

Evaluation Boards

EPC91128, EPC91129, EPC91130, EPC91131 Quick Start Guide

*15 to 29 A_{RMS}, 3-phase BLDC Motor Drive Inverter using the
ePower™ Stage ICs EPC23108, EPC23109, EPC23110, EPC23111*

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Document Revision 1.0

Board EPC91128 Revision 1.0

Board EPC91129 Revision 1.0

Board EPC91130 Revision 1.0

Board EPC91131 Revision 1.0



DESCRIPTION

The EPC91128-EPC91129-EPC91130-EPC91131 demonstration boards are 3-phase BLDC motor drive inverter board featuring the EPC23108-EPC23109-EPC23110-EPC23111 ePower™ Stage ICs 5.7 mΩ (EPC23108-EPC23109) and 8.7 mΩ (EPC23110-EPC23111) typical $R_{DS(on)}$, 100 V maximum device voltage. The EPC91128-EPC91129 can deliver up to 28 A_{pk} (20 A_{RMS}) steady-state output current and up to 41 A_{pk} (29 A_{RMS}) maximum output current. The EPC91130-EPC91131 can deliver up to 21 A_{pk} (15 A_{RMS}) steady-state output current and up to 28.5 A_{pk} (18.5 A_{RMS}) maximum output current. The four boards contain all the necessary critical function circuits to support a complete motor drive inverter including monolithic power stage with integrated driver, regulated auxiliary power rails for housekeeping supplies, voltage, and temperature sense, accurate, current sense, and protection functions. The various functional blocks are shown in Figure 1. All boards mate with an assortment of compatible controllers, supported by multiple manufacturers leveraging existing resources for quick development purposes.

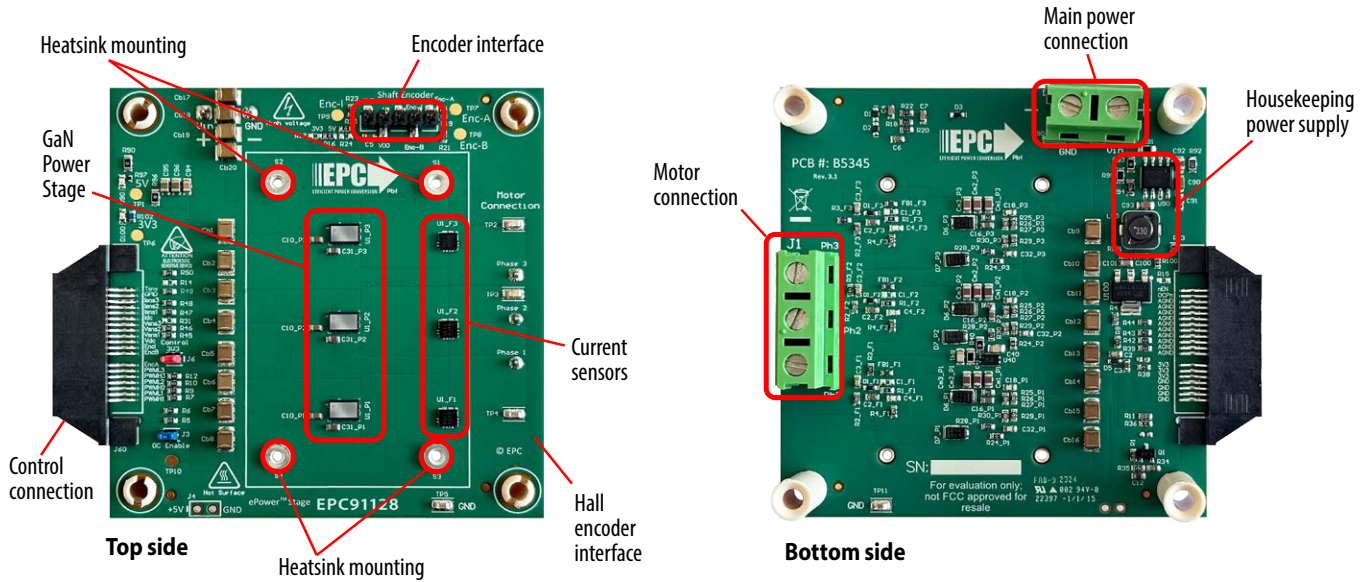


Figure 1: Photo overview of the EPC91128-EPC91129-EPC91130-EPC91131 boards highlighting the main sections

Figure 2 shows the functional block diagram of the EPC91128/EPC91130 reference design boards that details the phase current sense, phase and DC voltage sense, the half-bridge power stages, housekeeping power supply, and controller interface connection.

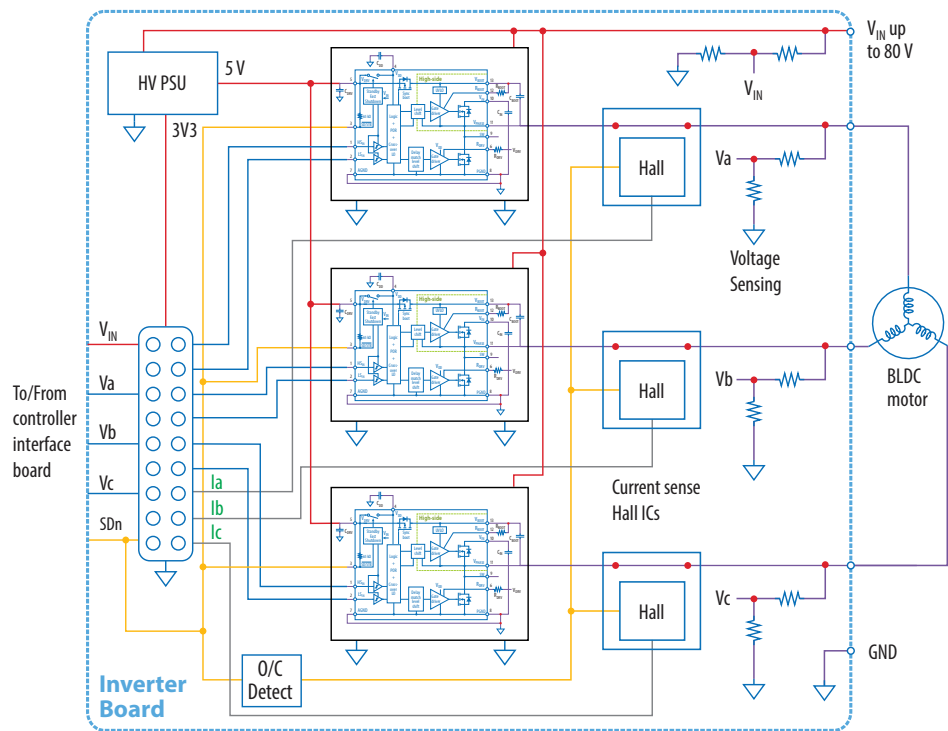


Figure 2. Block diagram of EPC91128/EPC91130 boards in BLDC drive example application.

Figure 3 shows the functional block diagram of the EPC91129/EPC91131 reference design boards that details the phase current sense, phase and DC voltage sense, the half-bridge power stages, housekeeping power supply, and controller interface connection.

