



# MIC45116 Evaluation Board

## 20V/6A/DC-to-DC Power Module

### General Description

Micrel's MIC45116 is a synchronous step-down regulator module, featuring a unique adaptive ON-time control architecture. The singular module package includes a DC-to-DC controller, power MOSFETs, bootstrap diode, bootstrap capacitor, and an inductor; simplifying the design and layout process for the end user.

This highly integrated solution expedites system design and improves product time-to-market. The internal MOSFETs and inductor have been optimized to achieve high efficiency at a low output voltage. The fully optimized design can deliver up to a 6A current under a wide input voltage range of 4.75V to 20V, without an additional cooling requirement.

The MIC45116-1 uses Micrel's HyperLight Load<sup>®</sup> (HLL). MIC45116-2 uses Micrel's Hyper Speed Control<sup>™</sup> architecture which enables ultra-fast load transient response and allows for a reduction of output capacitance. The MIC45116 offers 1% output accuracy that can be adjusted from 0.8V up to 85% of the input voltage with two external resistors. Note the output capacitor  $C_b$  is only rated to 6.3V.

The basic parameters of this evaluation board include a 4.75V to 20V input, a 0.8V to 5V at 6A output.

Datasheets and support documentation are available on Micrel's web site at: [www.micrel.com](http://www.micrel.com).

### Requirements

The MIC45116-1 and MIC45116-2 evaluation board's minimum requirement is one power supply with at least 6A current capability. No external linear regulator is required to power the internal biasing of the IC because the MIC45116 has an internal PVDD LDO. In the applications with  $V_{IN} < +5.5V$ , PVDD should be tied to  $V_{IN}$  to bypass the internal linear regulator. The output load can either be a passive or an active load.

### Precautions

The MIC45116 evaluation board does not have reverse polarity protection. Applying a negative voltage to the  $V_{IN}$  and GND terminals may damage the device. The maximum  $V_{IN}$  of the board is rated at 20V. Exceeding 30V on the  $V_{IN}$  could damage the device. The voltage rating of the output capacitor is 6.3V. The output capacitor should be replaced with higher voltage rated one to set the output voltage above 5V.

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### Getting Started

#### 1. VIN Supply

Connect a supply to the  $V_{IN}$  (TP6) and GND (TP7) terminals, paying careful attention to the polarity and the supply range ( $4.75V < V_{IN} < 20V$ ). Monitor  $I_{IN}$  with a current meter and monitor input voltage at  $V_{IN}$  and GND terminals with a voltmeter. Do not apply power until Step 4.

#### 2. Connect Load and Monitor Output

Connect a load to the  $V_{OUT}$  (TP8) and GND (TP9) terminals. The load can be either a passive (resistive) or an active (as in an electronic load) type. A current meter may be placed between the  $V_{OUT}$  terminal and load to monitor the output current. Ensure the output voltage is monitored at the  $V_{OUT}$  terminal.

#### 3. Enable Input

The EN pin has an on board 100k $\Omega$  pull-up resistor (R4) to  $V_{IN}$ , which allows the output to be turned on when PVDD exceeds its UVLO threshold. An EN connector (TP3) is provided on the evaluation board for users to easily access the enable feature. Applying an external logic signal on the EN pin to pull it low or using a jumper to short the EN pin to GND will shut off the output of the MIC45116 evaluation board.

#### 4. Turn Power

Turn on the  $V_{IN}$  supply and verify that the output voltage is regulated to 1.8V.

#### 5. Loop Measurement

Control loop frequency response can be measured by injecting AC sweep signal and measuring voltage across test points A and B. R3 should change to a small resistor value in the range of 10 $\Omega$  to 20 $\Omega$  for the loop measurement.

### Ordering Information

Part Number	Description
MIC45116-1YMP EV	MIC45116-1 Evaluation Board
MIC45116-2YMP EV	MIC45116-2 Evaluation Board

## Features

### Feedback Resistors

The output voltage on the MIC45116 evaluation board, which is preset to 1.8V, is determined by the feedback divider, as illustrated in [Equation 1](#):

$$V_{OUT} = V_{REF} \times \left( 1 + \frac{R51}{R_{BOTTOM}} \right) \quad \text{Eq. 1}$$

where  $V_{REF} = 0.8V$ , and  $R_{BOTTOM}$  is the lower feedback resistor.

