MIC2101/02 Evaluation Board

38V, Synchronous Buck Controllers featuring Adaptive On-Time Control

Hyper Speed Control™ Family

General Description

The Micrel MIC2101/02 are constant-frequency, synchronous buck controllers featuring a unique adaptive ON-time control architecture. The MIC2101/02 operates over an input supply range of 4.5V to 38V and can be used to supply up to 15A of output current. The output voltage is adjustable down to 0.8V with a guaranteed accuracy of ±1%. The device operates with programmable switching frequency from 200kHz to 600kHz.

The MIC2101 is Hyper Light Load® architecture so it operates in pulse skipping mode at light load but from medium load to heavy load it operates in fixed frequency CCM mode. The MIC2102 is Hyper Speed Control™ architecture so it operates in fixed-frequency CCM mode under all load conditions.

The basic parameters of the evaluation board are:

1. Input: 5V to 38V
2. Output: 0.8V to 5V at 12A[1]
3. 600kHz Switching Frequency (Adjustable 200kHz to 600kHz)

Datasheets and support documentation can be found on Micrel's web site at www.micrel.com.

Note:

1. Refer to the temperature curves shown in "Typical Characteristics".

Requirements

The MIC2101 and MIC2102 evaluation board requires only a single power supply with at least 10A current capability. The MIC2101/02 has internal VDD LDO so no external linear regulator is required to power the internal biasing of the IC. In the applications with VIN < +5.5V, VDD should be tied to VIN to by-pass the internal linear regulator. The output load can either be a passive or an active load.

Precautions

The MIC2103/04 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 38V. Exceeding 38V on the V_{IN} could damage the device.

Getting Started

1. **V_{IN} Supply**
   Connect a supply to the V_{IN} and GND terminals, paying careful attention to the polarity and the supply range (5V < V_{IN} < 38V). Monitor I_{IN} with a current meter and input voltage at V_{IN} and GND terminals with voltmeter. Do not apply power until step 4.
2. **Connect Load and Monitor Output**
   Connect a load to the V_{OUT} and GND 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 pull-up resistor (R22) to V_{IN}, which allows the output to be turned on when VDD exceeds its UVLO threshold. An EN connector 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 MIC2101/02 evaluation board.
4. **Turn on the Power**
   Turn on the V_{IN} supply and verify that the output voltage is regulated to 3.3V.

Ordering Information

Part Number	Description
MIC2101YML 12A EV	MIC2101 Evaluation Board with up to 5V Output
MIC2102YML 12 A EV	MIC2102 Evaluation Board with up to 5V Output

Features

Feedback Resistors

The output voltage on the MIC2101/02 evaluation board, which is preset to 3.3V, is determined by the feedback divider:

$$V_{OUT} = V_{REF} \times \left(1 + \frac{R1}{R_{BOTTOM}}\right) \quad \text{Eq. 1}$$

where V_{REF} = 0.8V, and R_{BOTTOM} is one of R4, R5, R6, R7, R8, R9, R10, R11 which corresponds to 0.9V, 1.0V, 1.2V, 1.5V, 1.8V, 2.5V, 3.3V, or 5V. Leaving the R_{BOTTOM} open gives a 0.8V output voltage. All other voltages not listed above can be set by modifying R_{BOTTOM} value according to:

$$R_{BOTTOM} = \frac{R1 \times V_{REF}}{V_{OUT} - V_{REF}} \quad \text{Eq. 2}$$

Note that the output voltage should not be set to exceed 5V due to the 6.3V voltage rating on the output capacitors.

SW Node

Test point J1 (VSW) is placed for monitoring the switching waveform, one of the most critical waveforms for the converter.

Current Limit

The MIC2101/02 uses the $R_{DS(ON)}$ and external resistor connected from ILIM pin to SW node to decides the current limit.

In each switching cycle of the MIC2101/02 converter, 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 resistor R17 (V_{CL}) is compared with the drop over the bottom FET generating the short current limit. The small capacitor (C18) 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 R17 and C18 should be much less than the minimum off time.

