EPC91118
3-phase Inverter for Humanoid Robot Joints Quick Start Guide

Featuring the EPC23104 ePower Stage IC

June 3, 2025

Version 1.3

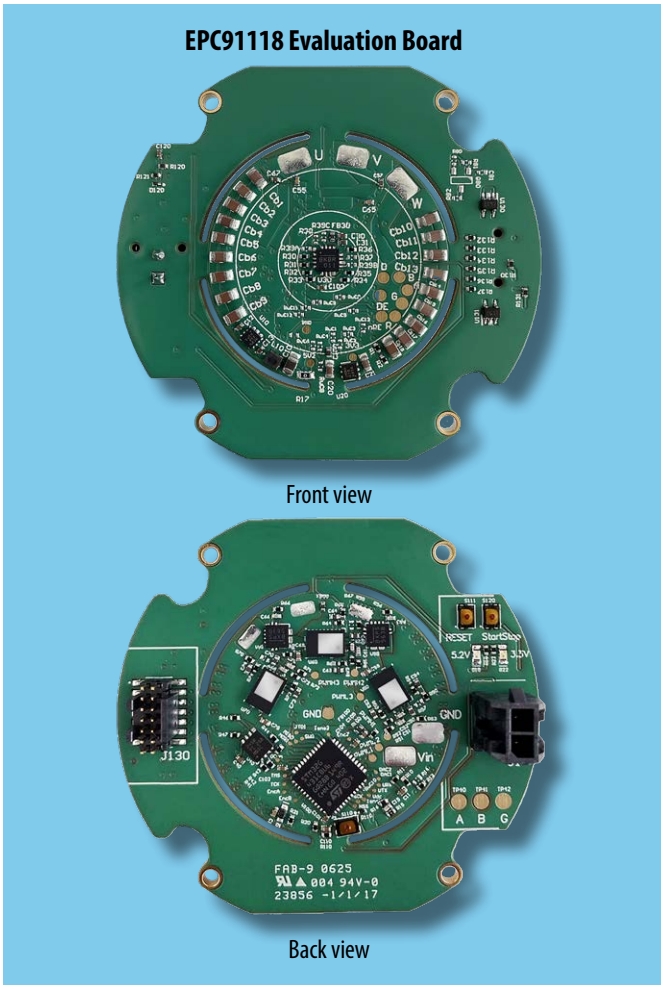
EFFICIENT POWER CONVERSION

DESCRIPTION

The EPC91118 evaluation board is a 3-phase BLDC motor drive inverter intended for humanoid robot joints motors. The board features EPC23104 ePower Stage IC, which is an 8.7 mΩ typical $R_{DS(on)}$, 100 V maximum voltage GaN monolithic integrated circuit.

The EPC91118 can deliver up to 14 Apk (10 A_{RMS}) steady-state output current and up to 21 Apk (15 A_{RMS}) pulsed output while inserted inside the motor chassis.

The EPC91118 is intended for driving humanoid robot joints and contains all the necessary critical function circuits to support a complete motor drive inverter, including a microcontroller, motor shaft angular sensor, housekeeping power supplies, accurate voltage and current sense, JTAG connector and RS485 interface. The various functional blocks are shown in Figure 1.



REGULATORY INFORMATION

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

KEY FEATURES OF THE EPC91118 EVALUATION BOARD

- 3-phase inverter based on EPC23104 eGaN IC with wide input DC voltage ranging from 15 V to 55 V
- Dimensions: 32 mm diameter inverter, 55 mm diameter external frame
- Phase current sense gain: 44 mV/A
- DC bus voltage sense gain: 44.89 mV/V
- Encoder default resolution: 1024 pulses with Z index, SPI communication for absolute position
- RS485 communication interface

