DC/DC Converter module
MPM00 Series
Application Note Rev.1.5

SANKEN ELECTRIC CO., LTD.
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contents

General Descriptions

The MPM series is a full molded hybrid IC which contains a non-insulated buck type DC/DC converter in one package. A power supply circuit can be composed in a simple way by using this hybrid IC which requires a small part count.
By connecting only an input smoothing electrolytic capacitor, an output smoothing electrolytic capacitor and an output voltage setting resistor, the hybrid IC can be operated. Because of this simple composition, time required for design evaluation is significantly reduced. Since a power inductor is built in, it is not required to select and evaluate the inductor separately.
By adopting a full molding package which can be fitted to the heat sink by screwing, board mounting can be made in self-supporting state without the heat sink subject to the output voltage setting and load conditions.

Features & Benefits

- Current mode type synchronization rectification PWM control system
- By connecting only an input smoothing electrolytic capacitor, an output smoothing electrolytic capacitor and an output voltage setting resistor, the hybrid IC can be operated.
- Since a power inductor is built in, it is not required to select and evaluate the inductor separately.
- Maximum efficiency 91%
- Output current range 0 to 3A
- Operating frequency 250kHz
- Reference voltage 0.5V±2%
- Built-in protection function
  Over Current Protection (OCP)
  Thermal Shutdown (TSD)
  Under Voltage Lockout (UVLO)
- Built-in phase compensation
- Built-in Soft-Start function

Package

- Full molding package SIP9

Pin Assignment		
Pin	Symbol	Function
1,3	GND	Ground terminal
2	VIN	Input power supply terminal
4	FB	Feedback terminal
5,6,7	OUT	Output terminal
8,9	SW	Switching terminal

Electrical Characteristics

- Input voltage range: MPM01 : 9V to 40V
  MPM04 : 16V to 40V
- Output voltage range: MPM01 : 1.8V to 12V
  MPM04 : 12V to 24V
- Output current I_O = 3A
- Operating frequency: 250kHz

Applications

- FA machine / Communications equipment
  Domestic products
- Amusement machine / others

Line up

Table.1

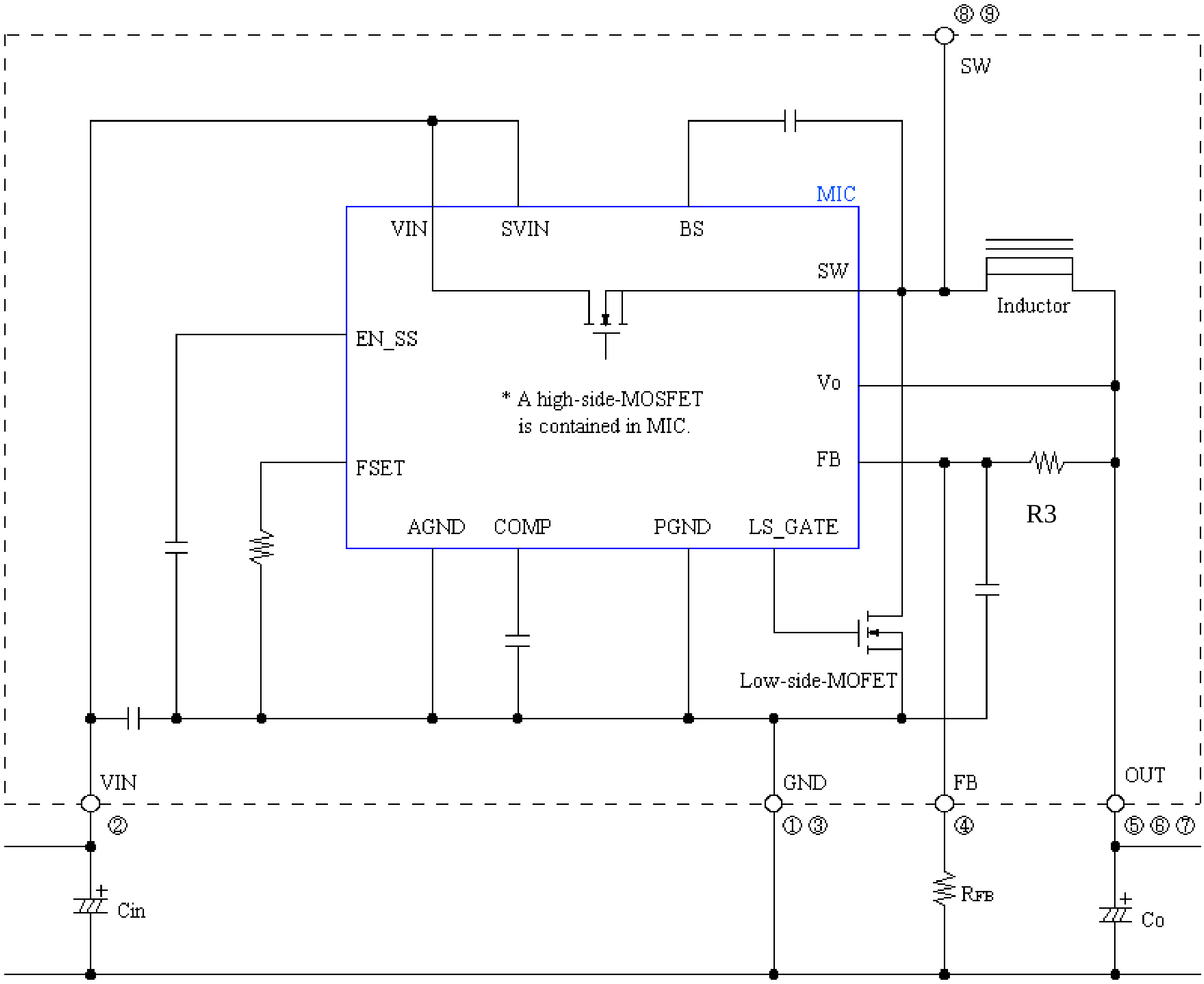
Product name	fsw	VIN		Vo	Io	Lead Forming	
MPM01	250kHz	9V to 40V	(1)	1.8V to 12V	3A	LF971	Self-supporting
						LF972	Right angle
MPM04		16V to 40V	(2)	12V to 24V		LF971	Self-supporting
						LF972	Right angle

