EPC9137

1.5 kW 48 V/12 V Bi-Directional Power Module Evaluation Board Quick Start Guide

20–60 V Input, 12 V 125 A Output (Buck)

12–16 V Input, 48 V 29 A Output (Boost)

Revised December 29, 2021

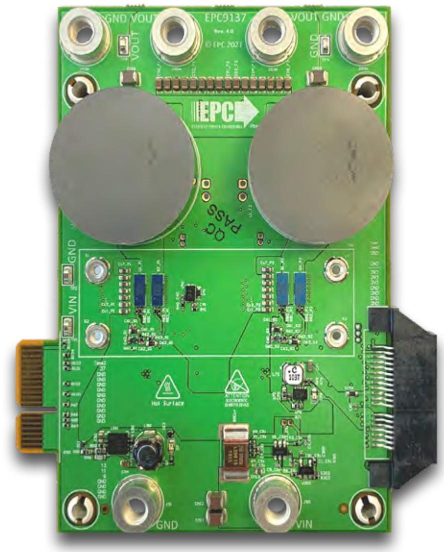
Version 4.0

EFFICIENT POWER CONVERSION

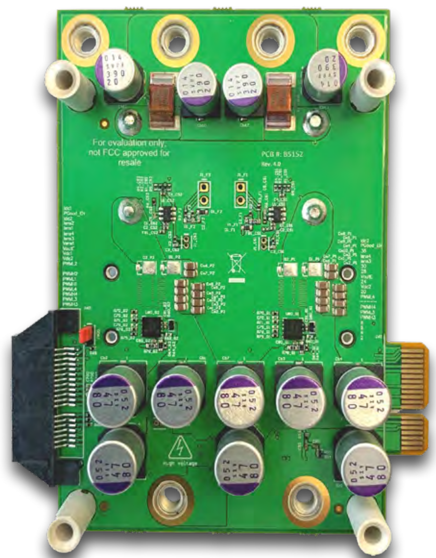
DESCRIPTION

The EPC9137 evaluation power module is designed for 48 V to/from 12 V DC-to-DC applications. It features the EPC2206 – enhancement mode eGaN® field effect transistors (FETs) with AEC-Q101 qualification. The EPC9137 is controlled using the EPC9528 controller module that includes the Microchip dsPIC33CK256MP503 16-bit digital controller. Other features include:

- High efficiency: >95.7% @ 12 V/125 A output (buck)
  >95.2% @ 48 V/29 A output (boost)
- Preset switching frequency: 250 kHz
- Re-programmable – Average current mode control (default)
- Fault protection:
  - o Input undervoltage
  - o Input overvoltage
  - o Regulation error
  - o Input undervoltage
  - o Inductor overcurrent
  - o Overtemperature



EPC9137 top view



EPC9137 bottom view

REGULATORY INFORMATION

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

FIRMWARE UPDATES

The EPC9528 module is programmed as a Buck converter by default. To change to Boost converter, please re-program the module with the boost firmware available at the **EPC website**. Using the incorrect firmware could result in damage.

Every effort has been made to ensure all control features function as specified. It may be necessary to provide updates to the firmware. Please check the EPC and Microchip websites for the latest firmware updates.

Table 1: Absolute Maximum Ratings

Symbol	Parameter	Conditions	Min	Max	Units
V_{IN}	Input voltage	Buck		64	V
		Boost		17	
I_{OUT}	Output current	Buck (1)		125	A
		Boost (1)		29	
$T_{C,MAX}$		Measured at heatsink base		95	°C

