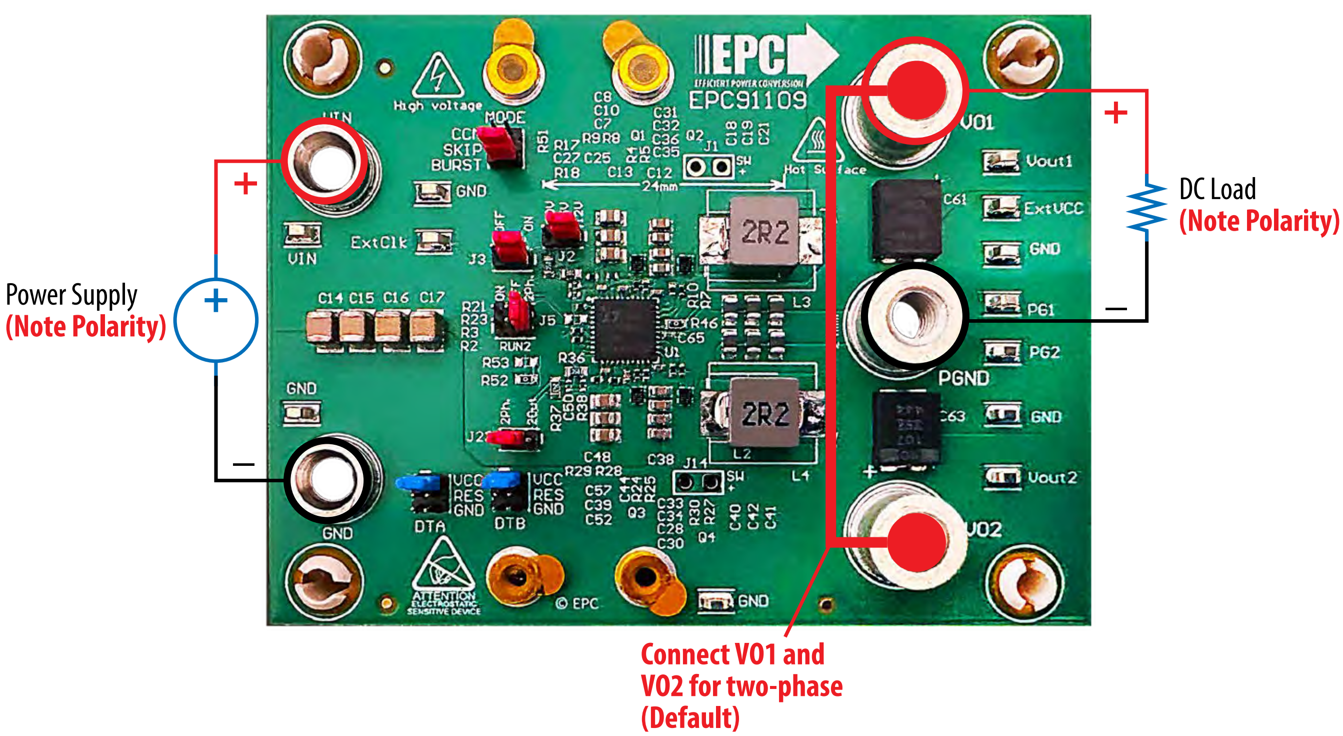


Figure 5: Power connections to the EPC91109 evaluation board

Test Points and Measurement Points

Figures 6 and 7 show the various measurement connections of the EPC91109 evaluation board.

