Evaluation System EPC9151 Quick Start Guide

18–60 V Input, 12 V, 25 A Output (Buck)
12–15 V Input, 48 V, 5.5 A Output (Boost)
300 W 1/16 th Brick Evaluation Module

October 30, 2020

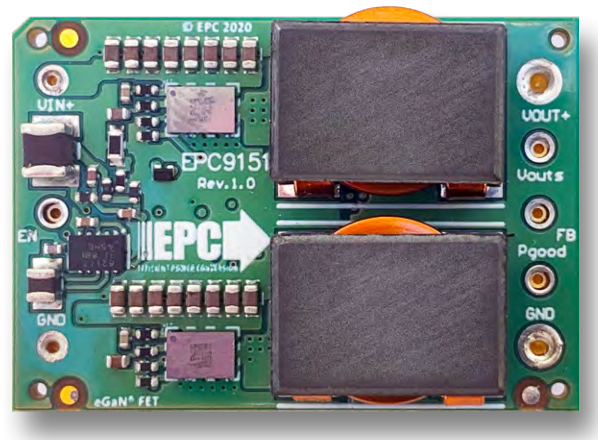
Version 1.0

EFFICIENT POWER CONVERSION

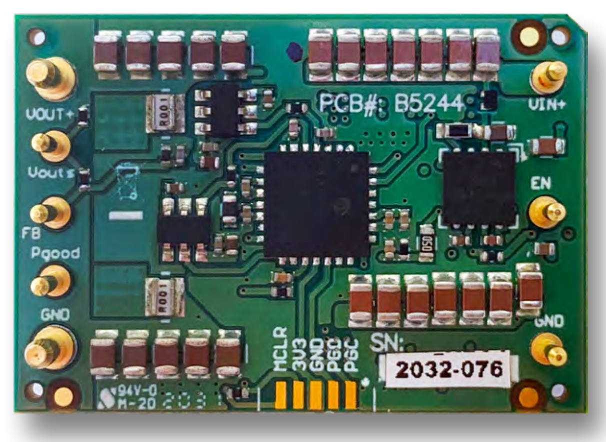
DESCRIPTION

The EPC9151 $^{1}/_{16}$th brick evaluation power module is designed for 48 V to/from 12 V DC-DC applications. It features the EPC2152 ePower™ stage – enhancement mode eGaN® field effect transistors (FETs) with integrated gate drivers, as well as the Microchip dsPIC33CK32MP102 16-bit digital controller. Other features include:

- High efficiency: 95% @ 12 V/25 A output (buck)
  95% @ 48 V/5.5 A output (boost)
- Dimension: 33 mm x 22.9 mm x 9 mm (1.30 in. x 0.90 in. x 0.35 in.)
- Industry standard footprint and pinout
- Power good output
- Constant switching frequency: 500 kHz
- Remote output voltage sense (buck)
- Re-programmable – Average current mode control (default)
- Fault protection:
  - o Input undervoltage
  - o Input overvoltage
  - o Regulation error
  - o Inductor overcurrent



EPC9151 top view



EPC9151 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 module is programmed as a Buck converter by default. To change to Boost converter, please re-program the module with the boost firmware. 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: Maximum Ratings

Symbol	Parameter	Conditions	Min	Max	Units
V_{IN}	Input voltage	Buck		65	V
		Boost		17	
I_{OUT}	Output current	Buck		25	A
		Boost		5.5	
T_C	Operating temperature	Measured at FET case as indicated in thermal measurement figure, airflow 1700 LFM		100	°C

Table 2: Electrical Characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Units
V_{IN}	Input voltage	Buck	18	48	60	V
		Boost, during operation	11.3	12	15	
		Boost, start up	12.3	12.5	15	
$V_{IN,on}$	Input UVLO turn on voltage	Buck		18		
		Boost		12.3		
$V_{IN,off}$	Input UVLO turn off voltage	Buck		17.5		
		Boost		11.3		
V_{OUT}	Output voltage	Buck	5	12	15	
		Boost	20	48	50	
C_{OUT}	External capacitance load	Buck	200		550	uF
		Boost	47			
$t_{OUT,rise}$	Output voltage rise time			100		ms
ΔV_{OUT}	Output voltage ripple	Buck, I_{OUT} = 25 A, C_{OUT} = 200 µF		100		mV
		Boost, I_{OUT} = 5.5 A, C_{OUT} = 47 µF		600		
I_{OUT}	Output current	Buck	0		25	A
		Boost	0		5.5	
$I_{OUT,limit}$	Output current limit threshold	Buck	26		27	
		Boost	6		6.8	
f_s	Switching frequency			500		kHz
On/off control input logic						
V_{on}/V_{off}	Function not available	Not implemented	0		3.3	V
Power good output logic						
P_{good}	Logic high (in regulation)		2.6	3.1	3.3	V
P_{good}	Logic low (not regulated)		0	0.25	0.7	