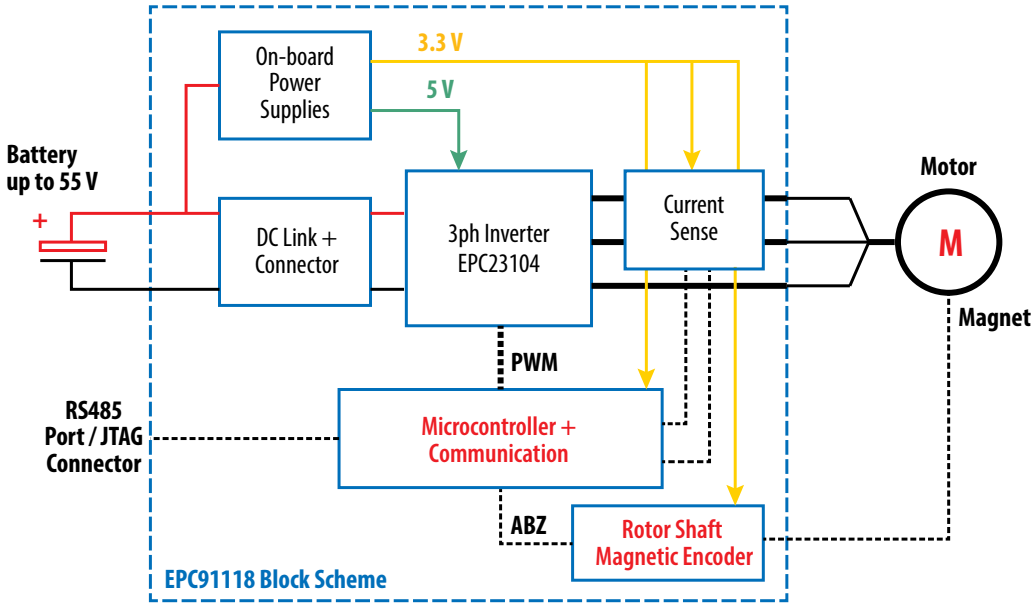
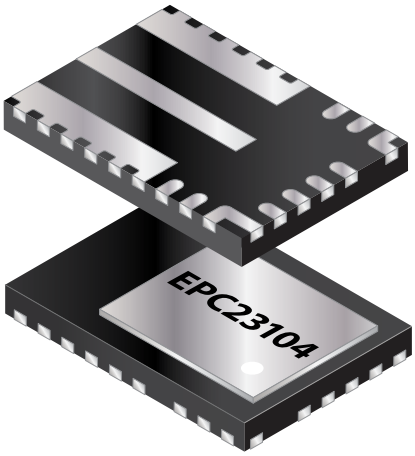
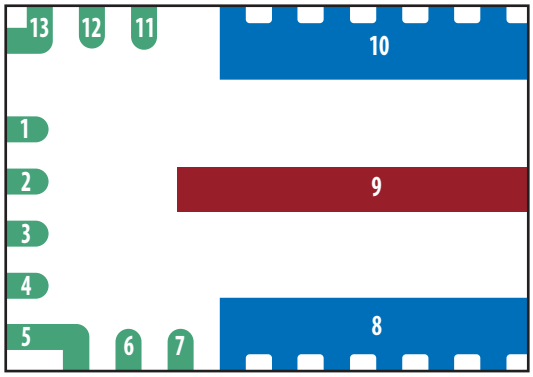


Figure 1: Block diagram overview of the EPC91118 evaluation board

FEATURED ePower Stage IC

The EPC91118 evaluation board features the features EPC23104 ePower Stage IC, which is an 8.7 mΩ typical $R_{DS(on)}$, 100 V maximum voltage GaN monolithic integrated circuit shown in figure 2.





Pin	Description
1	HS_{IN}
2	LS_{IN}
3	STB
4	V_{DD}
5	V_{DRV}
6	R_{DRV}
7	AGND
8	PGND
9	SW
10	V_{IN}
11	V_{PHASE}
12	R_{BOOT}
13	V_{BOOT}

Figure 2: Pin assignments of the EPC23104

For additional details, refer to the **EPC23104 datasheet available at www.epc-co.com**. The datasheet should be read in conjunction with this quick start guide.

OVERVIEW OF THE EPC91118 EVALUATION BOARD

Figure 3 shows an image of both sides of the EPC91118 evaluation board with the location of the various functional blocks highlighted.