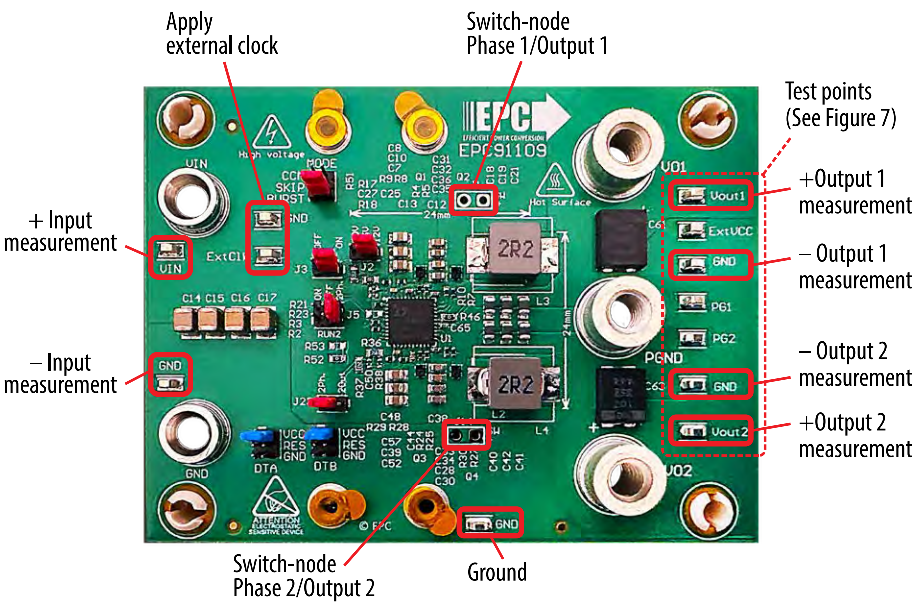


Figure 6: EPC91109 test point pad and hookup locations and designations

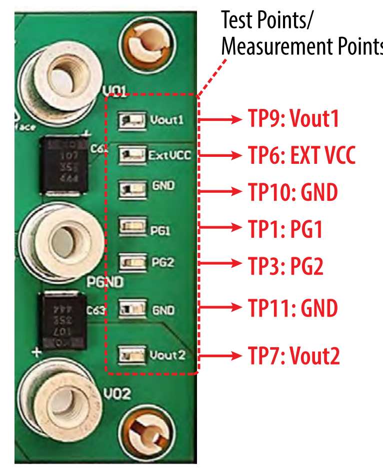


Figure 7: EPC91109 shows zoomed in photo of test point/measurement points

The available measurement nodes with their respective reference are:

- **Vout1-GND**: Output voltage 1 (**TP9** & **GND**),
- **EXT VCC-GND**: external supply voltage to controller (**TP6** & **GND**),
- **PG1-GND**: Power good logic output 1 (**TP1** & **GND**),
- **PG2-GND**: Power good logic output 2 (**TP3** & **GND**),
- **Vout2-GND**: Output voltage 2 (**TP7** & **GND**).

Please refer to table 1 and LTC7890 datasheet for more information.

Note: Exercise caution when using the bode measurements to ensure proper connection to the instrument.

Switch-node

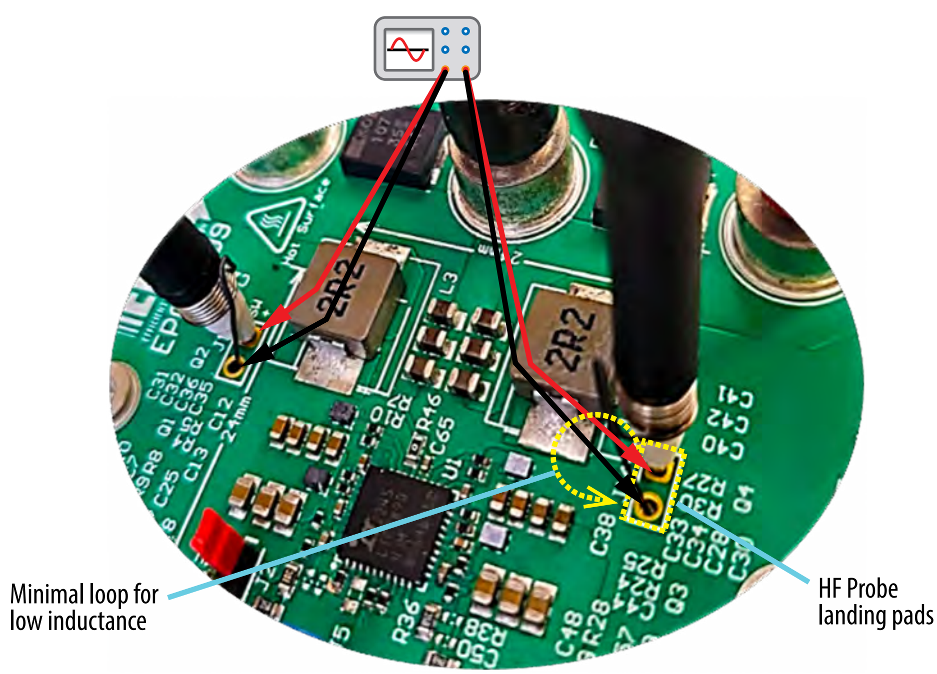


Figure 8: Recommended method to measure the switch- node measurement voltage waveform

Jumper Settings

Note: A jumper must be inserted to select a mode at each jumper connector.

Dead-Time settings

EPC91109 has two dead-time settings; 1) switch-node rising edge, and 2) switch-node falling edge. The rising edge is the dead time between low side FETs (Q2 & Q4) turn-off and high side FETs (Q1 & Q3) turn-on, and it is set using the DTA jumper (J13). The falling edge is the dead time between high side FETs (Q1 & Q3) turn-off and low side FETs (Q2 & Q4) turn-on, and it is set using the DTB jumper (J21). The available settings for both DTA and DTB are:

1) Position 1-2 (VCC), connects the DTCA/DTCB pins of the controller to VCC for near zero dead-time (default)
2) Position 3-4 (RES), connects the DTCA/DTCB pins of the controller to ground though a resistor (R41 and R42 respectively) for approximately 5 ns dead-time
3) Position 5-6 (GND), connects the DTCA/DTCB pins of the controller directly to ground for 20 ns dead-time

Details are shown in figure 9.

Light-Load Mode Selection

EPC91109 offers three light-load operating modes: 1) forced continuous inductor current (CCM), 2) pulse skipping (SKIP), and 3) burst mode (BURST). For detailed information on each mode, refer to the LTC7890 datasheet. The desired operating mode can be selected by placing a jumper on the MODE connector (J22). Place the jumper on pins 1-2 to select CCM, pins 3-4 to select SKIP and pins 5-6 to select BURST (default). See figure 10 for details.

Configuration Settings

EPC91109 can be configured in either two-phase or single-phase buck converter by adjusting the position of the jumpers on pin headers J3, J5, and J23 (see figure 10 for details).