(1)The minimum input voltage shall be either of 9V or V_O+4V, whichever is higher.
(2)The minimum input voltage shall be either of 16V or VO+4V, whichever is higher. And than Vin(MIN)36V in 20V<Vo<24V more than Vin(MIN)30v in 18V<Vo<20V.

1.Block diagram/pin assignment

Block diagram

Fig.1



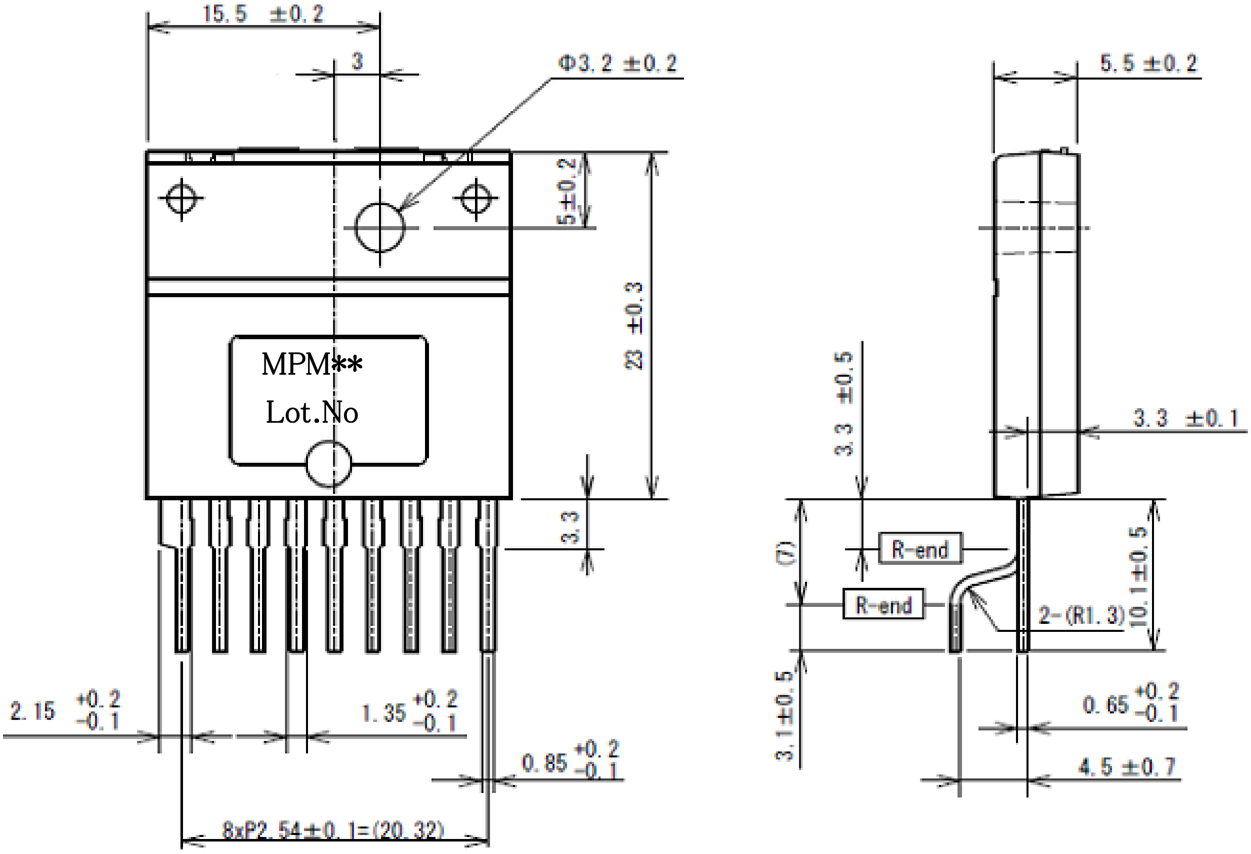
Numbers of lead terminals and their functions and names

