Evaluation Board EPC91125 Quick Start Guide

40 A_{RMS}, 3-phase BLDC Motor Drive Inverter using the EPC2367 eGaN® FET

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EFFICIENT POWER CONVERSION

DESCRIPTION

The EPC91125 demonstration board is a 3-phase BLDC motor drive inverter board featuring the EPC2367 eGaN FET 1.2 mΩ typical $R_{DS(on)}$, 100 V maximum device voltage. The EPC91125 can deliver up to 50 A_{pk} (35 A_{RMS}) steady-state output current and up to 56.4 A_{pk} (40 A_{RMS}) maximum output current. The board supports PWM switching frequencies up to 100 kHz in motor drive applications. The EPC91125 contains all the necessary critical functional circuits to support a complete motor drive inverter, including gate drivers, regulated auxiliary power rails for housekeeping supplies, voltage and temperature sensing, and accurate current sensing. The various functional blocks are shown in Figure 1. The EPC91125 mates with an assortment of compatible controllers, supported by various manufacturers leveraging existing resources for quick development purposes, and can then be quickly configured as a motor drive inverter.

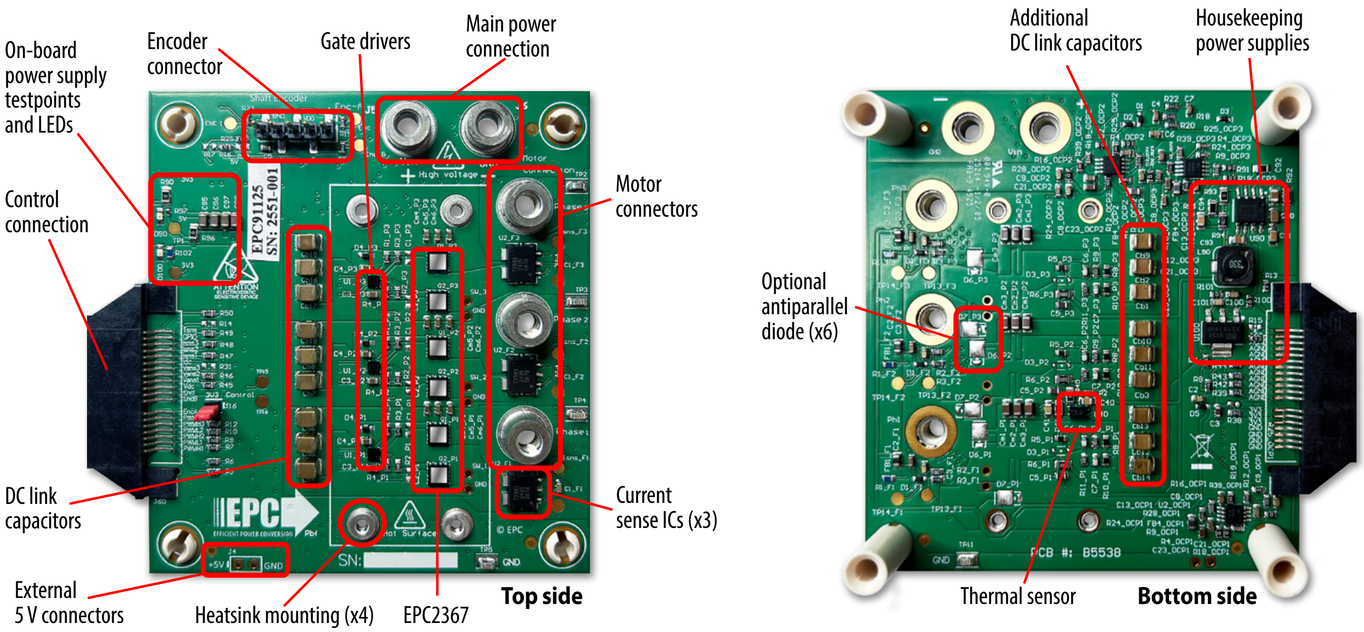


Figure 1: Photo overview of the EPC91125 evaluation board highlighting the main sections

A functional block diagram of the EPC91125 evaluation board is shown in figure 2 that details the phase current sense, phase and DC voltage sense, the half-bridge power stages, housekeeping power supply and controller interface connection.

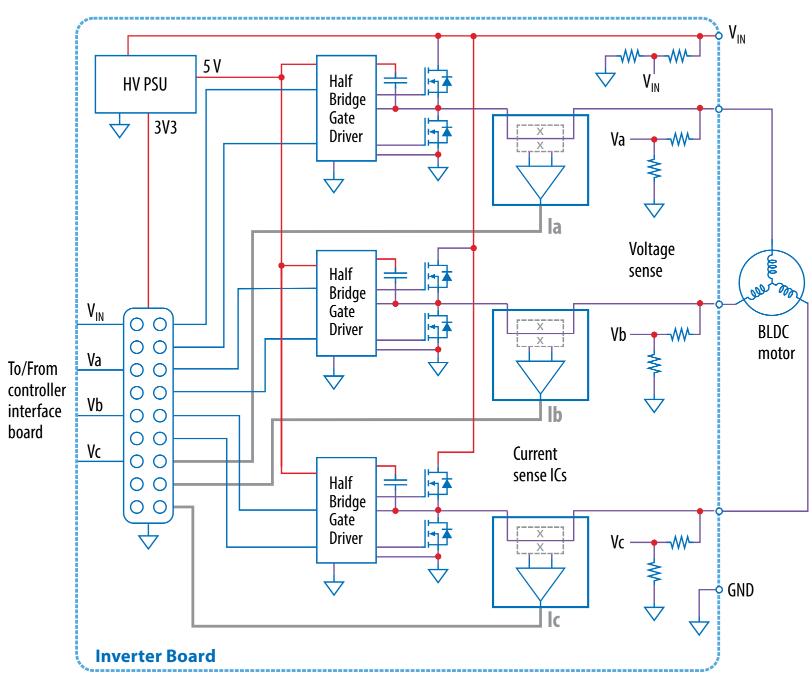


Figure 2. Block diagram of EPC91125 board in BLDC drive example application.

