# MIC2103/04 Evaluation Board

## 75V, Synchronous Buck Controllers featuring Adaptive On-Time Control

### Hyper Speed Control™ Family

## General Description

The Micrel MIC2103/04 are constant-frequency, synchronous buck controllers featuring a unique adaptive on-time control architecture. The MIC2103/04 operates over an input supply range of 4.5V to 75V 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 MIC2103 has Hyper Light Load® architecture, so it can operate in pulse skipping mode at light load. However, from medium load to heavy load, it operates in fixed frequency CCM mode. The MIC2104 has Hyper Speed Control architecture which operates in fixed frequency CCM mode under all load conditions.

The basic parameters of the evaluation board are:

1. Input: 12V to 75V
2. Output: 0.8V to 5V at 10A (1)
3. 200kHz Switching Frequency (Adjustable 200kHz to 600kHz)

**Note:**

1. Refer to temperature curves shown in Typical Characteristics section.

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

### Requirements

The MIC2103 and MIC2104 evaluation board requires only a single power supply with at least 10A current capability. The MIC2103/04 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 VIN and GND terminals may damage the device. The maximum VIN of the board is rated at 75V. Exceeding 75V on the VIN could damage the device.

## Getting Started

1. **VIN Supply**

Connect a supply to the VIN and GND terminals, paying careful attention to the polarity and the supply range (12V < VIN < 75V). Monitor $I_{IN}$ with a current meter and input voltage at VIN and GND terminals with voltmeter. Do not apply power until step 4.

2. **Connect Load and Monitor Output**

Connect a load to the VOUT 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 VOUT terminal and load to monitor the output current. Ensure the output voltage is monitored at the VOUT terminal.

3. **Enable Input**

The EN pin has an on board 100k pull-up resistor (R22) to VIN, 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 MIC2103/04 evaluation board.

4. **Turn on the Power**

Turn on the VIN supply and verify that the output voltage is regulated to 5.0V.

## Ordering Information

| Part Number | Description |
|---|---|
| MIC2103YML 10A EV | MIC2103 Evaluation Board up to 5V Output |
| MIC2104YML 10A EV | MIC2104 Evaluation Board up to 5V Output |

# Features

### Feedback Resistors

The output voltage on the MIC2103/04 evaluation board, which is preset to 5.0V, is determined by the feedback divider:

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

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:

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

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, which is one of the most critical waveforms for the converter.

### Current Limit

The MIC2103/04 uses the $R_{DS(ON)}$ and external resistor connected from ILIM pin to SW node to decide the current limit.

In each switching cycle of the MIC2103/04 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 to allow 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 (R17). If the absolute value of the voltage drop on the bottom FET is greater than $V_{CL}$, 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.

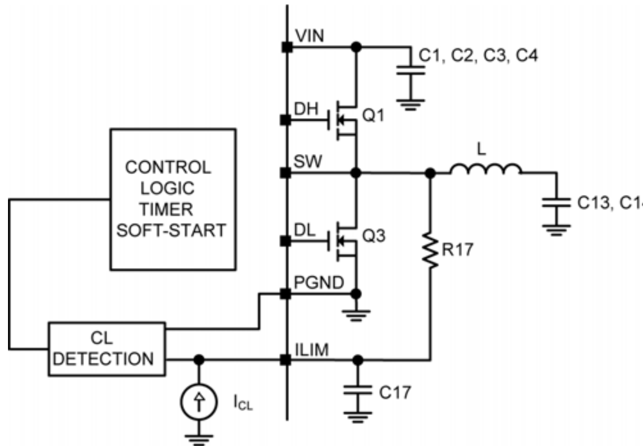



**Figure 1. MIC2103/04 Current Limiting Circuit**

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

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

Where $I_{CLIM}$ = Desired Current limit

$\Delta_{PP}$ = 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 a 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 $I_{CL}$ 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 MIC2103/04 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.