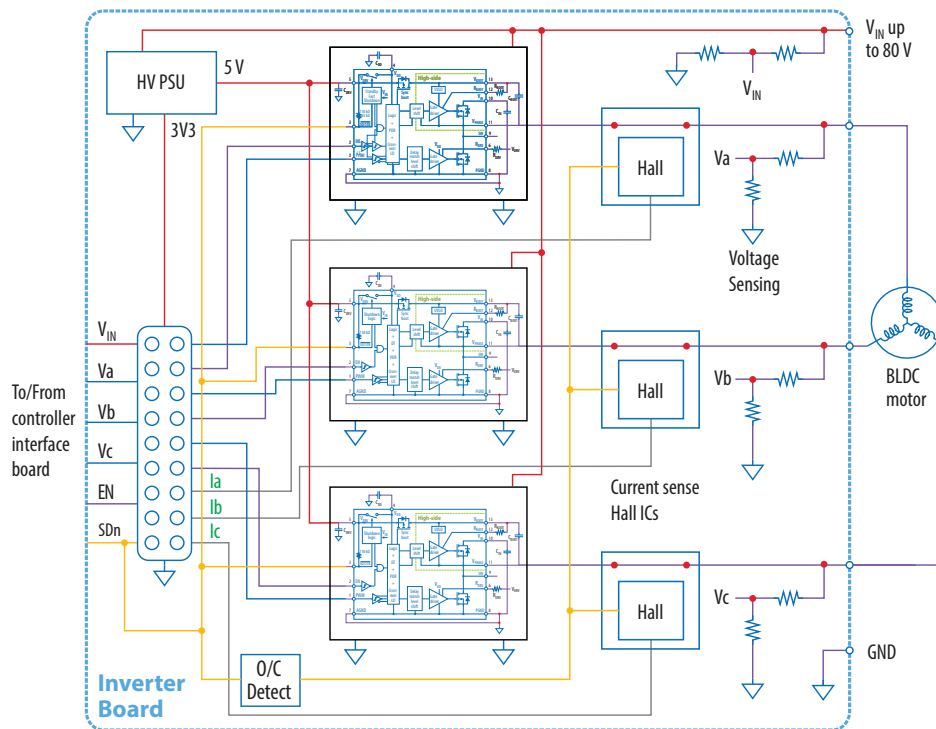


Figure 3. Block diagram of EPC91129/EPC91131 boards in BLDC drive example application.

MAIN FEATURES

- 3-phase inverter based on EPC23108-EPC23109-EPC23110-EPC23111 eGaN ICs with wide input DC voltage ranging from 10 V to 80 V
- Dimensions: L x W = 81 x 75 mm (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 the option to increase or decrease dv/dt by changing a resistor
- All current sense with 120 kHz Bandwidth
- All phases voltage sense
- Voltage sense for the DC supply to the drive
- Housekeeping power for the various circuits and external controller derived from the main power supply to the boards
- Temperature monitoring
- Protection features including over-current and input supply under-voltage lockout
- EPC91128/EPC91130 features complementary PWM signals for each leg- $HS_{IN} + LS_{IN}$.
- EPC91129/EPC91131 features single PWM signal and enable for each leg
- Shaft encoder/Hall sensors interface connector for motor drive application with two voltage levels selection option

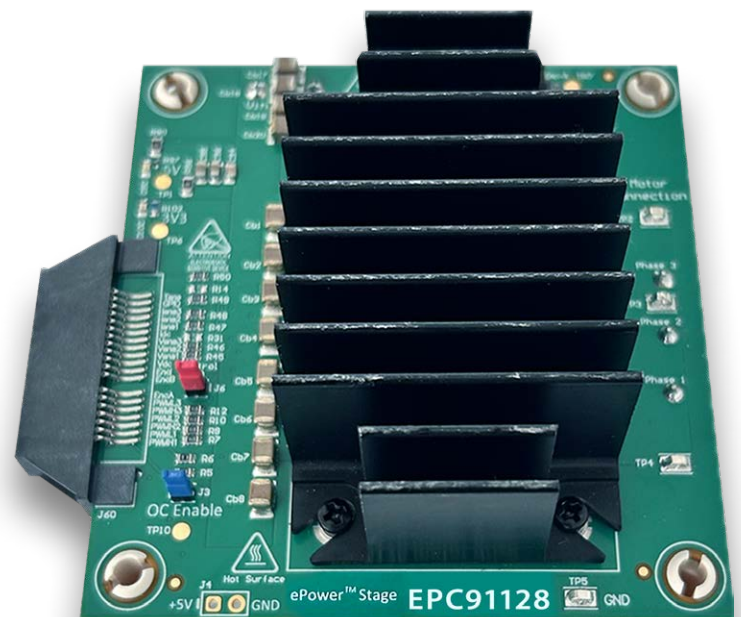


Figure 4. Demonstration board overview with heatsink attached

RECOMMENDED OPERATING CONDITIONS

Table 1: Electrical Specifications ($T_A = 25^\circ\text{C}$)

Symbol	Parameter	Conditions	Min	Nom	Max	Units
V_{IN}	Input supply voltage		14	48	80	V
I_{Phase}	EPC91130-EPC91131 RMS Phase current ⁽¹⁾				15	A
	EPC91128-EPC91129 RMS Phase current ⁽¹⁾				20	
f_{sw}	Switching frequency		20	100	150	kHz
t_{dt}	EPC91128/EPC91130 Dead Time		25	50	100 ⁽⁴⁾	ns
	EPC91129/EPC91131 Dead Time	Dead time is fixed with internal logic functions			22	
V_{IN_uvlo}	Input undervoltage lockout voltage			6		V
V_{IH}	PWM high-level logic threshold	PWM rising edge	2.4			
V_{IL}	PWM low-level logic threshold	PWM falling edge			0.8	
V_{IHyst}		V_{IH} Rising – V_{IL} Falling	0.3			
V_{ENC}	Encoder supply voltage ⁽⁵⁾		3.3		5	
R_{in}	PWM input pull-down resistance	HS_{IN} and LS_{IN} for EPC91128/EPC91130 and PWM/Enable for EPC91129/EPC91131		5		k Ω
$t_{Propdelay_ON}$	PWM inputs to Switch-node ON transition delay	High-side/Low-side		60		ns
$t_{Propdelay_OFF}$	PWM inputs to Switch-node OFF transition delay	High-side/Low-side		36		
V_{Isns_range}	Phase current sense voltage dynamic range	– I_{max} to I_{max}	0		3.3	V
V_{Isns_offset}	Amplified current sense signal offset voltage			1.65		
I_{Isns_range}	EPC91128-EPC91129 Phase current sense dynamic range	Current sense IC gain: 26.4 mV/A	-62.5		62.5	A
	EPC91130-EPC91131 Phase current sense dynamic range	Current sense IC gain: 44 mV/A	-37.5		37.5	
$I_{ovc}^{(2)}$	EPC91128-EPC91129 Over-current threshold	Over-current detect both positive and negative OVC		50		
	EPC91130-EPC91131 Over-current threshold	Over-current detect both positive and negative OVC		30		
SD_{pull}	SDn pin Internal pull-up resistance ⁽⁶⁾	Pulled-up to V_{DRV}		65		k Ω
OCD_{pull}	Current sensor overcurrent signal ⁽⁷⁾ OCDn pull-up resistance	External pull-up resistance to 3.3 V		100		
G_{Isns}	EPC91128-EPC91129 Amplified current sense gain	Current sense IC MCS1823GQTE-350BRN		26.4		mV/A
	EPC91130-EPC91131 Amplified current sense gain	Current sense IC MCS1823GQTE-330BRN		44		
G_{Vsns}	Phase and DC voltage sense gain ⁽³⁾			29.2		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 [EPC23108](#) - [EPC23109](#) - [EPC23110](#) - [EPC23111](#) datasheets for details.
- (2) All phases over-current are monitored. The over-current signal is sent to the controller connector via R1. Insert J3 to remove the SDn signal to the EPC231xx when overcurrent is detected.
- (3) **Maximum dynamic voltage range is 0 V to 113.3 V which exceeds maximum recommended voltage for the capacitors and other circuits on the board.**
- (4) Diodes are mounted to protect the board when the maximum dead time value is exceeded. If the dead time is kept within the specified range in the table, the diodes can be removed.
- (5) **The available voltage selections can be made by installing the applicable resistors: 5.2 V using R16 (default) and 3.3 V using R17.**
- (6) SDn signal is Active Low
- (7) OCD signal is Active Low

