Demonstration System EPC9143 Quick Start Guide

18–60 V Input, 12 V, 25 A Output

300 W 1/16 th Brick Evaluation Module

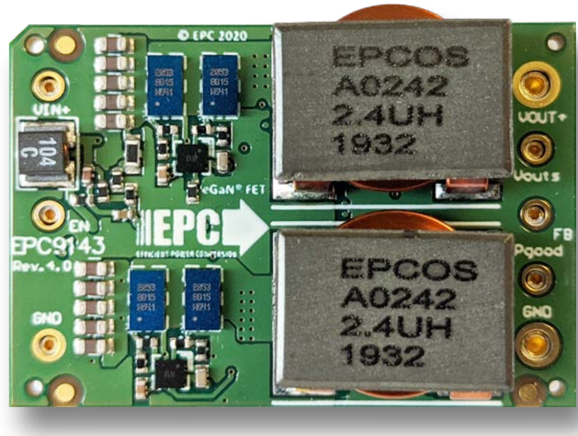
Revision 4.0

EFFICIENT POWER CONVERSION

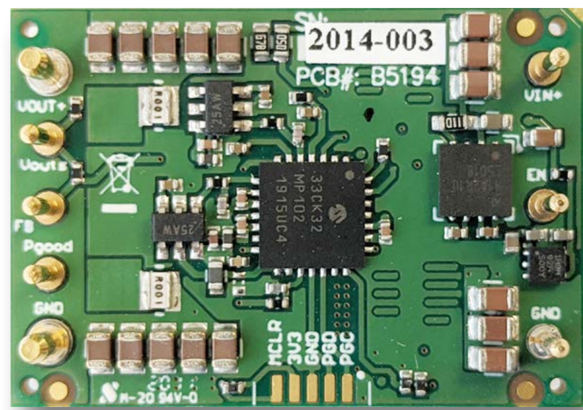
DESCRIPTION

The EPC9143 $^{1}/_{16}$th brick evaluation power module is designed for 48 V to 12 V DC-DC applications. It features the EPC2053 eGaN® FETGaN, and enhancement mode field effect transistors, as well as the Microchip dsPIC33CK32MP102 16-bit digital controller. Other features include:

- High efficiency: 95% @ 12 V/25 A output
- 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
- Positive logic on/off
- Power good output
- Constant switching frequency: 500 kHz
- Remote output voltage sense
- Re-program – Advanced voltage mode control (default)
- Fault protection:
  - o Input undervoltage
  - o Input overvoltage
  - o Regulation error



EPC9143 top view



EPC9143 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

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			65	V
I_{OUT}	Output current	With sufficient cooling		25	A
T_C	Operating temperature	Measured at FET case as indicated in thermal measurement figure, airflow 800 LFM		100	°C

Table 2: Electrical Characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Units
V_{IN}	Input voltage		18	48	60	V
$V_{IN,on}$	Input UVLO turn on voltage			18		V
$V_{IN,off}$	Input UVLO turn off voltage			17.5		V
V_{OUT}	Output voltage		5	12	15	V
C_{OUT}	External capacitance load	The output voltage is set in the controller	200		550	µF
$t_{OUT,rise}$	Output voltage rise time			100		ms
ΔV_{OUT}	Output voltage ripple	I_{OUT} = 25 A, mounted in EPC9531 test fixture		100		mV
I_{OUT}	Output current	With sufficient cooling	0		25	A
$I_{OUT,limit}$	Output current limit threshold		26		27	A
f_s	Switching frequency			500		kHz
On/off control input logic						
V_{off}	Logic low (Module Off)				1	V
V_{on}	Logic high (Module On)		1.3		10	V
I_{off}	Current sink for disable				1	mA
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	V
IP_{good}	Sink current capability of P_{good}				20	mA
IP_{good}	Source current capability of P_{good}				20	mA

