Evaluation Board EPC9171 Quick Start Guide

90–265 V_{RMS} Universal AC Input to 15 V–48 V_{DC}, 5 A Output USB PD3.1 Evaluation Board

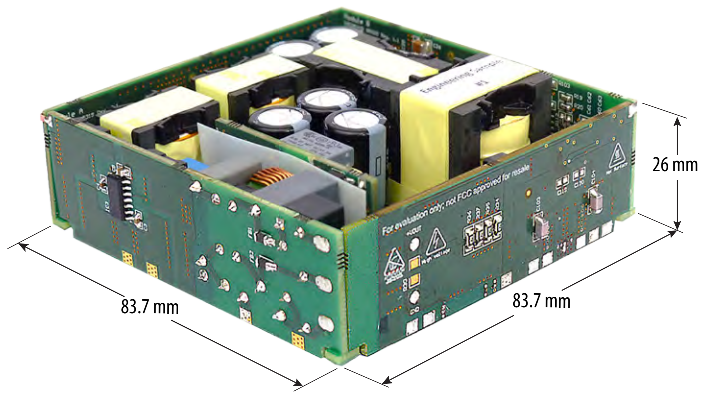
December 13, 2022

Version 1.0

EFFICIENT POWER CONVERSION

DESCRIPTION

The EPC9171 evaluation board is an universal AC input voltage range and frequency isolated power supply, designed for USB PD3.1 systems and supports operation in Extended Power Range (EPR) Mode. It is capable of supplying 240 W maximum output power at 48 V output voltage and 5A load current. A power density of about 1.1 W/cm^3 is achieved by employing, GaN power switches operated at high switching frequencies in both the primary and secondary circuits.



EPC9171 fully assembled evaluation board

The output voltage is variable over the whole Adjustable Voltage Supply (AVS) range of 15 V through 48 V as specified by the corresponding USB PD3.1 standard, when operating in constant voltage (CV) mode. A constant current (CC) mode with precise current control ensures that the output current never exceeds the selected current limit (5 A max.). This power supply topology building blocks consists of a two-phase interleaving boost converter PFC stage and an isolated LCC resonant power stage. This solution provides a higher power density than a conventional, three stage design typically consisting of active PFC, LLC and buck power stages.

The interleaving PFC stage ensures high power factor and low AC line current harmonics to meet the harmonics requirements of the EMC standards such as IEC 61000-3-2 / Class A. It supports full-power operation over a wide input voltage range of 90–265 VAC_{RMS}, while optimizing the light load efficiency by means of load dependent PFC phase control. The Critical Conduction Mode (CrCM) operation of the PFC stage in combination with 650 V GaN power switches enable high frequency operation well above 200 kHz. The power density advantage is gained by the elevated switching frequency that requires small physical dimension PFC inductors.

The LCC resonant power stage, operated from the pre-regulated PFC bus voltage, provides both the galvanic isolation and the output voltage/current regulation. Unlike the well-known LLC resonant power stages, which suffers from limited output voltage range, the LCC resonant converters are ideal for wide output voltage range applications with limited switching frequency variation, that also features superior constant-current characteristics. The LCC resonant converter also utilizes 650V GaN switches in primary high voltage circuit in this design and operates in the frequency range of 350 to 580 kHz, which helps to reduce the size of the power transformer as well as that of the other passive components in the resonant circuit.

A synchronous rectifier stage employs a pair of 100 V rated, 3.2 mΩ, EPC2218 GaN switches on the secondary side of the LCC stage. The GaN switches are driven by fast synchronous rectifier controllers to minimize the losses over the whole output voltage and current range and allow a simple yet effective thermal design.