Leaving the  $R_{BOTTOM}$  open by removing all jumpers on the feedback headers gives a 0.8V output voltage. All other voltages not listed above can be set by modifying  $R_{BOTTOM}$  value according to [Equation 2](#):

$$R_{BOTTOM} = \frac{R51 \times V_{REF}}{V_{OUT} - V_{REF}} \quad \text{Eq. 2}$$

Note that the output voltage should not be set to exceed 5V unless the output capacitor (C6) is replaced with a higher voltage rating.

**Table 1. Typical Values of Some Components**

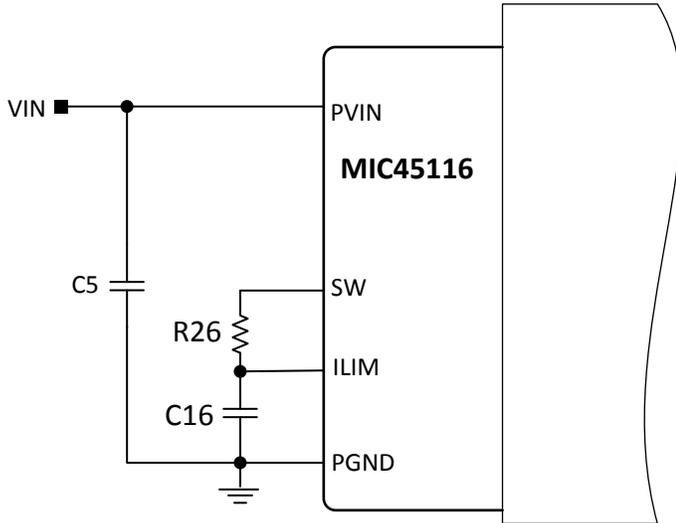
$V_{OUT}$	$V_{IN}$	R51 (Top Feedback Resistor)	R (Bottom Feedback Resistor)	C12 (C#)	$C_{OUT}$
1.0V	5V to 20V	10k $\Omega$	40.2k $\Omega$	1.0nF	100 $\mu$ F/6.3V
1.2V	5V to 20V	10k $\Omega$	20.0k $\Omega$	1.0nF	100 $\mu$ F/6.3V
1.5V	5V to 20V	10k $\Omega$	11.5k $\Omega$	1.0nF	100 $\mu$ F/6.3V
1.8V	5V to 20V	10k $\Omega$	8.06k $\Omega$	1.0nF	100 $\mu$ F/6.3V
2.5V	5V to 20V	10k $\Omega$	4.75k $\Omega$	1.0nF	100 $\mu$ F/6.3V
3.3V	5V to 20V	10k $\Omega$	3.24k $\Omega$	1.0nF	100 $\mu$ F/6.3V
5V	7V to 20V	10k $\Omega$	1.91k $\Omega$	1.0nF	100 $\mu$ F/6.3V

**SW Node**

A test pad (SW) is placed close to the module for monitoring the switching waveform. It is one of the most critical waveforms for the converter.

**Current Limit**

The MIC45116 uses the  $R_{DS(ON)}$  of the low-side MOSFET and external resistor connected from the ILIM pin to the SW node to decide the current limit.



**Figure 1. MIC45116 Current-Limiting Circuit**

In each switching cycle of the MIC45116, the inductor current is sensed by monitoring the low-side MOSFET in the OFF period. The sensed voltage ( $V_{(ILIM)}$ ) is compared with the power ground (PGND) after a blanking time of 150ns. In this way the drop voltage over the R26 resistor ( $V_{CL}$ ) is compared with the drop over the bottom FET generating the short current limit. The small capacitor (C16) connected from ILIM pin to PGND filters the switching node ringing during the off-time allowing a better short-limit measurement. The time constant created by R26 and C16 should be much less than the minimum off time.

The  $V_{CL}$  drop allows programming of short limit through the value of the resistor (R26) if the absolute value of the voltage drop on the bottom FET is greater than  $V_{CL}$ . In that case the  $V_{(ILIM)}$  is lower than PGND and a short circuit event is triggered. A hiccup cycle to treat the short event is generated. The hiccup sequence including the soft-start reduces the stress on the switching FETs and protects the load and supply for severe short conditions.

The short-circuit current limit can be programmed by using Equation 3:

$$R26 = \frac{(I_{CLIM} - \Delta I_{L(PP)} \times 0.5) \times R_{DS(ON)} + V_{CL}}{I_{CL}} \quad \text{Eq. 3}$$

where:

$I_{CLIM}$  = Desired current limit

$R_{DS(ON)}$  = On-resistance of low-side power MOSFET, 16mΩ typically

$V_{CL}$  = Current-limit threshold (typical absolute value is 14mV per Electrical Characteristics in the MIC45116 data sheet)

$I_{CL}$  = Current-limit source current (typical value is 80μA, per Electrical Characteristics in the MIC45116 data sheet).

