

PWM type AC/DC converter IC with Built-in 650V MOSFET
BM2P0XX series PWM Buck-Boost converter Technical Design

This application note describes the design of the PWM buck-boost 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 85-265Vac	Function	
		RDS(ON) (max)	IDP(max)		Brownout	VCC OVP
BM2P051F	SOP8	5.5 Ω	2.6A	8W	Yes	Latch stop
BM2P052F						Auto restart
BM2P053F					-	Latch stop
BM2P054F						Auto restart
BM2P091F		12 Ω	1.3A	5W	Yes	Latch stop
BM2P092F						Auto restart
BM2P093F					-	Latch stop
BM2P094F						Auto restart
BM2P011	DIP7	2.0 Ω	10.4A	20W	Yes	Latch stop
BM2P012						Auto restart
BM2P013					-	Latch stop
BM2P014						Auto restart
BM2P031		3.6 Ω	5.4A	15W	Yes	Latch stop
BM2P032						Auto restart
BM2P033					-	Latch stop
BM2P034						Auto restart
BM2P051		5.5 Ω	2.6A	10W	Yes	Latch stop
BM2P052						Auto restart
BM2P053					-	Latch stop
BM2P054						Auto restart
BM2P091		12 Ω	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 Non-Isolated Type Buck-Boost Converter DCM (Discontinuous Conduction Mode)

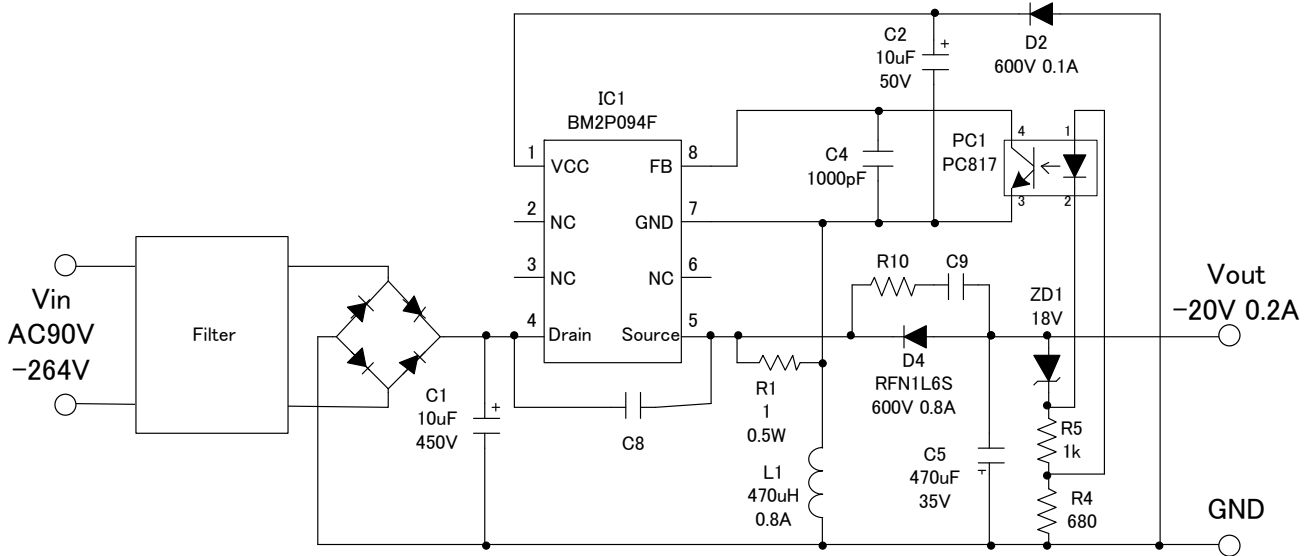
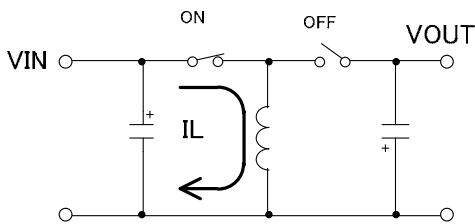