HIGHLIGHTED PARTS

Power Stage

The EPC91128-EPC91129-EPC91130-EPC91131 features a 3-phase inverter with EPC23108-EPC23109-EPC23110-EPC23111 eGaN ICs. For more information, please refer to each of their datasheets: [EPC23108](#) - [EPC23109](#) - [EPC23110](#) - [EPC23111](#) available from EPC at www.epc-co.com. The datasheet should be read in conjunction with this quick-start guide.

Onboard power supply

The boards include logic and housekeeping power supplies powered from the main input supply voltage to the inverter board. The 3.3 V controller supply voltage is also provided to the controller connector (J60) and can be disconnected by removing the jumper J6.

Current and voltage sense

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

Phase current is measured using a Hall current sensor IC on each phase. The EPC91128-EPC91129 sensor’s current range is ± 50 A. The EPC91130-EPC91131 sensor’s current range is ± 30 A.

The current sensors are bi-directional, ensuring the full four-quadrant operation.

The main input DC supply voltage and each phase voltage are measured using a resistor divider network that yields a total gain of 29.2 mV/V.

Temperature sensor

The boards are equipped with a temperature sensor (U40 – AD590) that is centrally located on the bottom of the board and reports an analog voltage reading proportional to the measured temperature using the following equation:

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

Connection and controller mate options

A 40-pin connector interfaces power, PWM signals, and analog feedback signals between the interface control board and the motor drive inverter. Table 2 gives the signal map of J60.

LED indicators

The boards have LED indicating the presence of the various supply voltages as follows:

- 5.2 V LED (**green**) – indicates the 5.2 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/PWM1 ⁽³⁾	GND	1
4	PWML1\EN1 ⁽⁴⁾	GND	3
6	PWMH2/PWM2 ⁽³⁾	GND	5
8	PWML2\EN2 ⁽⁴⁾	GND	7
10	PWMH3/PWM3 ⁽³⁾	3V3 ⁽¹⁾	9
12	PWML3\EN3 ⁽⁴⁾	3V3 ⁽¹⁾	11
14	EncA	3V3 ⁽¹⁾	13
Index Slot			
18	EncB	AGND	17
20	Encl	AGND	19
22	V _{DC}	AGND	21
24	V _{sns1}	AGND	23
26	V _{sns2}	AGND	25
28	V _{sns3}	AGND	27
30	I _{DC} (optional)	AGND	29
32	I _{sns1}	AGND	31
34	I _{sns2}	AGND	33
36	I _{sns3}	AGND	35
38	N.C.	nOCerr/ ⁽²⁾	37
40	T _{sns}	nEN/	39

⁽¹⁾ 3.3 V is connected through the jumper J6 (installed by default)

⁽²⁾ nOCerr/ is connected through the resistor R1 (installed by default)

⁽³⁾ Pin HS_{IN} of EPC23108/EPC23110 for PWMHx
Pin PWM of EPC23109/EPC23111 for PWMx

⁽⁴⁾ Pin LS_{IN} of EPC23108/EPC23110 for PWMLx
Pin EN of EPC23109/EPC23111 for ENx

Test Points

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

- Touch-point pad for the 5.2 V supply
- Touch-point pad for the 3.3 V supply
- Touch-point pad for the Over-current detect
- A SMD hookup for each phase voltage
- 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

All digital signals are measured with respect to the digital ground (GND) using a SMD hookup. Figure 5 shows all test point locations.

Over-current (OVC) protection

The board current sensors include an overcurrent detector that triggers if the current measurement exceeds the board overcurrent threshold.

The overcurrent signal OCDn is active low. Once an overcurrent is triggered, the active low OCDn signal will remain low for a short period and the SDn signal will be activated on eGaN ICs if jumper J3 is installed and will remain low according to the time constant given by R34 and C12. During SDn signal active, the ICs are switched off. The OCDn detect signal is also sent to the controller as nOCerr\ through R1 (installed by default).

Jumper Settings

The EPC91128-EPC91129-EPC91130-EPC91131 are provided with two jumpers with functions described in Table 3.

Table 3: Jumper settings function

Jumper	Installed	Open
J6	Board supplies the control board with 3.3 V	The board does not supply the control board with 3.3 V. In this case, the control board should be powered with an external supply.
J3	The over-current signal is sent to the micro-controller AND to the power stage EPC231xx IC standby input. Refer to EPC231xx data sheet for the standby function description	The over-current detection circuit does not disable the PWM signals independently from microcontroller. In this case R1 must be mounted and the microcontroller must promptly react to over-current detection.

Any combination of valid position settings may be selected.

Shaft Encoder / Hall Effect Sensors

The connector (J7) connects a shaft sensor to the motor drive inverter, which is compatible with optical quadrature encoders or hall effect sensors and provides a supply voltage for the encoder. The available voltage selections can be made by installing the applicable resistors: 5 V using R16 (default) and 3.3 V using R17. The pull-up voltage selections can be made by mounting the resistors: R25 for 3.3 V (default) and R24 for 5 V. The filtered signals are then provided to the controller connector (J60).

Compatible Controllers

A list of compatible controllers for the all boards is given in Table 4 for Motor drive applications.

Table 4: List of compatible controller interface boards

Controller Board Number	Controller Manufacturer	Controller	Target Application
EPC9147A - Rev. 2.1	Microchip - MA330031-2	dsPIC33EP256MC506	Motor Drive
EPC9147B- Rev. 1.0	Texas Instruments - LAUNCHXL-F28379D	TMS320F2837xD	Motor Drive
EPC9147C - Rev. 1.0	ST Microelectronics	NUCLEO-G431RB / NUCLEO-F401RE	Motor Drive
EPC9147D- Rev 1.1	Renesas-RTK0EMA270C00000BJ	RA6T2	Motor Drive
EPC9147E - Rev. 2.0	Generic Interface board	N/A	Motor Drive

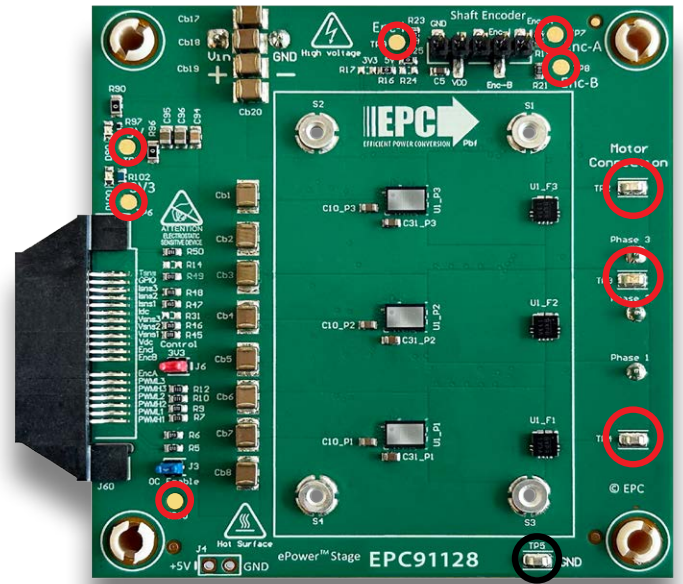


Figure 5: Test point pads and hookup locations and designations. Black circle is the PGND reference point.

