

## 26V, 14A DC-to-DC Power Module

### Features

- No Compensation Required
- Up to 14A Output Current
- >93% Peak Efficiency
- Output Voltage:  $0.8V$  to  $0.85 \cdot V_{IN}$  with  $\pm 1\%$  Accuracy
- Adjustable Switching Frequency from 200 kHz to 600 kHz
- Enable Input and Open-Drain Power Good Output
- Hyper Speed Control® (MIC45212-2) Architecture enables Fast Transient Response
- HyperLight Load® (MIC45212-1) improves Light Load Efficiency
- Supports Safe Start-up into Pre-Biased Output
- $-40^{\circ}C$  to  $+125^{\circ}C$  Junction Temperature Range
- Thermal Shutdown Protection
- Short-Circuit Protection with Hiccup mode
- Adjustable Current Limit
- Available in 64-Pin 12 mm x 12 mm x 4 mm QFN Package

### Applications

- High-Power Density Point-of-Load Conversion
- Servers, Routers, Networking, and Base Stations
- FPGAs, DSP and Low-Voltage ASIC Power Supplies
- Industrial and Medical Equipment

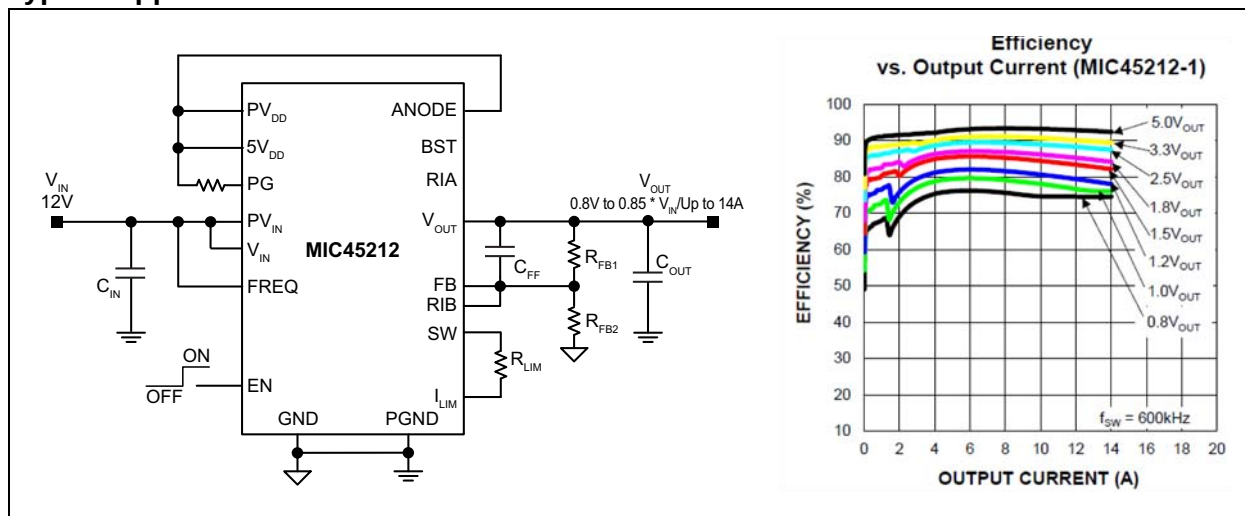
### General Description

The MIC45212 is a synchronous, step-down regulator module, featuring a unique adaptive ON-time control architecture. The module incorporates a DC-to-DC controller, power MOSFETs, bootstrap diode, bootstrap capacitor and an inductor in a single package, 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 are optimized to achieve high efficiency at a low output voltage. The fully optimized design can deliver up to 14A current under a wide input voltage range of 4.5V to 26V, without requiring additional cooling.

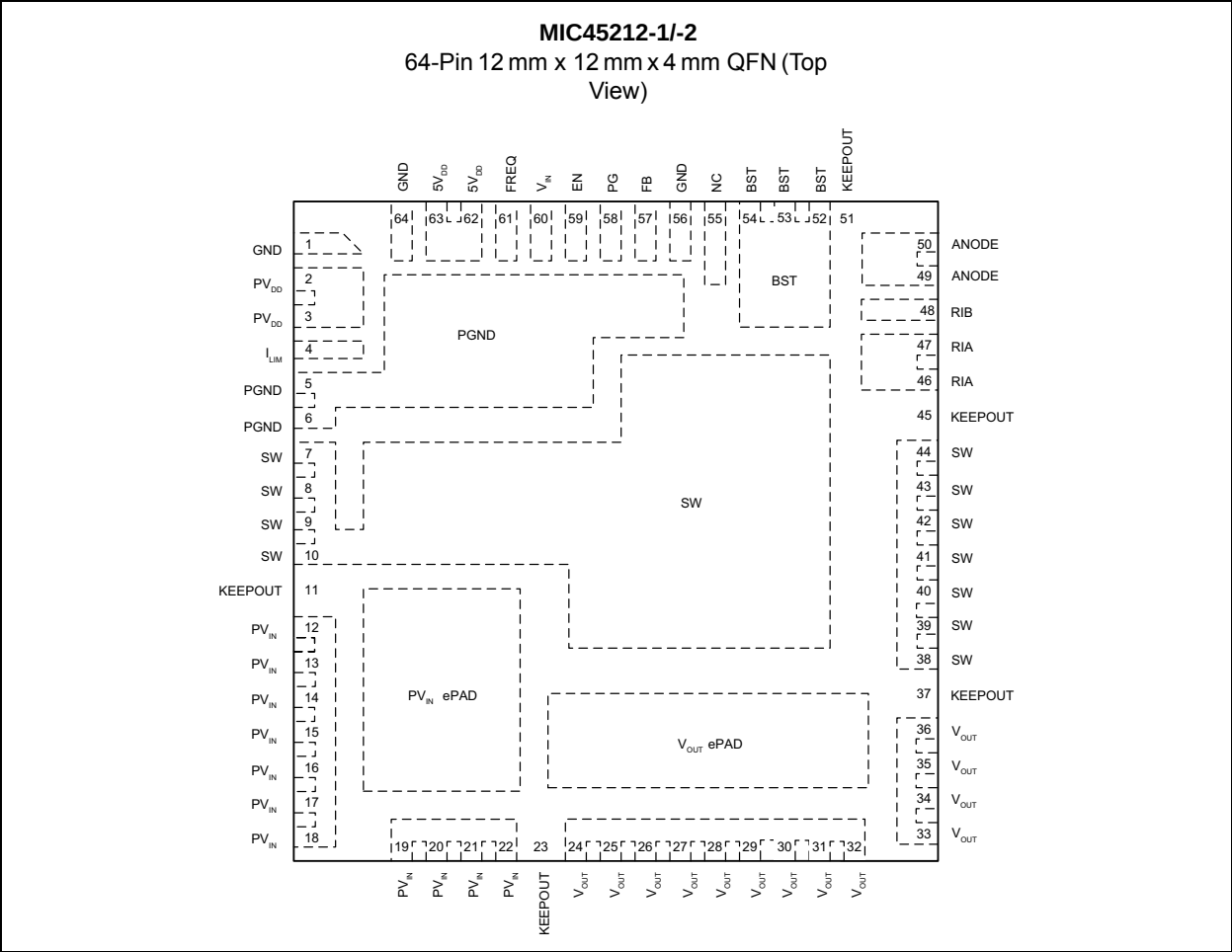
The MIC45212-1 uses the HyperLight Load (HLL) while the MIC45212-2 uses the Hyper Speed Control (HSC) architecture, which enables ultra-fast load transient response, allowing for a reduction of output capacitance. The MIC45212 offers 1% output accuracy that can be adjusted from 0.8V to  $0.85 \cdot V_{IN}$  with two external resistors. Additional features include thermal shutdown protection, input undervoltage lockout, adjustable current limit and short-circuit protection. The MIC45212 allows for safe start-up into a pre-biased output.

### Typical Application Schematic



# MIC45212-1/-2

## Package Types





# MIC45212-1/-2

## 1.0 ELECTRICAL CHARACTERISTICS

### Absolute Maximum Ratings†

|                                                             |                               |
|-------------------------------------------------------------|-------------------------------|
| $V_{PVIN}$ , $V_{VIN}$ to PGND .....                        | -0.3V to +30V                 |
| $V_{PVDD}$ , $V_{5VDD}$ , $V_{ANODE}$ to PGND .....         | -0.3V to +6V                  |
| $V_{SW}$ , $V_{FREQ}$ , $V_{ILIM}$ , $V_{EN}$ to PGND ..... | -0.3V to ( $V_{IN} + 0.3V$ )  |
| $V_{BST}$ to $V_{SW}$ .....                                 | -0.3V to +6V                  |
| $V_{BST}$ to PGND .....                                     | -0.3V to +36V                 |
| $V_{PG}$ to PGND .....                                      | -0.3V to ( $5V_{DD} + 0.3V$ ) |
| $V_{FB}$ , $V_{RIB}$ to PGND .....                          | -0.3V to ( $5V_{DD} + 0.3V$ ) |
| PGND to GND .....                                           | -0.3V to +0.3V                |
| Junction Temperature .....                                  | +150°C                        |
| Storage Temperature ( $T_S$ ) .....                         | -65°C to +150°C               |
| Lead Temperature (soldering, 10s) .....                     | +260°C                        |

† **Notice:** Stresses above those listed under “Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operational sections of this specification is not intended. Exposure to maximum rating conditions for extended periods may affect device reliability.

### Operating Ratings<sup>(1)</sup>

|                                                     |                 |
|-----------------------------------------------------|-----------------|
| Supply Voltage ( $V_{PVIN}$ , $V_{VIN}$ ) .....     | 4.5V to 26V     |
| Output Current .....                                | 14A             |
| Enable Input ( $V_{EN}$ ) .....                     | 0V to $V_{IN}$  |
| Power-Good ( $V_{PG}$ ) .....                       | 0V to $5V_{DD}$ |
| Junction Temperature ( $T_J$ ) .....                | -40°C to +125°C |
| Junction Thermal Resistance <sup>(2)</sup>          |                 |
| 12 mm x 12 mm x 4 mm QFN-64 ( $\theta_{JA}$ ) ..... | 12.6°C/W        |
| 12 mm x 12 mm 4 mm QFN-64 ( $\theta_{JC}$ ) .....   | 3.5°C/W         |

**Note 1:** The device is not ensured to function outside the operating range.

**2:**  $\theta_{JA}$  and  $\theta_{JC}$  were measured using the MIC45212 evaluation board.

**TABLE 1-1: ELECTRICAL CHARACTERISTICS<sup>(1)</sup>**

| <b>Electrical Specifications:</b> unless otherwise specified, $V_{PVIN} = V_{VIN}$ ; $V_{IN} = V_{EN} = 12V$ ; $V_{OUT} = 3.3V$ ; $V_{BST} - V_{SW} = 5V$ ; $T_J = +25^{\circ}C$ . <b>Boldface</b> values indicate $-40^{\circ}C \leq T_J \leq +125^{\circ}C$ . |                                       |              |      |              |         |                                                                                                |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------|--------------|------|--------------|---------|------------------------------------------------------------------------------------------------|
| Symbol                                                                                                                                                                                                                                                          | Parameter                             | Min.         | Typ. | Max.         | Units   | Test Conditions                                                                                |
| <b>Power Supply Input</b>                                                                                                                                                                                                                                       |                                       |              |      |              |         |                                                                                                |
| $V_{IN}, V_{PVIN}$                                                                                                                                                                                                                                              | Input Voltage Range                   | <b>4.5</b>   | —    | <b>26</b>    | V       | —                                                                                              |
| $I_Q$                                                                                                                                                                                                                                                           | Quiescent Supply Current (MIC45212-1) | —            | —    | <b>0.75</b>  | mA      | $V_{FB} = 1.5V$                                                                                |
| $I_Q$                                                                                                                                                                                                                                                           | Quiescent Supply Current (MIC45212-2) | —            | 2.1  | <b>3</b>     | mA      | $V_{FB} = 1.5V$                                                                                |
| $I_{IN}$                                                                                                                                                                                                                                                        | Operating Current: MIC45208-1         | —            | 0.37 | —            | mA      | $PV_{IN} = V_{IN} = 12V$ ,<br>$V_{OUT} = 1.8V$ , $I_{OUT} = 0A$ ,<br>$f_{SW} = 600\text{ kHz}$ |
|                                                                                                                                                                                                                                                                 | MIC45208-2                            | —            | 54   | —            |         |                                                                                                |
| $I_{SHDN}$                                                                                                                                                                                                                                                      | Shutdown Supply Current               | —            | 0.1  | <b>10</b>    | $\mu A$ | $SW = \text{Unconnected}$ , $V_{EN} = 0V$                                                      |
| <b>5V<sub>DD</sub> Output</b>                                                                                                                                                                                                                                   |                                       |              |      |              |         |                                                                                                |
| $V_{DD}$                                                                                                                                                                                                                                                        | 5V <sub>DD</sub> Output Voltage       | <b>4.8</b>   | 5.1  | <b>5.4</b>   | V       | $V_{IN} = 7V \text{ to } 26V$ , $I_{5VDD} = 10\text{ mA}$                                      |
| UVLO                                                                                                                                                                                                                                                            | 5V <sub>DD</sub> UVLO Threshold       | <b>3.8</b>   | 4.2  | <b>4.6</b>   | V       | $V_{5VDD}$ Rising                                                                              |
| UVLO_HYS                                                                                                                                                                                                                                                        | 5V <sub>DD</sub> UVLO Hysteresis      | —            | 400  | —            | mV      | $V_{5VDD}$ Falling                                                                             |
| $V_{DD(LR)}$                                                                                                                                                                                                                                                    | LDO Load Regulation                   | 0.6          | 2    | 3.6          | %       | $I_{5VDD} = 0 \text{ to } 40\text{ mA}$                                                        |
| <b>Reference</b>                                                                                                                                                                                                                                                |                                       |              |      |              |         |                                                                                                |
| $V_{FB}$                                                                                                                                                                                                                                                        | Feedback Reference Voltage            | 0.792        | 0.8  | 0.808        | V       | $T_J = +25^{\circ}C$                                                                           |
|                                                                                                                                                                                                                                                                 |                                       | <b>0.784</b> | 0.8  | <b>0.816</b> |         | $-40^{\circ}C \leq T_J \leq +125^{\circ}C$                                                     |
| $I_{FB\_BIAS}$                                                                                                                                                                                                                                                  | Feedback Bias Current                 | —            | 5    | <b>500</b>   | nA      | $V_{FB} = 0.8V$                                                                                |
| <b>Enable Control</b>                                                                                                                                                                                                                                           |                                       |              |      |              |         |                                                                                                |
| EN <sub>HIGH</sub>                                                                                                                                                                                                                                              | EN Logic Level High                   | <b>1.8</b>   | —    | —            | V       | —                                                                                              |
| EN <sub>LOW</sub>                                                                                                                                                                                                                                               | EN Logic level Low                    | —            | —    | <b>0.6</b>   | V       | —                                                                                              |
| EN <sub>HYS</sub>                                                                                                                                                                                                                                               | EN Hysteresis                         | —            | 200  | —            | mV      | —                                                                                              |
| $I_{ENBIAS}$                                                                                                                                                                                                                                                    | EN Bias Current                       | —            | 5    | <b>10</b>    | $\mu A$ | $V_{EN} = 12V$                                                                                 |
| <b>Oscillator</b>                                                                                                                                                                                                                                               |                                       |              |      |              |         |                                                                                                |
| $f_{SW}$                                                                                                                                                                                                                                                        | Switching Frequency                   | <b>400</b>   | 600  | <b>750</b>   | kHz     | $V_{FREQ} = V_{IN}$ , $I_{OUT} = 2A$                                                           |
|                                                                                                                                                                                                                                                                 |                                       | —            | 350  | —            |         | $V_{FREQ} = 50\% V_{IN}$ , $I_{OUT} = 2A$                                                      |
| $D_{MAX}$                                                                                                                                                                                                                                                       | Maximum Duty Cycle                    | —            | 85   | —            | %       | —                                                                                              |
| $D_{MIN}$                                                                                                                                                                                                                                                       | Minimum Duty Cycle                    | —            | 0    | —            | %       | $V_{FB} = 1V$                                                                                  |
| $t_{OFF(MIN)}$                                                                                                                                                                                                                                                  | Minimum OFF-Time                      | 140          | 200  | 260          | ns      | —                                                                                              |
| <b>Soft Start</b>                                                                                                                                                                                                                                               |                                       |              |      |              |         |                                                                                                |
| $t_{SS}$                                                                                                                                                                                                                                                        | Soft Start Time                       | —            | 3    | —            | ms      | FB Rising from 0V to 0.8V                                                                      |
| <b>Short-Circuit Protection</b>                                                                                                                                                                                                                                 |                                       |              |      |              |         |                                                                                                |
| $V_{CL\_OFFSET}$                                                                                                                                                                                                                                                | Current-Limit Threshold               | −30          | −14  | 0            | mV      | $V_{FB} = 0.79V$                                                                               |
| $V_{SC}$                                                                                                                                                                                                                                                        | Short-Circuit Threshold               | −23          | −7   | 9            | mV      | $V_{FB} = 0V$                                                                                  |
| $I_{CL}$                                                                                                                                                                                                                                                        | Current-Limit Source Current          | 50           | 70   | 90           | $\mu A$ | $V_{FB} = 0.79V$                                                                               |
| $I_{SC}$                                                                                                                                                                                                                                                        | Short-Circuit Source Current          | 25           | 35   | 45           | $\mu A$ | $V_{FB} = 0V$                                                                                  |
| <b>Leakage</b>                                                                                                                                                                                                                                                  |                                       |              |      |              |         |                                                                                                |
| $I_{SW\_Leakage}$                                                                                                                                                                                                                                               | SW, BST Leakage Current               | —            | —    | 10           | $\mu A$ | —                                                                                              |
| $I_{FREQ\_LEAK}$                                                                                                                                                                                                                                                | FREQ Leakage Current                  | —            | —    | 10           | $\mu A$ | —                                                                                              |

