PWM type AC/DC converter IC with Built-in 650V MOSFET

BM2P0XX series PWM Flyback converter Technical Design

This application note describes the design of the PWM flyback converters using ROHM's AC/DC converter IC BM2Pxxx series devices. It explains the selection of external components and provides PCB layout guidelines. Please note that all performance characteristics have to be verified. They are not guaranteed by the PCB layout shown here.

● Description

The BM2Pxxx series of ICs are AC/DC converters for PWM switching, incorporating a built-in starter circuit having withstanding voltage of 650V and a switching MOSFET having withstanding voltage of 650V. With ROHM's original high-speed switching MOSFET built inside, it is possible to increase the peak current, contributes to miniaturization of the magnetic components. BM2Pxxx supports both isolated and non-isolated circuits, enabling simpler design of various types of low-power converters.

● Key features

- PWM frequency 65kHz (with frequency-hopping function)/ Current mode
- Burst-operation and frequency reduction functions when load is light
- Built-in 650V starter circuit / Built-in 650V switching MOSFET
- VCC pin under-voltage protection/Over-voltage protection
- SOURCE pin Open/ Short protection, Leading-Edge-Blanking function
- Per-cycle over-current limiter function
- Over-current limiter AC correction function
- Soft-start function

● BM2Pxxx Series line-up

Product	Package	MOSFET		Max Output Power *1	Function	
		RDS(ON) (max)	IDP(max)	85-265Vac	Brownout	VCC OVP
BM2P051F	SOP8	5.5Ω	2.6A	8W	Yes	Latch stop
BM2P052F						Auto restart
BM2P053F					-	Latch stop
BM2P054F						Auto restart
BM2P091F		12Ω	1.3A	5W	Yes	Latch stop
BM2P092F						Auto restart
BM2P093F					-	Latch stop
BM2P094F						Auto restart
BM2P011	DIP7	2.0Ω	10.4A	20W	Yes	Latch stop
BM2P012						Auto restart
BM2P013					-	Latch stop
BM2P014						Auto restart
BM2P031		3.6Ω	5.4A	15W	Yes	Latch stop
BM2P032						Auto restart
BM2P033					-	Latch stop
BM2P034						Auto restart
BM2P051		5.5Ω	2.6A	10W	Yes	Latch stop
BM2P052						Auto restart
BM2P053					-	Latch stop
BM2P054						Auto restart
BM2P091		12Ω	1.3A	7W	Yes	Latch stop
BM2P092						Auto restart
BM2P093					-	Latch stop
BM2P094						Auto restart

*1 These are reference values in case of PWM Flyback converter. It is necessary to limit output power depending on power supply specification.

1. **Design Example of Isolated Type Flyback Converter DCM (Discontinuous Conduction Mode)**