To configure EPC91109 as a two-phase converter (default):

1) Place a jumper on RUN1 (J3) in the 1-2 (On) position.
2) Place a jumper on RUN2 (J5) in the 5-6 (2Ph) position.
3) Place a jumper on J23 in the 2-3 (2Ph) position.

To configure EPC91109 as a dual-output converter:

1) Place a jumper on RUN1 (J3) in the 1-2 (On) position.
2) Place a jumper on RUN2 (J5) in the 1-2 (On) position to enable the second output (VO2).
3) Place a jumper on J23 in the 1-2 (2Out) position.

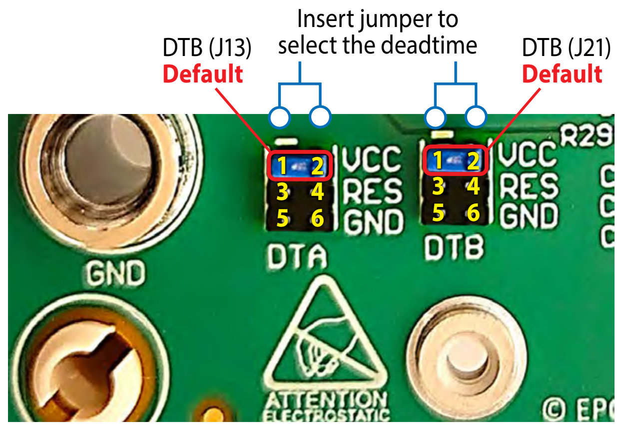


Figure 9: EPC91109 selector point locations and designations for dead time adjustment

Output Voltage Settings

The output voltage can be set to 12 V, 16 V, or 20 V. To select 12 V, insert a jumper on J2 pins 1-2. To select 20 V, insert a jumper on J2 pins 2-3. To select 16 V, do not insert a jumper.

Note: Since EPC91109 operates as a buck converter, the output voltage must be lower than the input voltage. Therefore, for output voltages of 20 V, the input voltage must be greater or equal to 22 V.

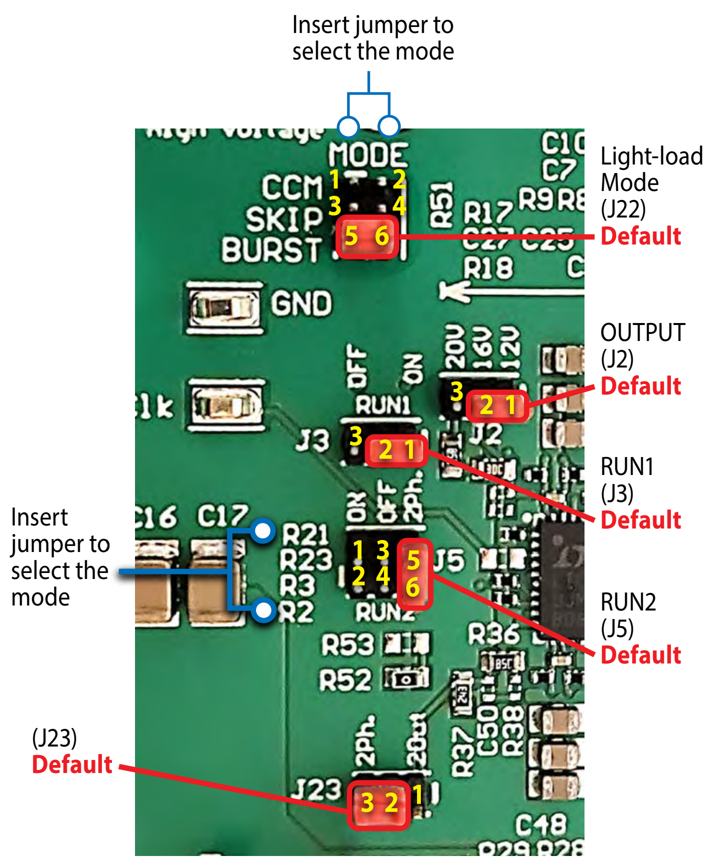


Figure 10: EPC91109 selector point locations and designations for mode settings

QUICK START PROCEDURE

The EPC91109 evaluation board is easy to set up to evaluate the performance of the EPC2057 GaN FETs. The following steps detail the two-phase configuration. Refer to figures 5, 6, 7, 8, 9 & 10 for proper connections and measurement setup and follow the procedure below to operate the board:

1. With power off, connect the input power supply between VIN and GND. Pay careful attention to the polarity of the supply as shown in figure 5. A shunt can be inserted in series with the positive supply to measure the input current.
2. Ensure the jumpers settings of J2, J3, J5, J13, J21, J22 and J23 are in the default positions.
3. With power off, short VO1 and VO2 as in figure 5.
4. Connect a suitable load between VO1 and GND. Pay careful attention to the polarity as shown in figure 5.
5. With power off, connect the various measurement probes as shown in figures 6 and 7.
6. Keeping the load off, turn on the main power supply. Observe the output voltage.
7. Adjust the load current within the current capability of the EPC91109 per table 1. Observe the temperature of the GaN FET and ensure that it does not exceed the maximum value given in the EPC2057 datasheet.
8. Collect the data measurements while adjusting the supply voltage and load current Ensure that all operating parameters remain within the specifications provided in table 1.
9. To shut down the EPC91109 evaluation board, decrease the main power supply to 0 V before turning off.