The V_{CL} drop allows programming of short limit through the value of the resistor (R_{CL}), 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.

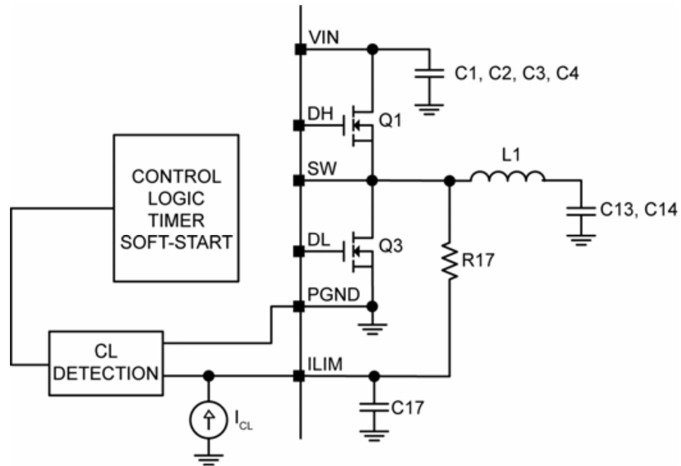


Figure 1. MIC2101/02 Current Limiting Circuit

The short circuit current limit can be programmed by using the following formula.

$$R17 = \frac{\left(I_{CLIM} - \Delta_{PP} \times 0.5\right) \times R_{DS(ON)} + V_{CL}}{I_{CL}} \quad \text{Eq. 3}$$

where:

I_{CLIM} = Desired current limit

Δ_{PP} = Inductor current peak-to-peak

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

V_{CL} = Current-limit threshold, the typical value is 14mV in EC table

I_{CL} = Current limit source current, the typical value is 80µA in EC table.

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 ICL in the above equation to avoid false current limiting due to increased MOSFET junction temperature rise. It is also recommended to connect SW pin directly to the drain of the low-side MOSFET to accurately sense the MOSFETs $R_{DS(ON)}$.

Loop Gain Measurement

The resistor, R14, is placed in series with the regulator feedback path. The control loop gain can be measured by connecting an impedance analyzer across the resistor and selecting the resistor value in between 20Ω to 50Ω.

Setting the Switching Frequency

The MIC2101/02 are adjustable-frequency, synchronous buck controllers featuring a unique adaptive on-time control architecture. The switching frequency can be adjusted between 200kHz and 600kHz by changing the resistor divider network consisting of R19 and R20.

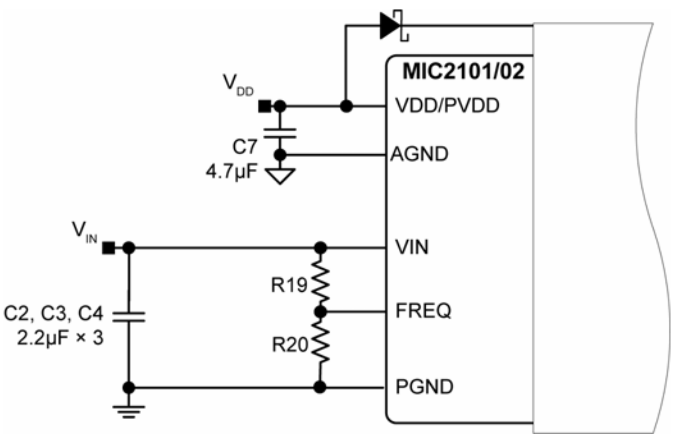


Figure 2. Switching Frequency Adjustment

The following formula gives the estimated switching frequency:

$$f_{SW\_ADJ} = f_O \times \frac{R20}{R19 + R20} \qquad \text{Eq. 4}$$

where:

f_O = Switching Frequency when R19 is 100k and R20 being open, f_O is typically 600kHz. For more precise setting, it is recommended to use the following graph:

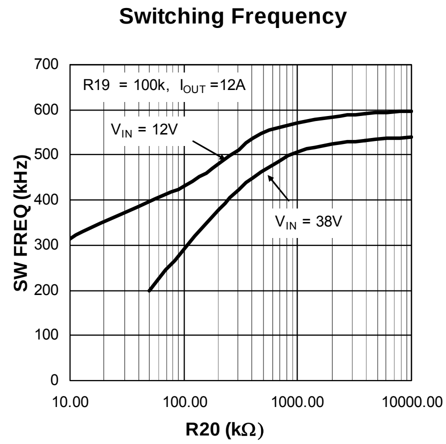
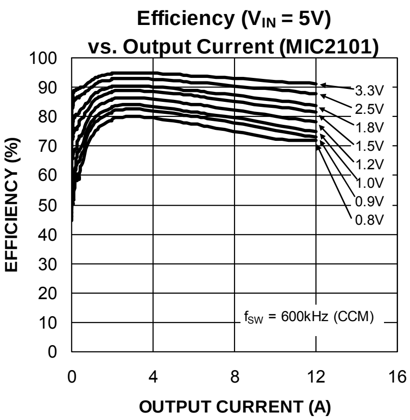
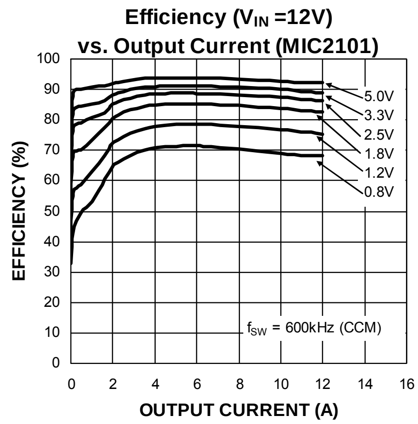


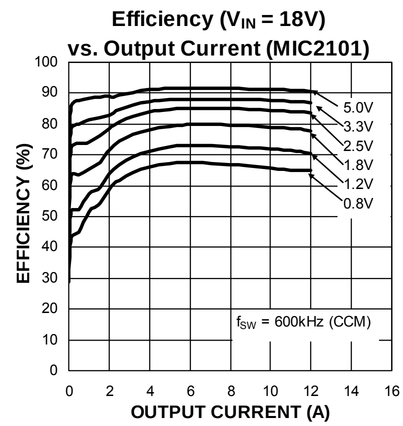
Figure 3. Switching Frequency vs. R20

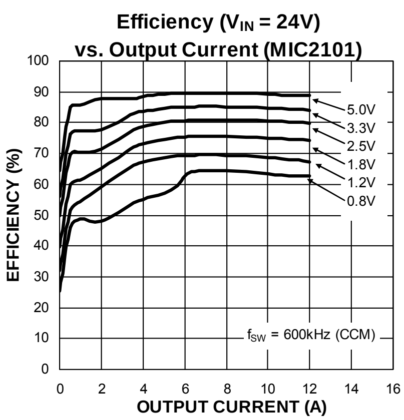
The evaluation board design is optimized for a switching frequency of 600kHz. If the switching frequency is programmed to either lower end or higher end, the design needs optimization.

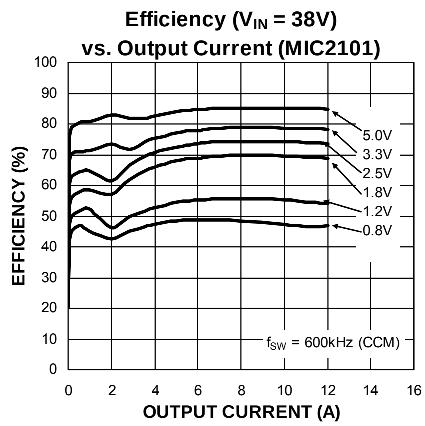
MIC2101/02 0.8V to 5V/12A Evaluation Board Typical Characteristics