APPLICATION CONFIGURATIONS

Motor Drive Inverter

A 3-phase BLDC motor drive inverter is the primary application for which the boards were designed for and can be used for sensor-less or shaft encoder sensor configurations. The motor drive controller options are given in Table 4, giving the user various mainstream choices that leverage existing resources to simplify and speed up development and evaluation. Figure 6 shows the simplicity of connecting a controller and motor to the EPC91129. **In the default configuration, the EPC911xx are paired a NEMA 34 size motor from Teknic M-3411P-LN-08D, with DC supply voltage of 48 V using sensor-less field orientated control with space vector pulse width modulation (SVPWM).**

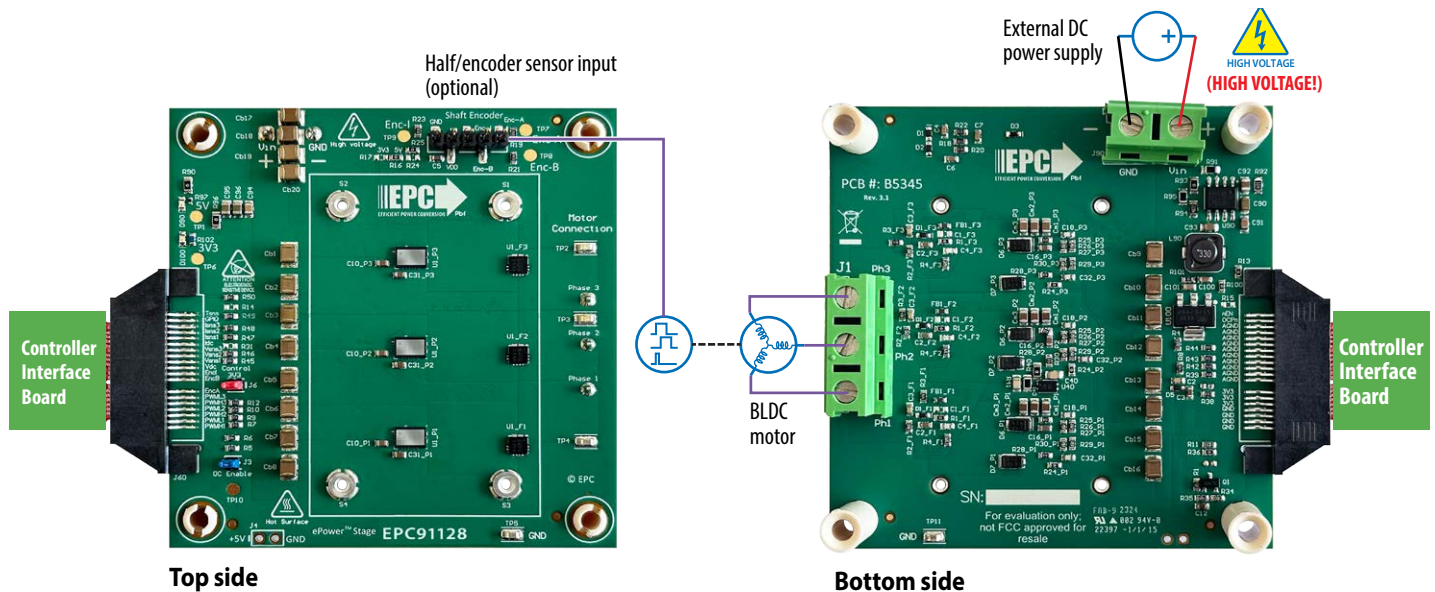


Figure 6: Connection diagram of the boards configured as a motor drive inverter

QUICK START PROCEDURE

For this quick start procedure, only the **motor drive application** using the [EPC9147A](#) controller is presented.

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

1. Mate the motor drive inverter board with an applicable controller interface board, as given in Table 4. Review the QSG of the corresponding control interface board for detailed operating procedures. For this procedure, the EPC9147A is used.
2. Connect the correct motor, whose parameters are programmed into the controller, to the board at connector J1 and the DC power supply at connectors J90 (**Observe correct polarity, there is no inverse polarity protection on board**) and shown in figure 6.
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. Adjust the speed and direction of the motor by pressing or adjusting the applicable button, knob or software setting. **Note that the user interface (buttons and knob) is not isolated, so use appropriate precautions when dealing with high voltage.** Please review the [EPC9147A 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 boards are intended for bench evaluation at room ambient temperatures and under natural convection or forced air cooling. Adding a heatsink can significantly improve the heat dissipation from the eGaN ICs and increase the current capacity of these devices while ensuring that the absolute maximum die temperature is not exceeded by 150°C.

All boards are equipped with four mechanical spacers (S1, S2, S3, S4) that can be used to easily attach a heatsink as shown in figures 7 and 8 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 mm long M2 x 0.4 mm thread screws such as McMasterCarr 95836A109.

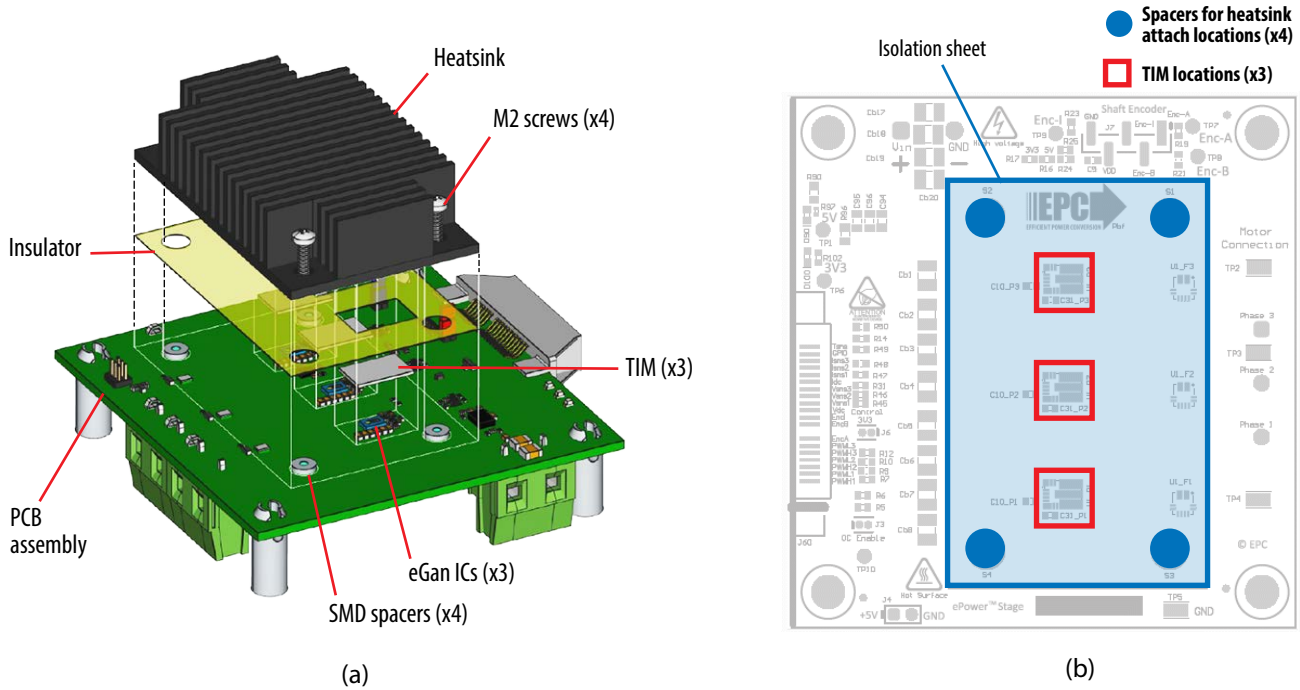


Figure 7: Details for attaching a heatsink to the board. (a) exploded 3D perspective, (b) top view showing the insulator sheet details with opening for the TIM with location of the eGaN ICs

