Isolated Flyback Type PWM Mode
BM2P26CK-Z Evaluation Board

User's Guide

＜High Voltage Safety Precautions＞

◇ Read all safety precautions before use

Please note that this document covers only the BM2P26CK-Z evaluation board (BM2P26CK-EVK-001) 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.

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 by 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.

AC/DC Converter (Output 2.5 W 5 V)

Isolated Flyback Type PWM Mode BM2P26CK-Z Evaluation Board

BM2P26CK-EVK-001

General Description

This evaluation board's output voltage is 5 V for an input voltage 90 Vac to 264 Vac and the maximum output current is 0.5 A. The BM2P26CK-Z is an AC/DC flyback converter in PWM Mode with integrated 800 V MOSFET. The built-in 650 V startup circuit in BM2P26CK-Z contributes to low power consumption. Current is restricted in each cycle and excellent performance is achieved in bandwidth and transient response since current mode control is utilized. The switching frequency is operating at 100 kHz. At light load, the switching frequency is reduced and high efficiency is achieved. A built-in frequency hopping function contributes to low EMI. Built-in the low on resistor (6.0 Ω) and high voltage tolerant MOSFET (800 V) make designs easy. The BMP2P26CK-Z has reached (achieved) IEC62368-1 standard authorization. This evaluation board is compliant with CISPR22 Class. B which is the test of the noise pin voltage and emission by an optimum EMI design.

Figure 1. BM2P26CK-EVK-001

Electronics Characteristics

Not guarantee the characteristics is representative value. Unless otherwise noted, V_{IN} = 230 Vac, I_{OUT} = 0.5 A, Ta = 25 °C

Parameter	Min	Typ	Max	Units	Conditions
Input Voltage Range	90	230	264	V	
Input Frequency	47	50/60	63	Hz	
Output Voltage	4.75	5.00	5.25	V	
Maximum Output Power	-	-	2.5	W	I_{OUT} = 0.5 A
Output Current Range^(Note 1)^	0.0	0.5	0.5	A	
Standby Power	-	40	-	mW	I_{OUT} = 0 A
Power Efficiency	65	71.1	-	%	
Output Ripple Voltage^(Note 2)^	-	60	-	mVpp	
Operating Temperature Range	-10	+25	+65	°C	

(Note 1) Adjust operating time, within any parts surface temperature under 105 °C

(Note 2) Not include spike noise.

Operation Procedure

1 Necessary Equipment

(1) AC power supply (90 Vac to 264 Vac, 10 W or more)

(2) Load equipment (0.5 A at maximum value)

(3) DC voltmeter

2 Connect to Each Equipment

(1) Set the AC power supply to 90 Vac to 264 Vac with power supply off.

(2) Set the load 0.5 A or less.

(3) Connect the N pin of the power supply to the CN1-1: AC (N) pin and the L pin to the CN1-2: AC (L) pin with mains cable (wires)

(4) Connect the plus pin of load to the CN2-2 (VOUT) pin and the minus pin to the CN2-1 (GND) pin with output cable (wires).

(5) Connect the wattmeter to the power supply in order to measure input voltage and current.

(6) Connect the plus pin of the DC voltmeter to the CN2-2 (VOUT) pin and the minus pin to the CN2-1 (GND) pin in order to measure the output voltage.

(7) Turn on the output of the AC power supply.

(8) Confirm that the DC voltmeter displays 5 V.

(9) Enable the load.

(10) Confirm by the DC voltmeter whether the voltage effect is occurred by the resistance of wires.

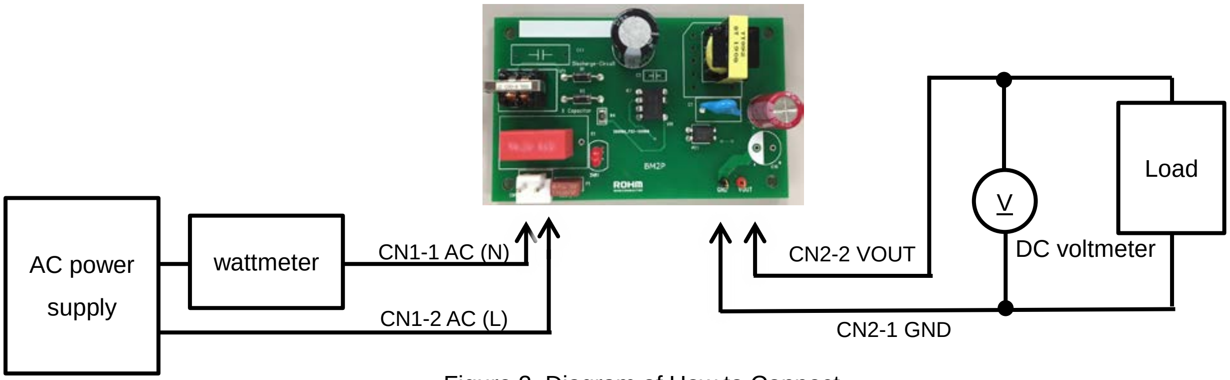


Figure 2. Diagram of How to Connect

Application Circuit

The flyback topology is adopted in this evaluation board.

The BM2P26CK-Z has a built in Super Junction MOSFET which is high voltage tolerant V_{DSS}: 800 V and low resistance $R_{DS(ON)}$: 6.0 Ω, and this MOSFET contributes to make the power consumption low.

It monitors the output voltage (VOUT) by the feedback circuit and feeds back to the FB pin of the BM2P26CK-Z through the optocoupler.

At startup, the voltage from the VH pin is supplied to the VCC pin thorough the startup circuit and it makes the VCC pin voltage increase. When the VCC pin voltage exceeds the UVLO released voltage 15.50 V (Typ), the BM2P26CK-Z switch begins. After start of switching, the startup circuit is turned off and it cut the supply from the VH pin, in order to have low power consumption for instance in standby mode. In addition, the BM2P26CK-Z has a built in current detection resistor of which the over current detection value is 0.192 A (Min). The residual voltage discharge circuit of the insert power supply plug (X capacitor discharge function) is built in the IC and it is possible to make the value of X capacitor large.

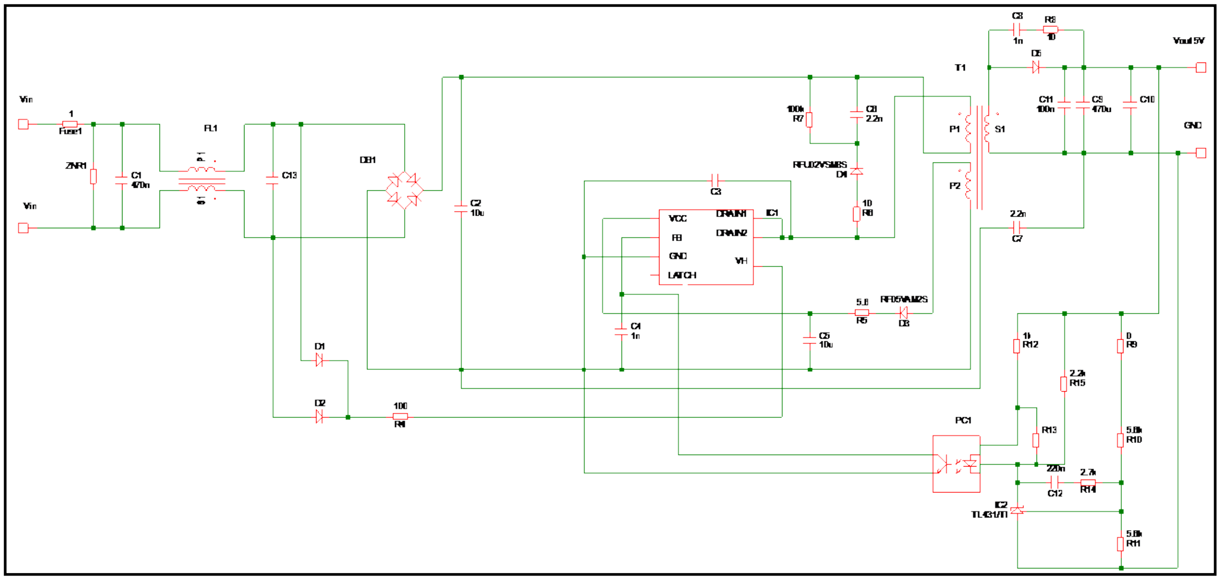


Figure 3. Application Circuit

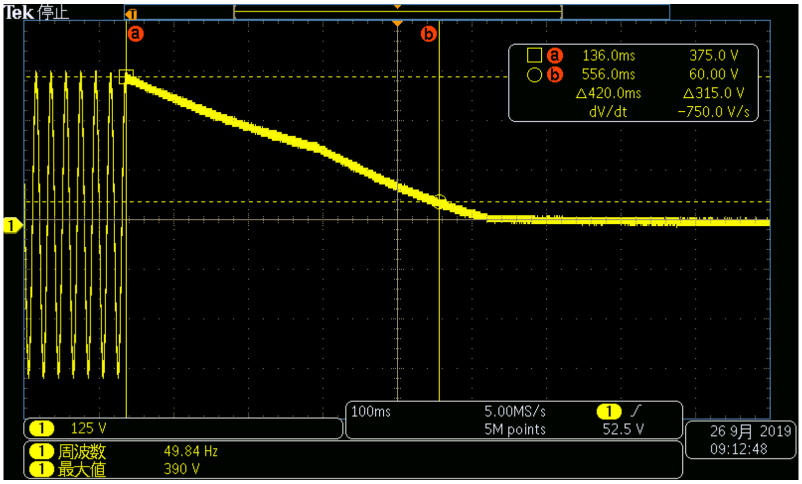


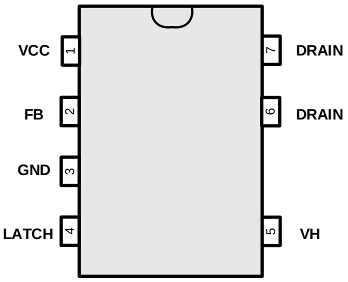
Figure 4. Wave Form of Residual Voltage

General Description of BM2P26CK-Z

Features

- X Capacitor Discharge Function
- PWM Current Mode
- Frequency Hopping Function
- Burst Operation at Light Load
- Frequency Reduction Function
- Built-in 650 V Startup Circuit
- Built-in 800 V Super Junction MOSFET
- VCC UVLO (Under Voltage Lockout)
- VCC OVP (Over Voltage Protection)
- Over Current Detection Function per Cycle
- Over Current Detection Function AC Compensation
- Soft Start Function
- External Latch Function

Pin Configuration



Key Specifications

- Operation Power Supply Voltage Range
  VCC Pin Voltage: 11.9 V to 25.5 V
  DRAIN Pin Voltage: 800 V (Max)
  VH Pin Voltage: 650 V (Max)
- Current at Switching Operation: 0.60 mA (Typ)
- Current at Burst Operation: 0.35 mA (Typ)
- Maximum Switching Frequency: 100 kHz (Typ)
- Operation Temperature Range: -40 °C to +105 °C
- MOSFET On Resistor: 6.0 Ω (Typ)

Applications

AC Adaptor, Various Household Applications (TV, Vacuum Cleaner, Humidifier, Air Cleaner, Air Conditioner, IH Cooking Heater and Rice Cooker, etc.)

