AC/DC Converter
Non-Isolation Buck Converter PWM method
12 W 12 V
BM2P016 Reference Board

User’s Guide
<High Voltage Safety Precautions>

◇ Read all safety precautions before use

Please note that this document covers only the BM2P016 evaluation board (BM2P016-EVK-002) and its functions. For additional information, please refer to the datasheet.

To ensure safe operation, please carefully read all precautions before handling the evaluation board

Depending on the configuration of the board and voltages used, **Potentially lethal voltages may be generated.**

Therefore, please make sure to read and observe all safety precautions described in the red box below.

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Before Use

[1] Verify that the parts/components are not damaged or missing (i.e. due to the drops).
[2] Check that there are no conductive foreign objects on the board.
[3] Be careful when performing soldering on the module and/or evaluation board to ensure that solder splash does not occur.
[4] Check that there is no condensation or water droplets on the circuit board.

During Use

[5] Be careful to not allow conductive objects to come into contact with the board.
[6] **Brief accidental contact or even bringing your hand close to the board may result in discharge and lead to severe injury or death.**

Therefore, **DO NOT touch the board with your bare hands or bring them too close to the board.**

In addition, as mentioned above please exercise extreme caution when using conductive tools such as tweezers and screwdrivers.

[7] If used under conditions beyond its rated voltage, it may cause defects such as short-circuit or, depending on the circumstances, explosion or other permanent damages.
[8] Be sure to wear insulated gloves when handling is required during operation.

After Use

[9] The ROHM Evaluation Board contains the circuits which store the high voltage. Since it stores the charges even after the connected power circuits are cut, please discharge the electricity after using it, and please deal with it after confirming such electric discharge.
[10] Protect against electric shocks by wearing insulated gloves when handling.

This evaluation board is intended for use only in research and development facilities and should be handled **only by qualified personnel familiar with all safety and operating procedures.**

We recommend carrying out operation in a safe environment that includes the use of high voltage signage at all entrances, safety interlocks, and protective glasses.

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AC/DC Converter
Non-Isolation Buck Converter PWM method Output 12 W 12 V
BM2P016 Reference Board
BM2P016-EVK-002

The BM2P016-EVK-002 evaluation board outputs a 12 V voltage from an input of 90 Vac to 264 Vac. The output current provides up to 1.0 A. The BM2P016 PWM type DC / DC converter IC with 650 V MOSFET is used. The BM2P016 contributes to low power consumption by incorporating a 650 V withstand voltage startup circuit. Using current mode control, cycle-by-cycle current limiting provides excellent performance in bandwidth and transient response. The switching frequency is fixed at 65 kHz. At light loads, frequency reduction achieves high efficiency. Built-in frequency hopping function contributes to low EMI. The low on-resistance 1.4 Ω · 650 V withstand voltage MOSFET is built in, contributing to low power consumption and easy design.
The optimized EMI design complies with CISPR 22 Class B for noise terminal voltage / radiation emission testing.

![Figure 1. BM2P016-EVK-002](image)

**Electronics Characteristics**

Not guarantee the characteristics, is representative value. Unless otherwise noted: Vin = 230 Vac, IOUT = 500 mA, Ta = 25 °C

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
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<tr>
<td>Input Voltage Range</td>
<td>90</td>
<td>230</td>
<td>264</td>
<td>Vac</td>
<td></td>
</tr>
<tr>
<td>Input Frequency</td>
<td>47</td>
<td>50/60</td>
<td>63</td>
<td>Hz</td>
<td></td>
</tr>
<tr>
<td>Output Voltage</td>
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<td>12.0</td>
<td>13.2</td>
<td>V</td>
<td></td>
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<tr>
<td>Maximum Output Power</td>
<td>-</td>
<td>-</td>
<td>12.0</td>
<td>W</td>
<td>IOUT = 1000mA</td>
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<tr>
<td>Output Current Range (NOTE1)</td>
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<td>500</td>
<td>1000</td>
<td>mA</td>
<td></td>
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<tr>
<td>Stand-by Power</td>
<td>-</td>
<td>110</td>
<td>-</td>
<td>mW</td>
<td>IOUT = 0A</td>
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<tr>
<td>Efficiency</td>
<td>-</td>
<td>81.2</td>
<td>-</td>
<td>%</td>
<td></td>
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<tr>
<td>Output Ripple Voltage (NOTE2)</td>
<td>-</td>
<td>42</td>
<td>-</td>
<td>mVpp</td>
<td></td>
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<tr>
<td>Operating Temperature Range</td>
<td>-10</td>
<td>25</td>
<td>65</td>
<td>ºC</td>
<td></td>
</tr>
</tbody>
</table>