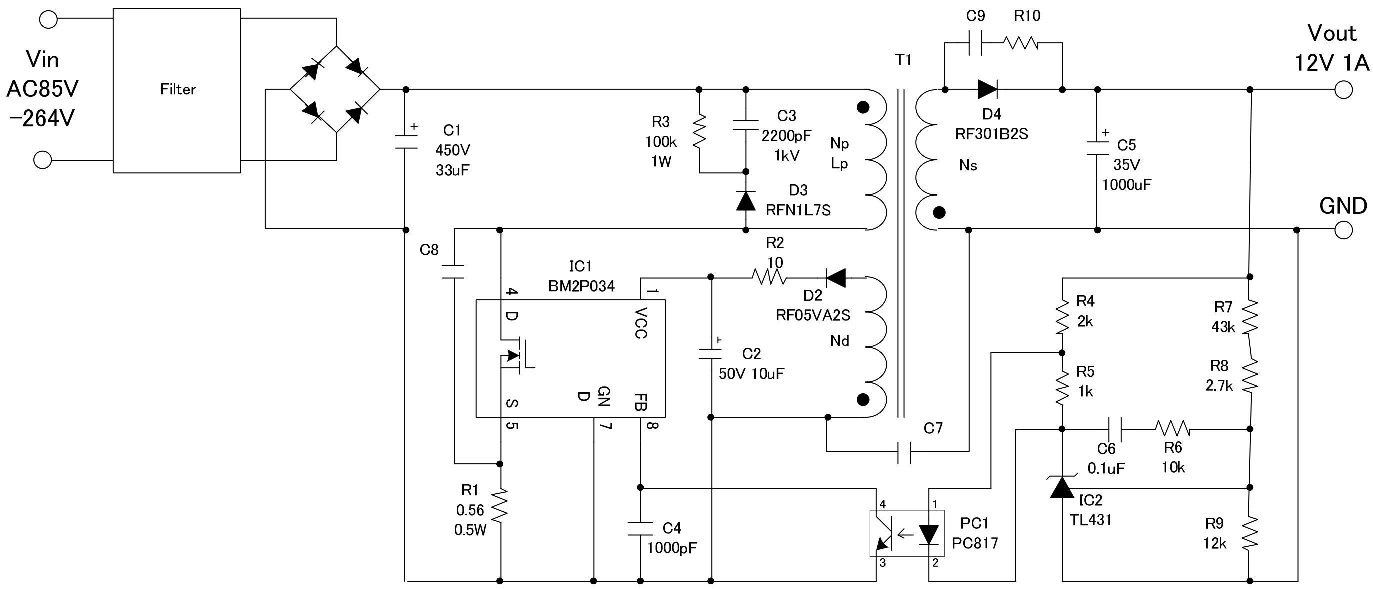
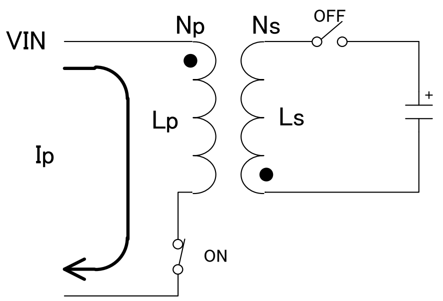


Figure 1-1.Isolated Type Flyback Converter Circuit Example

Basic operation of flyback converter

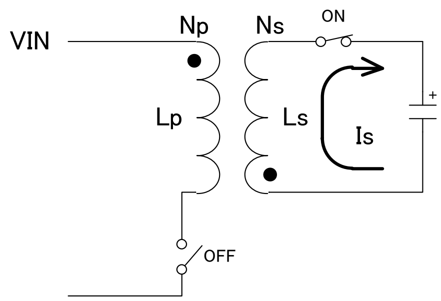
(1) When switching is turned ON



When MOSFET is ON, current Ip flows through the transformer's primary-side winding Lp, and energy is accumulated.
At that time, the diode is off.

$$Ip = \frac{VIN}{Lp} \times ton$$

(2) When switching is turned OFF



When MOSFET is OFF, the accumulated energy is output from the secondary-wide winding Ls, current Is flows via the diode.

$$Is = \frac{Np}{Ns} \times Ip - \frac{VO}{Ls} \times toff$$

$$VO = \frac{Ns}{Np} \times \frac{ton}{toff} \times VIN$$

1-1. Transformer T1 design

1-1-1. Determination of flyback voltage VOR

Flyback voltage VOR is determined along with turns-ratio Np:Ns and duty-ratio.

$$\mathrm{VOR} = \mathrm{VO} \times \frac{\mathrm{Np}}{\mathrm{Ns}} = \frac{\mathrm{ton}}{\mathrm{toff}} \times \mathrm{VIN}$$

$$\Rightarrow \frac{\mathrm{Np}}{\mathrm{Ns}} = \frac{\mathrm{VOR}}{\mathrm{VO}}$$

$$\Rightarrow \mathrm{Duty} = \frac{\mathrm{VOR}}{\mathrm{VIN} + \mathrm{VOR}}$$

When VIN = 95V (AC 85V x 1.4 x 0.8), VOR = 65V, Vf = 1V:

$$\frac{\mathrm{Np}}{\mathrm{Ns}} = \frac{\mathrm{VOR}}{\mathrm{VO}} = \frac{\mathrm{VOR}}{\mathrm{Vout} + \mathrm{Vf}} = \frac{65\mathrm{V}}{12\mathrm{V} + 1\mathrm{V}} = 5$$

$$\mathrm{Duty(max)} = \frac{\mathrm{VOR}}{\mathrm{VIN(min)} + \mathrm{VOR}} = \frac{65\mathrm{V}}{95\mathrm{V} + 65\mathrm{V}} = 0.406$$

(*) When duty is 0.5 or above, VOR is adjusted to set it below 0.5.