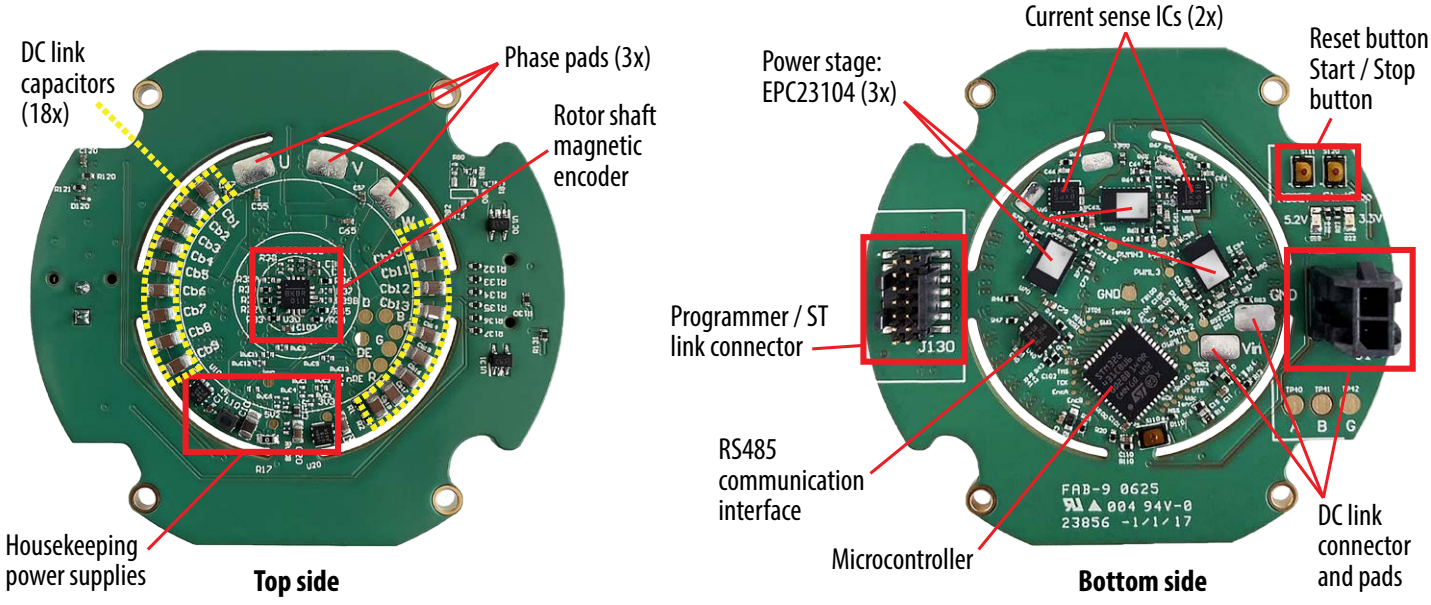


Figure 3: Top and bottom views of EPC91118

Figure 4 shows the inverter located in a 32 mm diameter circle. The external frame is meant for mechanical reasons to install the board into a specific humanoid joint motor and to place the connectors J130 and J1 meant for debugging the firmware and to do lab tests.