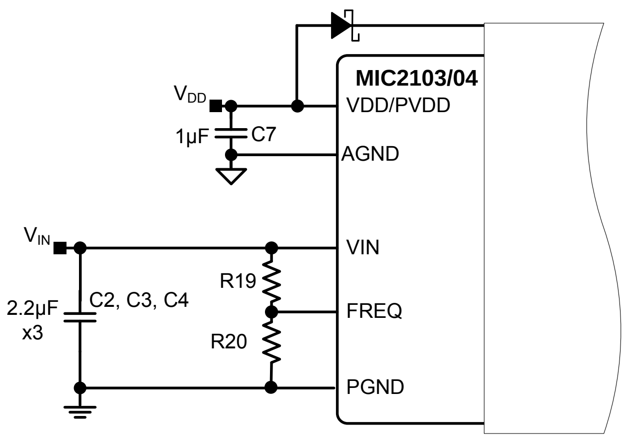



**Figure 2. Switching Frequency Adjustment**

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 at 12V input voltage. For more precise setting, it is recommended to use the following graph:

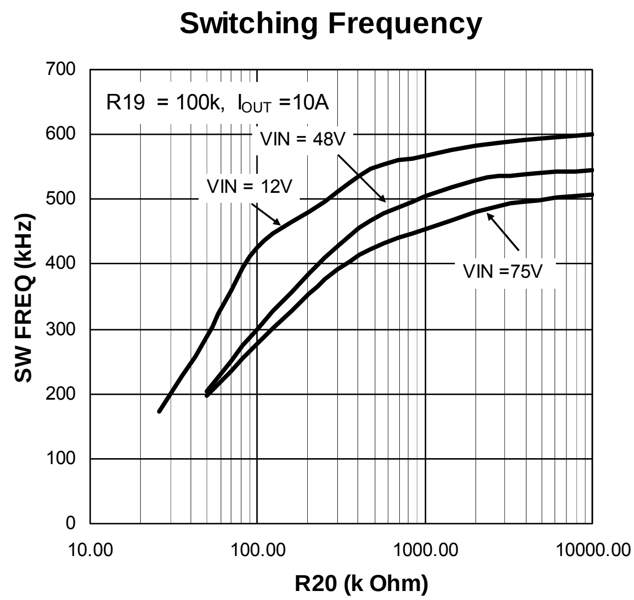
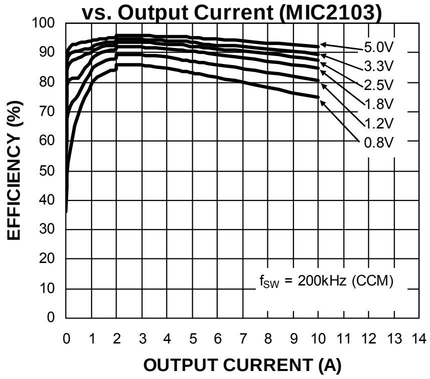


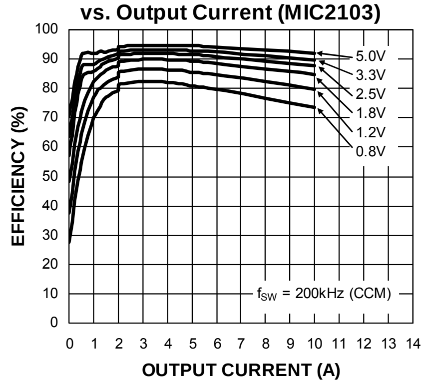

**Figure 3. Switching Frequency vs. R20**

# MIC2103/04 0.8V to 5V/10A Evaluation Board Typical Characteristics

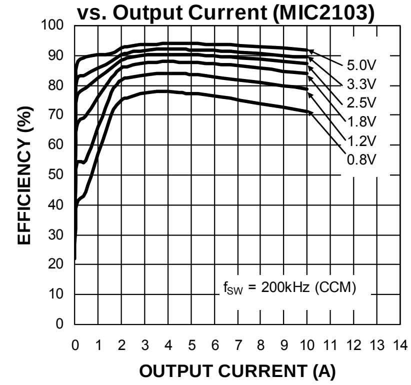
**Efficiency ($V_{IN}$ =12V) vs. Output Current (MIC2103)**