TYPICAL EFFICIENCY AND POWER LOSS

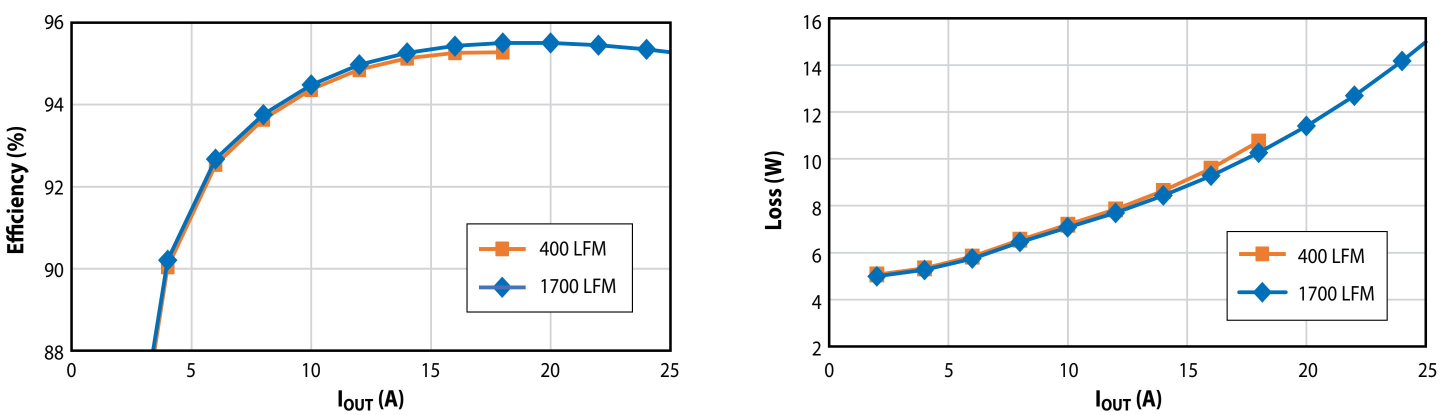


Figure 1. 48 V input, 12 V output (Buck)

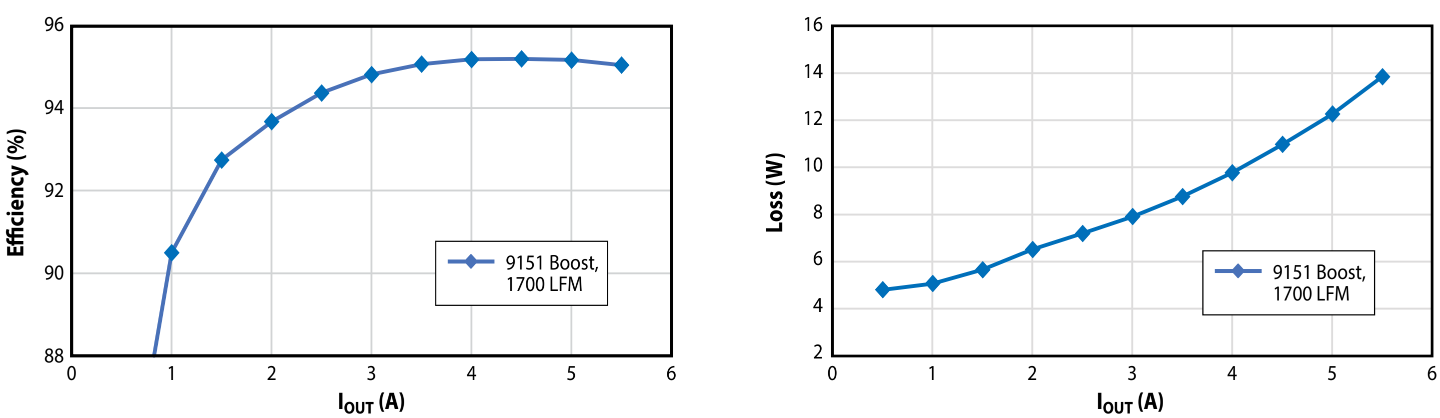


Figure 2. 12 V input, 48 V output (Boost)

ELECTRICAL PERFORMANCE

Typical output voltage ripple

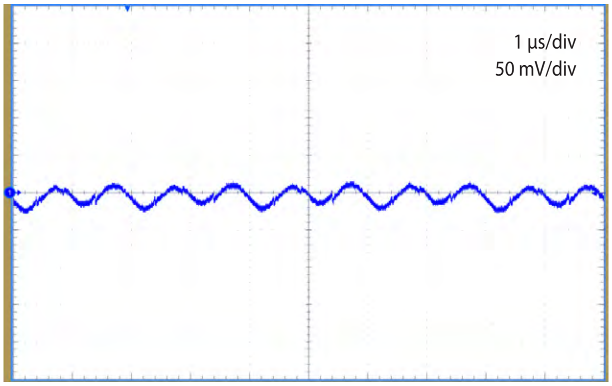


Figure 3: V_{IN} = 48 V, V_{OUT} = 12 V, I_{OUT} = 25 A (Buck)