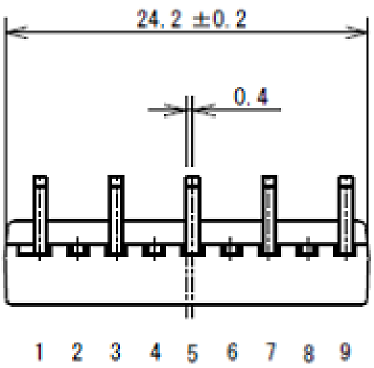
Table 2

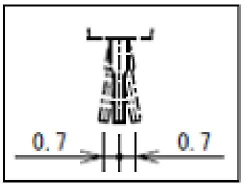
Terminal No.	Symbols	Functions/names
①	GND	Ground terminal
②	VIN	Input power supply terminal
③	GND	Ground terminal
④	FB	Feedback terminal/resistor RFB connection terminal for output voltage setting
⑤⑥⑦	OUT	Output terminal
⑧⑨	SW	Oscillating frequency measurement terminal

2.Dimensions

(Unit: mm) Sanken 3GR –S package lead forming LF971: self-supporting





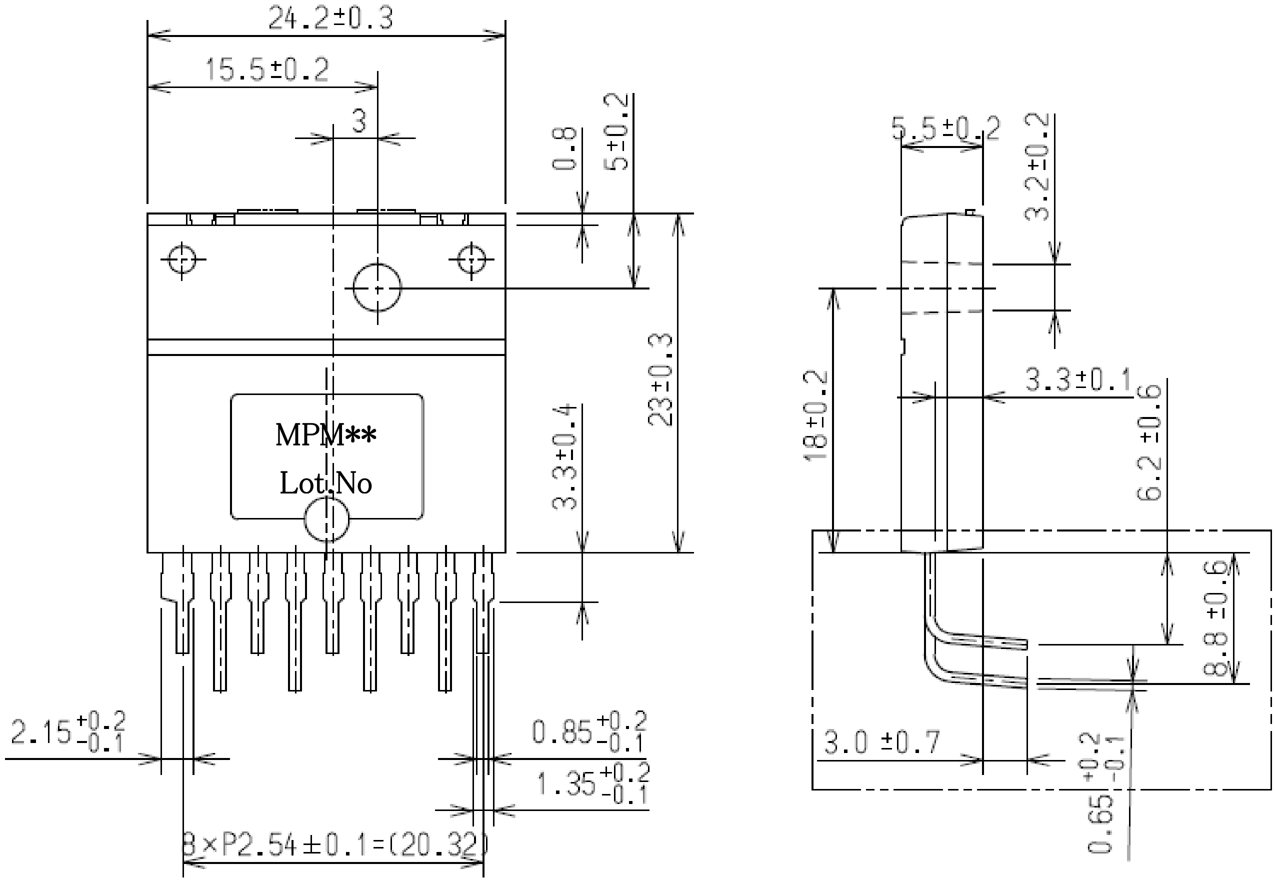


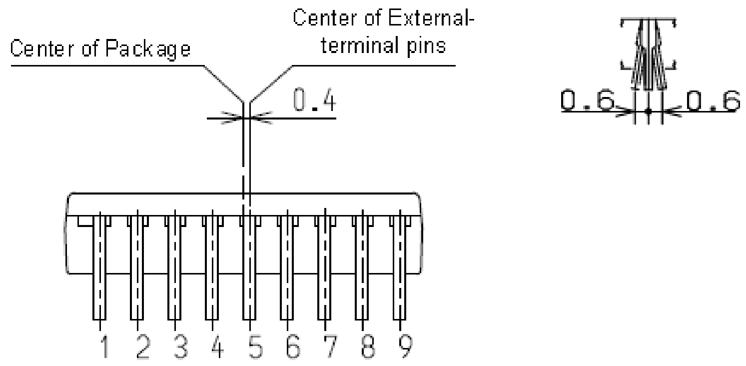
*Material of terminal：Cu
*Processing of terminal: Ni plating + solder dipping
*Product weight: approximately 20g
*Screwing torque：0.588 - 0.785 (N･m)

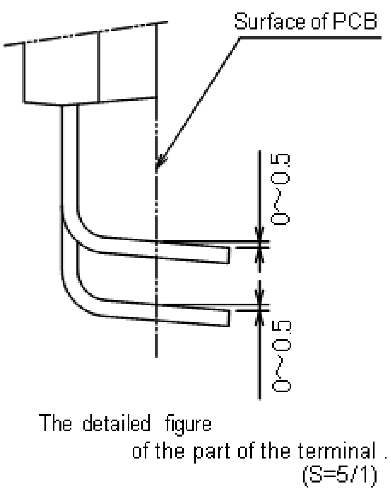
Fig.2

＊In the Figure 2 of front view which is common to MPM01-04, product numbers of each model name should be printed in **.

(Unit: mm) Sanken 3GR –S package lead forming LF972: right angle







*Material of terminal：Cu
*Processing of terminal: Ni plating + solder dipping
*Product weight: approximately 20g
*Screwing torque：0.588 - 0.785 (N･m)

Fig.3

＊In the Figure 3 of front view which is common to MPM01-04, product numbers of each model name should be printed in **.

3.Electrical characteristics

Absolute maximum ratings

Table 3

Item	symbols	Specifications	Units	Conditions
V_{IN} terminal voltage	V_{IN}	-0.3 to 41	V	
FB terminal voltage	V_{FB}	-0.3 to 6	V	
