EPC9195

High Power Density, Synchronous Buck Converter Quick Start Guide

Featuring the EPC2619 eGaN® FET and LTC7891 Controller

Revision 1.1

EFFICIENT POWER CONVERSION

DESCRIPTION

The EPC9195 is a half bridge buck configuration Evaluation Board with onboard controller, featuring the 100 V rated EPC2619 GaN field effect transistor (FET). The EPC9195 measures 61 x 61 mm that operates at 740 kHz with an input voltage range from 36 V through 60 V and can deliver up to 16 A load current into 13 V load. A diagram overview of the functional blocks of the EPC9195 with two EPC2619 GaN FETs is shown in figure 1.

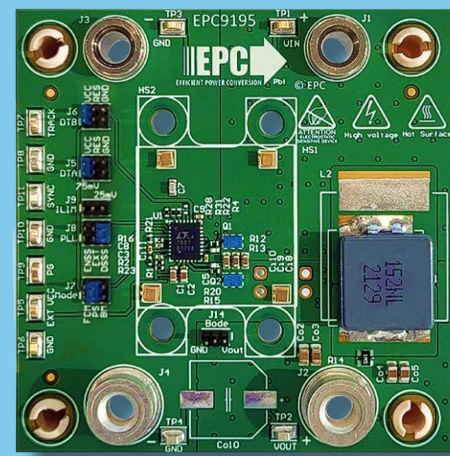
REGULATORY INFORMATION

This Evaluation Board is for evaluation purposes only. It is not a full-featured unit and cannot be used in final products. No EMI test was conducted. It is not FCC approved.

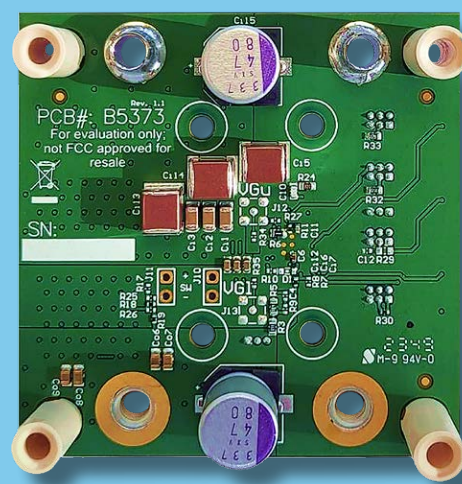
KEY FEATURES OF THE EPC9195 Evaluation Board

- Employs two low conduction and switching loss EPC2619 GaN FETs in half-bridge buck power stage,
- Features ADI's new **LTC7891 100 V synchronous GaN buck controller**
- Simple, high power-density, compact layout of 61 x 61 mm size board,
- Configured with a small inductor of just 12.5 x 13.5 x 3.5 mm size,
- Synchronous buck configuration for high efficiency,
- Fully protected and low component count solution,

EPC9195 Evaluation Board



Front view



Back view

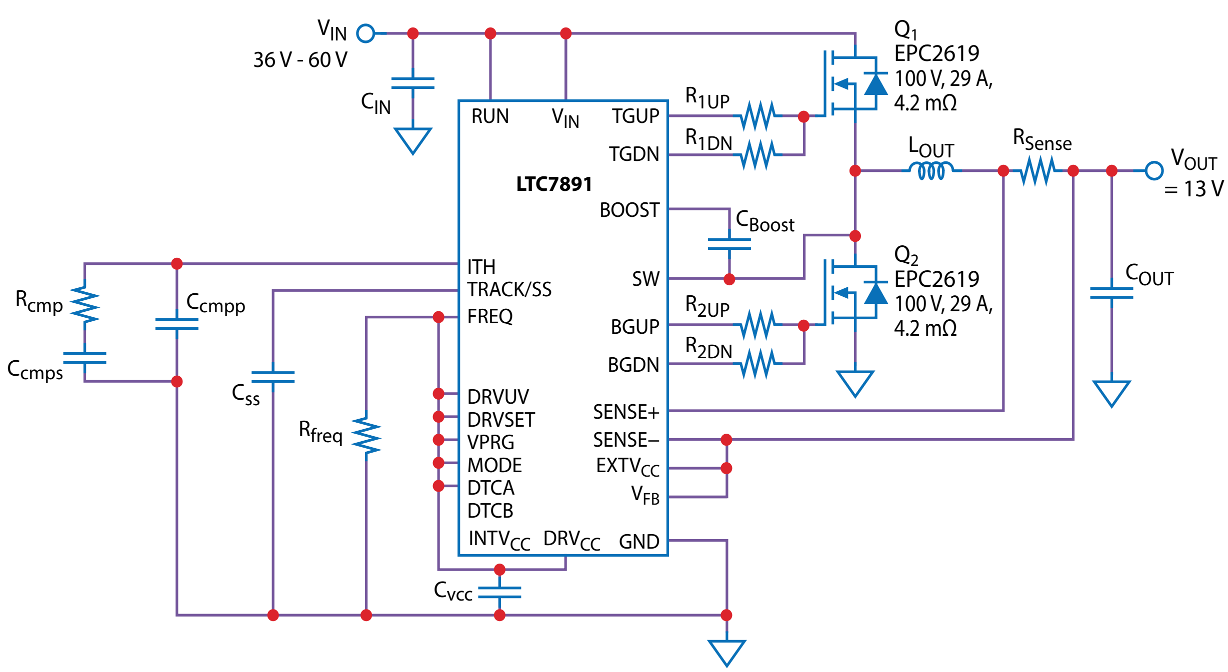


Figure 1: Diagram overview of the EPC9195 Evaluation Board

FEATURED GaN FETs

The EPC9195 Evaluation Board features the 100 V rated, 4.2 mΩ $R_{DS(on)}$ EPC2619 GaN FETs in a half bridge buck configuration. The symbol of GaN FET and photo with pin assignment are shown in figure 2.