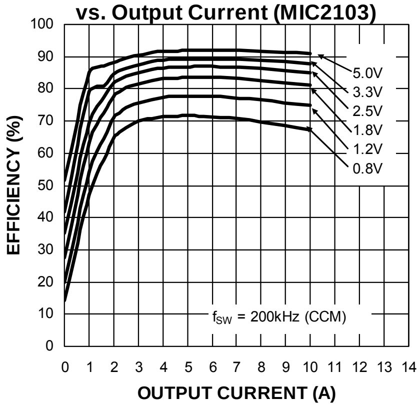

**Efficiency ($V_{IN}$ = 18V) vs. Output Current (MIC2103)**



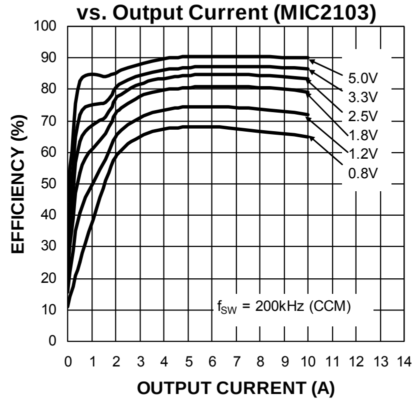

**Efficiency ($V_{IN}$ = 24V) vs. Output Current (MIC2103)**



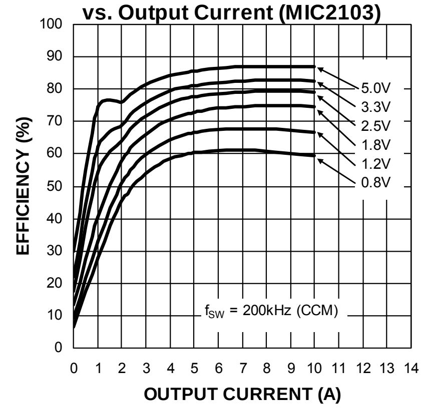

**Efficiency ($V_{IN}$ = 38V) vs. Output Current (MIC2103)**




**Efficiency ($V_{IN}$ = 48V) vs. Output Current (MIC2103)**

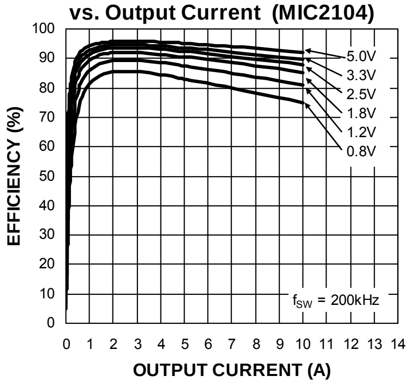



**Efficiency ($V_{IN}$ = 75V) vs. Output Current (MIC2103)**

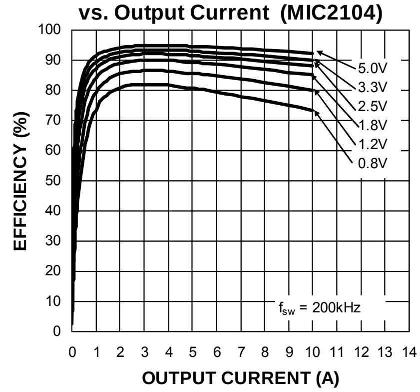


## MIC2103/04 0.8V to 5V/10A Evaluation Board Typical Characteristics (Continued)

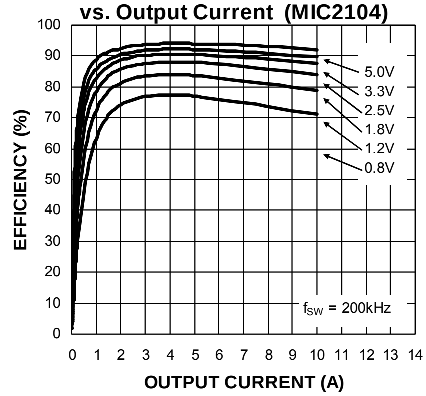
**Efficiency ($V_{IN}$ =12V) vs. Output Current (MIC2104)**