$\Delta I_{L(PP)}$  = Inductor current peak-to-peak, since the inductor is integrated, use Equation 4 to calculate the inductor ripple current.

The peak-to-peak inductor current ripple is:

$$\Delta I_{L(PP)} = \frac{V_{OUT} \times (V_{IN(MAX)} - V_{OUT})}{V_{IN(MAX)} \times f_{sw} \times L} \quad \text{Eq. 4}$$

The MIC45116 has 1.0μH inductor integrated into the module. In case of hard short, the short limit is folded down to allow an indefinite hard short on the output without any destructive effect. It is mandatory to make sure that the inductor current used to charge the output capacitance during soft start is under the folded short limit; otherwise the supply will go in hiccup mode and may not be finishing the soft start successfully.

The MOSFET  $R_{DS(ON)}$  varies 30% to 40% with temperature. Therefore, it is recommended to add a 50% margin to  $I_{CLIM}$  in the above equation to avoid false current limiting due to increased MOSFET junction temperature rise. With R26 = 1.62kΩ and C16 = 15pF, the typical output current limit is about 8.2A.

# MIC45116 Evaluation Board Schematic

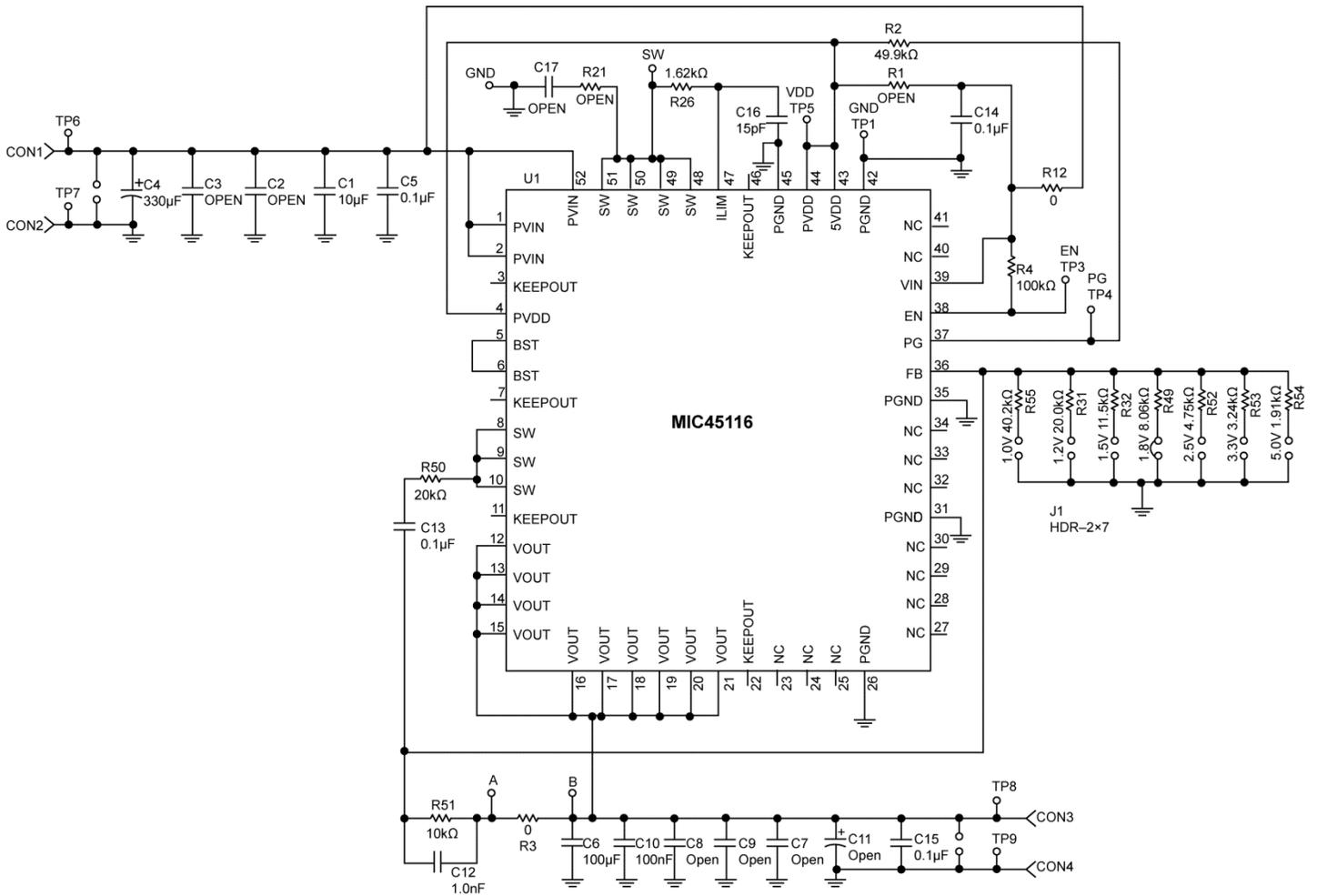