ELECTRICAL PERFORMANCE

Typical efficiency and power loss

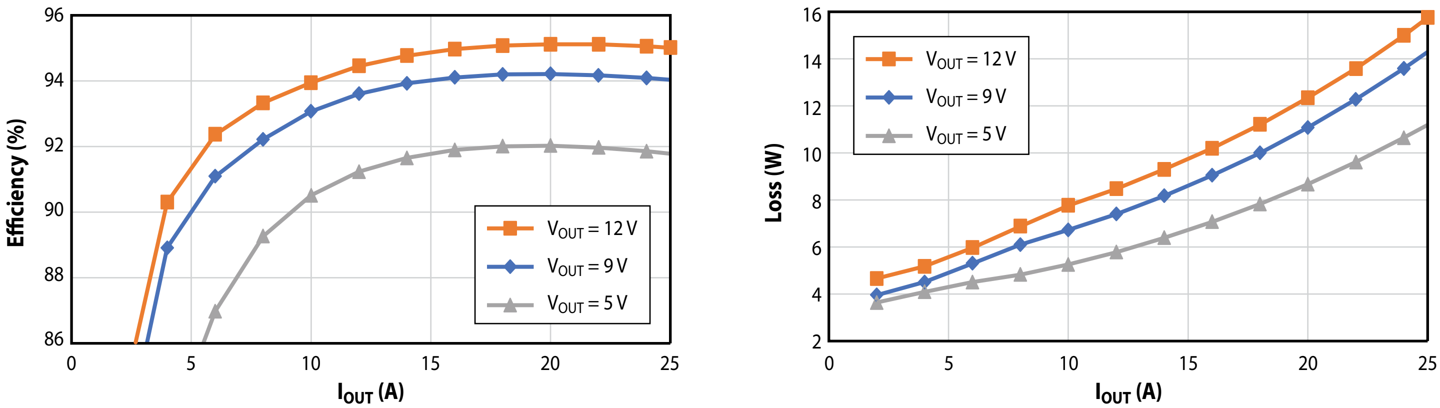


Figure 1: 48 V input, various output voltages

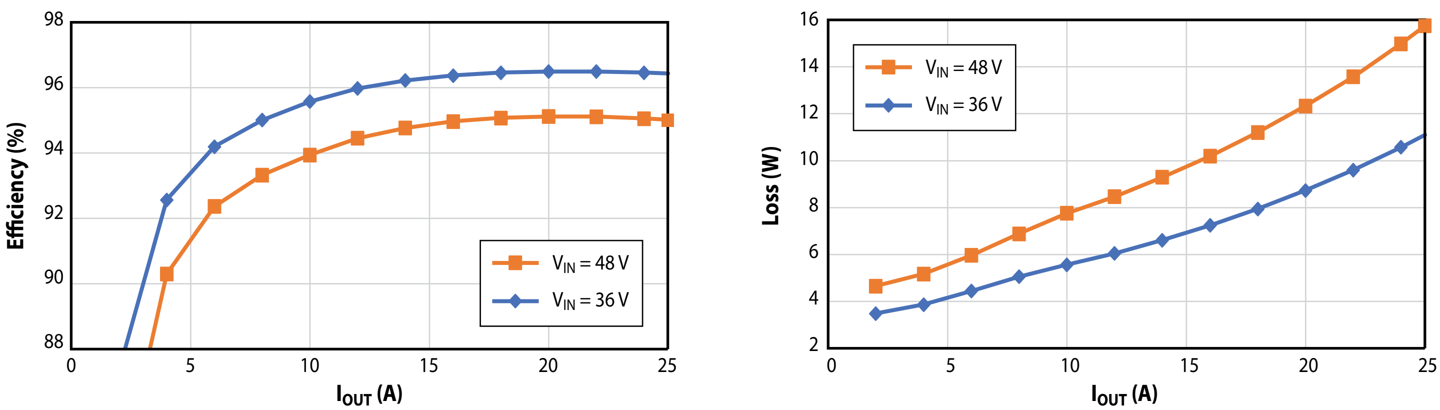


Figure 2: 12 V output, various input voltages

Typical output voltage ripple

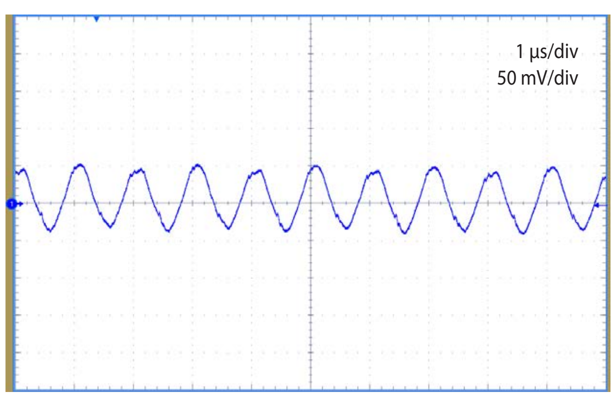


Figure 3: V_{IN} = 48 V, V_{OUT} = 12 V, I_{OUT} = 25 A

Typical transient response

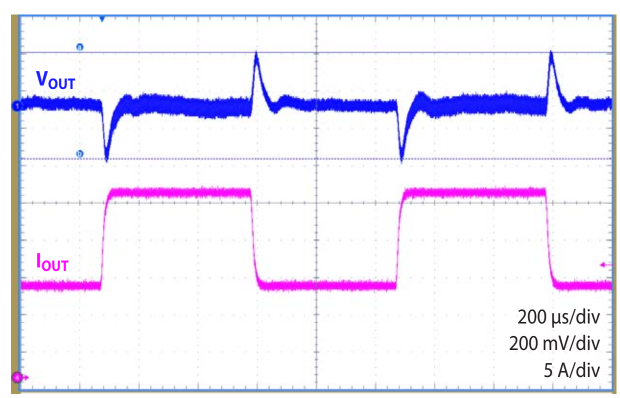


Figure 4: V_{IN} = 48 V, V_{OUT} = 12 V, 50% (12.5 A) to 100% (25 A) at 1 kHz repetition rate output current transitions