MAIN FEATURES

- 3-phase inverter based on EPC2367 eGaN FET with wide input DC voltage ranging from 18 V to 80 V
- Dimensions: L x W = 79 x 80 mm^2 (including connector)
- Low distortion switching that keeps motor audio emission low and reduces torque ripple
- dv/dt optimized for motor drives less than 10 V/ns with option to increase dv/dt for DC-DC applications
- All current sense with high accuracy and bandwidth
- All phases voltage sense
- Voltage sense for the DC supply to the drive
- Input supply under-voltage lockout
- Housekeeping power for the various circuits and external controller derived from the main power supply to the EPC91125
- Temperature monitoring circuit
- Shaft encoder/Hall sensors interface connector for motor drive application with two voltage levels selection option

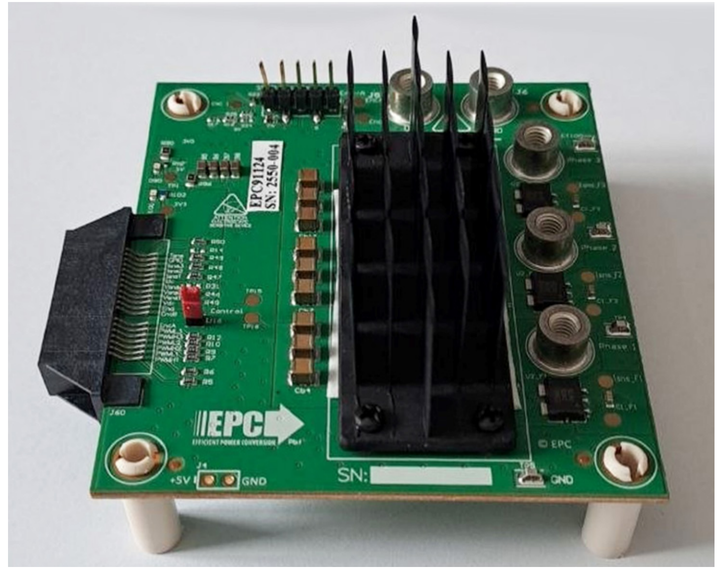


Figure 3: EPC91125 Evaluation board with heatsink attached

RECOMMENDED OPERATING CONDITIONS

Table 1: Electrical Specifications (T_A = 25°C) EPC91125

Symbol	Parameter	Conditions	Min	Nom	Max	Units
V_{IN}	Input supply voltage		18	48	80	V
I_{Phase}	EPC91125 Phase current[1]				35	A_{RMS}
f_{sw}	Switching frequency		20	50	100	kHz
V_{IN_uvlo}	Input under voltage lockout voltage			8		
$V_{IN\_uvlo\_hys}$	Input under voltage lockout voltage hysteresis			0.15		
V_{IH}	PWM high-level logic threshold	PWM rising edge	2.4			V
V_{IL}	PWM low-level logic threshold	PWM falling edge			0.8	
V_{IHyst}		V_{1H} Rising – V_{1L} Falling		0.5		
R_{in}	PWM input pulldown resistance			200		kΩ
PW_{min}	Minimum input pulse -width	50% level to 50% level – based on gate driver specs		120		ns
t_{Prop_delay}	PWM input to Switch-node transition delay	High-side/Low-side on/off		50		
V_{Isns_range}	Phase current sense voltage dynamic range	–Imax to Imax	0		3.3	V
I_{sns_range}	Phase current sense dynamic range	Current sense IC gain 13.2 mV/A	-125		125	A
I_{OC_range}	Overcurrent range		-70		+70	A
V_{Isns_offset}	Amplified current sense signal offset voltage			1.65		V
G_{Isns}	Amplified current sense gain	The current sense IC is ACS72981LLRATR-100B3		13.2		mV/A
G_{Vsns}	Phase and DC voltage sense gain			29.22		mV/V

(1) Maximum current depends on die temperature – actual maximum current is affected by switching frequency, bus voltage and thermal cooling. Refer to thermal performance section in this guide and to **EPC2367 datasheet** for details.

HIGHLIGHTED PARTS

Power Stage

The EPC91125 features a 3-phase inverter with EPC2367 eGaN FET and gate drivers. For more information on the EPC2367 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.

Onboard power supply

The EPC91125 board includes logic and gate driver house-keeping power supplies that are powered from the main input supply voltage to the inverter board. The 5.2 V supply for the gate drivers is generated directly from the mains power supply via a synchronous buck converter, while the 3.3 V supply for most of the on-board logic circuits is derived from the 5.2 V supply via a linear LDO regulator.

The 3.3 V controller supply voltage is also provided to the controller connector (J60) and can be disconnected by removing a jumper (J16).

Current and voltage sense

The EPC91125 inverter is equipped with voltage and current sense for all phases and voltage sense for the DC input.

The current sense ACS72981LLRATR-100B3 has a sensitivity of 13.2 mV/A with a bandwidth of 250 kHz which is adequate for accurate motor control operation at 100 kHz switching frequency.

The main input DC supply voltage and each phase are measured using a resistor divider network that yields a total gain of 29.22 mV/V.

Optional antiparallel diodes

Antiparallel silicon diodes are not necessary from an application standpoint; they are placed in the application board to prevent unwanted failure if firmware not well-suited to GaN devices is used, for instance, firmware derived from Si-MOSFET-based inverters that use long dead times.