PRECAUTIONS

Attention and Warnings:

- Only personnel with technical background should handle the EPC9171 at the stage of "**Engineering sample**". Failure to comply may result in personal injury and/or equipment damage.
- The EPC9171 "Engineering sample" provides a **functional insulation only**, therefore it shall always be operated from a proper isolation transformer. It does not provide a safety insulation as the insulation of the used components has not been tested and specific electrical creepage and clearance requirements for electrical safety may not be met.
- The EPC9171 "Engineering sample" **does not have any overtemperature protection**. Component temperatures must be carefully monitored during operation to avoid any potential damage caused by overheating.
- The EPC9171 system contains parts and assembly's sensitive to Electrostatic Discharge (ESD). Electrostatic control precautions are required when testing, servicing, or repairing this assembly. Component damage may result if ESD control procedures are not followed. If you are not familiar with electrostatic control procedures, refer to applicable ESD protection handbooks and guidelines.
- The EPC9171 system, incorrectly applied or installed, can result in component damage or reduction in product lifetime. Wiring or application errors such as under- or oversizing the load, operation with not authorized loads, supplying an incorrect or inadequate mains supply or excessive ambient temperatures may result in system malfunction or damage. This can result in personal injury and/or equipment damage.
- The EPC9171 system might be shipped with packing materials that need to be removed prior to installation. Failure to remove all packing materials which are unnecessary for system installation may result in overheating or abnormal operating condition.

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, and it is not FCC approved.

QUICK START PROCEDURE

The evaluation board EPC9171 is easy to set up to evaluate the performance of the EPC2218 eGaN® FETs in this USB PD 3.1 adapter. The main connection diagram is illustrated in Figure 1. The output voltage and output current limit can be set by adjusting the potentiometers R301 and R302 shown in Figure 2.

Power up procedure:

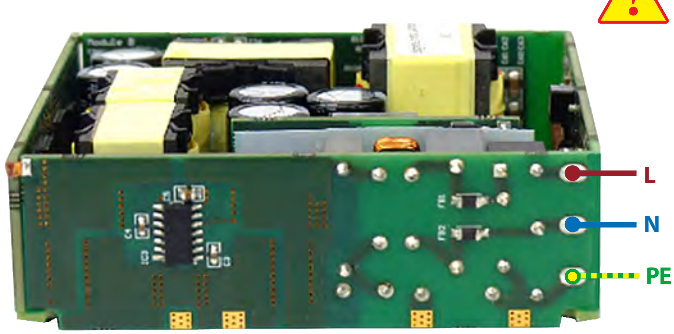
1) With power off, connect the EPC9171 to an appropriate AC source.
2) With power off, connect the EPC9171 to an appropriate DC load
3) Turn on the AC source.
4) Adjust the output voltage and current as needed using a non-conductive screw driver. **Observe caution as high voltage is present.**
5) When testing is complete, turn off the AC source.

Table 1: Electrical Characteristics (T_A = 25°C) EPC9171

Symbol	Parameter	Min	Typ	Max	Units
V_{IN}	Input voltage	90		265	VAC_{RMS}
V_{OUT}	Output voltage(1)	15		48	V_{DC}
ΔV_{OUT}	Output voltage ripple		100		mV
I_{OUT}	Output current(1)			5	A
f_S	Switching frequency	350		580	kHz
PF	Power Factor (120 VAC/60 Hz)		0.991		
THD	THD[%] (120 VAC/ 60 Hz)		12.7		%

(1) Variable adjustable

AC input connection (High voltage!)