Figure 2. Schematic of MIC45116 Evaluation Board

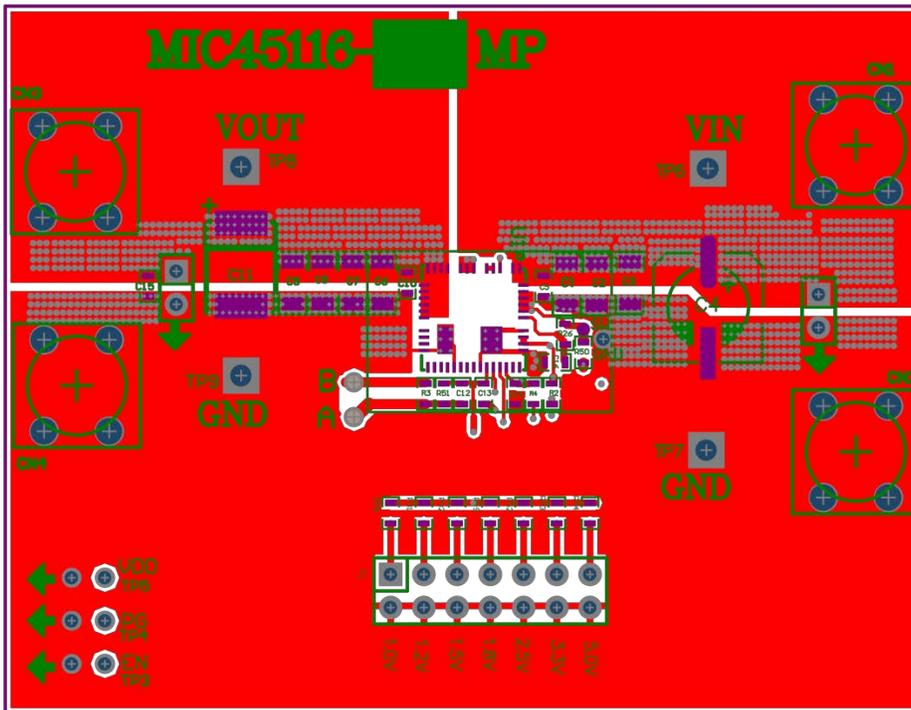
## Bill of Materials

Item	Part Number	Manufacturer	Description	Qty.
C4	B41125A5337M	TDK <sup>(1)</sup>	330µF/25V, ALE Capacitor (optional)	1
C2, C3, C7, C8, C9, C11, C17			Open	
C1	C3216X5R1E106M085AC	TDK	10µF/25V, 1206, X5R, 20%, MLCC	1
C5, C10, C13, C14, C15	GRM188R71H104KA93D	Murata <sup>(2)</sup>	0.1µF/50V, X7R, 0603, 10%, MLCC	5
C6	C3216X5R0J107M160AB	TDK	100µF/6.3V, X5R, 1206, 20%, MLCC	1
C12	C1608C0G1H102J080AA	TDK	1.0nF/50V, NP0, 0603, 5%, MLCC	1
C16	GRM1885C1H150JA01D	Murata	15pF/50V, NP0, 0603, 5%, MLCC	1
CON1, CON2, CON3, CON4	8191	Keystone <sup>(3)</sup>	15A, 4-Prong Through-Hole Screw Terminal	4
J1	M50-3500742	Harwin <sup>(4)</sup>	Header 2x7	1
J2, J3, TP3 – TP5	90120-0122	Molex <sup>(5)</sup>	Header 2	5
R4	CRCW0603100K0FKEA	Vishay Dale <sup>(6)</sup>	100kΩ, 1%, 1/10W, 0603, Thick Film	1
R21, R1			Open	
R55	CRCW060340K2FKEA	Vishay Dale	40.2kΩ, 1%, 1/10W, 0603, Thick Film	1
R31, R50	CRCW06020K0FKEA	Vishay Dale	20kΩ, 1%, 1/10W, 0603, Thick Film	2
R32	CRCW060311K5FKEA	Vishay Dale	11.5kΩ, 1%, 1/10W, 0603, Thick Film	1