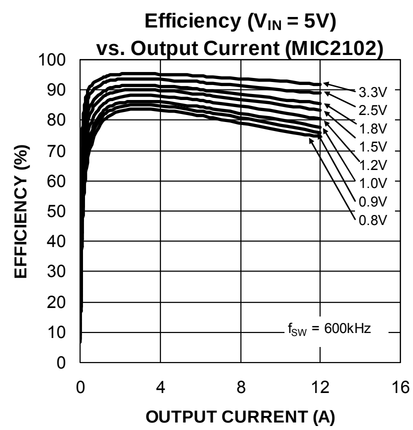


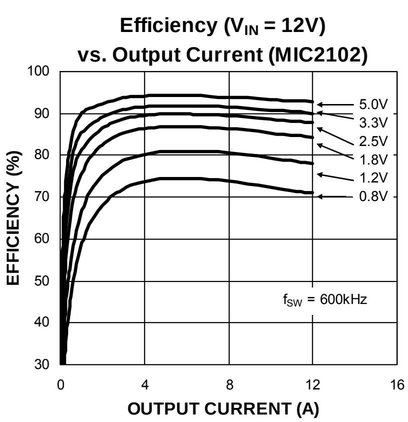


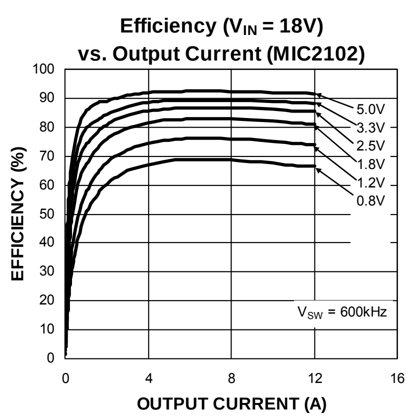


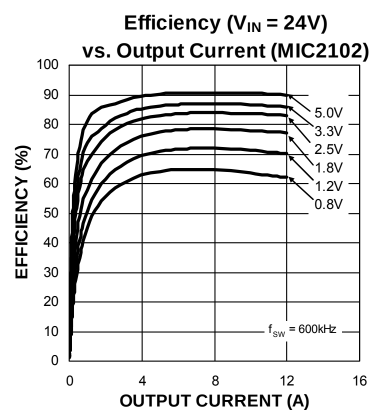






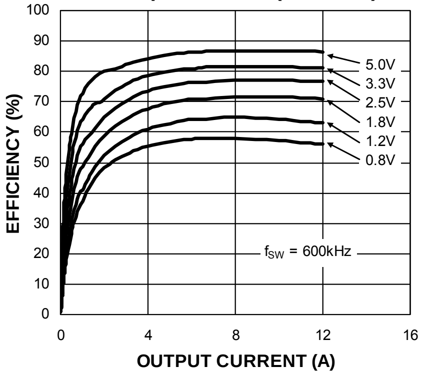




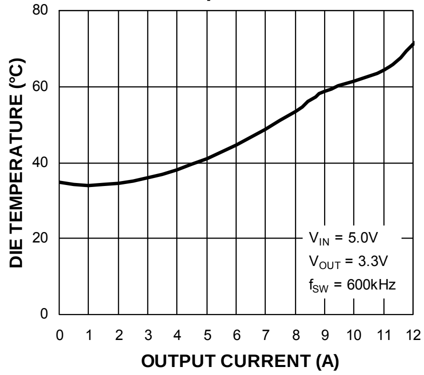


MIC2101/02 0.8V to 5V/12A Evaluation Board Typical Characteristics (Continued)

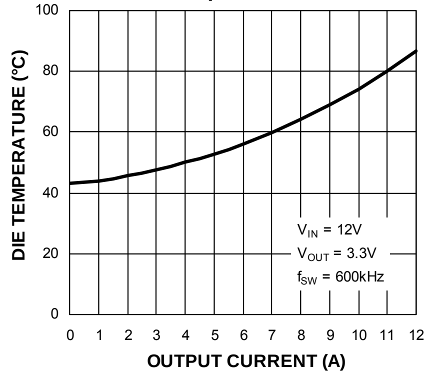
Efficiency (V_{IN} = 38V) vs. Output Current (MIC2102)