Package	W(Typ) x D(Typ) x H(Typ)
DIP7K	9.27 mm x 6.35 mm x 8.63 mm

(Note 1) Product structure: Silicon integrated circuit. This product has no designed protection against radioactive rays.

(Note 2) Operating the IC over the absolute maximum ratings may damage the IC. The damage can either be a short circuit between pins or an open circuit between pins and the internal circuitry. Therefore, it is important to consider circuit protection measures, such as adding a fuse, in case the IC is operated over the absolute maximum ratings.

Pin Description

No.	Pin Name	I/O	Function
1	VCC	I	Power supply input pin
2	FB	I	Feedback signal input pin
3	GND	-	GND pin
4	LATCH	I	External latch pin
5	VH	I	AC voltage startup pin
6	DRAIN	I/O	MOSFET DRAIN pin
7	DRAIN	I/O	MOSFET DRAIN pin

Design Overview

1 Key Parameters

Parameter	Symbol	Min	Typ	Max	Units	Conditions
Input Voltage Range	V_{IN}	90	230	264	V	
Output Voltage	V_{OUT}	4.75	5.00	5.25	V	
Output Current Range*(Note 1)*	I_{OUT}	0.0	0.5	0.5	A	
Maximum Switching Frequency	f_{SW}	94	100	106	kHz	
Over Current Detection Current	I_{PEAK}	0.192	-	-	A	At 10µs
Power Supply Efficiency	η	-	65	-	%	

(Note 1) The setting maximum output current I_{OUT_MAX} is calculated by the formula below. The value 1.1 indicates margin.

$$I_{OUT\_MAX} = \frac{I_{OUT}}{\eta} \times 1.1 = \frac{0.5}{0.65} \times 1.1 = 0.85 \quad \text{[A]}$$

I_{OUT_MAX} is the maximum output current.

I_{OUT} is the output current.

η is the power supply efficiency.

2 Input Capacitor: C2

Select the value of the input capacitor with Table 1 as an indication.

Table 1. Indication of Input Capacitor Selection

Input Voltage (Vac)	C_{IN} (µF) / P_{IN} (W)
85 to 264	2
180 to 264	1

(Note 1) P_{IN}: Input Power

Example: When the output electricity P_{OUT} = 2.5 W,

$$\frac{P_{OUT}}{\eta} \times 2 = \frac{2.5}{0.65} \times 2 = 7.7 \quad \text{[µF]}$$

P_{OUT} is the output power.

η is the power supply efficiency.

Therefore, it is necessary for the input capacitor to be equivalent to 7.7 µF. A 10 µF capacitor is selected in this case.

2 Input Capacitor: C2 – continued

It is necessary for C2's withstand voltage to be the maximum input voltage or more. The capacitor rated voltage is selected to it regarding the maximum value 264*√2 Vdc. Btw 400 V rated capacitor should be sufficient

The simulation circuit and result (the voltage wave form after smoothing) is shown in below.

The AC input is 90 V / 50 Hz, C2 is 10 μF x 0.8 (including a permissible difference).

Then the smoothing minimum voltage ($V_{INDCMIN}$) is 93 V.

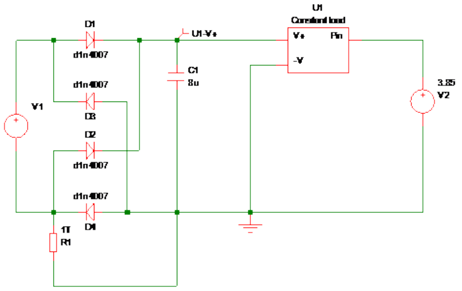


Figure 5. Simulation Circuit Diagram

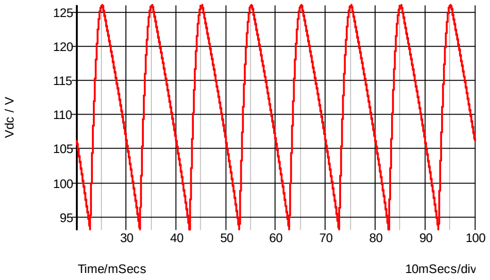


Figure 6. Simulation Result

3 Design of Transformer: T1

For design of the transformer, calculate like the following steps.

3.1 Decide on Transformer Current Slope Coefficient k

Solve the transformer current slope coefficient k by the steps below.

It is necessary for Duty to be set to 0.5 or less and for the transformer current slope coefficient k to be set to 1 or less. The duty cycle is set to 0.42 in this example.

The primary voltage occurred from the secondary voltage of the transformer V_{OR} is calculated by the formula below.

$$V_{OR} = \frac{V_{INDCMIN} \times Duty}{1 - Duty}$$

$$= \frac{93 \times 0.42}{1 - 0.42} = 67.3 \quad \text{[V]}$$

V_{OR} is the primary voltage occurred from the secondary voltage of the transformer
$V_{INDCMIN}$ is the smoothing minimum voltage.
$Duty$ is Duty cycle.

3.1 Decide on Transformer Current Slope Coefficient k – continued

Once V_{OR} is calculated, the winding ratio N of the transformer is calculated.

$$N = \frac{N_P}{N_S} = \frac{V_{OR}}{V_{OUT} + V_F}$$

$$= \frac{67.3}{5 + 0.8} = 11.6$$

N is the winding ratio of the transformer.
N_P is the number of primary winding turns.
N_S is the number of secondary winding turns.
V_{OUT} is the output voltage.
V_F is the forward voltage of the secondary diode.

Next, the secondary peak current I_{SP} and primary peak current I_{PP} is calculated by the formula below.
Firstly, calculate them without the delay time of the built-in MOSFET (t_{DELAY1}), do including t_{DELAY1} after calculating L_P.

$$I_{SP} = I_{PP} \times N$$

$$I_{PP} = I_{PEAK} + \frac{V_{IN}}{L_P \times t_{DELAY1}}$$

$$I_{PP} = 0.110 \quad \text{[A]}$$

It is calculated as $I_{PP} = I_{PEAK}$. Therefore,

$$I_{SP} = 0.192 \times 11.6 = 2.23 \quad \text{[A]}$$

I_{SP} is the secondary peak current.
I_{PP} is the primary peak current.
N is the winding ratio of the transformer.
I_{PEAK} is the over current detection current of BM2P26CK-Z.
L_P is the secondary inductance of the transformer.
t_{DELAY1} is the delay time of the built-in MOSFET.

3.1 Decide on Transformer Current Slope Coefficient k – continued

According to the above, the transformer current slope coefficient k is calculated by the formula below.

$$k = 2 - \frac{2 \times I_{OOU\_MAX}}{(1 - Duty) \times I_{SP}}$$

$$k = 2 - \frac{2 \times 0.85}{(1 - 0.42) \times 2.23} = 0.69$$

k is the transformer current slope coefficient

I_{OUT_MAX} is the setting maximum output current.

$Duty$ is the duty cycle.

I_{SP} is the secondary peak current.

In addition, it is possible to calculated ΔI_S from the above.

$$\Delta I_S = I_{SP} \times k = 2.23 \times 0.69 = \qquad \text{[A]}$$

ΔI_S is the amount of change of the secondary current.

I_{SP} is the secondary peak current.

k is the transformer current slope coefficient.

(Note) The output current is calculated by the formula below because it is the average value of the transformer's secondary current.

$$I_{OUT} = 0.5 \times (I_{SP} + I_{SB}) \times (1 - Duty)$$

$$\Delta I_S = I_{SP} - I_{SB} \qquad \textit{therefore,} \; k = \frac{\Delta I_S}{I_{SP}}$$

$$L_S = \frac{V_{OUT} + V_F}{\Delta I_S} \times \frac{1 - Duty}{f_{SW}}$$

I_{OUT} is the output current.

I_{SP} is the secondary peak current.

I_{SB} is the secondary bottom current.

ΔI_S is the amount of change of the secondary current.

k is the transformer current slope coefficient.

L_S is the secondary inductance of the transformer.

V_{OUT} is the output voltage.

V_F is the forward voltage of the secondary diode.

f_{SW} is the switching frequency.

$Duty$ is the duty cycle.