The operating instructions in this document do not cover how to perform bode measurements. Please contact EPC for more details.

EXPERIMENTAL VALIDATION

The EPC91109 evaluation board targets USB PD-based laptop and battery-powered devices by providing a step-down conversion from the input (USB connector) to the 12 V, 16 V, or 20 V output, common battery voltages in these applications. The board's maximum input current is limited to 5 A, complying with the USB PD 3.1 specification. Input voltages of 20 V, 28 V, and 36 V were tested to demonstrate efficiency and power loss of EPC91109. As shown in Figure 13, the board demonstrates high efficiency with the peak exceeding 98%. These tests were conducted with the default jumper setting configuration.

Power Performance

The measured efficiency and power loss of EPC91109 operating with various supply voltages are shown in Figures 11 through 13. In all cases the maximum input current was limited to 5 A following the USB-PD 3.1 specification. The tests were conducted without airflow and without a heatsink installed.

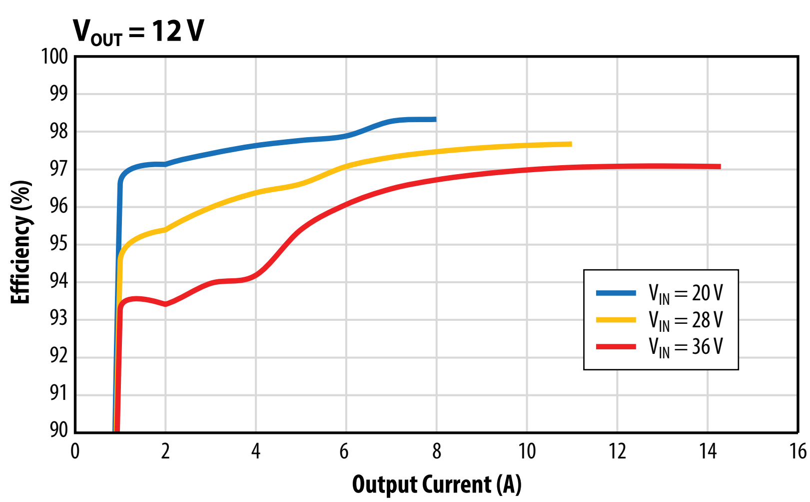


Figure 11: Measured the efficiency of the EPC91109 board for multiple input voltages and V_{OUT} = 12 V, without airflow and without a heatsink installed

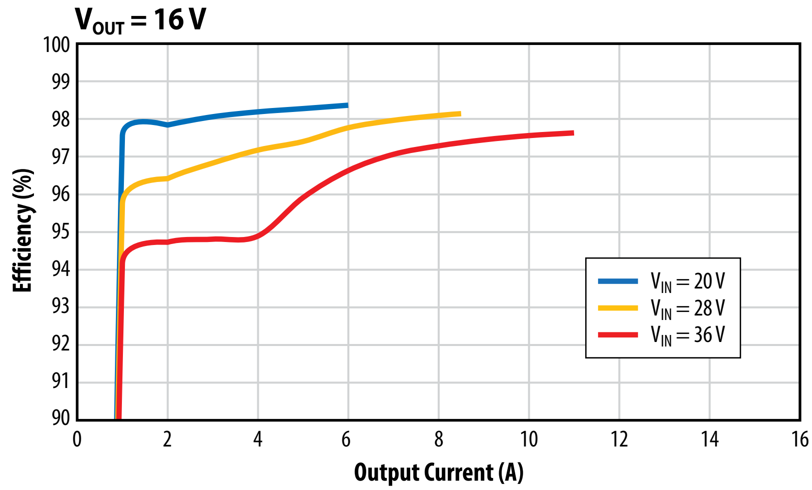


Figure 12: Measured the efficiency of the EPC91109 board for multiple input voltages and V_{OUT} = 16 V, without airflow and without a heatsink installed.

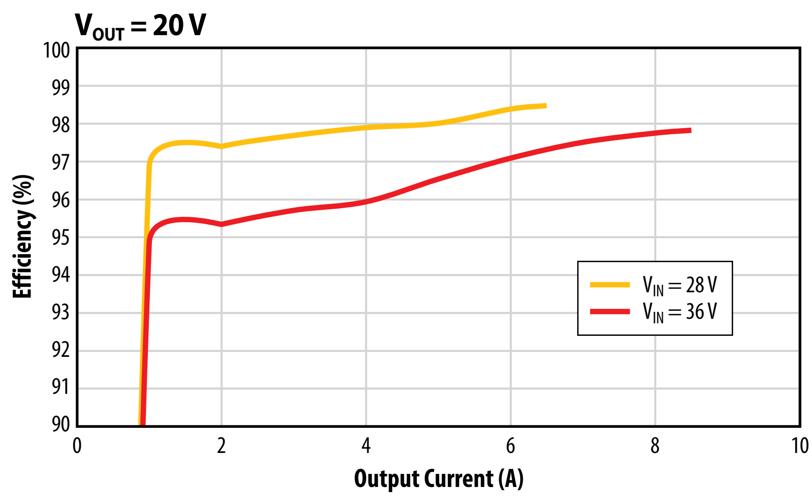


Figure 13: Measured the efficiency of the EPC91109 board for multiple input voltages and V_{OUT} = 20 V, without airflow and without a heatsink installed.