*(NOTE1)* Please adjust operating time, within any parts surface temperature under 105 °C

*(NOTE2)* Not include spike noise
**Operation Procedure**

1. Operation Equipment
   
   (1) AC Power supply 90 ~ 264 Vac, over 20W
   
   (2) Electronic Load capacity 1.0 A
   
   (3) Multi meter

2. Connect method
   
   (1) AC power supply presetting range 90~264 Vac, Output switch is off.
   
   (2) Load setting under 1.0 A. Load switch is off.
   
   (3) AC power supply N terminal connect to the board AC (N) of CN1-1, and L terminal connect to AC (L) of CN1-2.
   
   (4) Load + terminal connect to VOUT terminal, Load – terminal connect to GND terminal.
   
   (5) AC power meter connect between AC power supply and board.
   
   (6) Output test equipment connects to output terminal
   
   (7) AC power supply switch ON.
   
   (8) Check that output voltage is 12 V
   
   (9) Electronic load switch ON
   
   (10) Check output voltage drop by load connect wire resistance

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![Connection Circuit](image)

**Figure 2. Connection Circuit**
Deleting

The operating temperature range of this evaluation board is -10 to 65 °C. Make sure that the part surface temperature does not exceed 105 °C. The maximum power that can be supplied continuously is 6.0 W (I_{OUT} = 0.5 A). The figure below shows the derating curve. A load of 8.0 W (I_{OUT} = 0.67 A) can be applied continuously until the ambient temperature is -10 °C to 40 °C. The temperature from 40 °C to 65 °C follows the derating curve. The maximum power that can be supplied instantaneously is 12 W (I_{OUT} = 1.0 A). When using the product beyond the derating curve, adjust the load current time so that the component surface temperature does not exceed 105 °C within the operating temperature range (-10 to 65 °C).

![Derating Curve](image)

**Figure 3. Temperature Deleting curve**

Application Circuit

V_{IN} = 90 ~ 264 Vac, V_{OUT} = 12 V

![Application Circuit Diagram](image)

**Figure 4. BM2P016-EVK-002 Application Circuit**

Non-isolated buck converter method. The output voltage is monitored by a feedback circuit and fed back to the FB terminal through a photo coupler. At startup, the VCC voltage is charged from the DRAIN pin through the Starter circuit. The switching operation starts when the VCC voltage reaches the UVLO release voltage 13.5 V typ.
BM2P016 Overview

Feature
- PWM frequency : 65 kHz
- PWM current mode method
- Frequency hopping function
- Burst operation at light load
- Frequency reduction function
- Built-in 650V start circuit
- Built-in 650V switching MOSFET
- VCC pin under voltage protection
- VCC pin over voltage protection
- SOURCE pin Open protection
- SOURCE pin Short protection
- SOURCE pin Leading-Edge-Blanking function
- Per-cycle over current protection circuit
- AC Correction function of over current limiter
- Soft Start Function
- Secondary over current protection circuit

Key specifications
- Operation Voltage Range: VCC: 8.9 V ~ 26.0 V
  DRAIN: 650 V(Max)
- Normal Operating Current: 0.95 mA(Typ)
- Burst Operating Current: 0.30 mA(Typ)
- Oscillation Frequency: 65 kHz(Typ)
- Operating Temperature: -40 °C ~ +105 °C
- MOSFET Ron: 1.4 Ω(Typ)

Application
AC adapters and household appliance (vacuum cleaners, humidifiers, air cleaners, air conditioners, IH cooking heaters, rice cookers, etc.)