(1) with 1700 LFM airflow

Table 2: Electrical Characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Units
V_{IN}	Input voltage	Buck	20	48	60	V
		Boost, during operation	11.3	12	16	
		Boost, start up	12.3			
$V_{IN,on}$	Input UVLO turn on voltage	Buck		20		
		Boost		12.3		
$V_{IN,off}$	Input UVLO turn off voltage	Buck		17.5		
		Boost		11.3		
V_{OUT}	Output Voltage	Buck	5	12	16	
		Boost	20	48	50	
$t_{OUT,rise}$	Output voltage rise time			100		ms
ΔV_{OUT}	Output voltage ripple	Buck, I_{OUT} = 30 A		80		mV
		Boost		-		
I_{OUT}	Output Current	Buck	0		125	A
		Boost	0		29	
I_{MAX}	Maximum current limit threshold	Buck, output current	130		145	
		Boost, input current	130		145	
T_{MAX}	Maximum temperature limit threshold	During operation	93		98	°C
$T_{Start,MAX}$	Maximum temperature to start converter	Before startup, after over-temperature fault event			80	
f_{sw}	Switching frequency			250		kHz

ELECTRICAL PERFORMANCE

Typical efficiency and power loss

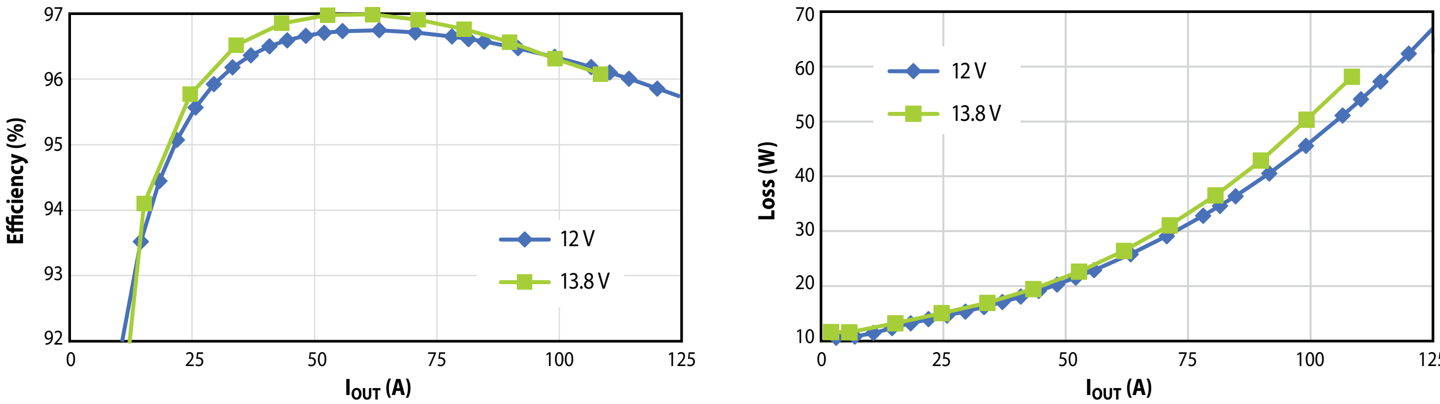


Figure 1. Measured buck converter efficiency and power loss at 12 V and 13.8 V load voltage up to 1.5 kW load power

Typical output voltage ripple

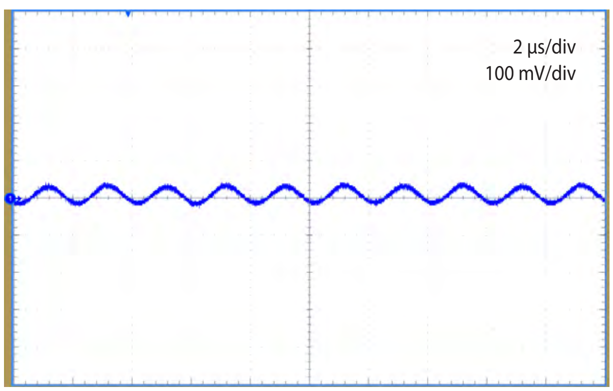


Figure 2: Measured buck converter output voltage ripple with V_{IN} = 48 V, V_{OUT} = 12 V, I_{OUT} = 30 A