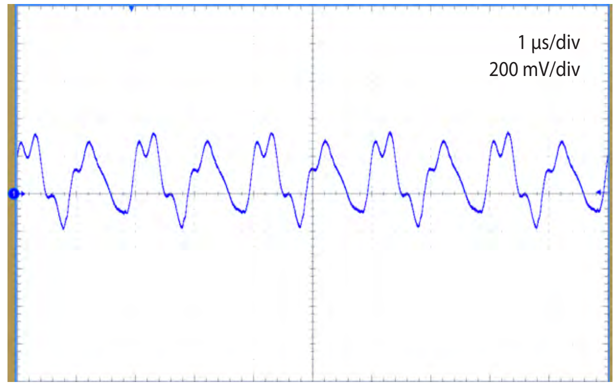


Figure 4: V_{IN} = 12 V, V_{OUT} = 48 V, I_{OUT} = 5.5 A (Boost)

Typical transient response

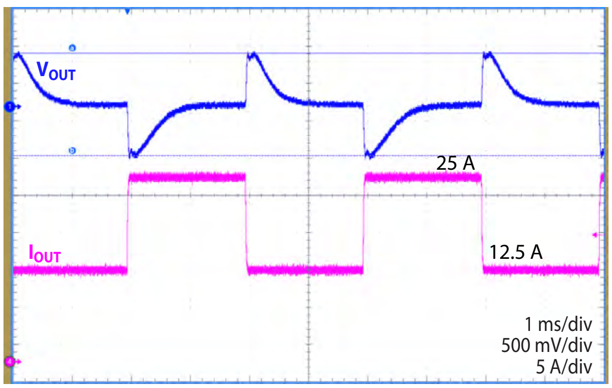


Figure 5: V_{IN} = 48 V, V_{OUT} = 12 V, output 50% (12.5 A) to 100% (25 A), 250 Hz transitions (Buck)

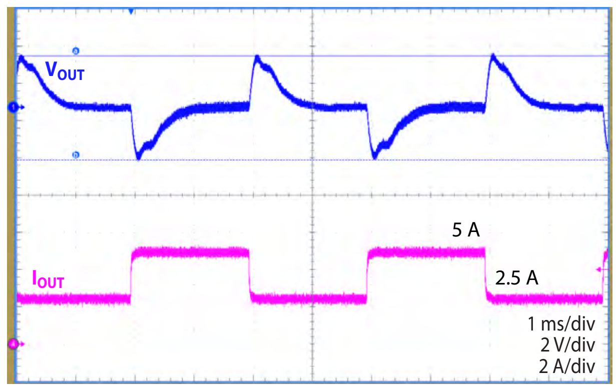


Figure 6: V_{IN} = 12 V, V_{OUT} = 48 V, output 45% (2.5 A) to 90% (5 A), 250 Hz transitions (Boost)

Startup waveform

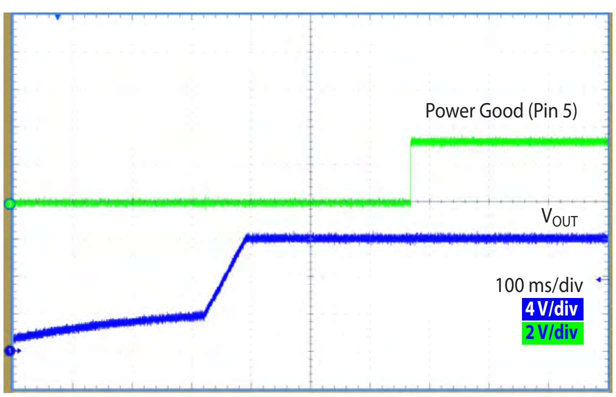


Figure 7: V_{IN} = 48 V (Buck)

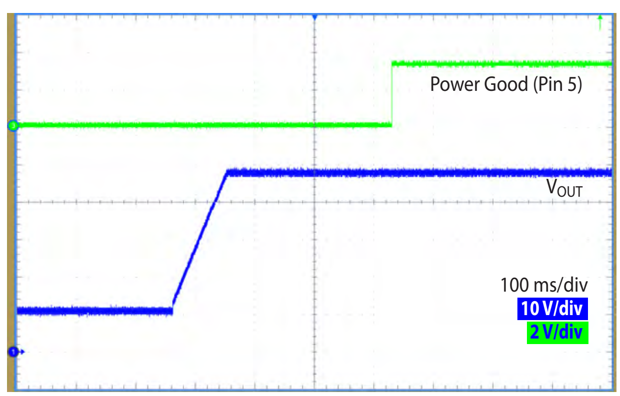


Figure 8: V_{IN} = 12 V (Boost)