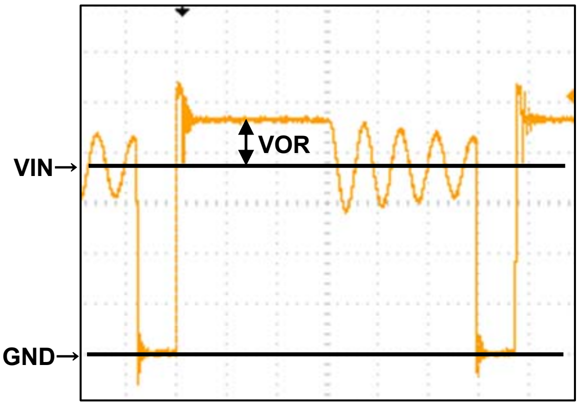


Figure 1-2. MOSFET Vds

1-1-2. Calculation of secondary-side winding inductance Ls and secondary-side maximum current Ispk

For better power efficiency, if Iomax = Io x 1.2 = 1.2A:

$$\mathrm{Ls} < \frac{(\mathrm{Vout} + \mathrm{Vf}) \times (1 - \mathrm{Duty})^2}{2 \times \mathrm{Iomax} \times \mathrm{fswmax}}$$

$$= \frac{(12\mathrm{V} + 1\mathrm{V}) \times (1 - 0.406)^2}{2 \times 1.2\mathrm{A} \times 70\mathrm{kHz}} = 27.3\mathrm{uH}$$

$$\mathrm{Ispk} = \frac{2 \times \mathrm{Iomax}}{1 - \mathrm{Duty(max)}} = \frac{2 \times 1.2\mathrm{A}}{1 - 0.406} = 4.04\mathrm{A}$$

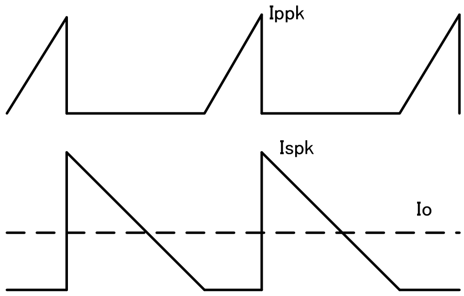


Figure 1-3. Primary-side and Secondary-side Current Waveforms

1-1-3. Calculation of primary-side winding inductance Lp and primary-side maximum current Ippk

$$\mathrm{Lp} = \mathrm{Ls} \times \left(\frac{\mathrm{Np}}{\mathrm{Ns}}\right)^2 = 27.3\mathrm{uH} \times 5^2 = 683\mathrm{uH}$$

$$\mathrm{Ippk} = \mathrm{Ispk} \times \frac{\mathrm{Ns}}{\mathrm{Np}} = 4.04\mathrm{A} \times \frac{1}{5} = 0.81\mathrm{A}$$

1-1-4. Determination of transformer size

Based on Po = 12W, the transformer's core size is EI22.

Table 1-1. Output Voltage and Transformer Core

Output voltage Po (W)	Core size	Core sectional area Ae (mm^2)
~5	EE13	16
~10	EI19/EE19	23
~20	EI22/EE22	37

(*) The above are guideline values. For details, check with the transformer manufacturer, etc.

1-1-5. Calculation of primary-side turn count Np

$$Np > \frac{VIN \times ton}{Ae \times Bsat} = \frac{Lp \times Ippk}{Ae \times Bsat}$$

Generally, the maximum magnetic flux density B(T) for an ordinary ferrite core is 0.4T @100°C, so Bsat = 0.3T.

$$Np > \frac{Lp \times Ippk}{Ae \times Bsat} = \frac{683uH \times 0.81A}{37mm^2 \times 0.3T} = 49.8 \text{ turns} \rightarrow \text{Np is 50 turns or above}$$

Since magnetic saturation does not result from this, Np is set based on the AL-value－NI characteristics.

When AL-value = 150 nH/turns^2 is set,

$$Np = \sqrt{\frac{Lp}{AL\text{-}Value}} = \sqrt{\frac{683uH}{150nH/turns^2}} = 67.5turns \rightarrow 68\ turns$$

$$NI = Np \times Ippk = 68turns \times 0.81A = 55.1A\cdot turns$$

The AL-value－NI characteristics of EI22 are used to confirm that this is within the tolerance range.