Dimension
DIP7 9.20 mm x 6.35 mm x 4.30 mm
Pitch 2.54 mm

(*) Product structure: Monolithic integrated circuit mainly made of silicon. No radiation resistant design
(*) Exceeding the absolute maximum ratings, such as applied voltage and operating temperature range, may lead to deterioration or destruction. Also, the short mode or open mode cannot assume the destruction state. If a special mode that exceeds the absolute maximum rating is assumed, Please consider physical safety measures such as fuses.

Table 1. BM2P016 PIN description

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>I/O</th>
<th>Function</th>
<th>ESD</th>
<th>Diode</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>SOURCE</td>
<td>I/O</td>
<td>MOSFET SOURCE pin</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>2</td>
<td>FADJ</td>
<td>I</td>
<td>MAX burst frequency setting pin</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>3</td>
<td>GND</td>
<td>I/O</td>
<td>GND pin</td>
<td>✓</td>
<td>-</td>
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<tr>
<td>4</td>
<td>FB</td>
<td>I</td>
<td>Feed-back signal input pin</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>5</td>
<td>VCC</td>
<td>I</td>
<td>Power supply input pin</td>
<td>-</td>
<td>✓</td>
</tr>
<tr>
<td>6</td>
<td>DRAIN</td>
<td>I/O</td>
<td>MOSFET DRAIN pin</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>DRAIN</td>
<td>I/O</td>
<td>MOSFET DRAIN pin</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Design Overview

1 Important parameter

- **V\text{IN}**: Input Voltage Range AC 90 V ~ 264 Vac (DC 100 V ~ 380 V)
- **V\text{OUT}**: Output Voltage DC 12 V
- **I\text{OUT(typ)}**: Constant Output Current 1 0.50 A
- **I\text{OUT(typ)}**: Constant Output Current 2 0.67 A
- **I\text{OUT(max)}**: Maximum Output Current 1.00 A
- **f\text{SW}**: Max Switching Frequency min:60 kHz, typ:65 kHz, max:70 kHz

There are three types of coil operation modes:

- **CCM (Continuous Current Mode)**: The primary side switching element is turned on before the charging current of the secondary side coil is completely discharged. Since the coil current is continuous.
- **BCM (Boundary Current Mode)**: The switching element on the primary side is turned on at the same time the discharge of the coil on the secondary side is completed.
- **DCM (Dis-continuous Current Mode)**: The primary side switching element turns on after the secondary side coil is completely discharged. It is called current discontinuous mode because the coil current is not continuous.

![Figure 6. Switching Waveform (MOSFET V\text{DS}, I\text{DS})](image)
Design Overview - Continued

2 Selection of Coil
2.1 Calculation of inductor

The switching operation mode determines the L value to be in discontinuous mode (DCM) as much as possible. In the case of continuous mode (CCM), the reverse current flows between the diode trr, which causes the diode loss to increase. Furthermore, this reverse current becomes the peak current when the MOSFET is ON, and the loss of the MOSFET also increases. Calculate the L value to be in boundary mode (BCM) at constant load current.

The steady-state load current I_{OUT} (Typ): 0.5 A, and the peak current I_P flowing through the inductor is

\[ I_P(BCM) = I_{OUT}(typ) \times 2 = 1.0 \text{ A} \]

When the input voltage drops, it tends to be in continuous mode (CCM). Calculate under the condition that the minimum voltage of input voltage V_{IN} (min) = 100 Vdc. Output voltage

Calculate the maximum value of Duty: Duty (max) from V_{OUT}: 12 V and diode V_F: 1 V.

\[ \text{Duty(max)} = \frac{V_{OUT} + V_F}{V_{IN}(min)} = 0.13 \]

From the switching frequency minimum value f_{SW} (min) = 60 kHz, calculate the on time t_{on} (max).

\[ t_{on}(max) = \frac{\text{Duty(max)}}{f_{SW}(min)} = 2.17 \mu\text{sec} \]

Calculate the L value to operate in discontinuous mode.

\[ L < t_{on}(Max) \times \frac{V_{IN}(min) - V_{OUT}}{I_P} = 191.0 \mu\text{H} \]

In EVK, the L value is tentatively selected 220 \mu H in consideration of versatility.
Design Overview - Continued