**Note 1:** Specification for packaged product only.

# MIC45212-1/-2

**TABLE 1-1: ELECTRICAL CHARACTERISTICS<sup>(1)</sup> (CONTINUED)**

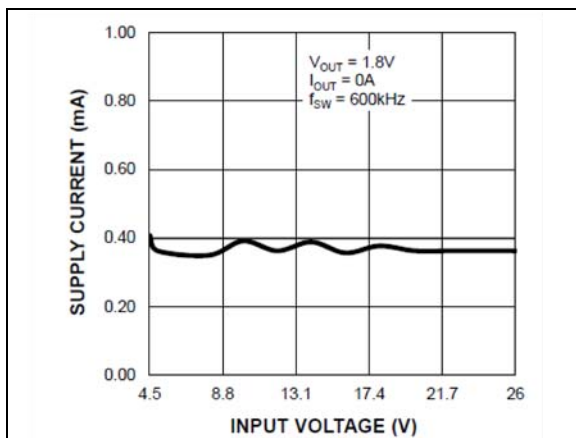
| <b>Electrical Specifications:</b> unless otherwise specified, $V_{PVIN} = V_{VIN}$ ; $V_{IN} = V_{EN} = 12V$ ; $V_{OUT} = 3.3V$ ; $V_{BST} - V_{SW} = 5V$ ; $T_J = +25^{\circ}C$ . <b>Boldface</b> values indicate $-40^{\circ}C \leq T_J \leq +125^{\circ}C$ . |                                     |           |      |            |             |                                                            |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------|-----------|------|------------|-------------|------------------------------------------------------------|
| Symbol                                                                                                                                                                                                                                                          | Parameter                           | Min.      | Typ. | Max.       | Units       | Test Conditions                                            |
| <b>Power Good (PG)</b>                                                                                                                                                                                                                                          |                                     |           |      |            |             |                                                            |
| $V_{PG\_TH}$                                                                                                                                                                                                                                                    | PG Threshold Voltage                | <b>85</b> | 90   | <b>95</b>  | % $V_{OUT}$ | Sweep $V_{FB}$ from Low-to-High                            |
| $V_{PG\_HYS}$                                                                                                                                                                                                                                                   | PG Hysteresis                       | —         | 6    | —          | % $V_{OUT}$ | Sweep $V_{FB}$ from High-to-Low                            |
| $t_{PG\_DLY}$                                                                                                                                                                                                                                                   | PG Delay Time                       | —         | 100  | —          | $\mu s$     | Sweep $V_{FB}$ from Low-to-High                            |
| $V_{PG\_LOW}$                                                                                                                                                                                                                                                   | PG Low Voltage                      | —         | 70   | <b>200</b> | mV          | $V_{FB} < 90\% \times V_{NOM}$ ,<br>$I_{PG} = 1\text{ mA}$ |
| <b>Thermal Protection</b>                                                                                                                                                                                                                                       |                                     |           |      |            |             |                                                            |
| $T_{SHD}$                                                                                                                                                                                                                                                       | Overtemperature Shutdown            | —         | 160  | —          | $^{\circ}C$ | $T_J$ Rising                                               |
| $T_{SHD\_HYS}$                                                                                                                                                                                                                                                  | Overtemperature Shutdown Hysteresis | —         | 15   | —          | $^{\circ}C$ | —                                                          |

**Note 1:** Specification for packaged product only.

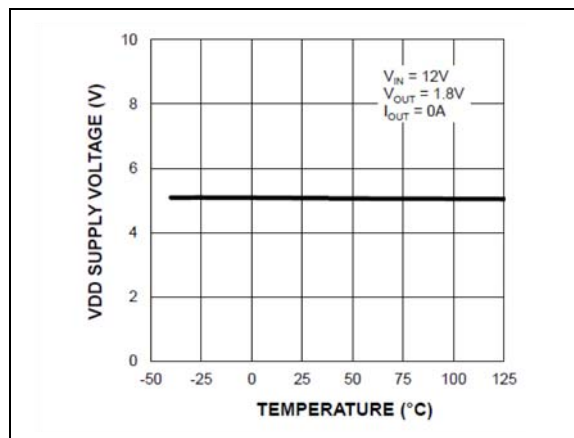
## 2.0 TYPICAL PERFORMANCE CURVES

**Note:** The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs or tables, the data presented may be outside the specified operating range (e.g., outside specified power supply range) and therefore outside the warranted range.

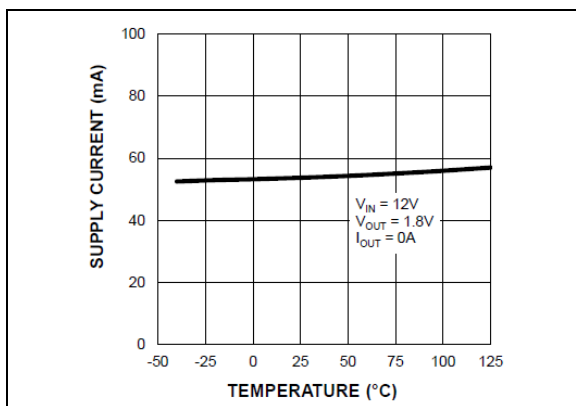
**Note:** Unless otherwise indicated,  $V_{IN} = V_{EN} = 12V$ ,  $V_{OUT} = 1.8V$ ,  $V_{BST} - V_{SW} = 5V$ ,  $T_J = +25^\circ C$ .



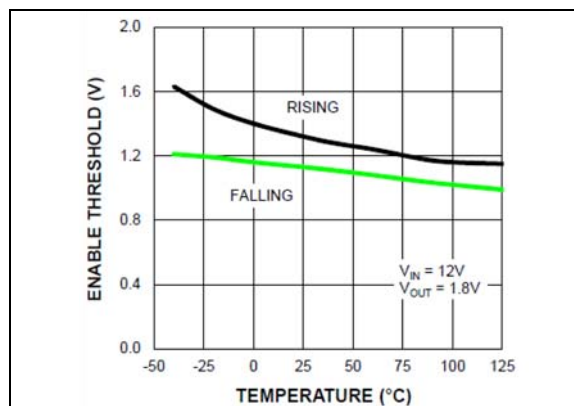
**FIGURE 2-1:**  $V_{IN}$  Operating Supply Current vs. Input Voltage (MIC45212-1).



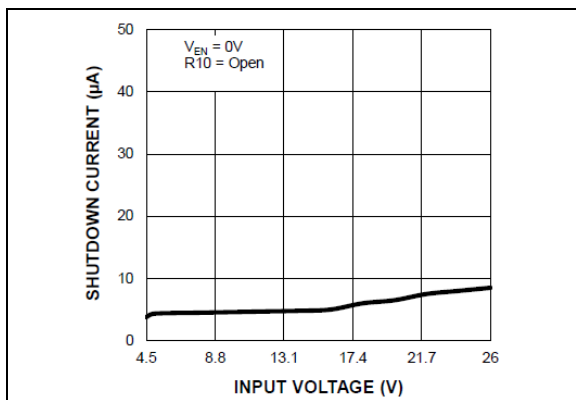
**FIGURE 2-4:**  $V_{DD}$  Supply Voltage vs. Temperature.



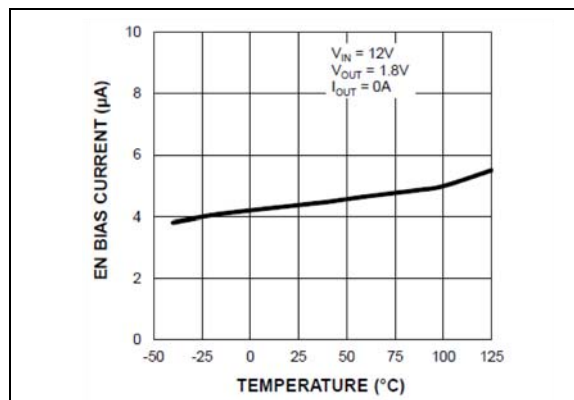
**FIGURE 2-2:**  $V_{IN}$  Operating Supply Current vs. Temperature (MIC45212-2).



**FIGURE 2-5:** Enable Threshold vs. Temperature.



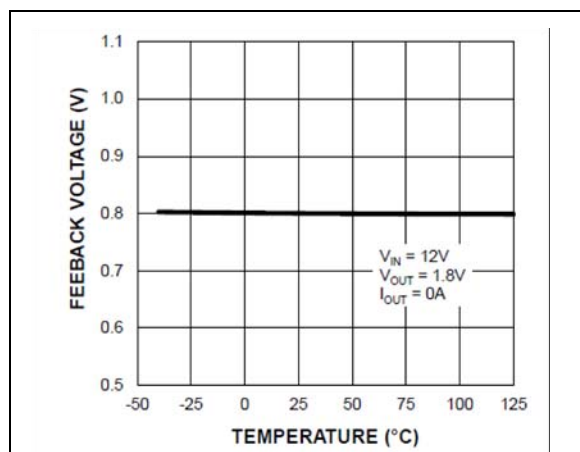
**FIGURE 2-3:**  $V_{IN}$  Shutdown Current vs. Input Voltage.



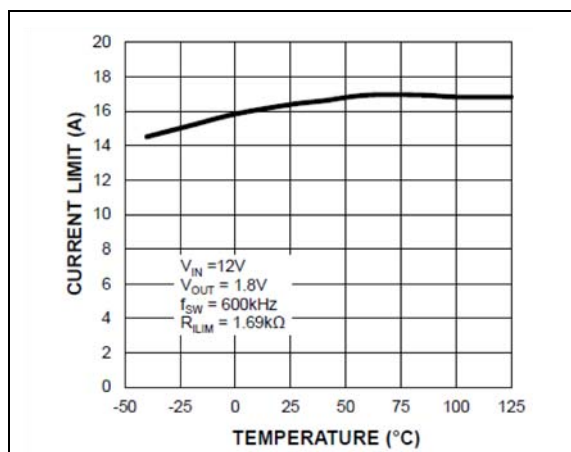
**FIGURE 2-6:** EN Bias Current vs. Temperature.

# MIC45212-1/-2

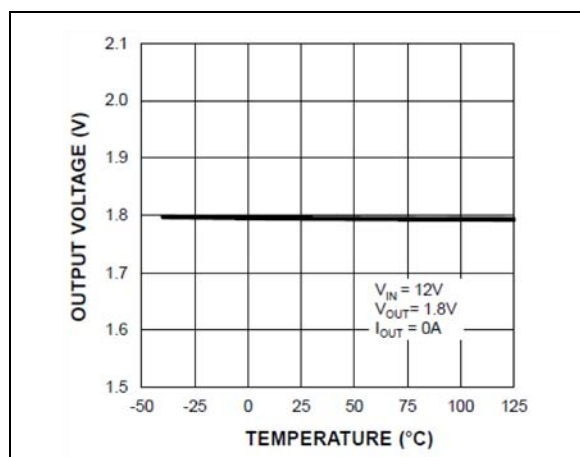
**Note:** Unless otherwise indicated,  $V_{IN} = V_{EN} = 12V$ ,  $V_{OUT} = 1.8V$ ,  $V_{BST} - V_{SW} = 5V$ ,  $T_J = +25^\circ C$ .



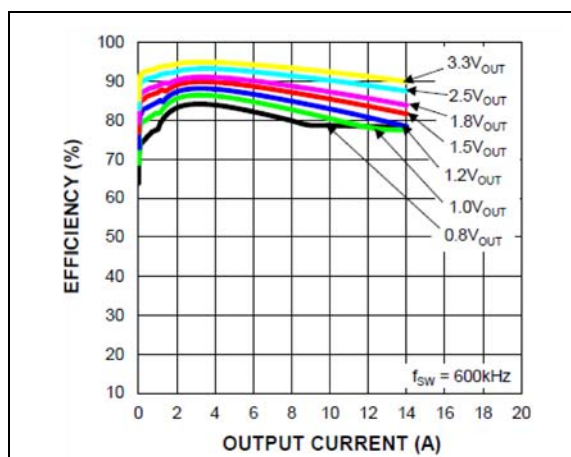
**FIGURE 2-7:** Feedback Voltage vs. Temperature.