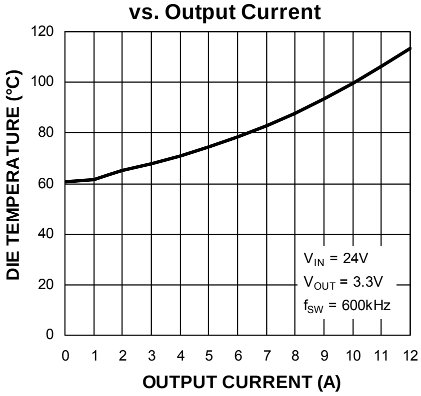
Die Temperature* (V_{IN} = 5.0V) vs. Output Current



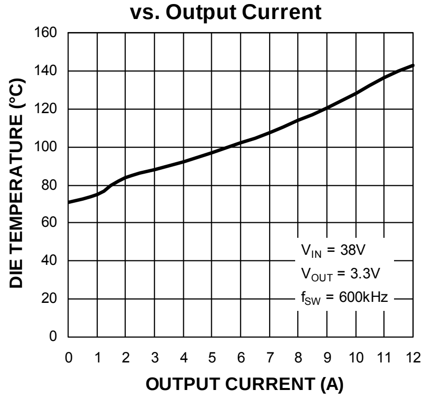
Die Temperature* (V_{IN} = 12V) vs. Output Current