Vo terminal voltage	Vo	-0.3 to 13	V	MPM01
Vo terminal voltage	Vo	-0.3 to 25	V	MPM04
SW terminal voltage	Vsw	-8 to Vin	V	Pulse width ≦20ns
		-1.3 to Vin		DC
V_{IN}-SW voltage	$V_{VIN\text{-}SW}$	55	V	<30nsec
Junction temperature *1	Tj	-20 to 150	°C	
Storage temperature	Tstg	-20 to 120	°C	
Thermal resistance (between MIC junction and frame)	θj-f	7.7	°C／W	

*1：Only MIC, However, it is limited for overheat protection. The overheat protection detection temperature is approximately 160°C.

Recommended operating conditions

Table 4

Items	Symbols	Specifications		Units	Conditions
		Min	Max		
Input voltage range	VIN	9(*4)	40	V	MPM01
Input voltage range	VIN	16(*4)	40	V	MPM04
Output current range *3	Io	0	3	A	
Junction temperature in operation	Tjop	-20	125	℃	
Ambient temperature range in operation*3	Ta	-20	85	℃	Note:refer to Thermal derating curve

*2. The recommended operating conditions means operating conditions required to maintain normal circuit functions shown in the electrical characteristics and in the actual use, they should be maintained within these recommended conditions.

*3. However, they should be used within the derating curve. →Please refer to the paragraph 7. 4 in page 7.

*4. VIN can be higher than Vo subject to the setting of the output voltage Vo.

Since this product is not designed for the boost converter system, VIN must be higher than Vo. Please refer to the paragraph 9 – 2 (page 10).