DC output connection

Figure 1: Input and output connections

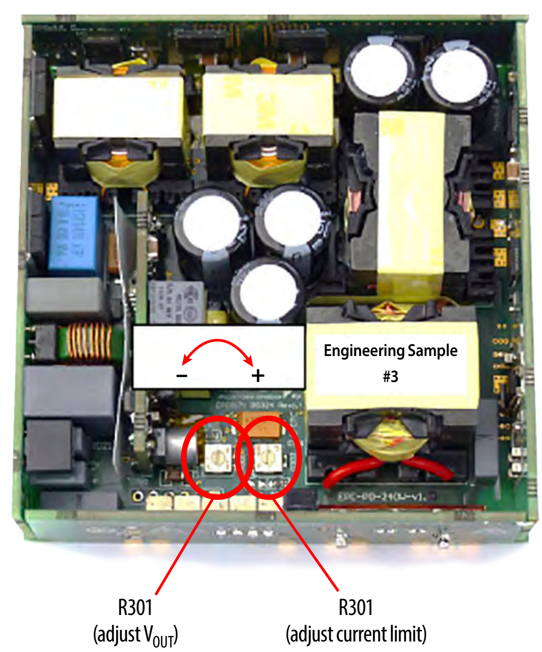
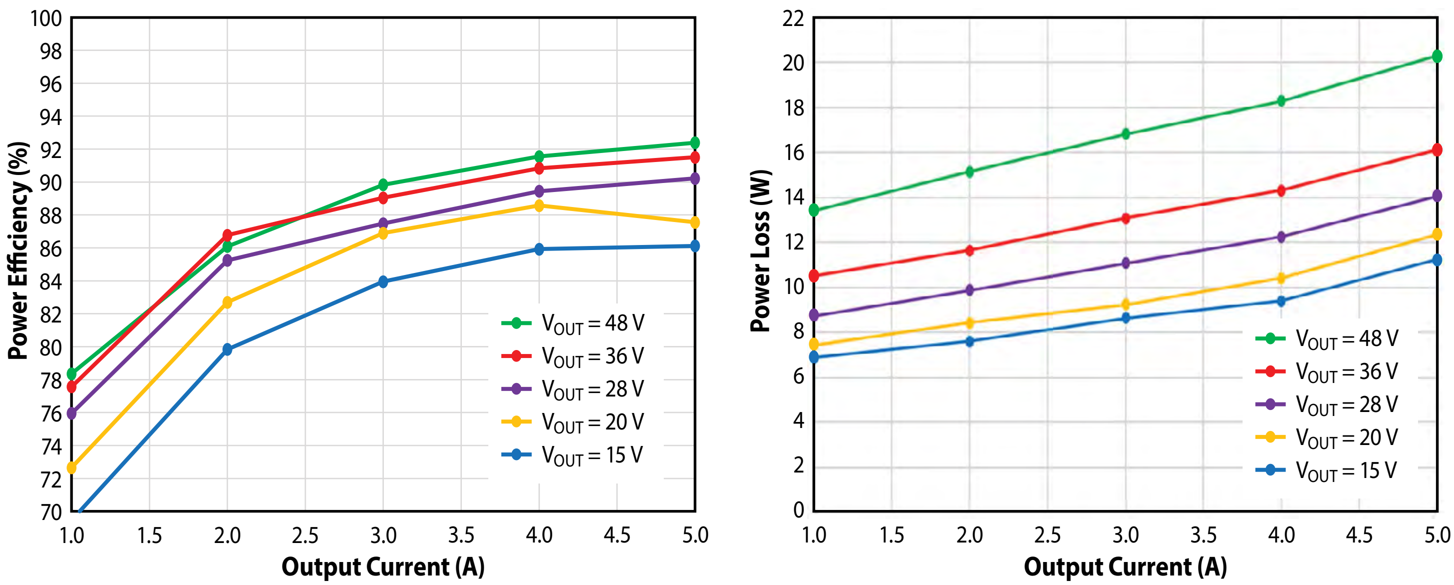


Figure 2: Output voltage adjustable by R301 and output current limit adjustable by R302