When assembling the heatsink, it is necessary to add a thin insulating layer to prevent the heat-spreader from short circuiting with components that have exposed conductors such as capacitors and resistors, as shown in figure 7 and 8. Note that the heatsink is ground connected. A rectangular opening in the insulator must be provided to allow the TIM to be placed over the ICs to be cooled with a minimum clearance of 3 mm on each side of the rectangle encompassing the ICs. The TIM will then be similar in size or slightly smaller than the opening in the insulator shown by the red dashed outline in figure 8. The insulator sheet material is made by Laird P/N A14692-30 Tgard K52 with thickness of 0.051 mm (0.0020”).

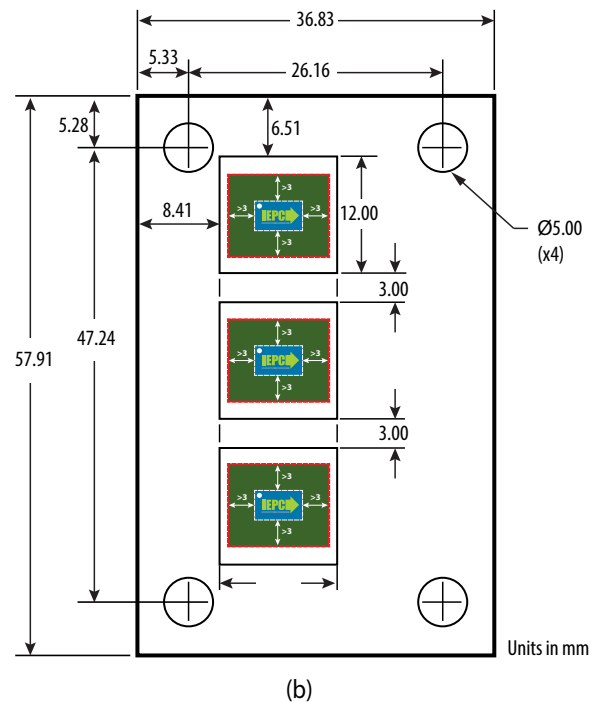


Figure 8: (a) minimum TIM coverage area (b) Insulator sheet details

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 ICs. This volume compression exerts a force on the ICs. 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 ICs is connected to power ground (PGND).
- **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)
- **Würth Elektronik** P/N: 40006005 (moderate conductivity of 6 W/m-K)

The default TIM used for the board is made by t-Global Technology, measures 20 x 20 x 0.5 mm thick with P/N TG-A6200-20-20-0.5. The natural convection cooling heatsink used for the board is Wakefield, model 547-95AB.

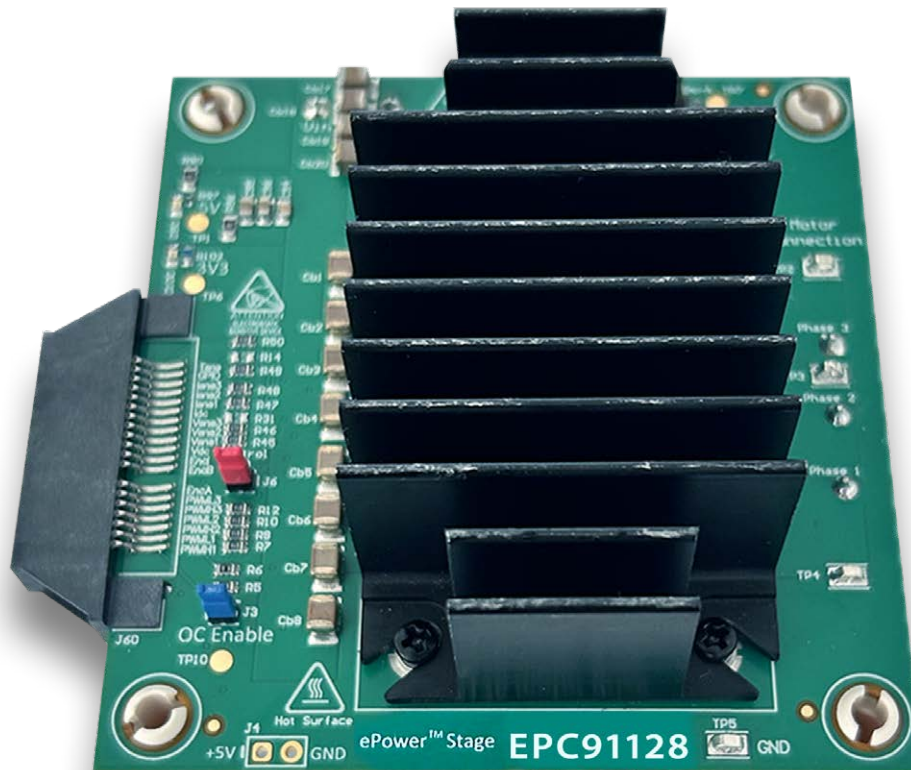


Figure 9: Natural convection cooling heatsink installed on the inverter board

The EPC Thermal Calculator provides quick estimates for the thermal performance parameters of PCB-mounted GaN devices subject to both board-side cooling through forced convection, and backside cooling through a thermal solution consisting of a heat spreader and heatsink. This calculator shows the excellent thermal properties of EPC's GaN FETs.

To simulate your thermal design please go to: <https://epc-co.com/epc/design-support/gan-power-bench/gan-fet-thermal-calculator>

EXPERIMENTAL VALIDATION EXAMPLE

- The EPC91128-EPC91129 motor drive inverters, paired with EPC9147C interface controller, was operated from a 48 V_{DC} power supply voltage while switching at 100 kHz, 50 ns dead-time, powering a 3 kW motor delivering to the motor a steady state phase current of 15 A_{RMS} without a heatsink and natural convection cooling and 20 A_{RMS} with a heatsink and natural convection cooling and an impulsive current up to 29 A_{RMS} with heatsink.
- The EPC91130-EPC91131 motor drive inverters, paired with EPC9147C interface controller, was operated from a 48 V_{DC} power supply voltage while switching at 100 kHz, 50 ns dead-time, powering a 3 kW motor delivering to the motor a steady state phase current of 10 A_{RMS} without a heatsink and natural convection cooling and 15 A_{RMS} with a heatsink and natural convection cooling and an impulsive current up to 18 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 10. There are two different thermal tests:

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

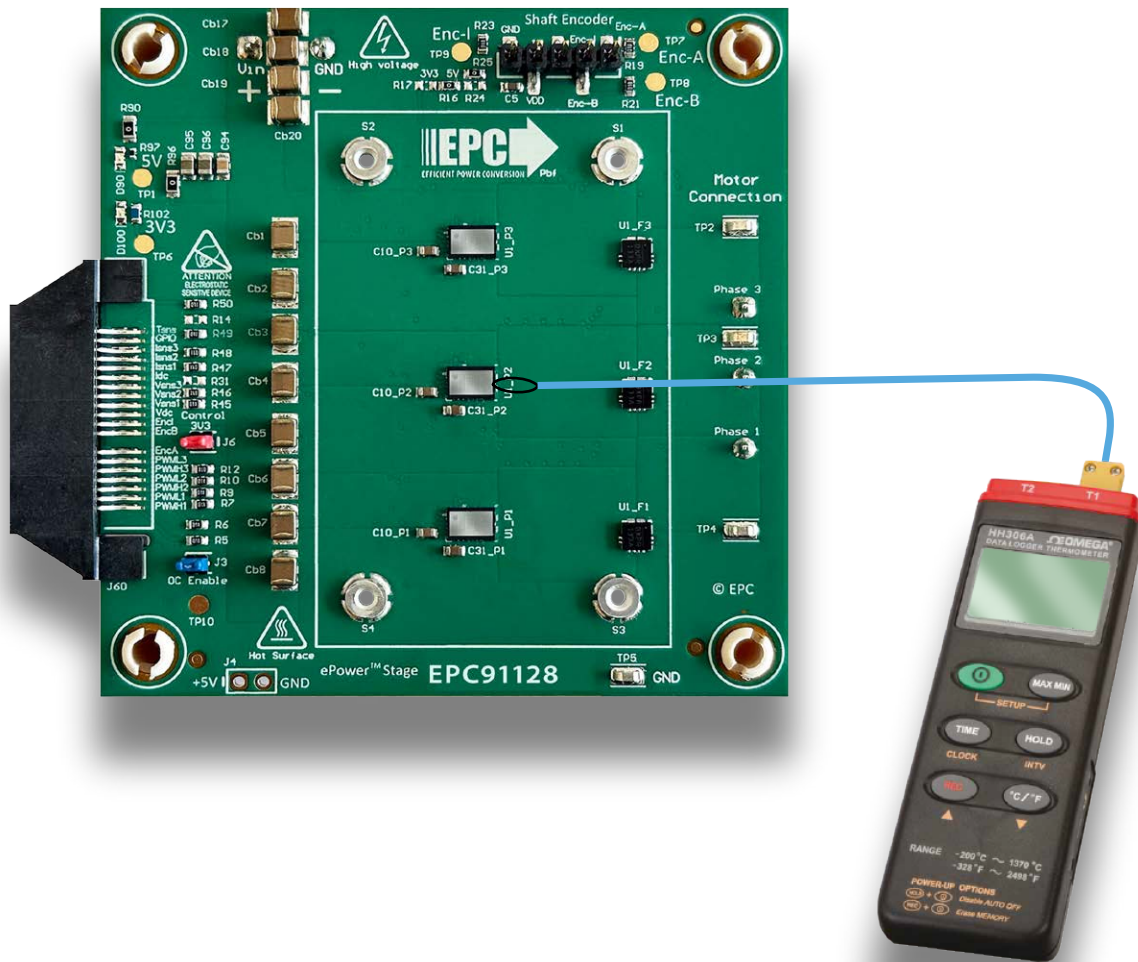


Figure 10. Thermal test setup configuration

STEADY STATE ANALYSIS

EPC91128 and EPC91129

Figure 11 depicts the steady-state thermal performance summary of the EPC91128-EPC91129 boards. When operated on a motor bench at an ambient temperature of 24°C, with a 48 V_{DC} supply and natural convection, the EPC91128-EPC91129 can deliver 15 A_{RMS} per phase without a heatsink and 20 A_{RMS} per phase with a heatsink attached, with a temperature rise below 90°C from the eGaN IC case to ambient.

Motor drive operating points at PWM = 20, 50, and 100 kHz, deadtime = 50 ns, with and without heatsink at 24°C ambient temperature, under natural convection.

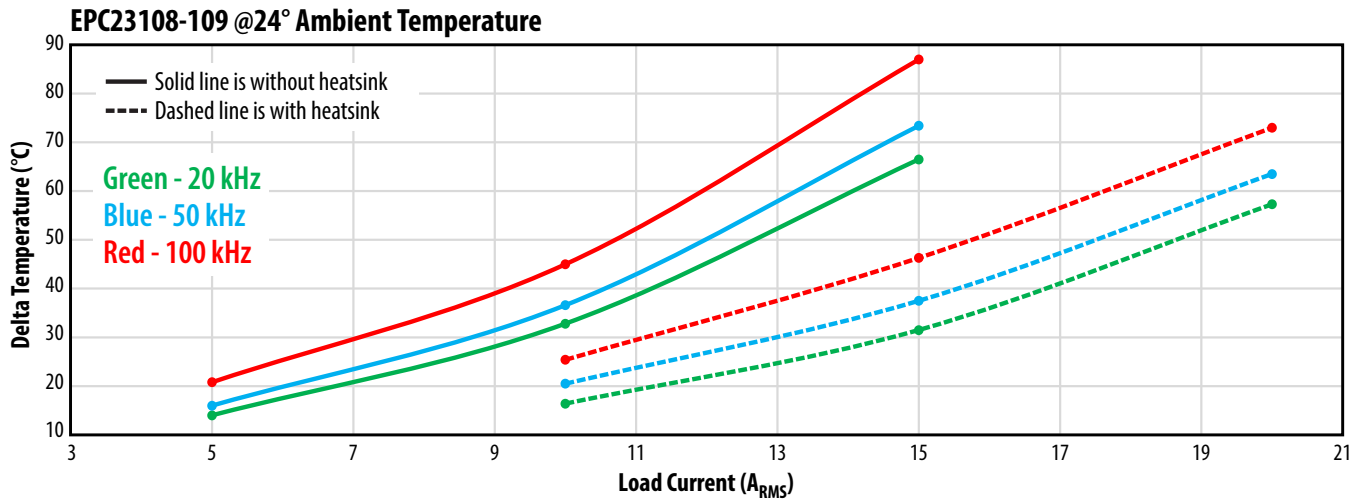


Figure 11: EPC91108-109 eGaN ICs temperature increase vs. the ambient temperature (22°C). Measurements were taken at various PWM frequencies.

EPC91130 and EPC91131

Figure 12 depicts the steady-state thermal performance summary of the EPC91130-EPC91131 boards. When operated on a motor bench at an ambient temperature of 26°C, with a 48 V_{DC} supply and natural convection, the EPC91130-EPC91131 can deliver 11 A_{RMS} per phase without a heatsink and 15 A_{RMS} per phase with a heatsink attached, with a temperature rise below 70°C from the eGaN IC 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.