ELECTRICAL PERFORMANCE *(continued)*

Startup

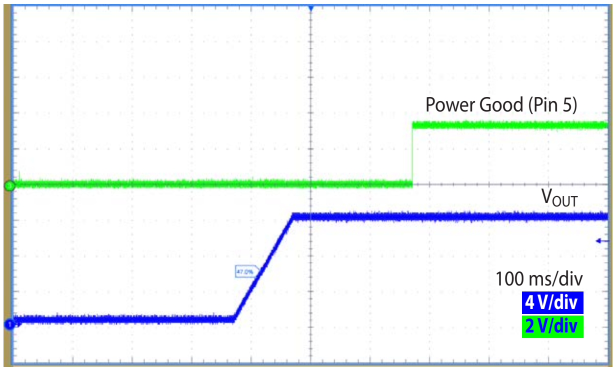


Figure 5: Start-up with EN pin floating

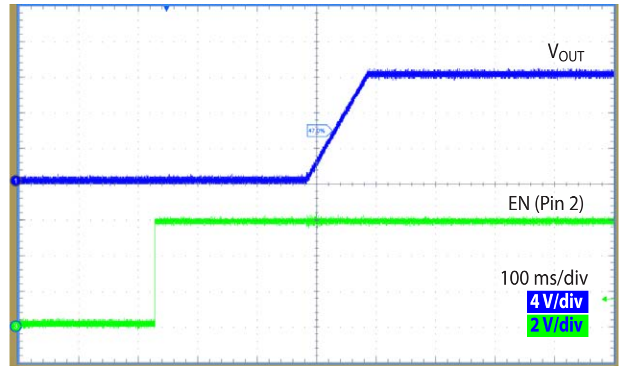


Figure 6: EN pin controlled turn on

Typical load regulation

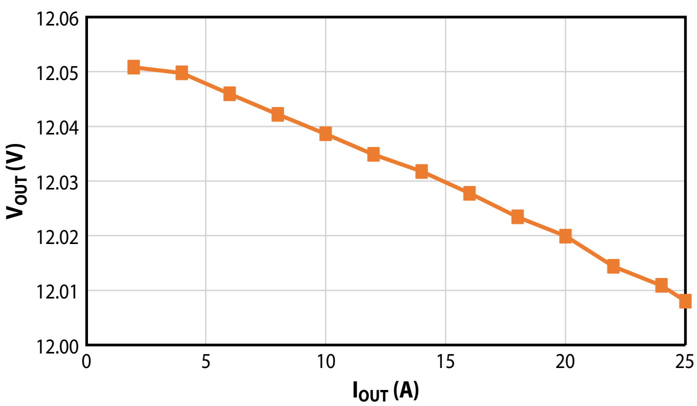


Figure 7: V_{IN} = 48 V, V_{OUT} = 12 V

Temperature vs. output current

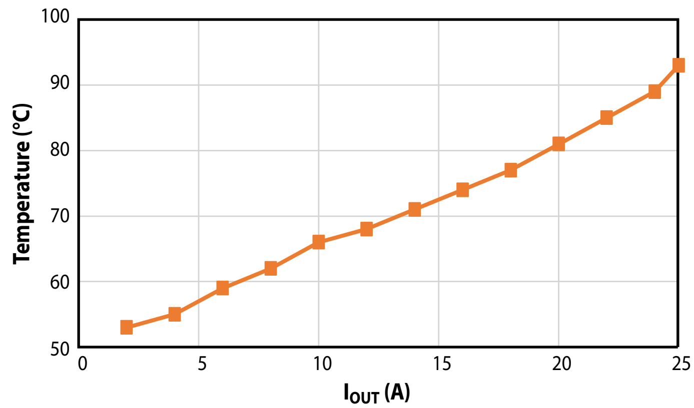


Figure 8: V_{IN} = 48 V, V_{OUT} = 12 V, 800 LFM forced air cooling

Typical waveform

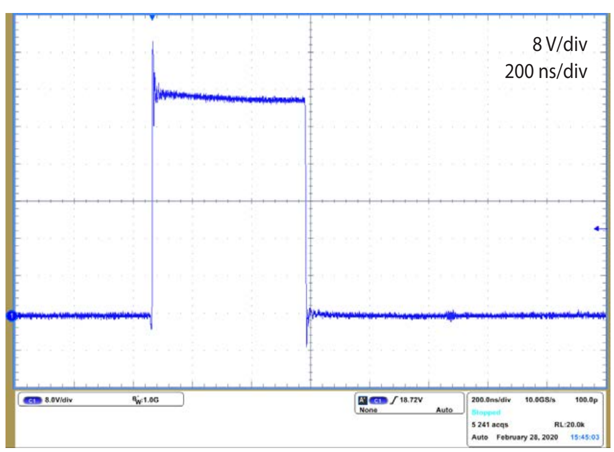


Figure 9: Measured switch-node voltage for one phase at V_{IN} = 48 V, V_{OUT} = 12 V, I_{OUT} = 25 A

OPERATING CONSIDERATIONS

Output capacitance

Minimum external output capacitance of 200 µF is required for stability. The maximum capacitance tested is 550 µF. Values higher than 550 µF will reduce the control bandwidth to below 15 kHz. The EPC9531 test fixture includes this extra capacitance and is recommended for testing.

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.

Over-current protection

This module supports two different control schemes that are discussed in more detail in the control section. The operating schemes are (1) conventional average current mode control (ACMC), and (2) advanced voltage mode control (AVMC), where over-current protection is implemented differently in each operating mode.

With ACMC operation and if the load current exceeds a pre-determined maximum setpoint, the module will operate in constant current mode where the output voltage will no longer be regulated. The module can operate indefinitely in this mode and once the load current falls below the maximum setpoint, then the module will revert back voltage regulation.

With AVMC operation and 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 module has positive on/off logic: the module is turned on during a logic high and off during a logic low.

Remote on/off can be controlled by an external switch between the on/off pin and the Vin- (GND) pin as shown in figure 10.

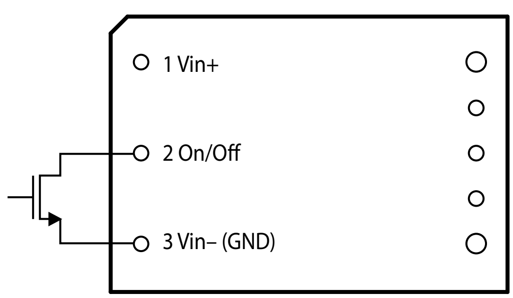


Figure 10. Adding an external MOSFET for remote enable/disable

The switch can be an open collector or open drain. If the remote on/off feature is not used, leave the on/off pin floating.