R49	CRCW06038K06FKEA	Vishay Dale	8.06kΩ, 1%, 1/10W, 0603, Thick Film	1
R52	CRCW06034K75FKEA	Vishay Dale	4.75kΩ, 1%, 1/10W, 0603, Thick Film	1
R53	CRCW06033K24FKEA	Vishay Dale	3.24kΩ, 1%, 1/10W, 0603, Thick Film	1
R54	CRCW06031K91FKEA	Vishay Dale	1.91kΩ, 1%, 1/10W, 0603, Thick Film	1
R2	CRCW060349K9FKEA	Vishay Dale	49.9kΩ, 1%, 1/10W, 0603, Thick Film	1
R51	CRCW060310K0FKEA	Vishay Dale	10kΩ, 1%, 1/10W, 0603, Thick Film	1
R26	CRCW06031K62FKEA	Vishay Dale	1.62kΩ, 1%, 1/10W, 0603, Thick Film	1
R3, R12	RCG06030000Z0EA	Vishay Dale	0Ω Resistor, 1%, 1/10W, 0603, Thick Film	2
TP6 – TP9, A, B	1502-2	Keystone	Single-End, Through-Hole Terminal	6
U1	MIC45116-1YMP	Micrel, Inc. <sup>(7)</sup>	20V/6A DC-to-DC Power Module	1
	MIC45116-2YMP			

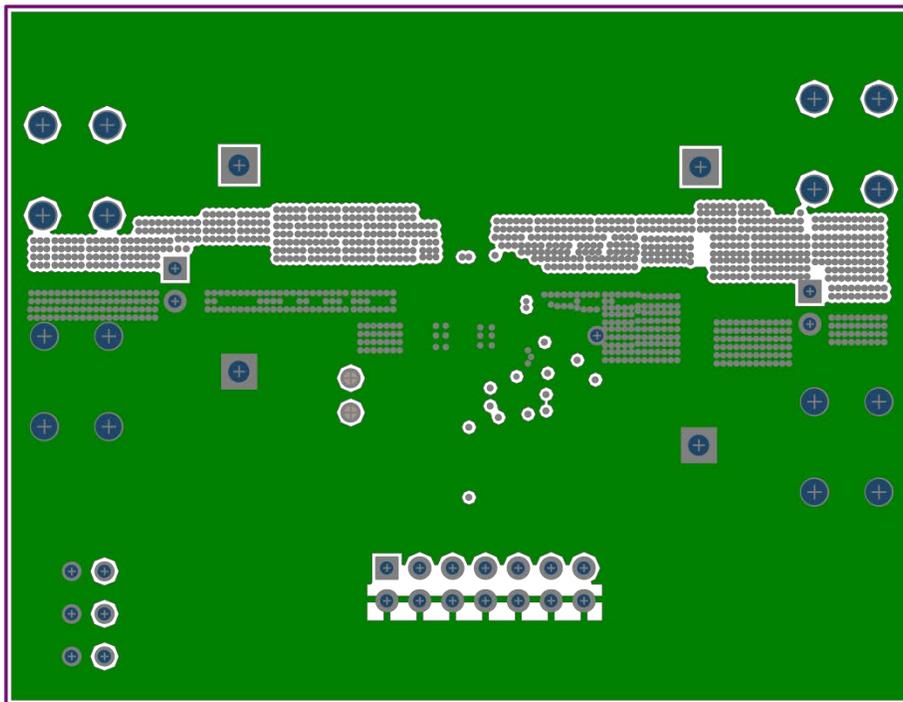
### Notes:

1. TDK: [www.tdk.com](http://www.tdk.com).
2. Murata: [www.murata.com](http://www.murata.com).
3. Keystone: [www.keyelco.com](http://www.keyelco.com).
4. Harwin: <http://www.harwin.com>
5. Molex: [www.molex.com](http://www.molex.com).
6. Vishay-Dale: [www.vishay.com](http://www.vishay.com).
7. Micrel: [www.micrel.com](http://www.micrel.com).