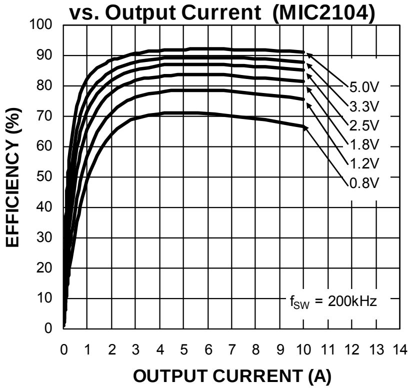

**Efficiency ($V_{IN}$ = 18V) vs. Output Current (MIC2104)**



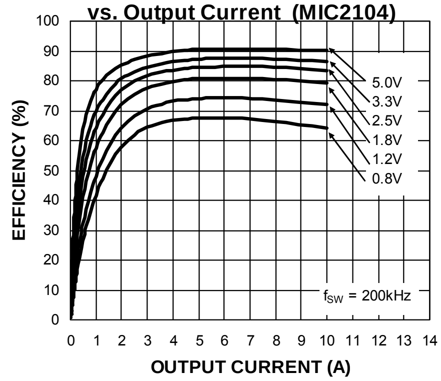

**Efficiency ($V_{IN}$ = 24V) vs. Output Current (MIC2104)**



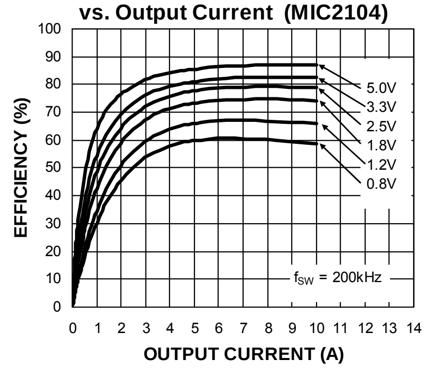

**Efficiency ($V_{IN}$ = 38V) vs. Output Current (MIC2104)**



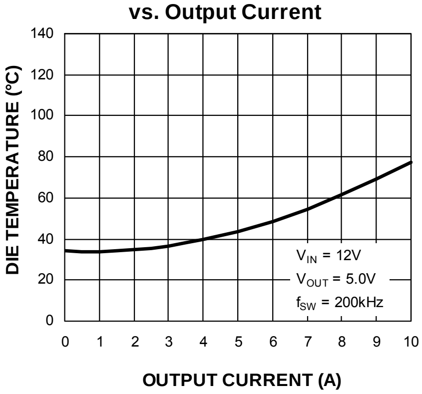

**Efficiency ($V_{IN}$ = 48V) vs. Output Current (MIC2104)**



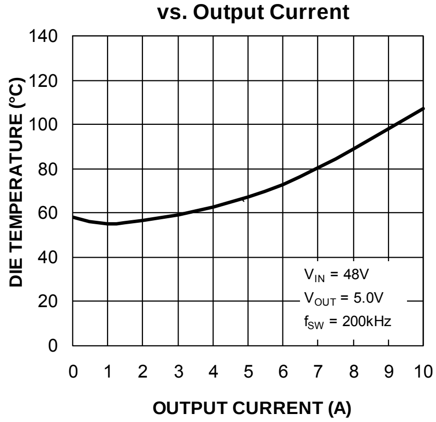

**Efficiency ($V_{IN}$ = 75V) vs. Output Current (MIC2104)**



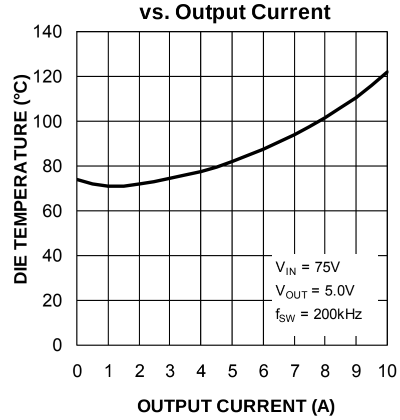

**Die Temperature* ($V_{IN}$ = 12V) vs. Output Current**




**Die Temperature* ($V_{IN}$ = 48V) vs. Output Current**




**Die Temperature* ($V_{IN}$ = 75V) 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.

## MIC2103/04 0.8V to 5V/10A Output Evaluation Board Schematic

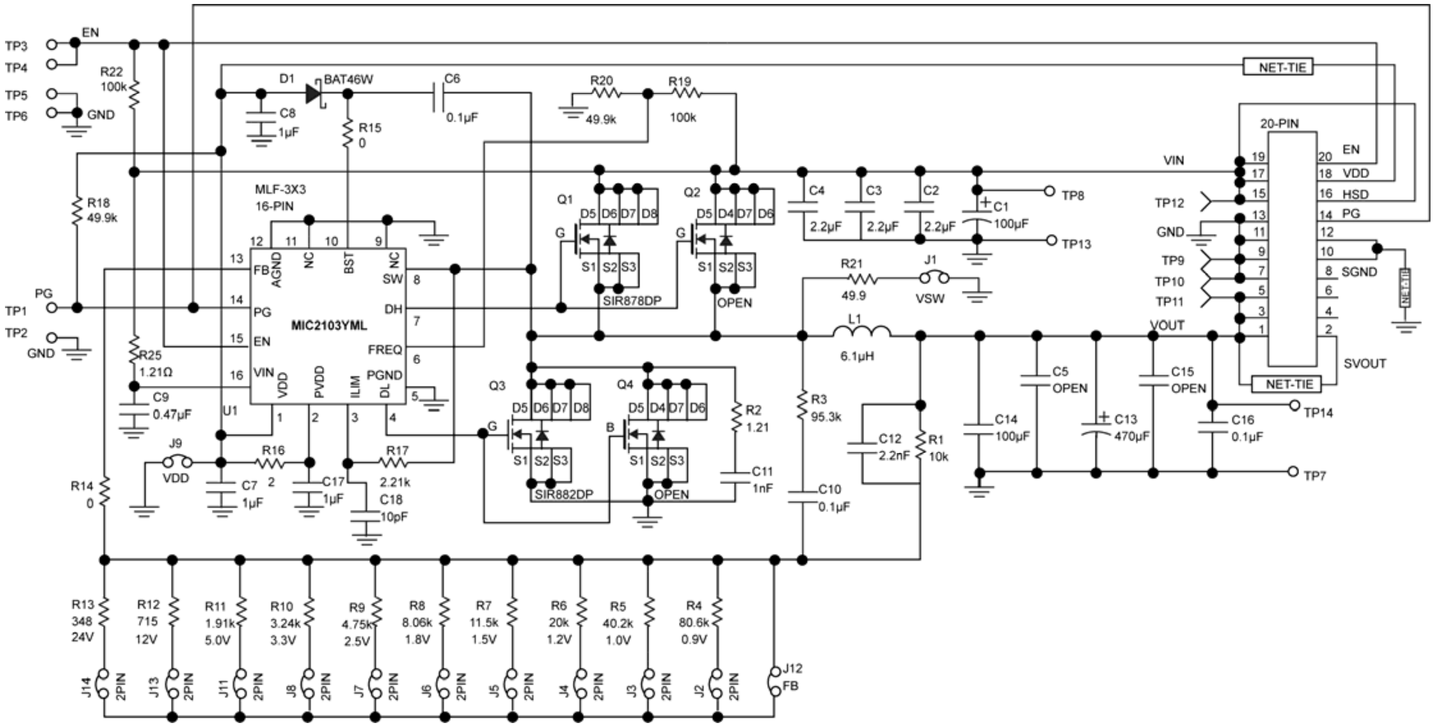



**Figure 1. MIC2103/04 Evaluation Board for 0.8V to 5V/10A Output**

## Bill of Materials 0.8V to 5V/10A Output

| Item | Part Number | Manufacturer | Description | Qty |
|---|---|---|---|---|
| C1 | EEU-FC2A101 | Panasonic[1] | 100µF Aluminum Capacitor, 100V | 1 |
| C2, C3, C4 | GRM32ER72A225K | Murata[2] | 2.2µF/100V Ceramic Capacitor, X7R, Size 1210 | 3 |
| | C3225X7R2A225K | TDK[3] | | |
| | 12101C225KAT2A | AVX[4] | | |
| C14 | GRM32ER60J107ME20L | Murata | 100µF/6.3V Ceramic Capacitor, X5R, Size 1210 | 1 |