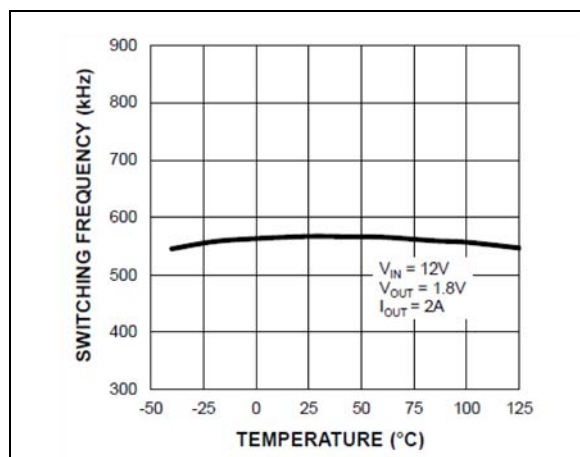
**FIGURE 2-10:** Output Peak Current-Limit vs. Temperature.



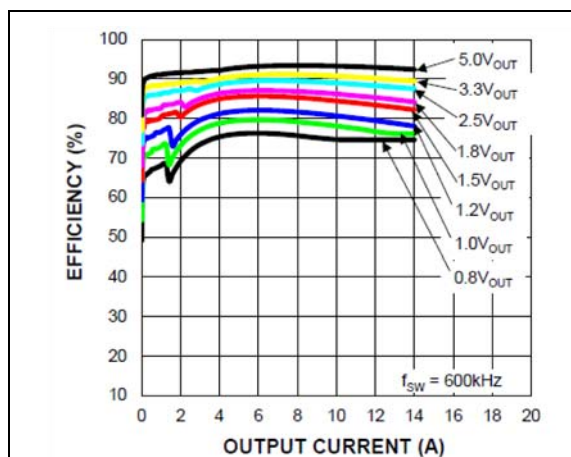
**FIGURE 2-8:** Output Voltage vs. Temperature.



**FIGURE 2-11:** Efficiency vs. Output Current (MIC45212-1,  $V_{IN} = 5V$ ).

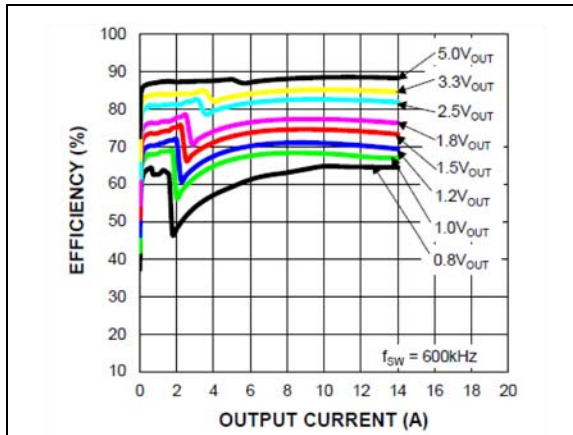


**FIGURE 2-9:** Switching Frequency vs. Temperature.

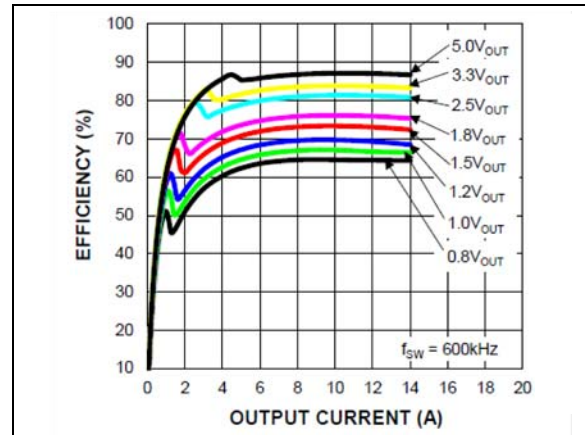


**FIGURE 2-12:** Efficiency vs. Output Current (MIC45212-1,  $V_{IN} = 12V$ ).

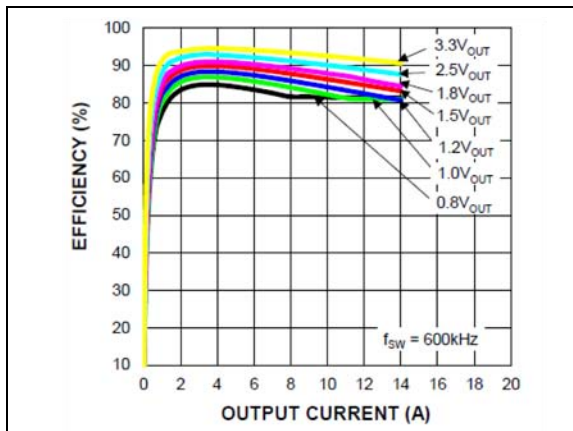
**Note:** Unless otherwise indicated,  $V_{IN} = V_{EN} = 12V$ ,  $V_{OUT} = 1.8V$ ,  $V_{BST} - V_{SW} = 5V$ ,  $T_J = +25^\circ C$ .



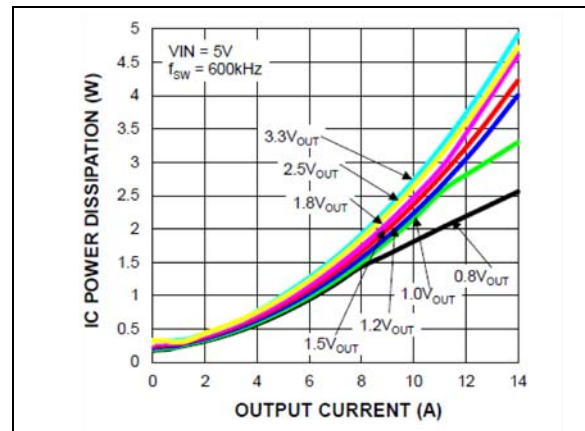
**FIGURE 2-13:** Efficiency vs. Output Current (MIC45212-1,  $V_{IN} = 24V$ ).



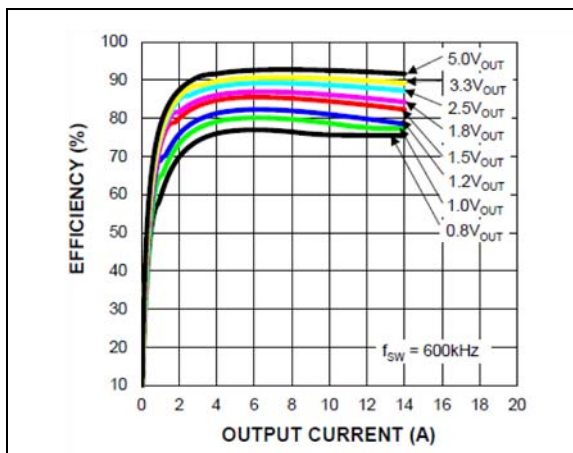
**FIGURE 2-16:** Efficiency vs. Output Current (MIC45212-2,  $V_{IN} = 24V$ ).



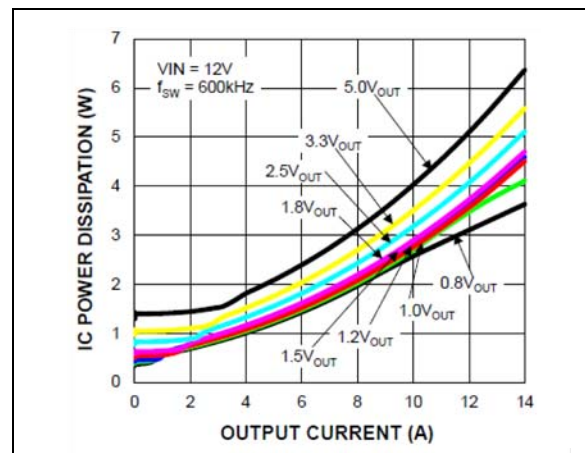
**FIGURE 2-14:** Efficiency vs. Output Current (MIC45212-2,  $V_{IN} = 5V$ ).



**FIGURE 2-17:** IC Power Dissipation vs. Output Current (MIC45212-2,  $V_{IN} = 5V$ ).



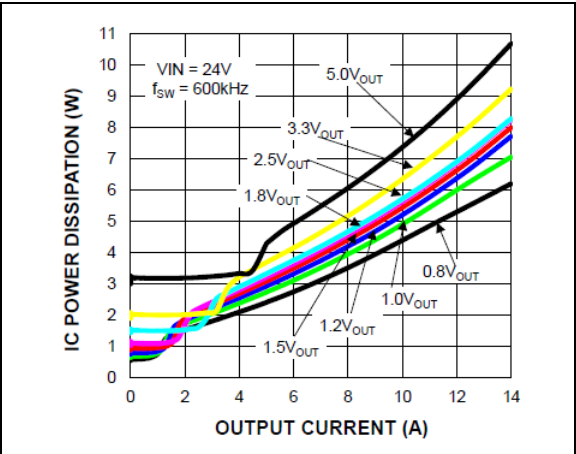
**FIGURE 2-15:** Efficiency vs. Output Current (MIC45212-2,  $V_{IN} = 12V$ ).



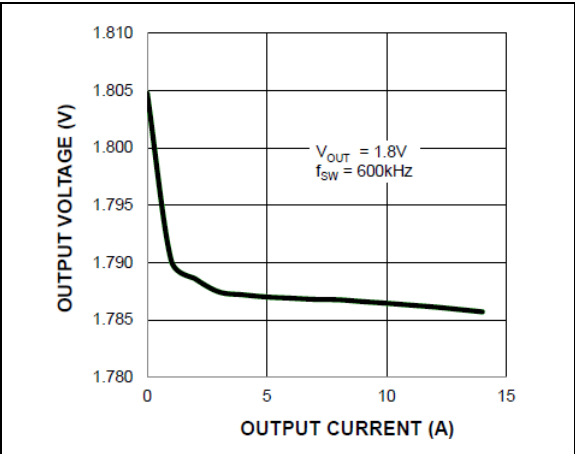
**FIGURE 2-18:** IC Power Dissipation vs. Output Current (MIC45212-2,  $V_{IN} = 12V$ ).

# MIC45212-1/-2

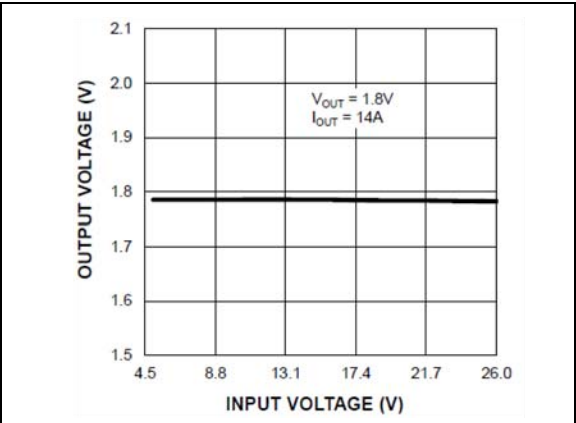
**Note:** Unless otherwise indicated,  $V_{IN} = V_{EN} = 12V$ ,  $V_{OUT} = 1.8V$ ,  $V_{BST} - V_{SW} = 5V$ ,  $T_J = +25^{\circ}C$ .



**FIGURE 2-19:** IC Power Dissipation vs. Output Current (MIC45212-2,  $V_{IN} = 24V$ ).

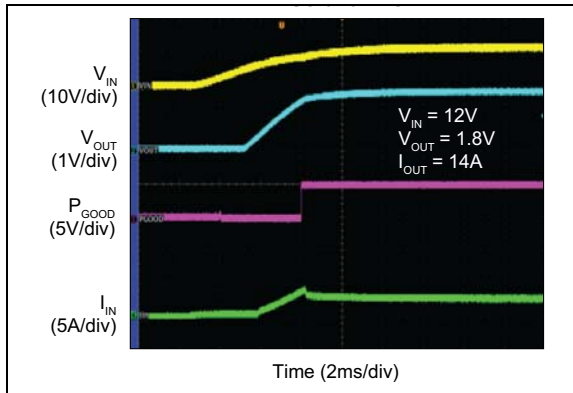


**FIGURE 2-21:** Load Regulation (MIC45212-1).

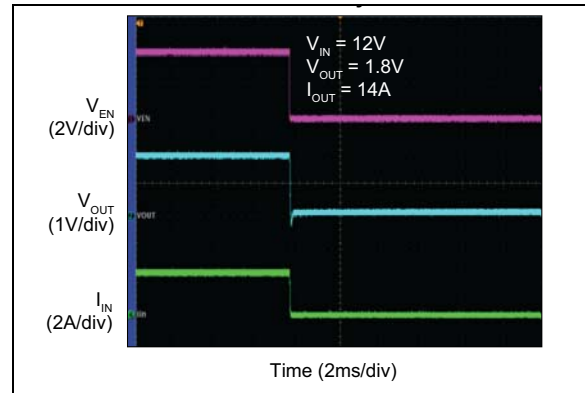


**FIGURE 2-20:** Line Regulation.

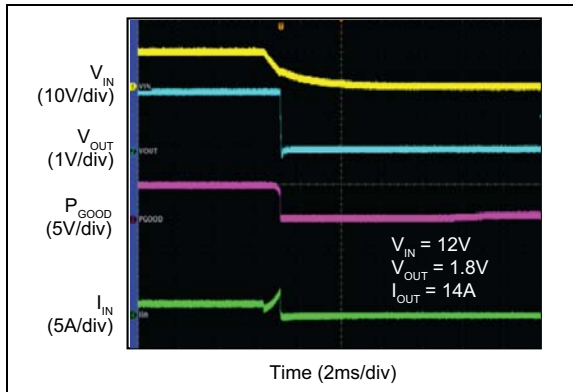
**Note:** Unless otherwise indicated,  $V_{IN} = V_{EN} = 12V$ ,  $V_{OUT} = 1.8V$ ,  $V_{BST} - V_{SW} = 5V$ ,  $T_J = +25^\circ C$ .



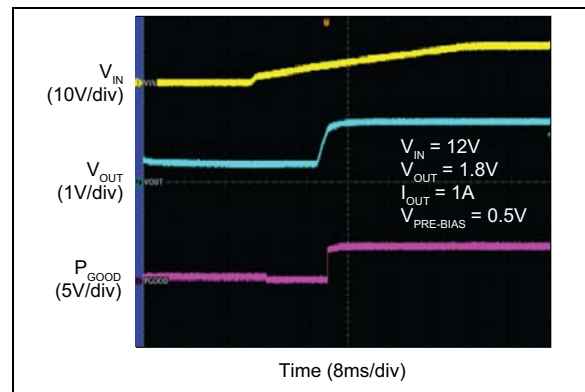
**FIGURE 2-22:**  $V_{IN}$  Soft Turn-On.