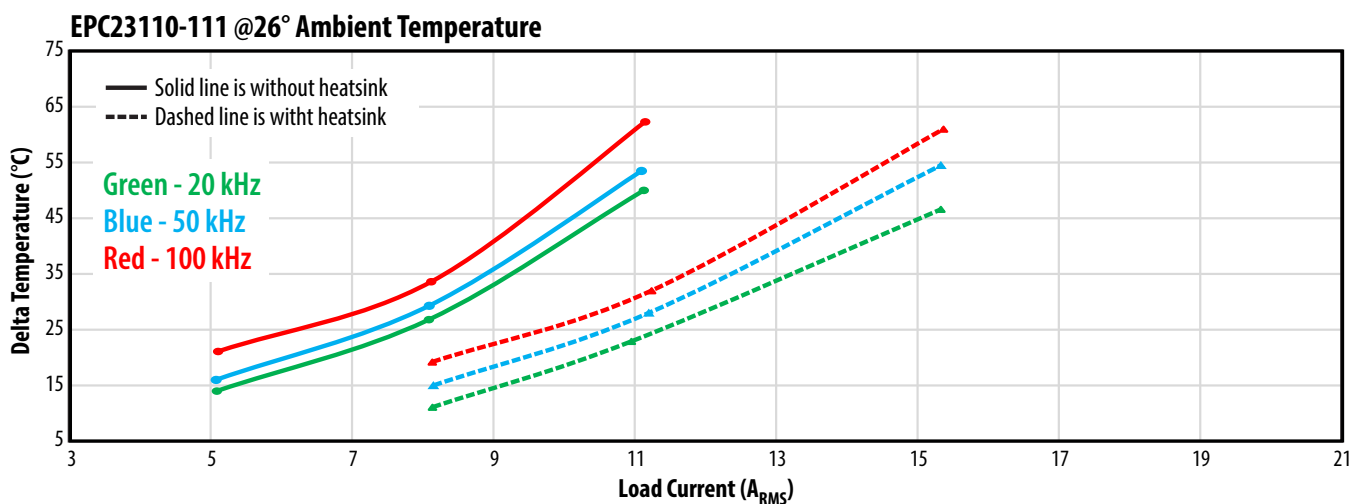


Figure 12: EPC91110-111 eGaN ICs temperature increase vs. the ambient temperature (26°C). Measurements were taken at various PWM frequencies.

PULSED TORQUE ANALYSIS

The pulsed torque thermal analysis describes the performance of EPC91128-EPC91129-EPC91130-EPC91131 for applications subject to a 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 24°C ambient temperature with 3kW motor using three different pulse time: 0.5 s, 1 s and 1.5 s (total period 10 s).

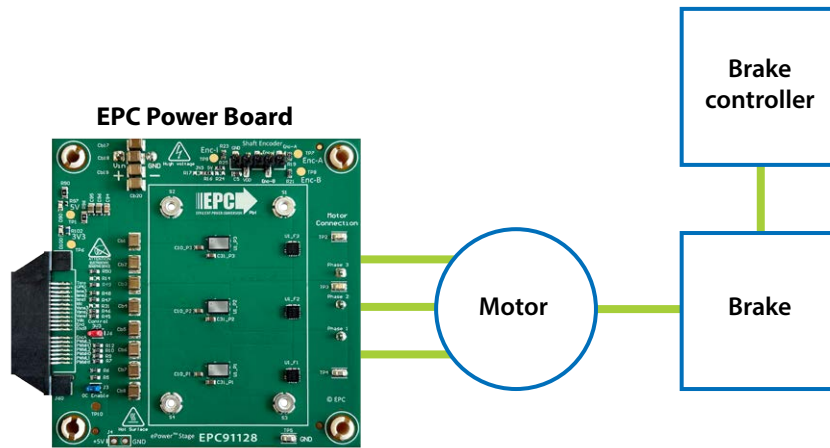


Figure 13: Pulsed torque test set up schematic

EPC91128 and EPC91129

As in the example in Figure 14, the motor braking generates an impulse with a total current of 29 A_{RMS} (43 Apk) for 1.5 s (total period 10 s), which returns in the no-load conditions after brake-off. The tests were done considering 10 minutes of pulse loop.

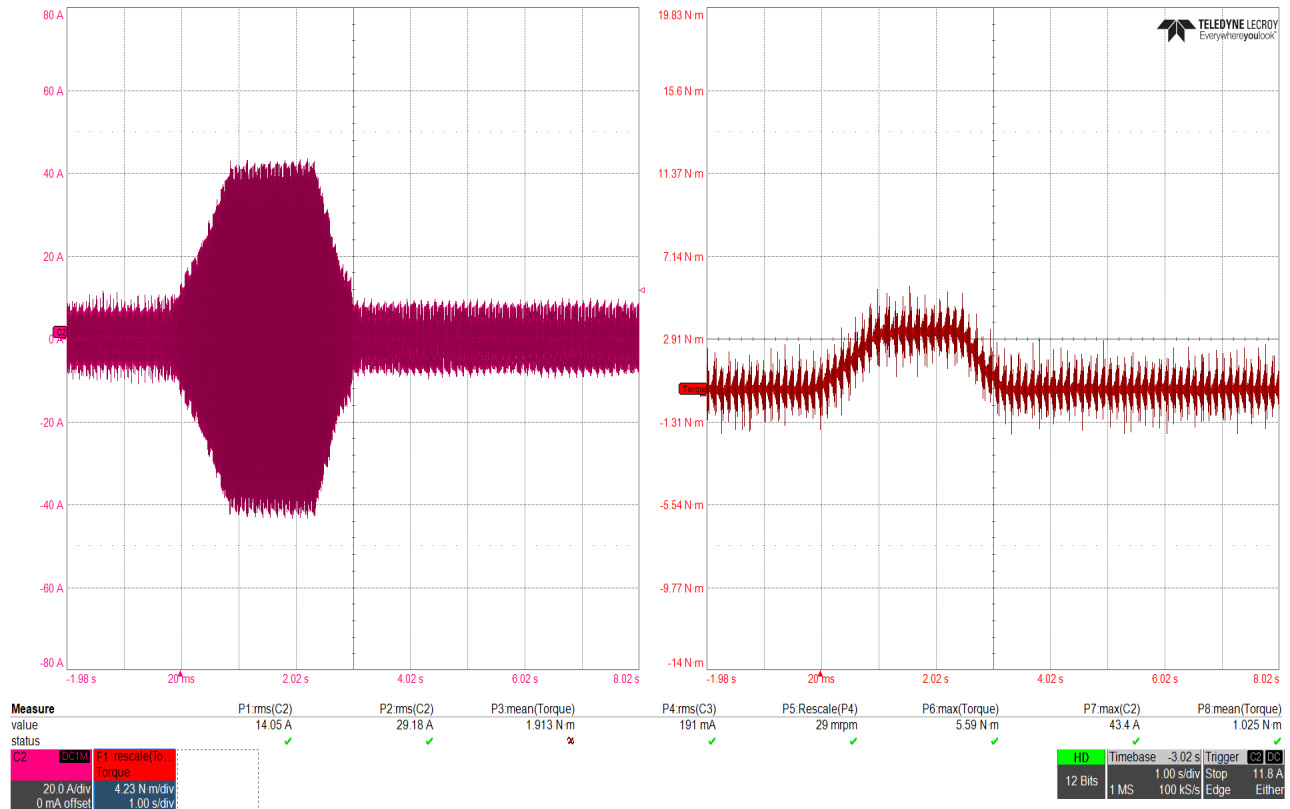


Figure 14: 1.5 s pulsed torque test

EPC91130 and EPC91131

As in the example in Figure 15, the motor braking generates an impulse with a total current of 18.7 Arms (29 Apk) for 1.5 s (total period 10 s), which returns in the no-load conditions after brake-off. The tests were done considering 10 minutes of pulse loop.