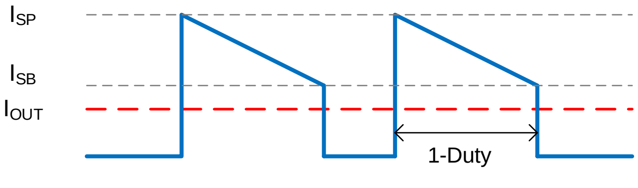


Figure 7. Secondary Current

3 Design of Transformer – continued

3.2 Calculating the Inductance L_S and L_P of the Transformer

Firstly, calculate the secondary inductance L_S of the transformer.

$$L_S = \frac{(V_{OUT} + V_F)}{\Delta I_S} \times \frac{(1 - Duty)}{f_{SW\_MIN}}$$

$$L_S = \frac{(5 + 0.8)}{1.54} \times \frac{(1 - 0.42)}{94} = 23.2 \qquad [\mu H]$$

L_S is the secondary inductance of the transformer.
V_{OUT} is the output voltage.
V_F is the forward voltage of the secondary diode.
ΔI_S is the amount of change of the secondary current.
$Duty$ is the duty cycle.
f_{SW_MIN} is the minimum switching frequency.

Secondarily, calculate the primary inductance L_P.

$$L_P = L_S \times N^2 = 23.2 \times 11.6^2 = 3.13 \qquad [mH]$$

L_P is the primary inductance of the transformer.
L_S is the secondary inductance of the transformer.
N is the ratio of winding number of the transformer.

BM2P26CK-Z has a built-in AC voltage compensation function and it compensates the over current detection current. The over current detection current I_{PP2} which corresponds to the delay time of the built-in MOSFET is calculated by the formula below.

$$I_{PP2} = I_{PEAK} + \frac{V_{DC}}{L_P} \times t_{DELAY2}$$

I_{PP2} is the over current detection current which corresponds to the delay time of a built-in MOSFET.
I_{PEAK} is the secondary inductance of the transformer.
V_{DC} is the ratio of winding number of the transformer.
L_P is the primary inductance of the transformer.
t_{DELAY2} is the delay time after the detection of over current.

Because the minimum value of t_{DELAY2} is 200 ns,

$$I_{PP2} = 0.192 + \frac{93}{3.13\ m} \times 200\ \ n = 0.198 \qquad [A]$$

3.2 Calculating the Inductance L_S and L_P of the Transformer – continued

Recalculate the below using the value I_{PEAK2} obtained in this section.

$$I_{SP} = I_{PP2} \times N = 0.198 \times 11.6 = 2.30 \quad \text{[A]}$$

$$k = 2 - \frac{2 \times 0.85}{(1 - 0.42) \times 2.30} = 0.72$$

$$\mathit{\Delta} I_S = I_{SP} \times k = 2.30 \times 0.72 = 1.65 \quad \text{[A]}$$

I_{SP} is the secondary peak current.

I_{PP2} is the over current detection current of BM2P26CK-Z which corresponds to the delay time of a built-in MOSFET.

N is the ratio of winding number of the transformer.

k is the transformer current slope coefficient.

$\mathit{\Delta} I_S$ is the amount of change of the secondary current.

Calculate the inductance values again.

$$L_S = \frac{(V_{OUT} + V_F)}{\Delta I_S} \times \frac{(1 - Duty)}{f_{SW\_MIN}}$$

$$L_S = \frac{(5 + 0.8)}{1.65} \times \frac{(1 - 0.42)}{94} = 21.6 \quad \text{[μH]}$$

$$L_P = L_S \times N^2 = 21.6 \times 11.6^2 = 2.91 \quad \text{[mH]}$$

L_S is the secondary inductance of the transformer.

V_{OUT} is the output voltage.

V_F is the forward voltage of the secondary diode.

$\mathit{\Delta} I_S$ is the amount of change of the secondary current.

$Duty$ is the duty cycle.

f_{SW_MIN} is the minimum switching frequency.

3.3 Decide on Transformer Size

By Po(max) = 2.5 W, EE16 is selected for the core size of transformer because of large winging number.

Table 2. Output Power and Transformer Core

Output Power Po (W)	Core Size	Core's Cross Section Ae (mm^2)
to 5	EI13/EE13	17.1
to 8	EI16/EE16	18.9
to 10	EI19/EE19	23.1

(Note) The above is reference value. Confirm their detail to the manufacture.

3 Design of Transformer – continued

3.4 Calculating of Primary Winding Number N_P

Maximum magnetic flux density B (T) of general ferrite cores is 0.4 T at Ta = 100 °C.

Thus, B_{SAT} is set to 0.35 T and the core whose cross section Ae is 18.9 mm^2 is selected.

$$N_P > \frac{L_P \times I_{PP2}}{Ae \times B_{SAT}} = \frac{2810\ \mu H \times 0.198\ A}{18.9\ mm^2 \times 0.35\ T} = 87.1 \qquad [T]$$

N_P is the primary winding number of the transformer.
L_P is the primary inductance of the transformer.
I_{PP2} is the over current detection current of BM2P26CK-Z which corresponds to the delay time of a built-in MOSFET.
A_e is the core's cross section.
B_{SAT} is the effective saturation magnetic flux density.

Therefore, the primary winding number N_P is set to 88 turns or more. For this example, it is calculated in N_P = 114 turns so that the wire is winded tightly from the bobbin size of the transformer.

3.4 Calculating of Secondary Winding Number N_S

The secondary winding number N_S is calculated by the formula below.

From $$\frac{N_P}{N_S} = 11.6 \quad ,$$

$$N_S = \frac{114}{11.6} = 9.8 \fallingdotseq 10 \qquad [T]$$

N_P is the primary winding number of the transformer.
N_S is the secondary winding number of the transformer.

Therefore, N_S is set to 10 turns. So the ratio of the winding number is shown in below.

$$N = \frac{N_P}{N_S} = \frac{114}{10} = 11.4$$

N is the winging ratio of the transformer.
N_S is the number of secondary turns of the transformer.
N_P is the number of primary turns of the transformer.

3 Design of Transformer – continued

3.6 Calculating of the VCC winding number N_D

When the VCC pin voltage V_{CC} = 16 V and the forward voltage of the VCC pin diode V_{F_VCC} = 1 V, the VCC winding number N_D is calculated by the formula below.

$$N_D = N_S \times \frac{V_{CC} + V_{F\_VCC}}{V_{OUT} + V_F} = 10\ \ T \times \frac{16\ \ V + 1.0V}{5.0\ \ V + 0.8\ \ V} = \qquad [\mathrm{T}]$$

N_D is the VCC winding number.
N_S is the secondary winding number of the transformer.
V_{CC} is the VCC pin voltage.
V_{F_VCC} is the forward voltage of the VCC pin diode.
V_{OUT} is the output voltage.
V_F is the forward voltage of the secondary diode.

According to above, N_D is set to 30 turns. And set the V_{CC} to 15 V or more.

3.7 Recalculation of the primary inductance value L_P

The all value it is necessary for the calculation of the primary inductance L_P is obtained, and then recalculation by the steps below.

$$V_{OR} = (V_{OUT} + V_F) \times N = (5 + 0.8) \times 11.4 = 66.1 \qquad [\mathrm{V}]$$

$$Duty = \frac{V_{OR}}{V_{OR} + V_{IN}} = \frac{66.1}{66.1 + 93} = 0.42$$

$$I_{PP2} = 0.192 + \frac{93}{2.91} \times 200 = 0.198 \qquad [\mathrm{A}]$$

$$I_{SP} = I_{PP2} \times N = 0.198 \times 11.4 = 2.26 \qquad [\mathrm{A}]$$

$$k = 2 - \frac{2 \times 0.85}{(1 - 0.41) \times 2.26} = 0.73$$

$$\Delta I_S = I_{SP} \times k = 2.26 \times 0.73 = 1.65 \qquad [\mathrm{A}]$$

$$L_S = \frac{(V_{OUT} + V_F)}{\Delta I_S} \times \frac{(1 - Duty)}{f_{SW\_MIN}} = \frac{(5 + 0.8)}{1.65} \times \frac{(1 - 0.42)}{94} = 22.1 \qquad [\mu\mathrm{H}]$$

$$L_P = L_S \times N^2 = 22.1 \times 11.4^2 = 2.87 \qquad [\mathrm{mH}]$$

(Note) The description of each parameter is mentioned in the next page.

3.7 Recalculation of the primary inductance value L_P – continued

V_{OR} is the primary voltage occurred from the secondary voltage of the transformer.
V_{OUT} is the output voltage.
V_F is the forward voltage of the secondary diode.
N is the ratio of winding number of the transformer.
$Duty$ is the duty cycle.
V_{IN} is the input voltage.
I_{PP2} is the over current detection current of BM2P26CK-Z which corresponds to the delay time of a built-in MOSFET.
I_{SP} is the secondary peak current.
k is the transformer current slope coefficient.
ΔI_S is the amount of change of the secondary current.
L_S is the secondary inductance of the transformer.
f_{SW_MIN} is the minimum switching frequency.
L_P is the primary inductance of the transformer.

According to the above, the specification of the transformer is determined like the below.