EXPERIMENTAL RESULTS

Typical efficiency and power losses

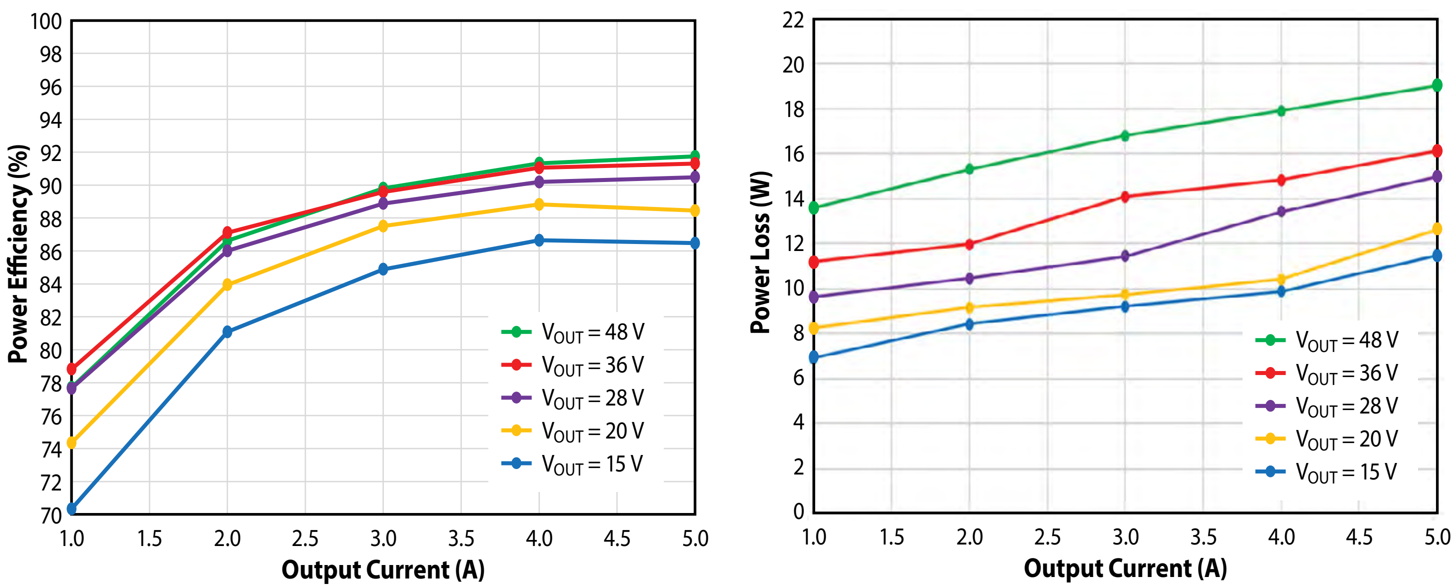
Power efficiency was measured over a output current range of 1-5 A at 15 V, 20 V, 28 V, 36 V and 48 V output voltages, and at 120 VAC_{RMS} and 230 VAC_{RMS} input voltages, respectively. The input power was measured by an AC power analyzer, while DC output parameters were recorded by precision digital multimeters.



(a) Power efficiency @ V_{IN} = 120 VAC_{RMS}

(b) Power losses @ V_{IN} = 120 VAC_{RMS}

Figure 3: Typical efficiency (a) and power losses (b) for various output voltages with V_{IN} = 120 VAC_{RMS}