2.2 Calculation of inductor current

The value of current flowing through the coil is maximum when the input voltage is maximum. Operates with the minimum ON time when the input voltage is maximum $V_{\text{in}}$ (max): 380 V. The maximum ON time is about 0.6 to 1.2 μsec depending on the conditions such as the output voltage and L value of the coil. The maximum peak current $I_p$ (max) is

$$I_p(\text{max}) = t_{\text{ON}}(\text{min}) \times \frac{V_{\text{IN}}(\text{max}) - V_{\text{OUT}}}{L} = 0.9 \mu s \times \frac{380 V - 12 V}{220 \mu H} = 1.51 [A]$$

Therefore, the inductor to be selected should have an inductor current of 1.5 A or more. The inductor current is checked on the actual device to confirm that magnetic saturation does not occur.

In this EVK, use an inductance value of 220 μH and an allowable current of 1.6 A.

Radial Inductor (Closed Magnetic Type)  Core Size Φ9.0 mm x 11.0 mm
Product Name: XE1501Y-221
Manufacturer: Alpha transformer Co., Ltd

3. Selection of current detection resistor $R_S$ (R1, R2)

The current detection resistance $R_S$ (R1, R2) is calculated so that the overcurrent detection becomes maximum load current $I_{\text{OUT}}$: 1000 mA or more. Set the load current $I_{\text{LIM}}$ for overcurrent detection to be $I_{\text{LIM}}$: 1200 mA with a 20% margin. When overcurrent is detected, switching operation is performed in continuous mode.

![Figure 8. Coil waveform at overcurrent detection (in continuous mode)](image)

The coil current $I_{\text{PEAK}}$ at the time of overcurrent detection is calculated by the following formula. Overcurrent detection turns off after a delay time $t_{\text{dy}}$ after coil current is detected by $I_{\text{PEAK}}$ current.

$$I_{\text{LIM}} = I_p - \frac{I_{\text{ripple}}}{2}$$

$$I_p = I_{\text{PEAK}} + \frac{V_{\text{IN}}}{L} \times t_{\text{dy}}$$

$$I_{\text{ripple}} = \Delta I_L \times t_{\text{ON}} = \frac{V_{\text{IN}}}{L} \times \frac{\text{Duty}}{f_{\text{SW}}} = \frac{V_{\text{OUT}} + V_F}{L \times f_{\text{SW}}}$$. 
3 Selection of current detection resistor - Continued

\[ I_{\text{LIM}} = I_{\text{PEAK}} + \frac{V_{\text{IN}}(\text{min})}{L} - \frac{1}{2} \times \frac{V_{\text{OUT}} + V_F}{L \times f_{\text{SW}}(\text{min})} \]

The coil current at the time of over current detection is as follows.

\[ I_{\text{PEAK}} = I_{\text{LIM}} - \frac{V_{\text{IN}}}{L \times t_{\text{diy}}} + \frac{V_{\text{OUT}} + V_F}{2 \times L \times f_{\text{SW}}(\text{min})} = 1.2 \times \frac{100 \ V}{220 \ \mu H \times 0.1 \ \mu s} + \frac{12 \ V + 1 \ V}{2 \times 220 \ \mu H \times 60 \ kHz} = 1.65 \ [A] \]

The time to which the IC detects an overcurrent is

\[ t'_{\text{ON}} = \frac{\text{Duty(max)}}{f_{\text{SW}}(\text{min})} = \frac{V_{\text{OUT}} + V_F}{V_{\text{IN}}(\text{min}) \times f_{\text{SW}}(\text{min})} - \frac{12 \ V + 1 \ V}{100 \ V \times 60 \ kHz} - 0.1 \ \mu s = 2.07 \ [\mu\text{sec}] \]

AC voltage compensation function is built into overload protection, and the difference of the overload protection point is compensated by the difference of input voltage (100 Vac, 200 Vac, etc). This function is an AC voltage correction function by increasing the over current limiter level \( V_{\text{CS,LIM}} \) with time.