GaN FETs exhibit reverse conduction, but the voltage drop is higher than with Si MOSFETs or PN-junction diodes. Therefore, reducing the dead time to very low values, such as 50 ns, not only improves motor performance but also ensures very low energy loss during reverse conduction in the GaN FET.

DC link capacitors

DC link capacitors are largely overdesigned to allow MOSFET-inverter-derived firmware to ensure the GaN inverter operates correctly, since Si-MOSFET-based inverters are operated at lower switching frequencies than GaN FET-based inverters and require greater DC link capacitance to limit DC voltage fluctuations. **Ask for EPC GaN expert support** to define the optimum number of DC link capacitors.

Temperature sensor

The EPC91125 board is equipped with a temperature sensor (U40 – AD590) that is located on the bottom of the board that reports an analog voltage reading proportional to the measured temperature using the following equation that was confirmed through characterization of the EPC91125 board :

$$T = \left(\frac{V \cdot 1000}{7.87}\right) - 273.16 \ \ [°C]$$

Connection and controller mate options

A 40 pin connector is used to interface power, PWM signals and analog feedback signals between the interface control board and the EPC91125 motor drive inverter. Table 1: Electrical Specifications (TA = 25°C) EPC91125. Table 2 gives the map (J60) for each signal.

LED indicators

The EPC has a number of LED indicators indicating the presence of the various supply voltages as follows:

- 5 V LED (**green**) – indicates the 5 V supply is operational
- 3.3 V LED (**yellow**) – indicates the 3.3 V supply is operational

Table 2: Controller interface connection (J60) pin assignment map

Pin #	Pin name		Pin #
2	PWMH1	GND	1
4	PWML1	GND	3
6	PWMH2	GND	5
8	PWML2	GND	7
10	PWMH3	3V3 (1)	9
12	PWML3	3V3 (1)	11
14	EncA	3V3 (1)	13
Index Slot			
18	EncB	AGND	17
20	EncI	AGND	19
22	Vdc	AGND	21
24	Vsns1	AGND	23
26	Vsns2	AGND	25
28	Vsns3	AGND	27
30	N.C.	AGND	29
32	Isns1	AGND	31
34	Isns2	AGND	33
36	Isns3	AGND	35
38	N.C	N.C	37
40	Tsns	N.C	39

(1) 3.3 V is connected through the jumper J16 (installed by default)

Test Points

A number of test-points are available for easy measurement of various nodes as follows:

- Touch-point pad for the 5 V supply
- Touch-point pad for the 3.3 V supply
- A SMD hookup for each phase voltage
- A Touch-point for each amplified current signal
- Touch-point pad for the shaft encoder A or Hall_A signal
- Touch-point pad for the shaft encoder B or Hall_B signal
- Touch-point pad for the shaft encoder Index or Hall_C signal
- 100 mil holes for oscilloscope probe tip insertion on the switching nodes

All analog signals are measured with respect to analog ground (AGND) using a Touch/point pad. All digital signals are measured with respect to digital ground (GND) using a SMD hookup. All the test point locations are shown in Figure 4.

The switching node can be measured inserting the probe tip in the 100 mil plated holes that are encircled in purple in Figure 4.

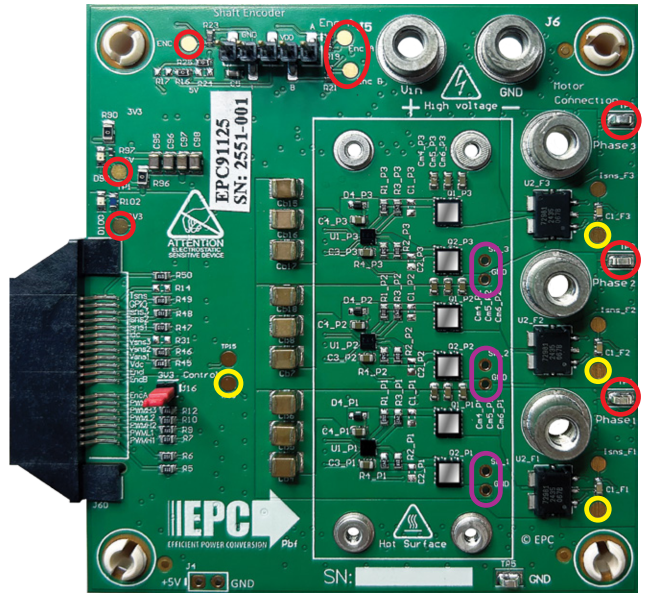


Figure 4: EPC91125 test point pad and hookup locations and designations in red. In black the GND reference points and in yellow the AGND reference point. In purple the 100 mils holes for the switching node measurements

Shaft Encoder / Hall Effect Sensors

Connector (J7) is used to connect a shaft sensor to the EPC91125 motor drive inverter that is compatible with optical quadrature encoders or hall effect sensors and provides supply voltage for the encoder. The available voltage selections can be made by installing the appliable resistors as follows: 5 V using R16 (default), and 3.3 V using R17. The filtered signals are then provided to the controller connector (J60).

Compatible Controllers

A list of compatible controllers for the EPC91125 is given in Table 3.