Figure 1-1. Non-Isolated Type Buck-Boost Converter Circuit Example

Basic operation of buck-boost converter

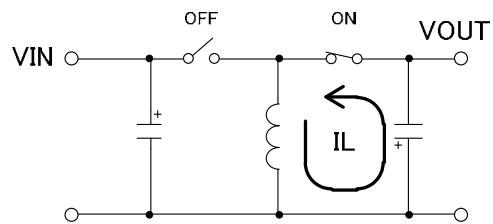
(1) When switching is turned ON



When MOSFET is ON, current I_L flows through the inductor, and energy is accumulated. At that time, the diode is off.

$$I_L = \frac{V_{IN}}{L} \times t_{on}$$

(2) When switching is turned OFF



When MOSFET is OFF, the accumulated energy is output from the inductor, current I_L flows via the diode.

$$I_L = \frac{V_{OUT}}{L} \times t_{off}$$

1-1. Selection of main components

1-1-1. IC1

In case of non-isolated type buck converter, Drain current of internal MOSFET is increased compared with flyback converter. Use of flyback converter's max output power of about 50 -70% is recommended. Since $P_{out} = 20V \times 0.2A = 4W$, BM2P094F is selected.

1-1-2. Input capacitor: C1

Use Table 1-1 to select the capacitance of the input capacitor. Since $P_{out} = 20V \times 0.2A = 4W$, $C1 = 2 \times 4 = 8 \rightarrow 10\mu F$.

Table 1-1.Input Capacitor Selection Table

Input voltage (Vac)	Cin (μF)
85-265	2 X Pout(W)
180-265	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, $V_{ac} (max) \times 1.41$. Say for AC 264V, it is $264V \times 1.41 = 372V$, so this should be 400V or more.

1-1-3. 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 1-2 illustrates VCC capacitor capacitance and startup time characteristics.

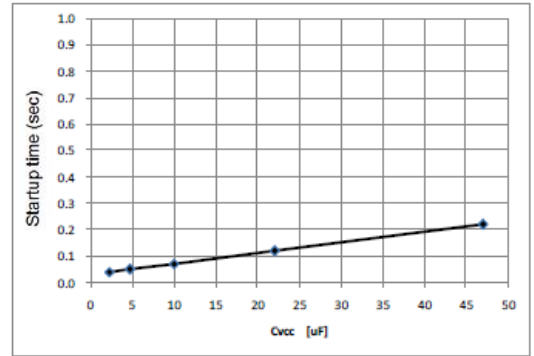


Figure 1-2. Startup Time (Reference Values)

1-1-4. Inductor; L1

L1 inductance is selected so that it may become the discontinuous mode. In case of the continuous mode, the reverse current flows to the output diode and MOSFET between reverse recovery time of the output diode when MOSFET is turned ON. This reverse current makes the loss of the output diode and MOSFET increase.

Calculation of L1 inductance

When $V_{IN} = 101V$ (AC 90V x 1.4 x 0.8),

$$t_{on} = \frac{V_o}{V_{IN}} \times t_{off} \rightarrow t_{on(max)} = \frac{V_o}{V_{IN(min)} + V_o} \times \frac{1}{f_{sw(min)}} = \frac{20V}{101V + 20V} \times \frac{1}{60kHz} = 2.76\mu s$$

When $I_{omax} = 0.2A \times 1.2 = 0.24A$, it is made to become the boundary point in continuous mode and discontinuous mode. $\rightarrow I_L = 2 \times I_o = 0.48A$

$$L = t_{on(max)} \times \frac{V_{IN(min)}}{I_L} = 2.76\mu s \times \frac{101V}{0.48A} = 581\mu H \rightarrow 470\mu H$$

Calculation of L1 current

When input voltage is maximum, L1 current is maximum, and this converter operates in minimum ON time.

Minimum ON time is set to about 0.6-1.5us according to output voltage and inductor value.