Figures 14 through 16 show the measured system power loss of EPC91109 operating at various supply voltages, with output voltages of 12 V, 16 V, and 20 V, respectively. The power loss includes the power consumption of the controller, as well as conduction and switching losses of all the elements within the power stage.

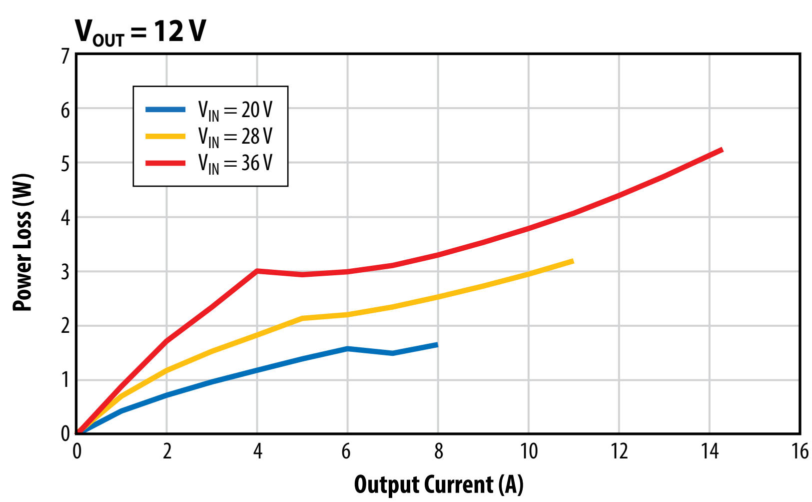


Figure 14: Measured system power loss of the EPC91109 board, operating for multiple input voltages and V_{OUT} = 12 V, without airflow and without a heatsink installed.

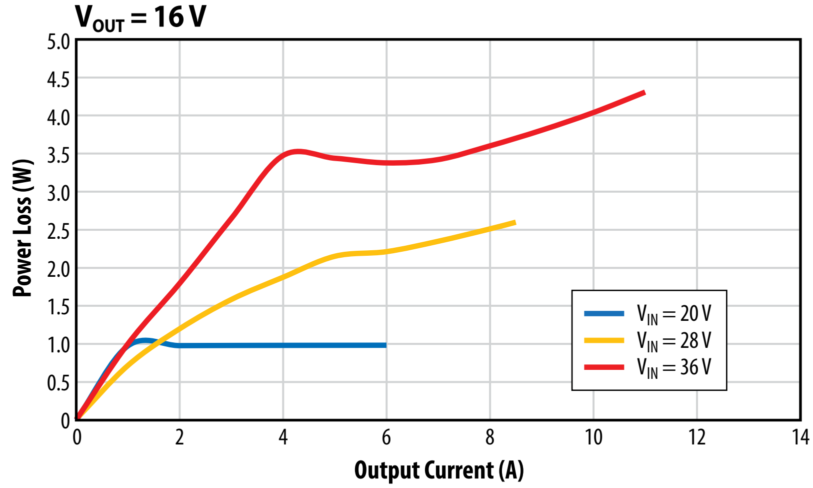


Figure 15: Measured system power loss of the EPC91109 board, operating for multiple input voltages and V_{OUT} = 16 V, without airflow and without a heatsink installed.

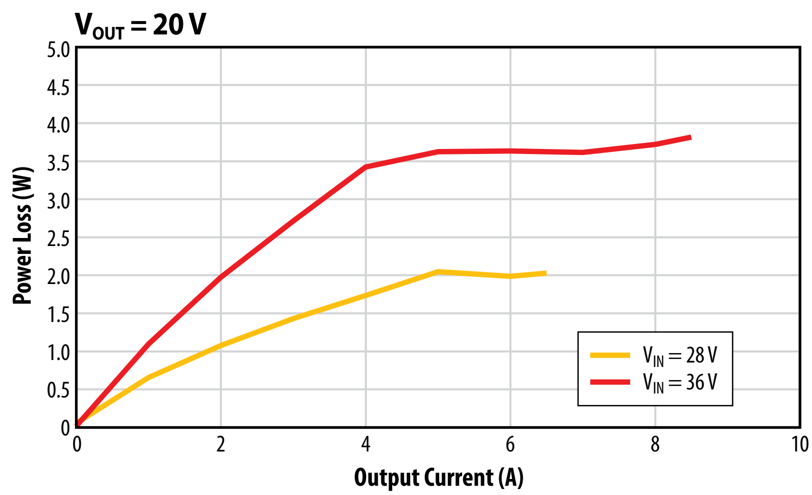


Figure 16: Measured system power loss of the EPC91109 board, operating for multiple input voltages and V_{OUT} = 20 V, without airflow and without a heatsink installed.

Waveforms

Figure 17 shows the measured switch-node waveforms taken with EPC91109 operating with 36 V input, 12 V output and delivering 7 A into the load. The switch-node between Q1 & Q2 is shown in blue and the switch-node between Q3 & Q4 is shown in red, demonstrating a 180-degree phase shift.