Typical transient response

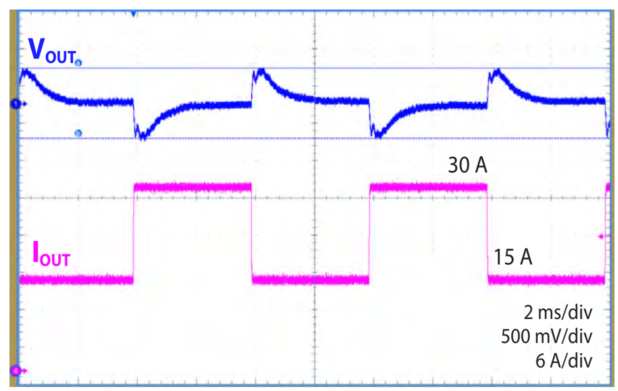
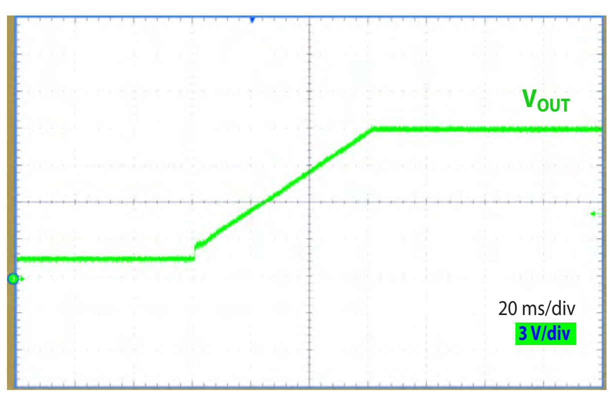


Figure 3: Measured transient response with V_{IN} = 48 V, V_{OUT} = 12 V, output 15 A to 30 A 125 Hz transitions (Buck)

Startup waveform



48 V input, 12 V output (buck)

Figure 4. Buck converter output voltage start up response

OPERATING CONSIDERATIONS

Buck/Boost Modes

The module is programmed with Buck mode by default. To operate as a Boost converter, please download the firmware available at the EPC website for Boost mode and re-program the control module.

Over-current protection

This module supports conventional average current mode control (ACMC).

Over-temperature protection

During operation, if the heatsink base temperature (sensed by AD590) exceeds 95°C, the over-temperature fault condition will be set, and the converter will shut down. After the temperature drops to below 80°C, the converter will be able to restart.

CONTROLLER

Please refer to EPC9528 Quick Start Guide for more information about the control module with Microchip dsPIC33CK256MP503.

The average current mode control (ACMC) is used for EPC9137.

Conventional, Robust Average Current Mode Control (ACMC) (*figure 5*): With this firmware the power converter is controlled by one outer voltage loop providing a shared reference to two independent inner average current loops controlling the phase current of each converter phase. This conventional approach ensures proper current balancing between both phases of this interleaved converter, operating 180° out of phase to minimize the input current ripple and filtering. The inner current loops are adjusted to average cross-over frequencies of 10 kHz. To balance the current reference perturbation of the inner current loops, the outer voltage loop has been adjusted to an average cross-over frequency of 2 kHz, which determines the overall response time of the converter.