Remote output voltage sense

Remote sense can compensate for output voltage distribution drop 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 setpoint, and logic low for all other conditions. The maximum sink/source current capability for this input is given in table 2. If the power good feature is not used, the pin should be left floating. During startup, the power good signal is set 200 ms after the output voltage has reached and maintained the nominal regulation set-point. This signal is reset instantly when a fault condition has been detected.

Output voltage trim (adjustment)

The output voltage of this module can be trimmed (adjusted) by connecting an external resistor between the Trim pin and Vout- (GND) pin as shown in figure 11.

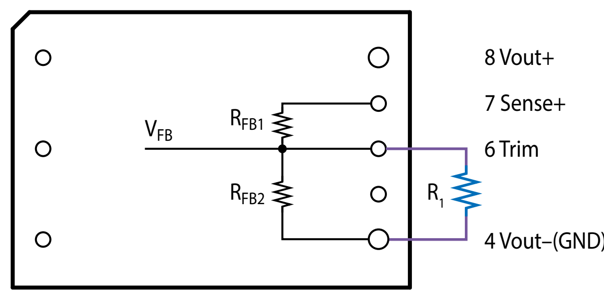


Figure 11. External resistor connection for output voltage trim adjust.

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. The programmable output voltage range is between 3.3 V and 15 V DC.

QUICK START PROCEDURE

The EPC9143 $^{1}/_{16}$th brick module is best tested plugged into EPC9531 test fixture. The EPC9531 QSG provides detailed operating procedure instructions. See **EPC9531 QSG**.

CONTROLLER

The EPC9143 $^{1}/_{16}$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 EPC9143 $^{1}/_{16}$th brick evaluation power module:

- **Conventional, Robust Average Current Mode Control (ACMC) (*figure 12*):** 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.
- **Adaptive Type IV Voltage Mode Control (AVMC) with featuring Adaptive Gain Control (AGC) and Phase Current Balancing PWM Steering (*figure 13*):** 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.

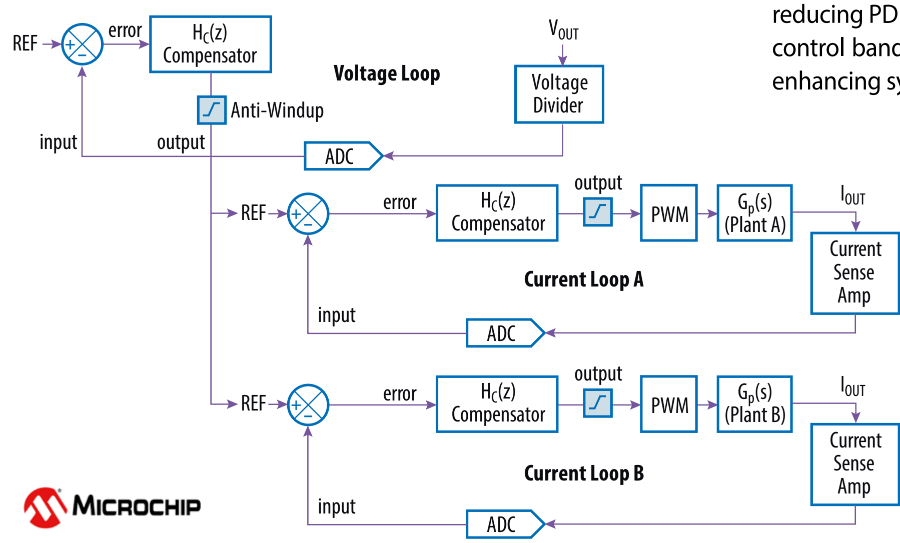


Figure 12. Interleaved buck converter average current mode control

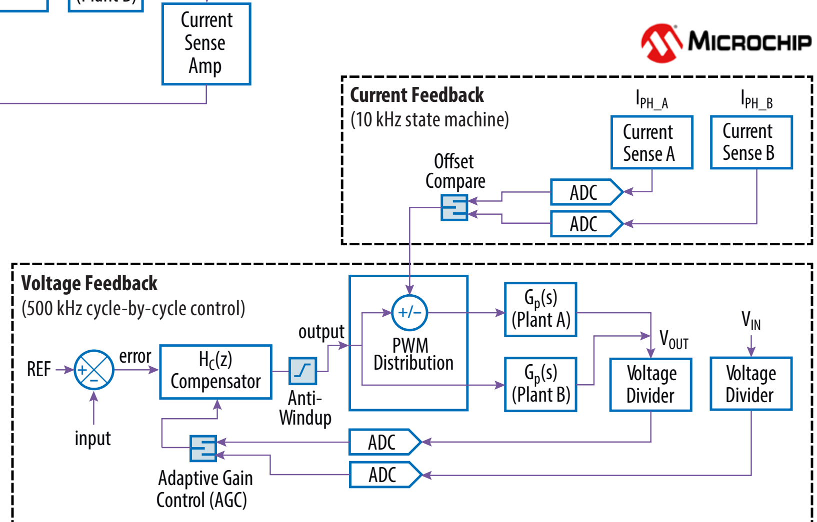


Figure 13. Interleaved buck converter advanced voltage mode control

PROGRAMMING

The Microchip dsPIC33CK controller can be re-programmed using the in-circuit serial programming port (ICSP) available on the RJ-11 programming interface as well as the 5-pin header provided by the EPC9531 test fixture. These interfaces support all of Microchip's in-circuit programmers/debuggers, such as MPLAB® ICD4, MPLAB® REAL ICE or MPLAB® PICkit4 and previous derivatives. See **EPC9531 QSG**.