Table 3. Specification of the Transformer (reference)

Parameter	Symbol	Value	Unit
Core	-	EE16 (compatible)	-
Primary Inductance	L_P	2.87	mH
Primary Winding Number	N_P	114	turns
Secondary Winding Number	N_S	10	turns
VCC Winding Number	N_D	30	turns

3 Design of Transformer – continued

3.8 Design Sample of the Transformer

Manufacture	Alphatrans Co., Ltd. (1-7-2, Bakurou-cho, Chuo-ku, Osaka City, 541-0059, Japan) http//www.alphatrans.jp/

Product Name	XE2373Y
Bobbin	10PIN
Core	EE16

- ■ Primary Inductance 2.87 mH ± 10 % (100 kHz, 1 V)
- ■ Voltage Endurance

Between Primary and Secondary	AC1500 V
Between Primary and Core	AC1500 V
Between Secondary and Core	AC500 V

- ■ Isolated Resistor 100 MΩ or over (DC500 V)

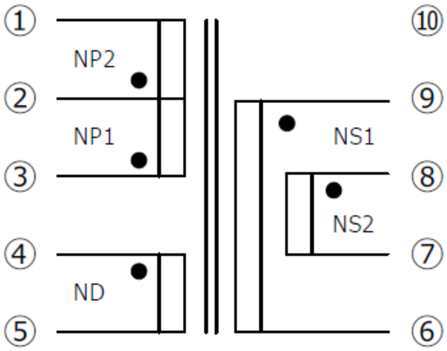


Figure 8. Circuit Diagram

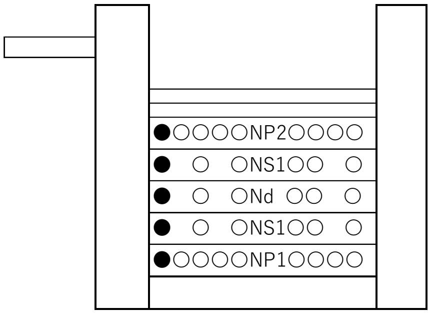


Figure 9. Structure Diagram

Table 4. Product Specification of XE2373Y

No.	Transformer	Winding Pin		Wire	Turn Number	Tape Layer	Wire Specification
		Start	Finish				
1	NP1	3	2	2UEW / Φ0.17 x 1	38	1	COMPACT
2	NS1	9	6	TEX / Φ0.32 x 2	10	1	COMPACT
3	ND	4	5	2UEW / Φ0.17 x 1	30	1	COMPACT
4	NS1	8	7	TEX / Φ0.32 x 1	10	1	COMPACT
5	NP2	2	1	2UEW / Φ0.17 x 1	76	2	COMPACT

Design Overview – continued

4 VCC Pin Diode: D3

A high-speed diode is recommended for the VCC pin diode.

The reverse voltage V_{D1} applied to the VCC pin diode is calculated by the formula below.

$$V_{D1} = V_{OVP\_MAX} + V_{IN\_MAX} \times \frac{N_D}{N_P}$$

$$V_{D1} = 29.0 + 374 \times \frac{30}{114} = 127 \qquad \text{[V]}$$

V_{D1} is the reverse voltage applied to the VCC pin diode.
V_{OVP_MAX} is 29.0 V which is the maximum value of VCC OVP detection voltage of BM2P26CK-Z.
V_{IN_MAX} is the maximum value of the input voltage.
N_D is the VCC winding number.
N_P is the primary winding number of transformer.

Considering the margin,

$$\frac{127}{0.7} = 181 \fallingdotseq 200 \qquad \text{[V]}$$

Therefore, a 200 V product is selected for the VCC pin diode D3.

(Recommended item: RF05VAM2S (ROHM) 200 V / 0.5 A)

5 Resistor for Surge Voltage Restrictions for VCC Winding: R5

By the leakage inductance (L_{LEAK}) of the transformer, large surge voltage (spike noise) occurs at the moment the MOSFET turns on to off. The VCC pin voltage rises and VCC OVP in BM2P26CK-Z may be misdetected when the VCC winging evokes this surge voltage.

To reduction the surge voltage evoked to the VCC winding, insert the resistor for restrictions (about 5 Ω to 22 Ω). It is necessary to confirm the state of the VCC pin voltage rising by implementing it in your product. The 5.6 Ω value is selected in this example.

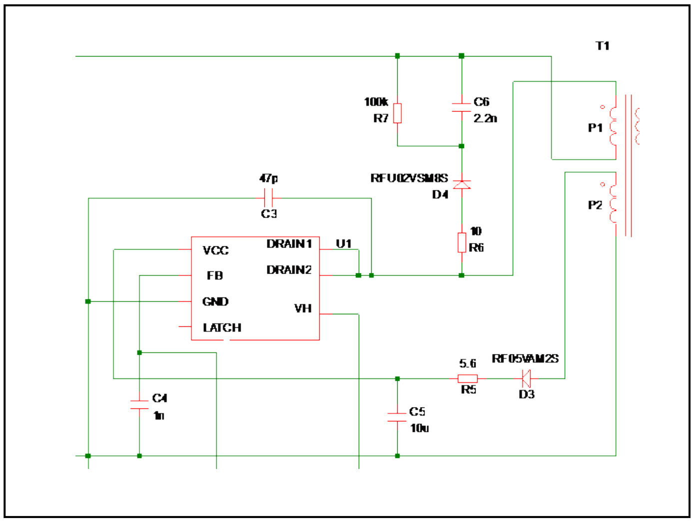


Figure 8. Circuit around BM2P26CK-Z

Design Overview – continued

6 VCC Pin Capacitor: C5

The value of the VCC pin capacitor C_{VCC} is necessary to stabilize the VCC pin voltage in BM2P26CK-Z. The value 4.7 µF to 22 µF is recommended. The relation of the startup time and VCC pin capacitor is shown in Figure 9. A capacitor (10 µF / 35 V) is selected.

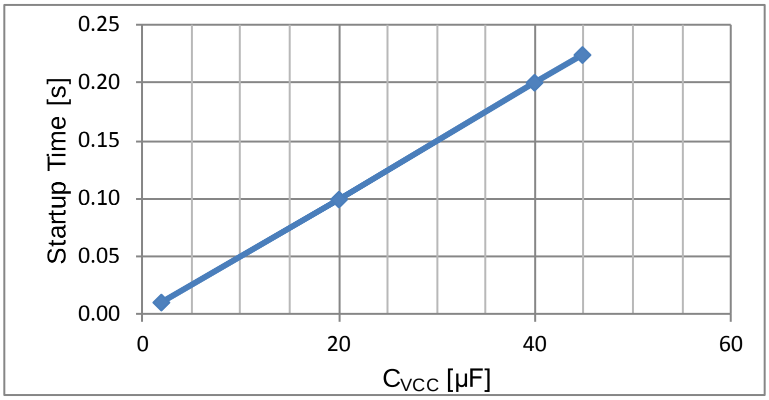


Figure 9. Startup Time (reference)

7 FB Pin Capacitor: C4

C4 is the capacitor for stability of the FB pin. (Recommend about 1000 pF to 0.01 µF)

A capacitor (1000 pF) is selected.

8 RCD Snubber Circuit: C6, R7, R6, D4

By the leakage inductance (L_{LEAK}) of the transformer, large surge voltage occurs at the moment the MOSFET turns on to off. In worst case, the MOSFET may be destroyed because this surge voltage is applied to the between DRAIN and SOURCE of MOSFET. To restrict it, it is recommended to insert the RCD snubber circuit.

(Recommended Value)	C6: 2200 pF	R7: 100 kΩ
	R6: 10 Ω	D4: 800 V / 0.2 A

Use a fast recovery diode for the diode D4. The voltage endurance is necessary to be Vds of MOSFET (Max) or more. (Recommended item: RFU02VSM8S (ROHM) 800 V / 0.2 A)

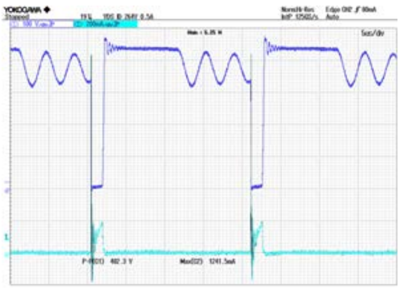


Figure 10. MOSFET DRAIN Voltage Wave Form

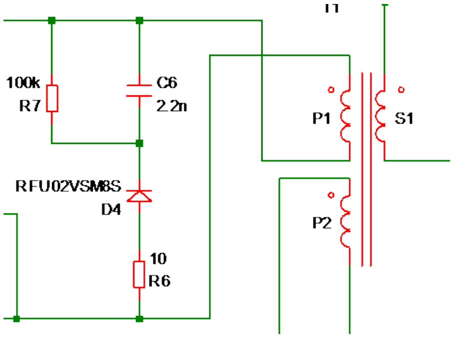


Figure 11. Snubber Circuit

Design Overview – continued

9 Output Rectification Diode: D5

Use a high-speed diode (schottky barrier diode or fast recovery diode) for the output rectification diode. When the output voltage V_{OUT} is set to 5.25 V, the reverse voltage V_{D2} applied to the output rectification diode is calculated by the formula below.

$$V_{D2} = V_{OUT} + V_{IN\_MAX} \times \frac{N_S}{N_P}$$

$$V_{D2} = 5.25 + 374 \times \frac{30}{114} = 38.5 \qquad \text{[V]}$$

V_{D2} is the reverse voltage applied to the output rectification diode.
V_{OUT} is the output voltage.
V_{IN_MAX} is the maximum input voltage.
N_S is the secondary winding number of the transformer.
N_P is the primary winding number of the transformer.

Considering the margin,

$$\frac{38.5}{0.7} = 55 \fallingdotseq 60 \qquad \text{[V]}$$

And the current I_S(rms) flowing to the output diode is calculated by the formula below.

$$I_{S(rms)} = I_{SP} \times \sqrt{\frac{1 - Duty}{3}} = 2.26 \times \sqrt{\frac{1 - 0.42}{3}} = 0.99 \qquad \text{[A]}$$

I_{SP} is the secondary peak current.
$Duty$ is the duty cycle.

A diode (3 A / 60 V) is selected in this evaluation board.

It is recommended to be set the voltage margin to 80 % or less and the current margin to 50 % or less.

(Recommended item: RB058LAM-60 (ROHM) 60 V / 3.0 A)

Design Overview – continued

10 Output Capacitor: C9

The output capacitor is determined by the peak to peak ripple voltage (ΔV_{PP}) and ripple current which are acceptable at the maximum load current value.

At the MOSFET on, the output diode is off. Then the current is supplied to the load current from the output capacitor.

At the MOSFET off, the diode becomes on, and the current supplied to both of the output capacitor and the load current.

The secondary peak current I_{SP} is calculated from the rating output current.

$$I_{SP} = \frac{I_{OUT}}{1 - Duty} + \frac{\Delta I_S}{2}$$

$$I_{SP} = \frac{0.5}{1 - 0.42} + \frac{1.48}{2} = 1.60 \qquad [\mathrm{A}]$$

I_{SP} is the secondary peak current.
I_{OUT} is the output current.
$Duty$ is the duty cycle.
ΔI_S is the amount of change of the secondary current.