| | 12106D107MAT2A | AVX | | |
| | C3225X5ROJ107M | TDK | | |
| C6, C16 | GRM188R71H104KA93D | Murata | 0.1µF/50V Ceramic Capacitor, X7R, Size 0603 | 2 |
| | 06035C104KAT2A | AVX | | |
| | C1608X7R1H104K | TDK | | |
| C7, C8, C17 | GRM188R70J105KA01D | Murata | 1µF/6.3V Ceramic Capacitor, X7R, Size 0603 | 3 |
| | 06036C105KAT2A | AVX | | |
| | C1608X5R0J105K | TDK | | |
| C9 | GRM21BR72A474KA73 | Murata | 0.47µF/100V Ceramic Capacitor, X7R, Size 0805 | 1 |
| | 08051C474KAT2A | AVX | | |
| C10 | GRM188R72A104KA35D | Murata | 0.1µF/100V Ceramic Capacitor, X7R, Size 0603 | 1 |
| | C1608X7S2A104K | TDK | 0.1µF/100V,X7S,0603 | |
| C11 | GRM188R72A102KA01D | Murata | 1nF/100V Cermiac Capacitor, X7R, Size 0603 | 1 |
| | 06031C102KAT2A | AVX | | |
| | C1608X7R2A102K | TDK | | |
| C12 | GRM188R72A222KA01D | Murata | 2.2nF/100V Cermiac Capacitor, X7R, Size 0603 | 1 |
| | 06031C222KAT2A | AVX | | |
| | C1608X7R2A222K | TDK | | |
| C13 | 6SEPC470MX | Sanyo[5] | 470µF/6.3V, 7m-ohms, OSCON | 1 |
| | 6SEPC470M | Sanyo | 470µF/6.3V, 7m-ohms, OSCON | |
| C15 (OPEN) | 6TPB470M | Sanyo | 470µF/6.3V, POSCAP | |
| C5 (OPEN) | GRM32ER60J107ME20L | Murata | 100µF/6.3V Ceramic Capacitor, X7R, Size 1210 | |
| C18 | GCM1885C2A100JA16D | Murata | 10pF, 100V, 0603, NPO | 1 |
| | 06031A100JAT2A | AVX | | |
| D1 | BAT46W-TP | MCC[6] | 100V Small Signal Schottky Diode, SOD123 | 1 |