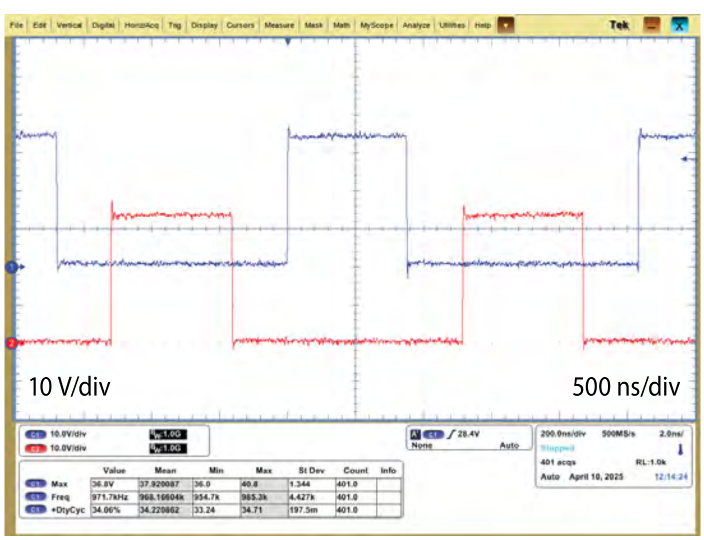


Figure 17: Measured switch-node voltage waveform of the EPC91109 operating with 36 V input, 12 V output and delivering 7 A into the load.

Figure 18 shows the measured output ripple voltage taken with EPC91109 operating with 36 V input, 12 V output and delivering 7 A into the load.

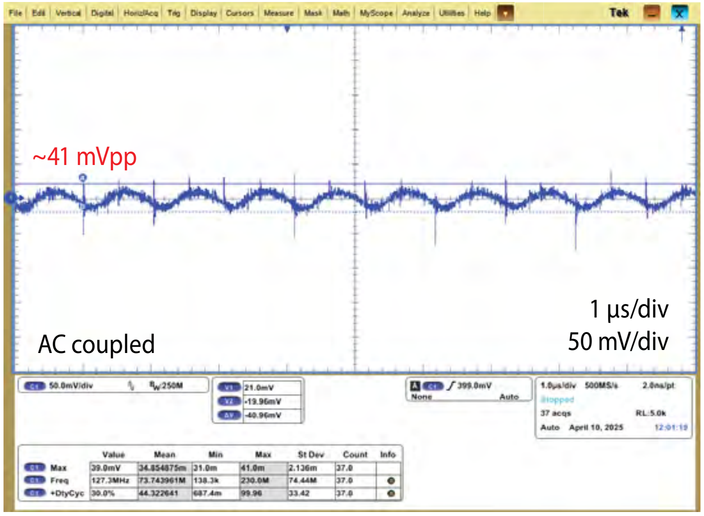


Figure 18: Measured ripple output voltage waveform of the EPC91109 operating with 36 V input, 12 V output and delivering 7 A into the load.

Transient Response

Figure 19 shows the measured transient response taken with EPC91109 operating with 36 V input, 12 V output with a load step change of 10% to 90% and 90% to 10% of 14 A output.

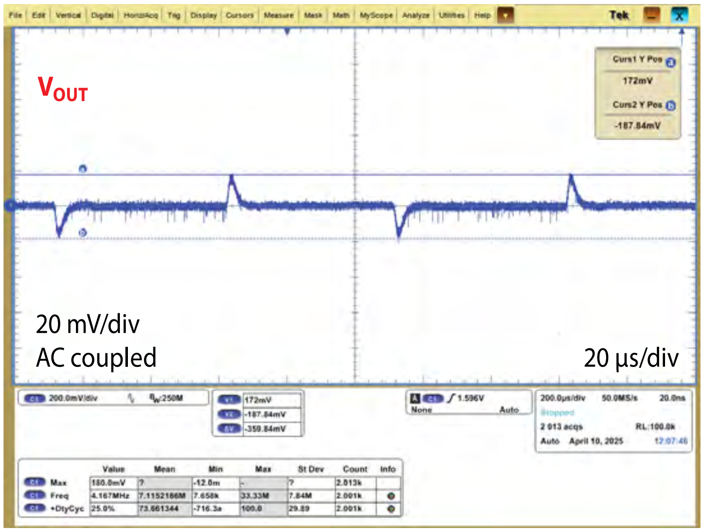


Figure 19: measured transient waveform of the EPC91109 operating with 36 V input, 12 V output and with a load step change of 10% to 90% and 90% to 10% of 14 A.

Voltage Regulation Performance

Figures 20 through 22 show the measured output voltage regulation of EPC91109 operating at various supply voltages, with output voltages of 12 V, 16 V, and 20 V, respectively.