At V_{IN} = 100 V, P_{OUT} = 2.5 W, the impedance Z_C of the output capacitor is calculated by the formula below when the ΔV_{PP} is set to be 0.15 V.

$$Z_C < \frac{\Delta V_{PP}}{I_{SP}} = \frac{0.15}{1.6} = 0.094 \qquad [\Omega]$$

Z_C is the impedance of the output capacitor.
ΔV_{PP} is the output ripple voltage.
I_{SP} is the secondary peak current.

And the ripple current I_C(rms) to the capacitor is calculated by the formula below.

$$I_{C(rms)} = \sqrt{{I_{C(rms)}}^2 - {I_{OUT}}^2} = \sqrt{0.73^2 - 0.5^2} = 0.53 \qquad [\mathrm{A}]$$

$I_{C(rms)}$ is the root mean square value of the ripple current to the capacitor.
I_{OUT} is the output current.

10 Output Capacitor: C9 – continued

Because the voltage endurance of the capacitor is determined by referring to 80 % of the derating corresponding to the output voltage.

$$\frac{5}{0.8} = 6.3 \qquad [\mathrm{V}]$$

Therefore, the voltage rating is set to be 10 V.

On this evaluation board, the low impedance type for the switching power supply is used.

(Recommend item: 860 040 75 008 (WURTH) 25 V, 470 µF, Rating ripple current: 1.2 A, Impedance: 68 mΩ (Max))

It is necessary to confirm the actual ripple voltage and current on the actual machines.)

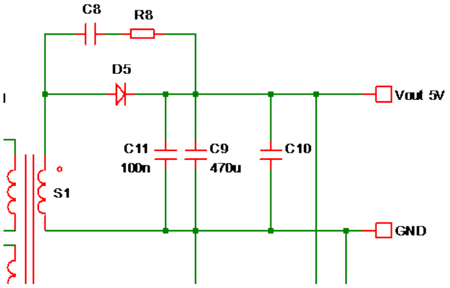


Figure 12. Circuit around Output

11 Setting Resistor of Output Voltage V_{OUT}: R9, R10, R11

The output voltage V_{OUT} is calculated by the formula below.

$$V_{OUT} = \left(1 + \frac{R_9 + R_{10}}{R_{11}}\right) \times V_{REF}$$

First, decide the value of R11. In this evaluation board, a resistor 5.6 kΩ is selected.

The combined resistance (R9 + R10) of the feedback resistor is calculated by the formula below.

$$R_9 + R_{10} = R_{11} \times \left(1 + \frac{V_{OUT}}{V_{REF}}\right) = 5.6 \times \left(1 + \frac{5}{2.495}\right) = 5.6 \qquad [\mathrm{k\Omega}]$$

V_{OUT} is the output voltage.
R_9 is the resistance value of R9.
R_{10} is the resistance value of R10.
R_{11} is the resistance value of R11.
V_{OUT} is the output voltage.
V_{REF} is the reference voltage of the shunt regulator. (2.495 V)

Therefore, the value below is recommended.

(Recommended value) R9: 0 Ω R10: 5.6 kΩ R11: 5.6 kΩ

Design Overview – continued

12 Design of the Feedback Circuit: R12, R14, R15, C12

R15 is the setting resistor of the dark current of the shunt regulator.

From its specifications, the current I_{MIN} which makes its operation stable is 1.0 mA. The current is supplied from R15.

The voltage applied to R15 is the value that is took the cathode voltage V_{KA} of the shunt regulator from the output voltage.

$$R_{14} < \frac{V_{OUT} - V_{KA}}{I_{MIN}} = \frac{5 - 2.495}{1} \quad [\mathrm{k\Omega}]$$

R_{14} is the resistance value of R14.
V_{OUT} is the output voltage.
V_{KA} is the cathode voltage of the shunt regulator.
I_{MIN} is the current which makes shunt regulator's operation stable

(Recommended Value)	R15 (Setting resistor of the dark current)	2.2 kΩ
	R12 (Current limiting Resistor of the feedback circuit)	300 Ω to 2.2 kΩ
	R14 (Phase Compensation Circuit)	2.7 kΩ
	C16(Phase Compensation Circuit)	0.22 µF

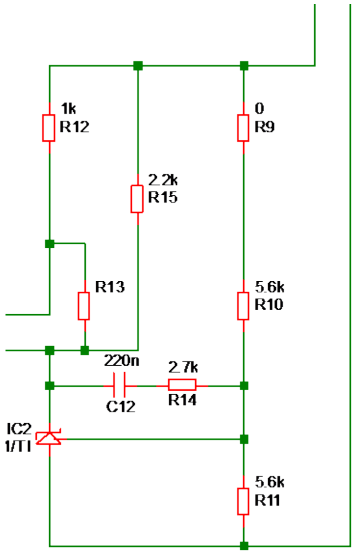


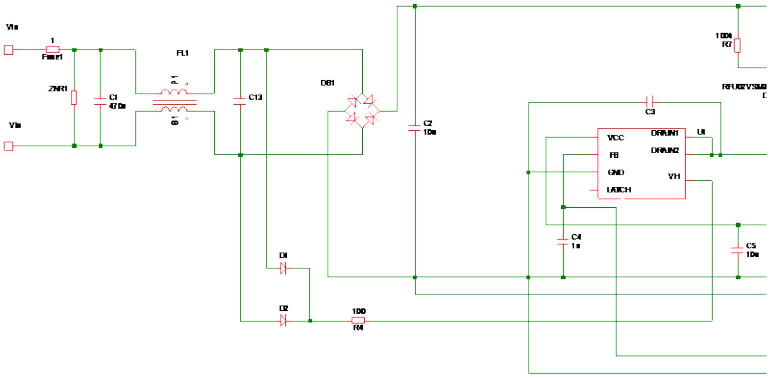
Figure 13. Feedback Circuit

Design Overview – continued

13 EMI Measures

For the EMI measures, a filter (FL1) and X Capacitor (C1) is connected to the input part.

A common mode filter is used for FL1 and the capacitor whose value is up to 6.8 μF can be connected to C1.



(Note) The constants is reference value. Design it considering the effect of noise.

Figure 14. Input Filter Circuit

13.1 Discharge Circuit of X Capacitor: D1, D2, R4

When the input voltage runs out, the charge stored in X Capacitor is discharged via D1, D2 and R4.

(Recommended item: D1 and D2: 1N4001 R4: 100 Ω)

13.2 Capacitor between Primary and Secondary Side: C7

Use the Y capacitor which is about 2200 pF for C7.

13.3 RC Snubber Circuit: C8, R8

For the emission measures, RC snubber circuit is added to the secondary rectification diode.

Use the 1000 pF capacitor for C8 and 10 Ω resistor for R8.

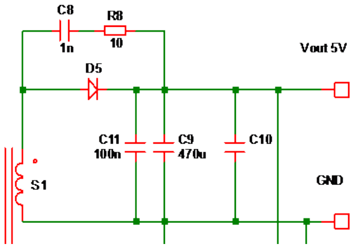


Figure 15. RC Snubber Circuit of secondary rectification diode.

Measurement DATA

1 Load Regulation

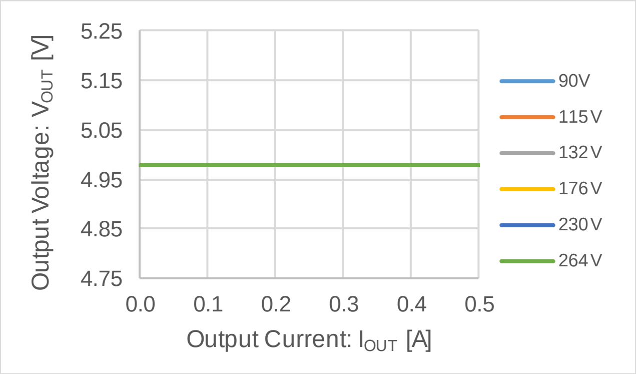


Figure 16. Load Regulation (V_{OUT} vs I_{OUT})

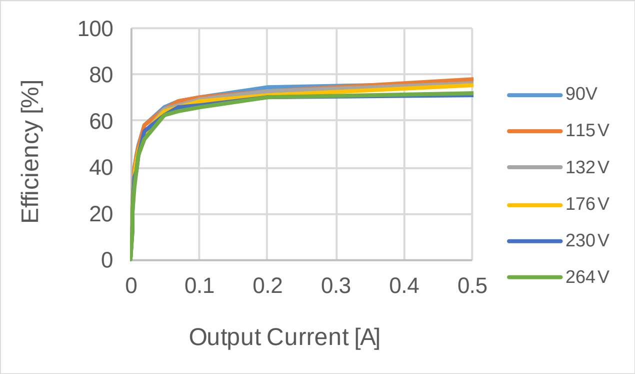


Figure 17. Load Regulation (Efficiency vs I_{OUT})

Table 5. Load Regulation (V_{IN}=115 Vac)

I_{OUT} [A]	V_{OUT} [V]	Efficiency [%]
0.01	4.981	48.83
0.02	4.981	57.92
0.05	4.981	65.54
0.07	4.981	68.23
0.1	4.981	70.35
0.2	4.980	73.13
0.5	4.980	78.01

Table 6. Load Regulation (V_{IN}=230 Vac)

I_{OUT} [A]	V_{OUT} [V]	Efficiency [%]
0.01	4.981	45.28
0.02	4.981	55.34
0.05	4.981	62.26
0.07	4.981	65.79
0.1	4.981	67.31
0.2	4.980	70.64
0.5	4.980	71.14