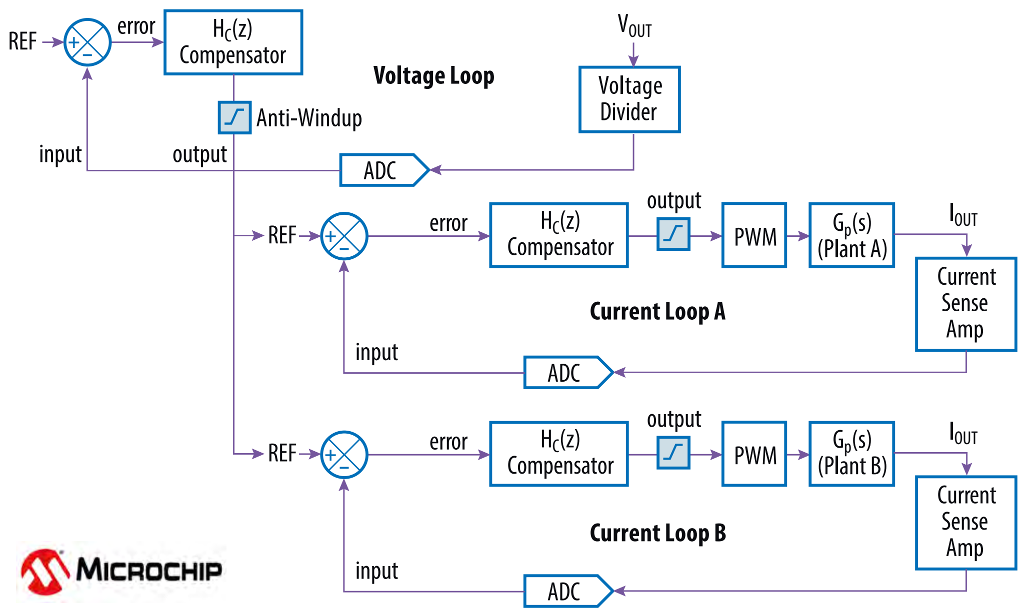


Figure 5. Interleaved buck converter average current mode control

TWO-BOARD (FOUR-PHASE) PARALLEL OPERATION

Two of the EPC9137s can be connected in parallel and controlled by one single EPC9528 controller for four-phase operation, as shown in Figure 6. The correct firmware (see next section: **Programming with Hex file**) needs to be programmed to the EPC9528 controller. The measured efficiency and loss at 48 V input, 12 V output is shown in Figure 7.

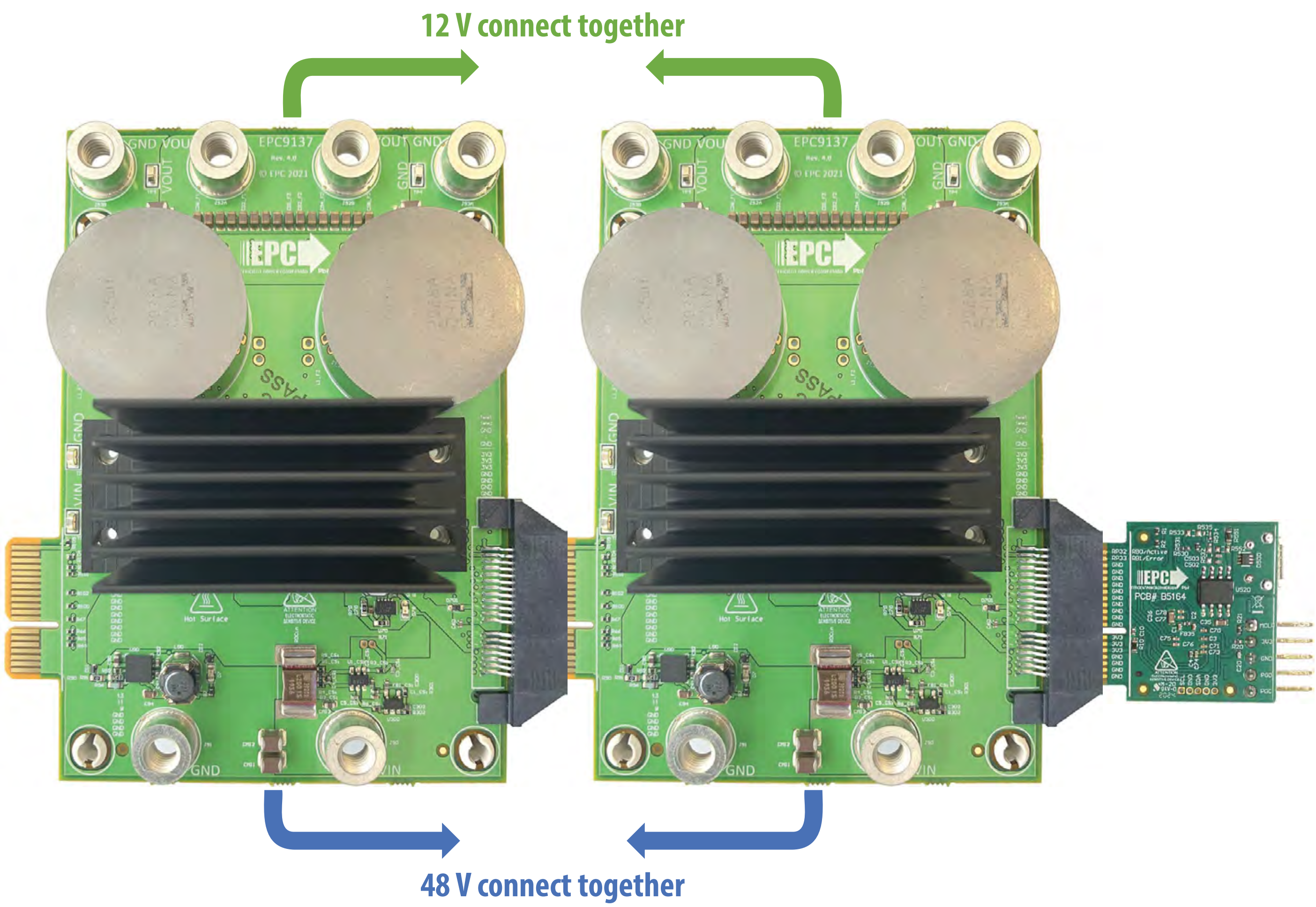
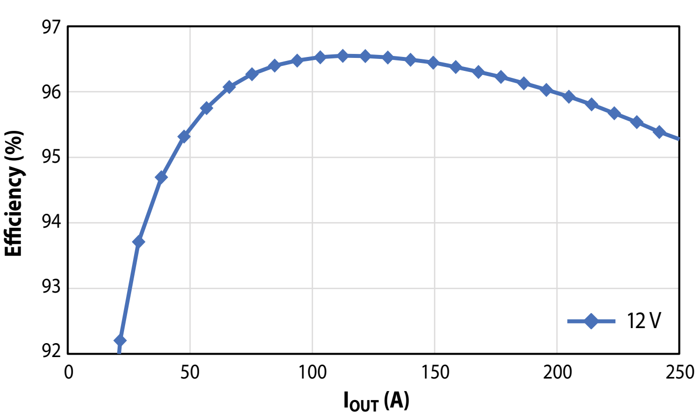