Electrical characteristics (Ta = 25℃) *5

Table 5

Parameter	Symbol	Ratings			Units	Test conditions
		MIN	MIN	MIN		
Reference voltage	VFBref	0.490	0.500	0.510	V	V_{IN}=33V,Io=1A
Efficiency *6	η	-	91	-	%	V_{IN}=33V,Vo=12V,Io=3A
Switching frequency	fo	212	250	288	kHz	V_{IN}=33V,Vo=12V,Io=3A
Line regulation *7	Vline	—	—	±2	%	VIN=16 to 40V, Vo=12V,Io=1A
Load regulation *7	Vload	—	—	±3	%	V_{IN}=33V,Vo=12V,Io=0 to 3A
Overcurrent protection threshold	Is	4.50	5.60	6.41	A	VIN=33V、Vo=12V Auto-restart *8
Supply Current	Iin	-	12	-	mA	V_{IN}=33V、Io=0A、VFB=1V
Thermal shutdown threshold temperature *9	Tj	151	160	-	℃	V_{IN}=16V to 40V
Under voltage lockout protection	UVLO	-	7.3	8.0	V	
Start-up delay time	Tstart	-	50	—	ms	Applied at V_{IN} = 16 to 40V up to the Vo constant voltage accuracy

*5 The electrical characteristics mean the characteristics to be assured in the case that the IC is operated under the above-mentioned measurement conditions in the circuits shown in the measurement circuit diagram .

*6 The efficiency can be calculated by the equation 1 as follows:

$$\eta\ (\%) = \frac{Vo \times Io}{VIN \times Iin} \times 100$$

･･･equation 1

*7 The line/load regulation does not include any set deviation of output voltage.
It should be noted that the deviation of set output voltage is affected by the accuracy of the external R_{FB}.
As for details, please refer to the paragraph 9 (application).

*8 At the time of setting the output voltages except Vo = 12V, it should be noted that the OCP operation point may fluctuate from the values of Vo = 12V because the inductance of the built-in coil and the frequency are constant.

*9 Overheat protection is of automatic recovery type.

Ambient temperature – load reduction curve (temperature derating curve)

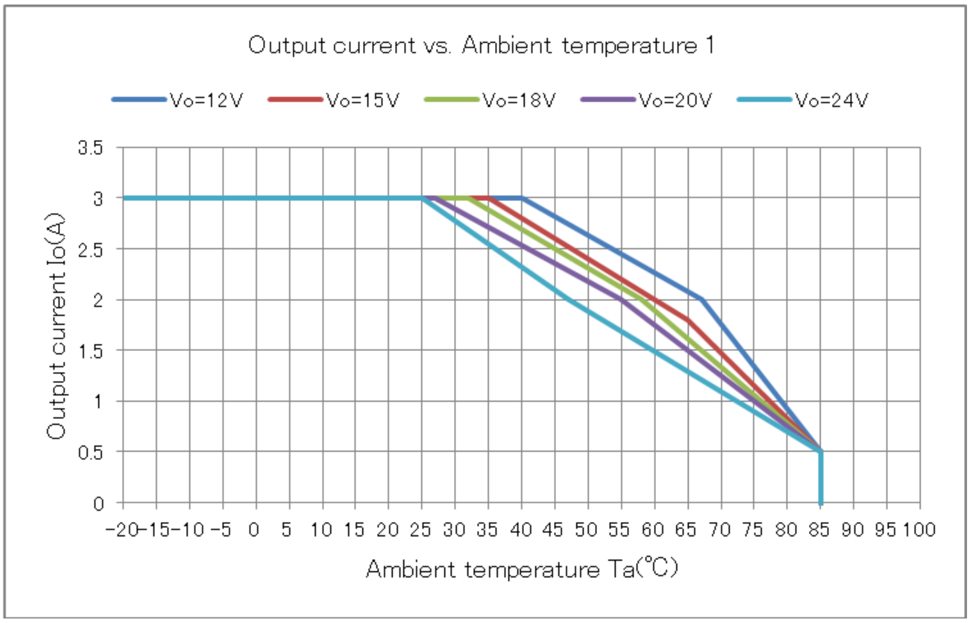


Fig.4
※Vo=12,15,18,
20V
VIN=33V(condition)
※Vo=24V
VIN=36V(condition)

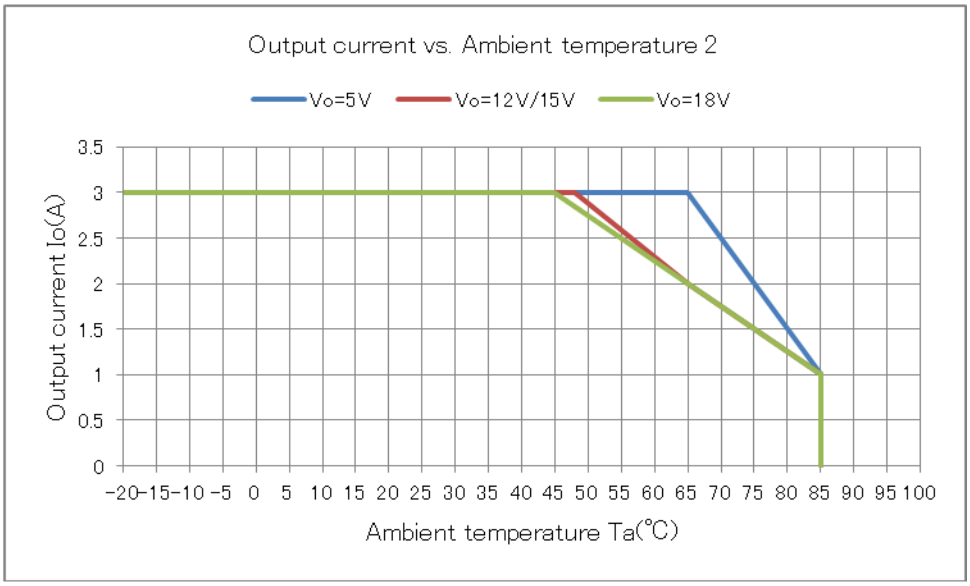


Fig.5
※Vo=5,12,15,18V
VIN=24V(condition)

Note 1. Common to MPM01 and 04 (however, Vo = 5V and 12 are for MPM01 and Vo = 15 – 24V is for MPM04.