MECHNICAL SPECIFICATIONS

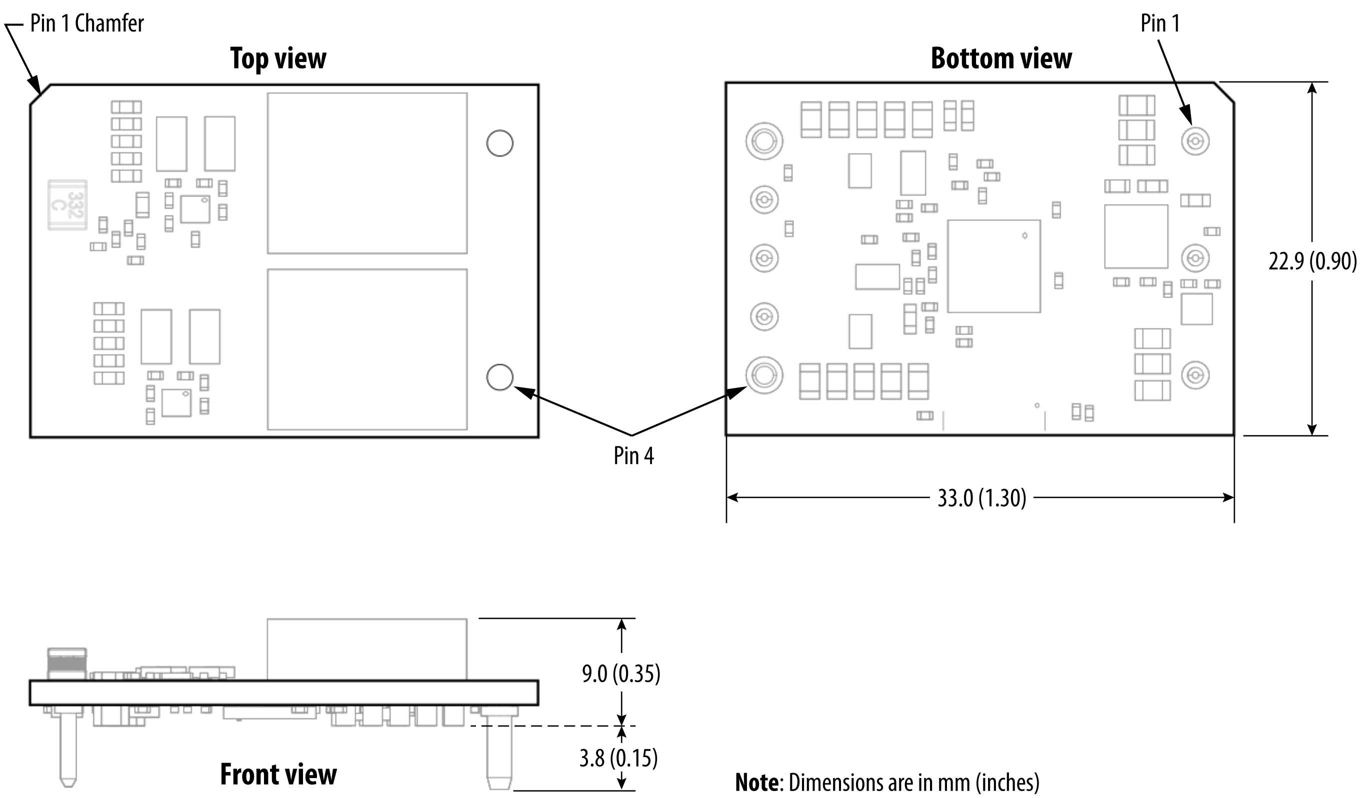


Figure 14. EPC9143 mechanical dimensions

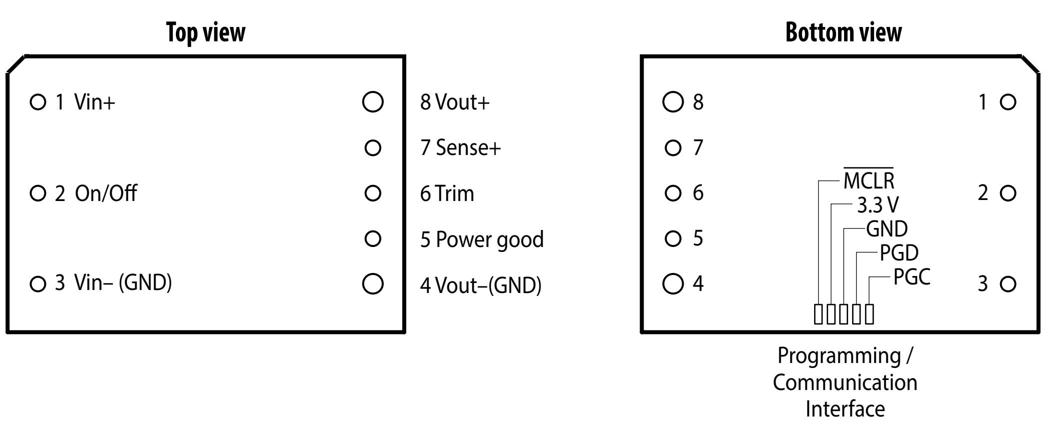


Figure 15: Pin assignment

THERMAL MANAGEMENT

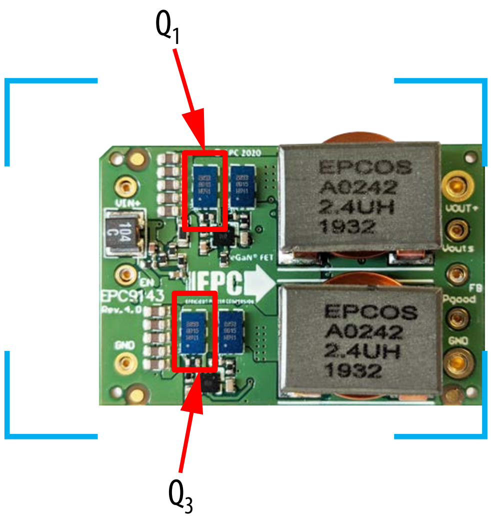
Thermal management is very important to ensure proper and reliable operation. Sufficient cooling is required for this module to operate in the full specified output current range. Forced air of 800 LFM is used for specification testing.