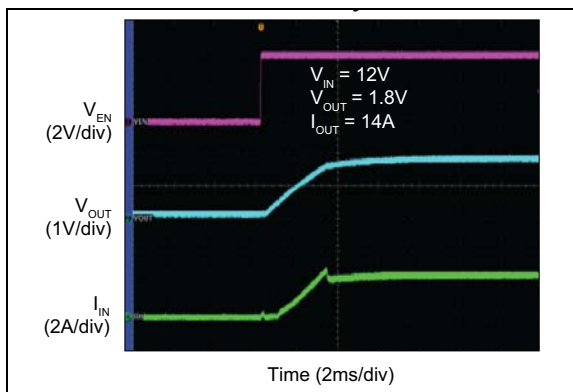
**FIGURE 2-25:** Enable Turn-Off Delay.



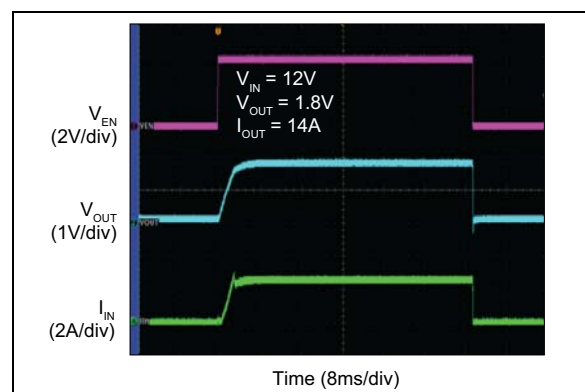
**FIGURE 2-23:**  $V_{IN}$  Soft Turn-Off.



**FIGURE 2-26:**  $V_{IN}$  Start-up with Pre-Biased Output.



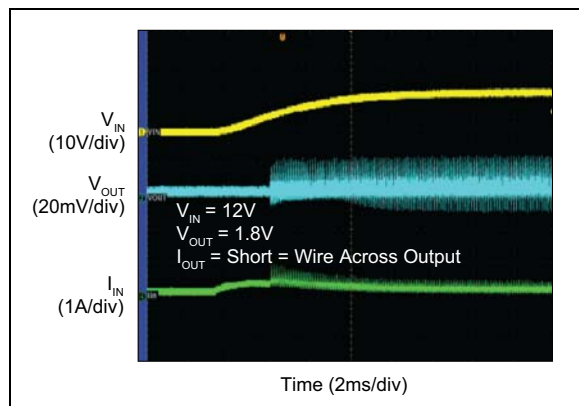
**FIGURE 2-24:** Enable Turn-On Delay and Rise Time.



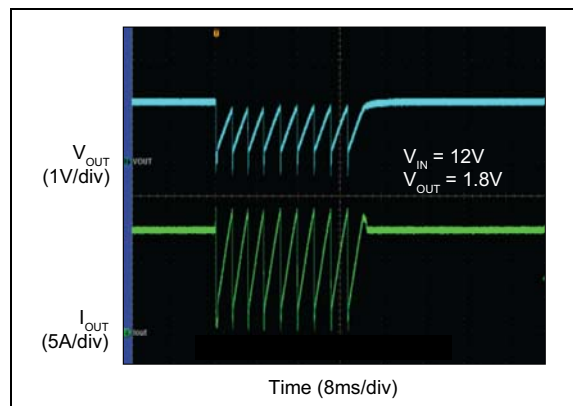
**FIGURE 2-27:** Enable Turn-On/Turn-Off.

# MIC45212-1/-2

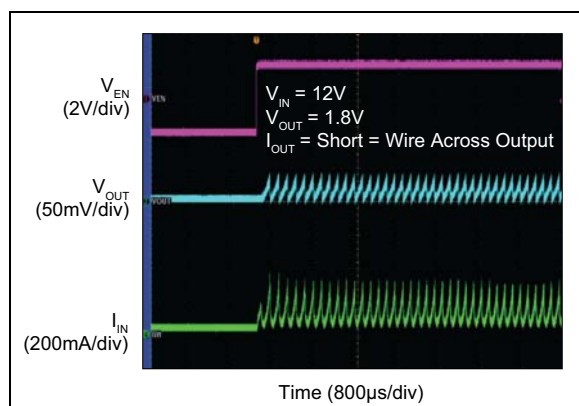
**Note:** Unless otherwise indicated,  $V_{IN} = V_{EN} = 12V$ ,  $V_{OUT} = 1.8V$ ,  $V_{BST} - V_{SW} = 5V$ ,  $T_J = +25^\circ C$ .



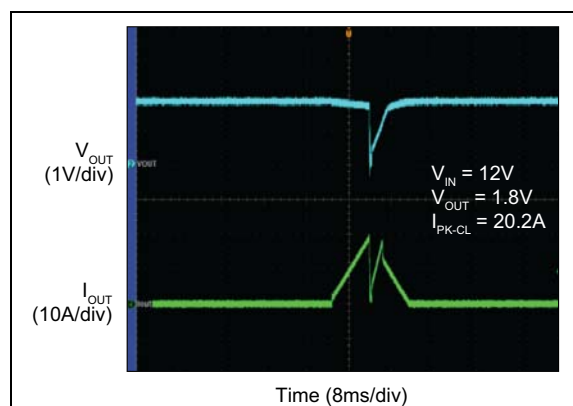
**FIGURE 2-28:** Power-up into Short Circuit.



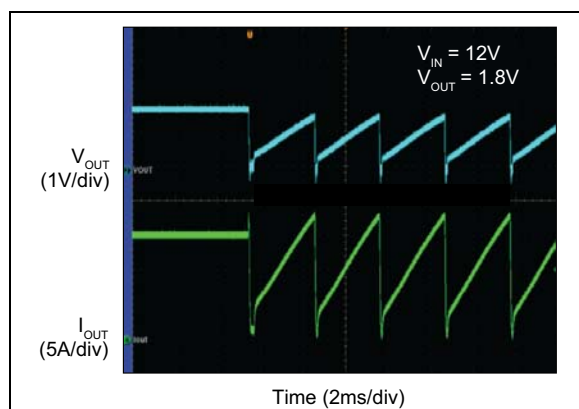
**FIGURE 2-31:** Output Recovery from Short Circuit.



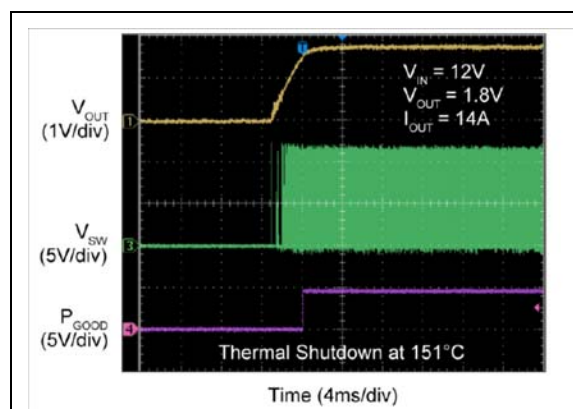
**FIGURE 2-29:** Enabled into Short Circuit.



**FIGURE 2-32:** Peak Current-Limit Threshold.

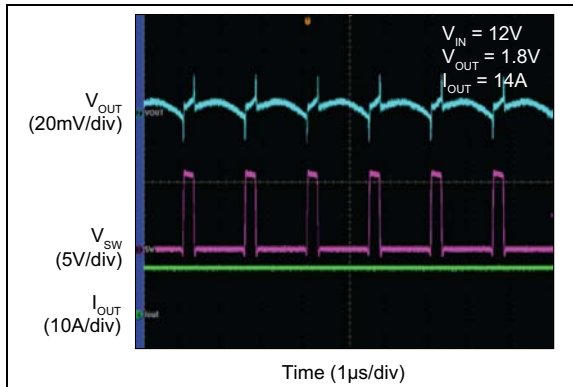


**FIGURE 2-30:** Short Circuit During Steady State with 14A Load.

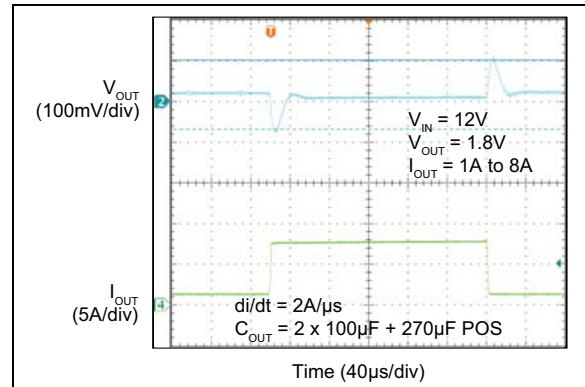


**FIGURE 2-33:** Output Recovery from Thermal Shutdown.

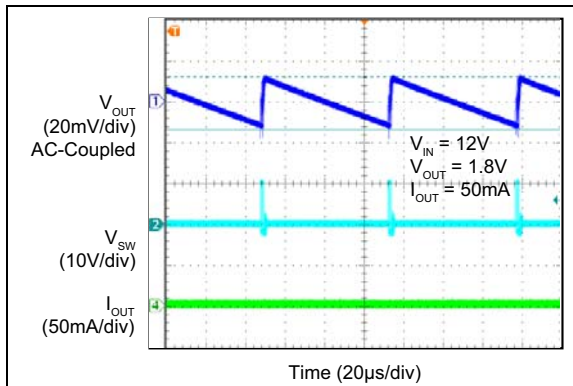
**Note:** Unless otherwise indicated,  $V_{IN} = V_{EN} = 12V$ ,  $V_{OUT} = 1.8V$ ,  $V_{BST} - V_{SW} = 5V$ ,  $T_J = +25^\circ C$ .



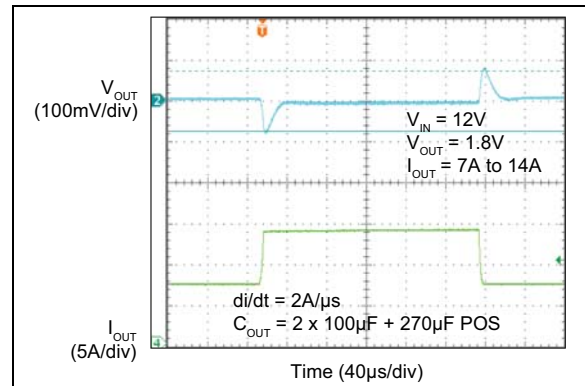
**FIGURE 2-34:** Switching Waveforms.



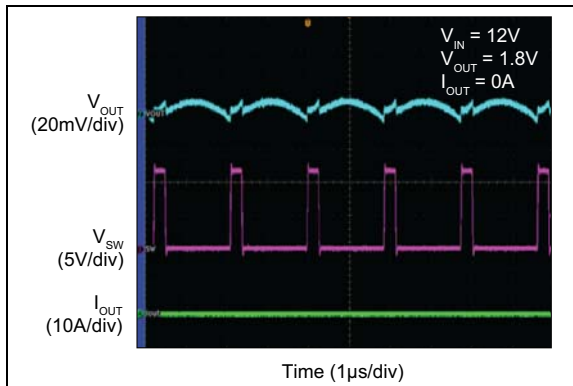
**FIGURE 2-37:** Transient Response (MIC45212-1).



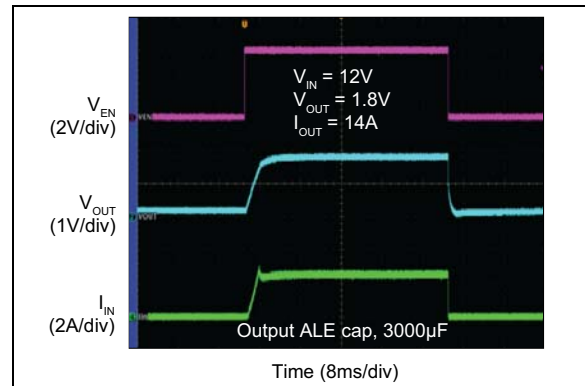
**FIGURE 2-35:** Switching Waveforms (MIC45212-1).



**FIGURE 2-38:** Transient Response (MIC45212-2).



**FIGURE 2-36:** Switching Waveforms ( $I_{OUT} = 0A$ , MIC45212-2)



**FIGURE 2-39:** Inrush with  $C_{OUT} = 3000 \mu F$ .

# MIC45212-1/-2

## 3.0 PIN DESCRIPTIONS

The descriptions of the pins are listed in [Table 3-1](#).

**TABLE 3-1: PIN FUNCTION TABLE**

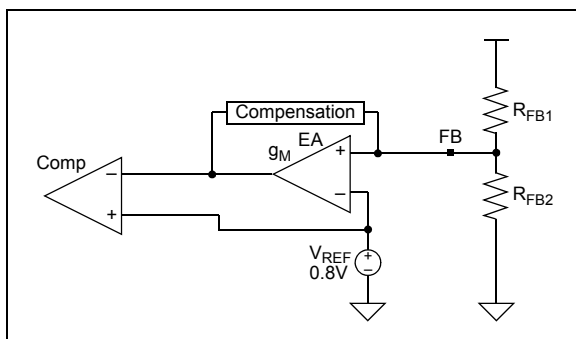
| MIC45212<br>Pin Number | Pin Name              | Pin Function                                                                                                                                                                                                                                                  |
|------------------------|-----------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1, 56, 64              | GND                   | Analog Ground: Connect bottom feedback resistor to GND. GND and PGND are internally connected.                                                                                                                                                                |
| 2, 3                   | PV <sub>DD</sub>      | PV <sub>DD</sub> : Supply input for the internal low-side power MOSFET driver.                                                                                                                                                                                |
| 4                      | I <sub>LIM</sub>      | Current Limit: Connect a resistor between I <sub>LIM</sub> and SW to program the current limit.                                                                                                                                                               |
| 5, 6                   | PGND                  | Power Ground: PGND is the return path for the step-down power module power stage. The PGND pin connects to the sources of the internal low-side power MOSFET, the negative terminals of input capacitors and the negative terminals of output capacitors.     |
| 7-10, 38-44            | SW                    | The SW pin connects directly to the switch node. Due to the high-speed switching on this pin, the SW pin should be routed away from sensitive nodes. The SW pin also senses the current by monitoring the voltage across the low-side MOSFET during off time. |
| 12-22                  | PV <sub>IN</sub>      | Power Input Voltage: Connection to the drain of the internal high-side power MOSFET. Connects an input capacitor from PV <sub>IN</sub> to PGND.                                                                                                               |
| 24-36                  | V <sub>OUT</sub>      | Power Output Voltage: Connected to the internal inductor. The output capacitor should be connected from this pin to PGND, as close to the module as possible.                                                                                                 |
| 46, 47                 | RIA                   | Ripple Injection Pin A: Leave floating, no connection.                                                                                                                                                                                                        |
| 48                     | RIB                   | Ripple Injection Pin B: Connect this pin to FB.                                                                                                                                                                                                               |
| 49-50                  | ANODE                 | Anode Bootstrap Diode: Anode connection of internal bootstrap diode; this pin should be connected to the PV <sub>DD</sub> pin.                                                                                                                                |
| 52-54                  | BST                   | Connection to the internal bootstrap circuitry and high-side power MOSFET drive circuitry. Leave floating, no connection.                                                                                                                                     |
| 55                     | NC                    | No Connection.                                                                                                                                                                                                                                                |
| 57                     | FB                    | Feedback: Input to the transconductance amplifier of the control loop. The FB pin is referenced to 0.8V. A resistor divider connecting the feedback to the output is used to set the desired output voltage. Connect the bottom resistor from FB to GND.      |
| 58                     | PG                    | Power Good: Open-Drain Output. If used, connect to an external pull-up resistor of at least 10 kOhm between PG and the external bias voltage.                                                                                                                 |
| 59                     | EN                    | Enable: A logic signal to enable or disable the step-down regulator module operation. The EN pin is TTL/CMOS compatible. Logic high = enable, logic low = disable or shutdown. Do not leave floating.                                                         |
| 60                     | V <sub>IN</sub>       | Internal 5V Linear Regulator Input: A 1 µF ceramic capacitor from V <sub>IN</sub> to GND is required for decoupling.                                                                                                                                          |
| 61                     | FREQ                  | Switching Frequency Adjust: Use a resistor divider from V <sub>IN</sub> to GND to program the switching frequency. Connecting FREQ to V <sub>IN</sub> sets frequency = 600 kHz.                                                                               |
| 62, 63                 | 5V <sub>DD</sub>      | Internal +5V linear regulator output. Powered by VIN, 5VDD is the internal supply bus for the device. In the applications with VIN<+5.5V, 5VDD should be tied to VIN to bypass the linear regulator.                                                          |
| 11, 23, 37, 45, 51     | KEEPOUT               | Depopulated pin positions.                                                                                                                                                                                                                                    |
| —                      | PV <sub>IN</sub> ePAD | PV <sub>IN</sub> Exposed Pad: Internally connected to the PV <sub>IN</sub> pins.                                                                                                                                                                              |
| —                      | V <sub>OUT</sub> ePAD | V <sub>OUT</sub> Exposed Pad: Internally connected to the V <sub>OUT</sub> pins.                                                                                                                                                                              |