Note 2. The graph is for the case of no heatsink and natural cooling condition.(a heatsink can be fitted by screws.

Note 3. In the case of Vo = 2.5 or 3.3V, please use inside the line of Vo = 5V in Figure 5.

4.Example of application circuit

Typical connection diagram

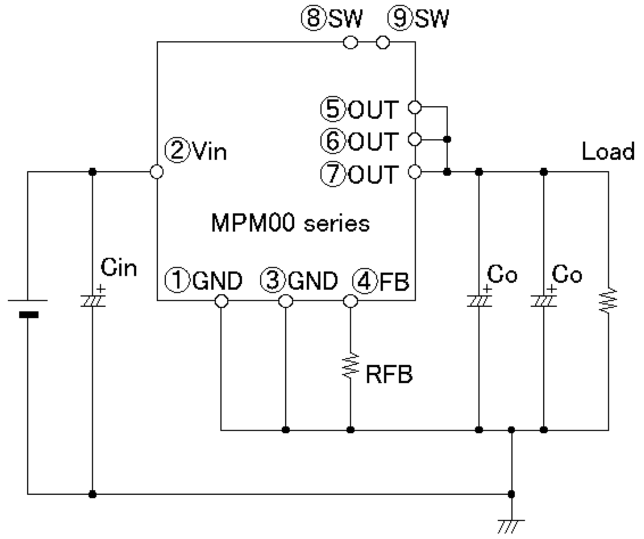


Fig.6

⑧ and ⑨ pins (SW terminals) are inspection terminals to be used for the measurement of oscillating frequencies. Please use them normally in open state.

C1: 50V/1000 μ F
C2 and 3: 25V/1000 μ F x 2 in parallel
*For C1, C2 and C3, please use capacitors for switch mode power supplies instead of the general electronic circuits.

R_{FB} is a resistor for output voltage setting. Please refer to Fig.8.

Recommended pattern

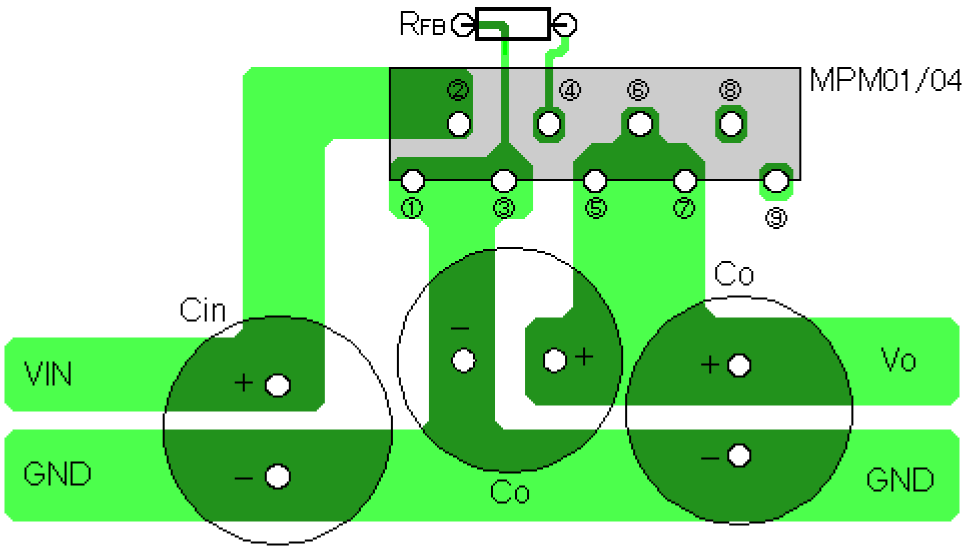


Fig.7

*For the GND pin of ① and ③, it is recommended to make the connection as short as possible in reference to the negative side of Co.
Please perform wiring in a manner that the commutation loop including the inner circuit of the IC is made as short as possible.