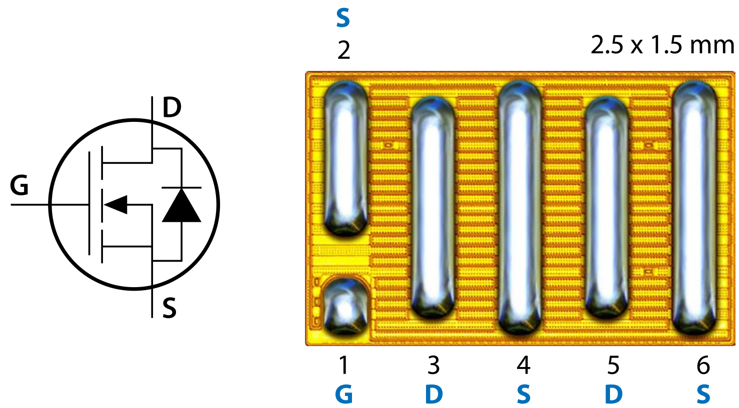


Figure 2: Symbol and photo with pin assignments of the EPC2619

Refer to the **EPC2619 datasheet** for additional details.

OVERVIEW OF THE EPC9195 Evaluation Board

Figure 3 shows an image of both sides of the EPC9195 Evaluation Board with the location of the various functional circuits highlighted.

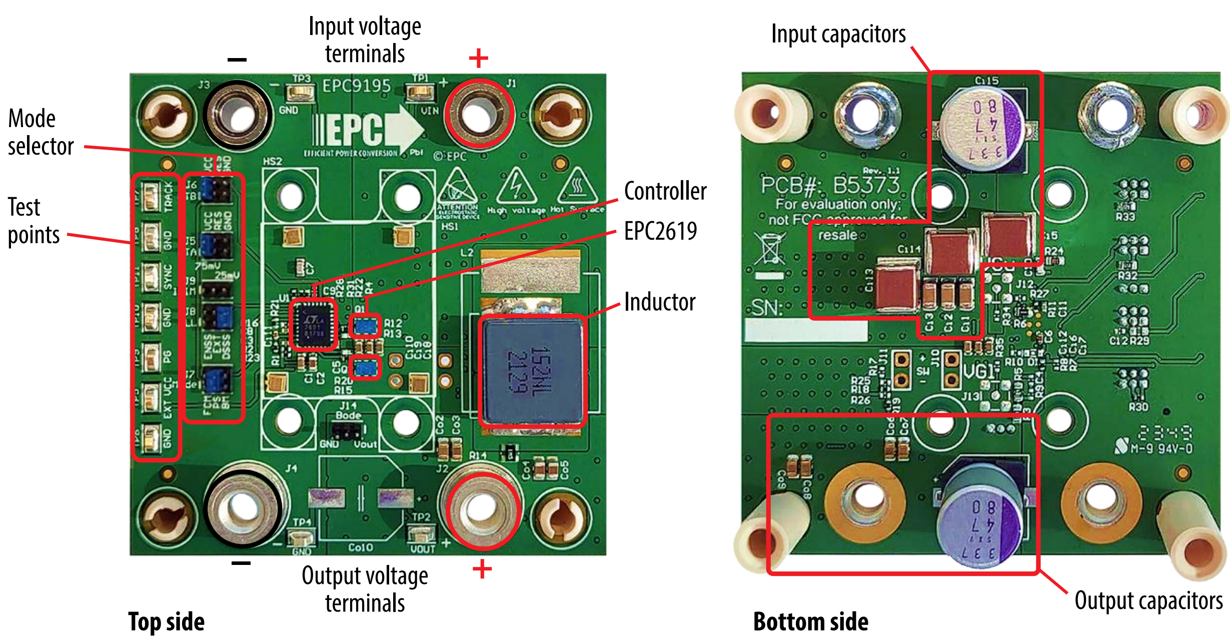


Figure 3: Photo overview of the EPC9195 Evaluation Board with various functional blocks highlighted

Figure 4 shows a photo of the zoomed-in area of the application circuit that fits within the highlighted area of approximately 20 x 20 mm that excludes the inductor, input capacitors, and output capacitors.

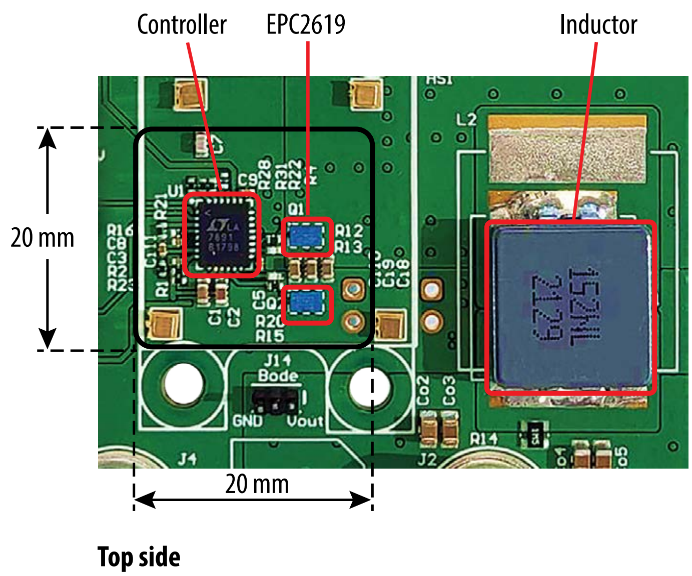


Figure 4: Zoomed-in photo details of the EPC9195 Evaluation Board with various components highlighted

RECOMMENDED OPERATING CONDITIONS

Table 1: Performance Summary (T_A = 25°C) EPC9195

Symbol	Parameter	Conditions	Min	Nominal	Max	Units
V_{IN}	Input Voltage Port (V_{IN})	I_{OUT} = 0 A to 16 A	36	48	60[1]	V
V_{OUT}	Output Voltage Port (V_{OUT})	V_{IN} = 36 V to 60 V		13		
I_{OUT}	Output Current	With no heatsink & 400 LFM airflow			16[2]	A
f_{SW}	Nominal Switching frequency			740[3]		kHz
TP11: Ext SYNC	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 64 V with 80% derating. In addition, the board was not tested in closed loop beyond 60 V input voltage.