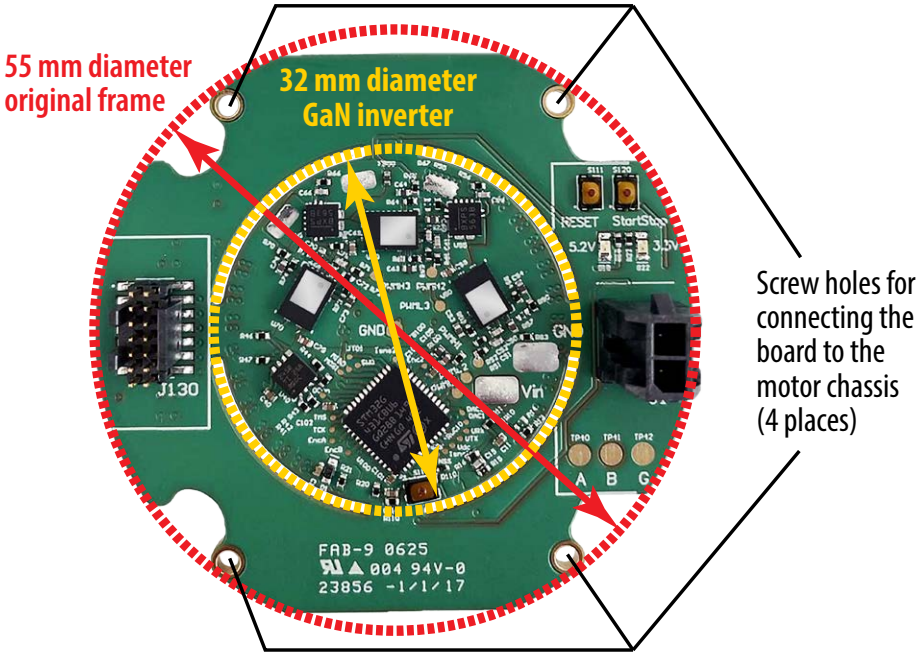


Figure 4: Mechanical details of EPC91118

The EPC91118 board was shaped a specific humanoid joint motor. The whole inverter is disposed in the 32 mm inner circle, while the external frame can be adjusted to fit in different motors. The design files are available on request from EPC website. Figure 5 shows the EPC91118 inverter board mounted inside the stator of the motor.

The EPC91118 is preprogrammed to operate the motor at 100 kHz PWM, with a 50 ns dead time, running at 50 rpm on the outer rotor, but different speed conditions can be set either by connecting to the real time GUI through the JTAG connector or by programming the microcontroller to communicate through the RS485 port.

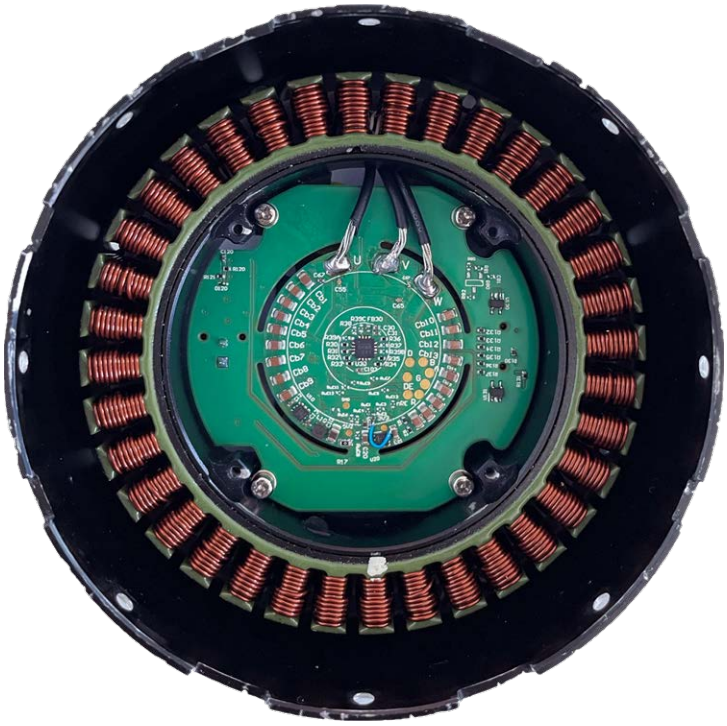


Figure 5. Mechanical details of EPC91118

HIGHLIGHTED PARTS OF THE EPC91118 CIRCUIT

Power Stage

The EPC91118 features a 3-phase inverter with EPC23104 eGaN ICs. For more information on the EPC23104 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 EPC91118 board includes house-keeping power supplies that are powered from the main input supply voltage to the inverter board. The 5 V supply is generated by a small DC-DC converter to supply the GaN FET ICs and LDO, which generates a 3.3 V that supplies the microcontroller, the current sensors, the magnetic encoder and RS485 interface chip.

A green LED is powered by the 5 V supply, while a yellow LED is powered by the 3.3 V supply.

Current and Voltage Sense

The EPC91118 inverter is equipped with current sense for phases U and V and voltage sense for the DC input.

The output current of phases U and V is measured using the current sense IC MCS1823-330BRN , that has a sensitivity of 44 mV/A. The two sensors also feature an overcurrent detection circuit that are pulled up and connected to the microcontroller in a wired-OR configuration.

The main input DC supply voltage and each phase voltage are measured using a resistor divider network that yields a total gain of 44.89 mV/V.

DC Link Capacitors

The entire DC link is made of MLCC capacitors and are dimensioned on the maximum RMS phase current that can be delivered by the board.