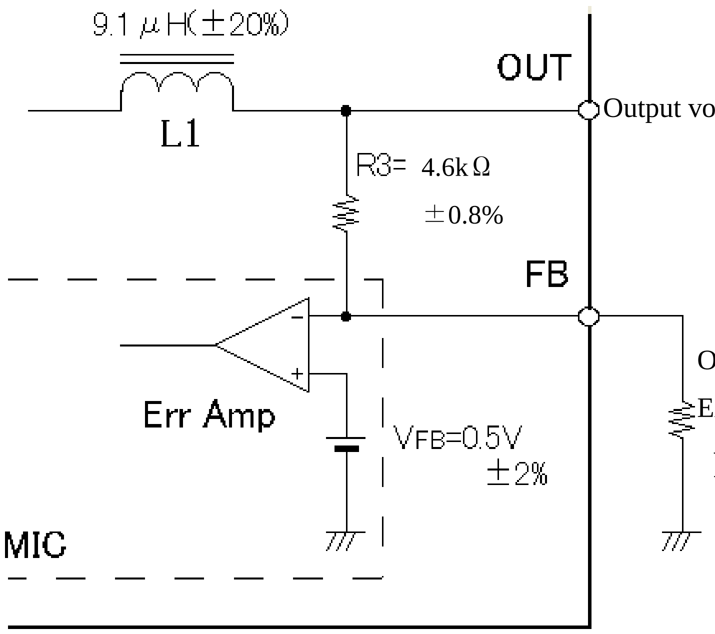
⑧ and ⑨pins (SW terminals) are inspection terminals to measure the oscillating frequency. Please use them in the open state.
As to ⑧ and ⑨ pins, please process them openly only in land. Please do not connect it with patterns of other electric potentials. If connected, it may cause a failure.
Please locate the R_{FB} near the module by means of the shortest wiring. Long wiring of FB line is likely to cause a failure.

5.Applications

Setting method of output voltage (common to MPM01 and MPM04)

The output voltage can be set by changing the R_{FB}. Refer to Fig.8.

(equation 2)

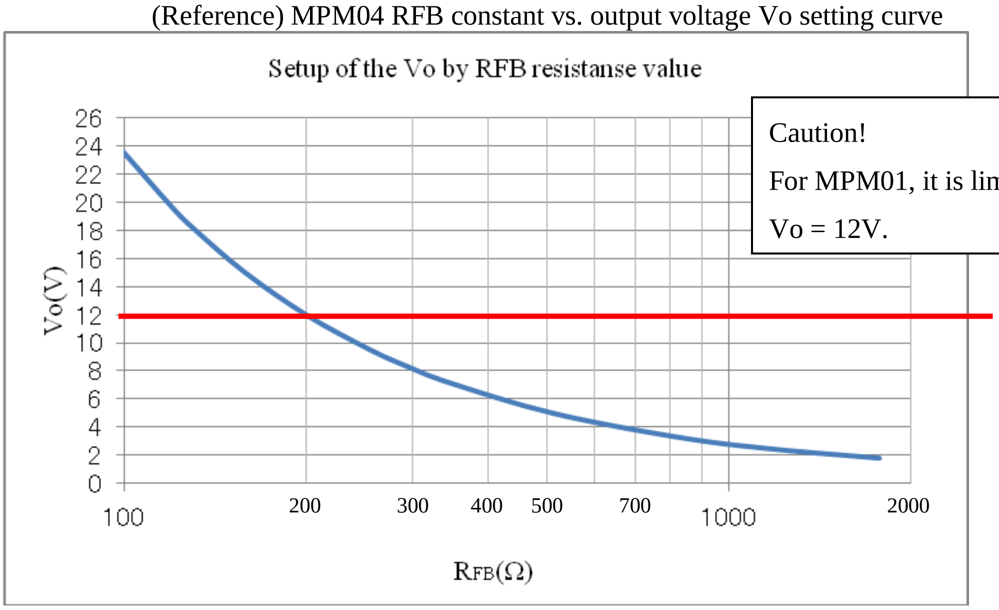


$$V_o = V_{FB}\left(1 + \frac{R3}{R_{FB}}\right)$$ ・・・equation 2

Fig.8

The R_{FB} can be calculated as 510Ωat output voltage of Vo = 5V and as 200Ωat Vo = 12V (typical values). In the case of MPM01 for the setting of output voltage (Vo), since the absolute maximum rating is 13V, the set voltage is limited up to 12V.

(Reference) MPM04 RFB constant vs. output voltage Vo setting curve



Caution!
For MPM01, it is limited up to Vo = 12V.

Fig.9

Minimum input output voltage difference (Table No. 6)

Model	VIN voltage range	Vo setting	Recommended input voltage
MPM01	9V to 40V	1.8V to 12V	VIN≧Vo＋4V *1
MPM04	16V to 40V	12V to 18V	VIN≧Vo＋4V
		20V	30V≦VIN≦40V
		24V	36V≦VIN≦40V *2

(Note) The table 6 shows the recommended values of input voltage VIN required for Vo value.

For VIN, voltages higher than values in the table are recommended, but it should be noted that the upper and lower limits of VIN voltage range are fixed.