Table 3: Compatible controller interface and controller boards to the EPC91125

Controller Board Number	Controller Manufacturer	Controller	Target Application
EPC9147A - Rev. 2.1	Microchip - MA330031-2	dsPIC33EP256MC506	Motor Drive
EPC9147B - Rev. 2.1	Texas Instruments - LAUNCHXL-F28379D	TMS320F2837xD	Motor Drive
EPC9147C - Rev. 2.2	ST Microelectronics	NUCLEO-G431 RB I NUCLEO-G474RE	Motor Drive
EPC9147D – Rev. 1.1	Renesas - RTK0EMA270C00000BJ	RA6T2	Motor Drive
EPC9147E - Rev. 2.0	Generic interface board	N/A	Motor Drive

APPLICATION CONFIGURATIONS

Motor Drive Inverter

A 3-phase BLDC motor drive inverter is the primary application case for which the EPC91125 board was designed for and can be used with either sensor-less or shaft encoder sensor configurations. The motor drive controller options are given in table 3 giving the user various mainstream choices that leverage existing resources to simplify and speed up development and evaluation . Figure 5 shows the simplicity of connecting a controller and motor to the EPC91125. **In the default configuration, the EPC91125 is paired with the EPC9147C that is pre-programmed to power and control a NEMA 34 size motor from Teknic M-3411P-LN-08D**, with DC supply voltage of 48 V using sensor-less field oriented control with space vector pulse width modulation (SVPWM).

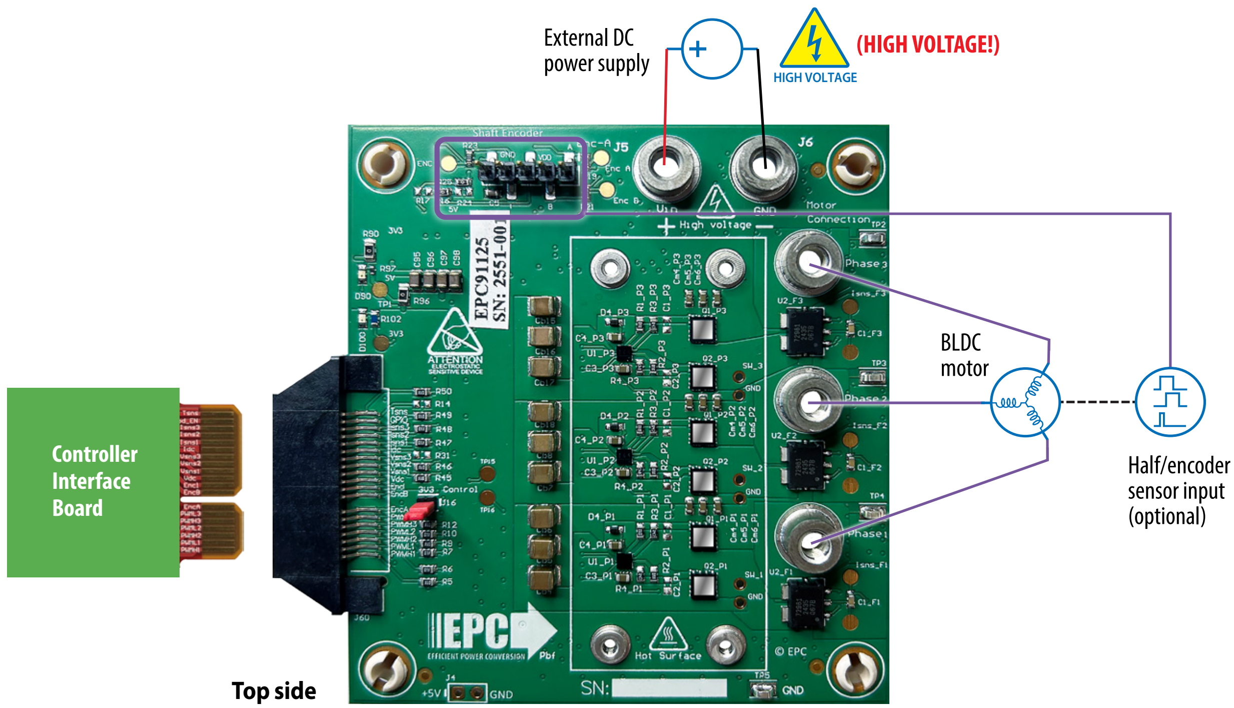


Figure 5: Connection diagram of the EPC91125 configured as a motor drive inverter

QUICK START PROCEDURE

For this quick start procedure only the **motor drive application** using the EPC9147C controller is presented.

Follow the procedure below to operate the specific motor Teknic M-3411P-LN-08D with EPC91125 and controller board:

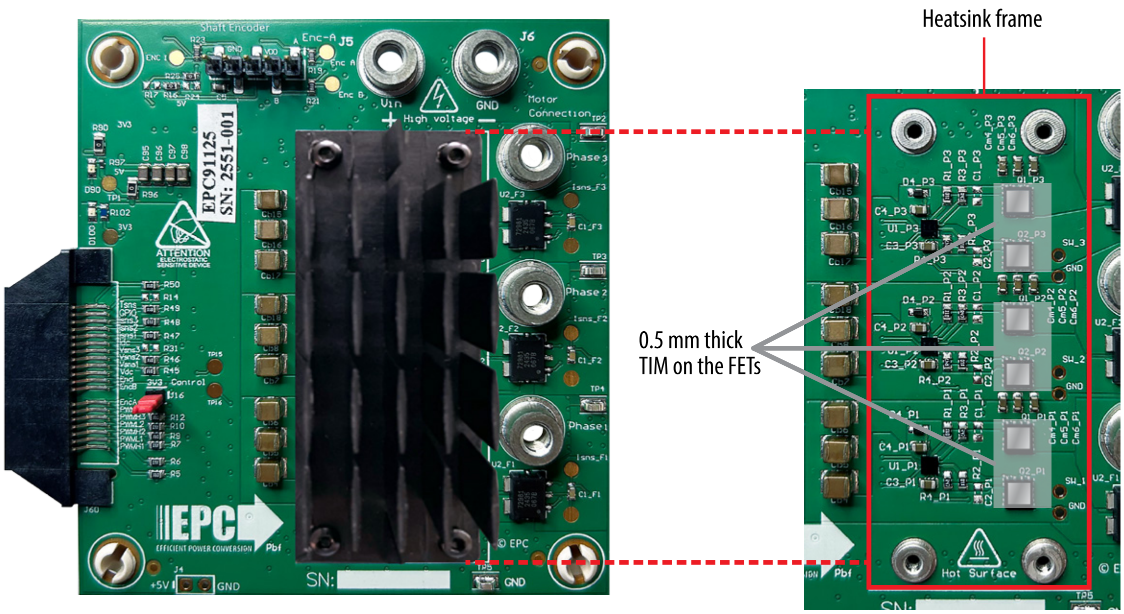
1. Mate the EPC91125 with an applicable controller interface board as given in Table 3. Review the QSG of corresponding control interface board for detailed operating procedures. For this procedure, the EPC9147C is used.
2. Connect the correct motor, whose parameters are programmed into the controller, to the EPC91125 at connectors J1, J2, J3, and the DC power supply at connectors J5, and J6 (**Observe correct polarity, there is no inverse polarity protection on board**) and shown in figure 5.
3. Preset the main supply voltage to the operating voltage and turn on and observe the power LEDs illuminate. Press the Start/Stop button to start the motor spinning. Additional controls are available using ST Microelectronics motor control software. Please review the **EPC9147C QSG** for details.
4. Once operational, make the necessary measurements.
5. For shutdown, press the Start/Stop button to stop the motor spinning, then turn off the main DC power supply.