ELECTRICAL PERFORMANCE *(continued)*

Typical load regulation

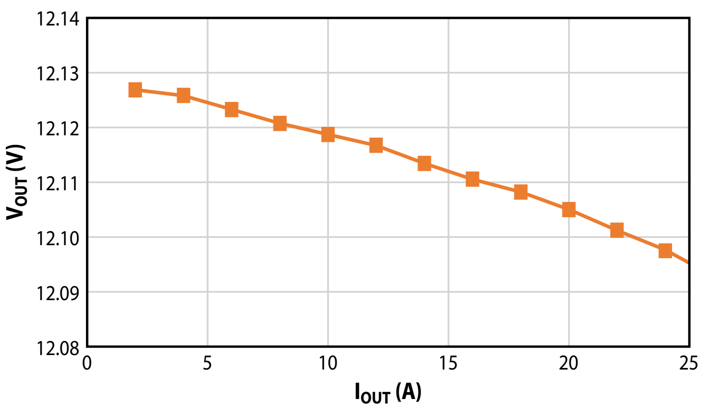


Figure 9: V_{IN} = 48 V, V_{OUT} = 12 V (Buck)

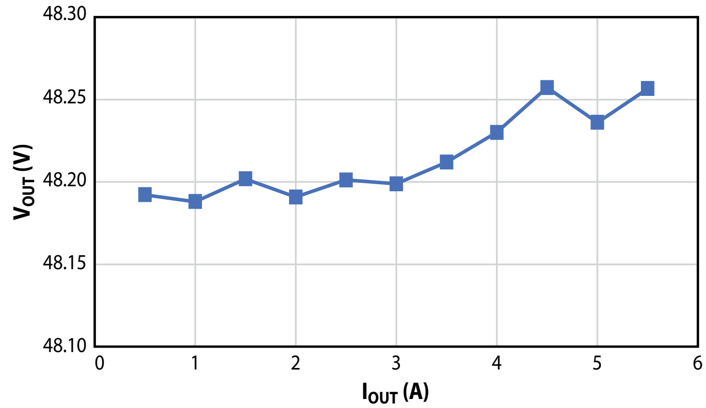


Figure 10: V_{IN} = 12 V, V_{OUT} = 48 V (Boost)

Temperature vs. output current

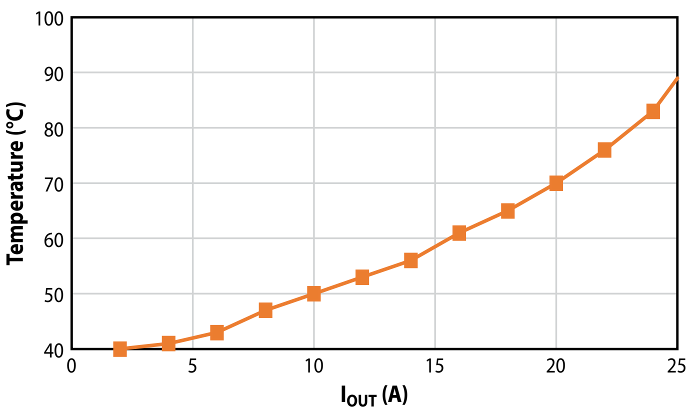


Figure 11: V_{IN} = 48 V, V_{OUT} = 12 V, 1700 LFM, Buck

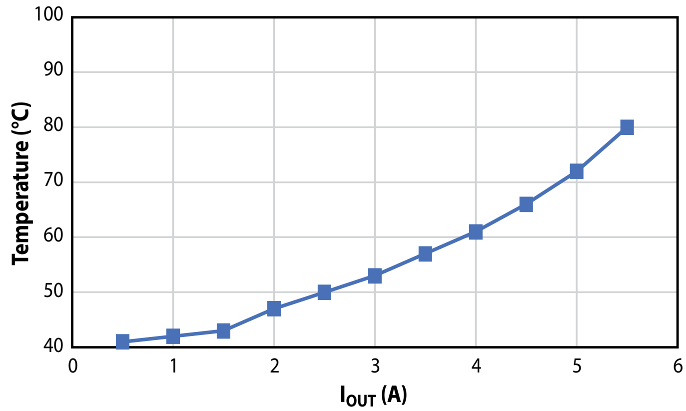


Figure 12: V_{IN} = 12 V, V_{OUT} = 48 V, 1700 LFM, Boost

OPERATING CONSIDERATIONS

Buck/Boost Modes

The module is programmed with Buck mode by default. To operate as a Boost converter, please download the firmware for Boost mode and re-program the module. In Boost mode, input voltage (12 V) is supplied to the Vout+ pin, and the output is at the Vin+ pin.

Output capacitance

Minimum external output capacitance of 200 µF is required for stability. The maximum capacitance tested is 550 µF. The EPC9531 test fixture includes this extra capacitance.

Input capacitance

To minimize the impact from the input voltage feeding line, low-ESR capacitors should be located at the input to the module. It is recommended that a 33 µF–100 µF input capacitor be placed near the module. This will also be the external output capacitance in boost mode.

Over-current protection

If the load current exceeds a pre-determined maximum setpoint, this condition will be regarded as a fault condition and the module will shut down. The module will then attempt to restart after 2 seconds. This shut down and restart cycle will continue until the over-current condition clears.