In this case, minimum ON time is 1us when input voltage is AC264V.

$$I_{Lpeak} = t_{on} (\text{minimum ON time}) \times \frac{V_{IN(max)}}{L} = 1\mu s \times \frac{372V}{470\mu H} = 0.791A$$

Inductor L1 is selected 470uH / 0.8A or above.

Check inductor current while assembled in the product and confirm that magnetic saturation has not occurred.

1-1-5. 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 inductance of inductor 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).

$$R1 = \frac{V_{cs_limit}}{I_L} = \frac{V_{cs} + t_{on(max)} \times 20mV/\mu s}{I_L} = \frac{0.4V + 2.76\mu s \times 20mV/\mu s}{0.48A} = 0.95 \Omega \rightarrow 1 \Omega$$

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

1-1-6. Output capacitors: C5

Determine the output capacitors based on the output load's allowable peak-to-peak ripple voltage (ΔV_{pp}) 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 $\Delta V_{pp} = 100mV$,

$$Z_{C5} < \frac{\Delta V_{pp}}{I_{Lpeak}} = \frac{0.1V}{0.791A} = 0.126 \Omega \quad \text{at } 60kHz \text{ (fsw min)}$$

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

$$Z_{C5} < 0.126 \Omega \times \frac{60}{100} = 0.08 \Omega \quad \text{at } 100kHz$$

Ripple-current I_s (rms):

$$I_s(\text{rms}) = I_{Lspk} \times \sqrt{\frac{1}{3}} = 0.791A \times \sqrt{\frac{1}{3}} = 0.457A$$

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

$V_{out} \times 2 = 20V \times 2 = 40V \rightarrow 35V$ above

Select an electrolytic capacitor that is suitable for these conditions.

(Example: low impedance type 35V, 470 μF for switching power supply)

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

1-1-7. Output rectification diode: D4

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

Reverse voltage applied to output diode is

$$V_{dr} = V_{IN(max)} / 0.7 = 372V / 0.7 = 531V \rightarrow 600V$$

Diode loss (approximate value) becomes $P_d = V_f \times I_{out} = 1V \times 0.2A = 0.2W$.

(Example: Rohm RFN1L6S: 600V 0.8A , PMDS package)

Check temperature rise while assembled in the product.

1-2. 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 MOSFET's drain and source (C8: approximately 500V, 47 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)

1-3. Output noise countermeasures

As an output noise countermeasure, add an LC filter (L2: 10μH, C10: approximately 10μF to 100μF) to the output.

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

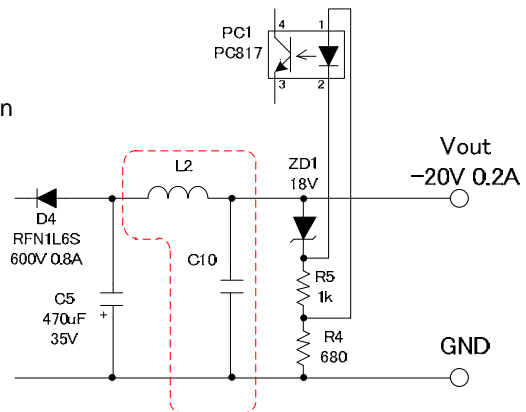


Figure 1-3. LC Filter Circuit

1-4. Proposed PCB layout

A proposed layout (example) for these circuits is shown in Figure 1-4.

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

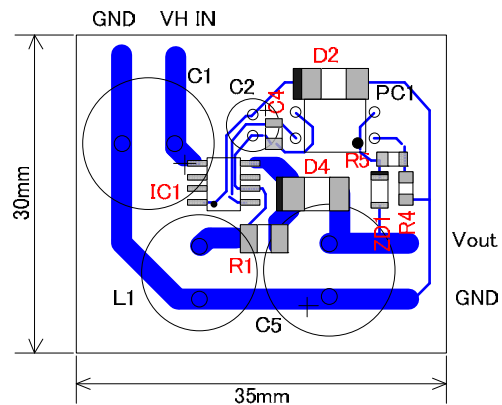


Figure 1-4. Proposed PCB Layout (Example)

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