2 Maximum current capability is lower than stated in EPC2619 datasheet as it is dependent on thermal conditions and die temperature, and on component choice and board design – 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 EPC2619 datasheet for details.

3 LTC7891 controller can operate from 200 kHz through 3MHz switching frequency. EPC9195 is set to operate at a fixed switching frequency of 740 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 13 V output voltage.

HIGHLIGHTED PARTS OF THE EPC9195 CIRCUIT

Refer to figures 1 and 4 for the main blocks and components that comprise the EPC9195 Evaluation Board.

Power Stage

The EPC9195 features a half-bridge converter using the EPC2619 GaN FETs. For more information on the EPC2619, please refer to the datasheet available from EPC at **www.epc-co.com**. The datasheet should be read in conjunction with this quick start guide.

Current and Voltage Sense

The EPC9195 Evaluation Board is equipped with voltage and current sense for feedback. Voltage is measured using simple resistor divider networks and bode measurement points are provided for closed loop tuning. **J14** is used for signal injection and measurement for bode plots.

Inductor current is measured using a current sense resistor, 1.5 mΩ shunt (**R14**), provides an accurate inductor current limit for the controller.

Controller

The power circuit of the EPC9195 Evaluation Board is controlled using the LTC7891RUFD synchronous step-down controller from Analog Devices and is configured in fixed frequency and peak current mode control. The functions of the LTC7891RUFD controller can be adjusted using the appropriate jumper-setting. For information on configuring the controller, please refer to jumper section.

CONNECTIONS, MEASUREMENT TEST POINTS & JUMPERS

Power Connections

To operate the EPC9195 in buck mode, connect the input supply to the load as shown in figure 5.

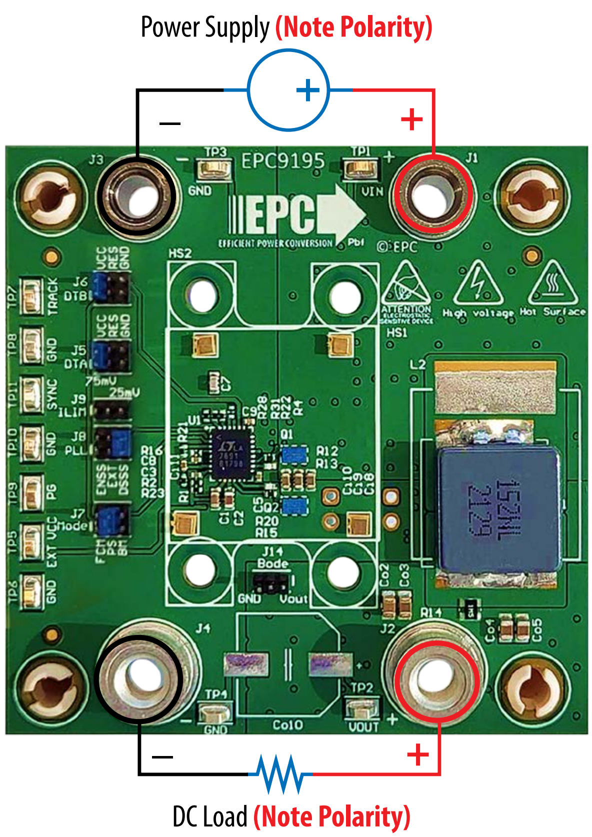


Figure 5: Power connections to the EPC9195 demonstration

Test Points and Measurement Setup

Figure 6 shows the various measurement connections of the EPC9195 Evaluation Board.

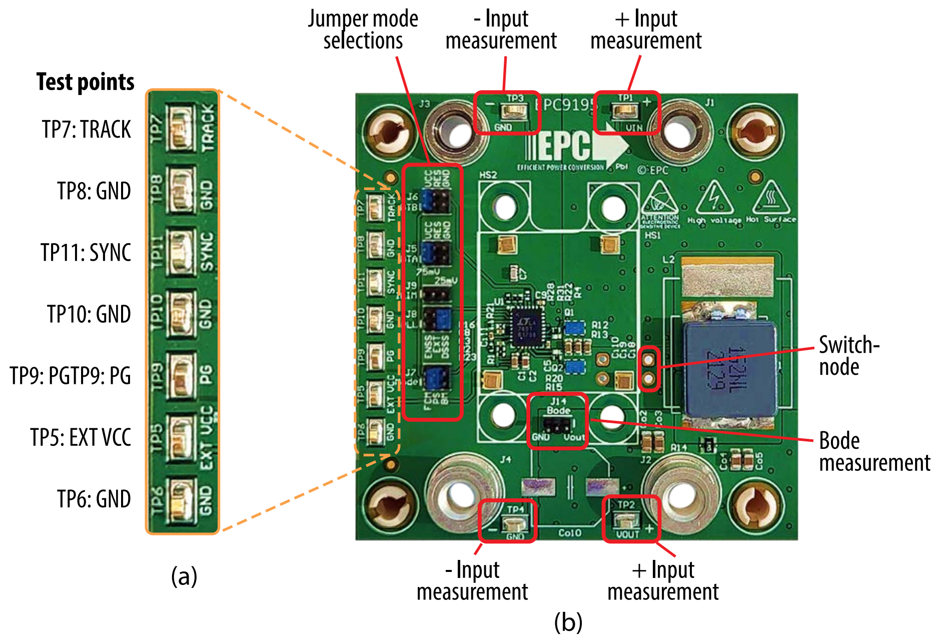


Figure 6: (a) Zoomed view of test points (b) EPC9195 test point pad and hookup locations and designations