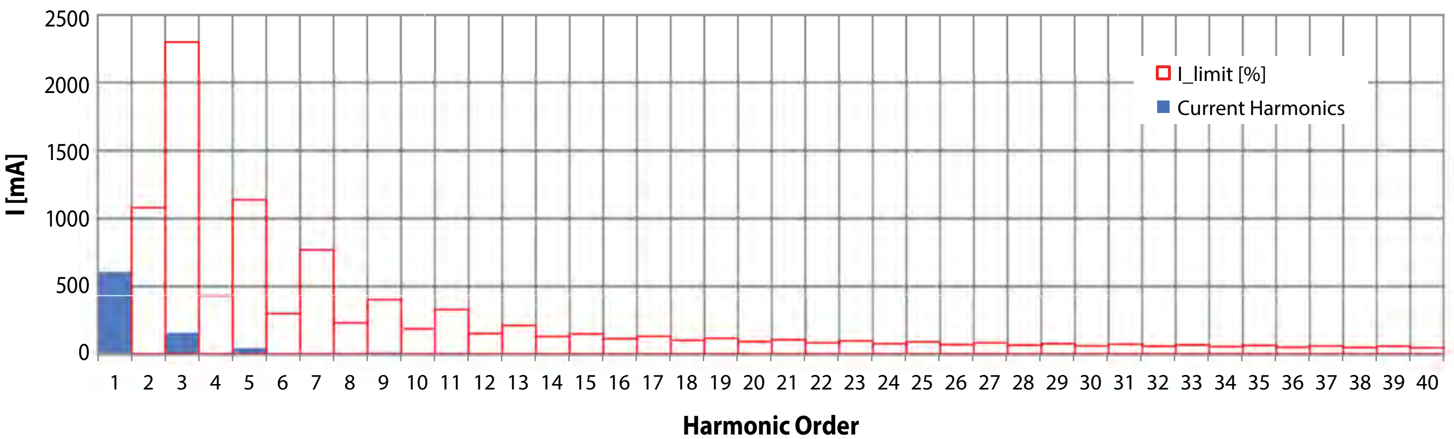
(a) Power efficiency @ V_{IN} = 230 VAC_{RMS}

(b) Power losses @ V_{IN} = 230 VAC_{RMS}

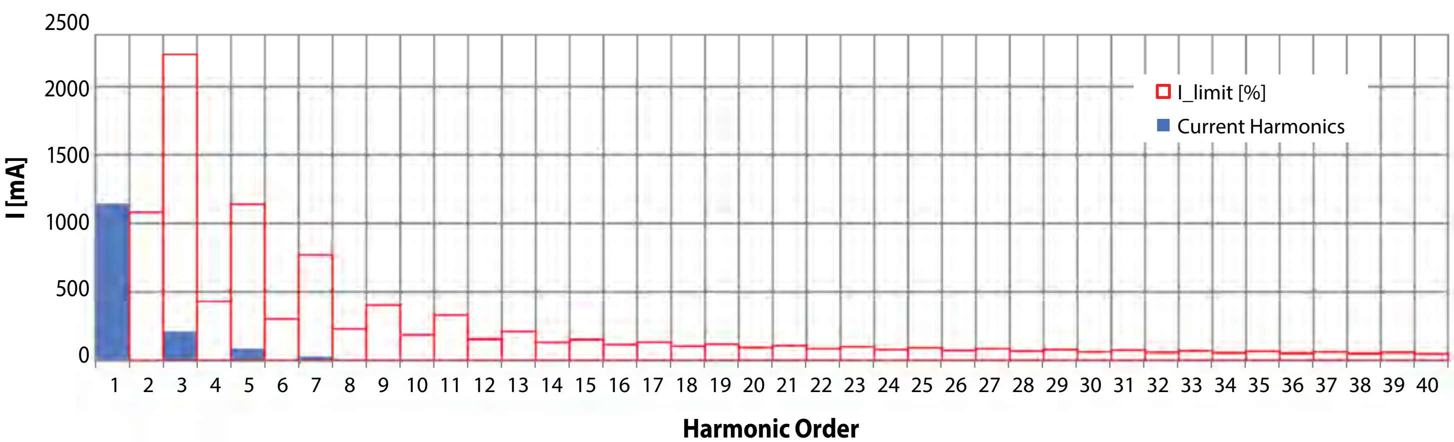
Figure 4: Typical efficiency (a) and power losses (b) for various output voltages with V_{IN} = 230 VAC_{RMS}

AC performance

AC line parameters were measured with an AC power analyzer at 48 V / 5A and 48 V / 2.5 A load, and at 120 VAC_{RMS} and 230 VAC_{RMS} input voltages, respectively. Line harmonics were evaluated and compared with the IEC 61000-3-2 / CLASS A line harmonic current limits. (only full-load curves are shown here)



(a)
Current harmonics @ V_{IN} = 120 VAC_{RMS} / 60 Hz / P_{OUT} = 240 W,
48 V/5000 mA