Die Temperature* (V_{IN} = 24V) vs. Output Current

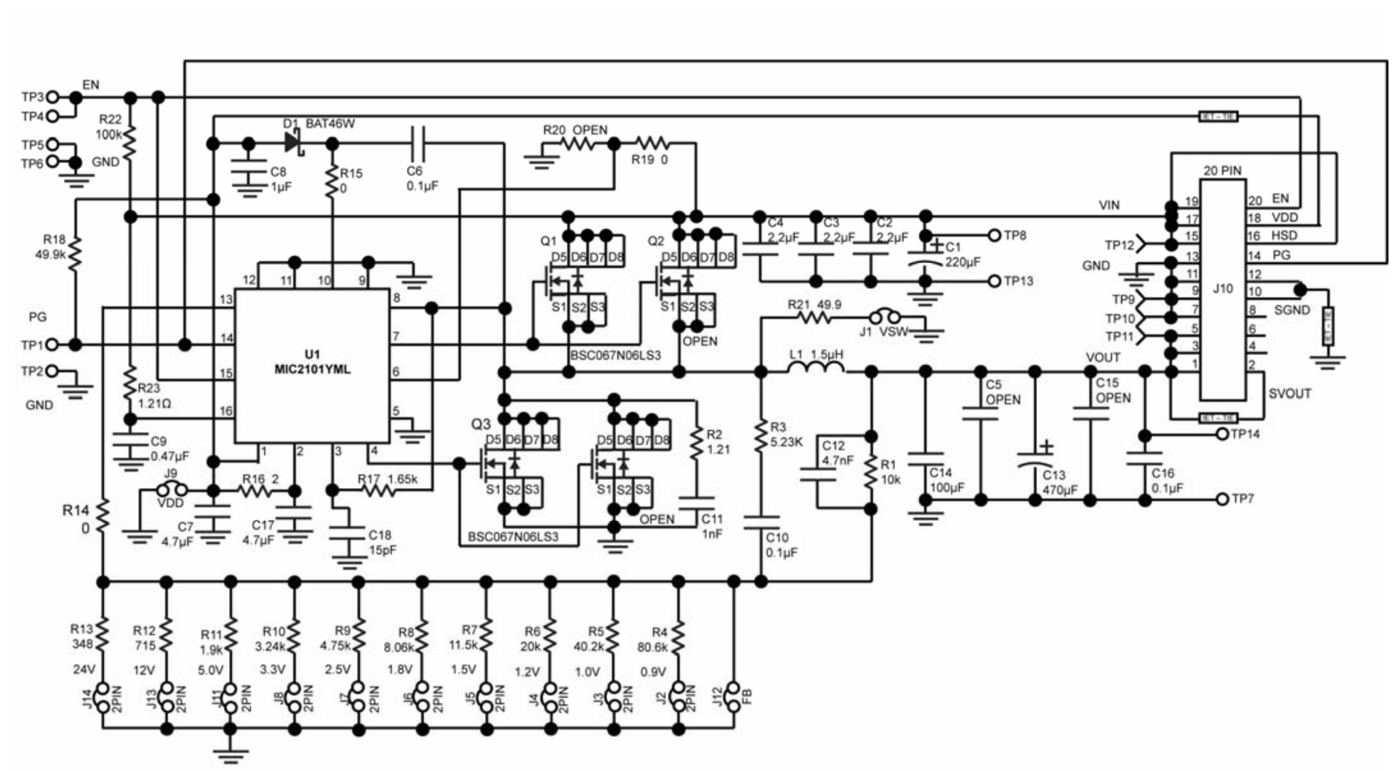


Die Temperature* (V_{IN} = 38V) vs. Output Current



Die Temperature* : The temperature measurement was taken at the hottest point on the MIC2103/04 case mounted on a 5 square inch 4 layer, 0.62”, FR-4 PCB with 2oz. finish copper weight per layer (see Thermal Measurement section). Actual results will depend upon the size of the PCB, ambient temperature and proximity to other heat emitting components.

MIC2101/02 0.8V to 5V/12A Output Evaluation Board Schematic



Bill of Materials

Item	Part Number	Manufacturer	Description	Qty.
C1	EEU-FC1J221S	Panasonic[1]	220µF Aluminum Capacitor, 63V	1
C2, C3, C4	12105C225KAT2A	AVX[2]	2.2µF/50V Ceramic Capacitor, X7R, Size 1210	3
	C3225X7R1H225K	TDK[3]		
C14	GRM32ER60J107ME20L	Murata[4]	100µF/6.3V Ceramic Capacitor, X7R, Size 1210	1
	12106D107MAT2A	AVX		
	C3225X5ROJ107M	TDK		
C6, C16, C10	GRM188R71H104KA93D	Murata	0.1µF/50V Ceramic Capacitor, X7R, Size 0603	3
	06035C104KAT2A	AVX		
	C1608X7R1H104K	TDK		
C7, C17	GRM188R60J475KE19D	Murata	4.7µF/6.3V Ceramic Capacitor, X7R, Size 0603	2
	06036D475KAT2A	AVX		
	C1608X5R0J475K	TDK		
C8	GRM188R70J105KA01D	Murata	1µF/6.3V Ceramic Capacitor, X7R, Size 0603	1
	06036C105KAT2A	AVX		
	C1608X5R0J105K	TDK		
C9	GRM21BR72A474KA73	Murata	0.47µF/100V,X7R,0805	1
	08051C474KAT2A	AVX		
C11	GRM188R71H102KA01D	Murata	1nF/50V Cermiac Capacitor, X7R, Size 0603	1
	06035C102KAT2A	AVX		
	C1608X7R1H102K	TDK		
C12	GRM188R71H472MA01D	Murata	4.7nF/50V Cermiac Capacitor, X7R, Size 0603	1
	06035C472KAT2A	AVX		
	C1608X7R1H472K	TDK		
C13	6SEPC470MX	Sanyo[5]	470µF/6.3V, 7mΩ, OSCON	1
	6SEPC470M	Sanyo	470µF/6.3V, 7mΩ, OSCON	
C15 (OPEN)	6TPB470M	Sanyo	470µF/6.3V, POSCAP	
C5 (OPEN)	GRM32ER60J107ME20L	Murata	100µF/6.3V Ceramic Capacitor, X7R, Size 1210	
C18	GRM1885C1H150JA01D	Murata	15pF, 50V, 0603, NPO	1
	06035A150JAT2A	AVX		
D1	BAT46W-TP	MCC[6]	100V Small Signal Schottky Diode, SOD123	1
L1	CDEP147NP- 1R5M-95	Sumida[7]	1.5µH, 27/22Asat, 20Arms for 40C rise	1

Notes:

1. Panasonic: www.panasonic.com.
2. AVX: www.avx.com.
3. TDK: www.tdk.com.
4. Murata: www.murata.com.
5. Sanyo: www.sanyo.com.
6. MCC: www.mccsemi.com.
7. Sumida: www.sumida.com.