The available measurement nodes with their respective reference are:

- **V_{IN}-GND**: Input voltage (**TP1** & **TP3**)
- **V_{OUT}-GND**: Output voltage (**TP2** & **TP4**)
- **SYNC-GND** : Clock waveform when external clock is applied (**TP11** & **TP10**)
- **TRACK-GND** : Initial ramp soft start (**TP7** & **TP8**)
- **EXTVCC-GND** : External supply voltage to controller (**TP5** & **TP6**)
- **PG-GND**: Power good logic output (**TP9** & **TP10**).

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

Switch-node

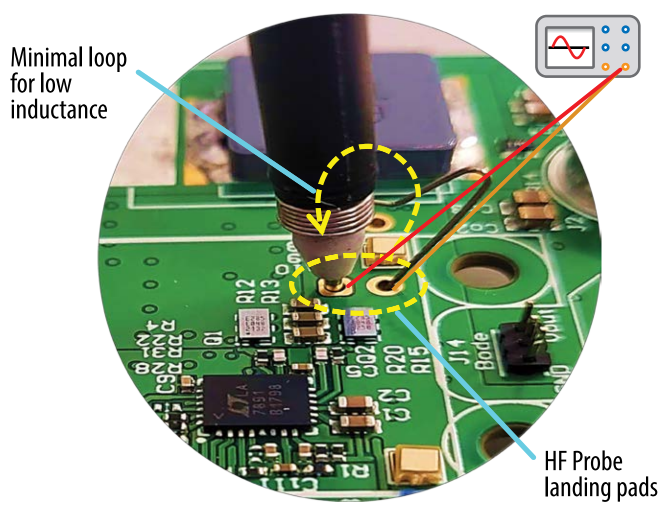


Figure 7: Recommended method to measure the switch- node measurement voltage waveform

Jumper Settings:

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

Dead-Time settings

The EPC9195 has two dead-time settings; 1) switch-node rising edge, and 2) switch-node falling edge. The rising edge is the dead time between Q2 turn-off and Q1 turn-on set using J5 and the falling edge is the dead time between Q1 turn-off and Q2 turn-on set using J6. The available settings for both J5 and J6 are; 1) position 1-2 (VCC) for near zero dead-time (default), 2) position 3-4 (RES) for approximately 10 ns dead-time, and 3) position 5-6 (GND) for 20 ns dead-time. Details are shown in figure 8.

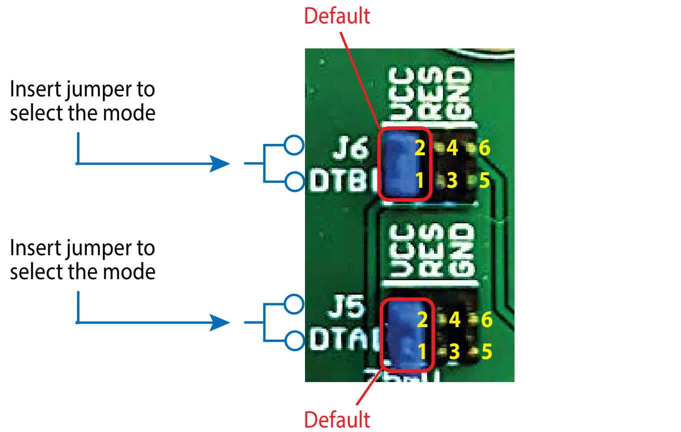


Figure 8: EPC9195 selector point locations and designations for dead time adjustment

Light-Load Mode Selection

The EPC9195 has three light-load operating modes available which are 1) forced continuous inductor current (FCM), 2) pulse skipping (PSM), and 3) burst mode (BM). See the LTC7891 datasheet for details on each operating mode. The desired operating mode can be selected by inserting a jumper into the appropriate position on J7 with position 1-2 for FCM, position 3-4 for PSM (default) and position 5-6 for BM, as shown in figure 9.

Oscillator Settings

The EPC9195 has three oscillator setting options; 1) Disable spread spectrum (DS SS), 2) External clock (EXT), and 3) Enable spread spectrum (EN SS). See the LTC7891 datasheet for details on each setting and refer to table 1 for external clock voltages. The desired setting can be selected by inserting a jumper into the appropriate position on J8 with position 1-2 for EN SS, position 3-4 for External clock (EXT SYNC), and position 5-6 for DS SS (default). When selecting the external clock option, the external signal can be connected between SYNC (TP11) and GND (TP10) and must be within the specifications of the LTC7891 IC given in table 1. See figure 9 for the location of the oscillator jumper settings.

Current Sense Settings

The LTC7891 internal current comparator can be configured with one of three maximum current sense threshold settings which are 25 mV, 50 mV and 75 mV. The threshold level can be selected by inserting the jumper on J9 with position 1-2 for 75 mV threshold, position 2-3 for 25 mV threshold, and without inserting jumper for 50 mV threshold (**default**), as shown in figure 9. Please refer to the **LTC7891 datasheet** for more information.