The overcurrent detection voltage \( V_{\text{SOURCE}} = 0.4 \ V \), the correction coefficient \( K_{\text{SOURCE}} \) is 20 mV / \( \mu \text{sec} \), and the voltage \( V_{\text{CS,LIM}} \) of the SOUCE pin at the time of overcurrent detection is

\[ V_{\text{CS,LIM}} = V_{\text{SOURCE}} + t_{\text{ON}} \times K_{\text{SOURCE}} = 0.4 \ V + 2.07 \ \mu s \times 20 \ mV/\mu s = 441.4 \ mV \]

The sense resistance \( R_s \) is as follows.

\[ R_s < \frac{V_{\text{CS-LIM}}}{I_{\text{PEAK}}} = \frac{441.4 \ mV}{1.65 \ A} = 0.267 \ \Omega \]

In this EVK, R1 and R2 have two 0.47 \( \Omega \) in parallel, and \( R_s = 0.235 \ \Omega \). The overload protection point needs to be checked in the board.

Voltage \( V_R \) applied to sense resistors R1 and R2 is

\[ V_R = \frac{I_F}{2} \times R_1 = \frac{1}{2} \times \left( I_{\text{PEAK}} + \frac{V_{\text{IN}}}{L} \times t_{\text{diy}} \right) \times R_1 = 0.5 \times \left( 1.65 \ A + \frac{100 \ V}{220 \ \mu H} \times 0.1 \ \mu s \right) \times 0.47 \ \Omega = 0.398 \ V \]

Power loss \( P_s \) of sense resistors R1 and R2 is

\[ P_s = \left( I_F \times \frac{\text{Duty}}{3} \right)^2 \times R_s = \left( 1.70 \ A \times \frac{0.13}{3} \right)^2 \times 0.235 \ \Omega = 29.4 \ [\text{mW}] \]

The resistors used are the MCR18 series, with a maximum device voltage of 1.51 V and a rated power of 0.25 W.
Design Overview - Continued

4 Selection of diode

4.1 Flywheel diode: D1

Flywheel diodes use high-speed diodes (fast recovery diodes). The reverse voltage applied to the diode is $V_{\text{IN}}$ (Max): 380 V when the output voltage at startup is 0 V. Ensure derating and select 600 V withstand voltage product.

The conditions for maximum diode effective current are when the input voltage is maximum voltage $V_{\text{IN}}$ (max): 380 V, maximum load current $I_{\text{OUT}}$ (Max): 1.0 A, and the switching frequency is a minimum of 60 kHz.

The peak current $I_p$ at this time is calculated. The ripple current $I_{\text{ripple}}$ is as follows.

$$I_{\text{ripple}} = \frac{\frac{d}{dt} \times t_{\text{ON}}}{L} = \frac{(V_{\text{IN}}(\text{max}) - (V_{\text{OUT}} + V_F))}{V_{\text{IN}}(\text{max}) \times f_{\text{SW}}(\text{min})} \times (V_{\text{OUT}} + V_F)$$

Applying to the peak current formula,

$$I_p = I_{\text{OUT}}(\text{max}) + \frac{I_{\text{ripple}}}{2} = 1.0 \, A + \frac{1}{2} \times \frac{380 \, V - (12 \, V + 1 \, V)}{220 \, \mu H} \times \frac{12 \, V + 1 \, V}{380 \, V \times 60 \, kHz} = 1.48 \, [A]$$

$$\text{Duty} = \frac{V_{\text{OUT}} + V_F}{V_{\text{IN}}(\text{max})} = \frac{12 \, V + 1 \, V}{380 \, V} = 3.4 \, [%]$$

The average current $I_D$ of the diode is from peak current $I_p$: 1.48 A

$$I_D(\text{rms}) = I_p \times \sqrt{\frac{1 - \text{Duty}}{3}} = 1.48 \, A \times \sqrt{\frac{1 - 0.034}{3}} = 0.84 \, [A]$$

Select a rated current of 0.84 A or more.

In practice, the 3A / 600V RFN3BM6S is used in consideration of board mounting and component heat generation.