Figure 6. Two EPC9137s connected in parallel to achieve 3 kW (four-phase) using one EPC9528 controller



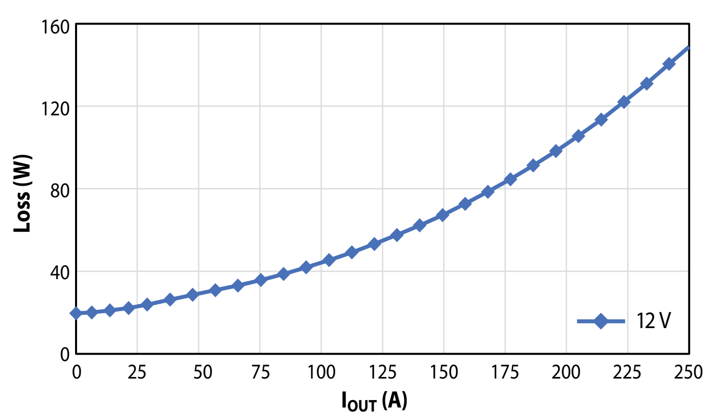


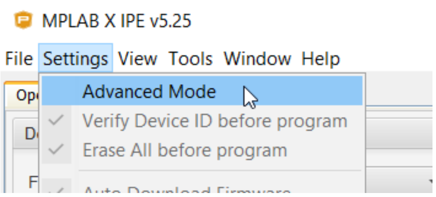
Figure 7. Measured four-phase (2xEPC9137) buck converter efficiency and power loss at 12 V load voltage up to 3 kW load power