## 4.0 FUNCTIONAL DESCRIPTION

The MIC45212 is an adaptive on-time synchronous buck regulator module, built for high input voltage to low output voltage conversion applications. The MIC45212 is designed to operate over a wide input voltage range, from 4.5V to 26V, and the output is adjustable with an external resistor divider. An adaptive ON-time control scheme is employed to obtain a constant switching frequency in steady state and to simplify the control compensation. Hiccup mode over-current protection is implemented by sensing low-side MOSFET's  $R_{DS(ON)}$ . The device features internal soft start, enable, UVLO and thermal shutdown. The module has integrated switching FETs, inductor, bootstrap diode, resistor, capacitor and controller.

### 4.1 Theory of Operation

As shown in Figure 4-1, in association with Equation 4-1, the output voltage is sensed by the MIC45212 Feedback pin, FB, via the voltage dividers,  $R_{FB1}$  and  $R_{FB2}$ , and compared to a 0.8V reference voltage,  $V_{REF}$ , at the error comparator through a low-gain transconductance ( $g_M$ ) amplifier. If the feedback voltage decreases and falls below 0.8V, then the error comparator will trigger the control logic and generate an ON-time period. The ON-time period length is predetermined by the "Fixed  $t_{ON}$  Estimator" circuitry.



**FIGURE 4-1:** Output Voltage Sense via FB Pin.

### EQUATION 4-1: ON-TIME ESTIMATION

$$t_{ON(ESTIMATED)} = \frac{V_{OUT}}{V_{IN} \times f_{SW}}$$

Where:

$V_{OUT}$  = Output voltage

$V_{IN}$  = Power stage input voltage

$f_{SW}$  = Switching frequency

At the end of the ON-time period, the internal high-side driver turns off the high-side MOSFET and the low-side driver turns on the low-side MOSFET. In most cases, the OFF-time period length depends upon the feedback voltage. When the feedback voltage decreases and the output of the  $g_M$  amplifier falls below 0.8V, the ON-time period is triggered and the OFF-time period ends. If the OFF-time period determined by the feedback voltage, is less than the minimum OFF-time  $t_{OFF(MIN)}$ , which is about 200ns, the MIC45212 control logic will apply the  $t_{OFF(MIN)}$  instead.  $t_{OFF(MIN)}$  is required to maintain enough energy in the Boost Capacitor ( $C_{BST}$ ) to drive the high-side MOSFET.

The maximum duty cycle is obtained from the 200 ns  $t_{OFF(MIN)}$ :

### EQUATION 4-2: MAXIMUM DUTY CYCLE

$$D_{MAX} = \frac{t_S - t_{OFF(MIN)}}{t_S} = 1 - \frac{200 \text{ ns}}{t_S}$$

Where:

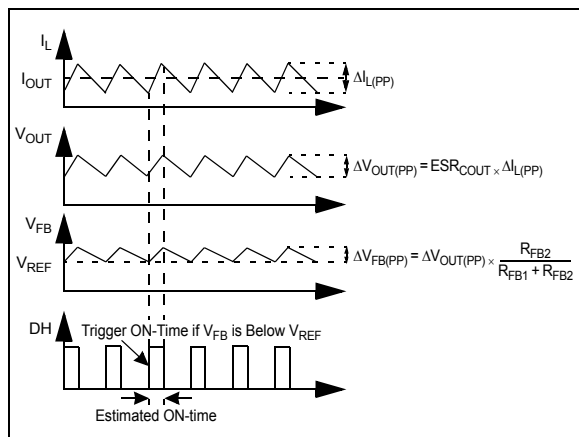
$$t_S = 1/f_{SW}$$

It is not recommended to use the MIC45212 device with an OFF-time close to  $t_{OFF(MIN)}$  during steady-state operation.

The adaptive ON-time control scheme results in a constant switching frequency in the MIC45212 during steady-state operation. Also, the minimum  $t_{ON}$  results in a lower switching frequency in high  $V_{IN}$  to  $V_{OUT}$  applications. During load transients, the switching frequency is changed due to the varying OFF-time.

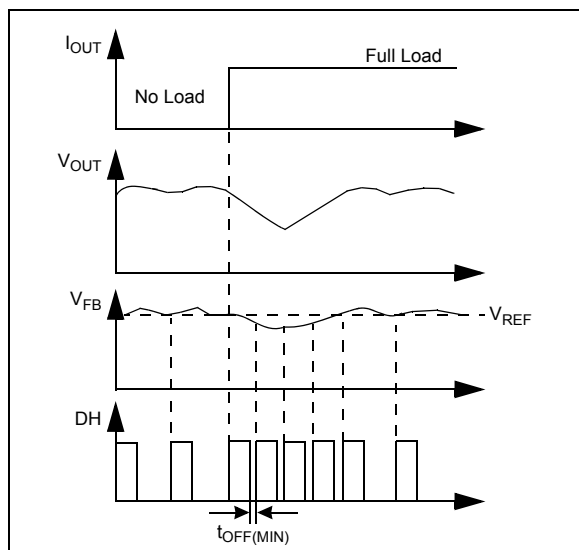
To illustrate the control loop operation, we will analyze both the steady-state and load transient scenarios. For easy analysis, the gain of the  $g_M$  amplifier is assumed to be 1. With this assumption, the inverting input of the error comparator is the same as the feedback voltage.

Figure 4-2 shows the MIC45212 control loop timing during steady-state operation. During steady-state operation, the  $g_M$  amplifier senses the feedback voltage ripple, which is proportional to the output voltage ripple, plus injected voltage ripple, to trigger the ON-time period. The ON-time is predetermined by the  $t_{ON}$  estimator. The termination of the OFF-time is controlled by the feedback voltage. At the valley of the feedback voltage ripple, which occurs when  $V_{FB}$  falls below  $V_{REF}$ , the OFF-time period ends and the next ON-time period is triggered through the control logic circuitry.



**FIGURE 4-2:** MIC45212 Control Loop Timing.

Figure 4-3 shows the operation of the MIC45212 during a load transient. The output voltage drops due to the sudden load increase, which causes the  $V_{FB}$  to be less than  $V_{REF}$ . This will cause the error comparator to trigger an ON-time period. At the end of the ON-time period, a minimum OFF-time,  $t_{OFF(MIN)}$ , is generated to charge the Bootstrap Capacitor ( $C_{BST}$ ) since the feedback voltage is still below  $V_{REF}$ . Then, the next ON-time period is triggered due to the low feedback voltage. Therefore, the switching frequency changes during the load transient, but returns to the nominal fixed frequency once the output has stabilized at the new load current level. With the varying duty cycle and switching frequency, the output recovery time is fast and the output voltage deviation is small. Note that the instantaneous switching frequency during load transient remains bounded and cannot increase arbitrarily. The minimum is limited by  $t_{ON} + t_{OFF(MIN)}$ . Because the variation in  $V_{OUT}$  is relatively limited during load transient,  $t_{ON}$  stays virtually close to its steady-state value.



**FIGURE 4-3:** MIC45212 Load Transient Response.

Unlike true Current mode control, the MIC45212 uses the output voltage ripple to trigger an ON-time period. The output voltage ripple is proportional to the inductor current ripple if the ESR of the output capacitor is large enough.

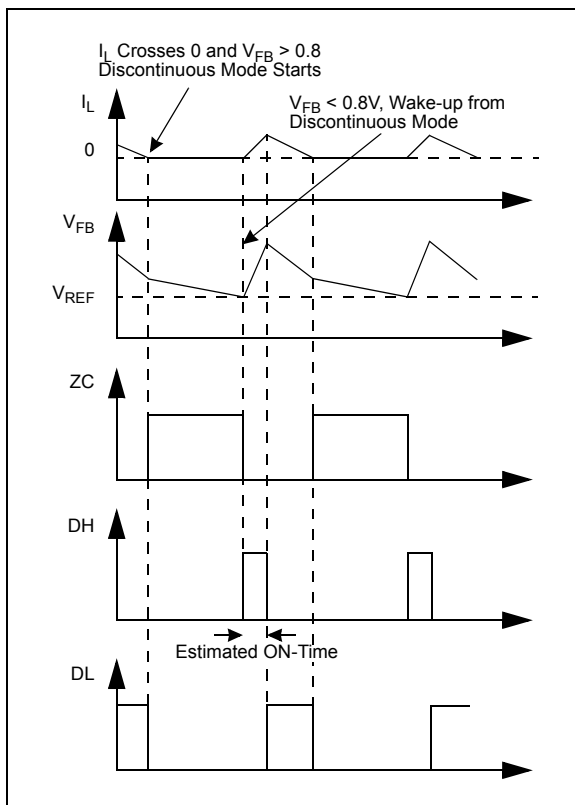
In order to meet the stability requirements, the MIC45212 feedback voltage ripple should be in phase with the inductor current ripple, and is large enough to be sensed by the  $g_M$  amplifier and the error comparator. The recommended feedback voltage ripple is 20 mV ~ 100 mV over full input voltage range. If a low-ESR output capacitor is selected, then the feedback voltage ripple may be too small to be sensed by the  $g_M$  amplifier and the error comparator. Also, the output voltage ripple and the feedback voltage ripple are not necessarily in phase with the inductor current ripple if the ESR of the output capacitor is very low. In these cases, ripple injection is required to ensure proper operation. Please refer to [Section 5.5 “Ripple Injection”](#) in [Section 5.0 “Application Information”](#) for more details about the ripple injection technique.

## 4.2 Discontinuous Mode (MIC45212-1 only)

In Continuous mode, the inductor current is always greater than zero; however, at light loads, the MIC45212-1 is able to force the inductor current to operate in Discontinuous mode. Discontinuous mode is where the inductor current falls to zero, as indicated by trace ( $I_L$ ) shown in [Figure 4-4](#). During this period, the efficiency is optimized by shutting down all the non-essential circuits and minimizing the supply current as the switching frequency is reduced. The MIC45212-1 wakes up and turns on the high-side MOSFET when the feedback voltage,  $V_{FB}$ , drops below 0.8V.

The MIC45212-1 has a Zero-Crossing (ZC) comparator that monitors the inductor current by sensing the voltage drop across the low-side MOSFET during its ON-time. If the  $V_{FB} > 0.8V$  and the inductor current goes slightly negative, then the MIC45212-1 automatically powers down most of the IC circuitry and goes into a Low-Power mode.

Once the MIC45212-1 goes into Discontinuous mode, both DL and DH are low, which turns off the high-side and low-side MOSFETs. The load current is supplied by the output capacitors and  $V_{OUT}$  drops. If the drop of  $V_{OUT}$  causes  $V_{FB}$  to go below  $V_{REF}$ , then all the circuits will wake-up into normal Continuous mode. First, the bias currents of most circuits reduced during the Discontinuous mode are restored, and then a  $t_{ON}$  pulse is triggered before the drivers are turned on to avoid any possible glitches. Finally, the high-side driver is turned on. [Figure 4-4](#) shows the control loop timing in Discontinuous mode.



**FIGURE 4-4:** MIC45212-1 Control Loop Timing (Discontinuous Mode).

During Discontinuous mode, the bias current of most circuits is substantially reduced. As a result, the total power supply current during Discontinuous mode is only about 370  $\mu$ A, allowing the MIC45212-1 to achieve high efficiency in light load applications.

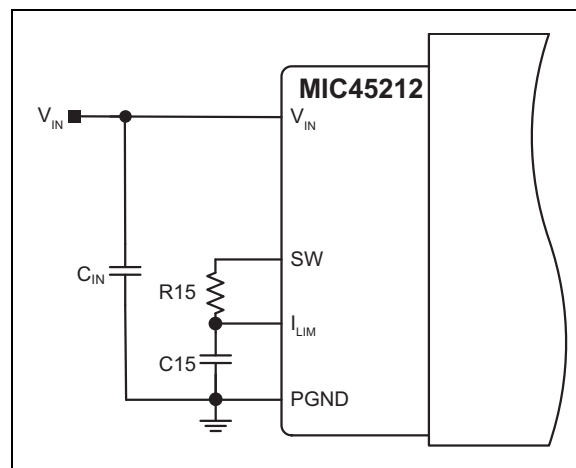
## 4.3 Soft Start

Soft start reduces the input power supply surge current at start-up by controlling the output voltage rise time. The input surge appears while the output capacitor is charged up.

The MIC45212 implements an internal digital soft start by making the 0.8V reference voltage,  $V_{REF}$ , ramp from 0 to 100% in about 3 ms with 9.7 mV steps. Therefore, the output voltage is controlled to increase slowly by a staircase  $V_{FB}$  ramp. Once the soft start cycle ends, the related circuitry is disabled to reduce current consumption.  $PV_{DD}$  must be powered up at the same time or after  $V_{IN}$  to make the soft start function correctly.