4.2 VCC rectifier diode: D2

The diode supplying VCC uses a rectifying diode. The reverse voltage applied to the diode is $V_{\text{IN}}$ (Max): 380V. Ensure derating and select 600 V withstand voltage product. Because the current flowing to the IC is small enough, we use the 0.2 A / 600 V RRE02VSM6S.
Design Overview - Continued

5  Selection of capacitor

5.1 Input Capacitor: C3

The input capacitor is determined by the input voltage \( V_I \) and the output power \( P_{OUT} \). As a guide, for an input voltage of 90 to 264 Vac, \( 2 \times P_{OUT} \) [W] \( \mu \)F. In the case of 176 to 264 Vac, it is \( 1 \times P_{OUT} \) [W] \( \mu \)F. Since the output power \( P_{OUT} = 12.0 \) W, use 33 \( \mu \)F / 450 V with a standard of 24.0 \( \mu \)F.

5.2 VCC Capacitor: C7

VCC capacitor C7 is necessary for stable operation of the IC and stable feedback of the output voltage. We recommend 1.0 \( \mu \)F to 22 \( \mu \)F at a withstand voltage of 25 V or more. I am using 10 \( \mu \)F / 35 V.

5.3 Output Capacitor: C8, C9

The output capacitor should be 25 V or more in consideration of derating for the output voltage \( V_O \). The C2 electrolytic capacitor needs to consider the capacitance, impedance and rated ripple current. The output ripple voltage is the combined waveform generated by the ripple current of inductor current: \( \Delta I_L \) flowing into the output capacitor and the capacitance: \( C_{out} \), impedance: ESR, and is expressed by the following formula.

\[
\Delta V_{Ripple} = \Delta I_L \times \left( \frac{1}{8 \times C_{out} \times f_{sw}} \right) + ESR
\]

Inductor current ripple current: \( I_L \), DC current: \( I_{DC} \)

\[
\Delta I_L = 2 \times (I_P - I_{OUT(max)}) = 2 \times (1.48 - 1.00) = 0.96 \text{ [A]} \quad I_{DC} = I_P - \Delta I_L = 1.48 \text{ A} - 0.96 \text{ A} = 0.52 \text{ [A]}
\]

In this EVK, using capacitance: 680 \( \mu \)F, ESR: 0.049 \( \Omega \), the design value of the output ripple voltage is 100 mV or less.

\[
\Delta V_{Ripple} = \Delta I_L \times \left( \frac{1}{8 \times C_{out} \times f_{sw}} \right) + ESR = 0.96 \times \left( \frac{1}{8 \times 680 \mu \times 65k} \right) + 0.049 = 49.8 \text{ [mV]}
\]

Next, check if the ripple current of the capacitor satisfies the rated ripple current. Inductor ripple current RMS conversion,

\[
I_{L[\text{rms}]} = \Delta I_L \times \frac{1}{\sqrt{3}} + I_{DC} = 0.96 \times \frac{1}{\sqrt{3}} + 0.52 \text{ A} = 1.07 \text{ [Arms]}
\]

The ripple current of the capacitor is

\[
I_{C[\text{rms}]} = \sqrt{I_L^2 - I_{OUT}^2} = \sqrt{1.07^2 - 1.0^2} = 0.381 \text{ [A]}
\]

Select a rated current of 0.381 A or more. The output capacitor C8 used rated ripple current 1.24 A at 680 \( \mu \)F / 25 V. C9 adds a 0.1 \( \mu \)F ceramic capacitor to reduce switching noise.
Design Overview - Continued

6 Output voltage setting resistor: R6,R7,R8

The output voltage is set by the following formula.

\[ V_{OUT} = \left( 1 + \frac{R6 + R7}{R8} \right) \times V_{ref} \]

Set the feedback current \( I_{BIAS} \) flowing to R8 at 0.1 mA to 1.0 mA.
Assuming that \( I_{BIAS} = 0.25 \text{ mA} \), and the reference voltage \( V_{REF} = 2.485 \text{ V} \) of the shunt regulator IC2, the resistance value of R8 is

\[ R8 = \frac{V_{REF}}{I_{BIAS}} = \frac{2.485 \text{ V}}{0.25 \text{ mA}} = 9.9 \text{ [kΩ]} \]

In this EVK, select R8: 10 kΩ.