Remote On/Off

This feature is not implemented for this module. Please leave EN pin floating.

Remote sense

For Buck mode only: remote sense can compensate for output voltage distribution drops by sensing the actual output voltage at the point of load. The maximum voltage allowed between the output and sense pins is 5% of the output voltage (0.6 V for 12 V output). If the remote sense feature is not used, the pin can be either left floating or connected to Vout+.

Power good

This module features a power good signal with 3.3 V logic. This signal will be logic high when the output voltage is regulated to +/- 10% of the set point; and logic low for all other conditions. The maximum sink/source current on this pin is 6 mA. If the power good feature is not used, the pin should be left floating.

Output voltage trim (adjustment)

For Buck mode only: the output voltage of this module can be trimmed (adjusted) by connecting an external resistor between the Trim pin and Vout- (GND) pin. The new output voltage can be calculated as follows:

$$V_{OUT} = V_{FB} R_{FB1} \left(\frac{1}{R_{FB2}} + \frac{1}{R_1} \right) + V_{FB}$$

For this design, V_{FB} is 2.5 V, R_{FB1} is 18 kΩ, R_{FB2} is 4.75 kΩ, therefore

$$V_{OUT} = 12 + \frac{45}{R_1\ [k\Omega]}$$

The maximum trim voltage is 1 V using this method. It is recommended to re-program the controller to further change the output voltage set point.

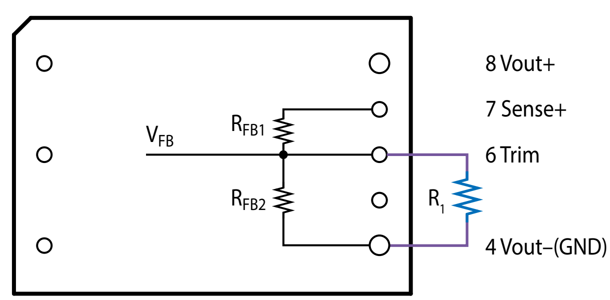


Figure 13. External resistor connection for output voltage trim adjust.

CONTROLLER

The EPC9151 $^{1}/_{16}$th brick evaluation power module features a Microchip dsPIC33CK32MP102 Digital Signal Controller (DSC). This 100 MHz single core device is equipped with dedicated peripheral modules for Switched-Mode Power Supply (SMPS) applications, such as a feature-rich 4-channel (8x output), 250 ps resolution pulse-width modulation (PWM) logic, three 3.5 Msps Analog-To-Digital Converters (ADC), three 15 ns propagation delay analog comparators with integrated Digital-To-Analog Converters (DAC) supporting ramp signal generation, three operational amplifiers as well as Digital Signal Processing (DSP) core with tightly coupled data paths for high-performance real-time control applications. The device used is the smallest derivative of the dsPIC33CK single core and dsPIC33CH dual core DSC families. The device used in this design comes in a 28 pin 6x6 mm UQFN package, specified for ambient temperatures from -40 to +125° C. Other packages including a 28 pin UQFN package with only 4x4 mm are available.

The dsPIC33CK device is used to drive and control the converter in a fully digital fashion where the feedback loops are implemented and executed in software. Migrating control loop execution from analog circuits to embedded software enhances the flexibility in terms of applied control laws as well as making modifications to the feedback loop and control signals during runtime, optimizing control schemes and adapting control accuracy and performance to most recent operating conditions. As a result, digital control allows users to tailor the behavior of the converter to application specific requirements without the need for modifying hardware.

There are two firmware versions available for the EPC9151 $^{1}/_{16}$th brick evaluation power module in buck mode: average current mode control (ACMC) and adaptive voltage mode control (AVMC). For the boost mode, only ACMC is available.

- **Conventional, Robust Average Current Mode Control (ACMC) (*figure 14*):** 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.

For Buck mode only:

- **Adaptive Type IV Voltage Mode Control (AVMC) with featuring Adaptive Gain Control (AGC) and Phase Current Balancing PWM Steering (*figure 15*):** The second, alternative firmware is tailored to intermediate bus converter module applications in power distribution networks (PDN). The major focus of this firmware lies on reducing PDN segment decoupling capacitance by maximizing the control bandwidth and the output impedance tuning capabilities, enhancing system robustness while minimizing cost.