Programming with HEX file

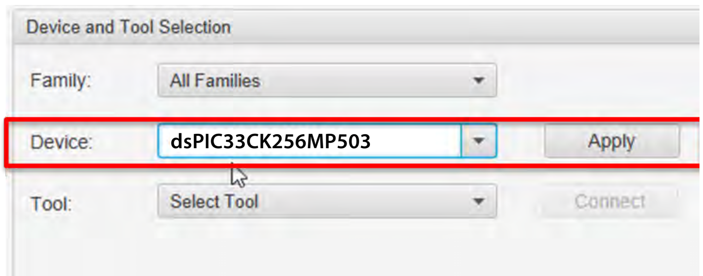
Download the latest MPLAB® X IPE from Microchip website and follow the five steps below:

https://www.microchip.com/mplab/mplab-integrated-programming-environment

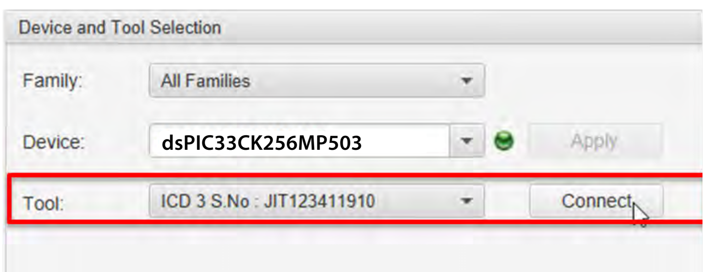
1. Enable Advanced Mode:



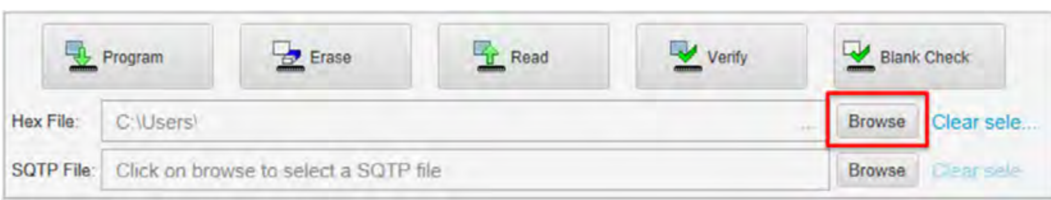
2. Select Device: dsPIC33CK256MP503 and then apply:



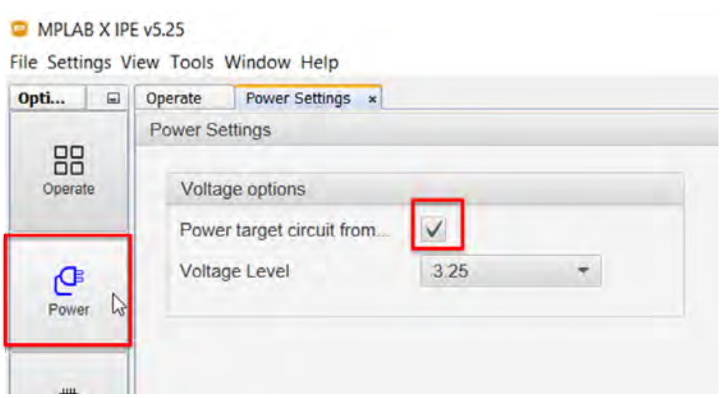
3. Select programming tool and then connect:



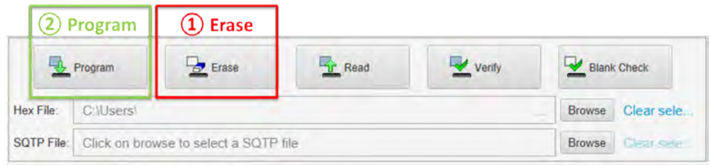
4. Click 'Browse' to select the provided .hex file:



Optional:



5. Erase device, and then program device:



MECHANICAL SPECIFICATIONS

Unit: mm [in]