## 4.4 Current Limit

The MIC45212 uses the  $R_{DS(ON)}$  of the low-side MOSFET and the external resistor, connected from the  $I_{LIM}$  pin to the SW node, to set the current limit.



**FIGURE 4-5:** MIC45212 Current-Limiting Circuit.

In each switching cycle of the MIC45212, 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 150 ns. In this way, the drop voltage over the resistor, R15 ( $V_{CL}$ ), is compared with the drop over the bottom FET generating the short current limit. The small Capacitor (C15) connected from the  $I_{LIM}$  pin to PGND filters the switching node ringing during the OFF-time, allowing a better short limit measurement. The time constant created by R15 and C15 should be much less than the minimum OFF-time.

The  $V_{CL}$  drop allows programming of the short limit through the value of the Resistor (R15). If the absolute value of the voltage drop on the bottom FET becomes greater than  $V_{CL}$ , and the  $V_{ILIM}$  falls below PGND, an overcurrent is triggered causing the IC to enter Hiccup mode. The hiccup mode 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 4-3](#).

## EQUATION 4-3: PROGRAMMING CURRENT LIMIT

$$R15 = \frac{(I_{CLIM} + \Delta I_{L(PP)} \times 0.5) \times R_{DS(ON)} + V_{CL\_OFFSET}}{I_{CL}}$$

Where:

$I_{CLIM}$  = Desired current limit

$R_{DS(ON)}$  = On resistance of low-side power MOSFET, 6 mΩ typically

$V_{CL\_OFFSET}$  = Current-limit threshold (typical absolute value is 14 mV per [Table 1-1](#))

$I_{CL}$  = Current-limit source current (typical value is 70 μA per [Table 1-1](#))

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

The peak-to-peak inductor current ripple is:

## EQUATION 4-4: PEAK-TO-PEAK INDUCTOR CURRENT RIPPLE

$$\Delta I_{L(PP)} = \frac{V_{OUT} \times (V_{IN(MAX)} - V_{OUT})}{V_{IN(MAX)} \times f_{SW} \times L}$$

The MIC45212 has a 0.6 μH inductor integrated into the module. 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 into hiccup mode and may not finish the soft start successfully.

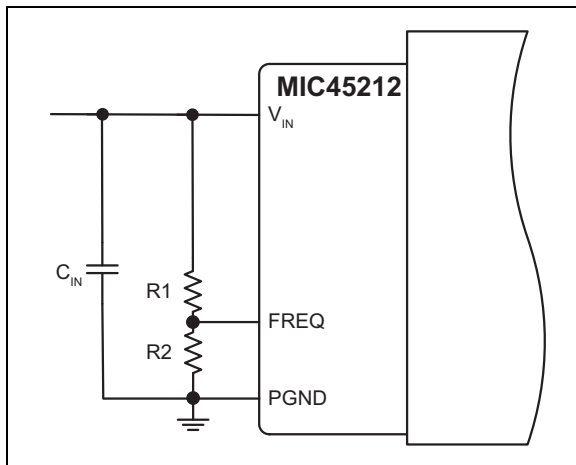
The MOSFET  $R_{DS(ON)}$  varies 30% to 40% with temperature; therefore, it is recommended to add a 50% margin to  $I_{CLIM}$  in [Equation 4-3](#) to avoid false current limiting due to increased MOSFET junction temperature rise.

With  $R15 = 1.69 \text{ k}\Omega$  and  $C15 = 15 \text{ pF}$ , the typical output current limit is 16.8A.

## 5.0 APPLICATION INFORMATION

### 5.1 Setting the Switching Frequency

The MIC45212 switching frequency can be adjusted by changing the value of resistors, R1 and R2.



**FIGURE 5-1:** Switching Frequency Adjustment.

Equation 5-1 gives the estimated switching frequency:

#### EQUATION 5-1: ESTIMATED SWITCHING FREQUENCY

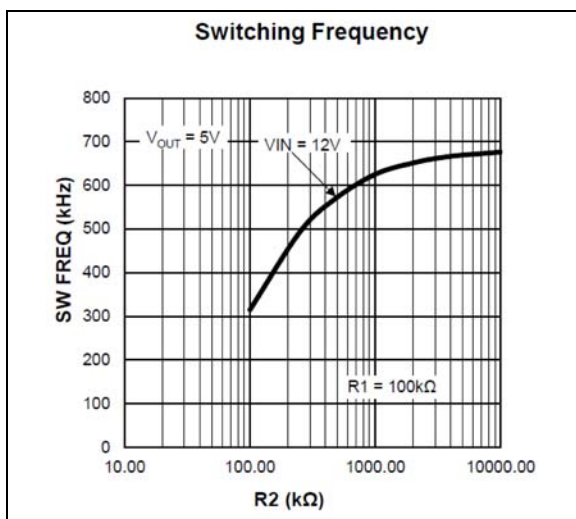
$$f_{SW} = f_O \times \frac{R2}{R1 + R2}$$

Where:

$f_O = 600$  kHz (typical per [TABLE 1-1: "Electrical Characteristics\(1\)"](#) table)

$R1 = 100$  k $\Omega$  is recommended

$R2$  = Needs to be selected in order to set the required switching frequency



**FIGURE 5-2:** Switching Frequency vs. R2.

### 5.2 Output Capacitor Selection

The type of output capacitor is usually determined by the application and its Equivalent Series Resistance (ESR). Voltage and RMS current capability are two other important factors for selecting the output capacitor. Recommended capacitor types are MLCC, OS-CON and POSCAP. The output capacitor's ESR is usually the main cause of the output ripple. The MIC45212 requires ripple injection and the output capacitor ESR affects the control loop from a stability point of view.

The maximum value of ESR is calculated as in [Equation 5-2](#):

#### EQUATION 5-2: ESR MAXIMUM VALUE

$$ESR_{COUT} \leq \frac{\Delta V_{OUT(PP)}}{\Delta I_{L(PP)}}$$

Where:

$\Delta V_{OUT(PP)}$  = Peak-to-peak output voltage ripple

$\Delta I_{L(PP)}$  = Peak-to-peak inductor current ripple

The total output ripple is a combination of the ESR and output capacitance. The total ripple is calculated in [Equation 5-3](#):

#### EQUATION 5-3: TOTAL OUTPUT RIPPLE

$$\Delta V_{OUT(PP)} = \sqrt{\left(\frac{\Delta I_{L(PP)}}{C_{OUT} \times f_{SW} \times 8}\right)^2 + (\Delta I_{L(PP)} \times ESR_{COUT})^2}$$

Where:

$C_{OUT}$  = Output capacitance value

$f_{SW}$  = Switching frequency

# MIC45212-1/-2

As described in [Section 4.1 “Theory of Operation”](#) in [Section 4.0 “Functional Description”](#), the MIC45212 requires at least a 20 mV peak-to-peak ripple at the FB pin to make the  $g_m$  amplifier and the error comparator behave properly. Also, the output voltage ripple should be in phase with the inductor current. Therefore, the output voltage ripple caused by the output capacitors' value should be much smaller than the ripple caused by the output capacitor, ESR. If low-ESR capacitors, such as ceramic capacitors, are selected as the output capacitors, a ripple injection method should be applied to provide enough feedback voltage ripple. Please refer to [Section 5.5 “Ripple Injection”](#) in [Section 5.0 “Application Information”](#) for more details.

The output capacitor RMS current is calculated in [Equation 5-4](#):

## EQUATION 5-4: OUTPUT CAPACITOR RMS CURRENT

$$I_{COUT(RMS)} = \frac{\Delta I_L(PP)}{\sqrt{12}}$$

The power dissipated in the output capacitor is:

## EQUATION 5-5: DISSIPATED POWER IN OUTPUT CAPACITOR

$$P_{DISS(COUT)} = I_{COUT(RMS)}^2 \times ESR_{COUT}$$

## 5.3 Input Capacitor Selection

The input capacitor for the Power Stage Input,  $PV_{IN}$ , should be selected for ripple current rating and voltage rating. The input voltage ripple will primarily depend on the input capacitor's ESR. The peak input current is equal to the peak inductor current, so:

## EQUATION 5-6: CONFIGURING RIPPLE CURRENT AND VOLTAGE RATINGS

$$\Delta V_{IN} = I_{L(pk)} \times ESR_{CIN}$$

The input capacitor must be rated for the input current ripple. The RMS value of input capacitor current is determined at the maximum output current. Assuming the peak-to-peak inductor current ripple is low:

## EQUATION 5-7: RMS VALUE OF INPUT CAPACITOR CURRENT

$$I_{CIN(RMS)} \approx I_{OUT(MAX)} \times \sqrt{D \times (1 - D)}$$

Where:

D = Duty cycle

The power dissipated in the input capacitor is:

## EQUATION 5-8: POWER DISSIPATED IN INPUT CAPACITOR

$$P_{DISS(CIN(RMS))} = I_{CIN(RMS)}^2 \times ESR_{CIN}$$

The general rule is to pick the capacitor with a ripple current rating equal to or greater than the calculated worst-case RMS capacitor current.

[Equation 5-9](#) should be used to calculate the input capacitor. Also, it is recommended to keep some margin on the calculated value:

## EQUATION 5-9: INPUT CAPACITOR CALCULATION

$$C_{IN} \approx \frac{I_{OUT(MAX)} \times (1 - D)}{f_{SW} \times dV}$$

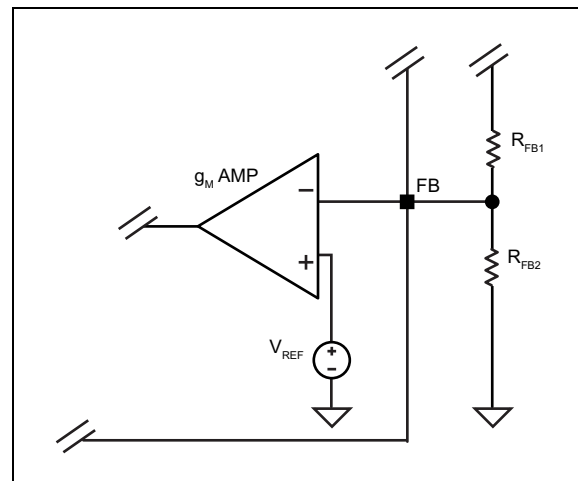
Where:

dV = Input ripple

$f_{SW}$  = Switching frequency

## 5.4 Output Voltage Setting Components

The MIC45212 requires two resistors to set the output voltage, as shown in [Figure 5-3](#):



**FIGURE 5-3:** Voltage/Divider Configuration.

The output voltage is determined by [Equation 5-10](#):

## EQUATION 5-10: OUTPUT VOLTAGE DETERMINATION

$$V_{OUT} = V_{FB} \times \left(1 + \frac{R_{FB1}}{R_{FB2}}\right)$$

Where:

$$V_{FB} = 0.8V$$

A typical value of  $R_{FB1}$  used on the standard evaluation board is 10 k $\Omega$ . If  $R_{FB1}$  is too large, it may allow noise to be introduced into the voltage feedback loop. If  $R_{FB1}$  is too small in value, it will decrease the efficiency of the power supply, especially at light loads. Once  $R_{FB1}$  is selected,  $R_{FB2}$  can be calculated using [Equation 5-11](#):

## EQUATION 5-11: CALCULATING $R_{FB2}$

$$R_{FB2} = \frac{V_{FB} \times R_{FB1}}{V_{OUT} - V_{FB}}$$

For fixed  $R_{FB1} = 10$  k $\Omega$ , the output voltage can be selected by  $R_{FB2}$ . [Table 5-1](#) provides  $R_{FB2}$  values for some common output voltages.

**TABLE 5-1:  $V_{OUT}$  PROGRAMMING RESISTOR LOOK-UP**

| $R_{FB2}$       | $V_{OUT}$ |
|-----------------|-----------|
| OPEN            | 0.8V      |
| 40.2 k $\Omega$ | 1.0V      |
| 20 k $\Omega$   | 1.2V      |
| 11.5 k $\Omega$ | 1.5V      |
| 8.06 k $\Omega$ | 1.8V      |
| 4.75 k $\Omega$ | 2.5V      |
| 3.24 k $\Omega$ | 3.3V      |
| 1.91 k $\Omega$ | 5.0V      |

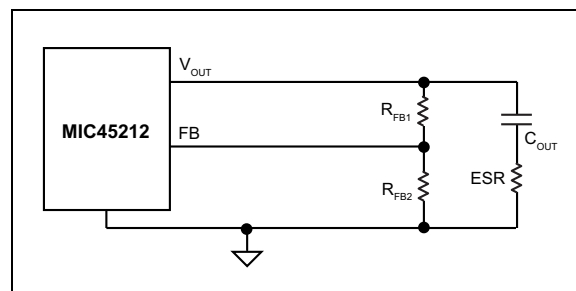
## 5.5 Ripple Injection

The  $V_{FB}$  ripple required for proper operation of the MIC45212  $g_M$  amplifier and error comparator is 20 mV to 100 mV. However, the output voltage ripple is generally too small to provide enough ripple amplitude at the FB pin and this issue is more visible in lower output voltage applications. If the feedback voltage ripple is so small that the  $g_M$  amplifier and error comparator cannot sense it, then the MIC45212 will lose control and the output voltage is not regulated. In order to have some amount of  $V_{FB}$  ripple, a ripple injection method is applied for low output voltage ripple applications.

The applications are divided into two situations according to the amount of the feedback voltage ripple:

1. Enough ripple at the feedback voltage due to the large ESR of the output capacitors:

As shown in [Figure 5-4](#), the converter is stable without any ripple injection.



**FIGURE 5-4:** Enough Ripple at FB from ESR.

The feedback voltage ripple is:

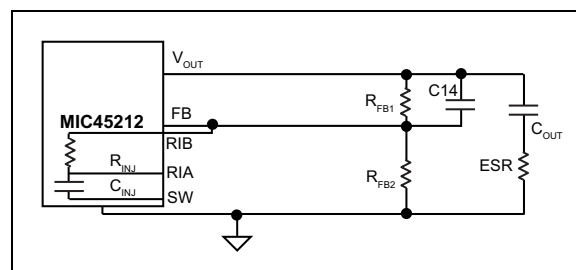
## EQUATION 5-12: FEEDBACK VOLTAGE RIPPLE

$$\Delta V_{FB(PP)} = \frac{R_{FB2}}{R_{FB1} + R_{FB2}} \times ESR_{C_{OUT}} \times \Delta I_{L(PP)}$$

Where:

$\Delta I_{L(PP)}$  = The peak-to-peak value of the inductor current ripple

2. There is virtually inadequate or no ripple at the FB pin voltage due to the very low-ESR of the output capacitors; such is the case with the ceramic output capacitor. In this case, the  $V_{FB}$  ripple waveform needs to be generated by injecting a suitable signal. MIC45212 has provisions to enable an internal series RC injection network,  $R_{INJ}$  and  $C_{INJ}$ , as shown in [Figure 5-5](#), by connecting RIB to the FB pin. This network injects a square wave current waveform into the FB pin, which by means of integration across the capacitor ( $C_{14}$ ), generates an appropriate sawtooth FB ripple waveform.