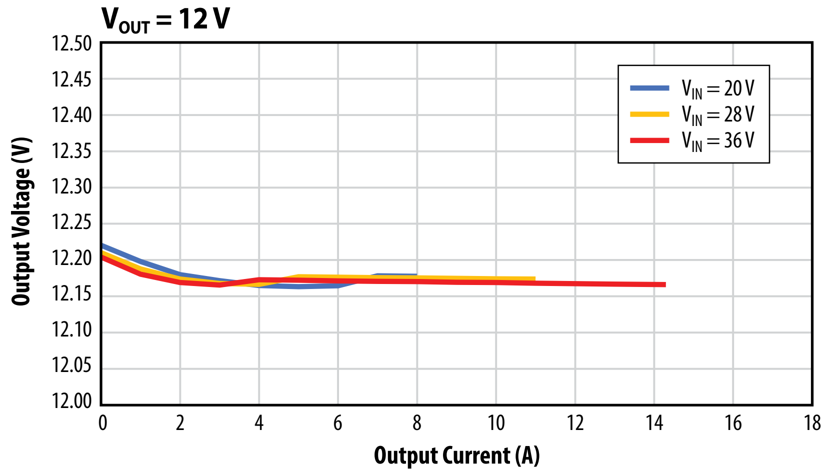


Figure 20: Measured output voltage regulation of the EPC91109 operating with various input voltages and delivering 12 V into the load as function of load current.

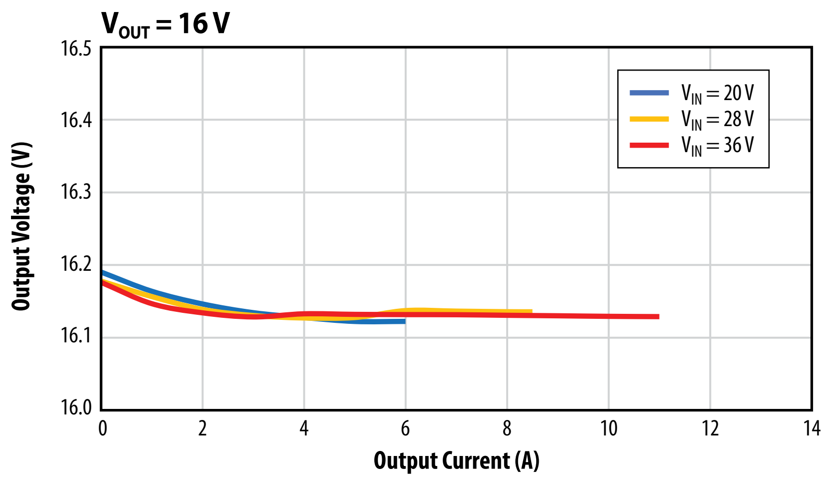


Figure 21: Measured output voltage regulation of the EPC91109 operating with various input voltages and delivering 16 V into the load as function of load current.

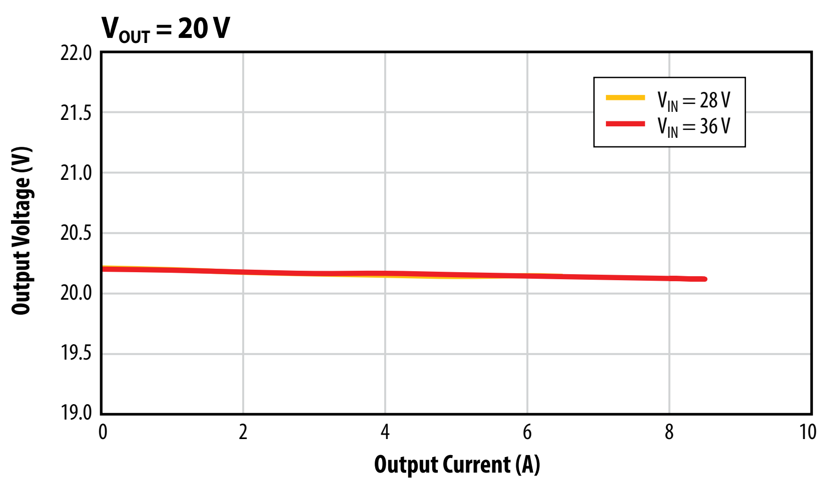


Figure 22: Measured output voltage regulation of the EPC91109 operating with various input voltages and delivering 20 V into the load as function of load current.

Thermal Performance

Figure 23 through 25 show the measured thermal performance taken with EPC91109 operating with 20 V, 28 V and 36 V input voltage respectively. The output voltage was set to 12 V, and the input current to 5 A, corresponding to 8 A, 11.2 A and 14.3 A respectively. These images were captured after the board had reached thermal steady state without a heatsink or airflow.

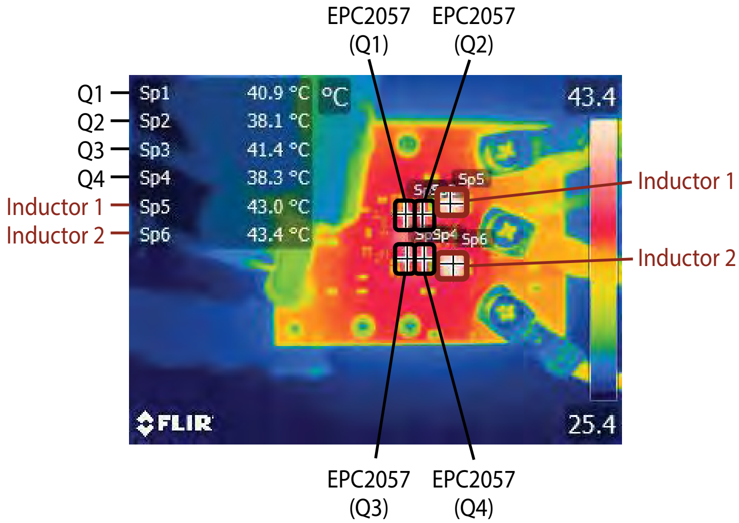


Figure 23: Steady state measured thermal image of the EPC91109 operating with 20 V input, 12 V output and delivering 8 A into the load, without airflow or heatsink.