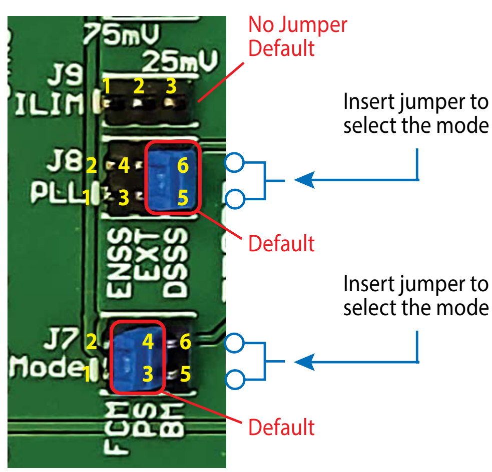


Figure 9: EPC9195 selector jumper locations and designations for oscillator, current sense level, and light load mode settings

QUICK START PROCEDURE

The EPC9195 Evaluation Board is easy to set up to evaluate the performance of the EPC2619 GaN FETs. Refer to figures 5, 6, 7, 8, & 9 for proper connection and measurement setup and follow the procedure below to operate the board:

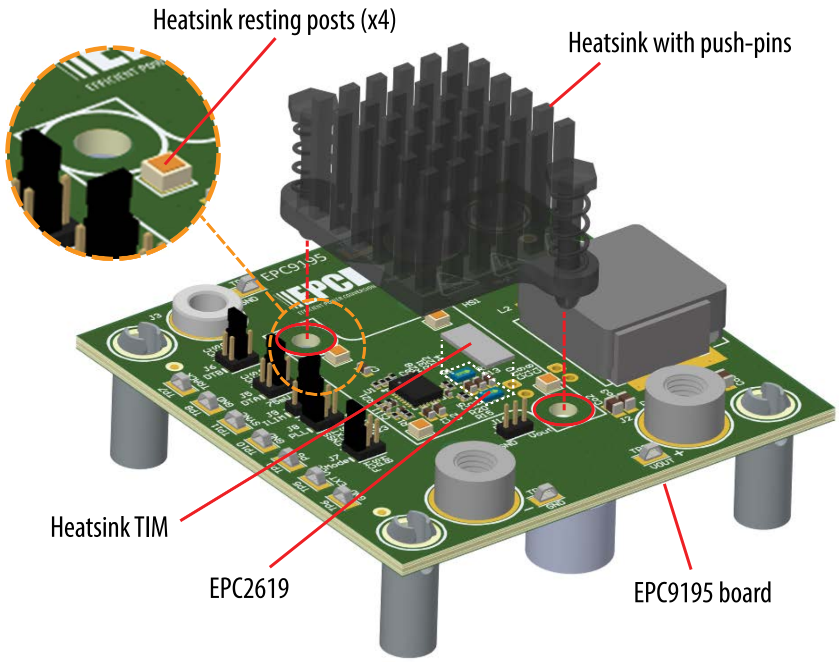
1. With power off, connect the input power supply between VIN (J1) and GND (J3). Pay careful attention to the polarity of the supply as shown in figure 5. A shunt can be inserted in series with the positive supply to measure the input current.
2. Ensure the jumpers settings of J5, J6, J7 and J8 are in the default positions.
3. With power off, connect a suitable load between VOUT (J2) and GND (J4). Pay careful attention to the polarity as shown in figure 5.
4. With power off, connect the various measurement probes as shown in figure 6 and 7.
5. **Keeping the load off**, turn on the main power supply. Observe that the output voltage is 13 V.
6. Adjust the load current within the current capability of the EPC9195 per table 1. Observe the temperature of the GaN FET and ensure that it does not exceed the maximum value given in the **EPC2619 datasheet**.
7. 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.
8. To shut down the EPC9195 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 refer to the equipment manufacturer for those instructions.

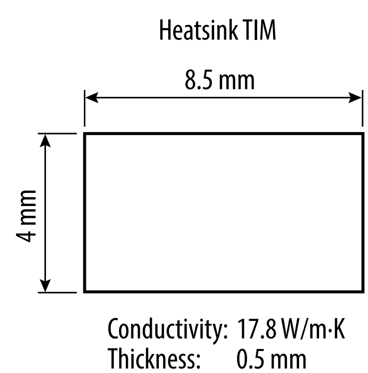
THERMAL MANAGEMENT (Optional)

The EPC9195 is intended for bench evaluation at room ambient temperatures and under forced air convection cooling. The addition of heatsink along with forced air cooling is not required but can significantly improve the heat dissipation from heating parts by adding cooling from the top side of the device and thus increase the current capacity of the application.

Figure 10 shows an exploded 3D view of the simple cooling system for the EPC9195 Evaluation Board that comprises just 3 elements; a heatsink, a 4 x 8.5 mm Thermal Interface Material (TIM), and heatsink resting posts.



(a)



(b)

Figure 10: (a) Exploded view of the EPC9195 heatsink assembly, (b) Details of the recommended TIM's used on the EPC9195 Evaluation Board.

It is important that the TIM properly cover both eGaN FETs. The heatsink is then carefully placed on top aligned with the pop-in pins located into their respected holes in the EPC9195 PCB. The heatsink rests on custom 2 x 2 mm a 1 mm tall standoff posts located at the corners of the heatsink landing made from low cost FR4. The pins are then carefully popped into place to secure the heatsink.