The combined resistance of the feedback resistors (R6+R7+R8) is

\[ R6 + R7 + R8 = \frac{V_{OUT}}{I_{BIAS}} = \frac{12 \text{ V}}{0.25 \text{ mA}} = 48 \text{ [kΩ]} \]

In this EVK, R6 = 33 kΩ and R7 = 5.6 kΩ are selected. The theoretical value of the output voltage is as follows.

\[ V_{OUT} = \left( 1 + \frac{33 \text{ kΩ} + 5.6 \text{ kΩ}}{10 \text{ kΩ}} \right) \times 2.485 \text{ V} = 12.08 \text{ V} \]

7 Control circuit adjustment: R9,R10,R11,C10

R10 is the dark current setting resistor for shunt regulator IC2. The current value \( I_{min} \) for stable operation of the shunt regulator is 1.2 mA according to the data sheet of the IC. This current is the combined current of R10 and the photo coupler’s \( I_c \). Since the voltage applied to R10 is the \( V_F \) of the photo coupler, assuming that the \( V_F \) of the photo coupler is 1.1 V,

\[ R10 < \frac{V_F}{I_{min}} = \frac{1.1 \text{ V}}{1.2 \text{ mA}} = 0.92 \text{ [kΩ]} \]

In this EVK, select R10 = 1.0 kΩ.

R9 is the control circuit current limiting resistor. Adjust with 300 to 2.2 kΩ.

In this EVK, select R9 = 1.0 kΩ.

R11 and C10 are phase compensation circuits. Adjust R11 = 1 k-30 kΩ, C10 = 0.1 μF or so with the actual device.
Performance Data

Load Regulation

Table 2. Load Regulation (VIN=100 Vac)

<table>
<thead>
<tr>
<th>IOUT</th>
<th>VOUT</th>
<th>Efficiency</th>
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</thead>
<tbody>
<tr>
<td>250 mA</td>
<td>12.003 V</td>
<td>82.99 %</td>
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<tr>
<td>500 mA</td>
<td>11.997 V</td>
<td>83.20 %</td>
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<tr>
<td>667 mA</td>
<td>11.991 V</td>
<td>82.45 %</td>
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<tr>
<td>1000 mA</td>
<td>11.984 V</td>
<td>80.32 %</td>
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</tbody>
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Table 3. Load Regulation (VIN=230 Vac)

<table>
<thead>
<tr>
<th>IOUT</th>
<th>VOUT</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
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Figure 10. Load Regulation (IOUT vs VOUT)

Figure 11. Load Regulation (IOUT vs Efficiency)

Figure 12. Load Regulation (IOUT vs PLOSS)

Figure 13. Load Regulation (IOUT vs PLOSS)
### Performance Data – Continued

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Performance Data – Continued

**Line Regulation**

![Line Regulation Graph](image1)

Figure 14. Line Regulation (VIN vs VOUT)

![Line Regulation Graph](image2)

Figure 15. Line Regulation (VIN vs Efficiency)

**Switching Frequency**

![Switching Frequency Graph](image3)

Figure 16. Switching Frequency (IOUT vs fSW)

**Coil Peak Current**

![Coil Peak Current Graph](image4)

Figure 17. Coil Peak Current (IOUT vs lnR)
Performance Data – Continued

Output Ripple Voltage

Figure 18. $V_{IN} = 100$ Vdc, $I_{OUT} = 10$ mA

Figure 19. $V_{IN} = 230$ Vac, $I_{OUT} = 10$ mA

Figure 20. $V_{IN} = 100$ Vac, $I_{OUT} = 500$ mA

Figure 21. $V_{IN} = 230$ Vac, $I_{OUT} = 500$ mA

Figure 22. $V_{IN} = 100$ Vac, $I_{OUT} = 1000$ mA

Figure 23. $V_{IN} = 230$ Vac, $I_{OUT} = 1000$ mA
Performance Data – Continued

Parts surface temperature

Table 6. Parts surface temperature  \( T_a = 25 ^\circ C \), measured 30 minutes after startup

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<th>( V_{IN}=90 \text{ Vac}, I_{OUT}=0.67 \text{ A} )</th>
<th>( V_{IN}=264 \text{ Vac}, I_{OUT}=0.50 \text{ A} )</th>
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EMI

Figure 24. Conducted Emission.1
- \( V_{IN}=110 \text{ Vac}/60 \text{ Hz}, I_{OUT}=0.5 \text{ A} \)
- QP margin : 9.6 dB, AV margin = 13.6 dB