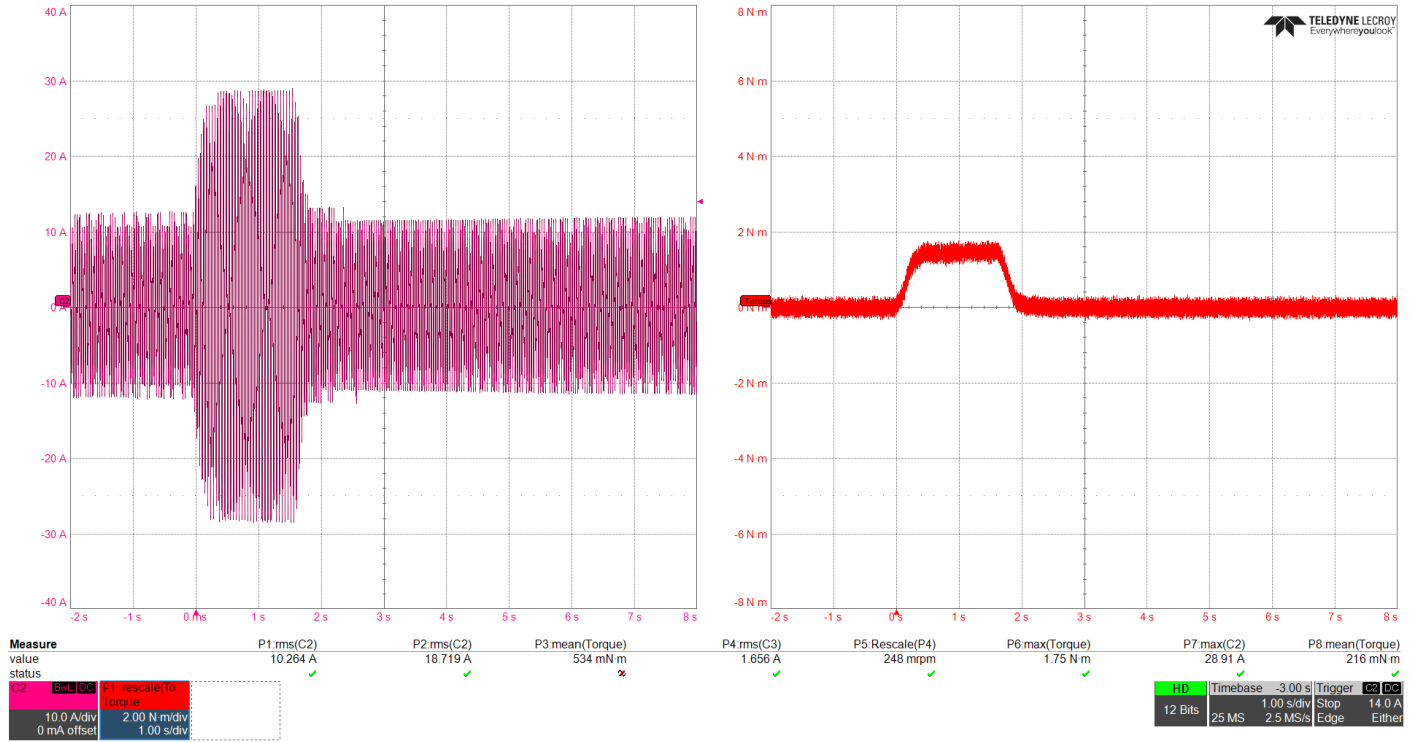


Figure 15: 1.5 s pulsed torque test

The graph in Figure 16 shows the correlation between the measured temperature by the on-board temperature sensor on bottom side of the PCB and the thermocouple die case temperature for same eGaN IC with only natural convection cooling. Figure 17 shows the location of the temperature sensor used to measure the top side of the PCB temperature.

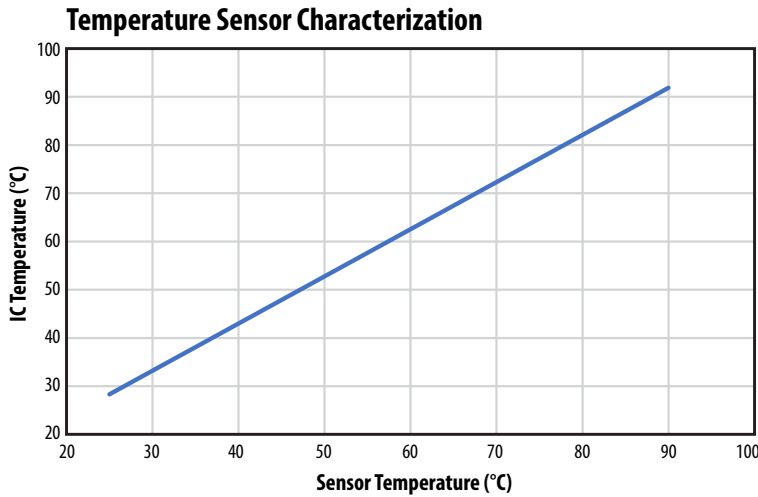


Figure 16: eGaN IC case temperature vs. temperature sensor placed on bottom of the PCB. Operation under natural convection without heatsink.

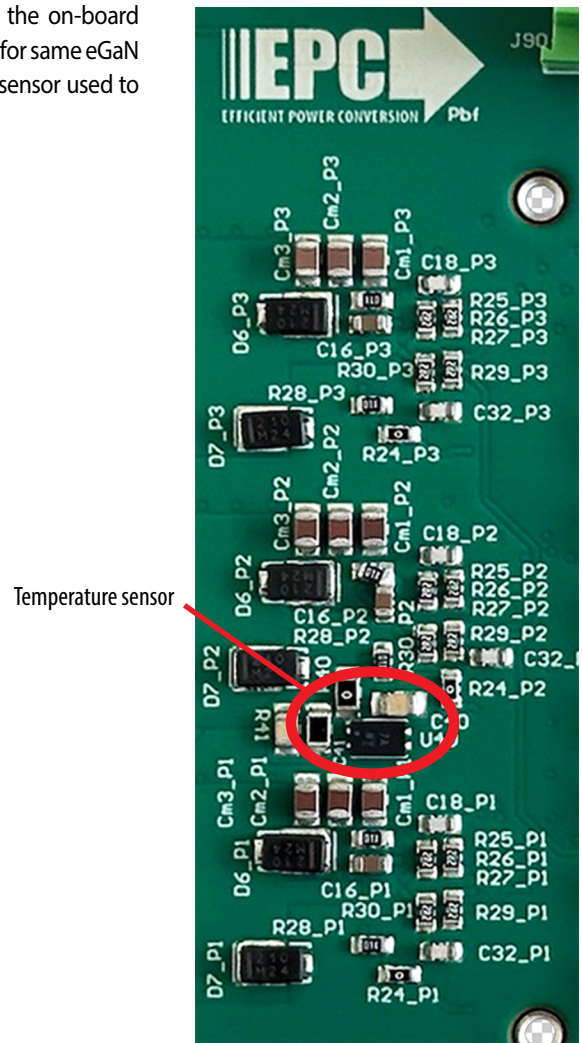


Figure 17: Temperature sensor location on the top side of the PCB

For support files including schematic, Bill of Materials (BOM), and gerber files please visit the EPC91128/EPC91129 landing page at: <https://epc-co.com/epc/products/evaluation-boards/epc91128> and for EPC91130/EPC91131 landing page at: <https://epc-co.com/epc/products/evaluation-boards/epc91130>

Change Log

STATUS	VERSION	DATE	REMARK
1.0	Production	16 April 2026	Production release

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