The choice of TIM for the GaN FETs needs to consider the following characteristics:

- **Mechanical compliance** – During the attachment of the heat spreader, the TIM underneath is compressed from its original thickness to the vertical gap distance between the spacers and the FETs. This volume compression exerts a force on the eGaN FET/IC. A maximum compression of 2:1 is recommended for maximum thermal performance and to constrain the mechanical force which maximizes thermal mechanical reliability.
- **Electrical insulation** – The backside of the eGaN FET/IC is a silicon substrate that is connected to ground. Electrical insulation is not required but is still recommended to isolate the GaN IC from the thermal solution.
- **Thermal performance** – The choice of thermal interface material will affect the thermal performance of the thermal solution. Higher thermal conductivity materials are preferred to provide higher thermal conductance at the interface.

EPC recommends the t-Global Part Number: TG-A1780 for the GaN FETs TIM as it has a high thermal conductivity of 17.8 W/m·K.

EXPERIMENTAL VALIDATION

The target applications for the EPC9195 Evaluation Board are battery chargers for eBikes or in board USB PD 3.1 laptops that use 12 V batteries. The board is configured in using the default jumper settings and operated from a supply ranging from 36 V through 60 V.

Power Performance

The measured efficiency of the EPC9195 operating with various supply voltages is shown in figure 11.

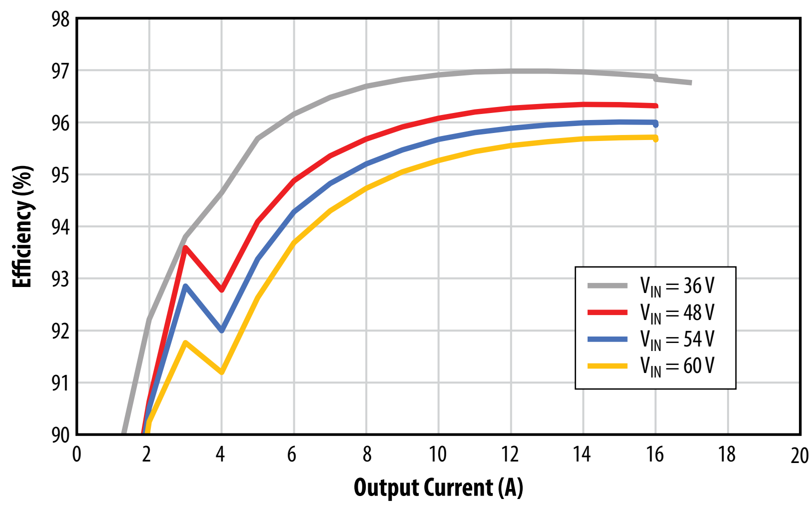


Figure 11: Measured the efficiency of the EPC9195 board for multiple input voltages and V_{OUT} = 13 V, 400 LFM airflow and without a heatsink installed.

The measured system power loss of the EPC9195 operating from various supply voltages is shown in figure 12. The power loss includes the power consumption of the controller and switching losses of the EPC2619 eGaN FET.

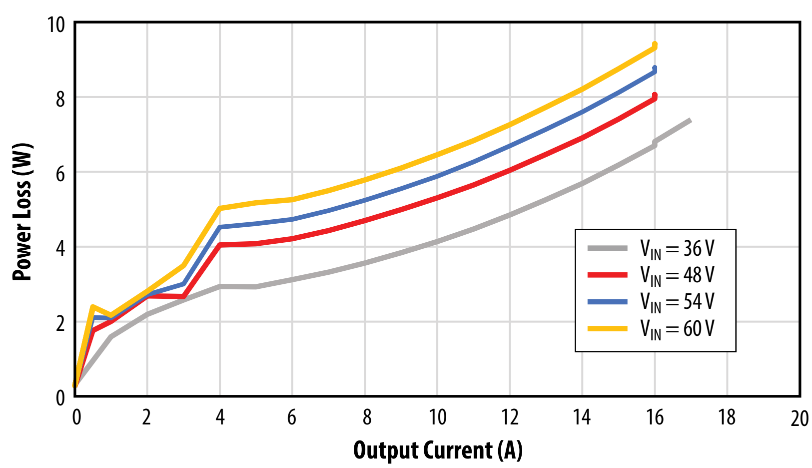


Figure 12: Measured system power loss of the EPC9195 board, operating for multiple input voltages and V_{OUT} = 13 V, 400 LFM airflow and without a heatsink installed.

Waveforms

Figure 13 shows the measured switch-node waveform taken with the EPC9195 operating with 48 V input, 13 V output and delivering 16 A into the load.