(b)
Current harmonics @ V_{IN} = 230 VAC_{RMS} / 50 Hz / P_{OUT} = 240 W,
48 V/5000 mA

Figure 5: (a) Measured current harmonics, V_{IN}= 120 VAC_{RMS} / 60 Hz,
(b) Measured current harmonics, V_{IN} = 230 VAC_{RMS} / 50 Hz

Typical load regulation

The output voltage regulation characteristic was measured at voltage settings V_{OUT} = 48 V, 36 V, 28 V, 20 V and 15 V, respectively (CV aka. Constant voltage mode). The current limit was set to 5 A.

Output Voltage / Current Regulation

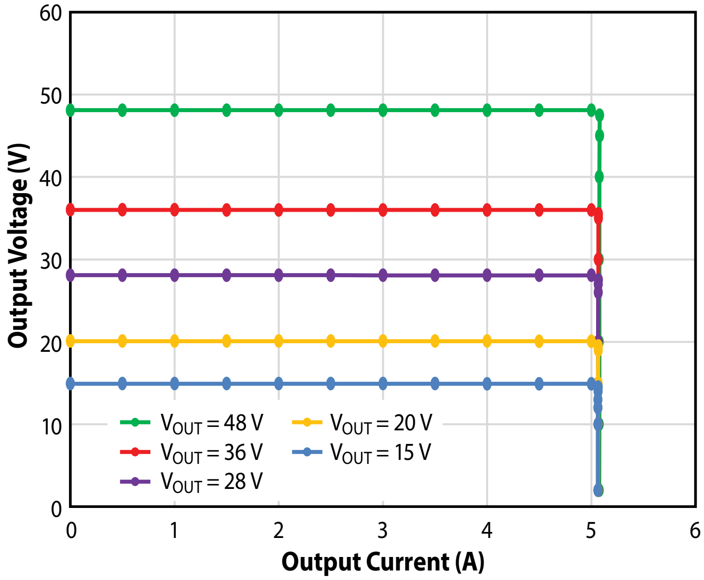


Figure 6: Typical load regulation for output voltages from 15 V–48 V, V_{IN} = 120 VAC_{RMS} / 60 Hz