When it is beyond the tolerance range, Np is adjusted.

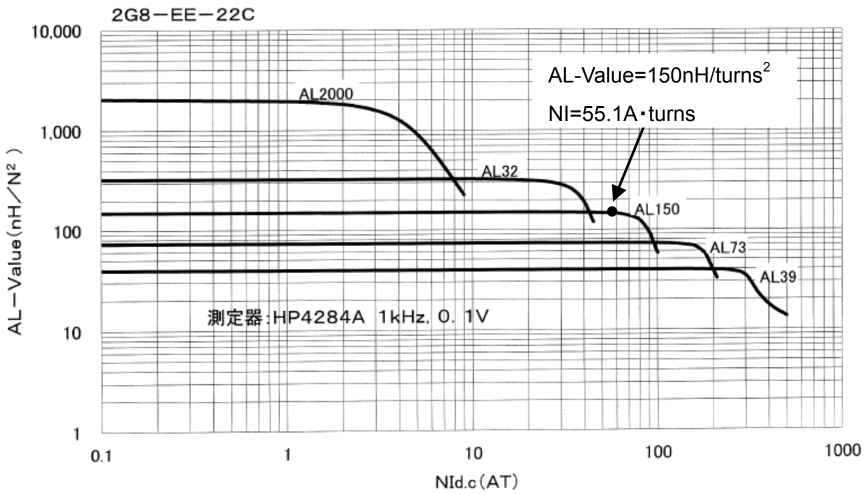


Figure 1-4. EI22 AL-value vs. NI Limit Characteristics (Tomita 2G8-EE22)

1-1-6. Calculation of secondary-side turn count Ns

$$\frac{Np}{Ns} = 5 \rightarrow Ns = \frac{68}{5} = 13.6 \text{ turns} \rightarrow 14 \text{ turns}$$

1-1-7. Calculation of VCC turn count Nd

When VCC = 15V, Vf_vcc = 1V,

$$Nd = Ns \times \frac{VCC + Vf\_vcc}{Vout + V\ f} = 14 \text{ turns} \times \frac{15V + 1V}{12V + 1V} = 17.2turns \rightarrow 17 \text{ turns}$$

As a result, the transformer specifications are as follows.

Table 1-2. Transformer Specifications

Core	Tomita 2G8-EI22/EE22 or compatible
Lp	683 uH
Np	68 turns
Ns	14 turns
Nd	17 turns

1-2. Selection of main components

1-2-1. IC1

Since Pout = 12V × 1A = 12W, BM2P034 is selected.

1-2-2. Input capacitor: C1

Use Table 1-3 to select the capacitance of the input capacitor.

Since Pout = 12V × 1A = 12W, C1 = 2 × 12 = 24 → 33µF.

Table 1-3. Input Capacitor Selection Table

Input voltage (Vac)	Cin (µF)
85-264	2 X Pout(W)
180-264	1 x Pout(W)

(*) The above values are guidelines for full-wave rectification. When selecting, also consider other specifications such as the retention-time.

The withstanding voltage of the capacitor becomes, Vac (max) × 1.41. Say for AC 264V, it is 264V × 1.41 = 372V, so this should be 400V or more.

1-2-3. Current-sensing resistor: R1

The current-sensing resistor limits the current that flows on the primary side to provide protection against output overload, and is used for slope compensation of current mode control. Consequently, in some cases limits may be imposed according to the transformer's primary-side inductance and input voltage.

In the BM2P0XX Series, an AC voltage correction function is built-in the chip for overload protection. This corrects offsetting of the overload protection point caused by different input voltages (such as AC 100V and AC 200V).

$$R1 = \frac{\mathrm{Vcs\_limit}}{\mathrm{Ippk}} = \frac{\mathrm{Vcs} + \mathrm{ton} \times 20\mathrm{mV/us}}{\mathrm{Ippk}} = \frac{\mathrm{Vcs} + \frac{\mathrm{Duty}}{\mathrm{fsw}} \times 20\mathrm{mV/us}}{\mathrm{Ippk}} = \frac{0.4\mathrm{V} + \frac{0.406}{65\mathrm{kHz}} \times 20\mathrm{mV/us}}{0.81\mathrm{A}} = 0.64\ \Omega \rightarrow 0.56\ \Omega$$

Confirm the overload protection point while the resistor is assembled in the product.