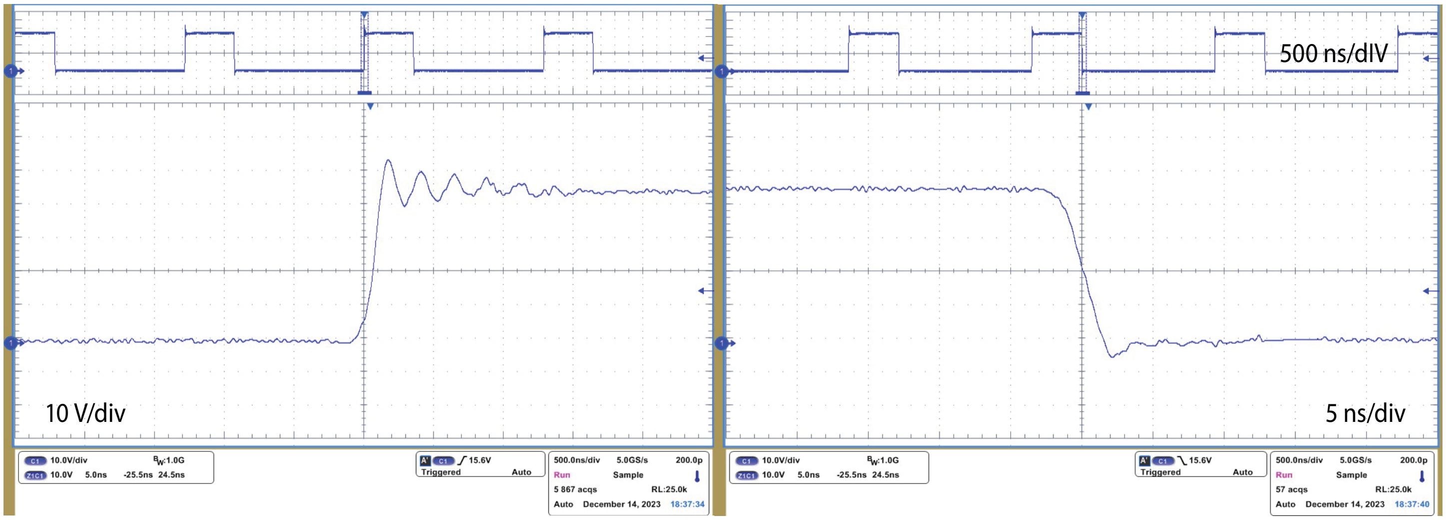


Figure 13: Measured switch-node voltage waveform of the EPC9195 operating with 48 V input, 13 V output and delivering 16 A into the load.

Figure 14 shows the measured output ripple voltage taken with the EPC9195 operating with 48 V input, 13 V output and delivering 16 A into the load.

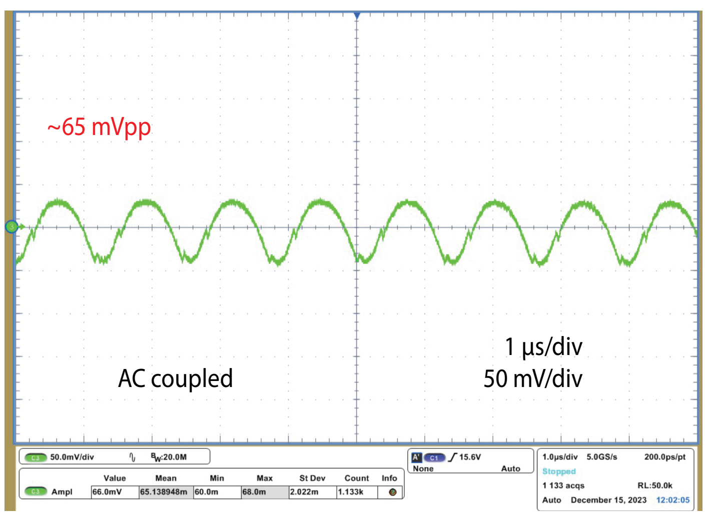


Figure 14: measured transient waveform of the EPC9195 operating with 48 V input, 13 V output and with a load step change of 10% to 90% and 90% to 10% of 16 A.

Transient Response

Figure 15 shows the measured transient response taken with the EPC9195 operating with 48 V input, 13 V output with a load step change of 10% to 90% and 90% to 10% of 16 A output.

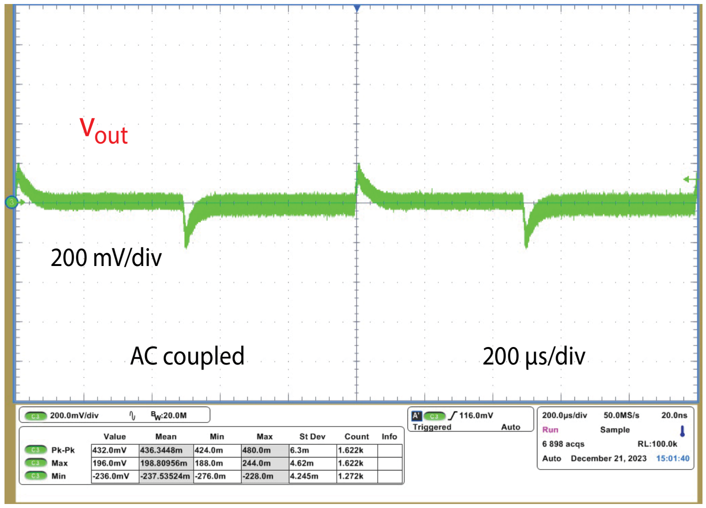


Figure 15: Measured transient waveform of the EPC9195 operating with 48 V input, 13 V output and with a load step change of 10% to 90% and 90% to 10% of 16 A.

Voltage Regulation Performance

Figure 16 shows the measured output voltage regulation taken with the EPC9195 operating with different input voltages and delivering 13 V into the load as function of load current.

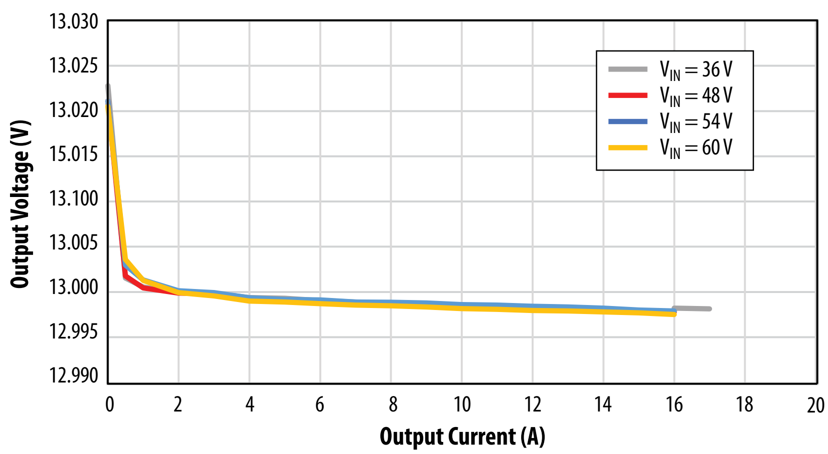


Figure 16: Measured output voltage regulation of the EPC9195 operating with various input voltages and delivering 13 V into the load as function of load current.