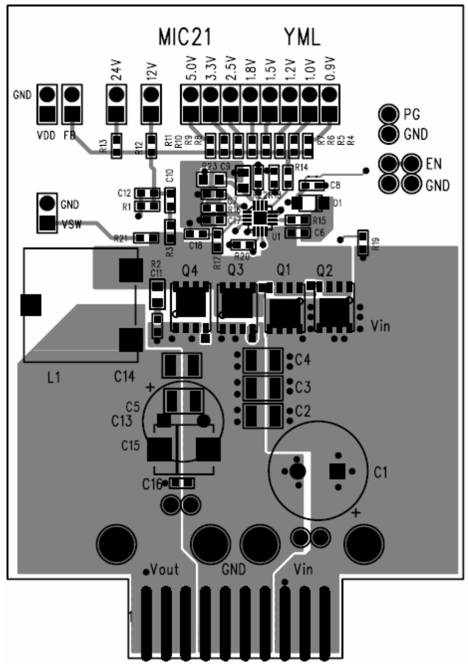
Bill of Materials (Continued)

Item	Part Number	Manufacturer	Description	Qty.
Q1, Q3	BSC067N06LS3	Infineon[8]	MOSFET, N-CH, Power SO-8	2
Q2, Q4 (OPEN)				
R1	CRCW060310K0FKEA	Vishay Dale[9]	10kΩ Resistor, Size 0603, 1%	1
R2, R23	CRCW08051R21FKEA	Vishay Dale	1.21Ω Resistor, Size 0805, 5%	2
R3	CRCW06035K23FKEA	Vishay Dale	5.23K,1%,1/10W,0603.	1
R4	CRCW060380K6FKEA	Vishay Dale	80.6kΩ Resistor, Size 0603, 1%	1
R5	CRCW060340K2FKEA	Vishay Dale	40.2kΩ Resistor, Size 0603, 1%	1
R6	CRCW060320K0FKEA	Vishay Dale	20kΩ Resistor, Size 0603, 1%	1
R7	CRCW060311K5FKEA	Vishay Dale	11.5kΩ Resistor, Size 0603, 1%	1
R8	CRCW06038K06FKEA	Vishay Dale	8.06kΩ Resistor, Size 0603, 1%	1
R9	CRCW06034K75FKEA	Vishay Dale	4.75kΩ Resistor, Size 0603, 1%	1
R10	CRCW06033K24FKEA	Vishay Dale	3.24kΩ Resistor, Size 0603, 1%	1
R11	CRCW06031K91FKEA	Vishay Dale	1.91kΩ Resistor, Size 0603, 1%	1
R12 (OPEN)	CRCW0603715R0FKEA	Vishay Dale	715Ω Resistor, Size 0603, 1%	
R13 (OPEN)	CRCW0603348R0FKEA	Vishay Dale	348Ω Resistor, Size 0603, 1%	
R14, R15, R19	CRCW06030000FKEA	Vishay Dale	0Ω Resistor, Size 0603, 5%	3
R16	CRCW08052R0FKEA	Vishay Dale	2Ω Resistor, Size 0805, 5%	1
R17	CRCW06031K65FKEA	Vishay Dale	1.65kΩ Resistor, Size 0603, 1%	1
R18	CRCW060349K9FKEA	Vishay/Dale	49.9K,1%,1/10W,0603	1
R20 (OPEN)	No Load			
R21	CRCW060349R9FKEA	Vishay Dale	49.9Ω Resistor, Size 0603, 1%	1
R22	CRCW0603100KFKEA	Vishay Dale	100kΩ Resistor, Size 0603, 1%	1
U1	**MIC2101YML** **MIC2102YML**	**Micrel. Inc.[10]**	**38V Synchronous Buck DC/DC Controller**	**1**