**FIGURE 5-5:** Internal Ripple Injection at FB via RIB Pin.

# MIC45212-1/-2

The injected ripple is:

## EQUATION 5-13: INJECTED RIPPLE

$$\Delta V_{FB(PP)} = V_{IN} \times K_{div} \times D \times (1 - D) \times \frac{1}{f_{SW} \times \tau}$$

$$K_{div} = \frac{R_{FB1} // R_{FB2}}{R_{INJ} + R_{FB1} // R_{FB2}}$$

Where:

$V_{IN}$  = Power stage input voltage

$D$  = Duty cycle

$f_{SW}$  = Switching frequency

$\tau = (R_{FB1} // R_{FB2} // R_{INJ}) \times C14$

$R_{INJ} = 10 \text{ k}\Omega$

$C_{INJ} = 0.1 \text{ }\mu\text{F}$

In [Equation 5-13](#) and [Equation 5-14](#), it is assumed that the time constant associated with C14 must be much greater than the switching period:

## EQUATION 5-14: CONDITION ON TIME CONSTANT OF C14

$$\frac{1}{f_{SW} \times \tau} = \frac{T}{\tau} \ll 1$$

If the voltage divider resistors,  $R_{FB1}$  and  $R_{FB2}$ , are in the  $\text{k}\Omega$  range, then a C14 of 1 nF to 100 nF can easily satisfy the large time constant requirements.

## 5.6 Thermal Measurements and Safe Operating Area (SOA)

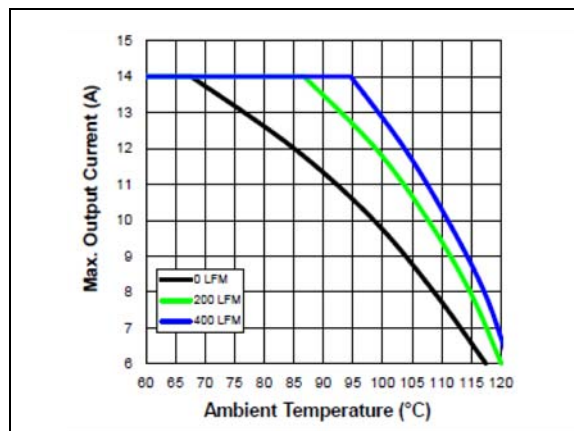
Measuring the IC's case temperature is recommended to ensure it is within its operating limits. Although this might seem like a very elementary task, it is easy to get erroneous results. The most common mistake is to use the standard thermal couple that comes with a thermal meter. This thermal couple wire gauge is large, typically 22 gauge, and behaves like a heat sink, resulting in a lower case measurement.

Two methods of temperature measurement are using a smaller thermal couple wire or an infrared thermometer. If a thermal couple wire is used, it must be constructed of 36-gauge wire or higher (smaller wire size) to minimize the wire heat sinking effect. In addition, the thermal couple tip must be covered in either thermal grease or thermal glue to make sure that the thermal couple junction is making good contact with the case of the IC. Omega® Engineering brand thermal couple (5SC-TT-K-36-36) is adequate for most applications.

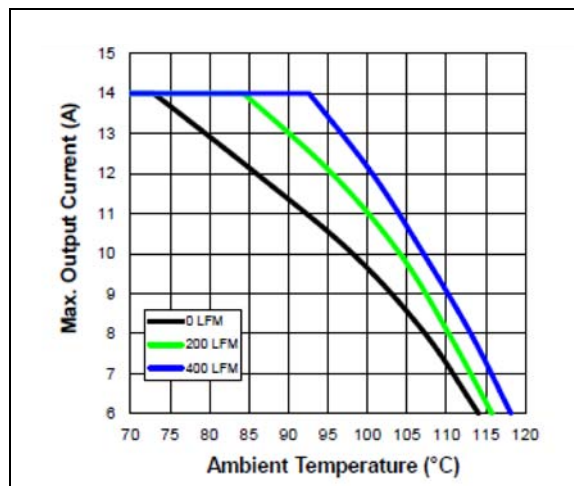
Wherever possible, an infrared thermometer is recommended. The measurement spot size of most infrared thermometers is too large for an accurate reading on a small form factor IC. However, an IR thermometer from Optris® has a 1 mm spot size, which makes it a good choice for measuring the hottest point on the case. An optional stand makes it easy to hold the beam on the IC for long periods of time.

The Safe Operating Area (SOA) of the MIC45212 is shown in Figure 5-6 through Figure 5-10. These thermal measurements were taken on the MIC45212 evaluation board. Since the MIC45212 is an entire system comprised of a switching regulator controller, MOSFETs and inductor, the part needs to be considered as a system. The SOA curves will give guidance to reasonable use of the MIC45212.

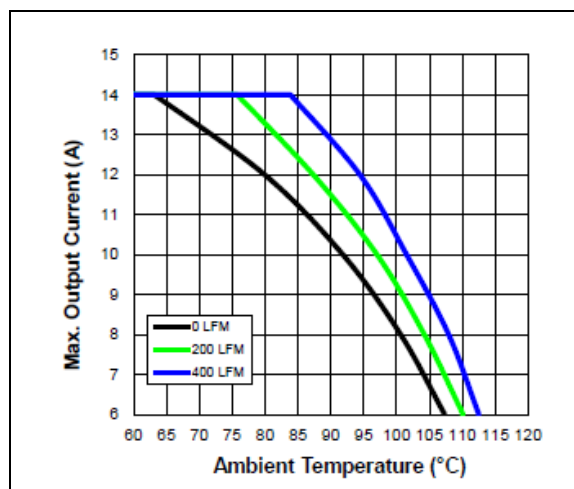
SOA curves should only be used as a point of reference. SOA data was acquired using the MIC45212 evaluation board. Thermal performance depends on the PCB layout, board size, copper thickness, number of thermal vias and actual airflow.



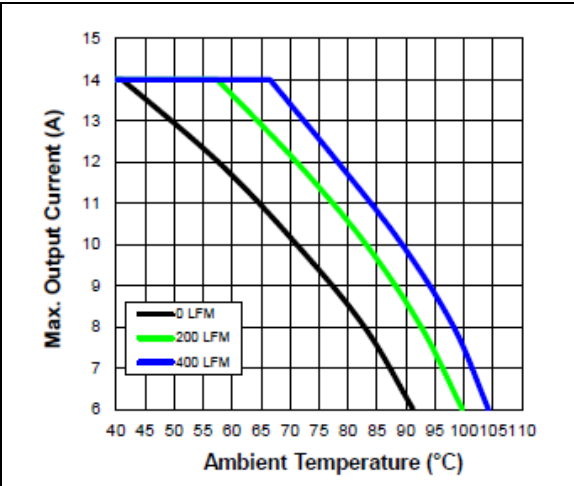
**FIGURE 5-6:** MIC45212 Power Derating vs. Airflow (60  $V_{IN}$  to 1.5  $V_{OUT}$ ).



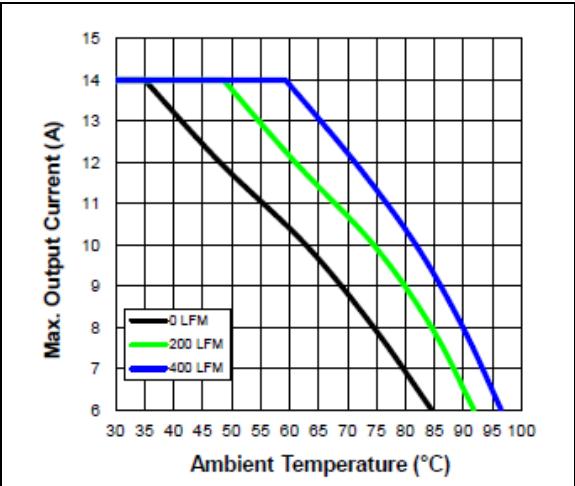
**FIGURE 5-7:** MIC45212 Power Derating vs. Airflow (12  $V_{IN}$  to 1.5  $V_{OUT}$ ).



**FIGURE 5-8:** MIC45212 Power Derating vs. Airflow (12  $V_{IN}$  to 3.3  $V_{OUT}$ ).



**FIGURE 5-9:** MIC45212 Power Derating vs. Airflow (24  $V_{IN}$  to 1.5  $V_{OUT}$ ).

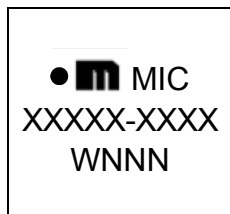


**FIGURE 5-10:** MIC45212 Power Derating vs. Airflow (24  $V_{IN}$  to 3.3  $V_{OUT}$ ).

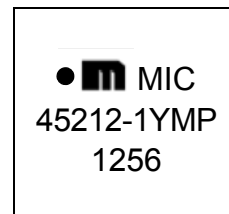
## 6.0 PACKAGING INFORMATION

### 6.1 Package Marking Information

64-Lead 12 mm x 12 mm B2QFN



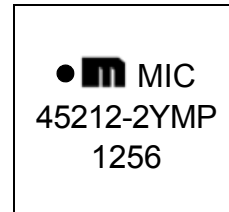
Example



64-Lead 12 mm x 12 mm B2QFN



Example



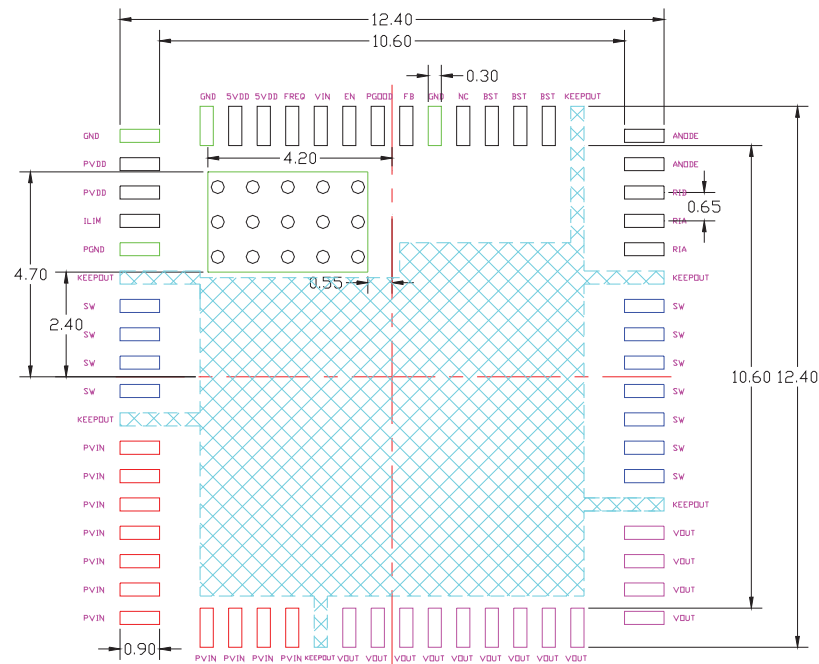
|                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Legend:</b> | <p>XX...X Product code or customer-specific information</p> <p>Y Year code (last digit of calendar year)</p> <p>YY Year code (last 2 digits of calendar year)</p> <p>WW Week code (week of January 1 is week '01')</p> <p>NNN Alphanumeric traceability code</p> <p>(e3) Pb-free JEDEC® designator for Matte Tin (Sn)</p> <p>* This package is Pb-free. The Pb-free JEDEC designator ((e3)) can be found on the outer packaging for this package.</p> <p>•, ▲, ▼ Pin one index is identified by a dot, delta up, or delta down (triangle mark).</p> |
| <b>Note:</b>   | <p>In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer-specific information. Package may or may not include the corporate logo.</p> <p>Underbar ( _ ) and/or Overbar ( ¯ ) symbol may not be to scale.</p>                                                                                                                                                                                                            |



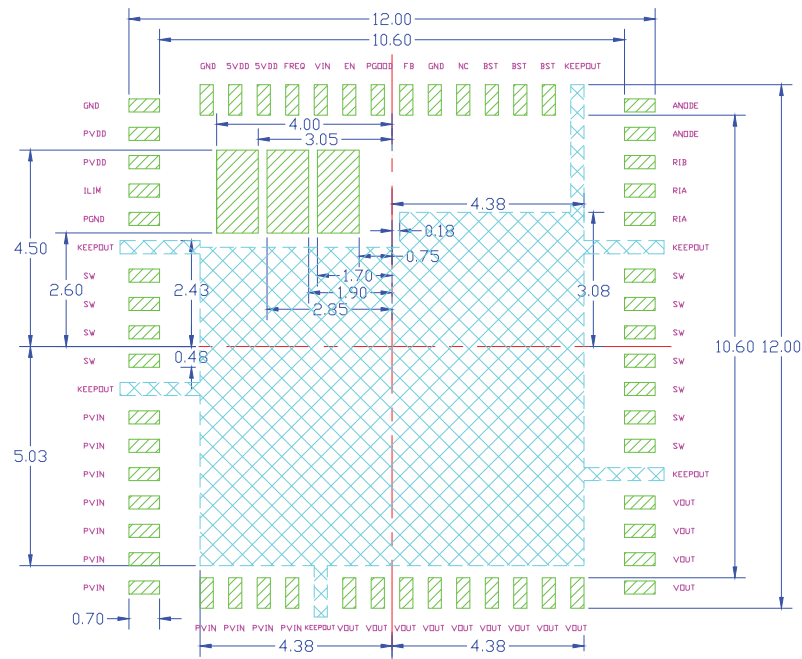
## Recommended Land Pattern

NOTE: 4, 5, 6

### Simplified LP



### EXPOSED METAL TRACE



---

NOTE: 4, 5, 6

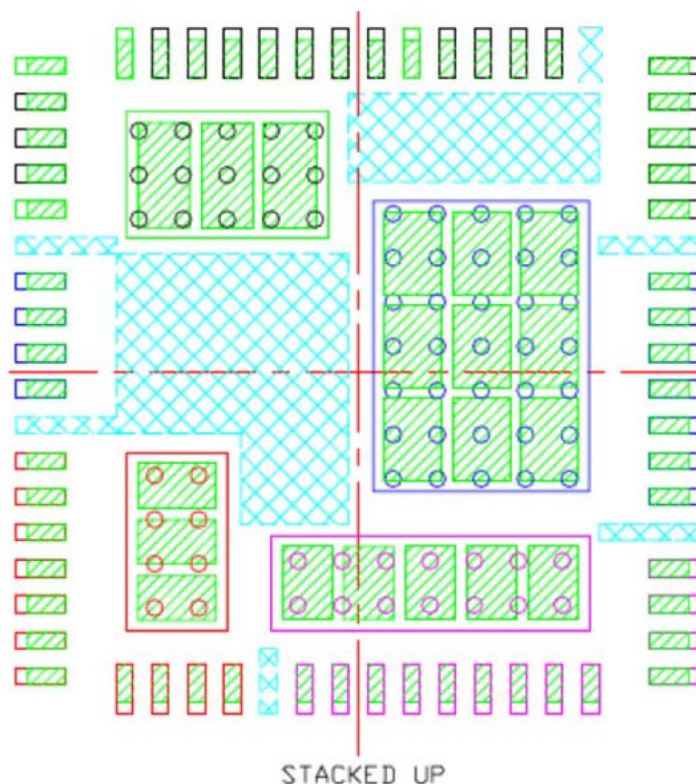
Pin configuration diagram for the ATmega328P microcontroller in a 28-pin DIP package. The diagram shows the pin numbers 1 through 28 around the perimeter. Pins 1-16 are on the left, and pins 17-28 are on the right. A central grid shows the internal connections between pins. A legend on the right identifies the pin functions: GND, 5VDD, 5VDD, FREQ, VIN, EN, PGD, FB, GND, NC, BST, BST, KEEPOUT, and VOUT. The diagram is color-coded: green for power and ground, blue for digital I/O, red for analog I/O, and yellow for power and ground. A large blue cross-hatched area covers the central pins (17-28).