Sensing resistance loss P_R1:

$$\mathrm{P\_R1(peak)} = \mathrm{Ippk}^2 \times \mathrm{R1} = 0.81^2 \times 0.56 = 0.37\mathrm{W}$$

$$\mathrm{P\_R1(rms)} = \mathrm{Iprms}^2 \times \mathrm{R1} = \left(\mathrm{Ippk} \times \sqrt{\frac{\mathrm{Duty}}{3}}\right)^2 \times \mathrm{R1} = \left(0.81 \times \sqrt{\frac{0.406}{3}}\right)^2 \times 0.56 = 0.05\mathrm{W}$$

Set to 0.5W or above in consideration of pulse resistance.

With regard to pulse resistance, the structure of the resistance may vary even with the same power rating.

Check with the resistor manufacturers for details.

1-2-4. VCC-diode: D2

A high-speed diode is recommended as the VCC-diode.

Reverse voltage applied to the VCC-diode:

$$\mathrm{Vdr} = \mathrm{VCC(max)} + \mathrm{VINmax} \times \frac{\mathrm{Nd}}{\mathrm{Np}}$$

When VCC (max) = 29 V,

$$\mathrm{Vdr} = 29\mathrm{V} + 374\mathrm{V} \times \frac{15}{60} = 122.5\mathrm{V}$$

With a design-margin taken into account, 122.5V / 0.7 = 175V → 200V component is selected.

(Example: ROHM's RF05VA2S 200V, 0.5A)

1-2-5. VCC capacitor: C2

A VCC capacitor is needed to stabilize the IC's VCC voltage.
Capacitance of 2.2µF or above is recommended (example: 50V, 10µF).
Next, determine the startup time of the IC at power-on.
Figure 1-5 illustrates VCC capacitor capacitance and startup time characteristics.

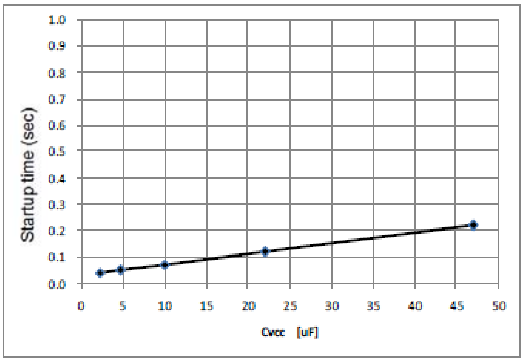


Figure 1-5. Startup Time (Reference Values)

1-2-6. VCC winding surge-voltage limiting resistor: R2

Based on the transformer's leakage inductance (Lleak), a large surge-voltage (spike noise) may occur during the instant when the MOSFET is switched from ON to OFF. This surge-voltage is induced in the VCC winding, and as the VCC voltage increases the IC's VCC overvoltage protection may be triggered.
A limiting resistor R2 (approximately 5Ω to 22Ω) is inserted to reduce the surge-voltage that is induced in the VCC winding.
Confirm the rise in VCC voltage while the resistor is assembled in the product.

1-2-7. Snubber circuits: C3, D3, R3

Based on the transformer's leakage inductance (Lleak), a large surge-voltage (spike noise) may occur during the instant when the MOSFET is switched from ON to OFF. This surge-voltage is applied between the MOSFET's Drain and Source, so in the worst case damage to MOSFET might occur. RCD snubber circuits are recommended to suppress this surge-voltage.

(1) Determination of clamp voltage (Vclamp) and clamp ripple-voltage (Vripple)

Consider to take a design-margin based on the MOSFET's withstand voltage, when determining the clamp voltage.
Vclamp = 650V × 0.8 = 520V
The clamp ripple-voltage (Vripple) is about 50V.

(2) Determination of R3

$$\mathrm{R3} < 2 \times \mathrm{Vclamp} \times \frac{\mathrm{Vclamp} - \mathrm{VOR}}{\mathrm{Lleak} \times \mathrm{Ip}^2 \times \mathrm{fsw(max)}}$$

When Lleak = Lp × 10% = 683µH × 10% = 68µH, R3 is derived as:

$$\mathrm{R3} < 2 \times 520\mathrm{V} \times \frac{520\mathrm{V} - 65\mathrm{V}}{68\mathrm{uH} \times 0.81^2 \times 70\mathrm{kHz}} = 145\mathrm{k}\ \Omega \rightarrow 100\mathrm{k}\ \Omega$$

R3 loss P_R3 is expressed as

$$\mathrm{P\_R3} = \frac{(\mathrm{Vclamp} - \mathrm{VIN})^2}{\mathrm{R3}} = \frac{(520 - 265\mathrm{V} \times 1.41)^2}{100\mathrm{k}\ \Omega} = 0.22\mathrm{W}$$

A 1W component is determined with consideration for design margin.