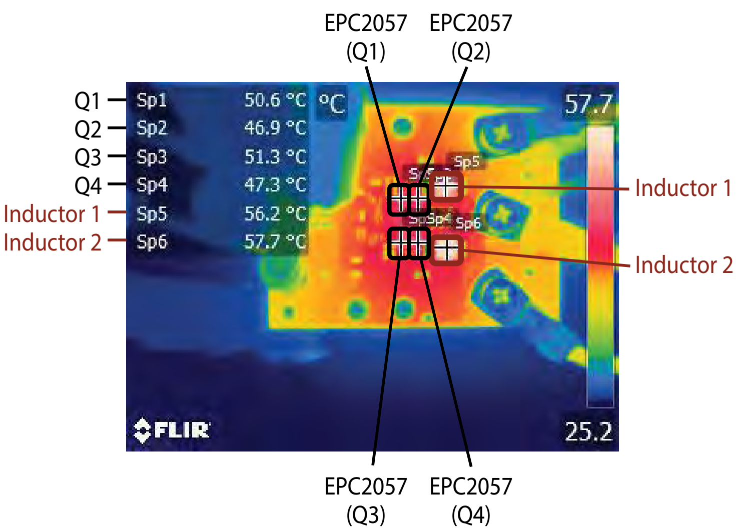


Figure 24: Steady state measured thermal image of the EPC91109 operating with 28 V input, 12 V output and delivering 11.2 A into the load, without airflow or a heatsink.

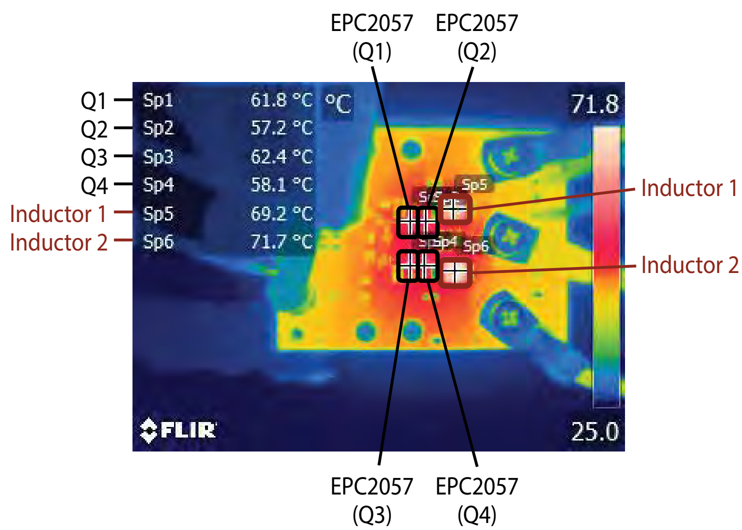


Figure 25: Steady state measured thermal image of the EPC91109 operating with 36 V input, 12 V output and delivering 14.3 A into the load, without airflow or a heatsink.

For support files including schematic, Bill of Materials (BOM), and gerber files please visit the EPC91109 landing page at: https://epc-co.com/epc/products/demo-boards/EPC91109

Reference

[1] Arribas, A., Chantarasereekul, P. (May, 2024). Advancements in USB Power Delivery: GaN Technology for Efficiency and High-Power Density. Bodo's Power Systems, 30-33.

ACKNOWLEDGEMENTS

ANALOG DEVICES

AHEAD OF WHAT'S POSSIBLE™

EPC would like to acknowledge Analog Devices Inc. (www.analog.com) for their support of this project. Analog Devices (NASDAQ: ADI) is a world leader in the design, manufacture, and marketing of a broad portfolio of high-performance analog, mixed-signal, and digital signal processing (DSP) integrated circuits (ICs) used in virtually all types of electronic equipment. Since their inception in 1965, they have focused on solving the engineering challenges associated with signal processing in electronic equipment. Used by over 100,000 customers worldwide, their signal processing products play a fundamental role in converting, conditioning, and processing real-world phenomena such as temperature, pressure, sound, light, speed, and motion into electrical signals to be used in a wide array of electronic devices.

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EFFICIENT POWER CONVERSION

Evaluation Board Notification

The EPC91109 board is intended for product evaluation purposes only. It is not intended for commercial use nor is it FCC approved for resale. Replace components on the Evaluation Board only with those parts shown on the parts list (or Bill of Materials) in the Quick Start Guide. Contact an authorized EPC representative with any questions. This board is intended to be used by certified professionals, in a lab environment, following proper safety procedures. Use at your own risk.

As an evaluation tool, this board is not designed for compliance with the European Union directive on electromagnetic compatibility or any other such directives or regulations. As board builds are at times subject to product availability, it is possible that boards may contain components or assembly materials that are not RoHS compliant. Efficient Power Conversion Corporation (EPC) makes no guarantee that the purchased board is 100% RoHS compliant.

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