Heatsink or heat spreader can also be used.

The hot spots are the control FETs of the buck converter (Q1 and Q3) as shown in figure 16:

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.



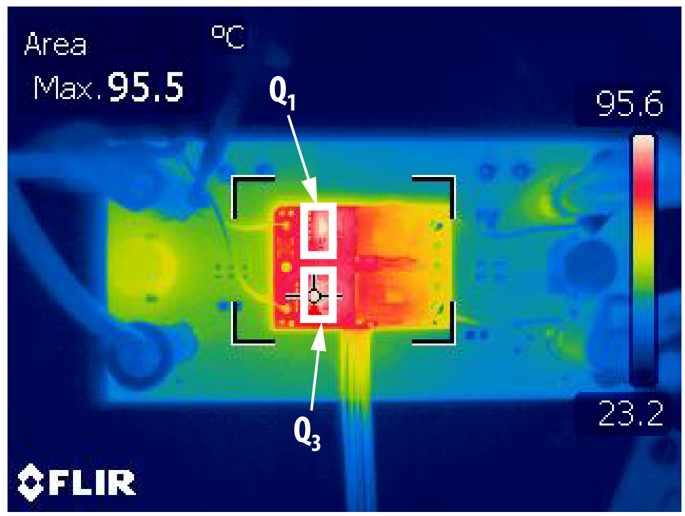


Figure 16. V_{IN} *= 48 V,* V_{OUT} *= 12 V, 800 LFM forced air cooling*

Table 3: Bill of Materials

Item	Qty	Reference	Part Description	Manufacturer	Part #
1	6	C1, C2, C3, C19, C21, C35	Capacitor, 1 µF, 20%, 100 V, X7S, 0805	TDK	C2012X7S2A105M125AB
2	10	C5, C6, C7, C8, C10, C27, C28, C29, C30, C37	Capacitor, 22 µF, 25 V, 0805	Murata	GRT21BR61E226ME13L
3	7	C14, C22, C38, C49, C50, C62, C65	Capacitor, 0.1 µF ±10% 25 V, X7R, 0402	Yageo	CC0402KRX7R8BB104
4	2	C15, C32	Capacitor, 4.7 µF, 10 V, X5R, 0402	TDK	C1005X5R1A475K050BC
5	10	C20, C23, C40, C41, C42, C43, C44, C45, C46, C47	Capacitor, 0.22 µF, 100 V, X7S, 0603	Taiyo Yuden	HMK107C7224
6	1	C33	Capacitor, 10 nF, 5%, 25 V X7R, 0402	Kemet	C0402C103J3REC
7	1	C34	Capacitor, 1000 pF, 25 V, C0G/NP0 0402	Murata	GRM1555C1E102JA01D
8	1	C39	Capacitor, 10 nF, 10%, 16 V, X7R , 0402	Kemet	C0402C103K4RECAUTO
9	2	C60, C63	Capacitor, 560 pF, 50 V, C0G/NP0, 0402	Murata	GRM1555C1H561JA01D
10	2	C61, C64	Capacitor, 2.2 µF, 25 V	Murata	GRM155R61E225ME15D
11	4	C67, C69, C92, C95	Capactior, 10000 pF, 50 V, X7R, 0402	Murata	GRM155R71H103KA88D
12	1	C68	Capacitor, 220 pF, 10%, 50 V, X7R, 0402	Kemet	C0402C221K5RACTU
13	1	C90	Capacitor, 0.1 µF, 100 V, X7S, 0603	TDK	CGA3E3X7S2A104K080AB
14	1	C91	Capacitor, 1 µF, 16 V, X6S, 0402	TDK	C1005X6S1C105K050BC
15	1	C93	Capacitor, 10 µF, ±10%, 16 V, X5R, 0603	Murata	GRM188R61C106KAALD
16	1	C94	Capacitor, 3300 pF, 100 V, X7S, 0402	TDK	CGA2B3X7S2A332M050BB
17	2	C96, C98	Capacitor, 1 µF, 25 V, X5R, 0402	Murata	GRT155R61E105ME01D
18	1	C97	Capacitor, 22 µF, 6.3 V, X5R, 0402	Samsung	CL05A226MQ5N6J8
19	4	Q1, Q2, Q3, Q4	eGaN® FET, 100 V, 3.8 mΩ	EPC	EPC2053
20	2	R1, R63	Resistor, 10 kΩ, ±5%, 0.063 W, 1/16 W, 0402	Yageo	RC0402JR-0710KL
21	4	R7, R9, R13, R15	Resistor, 1 Ω ±1%, 0.063 W, 1/16 W, 0402	Yageo	RC0402FR-071RL
22	4	R8, R10, R14, R16	Resistor, 0.5 Ω 1% ,1/8 W, 0402	Yageo	PT0402FR-7W0R5L
23	3	R20, R64, R65	Resistor, 20 Ω 1%, 1/16 W, 0402	Yageo	RC0402FR-0720RL
24	1	R21	Resistor, 110 kΩ, 1%, 1/10 W, 0603	Panasonic	RC0603FR-07110KL
25	1	R22	Resistor, 4.87 kΩ 1%, 1/10 W, 0603	Panasonic	RC0603FR-074K87L
26	1	R23	Resistor, 18 kΩ 0.1%, 1/16 W, 0402	Panasonic	ERA-2AEB183X
27	1	R24	Resistor, 4.75 kΩ 0.1%, 1/16 W, 0402	Panasonic	ERA-2AEB4751X
28	1	R26	Ferrite Bead, 180 Ω, 0603, 1LN	Murata	BLM18PG181SN1D
29	4	R32, R33, R34, R35	Resistor, 22 kΩ 5%, 1/16 W, 0402	Yageo	RC0402JR-0722KL
30	2	R61, R62	Resistor, 1 mΩ ±5%, 1 W, 0805	Susumu	KRL2012E-M-R001-J-T5
31	1	R90	Resistor, 127 kΩ 1%, 1/10 W, 0603	Yageo	RC0603FR-07127KL
32	1	R91	Resistor, 3.65 kΩ 1%, 1/16 W, 0402	Yageo	RC0402FR-073K65L
33	1	R92	Resistor, 11.3 kΩ 1%, 1/16 W, 0402	Yageo	RC0402FR-0711K3L
34	1	R94	Resistor, 68 kΩ 5%, 1/16 W, 0402	Yageo	RC0402JR-0768KL
35	1	R95	Resistor, 0 Ω JUMPER, 1/16 W, 040	Yageo	RC0402JR-070RL
36	1	R98	Resistor, 16.5 kΩ 1%, 1/16 W, 0402	Yageo	RC0402FR-0716K5L
37	1	R99	Resistor, 86.6 kΩ 1%, 1/10 W, 0603	Yageo	RC0603FR-0786K6L
38	6	J1, J2, TP1, TP2, TP9, TP10	PC PIN .040 DIA 3102-1 SERIES	Mill-Max	3102-1-00-21-00-00-08-0
39	2	J4, J5	CONN PC PIN CIRC 0.062DIA GOLD	Mill-Max	3144-1-00-15-00-00-08-0
40	2	L1, L2	Inductor, 2.4 µH, 16.5A, 2.76 mΩ	TDK	B82559A0242A013
41	1	L90	Inductor, 100 µH, 160 MA, 3.5 Ω	Murata	82104C
42	2	U2, U5	UPI, UP1966A, USMD, BGA	uPI	uP1966A
43	1	U20	IC, Conroller, 16 BIT DSC SINGLE CORE 32 K FLASH	Microchip	DSPIC33CK32MP102-E/2N
44	2	U61, U62	IC, Current Sense Amplifier, 1 CIRCUIT SOT23-6	Microchip	MCP6C02T-050E/CHY
45	1	U90	IC, REG BUCK ADJ, 300 MA, 8LLP	Texas Instruments	LM5018SD/NOPB
46	1	U91	IC, LDO, 500 mA	TI	TLV75533PDRVR