(3) Determination of C3

$$\mathrm{C3} > \frac{\mathrm{Vclamp}}{\mathrm{Vripple} \times \mathrm{fsw(min)} \times \mathrm{R3}} = \frac{520\mathrm{V}}{50\mathrm{V} \times 60\mathrm{kHz} \times 100\mathrm{k}\ \Omega} = 1733\mathrm{pF} \rightarrow 2200\mathrm{pF}$$

The voltage applied to C3 is 520V – 264×1.41 = 148V.
300V or above is set with consideration for design margin.

(4) Determination of D3

Choose a fast recovery diode as the diode, with a withstanding voltage that is at or above the MOSFET's Vds (max) value.
(Example: Rohm RFN1L7S: 200V, 0.8A)

The surge-voltage affects not only the transformer's leakage inductance but also the PCB substrate's pattern.
Confirm the Vds voltage while assembled in the product, and adjust the snubber circuit as necessary.

1-2-8. Output rectification diode: D4

Choose a high-speed diode (Schottky barrier diode or fast recovery diode) as the output rectification diode.

Reverse voltage applied to output diode is

$$\mathrm{Vdr} = \mathrm{Vout(max)} + \mathrm{VINmax} \times \frac{\mathrm{Ns}}{\mathrm{Np}}$$

When Vout (max) = 12 V + 5% = 12.6V:

$$\mathrm{Vdr} = 12.6\mathrm{V} + 372\mathrm{V} \times \frac{12}{60} = 87\mathrm{V}$$

A 87.4V/0.7 = 125V → 200V component is determined with consideration for design margin.

Also, diode loss (approximate value) becomes Pd = Vf × Iout = 1V × 1A = 1W.

(Example: Rohm RF301B2S：200V 3A , CPD package)

Use of a voltage margin of 70% or less and current of 50% or less is recommended.

Check temperature rise while assembled in the product. When necessary, reconsider the component and use a heat sink or similar to dissipate the heat.

1-2-9. Output capacitors: C5

Determine the output capacitors based on the output load's allowable peak-to-peak ripple voltage (ΔVpp) and ripple-current.

When the MOSFET is ON, the output diode is OFF. At that time, current is supplied to the load from the output capacitors.

When the MOSFET is OFF, the output diode is ON. At that time, the output capacitors are charged and a load current is also supplied.

When ΔVpp = 200mV,

$$\mathrm{Z\_C5} < \frac{\Delta\,\mathrm{Vpp}}{\mathrm{Ispk}} = \frac{0.2\mathrm{V}}{4.04\mathrm{A}} = 0.05\ \Omega \qquad \text{at} \quad 60\mathrm{kHz\ (fsw\ min)}$$

With an ordinary switching power supply electrolytic-capacitor (low-impedance component), impedance is rated at 100kHz, so it is converted to 100kHz.

$$\mathrm{Z\_C5} < 0.05\ \Omega \times \frac{60}{100} = 0.03\ \Omega \qquad \text{at} \quad 100\mathrm{kHz}$$

Ripple-current Is (rms):

$$\mathrm{Is(rms)} = \mathrm{Ispk} \times \sqrt{\frac{1 - \mathrm{Duty}}{3}} = 4.04\mathrm{A} \times \sqrt{\frac{1 - 0.406}{3}} = 1.798\mathrm{A}$$

The capacitor's withstanding voltage should be set to about twice the output voltage.

Vout × 2 = 12V × 2 = 24V → 25V or above

Select an electrolytic capacitor that is suitable for these conditions.

(Example: low impedance type 35V, 1000 μF for switching power supply)

(*) Use the actual equipment to confirm the actual ripple-voltage and ripple-current.

1-3. EMI countermeasures

Confirm the following with regard to EMI countermeasures.

(*) Constants are reference values. Need to be adjusted based on noise effects.