Measurement DATA – continued

2 Line Regulation

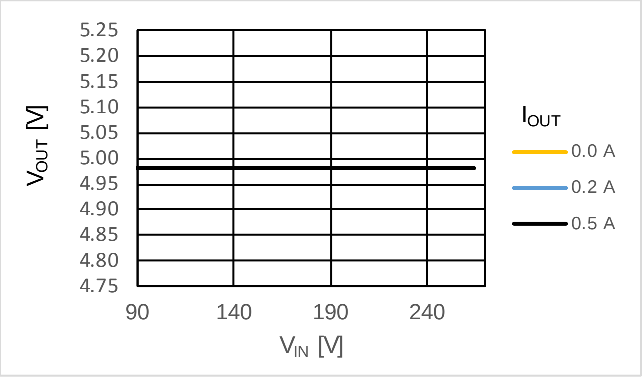


Figure 18. Line Regulation (V_{OUT} vs V_{IN})

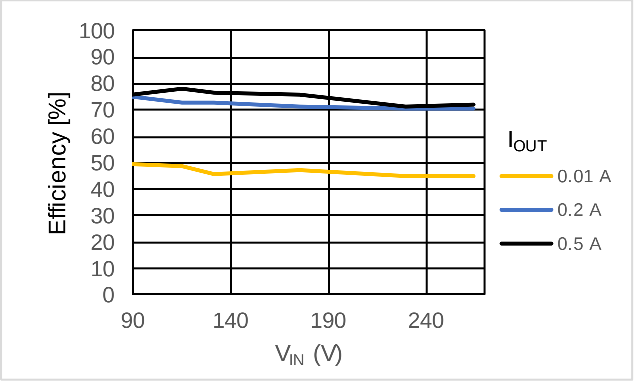


Figure 19. Line Regulation (Efficiency vs V_{IN})

Table 7. Line Regulation

V_{IN} [Vac]	I_{OUT} (A)		
	0.0	0.2	0.5
90	4.980	4.980	4.980
115	4.981	4.980	4.980
132	4.980	4.980	4.980
176	4.981	4.981	4.980
230	4.981	4.980	4.980
264	4.980	4.981	4.980

Table 8. Efficiency Regulation

V_{IN} [Vac]	I_{OUT} (A)		
	0.0	0.2	0.5
90	49.80	75.00	76.15
115	48.83	73.13	78.01
132	45.69	72.59	76.66
176	47.44	71.26	75.41
230	45.28	70.64	71.14
264	45.28	70.15	72.38

Measurement DATA – continued

3 Switching Frequency

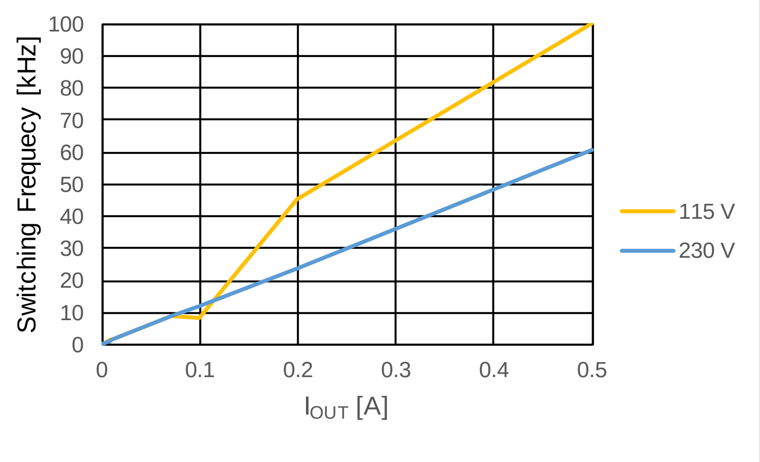


Figure 20. Switching Frequency vs I_{OUT}

Table 9. Measurement Result of Switching Frequency

I_{OUT} [A]	V_{IN} (V)	
	115	**230**
0	0.28	0.27
0.001	0.42	0.40
0.002	0.56	0.50
0.005	1.00	0.89
0.007	1.29	1.12
0.01	1.67	1.49
0.02	2.94	2.79
0.05	6.36	6.25
0.07	8.72	8.62
0.1	8.23	11.76
0.2	45.40	23.58
0.5	100.00	60.97