| L1 | CDEP147NP-6R1MC-95 | Sumida[7] | 6.1µH Inductor, 14.8A RMS Current | 1 |

**Notes:**

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

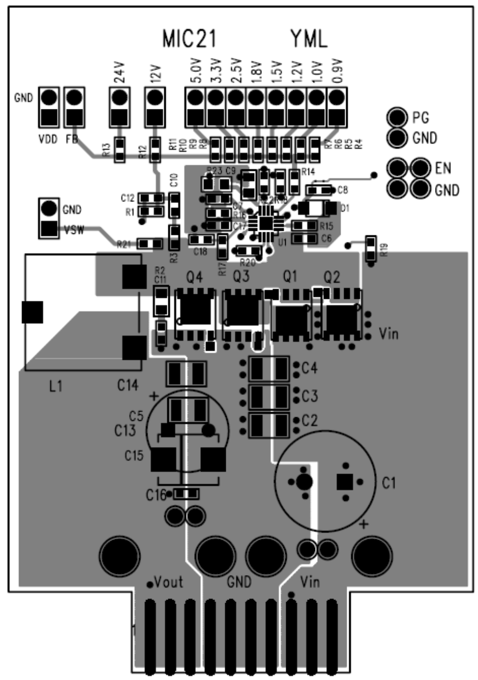
## Bill of Materials 0.8V to 5V/10A Output (Continued)

| Item | Part Number | Manufacturer | Description | Qty |
|---|---|---|---|---|
| Q1 | SIR878DP | Vishay[8] | MOSFET, N-CH, Power SO-8 | 1 |
| Q3 | SIR882DP | Vishay | MOSFET, N-CH, Power SO-8 | 1 |
| Q2, Q4 (OPEN) | | | | |
| R1 | CRCW060310K0FKEA | Vishay Dale | 10kΩ Resistor, Size 0603, 1% | 1 |
| R2, R23 | CRCW08051R21FKEA | Vishay Dale | 1.21Ω Resistor, Size 0805, 5% | 2 |
| R3 | CRCW060395K30FKEA | Vishay Dale | 95.3kΩ Resistor, Size 0603, 1% | 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 | CRCW06030000FKEA | Vishay Dale | 0Ω Resistor, Size 0603, 5% | 2 |
| R16 | CRCW08052R0FKEA | Vishay Dale | 2Ω Resistor, Size 0805, 5% | 1 |
| R17 | CRCW06032K21FKEA | Vishay Dale | 2.21kΩ Resistor, Size 0603, 1% | 1 |
| R18, R20 | CRCW060349K9FKEA | Vishay Dale | 49.9kΩ Resistor, Size 0603, 1% | 2 |
| R19, R22 | CRCW0603100K0FKEA | Vishay Dale | 100kΩ Resistor, Size 0603, 1% | 2 |
| R21 | CRCW060349R9FKEA | Vishay Dale | 49.9Ω Resistor, Size 0603, 1% | 1 |
| **U1** | **MIC2103YML**<br>**MIC2104YML** | **Micrel. Inc.[9]** | **75V Synchronous Buck DC-DC Controller** | **1** |