- Addition of filter to input block
- Addition of capacitor between primary-side and secondary-side (C7: approximately Y-Cap 2200pF)
- Addition of capacitor between MOSFET's drain and source (C8: approximately 1kV, 10 to 100pF)
  (When a capacitor has been added between the drain and source, loss is increased. Check for temperature rise and adjust accordingly)
- Addition of RC snubber to diode (C9: 500V 1000pF, R10: approximately 10Ω, 1W)

1-4. Output noise countermeasures

As an output noise countermeasure, add an LC filter (L:10µH, C10: approximately 10µF to 100µF) to the output.

(*) Constants are reference values. Need to be adjusted based on noise effects.

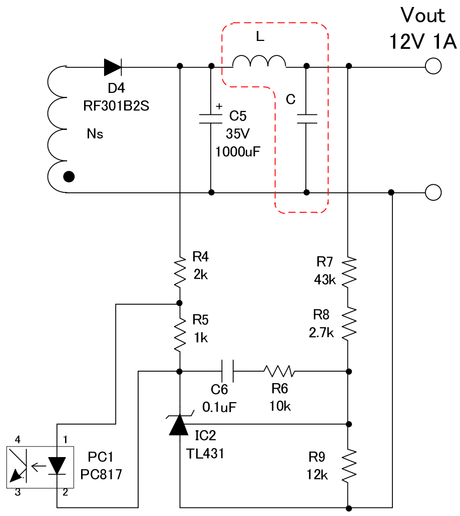


Figure 1-6. LC Filter Circuit

1-5. Proposed PCB layout

A proposed layout (example) for these circuits is shown in Figure 1-7.

- Single-sided board, lead component view
- Components in red are surface-mounted components

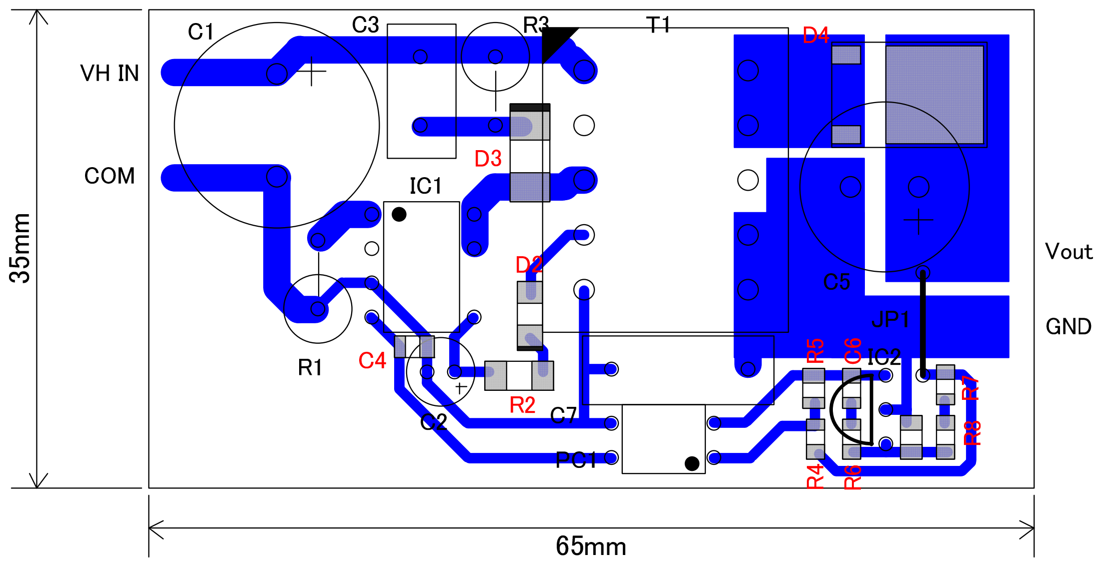


Figure 1-7. Proposed PCB Layout (Example)

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 are intended for use in general electronic equipment (i.e. AV/OA devices, communication, consumer systems, gaming/entertainment sets) as well as the applications indicated in this document.

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

8) 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.

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

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

11) ROHM has used reasonable care to ensur 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.

12) 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.

13) 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.

14) This document, in part or in whole, may not be reprinted or reproduced without prior consent of ROHM.

ROHM SEMICONDUCTOR

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

ROHM Customer Support System

http://www.rohm.com/contact/