THERMAL CONSIDERATIONS

The EPC91125 is intended for bench evaluation at ambient room temperature and under either natural convection or forced-air cooling. The addition of a heatsink can significantly improve heat dissipation from the eGaN FETs and increase their current capacity, while ensuring that the absolute maximum die temperature of 150°C is not exceeded.

The EPC91125 board is equipped with four mechanical spacers (S1, S2, S3, S4) that can be used to easily attach a standard quarter-brick converter heatsink as shown in Figure 6, and only requires a thermal interface material (TIM), a heatsink, and screws.

The heatsink is held in place using screws that fasten to the mechanical spacers, which will accept 6 to 10 mm long M2 x 0.4 mm thread screws



(a) (b)

Figure 6: (a) passive heatsink mounted on EPC91125 board (b) details on TIM placement

When assembling the heatsink, add a thin insulating layer to prevent the heat-spreader from short-circuiting components with exposed conductors, such as capacitors and resistors, since the heatsink is grounded through the mechanical spacers.

A TIM is added to improve the interface thermal conductance between the GaN ICs and the attached heatsink. The choice of TIM 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 FETs. 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 is a silicon substrate that is connected to source and thus the upper FET in a half-bridge configuration is connected to the switch-node. To prevent short-circuiting the switch-node to the grounded thermal solution, the TIM must be of high dielectric strength to provide adequate electrical insulation in addition to its thermal properties.
- **Thermal performance** – The choice of thermal interface material will affect the thermal performance of the thermal solution. Higher thermal conductivity materials is preferred to provide higher thermal conductance at the interface.

EPC recommends the following thermal interface materials:

- **t-Global** P/N: TG-A1780 x 0.5 mm (highest conductivity of 17.8 W/m·K)
- **t-Global** P/N: TG-A6200 x 0.5 mm (moderate conductivity of 6.2 W/m·K)
- **Bergquist** P/N: GP5000-0.02 (~0.5 mm with conductivity of 5 W/m·K)
- **Bergquist** P/N:GPTGP7000ULM-0.020 (conductivity of 7 W/m·K)
- **Wurth Elektronik** P/N: 40006005 (conductivity of 6 W/m·K)

The default TIM used for the EPC91125 to cover the FETs is made by t-Global Technology and measures 20 x 20 x 0.5 mm thick with P/N TG-A1780-20-20-0.5, while the TIM used to fill the openings on the soldermask should be 1 mm-thick, for instance, P/N TG-A1780- 10-10-1.

The natural convection cooling heatsink used for the EPC91125 is Alpha Novatech, Inc., model # LPD2790-35BM-3V6.

EXPERIMENTAL VALIDATION EXAMPLE

For validation purpose, the EPC91125 motor drive inverter, paired with the EPC9147C interface controller, was operated from a 48 V_{DC} supply voltage while switching at 100 kHz, 50 ns dead-time setting, powering a 5 kW servo and delivering to the motor a phase current of 30 A_{RMS} without a heatsink and natural convection cooling and 35 A_{RMS} with a heatsink and natural convection cooling and an impulsive current up to 40 A_{RMS} with heatsink.

THERMAL PERFORMANCE

In the thermal analyses, a thermocouple placed on the top side of the central device relating to phase 2 is used, as described in Figure 7.

There are two different thermal tests:

1) Steady-state thermal analysis
2) Pulsed torque thermal analysis

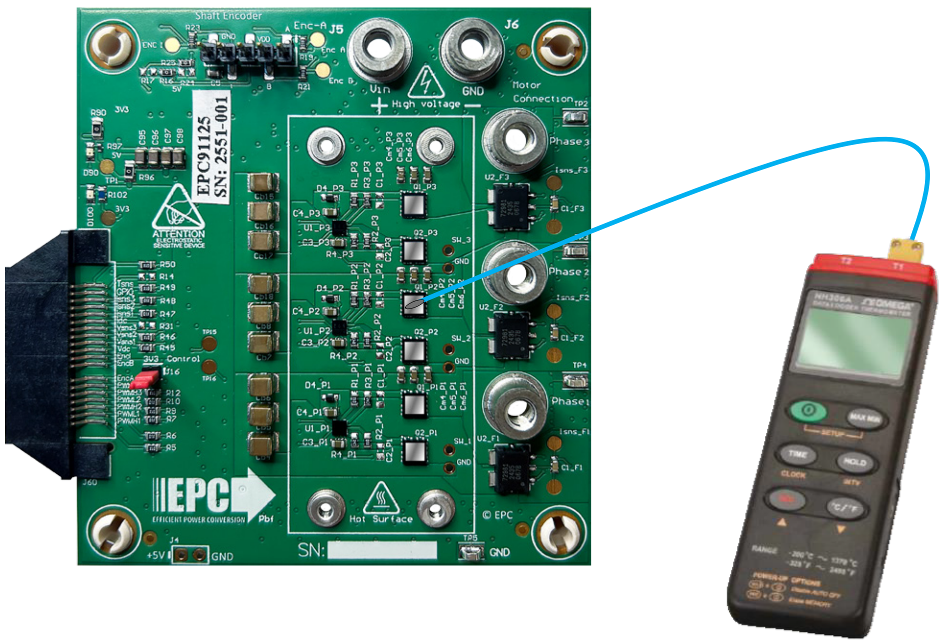


Figure 7: Thermal test setup configuration

STEADY STATE ANALYSIS

Figure 8 depicts the steady-state thermal performance summary of the EPC91125 board. When operated on a motor bench at an ambient temperature of 26°C, with a 48 V_{DC} supply and natural convection, the EPC91125 can deliver 30 A_{RMS} per phase without a heatsink and 35 A_{RMS} per phase with a heatsink attached, with a delta temperature rise below 90°C from the eGaN FET case to ambient. Motor drive operating points at PWM = 20, 50, and 100 kHz, deadtime = 50 ns, with and without heatsink at 26°C ambient temperature, under natural convection.

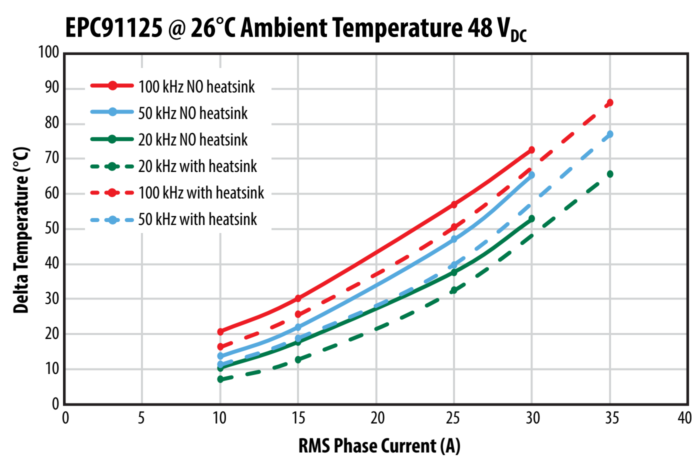


Figure 8: EPC91125 (EPC2367 eGaN® FET) temperatures increase vs. the ambient temperature (26°C). Measurements were taken at various PWM frequencies

PULSED TORQUE ANALYSIS

The pulsed-torque thermal analysis describes the performance of EPC91125 in applications subject to dynamic operation. The tests were done using a system with a hysteretic brake controlled by current pulses. Figure 13 shows a schematic model of the analysis setup. The tests were executed with a 48 V_{DC} supply, 100 kHz PWM frequency, and 50 ns dead time at 26°C ambient temperature with a 3 kW motor using three different pulse time: 0.75 s, 1 s and 1.5 s (total period 5 s), respectively 15%, 20% and 30% duty cycle.

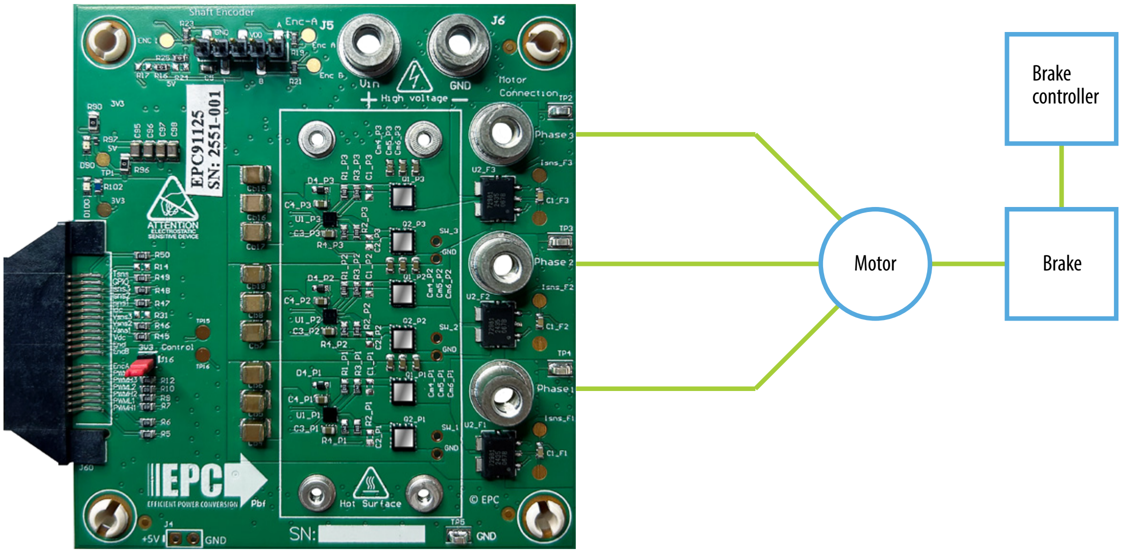


Figure 9: Pulsed torque test set up schematic

As in the example in Figure 10, the motor braking generates an impulse with a total current of 40 A_{RMS} (56.4 A_{pk}) for 1.5 s (total period 5 s). The tests were conducted with a 10-minute pulse loop.