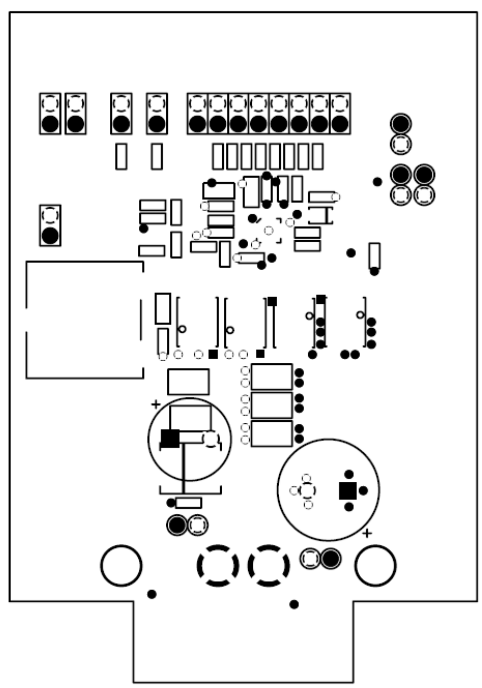
**Notes:**

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

## Evaluation Board PCB Layout

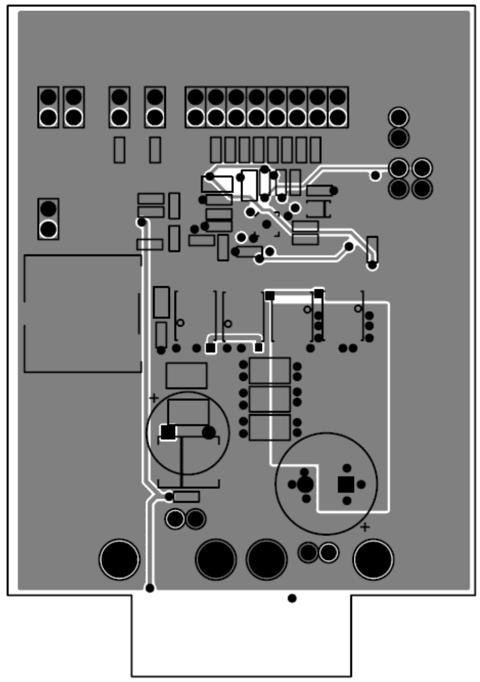



**MIC2103/04 Evaluation Board – Copper Layer 1 (Top)**

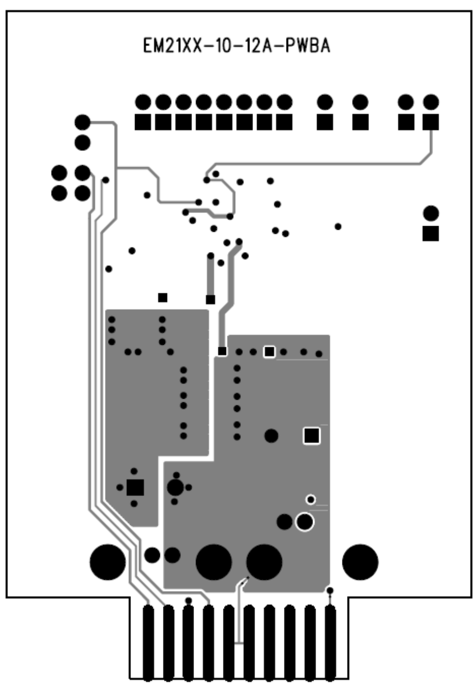


**MIC2103/04 Evaluation Board – Copper Layer 2 (Mid-Layer 1)**

## Evaluation Board PCB Layout (Continued)



**MIC2103/04 Evaluation Board – Copper Layer 3 (Mid-Layer 2)**




**MIC2103/04 Evaluation Board – Copper Layer 4 (Bottom)**

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