Typical output voltage ripple

Output ripple voltage measured with 20MHz bandwidth

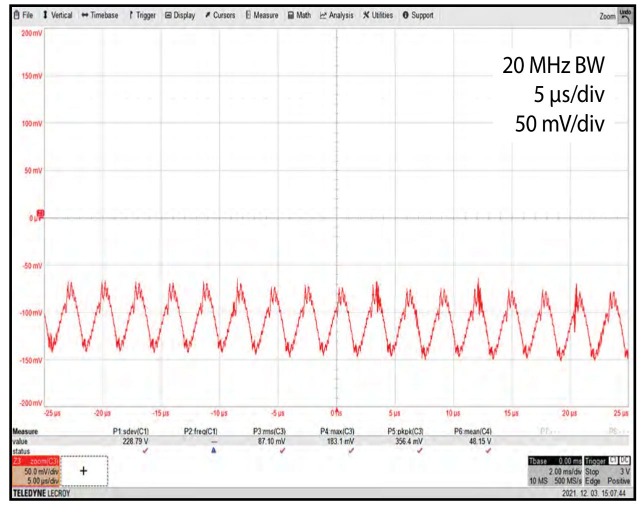


Figure 7: Typical output ripple V_{IN} = 120 VAC_{RMS} / 60 Hz

Typical load transient waveforms

Measured load step waveform from 0% to 100 % and vice versa

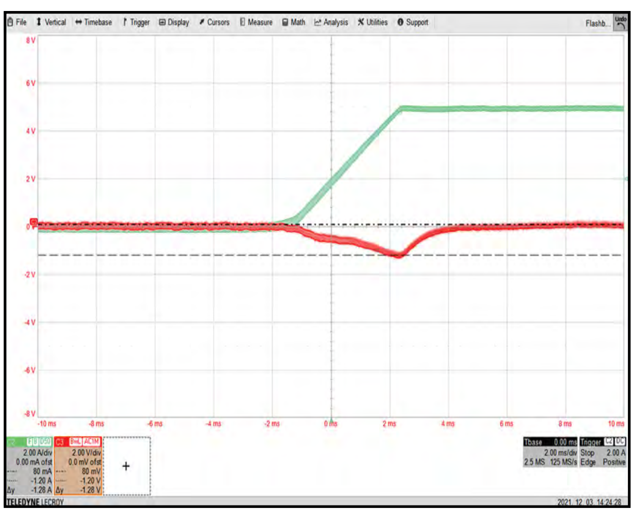


Figure 8: Typical load transient waveforms: V_{OUT} = 48 V, output 0% (0 A) to 100% (5 A), V_{IN} = 120 VAC_{RMS} / 60 Hz.

Typical output voltage ripple

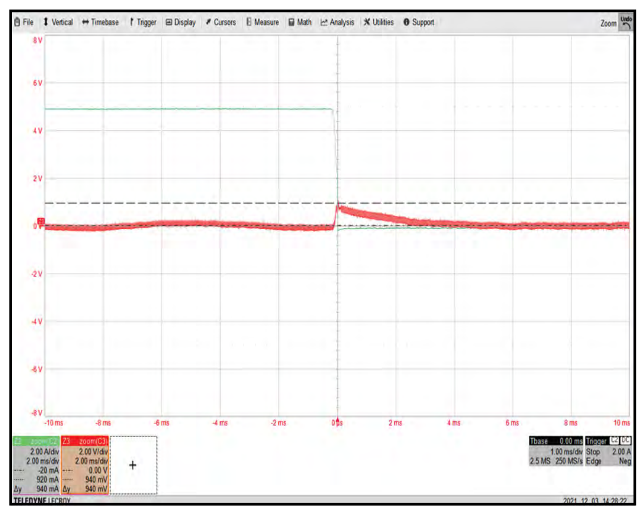
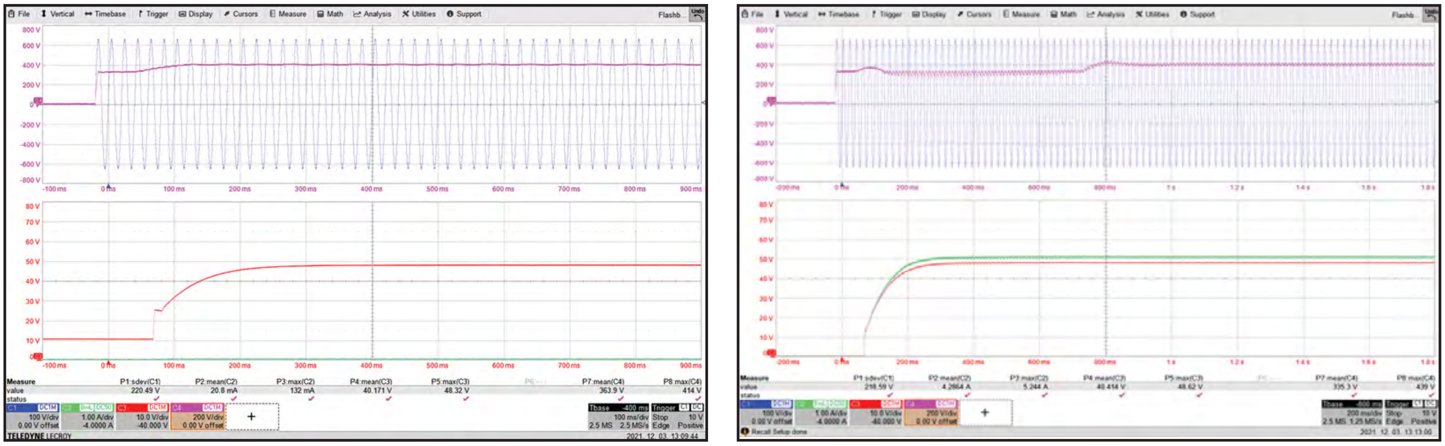