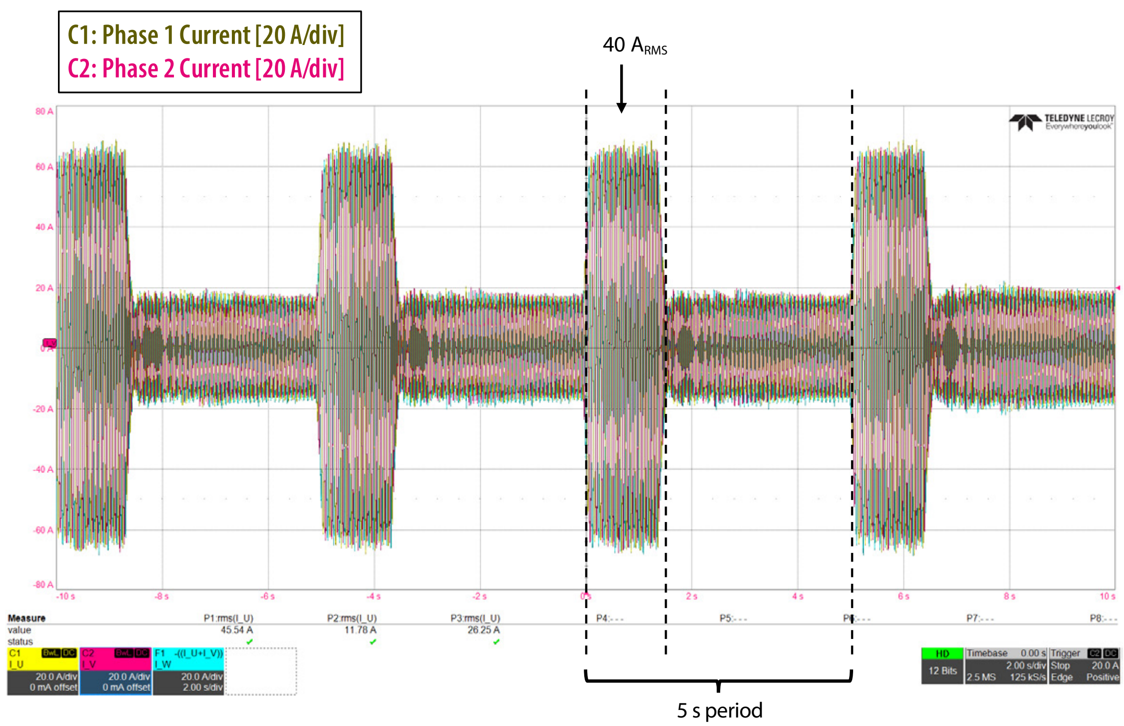


Figure 10: 1.5 s pulsed torque test, phase currents

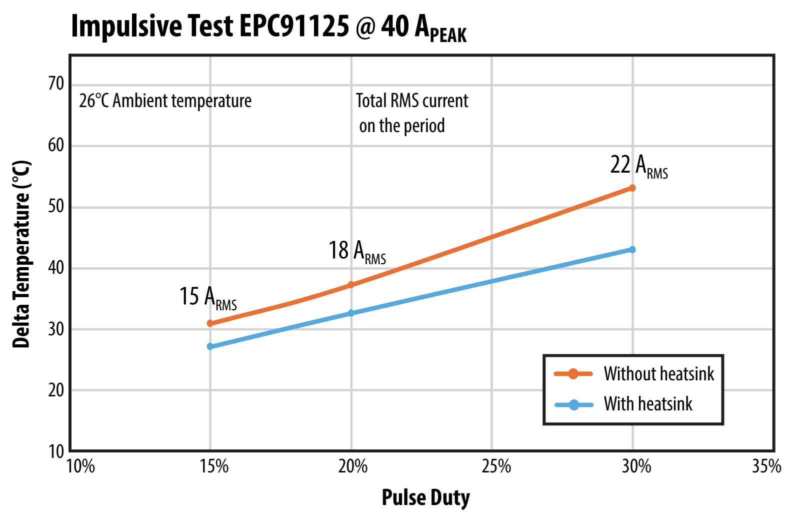


Figure 11: EPC91125 (EPC2367 eGaN® FET) temperature increase vs. ambient temperature (26°C).

MEASURED PHASE WAVEFORMS

The measured waveforms of EPC91125 while delivering 20 A_{RMS} (42 A_{pk}) to each motor phase with a 48 V_{DC} bus are shown in Fig. 12: the phase current, phase voltage, and gate-source voltage of the high- and low-side FETs. In hard-switching topologies, the off transistor may turn ON due to capacitive coupling during the switching node transitions; due to the low-inductance PCB layout of EPC91125 and the below-1 Miller ratio of GaN devices, the OFF transistor remains off during these transitions, as can be seen in the zoomed portion.