Measurement DATA – continued

4 Switching Wave Form

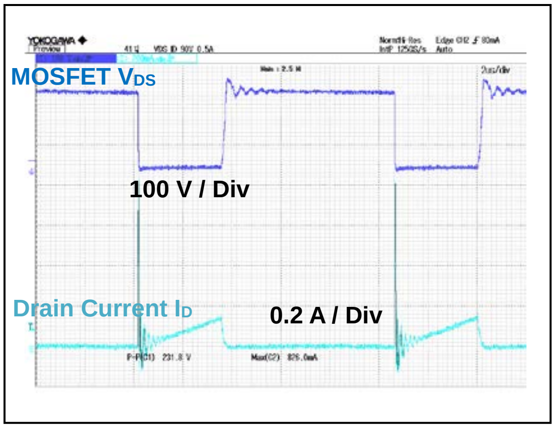


Figure 21. MOSFET Wave Form V_{IN} = 90 Vac, I_{OUT} = 0.-5 A

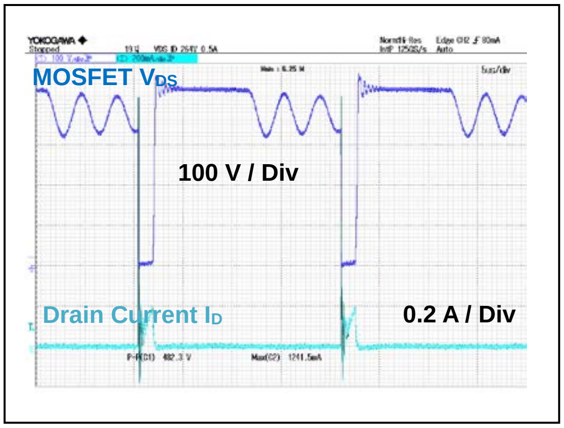


Figure 22. MOSFET Wave Form V_{IN} = 264 Vac, I_{OUT}= 0.5 A

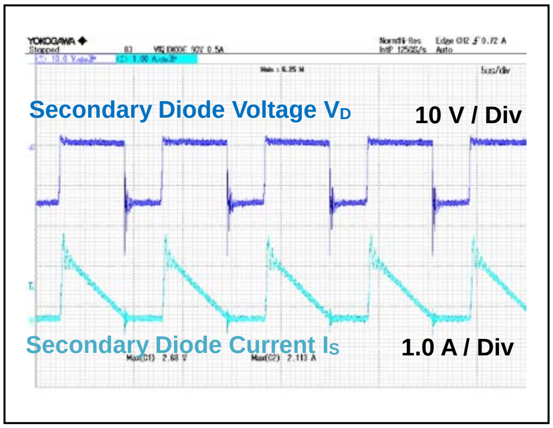


Figure 23. Diode Wave Form V_{IN} = 90 Vac, I_{OUT} = 0.5 A

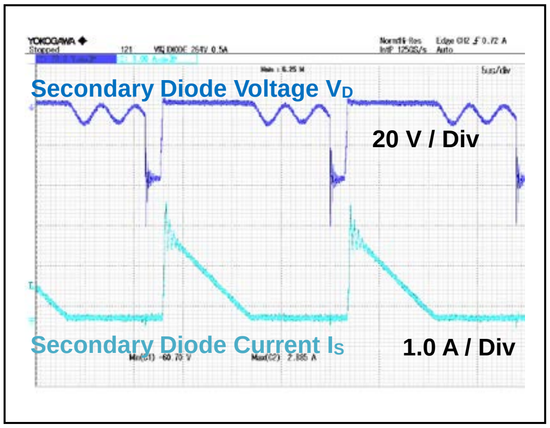


Figure 24. Diode Wave Form V_{IN} = 264 Vac, I_{OUT} = 0.5 A

4 Switching Wave Form – continued

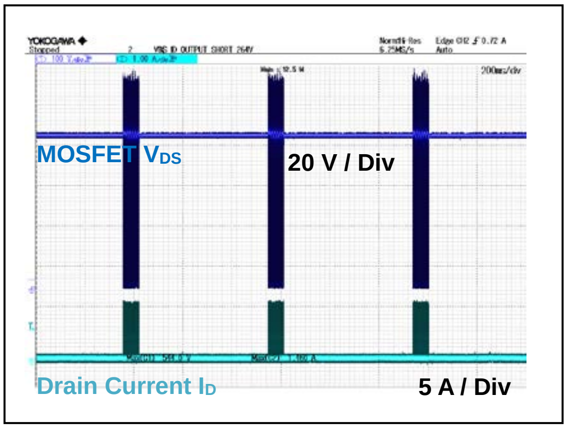


Figure 25. MOSFET Wave Form V_{IN} = 90 Vac

Output Shorted

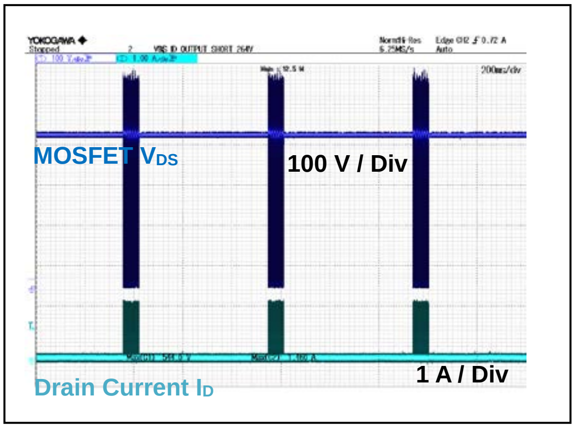


Figure 26.Diode Wave Form V_{IN} = 264 Vac

Output Shorted

5 Startup Wave Form

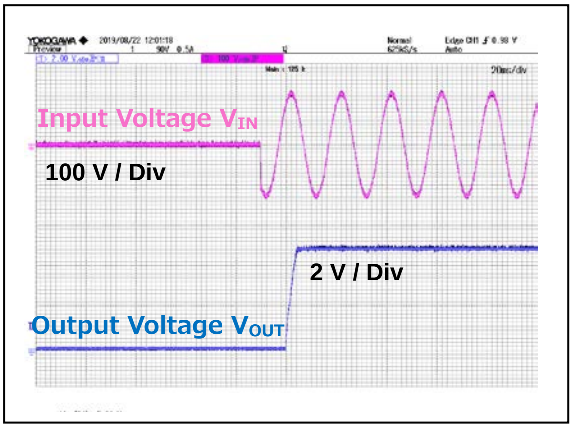


Figure 27. V_{IN} = 90 Vac, I_{OUT} = 0.5 A

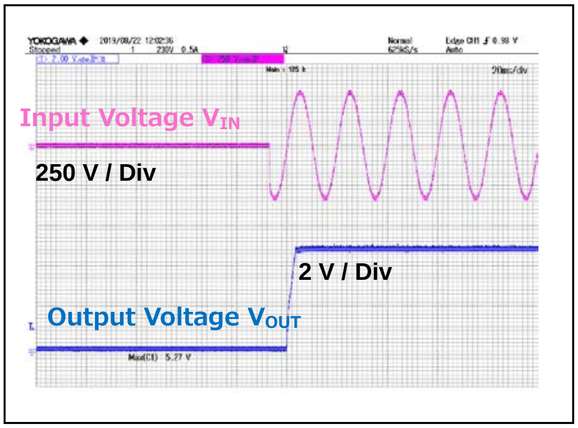
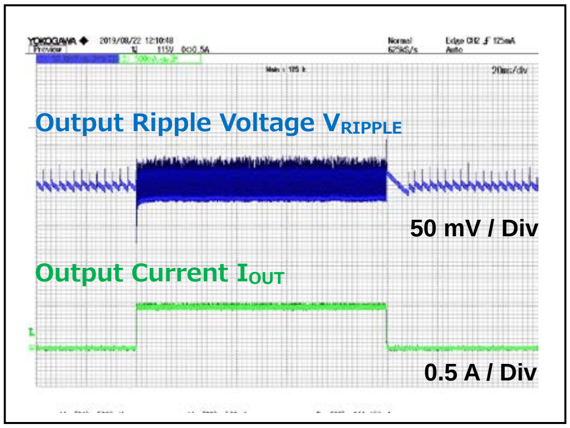


Figure 28. V_{IN} = 264 Vac, I_{OUT} = 0.5 A

Measurement DATA – continued

6 Dynamic Load Fluctuation



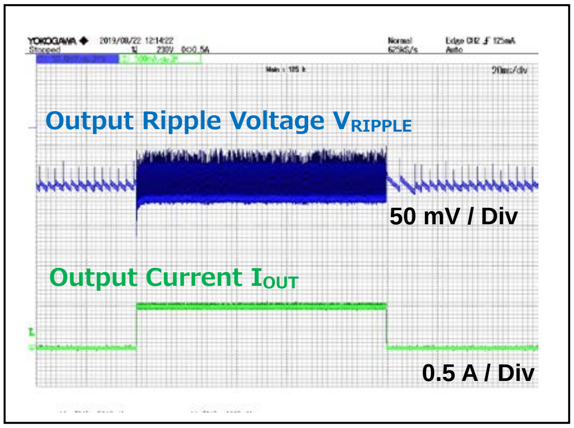
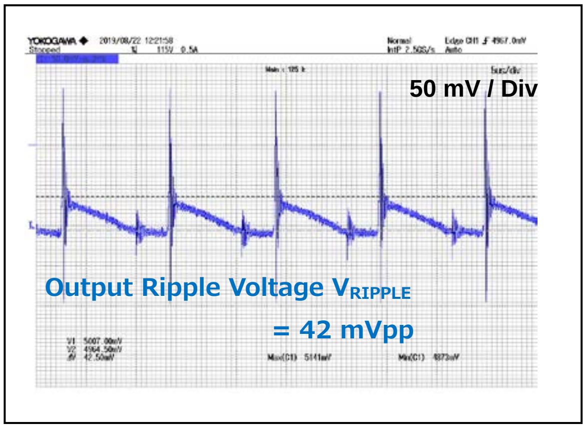


Figure 29. V_{IN} = 115 Vac, I_{OUT} = switch 0 A /0.5 A

Figure 30. V_{IN} = 230 Vac, I_{OUT} = switch 0 A / 0.5 A

7 Output Voltage Ripple Wave Form



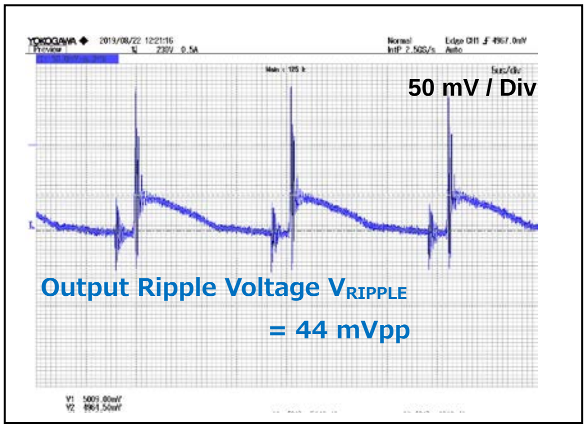


Figure 31. V_{IN} = 115 Vac, I_{OUT} = 0.5 A

Figure 32. V_{IN} = 230 Vac, I_{OUT} = 0.5 A

8 Temperature of Parts Surface

They are measured after 15 minutes from applying a power supply.

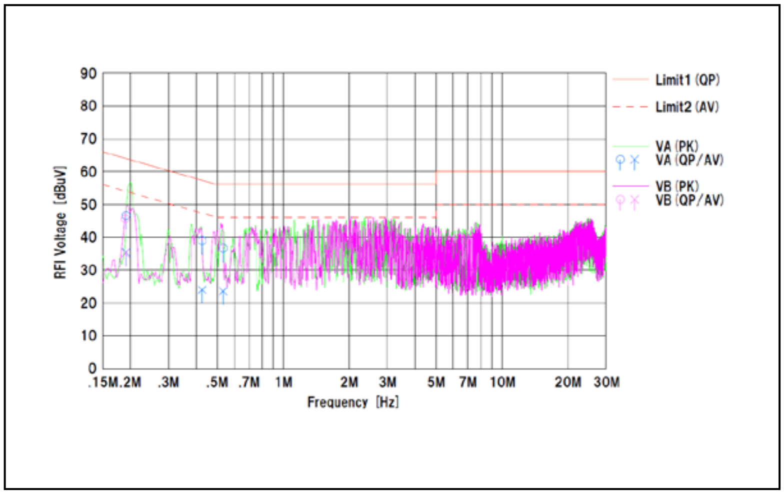
Table 10. Surface Temperature of Parts (Ta = 27 °C)

Part	Condition	
	V_{IN} = 90 Vac, I_{OUT} = 0.5 A	V_{IN} = 264 Vac, I_{OUT} = 0.5 A
BM2P26CK-Z	47.6 °C	57.8 °C
Diode	50.5 °C	54.0 °C