Thermal Performance

Figure 17 through 20 shows the measured thermal performance taken with the EPC9195 operating with 36 V, 48 V, 54 V, and 60 V input respectively. The output was set to 13 V and delivered 16 A into the load, with no heatsink installed and with 400 LFM airflow.

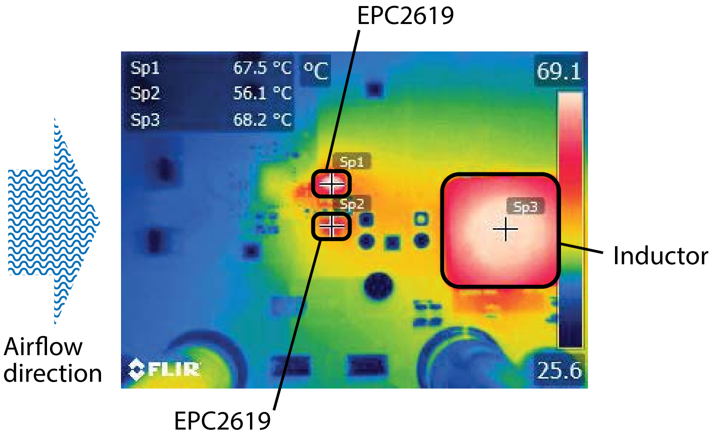


Figure 17: Steady state measured thermal image of the EPC9195 operating with 36 V input, 13 V output and delivering 16 A into the load, 400 LFM airflow and no heatsink attached.

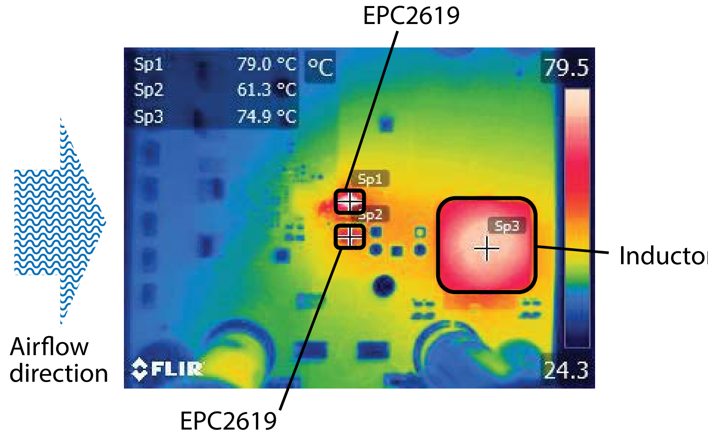


Figure 18: Steady state measured thermal image of the EPC9195 operating with 48 V input, 13 V output and delivering 16 A into the load, 400 LFM airflow and no heatsink attached.

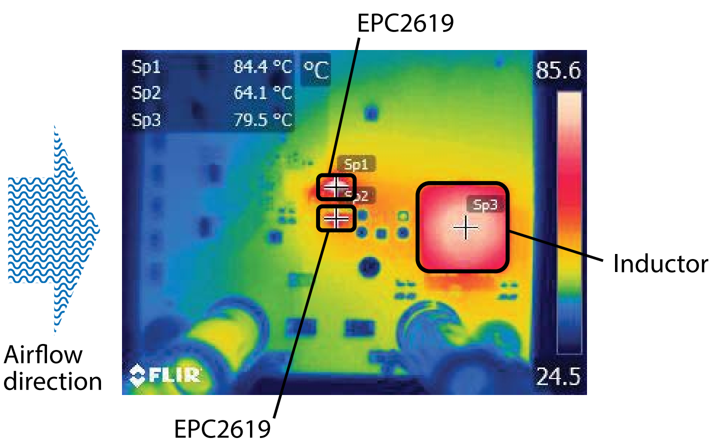


Figure 19: Steady state measured thermal image of the EPC9195 operating with 54 V input, 13 V output and delivering 16 A into the load, 400 LFM airflow and no heatsink attached.

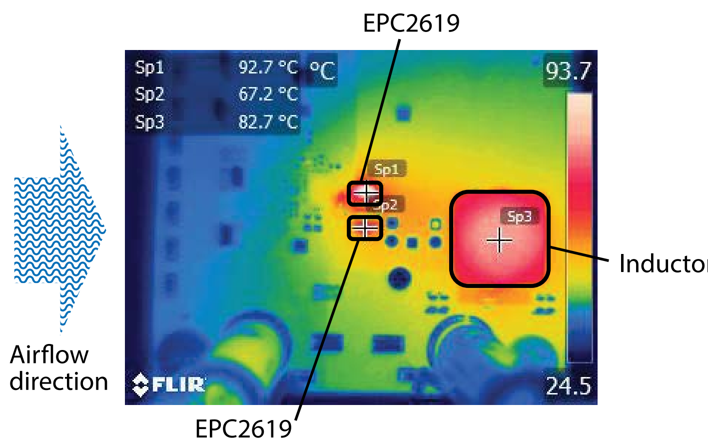


Figure 20: Steady state measured thermal image of the EPC9195 operating with 60 V input, 13 V output and delivering 16 A into the load, 400 LFM airflow and no heatsink attached.

For support files including schematic, Bill of Materials (BOM), and gerber files please visit the EPC9195 landing page at: https://epc-co.com/epc/products/evaluation-boards/epc9195

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 EPC9195 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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