STACKED UP

1. MAX PACKAGE WARPAGE IS 0.05 MM
2. MAX ALLOWABLE BURR IS 0.076MM IN ALL DIRECTIONS
3. PIN #1 IS ON TOP WILL BE LASER MARKED
4. BLACK CIRCLES IN LAND PATTERN REPRESENT THERMAL VIA, RECOMMENDED SIZE IS 0.30-0.35mm, AT 0.80mm PITCH & SHOULD BE CONNECTED TO GND FOR MAXIMUM PERFORMANCE.
5. GREEN RECTANGLES (SHADED AREA) REPRESENT SOLDER STENCIL OPENING ON EXPOSED PAD AREA.
6. CYAN COLORED SHADED PAD REPRESENT EXPOSED TRACE KEEP OUT AREA.



## 6.3 Thermally Enhanced Landing Pattern (Continued)



### NOTE:

1. MAX PACKAGE WARPAGE IS 0.05 MM
2. MAX ALLOWABLE BURR IS 0.076MM IN ALL DIRECTIONS
3. PIN #1 IS ON TOP WILL BE LASER MARKED
4. BLACK CIRCLES IN LAND PATTERN REPRESENT THERMAL VIA, RECOMMENDED SIZE IS 0.30-0.35mm, AT 0.80mm PITCH & SHOULD BE CONNECTED TO GND FOR MAXIMUM PERFORMANCE.
5. GREEN RECTANGLES (SHADED AREA) REPRESENT SOLDER STENCIL OPENING ON EXPOSED PAD AREA.
6. CYAN COLORED SHADED PAD REPRESENT EXPOSED TRACE KEEP OUT AREA.

Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>.

## APPENDIX A: REVISION HISTORY

### Revision A (November 2017)

- Converted Micrel document MIC45212-1/-2 to Microchip data sheet DS20005607A.
- Minor text changes throughout document.

### Revision B (May 2018)

- Corrected references to Pin 51 name and functionality in [Package Types](#), [Table 3-1](#), and [Section 6.3 “Thermally Enhanced Landing Pattern”](#).

# MIC45212-1/-2

---

NOTES:

## PRODUCT IDENTIFICATION SYSTEM

To order or obtain information, e.g., on pricing or delivery, contact your local Microchip representative or sales office.

| <u>PART NO.</u>    |           | - | <u>X</u>                       |  | <u>XXX</u> | - | <u>XX</u>  |
|--------------------|-----------|---|--------------------------------|--|------------|---|------------|
| Device             |           |   | Option                         |  | Package    |   | Media Type |
| <b>Device:</b>     | MIC45212: |   | 26V, 14A DC-to-DC Power Module |  |            |   |            |
| <b>Option:</b>     | 1         | = | HLL                            |  |            |   |            |
|                    | 2         | = | HSC                            |  |            |   |            |
| <b>Package:</b>    | YMP       | = | 64-Pin 12 mm x 12 mm B2QFN     |  |            |   |            |
| <b>Media Type:</b> | T1        | = | 100/Reel                       |  |            |   |            |
|                    | TR        | = | 750/Reel                       |  |            |   |            |

### Examples:

- a) MIC45212-1YMP-T1: MIC45212, HLL, 64-Pin B2QFN, 100/Reel
- b) MIC45212-1YMP-TR: MIC45212, HLL, 64-Pin B2QFN, 750/Reel
- c) MIC45212-2YMP-T1: MIC45212,HSC, 64-Pin B2QFN, 100/Reel
- d) MIC45212-2YMP-TR: MIC45212,HSC, 64-Pin B2QFN, 750/Reel

# MIC45212-1/-2

---

NOTES:

---

**Note the following details of the code protection feature on Microchip devices:**

- Microchip products meet the specification contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is one of the most secure families of its kind on the market today, when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods used to breach the code protection feature. All of these methods, to our knowledge, require using the Microchip products in a manner outside the operating specifications contained in Microchip's Data Sheets. Most likely, the person doing so is engaged in theft of intellectual property.
- Microchip is willing to work with the customer who is concerned about the integrity of their code.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of their code. Code protection does not mean that we are guaranteeing the product as "unbreakable."

Code protection is constantly evolving. We at Microchip are committed to continuously improving the code protection features of our products. Attempts to break Microchip's code protection feature may be a violation of the Digital Millennium Copyright Act. If such acts allow unauthorized access to your software or other copyrighted work, you may have a right to sue for relief under that Act.

---

Information contained in this publication regarding device applications and the like is provided only for your convenience and may be superseded by updates. It is your responsibility to ensure that your application meets with your specifications. MICROCHIP MAKES NO REPRESENTATIONS OR WARRANTIES OF ANY KIND WHETHER EXPRESS OR IMPLIED, WRITTEN OR ORAL, STATUTORY OR OTHERWISE, RELATED TO THE INFORMATION, INCLUDING BUT NOT LIMITED TO ITS CONDITION, QUALITY, PERFORMANCE, MERCHANTABILITY OR FITNESS FOR PURPOSE. Microchip disclaims all liability arising from this information and its use. Use of Microchip devices in life support and/or safety applications is entirely at the buyer's risk, and the buyer agrees to defend, indemnify and hold harmless Microchip from any and all damages, claims, suits, or expenses resulting from such use. No licenses are conveyed, implicitly or otherwise, under any Microchip intellectual property rights unless otherwise stated.

*Microchip received ISO/TS-16949:2009 certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona; Gresham, Oregon and design centers in California and India. The Company's quality system processes and procedures are for its PIC® MCUs and dsPIC® DSCs, KEELOQ® code hopping devices, Serial EEPROMs, microperipherals, nonvolatile memory and analog products. In addition, Microchip's quality system for the design and manufacture of development systems is ISO 9001:2000 certified.*

**QUALITY MANAGEMENT SYSTEM**  
**CERTIFIED BY DNV**  
**== ISO/TS 16949 ==**

### Trademarks

The Microchip name and logo, the Microchip logo, AnyRate, AVR, AVR logo, AVR Freaks, BeaconThings, BitCloud, CryptoMemory, CryptoRF, dsPIC, FlashFlex, flexPWR, Helder, JukeBlox, KEELOQ, KEELOQ logo, Klear, LANCheck, LINK MD, maxStylus, maxTouch, MediaLB, megaAVR, MOST, MOST logo, MPLAB, OptoLyzer, PIC, picoPower, PICSTART, PIC32 logo, Prochip Designer, QTouch, RightTouch, SAM-BA, SpyNIC, SST, SST Logo, SuperFlash, tinyAVR, UNI/O, and XMEGA are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

ClockWorks, The Embedded Control Solutions Company, EtherSynch, Hyper Speed Control, HyperLight Load, IntelliMOS, mTouch, Precision Edge, and Quiet-Wire are registered trademarks of Microchip Technology Incorporated in the U.S.A.

Adjacent Key Suppression, AKS, Analog-for-the-Digital Age, Any Capacitor, AnyIn, AnyOut, BodyCom, chipKIT, chipKIT logo, CodeGuard, CryptoAuthentication, CryptoCompanion, CryptoController, dsPICDEM, dsPICDEM.net, Dynamic Average Matching, DAM, ECAN, EtherGREEN, In-Circuit Serial Programming, ICSP, Inter-Chip Connectivity, JitterBlocker, KlearNet, KlearNet logo, Mindi, MiWi, motorBench, MPASM, MPF, MPLAB Certified logo, MPLIB, MPLINK, MultiTRAK, NetDetach, Omniscient Code Generation, PICDEM, PICDEM.net, PICKit, PICtail, PureSilicon, QMatrix, RightTouch logo, REAL ICE, Ripple Blocker, SAM-ICE, Serial Quad I/O, SMART-I.S., SQI, SuperSwitcher, SuperSwitcher II, Total Endurance, TSHARC, USBCheck, VariSense, ViewSpan, WiperLock, Wireless DNA, and ZENA are trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

SQTP is a service mark of Microchip Technology Incorporated in the U.S.A.

Silicon Storage Technology is a registered trademark of Microchip Technology Inc. in other countries.

GestIC is a registered trademark of Microchip Technology Germany II GmbH & Co. KG, a subsidiary of Microchip Technology Inc., in other countries.

All other trademarks mentioned herein are property of their respective companies.

© 2018, Microchip Technology Incorporated, All Rights Reserved.  
ISBN: 978-1-5224-3011-7

---

**NOTES:**

## Worldwide Sales and Service

### AMERICAS

**Corporate Office**  
 2355 West Chandler Blvd.  
 Chandler, AZ 85224-6199  
 Tel: 480-792-7200  
 Fax: 480-792-7277  
 Technical Support:  
<http://www.microchip.com/support>  
 Web Address:  
[www.microchip.com](http://www.microchip.com)

**Atlanta**  
 Duluth, GA  
 Tel: 678-957-9614  
 Fax: 678-957-1455

**Austin, TX**  
 Tel: 512-257-3370

**Boston**  
 Westborough, MA  
 Tel: 774-760-0087  
 Fax: 774-760-0088

**Chicago**  
 Itasca, IL  
 Tel: 630-285-0071  
 Fax: 630-285-0075

**Dallas**  
 Addison, TX  
 Tel: 972-818-7423  
 Fax: 972-818-2924

**Detroit**  
 Novi, MI  
 Tel: 248-848-4000

**Houston, TX**  
 Tel: 281-894-5983

**Indianapolis**  
 Noblesville, IN  
 Tel: 317-773-8323  
 Fax: 317-773-5453  
 Tel: 317-536-2380

**Los Angeles**  
 Mission Viejo, CA  
 Tel: 949-462-9523  
 Fax: 949-462-9608  
 Tel: 951-273-7800

**Raleigh, NC**  
 Tel: 919-844-7510

**New York, NY**  
 Tel: 631-435-6000

**San Jose, CA**  
 Tel: 408-735-9110  
 Tel: 408-436-4270

**Canada - Toronto**  
 Tel: 905-695-1980  
 Fax: 905-695-2078

### ASIA/PACIFIC

**Australia - Sydney**  
 Tel: 61-2-9868-6733

**China - Beijing**  
 Tel: 86-10-8569-7000

**China - Chengdu**  
 Tel: 86-28-8665-5511

**China - Chongqing**  
 Tel: 86-23-8980-9588

**China - Dongguan**  
 Tel: 86-769-8702-9880

**China - Guangzhou**  
 Tel: 86-20-8755-8029

**China - Hangzhou**  
 Tel: 86-571-8792-8115

**China - Hong Kong SAR**  
 Tel: 852-2943-5100

**China - Nanjing**  
 Tel: 86-25-8473-2460

**China - Qingdao**  
 Tel: 86-532-8502-7355

**China - Shanghai**  
 Tel: 86-21-3326-8000

**China - Shenyang**  
 Tel: 86-24-2334-2829

**China - Shenzhen**  
 Tel: 86-755-8864-2200

**China - Suzhou**  
 Tel: 86-186-6233-1526

**China - Wuhan**  
 Tel: 86-27-5980-5300

**China - Xian**  
 Tel: 86-29-8833-7252

**China - Xiamen**  
 Tel: 86-592-2388138

**China - Zhuhai**  
 Tel: 86-756-3210040

### ASIA/PACIFIC

**India - Bangalore**  
 Tel: 91-80-3090-4444

**India - New Delhi**  
 Tel: 91-11-4160-8631

**India - Pune**  
 Tel: 91-20-4121-0141

**Japan - Osaka**  
 Tel: 81-6-6152-7160

**Japan - Tokyo**  
 Tel: 81-3-6880-3770

**Korea - Daegu**  
 Tel: 82-53-744-4301

**Korea - Seoul**  
 Tel: 82-2-554-7200

**Malaysia - Kuala Lumpur**  
 Tel: 60-3-7651-7906

**Malaysia - Penang**  
 Tel: 60-4-227-8870

**Philippines - Manila**  
 Tel: 63-2-634-9065

**Singapore**  
 Tel: 65-6334-8870

**Taiwan - Hsin Chu**  
 Tel: 886-3-577-8366

**Taiwan - Kaohsiung**  
 Tel: 886-7-213-7830

**Taiwan - Taipei**  
 Tel: 886-2-2508-8600

**Thailand - Bangkok**  
 Tel: 66-2-694-1351

**Vietnam - Ho Chi Minh**  
 Tel: 84-28-5448-2100

### EUROPE

**Austria - Wels**  
 Tel: 43-7242-2244-39  
 Fax: 43-7242-2244-393

**Denmark - Copenhagen**  
 Tel: 45-4450-2828  
 Fax: 45-4485-2829

**Finland - Espoo**  
 Tel: 358-9-4520-820

**France - Paris**  
 Tel: 33-1-69-53-63-20  
 Fax: 33-1-69-30-90-79

**Germany - Garching**  
 Tel: 49-8931-9700

**Germany - Haan**  
 Tel: 49-2129-3766400

**Germany - Heilbronn**  
 Tel: 49-7131-67-3636

**Germany - Karlsruhe**  
 Tel: 49-721-625370

**Germany - Munich**  
 Tel: 49-89-627-144-0  
 Fax: 49-89-627-144-44

**Germany - Rosenheim**  
 Tel: 49-8031-354-560

**Israel - Ra'anana**  
 Tel: 972-9-744-7705

**Italy - Milan**  
 Tel: 39-0331-742611  
 Fax: 39-0331-466781

**Italy - Padova**  
 Tel: 39-049-7625286

**Netherlands - Drunen**  
 Tel: 31-416-690399  
 Fax: 31-416-690340

**Norway - Trondheim**  
 Tel: 47-7289-7561

**Poland - Warsaw**  
 Tel: 48-22-3325737

**Romania - Bucharest**  
 Tel: 40-21-407-87-50

**Spain - Madrid**  
 Tel: 34-91-708-08-90  
 Fax: 34-91-708-08-91

**Sweden - Gothenberg**  
 Tel: 46-31-704-60-40

**Sweden - Stockholm**  
 Tel: 46-8-5090-4654

**UK - Wokingham**  
 Tel: 44-118-921-5800  
 Fax: 44-118-921-5820