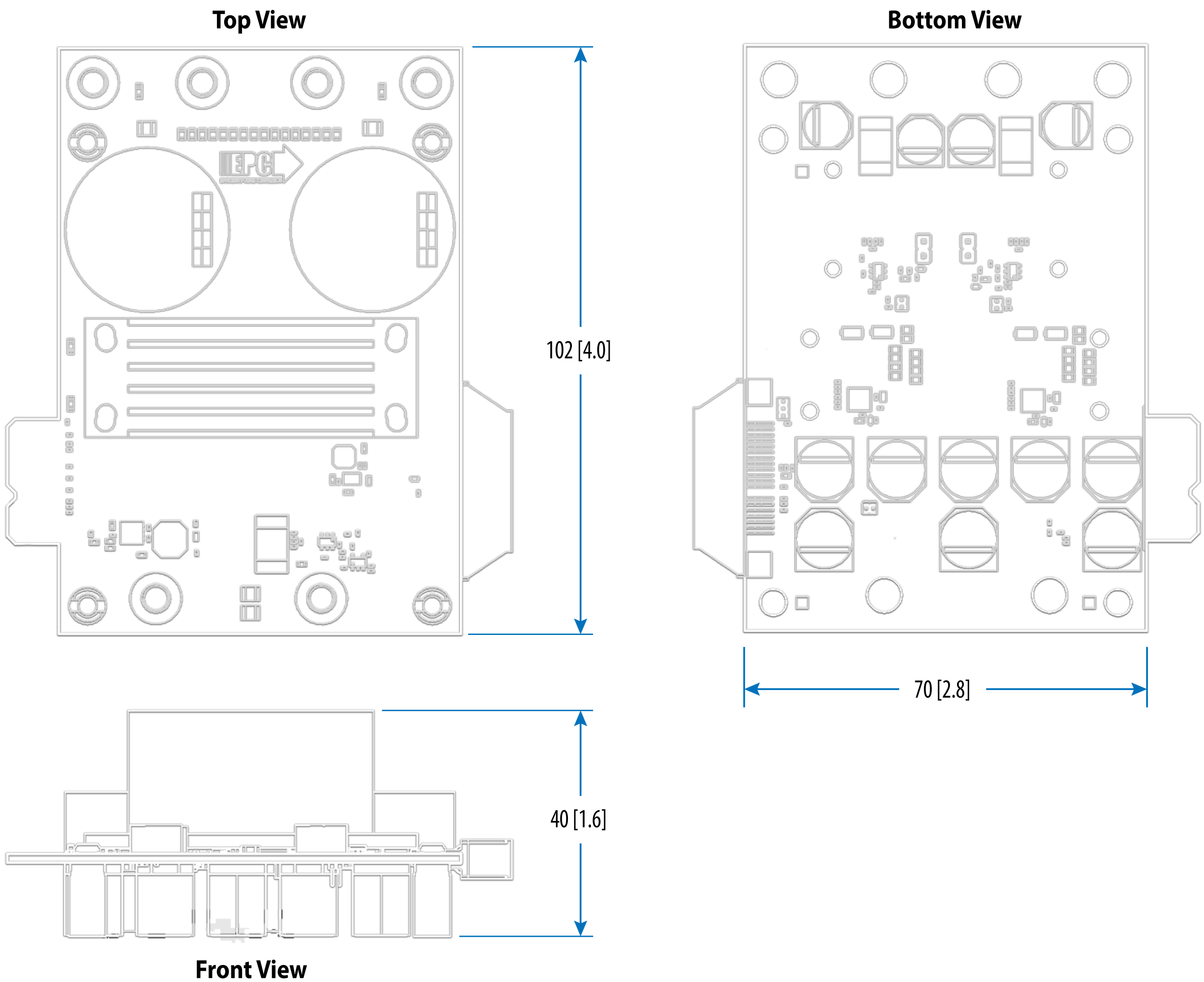


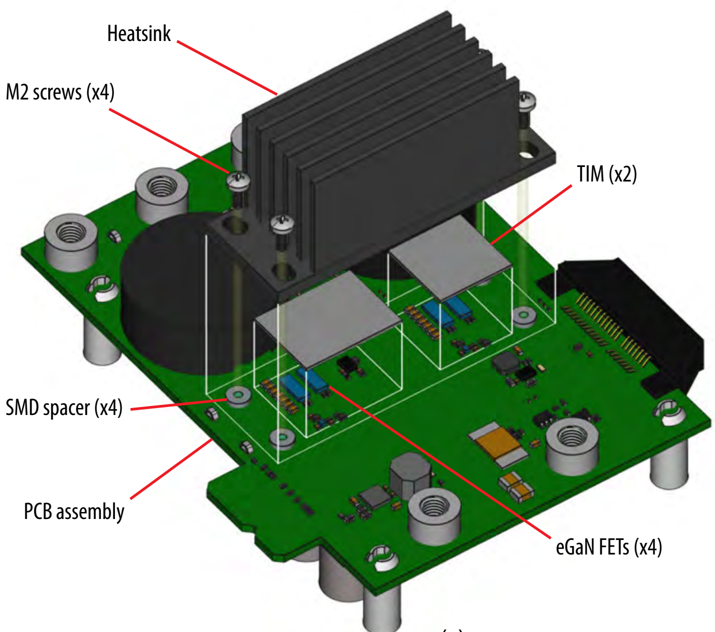
Figure 8: Mechanical dimensions of the EPC9137 board

THERMAL MANAGEMENT

The EPC9137 is intended for bench evaluation at room ambient temperatures and under forced air cooling. The addition of a heatsink can significantly improve the heat dissipation from the eGaN IC's and increase the current capacity of these devices, while ensuring to not exceed the absolute maximum die temperature of 150°C.

The EPC9137 board is equipped with four mechanical spacers (S1, S2, S3, S4) that can be used to easily attach a standard eighth-brick converter heatsink as shown in figure 9, and only requires a thermal interface material (TIM), a heatsink, and screws.

The pre-installed 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.



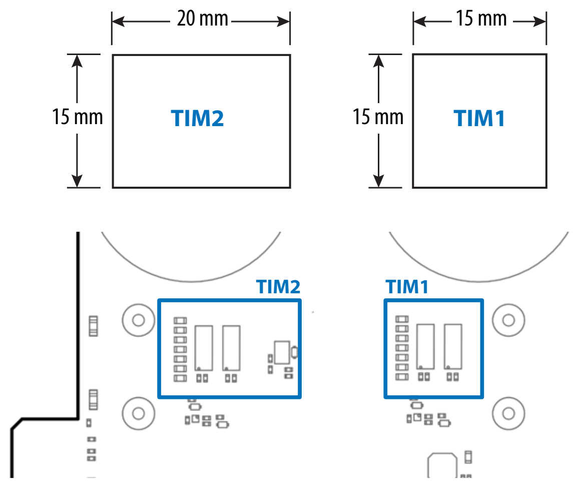


Figure 9: Details for attaching a heatsink to the board. (a) exploded 3D perspective, (b) top view showing the TIM location with respect to the eGaN FETs

A TIM is required between the FETs and the 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-A620 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)

The default TIM used for the EPC9137 is made by t-Global Technology, with P/N TG-A1780 and it 0.5 mm thick.

Thermal derating

Without sufficient cooling, the output current capability is reduced. The module temperature should be monitored to ensure the maximum temperature does not exceed the rating. Especially when the input voltage is higher than 48 V, the maximum output current is reduced.

EPC would like to acknowledge Microchip Technology Inc. (www.microchip.com) for their support of this project.

Microchip Technology Incorporated is a leading provider of smart, connected and secure embedded control solutions. Its easy-to-use development tools and comprehensive product portfolio enable customers to create optimal designs, which reduce risk while lowering total system cost and time to market. The company's solutions serve customers across the industrial, automotive, consumer, aerospace and defense, communications and computing markets.

The EPC9137 system features the dsPIC33CK256MP503 16-Bit Digital Signal Controller with High-Speed ADC, Op Amps, Comparators and High-Resolution PWM. Learn more at www.microchip.com.

For support files including schematic, Bill of Materials (BOM), and gerber files please visit the EPC9137 landing page at: https://epc-co.com/epc/products/demo-boards/epc9137

For More Information:

Please contact **info@epc-co.com**
or your local sales representative

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EFFICIENT POWER CONVERSION

Evaluation board Notification

The EPC9137 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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