# PCB Layout Recommendations

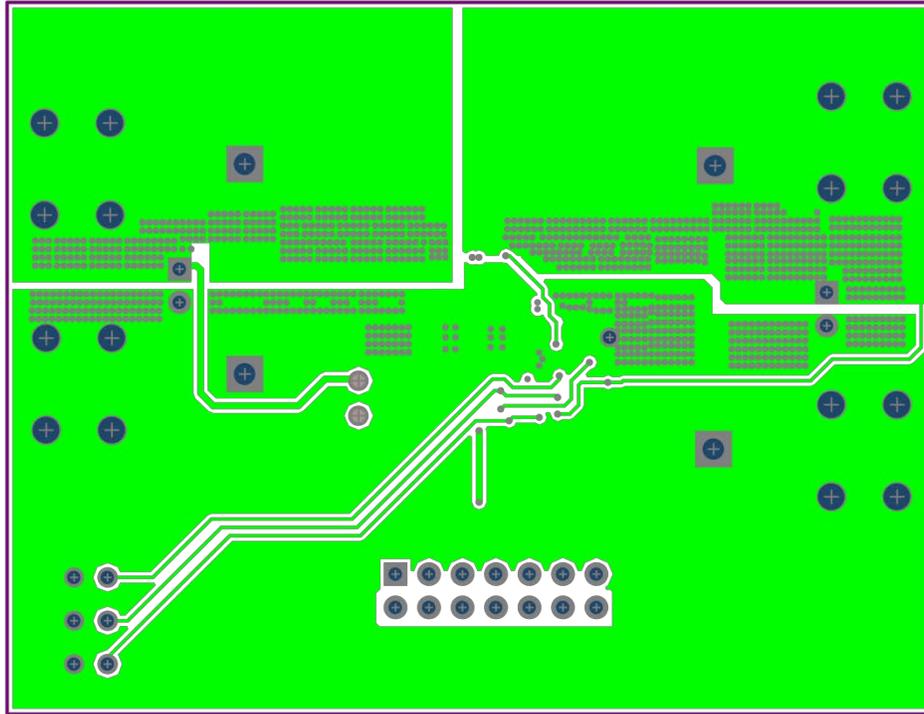


MIC45116 Evaluation Board Top Layer

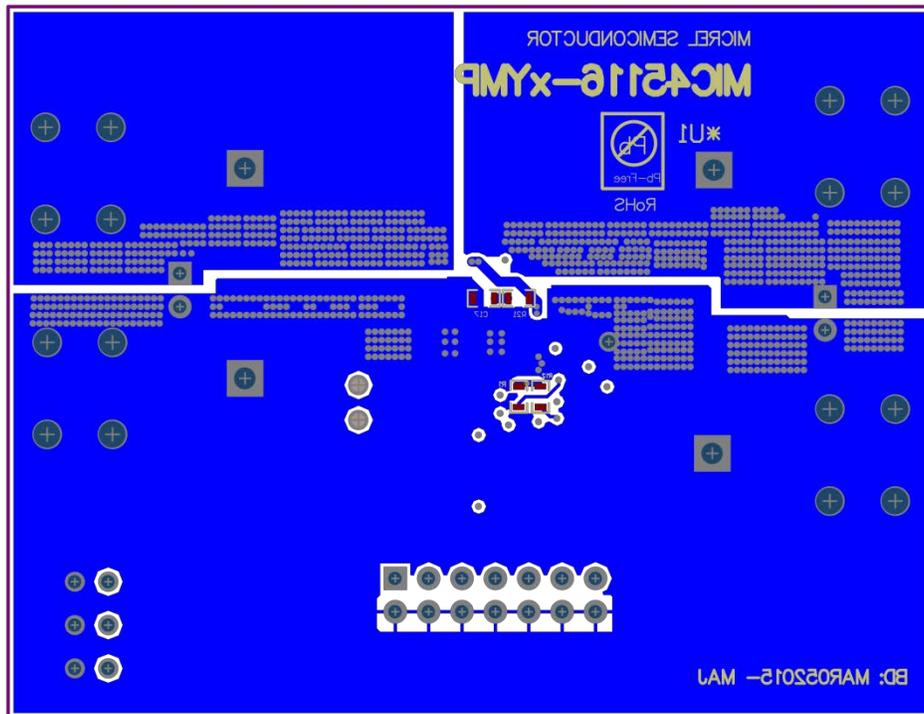


MIC45116 Evaluation Board Copper Layer 2

### PCB Layout Recommendations (Continued)



MIC45116 Evaluation Board Copper Layer 3



MIC45116 Evaluation Board Bottom Layer

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