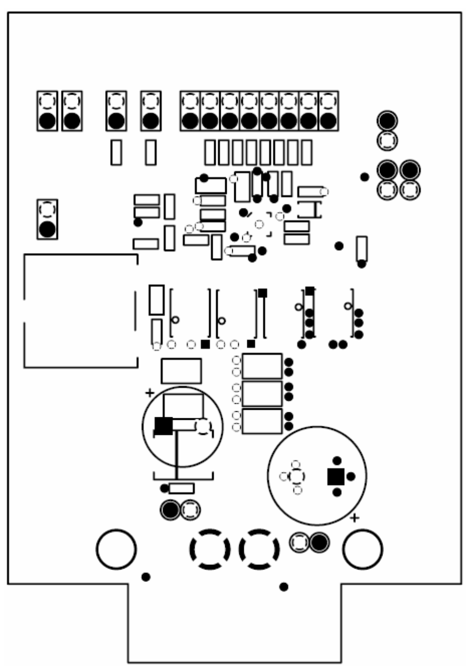
Notes:

8. Infineon: www.infineon.com.
9. Vishay: www.vishay.com.
10. **Micrel, Inc.: www.micrel.com.**

Evaluation Board PCB Layout

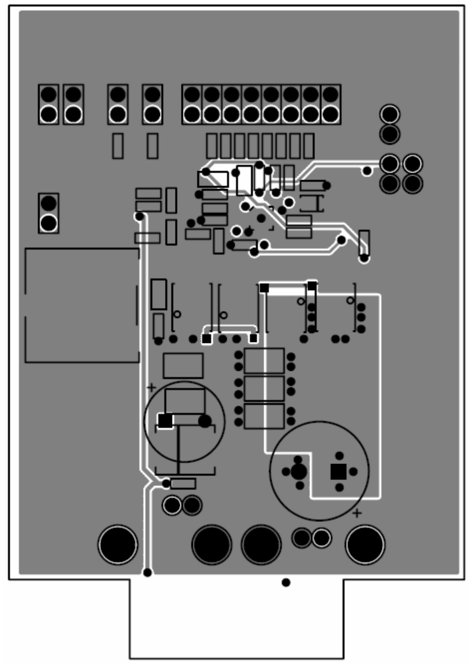


MIC2101/02 Evaluation Board – Copper Layer 1 (Top)

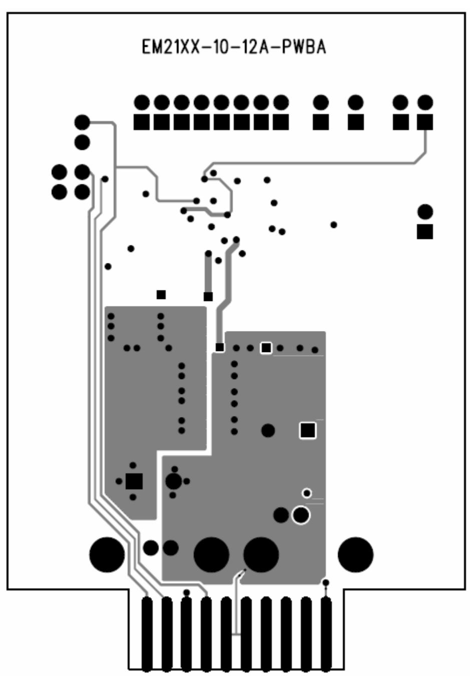


MIC2101/02 Evaluation Board – Copper Layer 2 (Mid-Layer 1)

Evaluation Board PCB Layout



MIC2101/02 Evaluation Board – Copper Layer 3 (Mid-Layer 2)



MIC2101/02 Evaluation Board – Copper Layer 4 (Bottom)

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