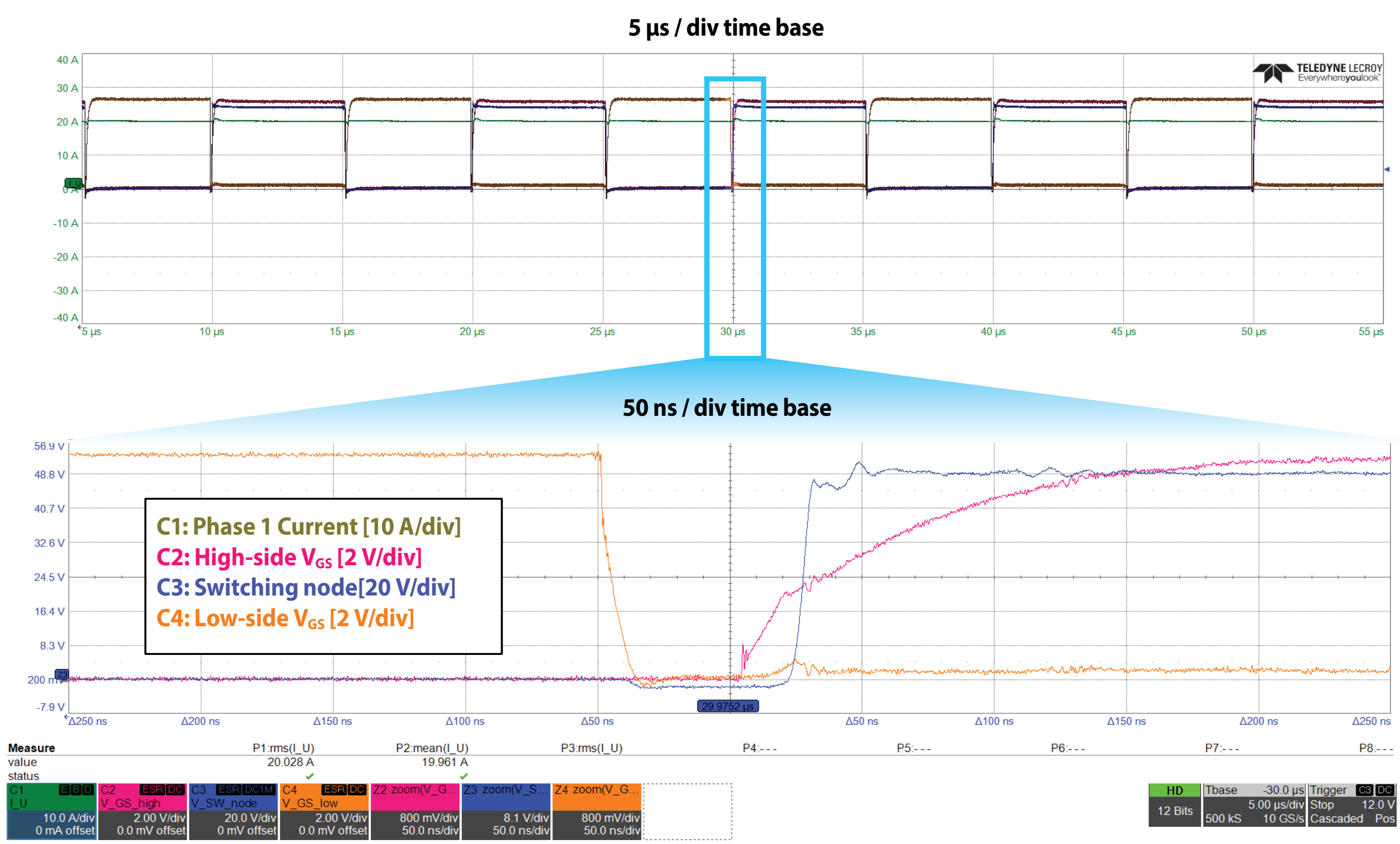


Figure 12: Phase leg key waveforms during switching transitions

THERMAL SENSOR CHARACTERIZATION

The graph in Figure 13 shows the correlation between the temperature measured by the on-board temperature sensor placed beneath the phase-V eGaN FETs on the bottom side of the PCB and the infrared camera die temperature for the same eGaN FET, measured without a heatsink and with only natural convection cooling. Figure 14 shows the location of the temperature sensor used to measure the bottom side of the PCB.

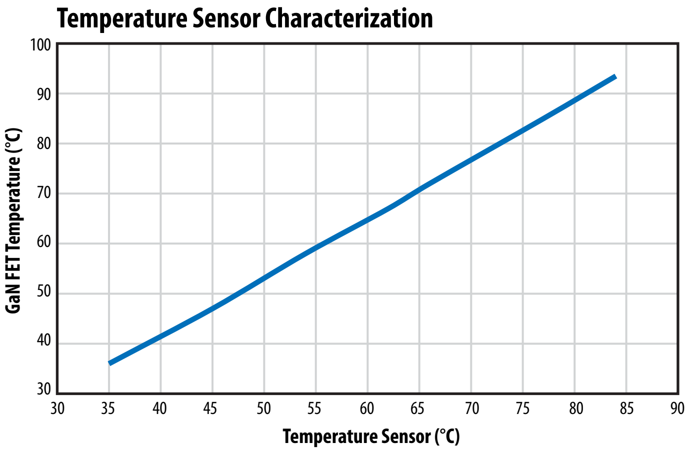


Figure 13: Temperature sensor characterization

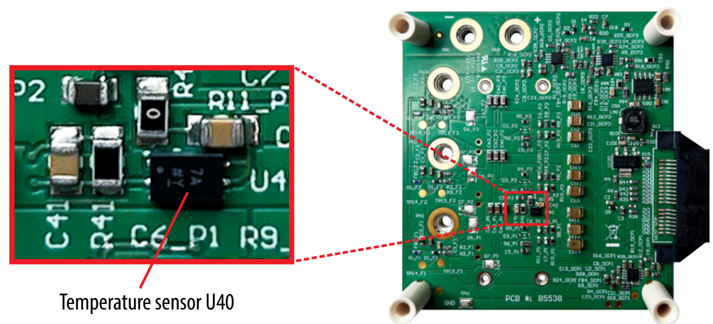


Figure 14: Temperature sensor location on the bottom side of the board

For support files including schematic, Bill of Materials (BOM), and gerber files please visit the EPC91125 landing page at: https://epc-co.com/epc/products/demo-boards/EPC91125

Change Log

STATUS	VERSION	DATE	REMARK
1.0	Production	13 August 2026	Production release

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EFFICIENT POWER CONVERSION

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