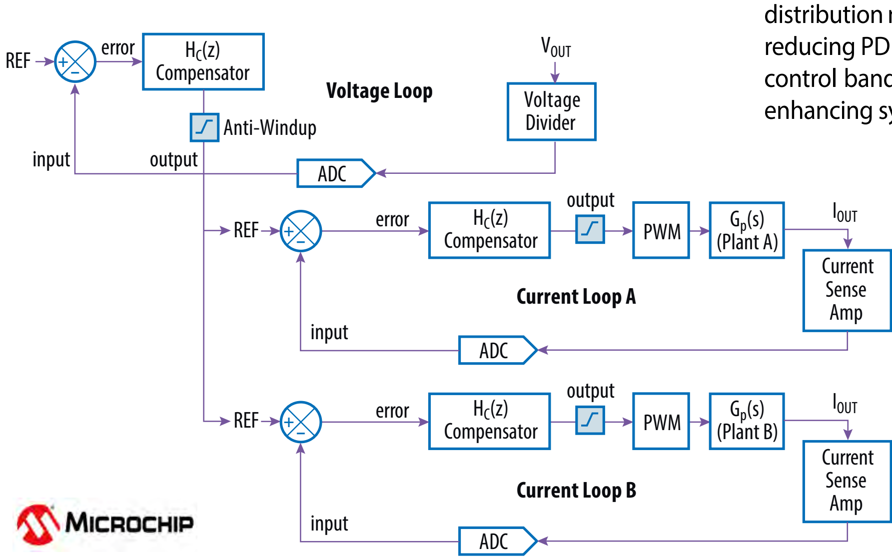


Figure 14. Interleaved buck converter average current mode control

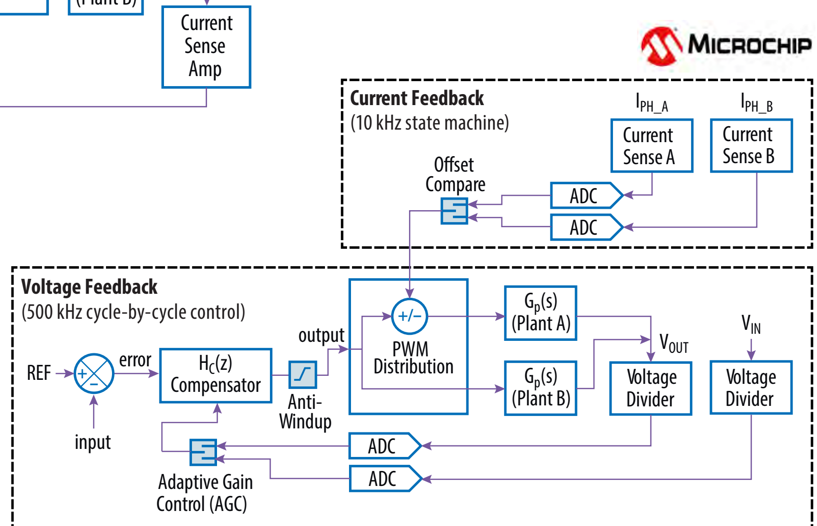


Figure 15. Interleaved buck converter advanced voltage mode control

PROGRAMMING

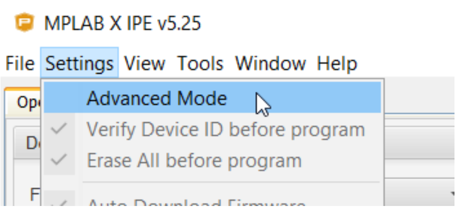
The Microchip dsPIC33CK controller can be re-programmed using the in-circuit serial programming port (ICSP) available on the RJ-11 programming interface. It supports all of Microchip's in-circuit programmers/debuggers, such as MPLAB® ICD4, MPLAB® REAL ICE or MPLAB® PICkit4 and previous derivatives.

Development tools: https://www.microchip.com/development-tools

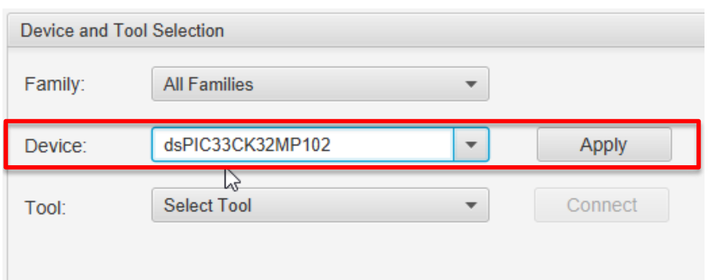
Programming with HEX file

Download the latest MPLAB IPE from Microchip website and follow the steps below:
https://www.microchip.com/mplab/mplab-integrated-programming-environment

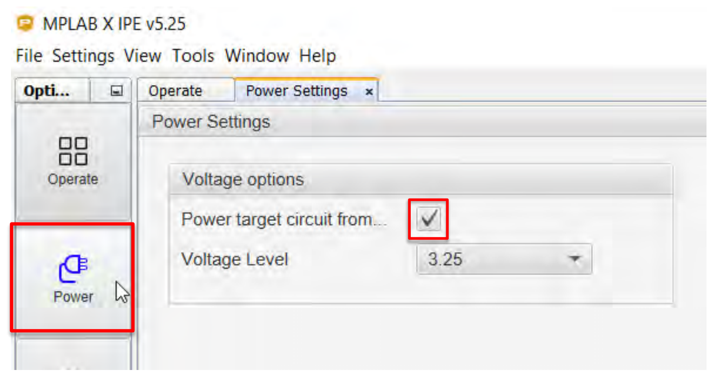
1 Enable Advanced Mode:



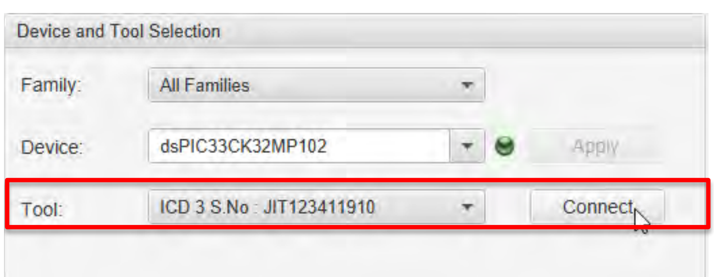
2 Select Device: dsPIC33CK32MP102 and then apply:



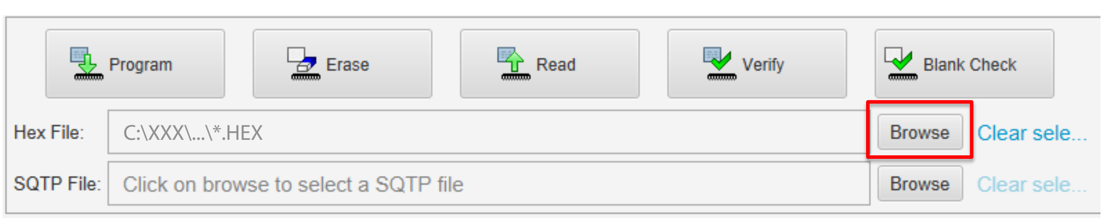
Optional: Enable 'Power target circuit from programming tool' from left panel 'power' tab so that no additional power supply is necessary during programming:



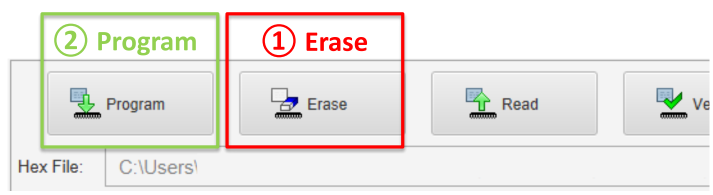
3 Select programming tool and then connect:



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



5 Erase device, and then program device:



MECHNICAL SPECIFICATIONS

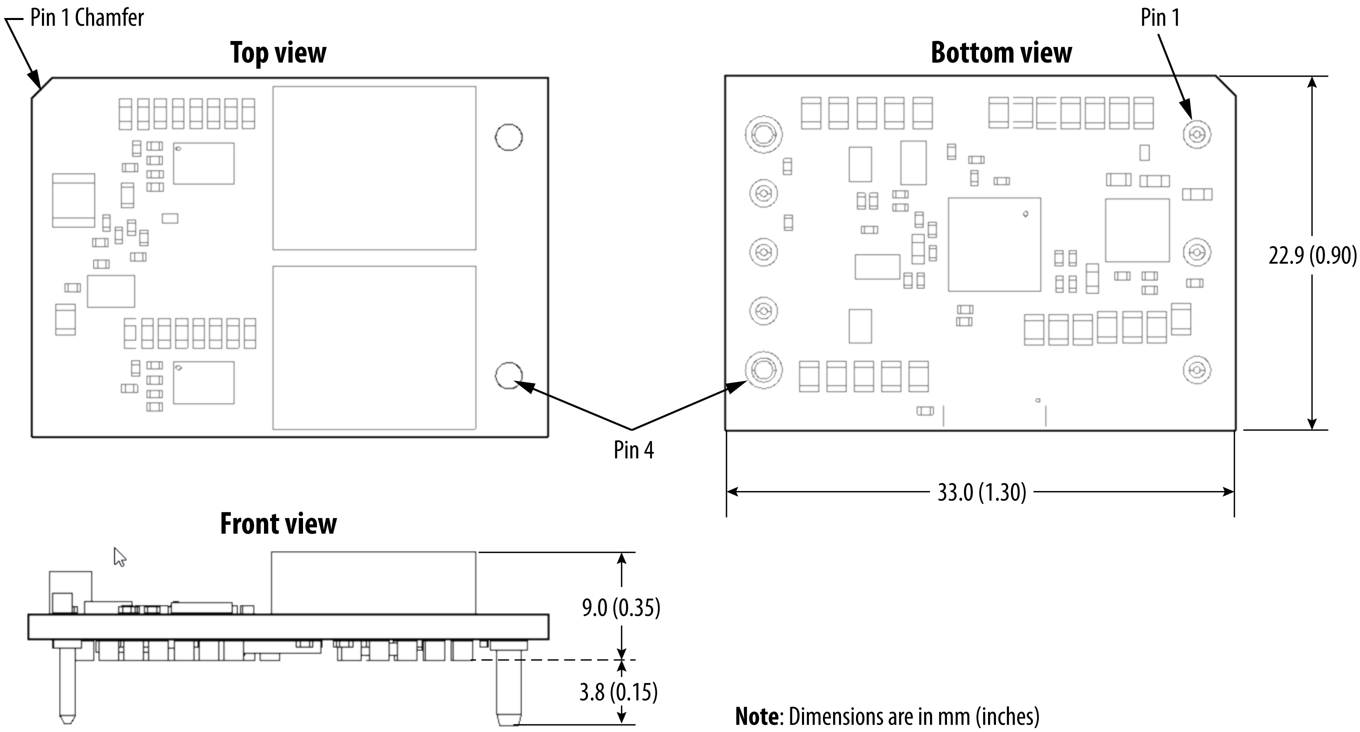


Figure 16. EPC9151 mechanical dimensions

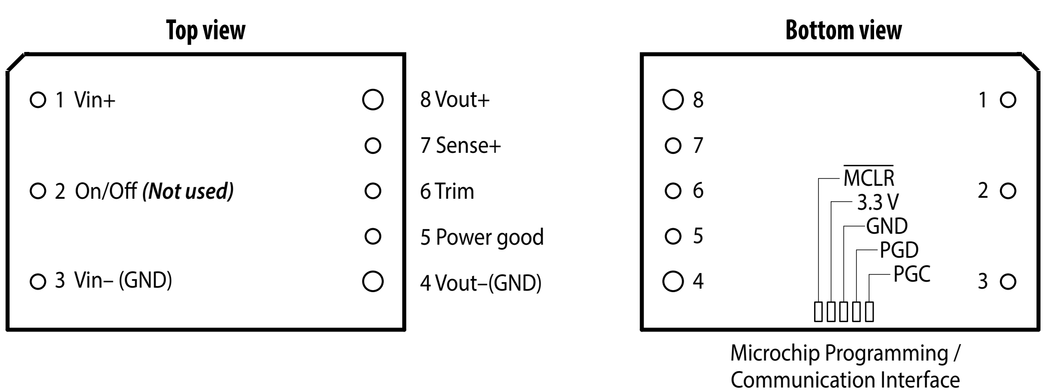


Figure 17. Pin assignment

THERMAL MANAGEMENT

Thermal management is very important to ensure proper and reliable operation. Sufficient cooling is required for this module to operate in the full specified output current range. Forced air of 1700 LFM is used for specification testing.

Heatsink or heat spreader can also be used.

The hot spots are the GaN ICs (U1 and U2) as shown in figure 18.

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.

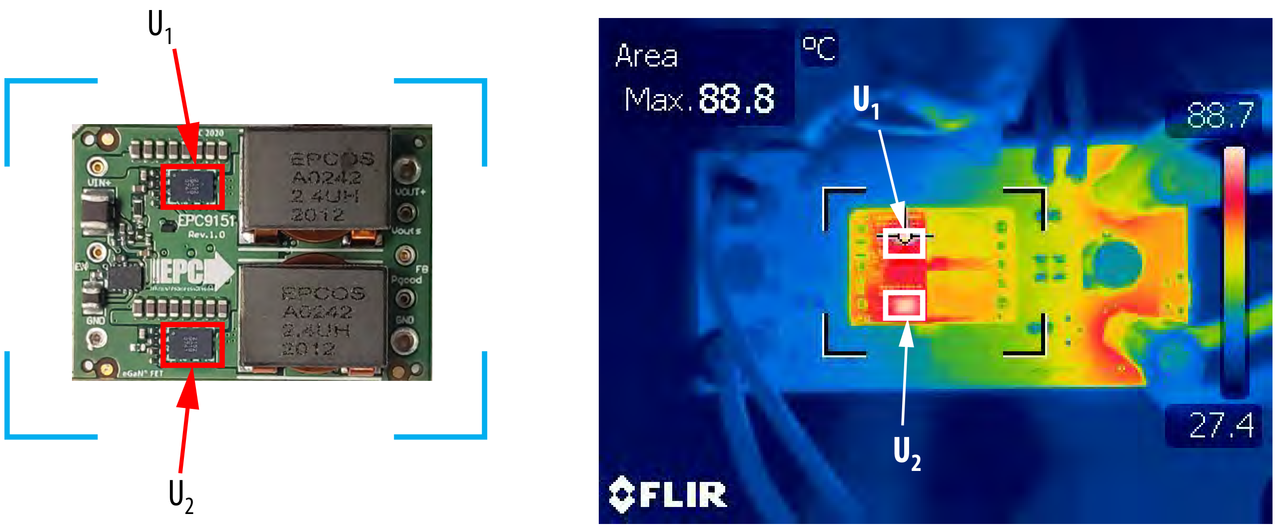


Figure 18. V_{IN} = 48 V, V_{OUT} = 12 V, 1700 LFM forced air cooling

For support files including schematic, Bill of Materials (BOM), and gerber files please visit the EPC9151 landing page at: https://epc-co.com/epc/products/demo-boards/epc9151

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

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The EPC9151 system features the **dsPIC33CK32MP102** 16-Bit Digital Signal Controller with High-Speed ADC, Op Amps, Comparators and High-Resolution PWM. Learn more at **www.microchip.com**.

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