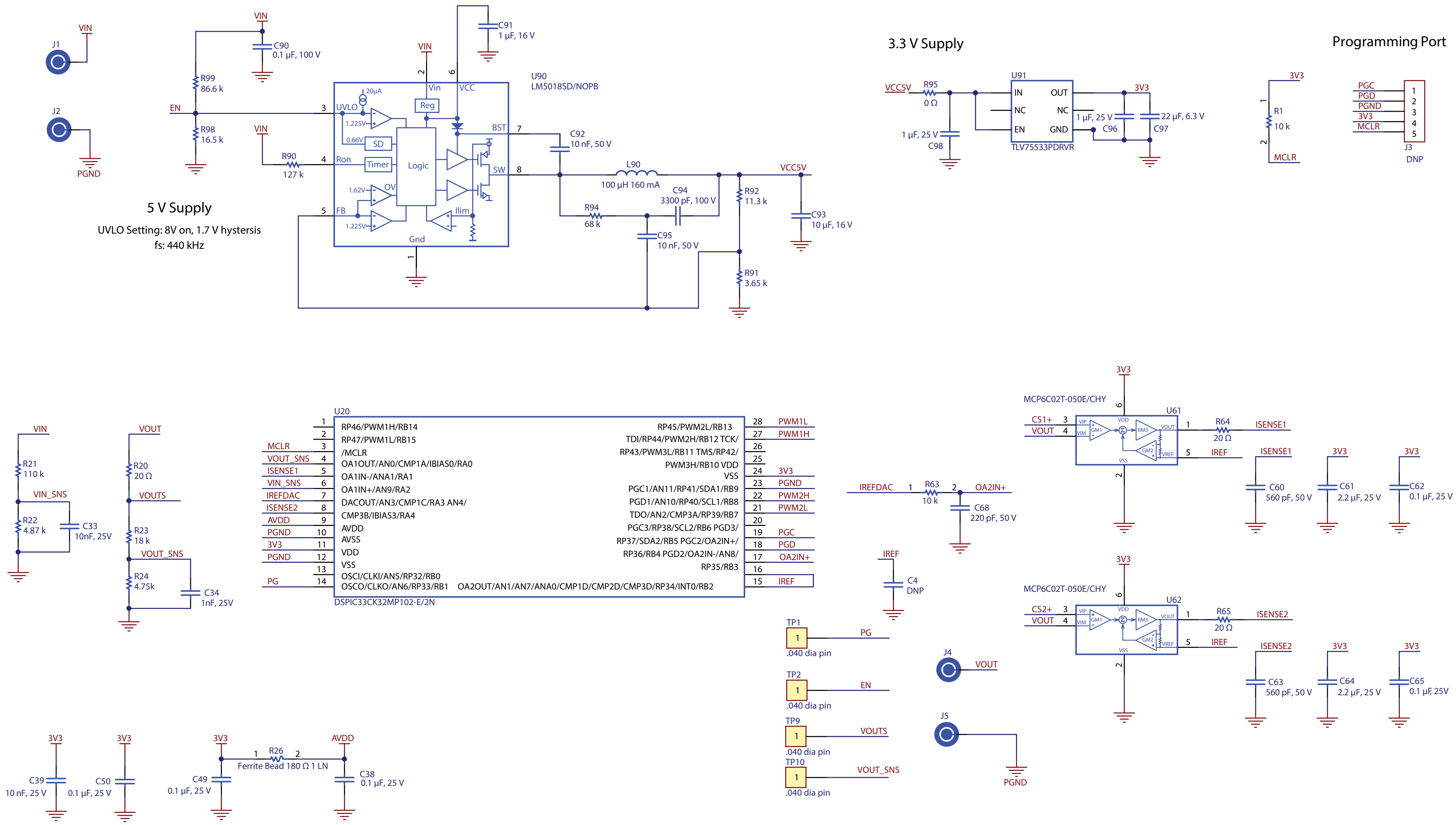


Figure 17: EPC9143 Controller schematic

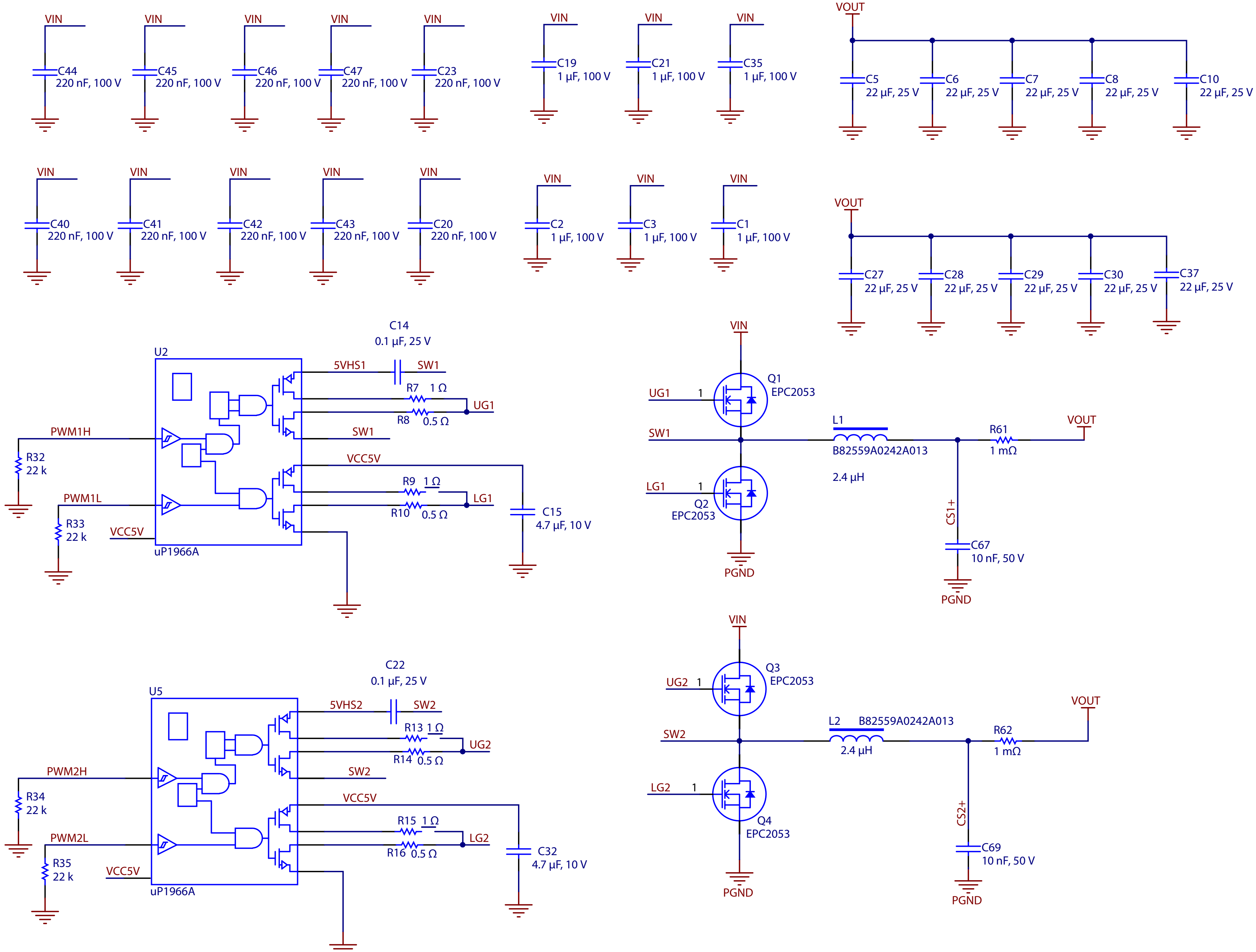


Figure 18: EPC9143 Power Stage schematic

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

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The EPC9143 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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EFFICIENT POWER CONVERSION

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Demonstration Board Notification

The EPC9143 is intended for product evaluation purposes only and is not intended for commercial use. 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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