Rotor Shaft Magnetic Encoder

An encoder located in the center of the board detects the position of the magnet placed at the end of the rotor shaft. The encoder has a resolution of 1024 pulses and the Z index pin. The sensor can also communicate through the SPI port the absolute position of the rotor.

Microcontroller

The microcontroller provided on the board is the small 7x7 mm QFN STM32G431CBU6. For deeper information on its complete functions, please visit ST microelectronics website (**www.st.com**).

JTAG Connector

A 14-pin connector is present on the board and can be used to program the microcontroller and to use real-time software to control the motor from the computer.

RS485 Interface

The inverter is equipped with a RS485 port to meet the typical communication interface of humanoid robots motors.

RECOMMENDED OPERATING CONDITIONS

Table 1: Electrical specifications as in the other boards 44.89 mV/V

Symbol	Parameter	Conditions	Min	Nom	Max	Units
V_{IN}	Input supply voltage		15	24	55	V
I_{Phase}	EPC91118 Phase current(1)			10	15	A_{RMS}
f_{sw}	Switching frequency		80	100	150	kHz
V_{IN_uvlo}	Input under voltage lockout voltage			6		V
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 44 mV/A	-37.5		37.5	A
I_{ovc}	Positive over-current threshold	Over-current circuits detects both positive negative OVC		|30|		
V_{Isns_offset}	Amplified current sense signal offset voltage			1.65		V
G_{Isns}	Amplified current sense gain	Default current sense IC is MCS1823-330BRN		44		mV/A
G_{Vsns}	Phase and DC voltage sense gain(2)			44.89		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 **EPC23104 data sheet** for details.

(2) **Maximum dynamic voltage range is 0 V to 73.5 V which exceeds maximum recommended supply voltage for the EPC23104 eGaN IC.**

EXPERIMENTAL VALIDATION

As experimental evaluation, the EPC91118 board was tested on a dynamometric bench in various load torque and rotor speed conditions. The inverter was operated at a 100 kHz PWM, 50 ns deadtime.

The total system efficiency from the DC electrical input to the output mechanical power vs. the load torque is reported in Figure 6 at rotor speed ranging from 50 rpm to 150 rpm. The system efficiency hence includes the inverter efficiency and the motor efficiency.

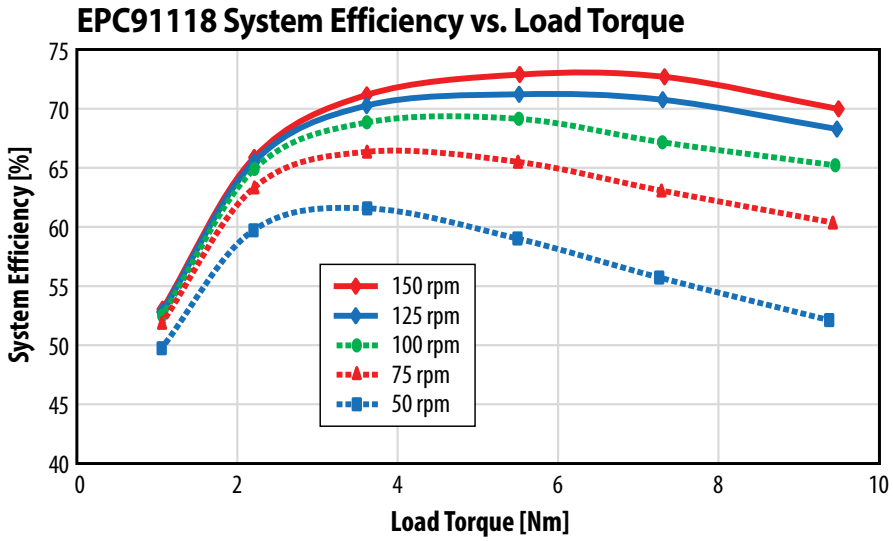


Figure 6: System efficiency vs. load torque at various rotor speeds

Note: The EPC91118 inverter was designed to fit into the Unitree A1 motor.

For support files including schematic, Bill of Materials (BOM), and gerber files please visit the EPC91118 landing page at: https://epc-co.com/epc/products/demo-boards/EPC91118

For More Information:

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Evaluation Board Notification

The EPC91118 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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