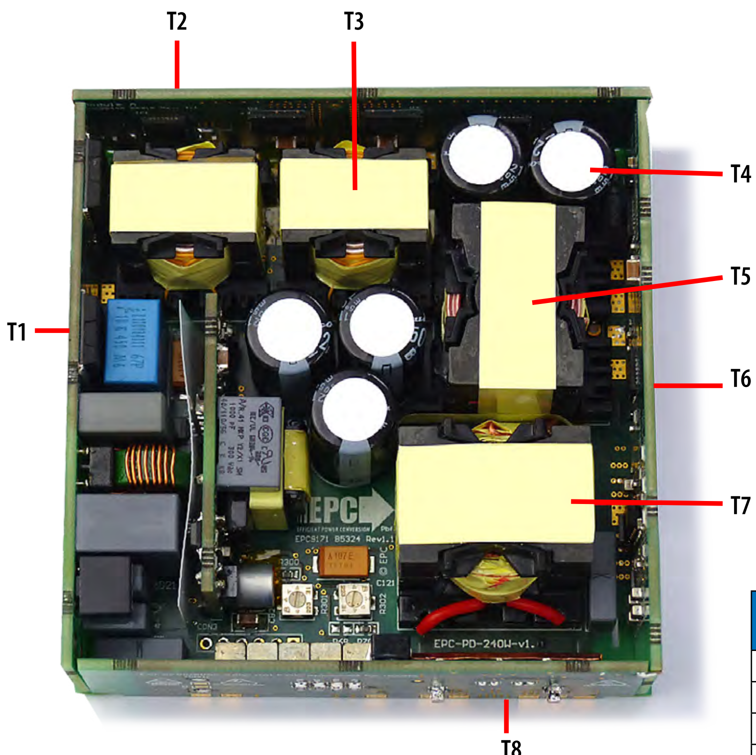
Figure 9: Typical load transient waveforms: V_{OUT} = 48 V, output 100% (5 A) to 0% (0 A), V_{IN} = 120 VAC_{RMS} / 60 Hz.

Startup waveform



(a) (b)

Figure 10: Start up waveform at (a) V_{IN}=120 VAC_{RMS}/50 Hz, I_{OUT} = 5 A
(b) Start up waveform at V_{IN} = 230 VAC_{RMS} / 50 Hz, V_{OUT} = 48 V, I_{OUT} = 5 A



Input: **230 VAC/50 Hz or 120 VAC/60 Hz**

Output: **48 V/5 A**

Test interval: 10 min

Tamb: 21°C

Notes: DUT placed on 20 mm distance holders to ensure some airflow underneath

Location	Description	Max. temperature 120 VAC/60 Hz	Max. temperature 230 VAC/50 Hz
T1	Input active rectifier	68°C	51°C
T2	PFC switch (IC1)	75°C	77°C
T3	PFC inductor (L5)	81°C	65°C
T4	PFC bus capacitor (C99)	73°C	72°C
T5	LCC resonant inductor (L2)	94°C	95°C
T6	LCC switch (IC6)	93°C	94°C
T7	Transformer (T1)	97°C	96°C
T8	Output sync. rectifier (Q5/Q6)	89°C	90°C

Figure 11: Thermal performance when operating from 120 VAC_{RMS} and 230 VAC_{RMS} input and delivering 5 A into 48 V in an ambient of 21°C.

For support files including schematic, Bill of Materials (BOM), and gerber files please visit the EPC9171 landing page at: https://epc-co.com/epc/products/demo-boards/epc9171

EPC would like to acknowledge ONgineer GmbH (**https://www.ongineer.de/en/home/**) for their support of this project.

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The EPC9171 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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