Figure 25 Conduction Emission.2
- \( V_{IN}=230 \text{ Vac}/50 \text{ Hz}, I_{OUT}=0.5 \text{ A} \)
- QP margin : 17.7 dB, AV margin = 24.5 dB
Schematics

Vin = 90 – 264 Vdc, Vout = 12 V

Figure 26. BM2P016-EVK-002 Schematics

Bill of Materials

Table 7. BoM of BM2P016-EVK-002

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<td>Resistor</td>
<td>3.3kΩ</td>
<td>0.1W, ±1%</td>
<td>MCR03EZPFX3301</td>
<td>ROHM</td>
<td>1608 (0603)</td>
</tr>
<tr>
<td>R10</td>
<td>1</td>
<td>Resistor</td>
<td>1kΩ</td>
<td>0.1W, ±5%</td>
<td>MCR03EZP102</td>
<td>ROHM</td>
<td>1608 (0603)</td>
</tr>
<tr>
<td>R11</td>
<td>1</td>
<td>Resistor</td>
<td>10kΩ</td>
<td>0.1W, ±5%</td>
<td>MCR03EZP103</td>
<td>ROHM</td>
<td>1608 (0603)</td>
</tr>
<tr>
<td>ZNR1</td>
<td>1</td>
<td>Varistor</td>
<td>-</td>
<td>470V, 400A</td>
<td>V470ZA05P</td>
<td>LittleFuse</td>
<td>-</td>
</tr>
</tbody>
</table>
PB20120 Rev.A

Figure 27. Top Layout (Top view)

Figure 28. Bottom Layout (Top view)
Notice

ROHM  Customer Support System
http://www.rohm.com/contact/

Thank you for your accessing to ROHM product informations.
More detail product informations and catalogs are available, please contact us.

Notes

1) The information contained herein is subject to change without notice.

2) Before you use our Products, please contact our sales representative and verify the latest specifications.

3) Although ROHM is continuously working to improve product reliability and quality, semiconductors can break down and malfunction due to various factors. Therefore, in order to prevent personal injury or fire arising from failure, please take safety measures such as complying with the derating characteristics, implementing redundant and fire prevention designs, and utilizing backups and fail-safe procedures. ROHM shall have no responsibility for any damages arising out of the use of our Products beyond the rating specified by ROHM.

4) Examples of application circuits, circuit constants and any other information contained herein are provided only to illustrate the standard usage and operations of the Products. The peripheral conditions must be taken into account when designing circuits for mass production.

5) The technical information specified herein is intended only to show the typical functions of and examples of application circuits for the Products. ROHM does not grant you, explicitly or implicitly, any license to use or exercise intellectual property or other rights held by ROHM or any other parties. ROHM shall have no responsibility whatsoever for any dispute arising out of the use of such technical information.

6) The Products specified in this document are not designed to be radiation tolerant.

7) For use of our Products in applications requiring a high degree of reliability (as exemplified below), please contact and consult with a ROHM representative: transportation equipment (i.e. cars, ships, trains), primary communication equipment, traffic lights, fire/crime prevention, safety equipment, medical systems, servers, solar cells, and power transmission systems.

8) Do not use our Products in applications requiring extremely high reliability, such as aerospace equipment, nuclear power control systems, and submarine repeaters.

9) ROHM shall have no responsibility for any damages or injury arising from non-compliance with the recommended usage conditions and specifications contained herein.

10) ROHM has used reasonable care to ensure the accuracy of the information contained in this document. However, ROHM does not warrants that such information is error-free, and ROHM shall have no responsibility for any damages arising from any inaccuracy or misprint of such information.

11) Please use the Products in accordance with any applicable environmental laws and regulations, such as the RoHS Directive. For more details, including RoHS compatibility, please contact a ROHM sales office. ROHM shall have no responsibility for any damages or losses resulting non-compliance with any applicable laws or regulations.

12) When providing our Products and technologies contained in this document to other countries, you must abide by the procedures and provisions stipulated in all applicable export laws and regulations, including without limitation the US Export Administration Regulations and the Foreign Exchange and Foreign Trade Act.

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