Measurement DATA – continued

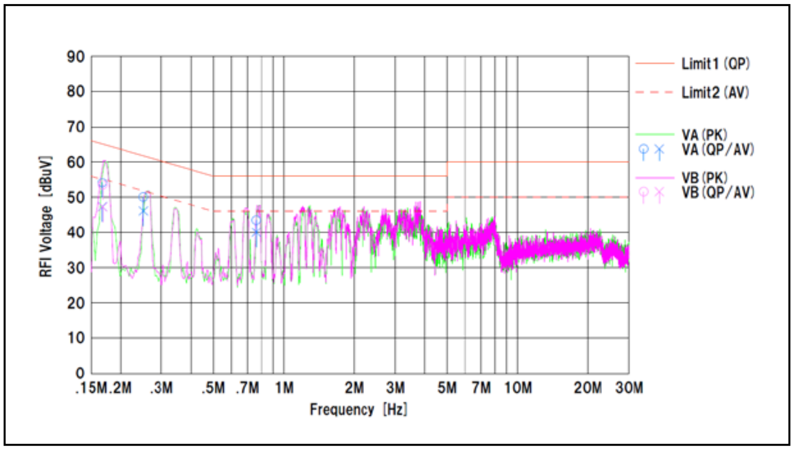
9 EMI

9.1 Noise Pin Voltage



QP margin:	17.3 dB
AVE margin:	18.5 dB

Figure 33. V_{IN} 115 Vac / 60 Hz, I_{OUT} 0.5 A

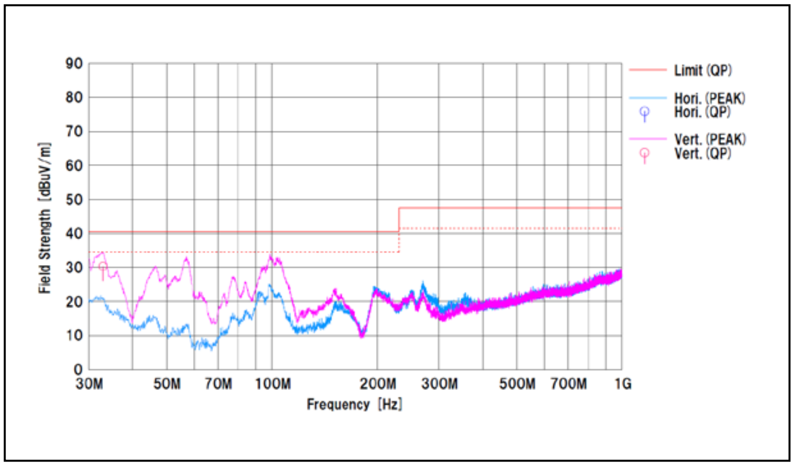


QP margin:	10.9 dB
AVE margin:	5.5 dB

Figure 34. V_{IN} 230 Vac / 50 Hz, I_{OUT} 0.5 A

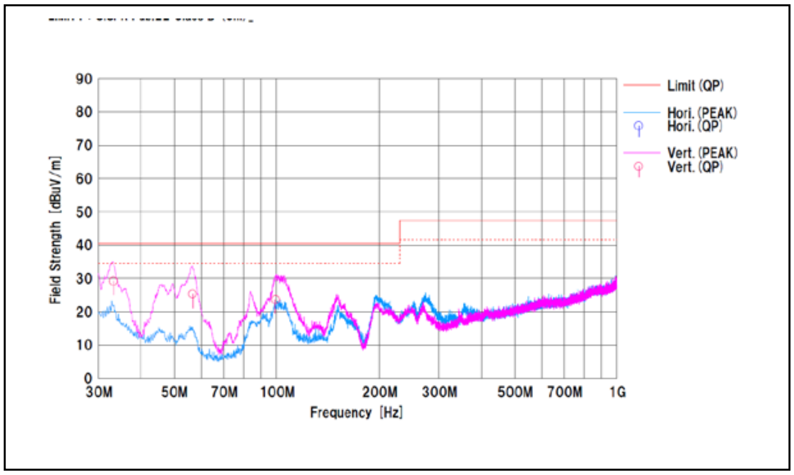
9 EMI – continued

9.2 Electric Field Strength (3 m Method)



QP margin: 10.2 dB

Figure 35. V_{IN} 115 Vac / 60 Hz, I_{OUT} 0.5 A



QP margin: 11.3 dB

Figure 36. V_{IN} 230 Vac / 50 Hz, I_{OUT} 0.5 A

Circuit Diagram

(Condition) V_{IN} = 90 Vac to 264 Vac, V_{OUT} = 5 V

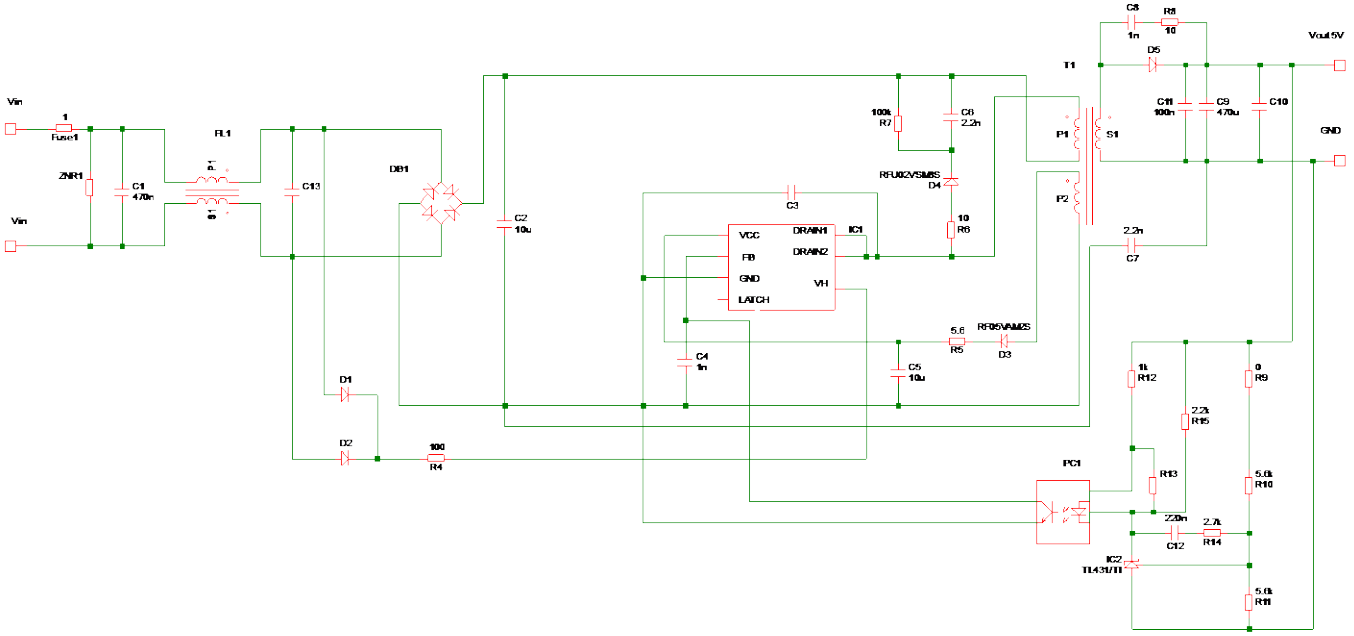


Figure 37. Circuit Diagram of BM2P26CK-EVK-001

Bill of Materials

	Item	Spec	Parts name	Maker
Capacitor	C1	0.47uF/310V	890 334 025 039 CS	WURTH
	C2	10uF/450V	450BXC10MFC 10×20	Rubycon
	C3	-	-	-
	C4	1000pF/100V	GRM2165C2A102J	Murata
	C5	10uF/35V	GMK316AB7106KL-TR	Murata
	C6	2.2nF/1kV	GRM31BR73A222KW01L	Murata
	C7	2200pF/250V	DE1E3RA222MJ4BQ01F	Murata
	C8	1000pF/100V	GRM2165C2A102J	Murata
	C9	470uF/25V	860 040 75 008	WURTH
	C10	-		
	C11	0.1uF/100V	HMK107B7104MA-T	Taiyou Yuden
	C12	0.22uF/16V	EMK107B7224KAHT	Taiyou Yuden
	C13	-	-	-
Diode	D1	1kV 1A	1N4007	
	D2	1kV 1A	1N4007	
	D3	0.5A/200V	RF05VSM2S	ROHM
	D4	0.2A / 800 V	RFU02VSM8S	ROHM
	D5	3A/60V	RB058LAM-60	ROHM
Diode - Bridge	DB1	1A/800V	D1UBA80-7062	SHINDENGEN
Fuse	F1	1A/300V	36911000000	Littelfuse
IC	IC1		BM2P26CK	ROHM
	IC2		TL431BIDBZT	TI
Opto-coupler	PC1		LTV-817-B	LiteOn
CommonMode-Coil	LF1		UF9.8V-20	ALPHA TRANS
Connector	CN1		B02P-NV(LF)(SN)	JST
Varistor	ZNR1	470V	V470ZA05P	Littelfuse
Resistor	R4	100	KTR18PZPZJ101	ROHM
	R5	5.6	MCR18PZPZJ 5 R6	ROHM
	R6	10	MCR18EZPJ100	ROHM
	R7	100k	MCR25JZHJ104	ROHM
	R8	10	MCR18EZPJ100	ROHM
	R9	0	MCR03PZPZJ000	ROHM
	R10	5.6k	MCR03EZPFX5601	ROHM
	R11	5.6k	MCR03EZPFX5601	ROHM
	R12	1k	MCR03PZPZJ102	ROHM
	R13	-	-	
	R14	2.7k	MCR03PZPZJ272	ROHM
	R15	2.2k	MCR03PZPZJ222	ROHM
Transfomer	T1	3.49mH	TT0092	ALPHA TRANS

Layout

Size 55 mm x 90 mm

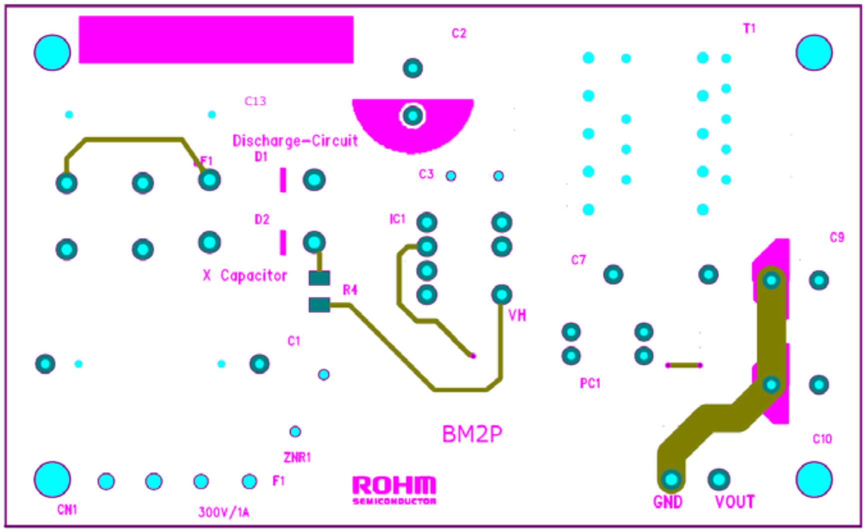


Figure 38. TOP Silk Screen (Top view)

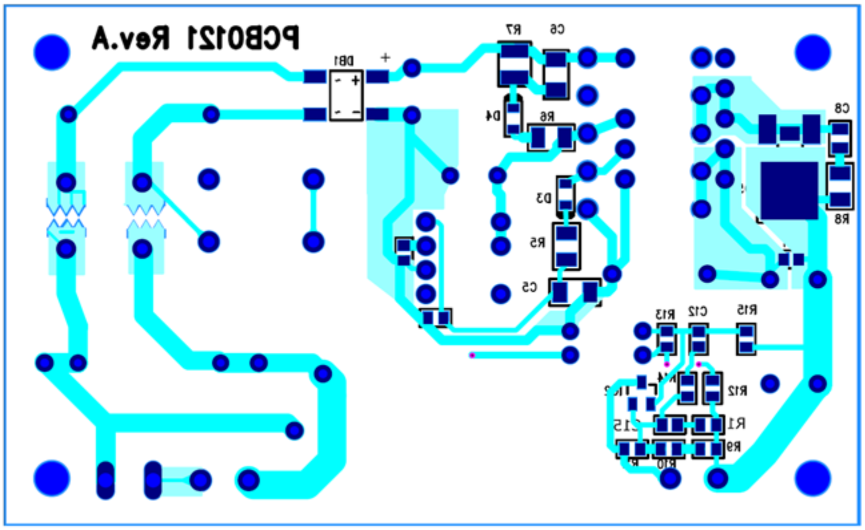


Figure 39. Bottom Layout (Top View)

Revision History

Date	Rev.	Changes
10.Oct.2019	001	New Release

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 Poducts 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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