*1 : (Example) Vo = 2. 5V being set →the minimum input output voltage difference of VIN ≧ Vo + 4V is 6. 5V, but it should be noted that it is VIN ≧ 9V (Min.) from the recommended operating conditions (page 5).
In the MPM series where the internal frequency and internal inductance are fixed, sub-harmonic oscillation may happen in the input voltage area where the duty of input and output conditions exceeds 50%.
In this concern, please check that any trouble like output ripple does not occur, when it is used at the above recommended values.

*2: At Vo = 24V, VIN = 36V or higher is recommended, but as the margin up to the upper limit of 40V is scarce, please use the stabilized power supply voltage.

How to select an input smoothing capacitor (common to MPM01 and MPM04)

There are 3 conditions for the calculation of the input rectifier capacitor Cin.

1)Ripple current condition

When the power source supplied to this module has an impedance = 0 which is an ideal case, the input current to this module is supplied 100% by the power supply and ripple current scarcely flows across the smoothing capacitor, but in specifying the ripple current of the capacitor, the worst condition is considered on the assumption that there exists no ideal power supply.It is assumed that the current is supplied 100% by the worst smoothing capacitor.

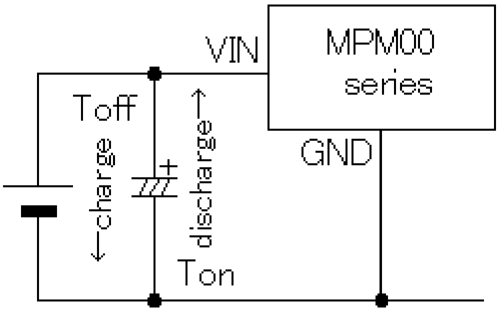


Fig.10 Charging/discharging of input capacitor

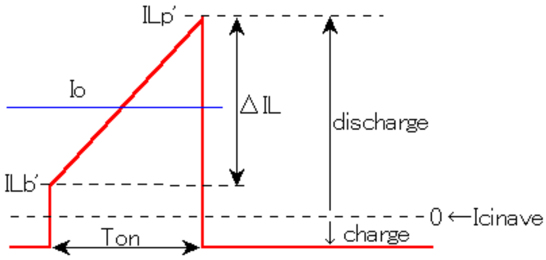


Fig.11 Ripple current model of input capacitor

$Icinave = Io \times D$ ･･･Equation 3 *D represents the Duty and Io the load current (DC).

$$\Delta IL = \frac{(VIN - Vo) \times Ton}{L}$$ ･･･Equation 4

*L represents the inductance of built-in coil and Ton the ON time.

$$ILp' = \left\{Io + \left(\frac{\Delta IL}{2}\right)\right\} - Icinave$$ ･･･Equation 5

$$ILb' = \left\{Io - \left(\frac{\Delta IL}{2}\right)\right\} - Icinave$$ ･･･Equation 6

Since the ripple current of capacitor has the waveform of alternating current, it is calculated by the root-mean-square of discharging side and charging side.

･Discharging side

$$Icin\ ripple(Dis) = \sqrt{\frac{Ton \times (ILp'^2 + ILp' \times ILb' + ILb'^2)}{3 \times T}}$$ ･･･Equation 7

T represents a cycle.

･Charging side

$$Icin\ ripple(Chg) = \sqrt{(1 - D) \times Icinave^2}$$ ･･･Equation 8

･The total ripple current of input smoothing capacitor will be expressed as follows

$$Icin\ ripple = \sqrt{Icin\ ripple(Dis)^2 + Icin\ ripple(Chg)^2}$$ ･･･Equation 9

(Calculation example)

-Conditions

VIN=24(V)、Vo=12(V)、Io=3(A)、Frequency =250(kHz)→Cycle T=4(μ s)、

D=12(V)／24(V)=0.5(Ton=2 μ s)、built-in inductor/inductance value =9.1(μ H)

Icinave=3(A)×0.5=1.5(A)

$$\Delta IL = \frac{\{24(V) - 12(V)\} \times 2(\mu s)}{9.1(\mu H)}$$

=2.637(A)

$$ILp' = \left[3(A) + \left\{\frac{2.637(A)}{2}\right\}\right] - 1.5(A)$$

=2.8185(A)

$$ILb'' = \left[3(A) - \left\{\frac{2.637(A)}{2}\right\}\right] - 1.5(A)$$

=0.1815(A)

From the calculated ILp' and ILb', Icin ripple (Dis) will be as follows:

$$Icin\ ripple(Dis) = \sqrt{\frac{2(\mu s) \times [2.8185(A)^2 + \{2.8185(A) \times 0.1815(A)\} + 0.1815(A)^2]}{3 \times 4(\mu s)}}$$

= 1.1894(A)

Icin ripple (Chg) will be as follows:

$$Icin\ ripple(Chg) = \sqrt{\{1 - D\} \times 1.5(A)^2}$$

=1.0606(A)

Therefore, the total ripple current of input smoothing capacitor Icin (ripple) will be as follows:

$$Icin(ripple) = \sqrt{1.1894(A)^2 + 1.0606(A)^2}$$

=1.594(Arms)

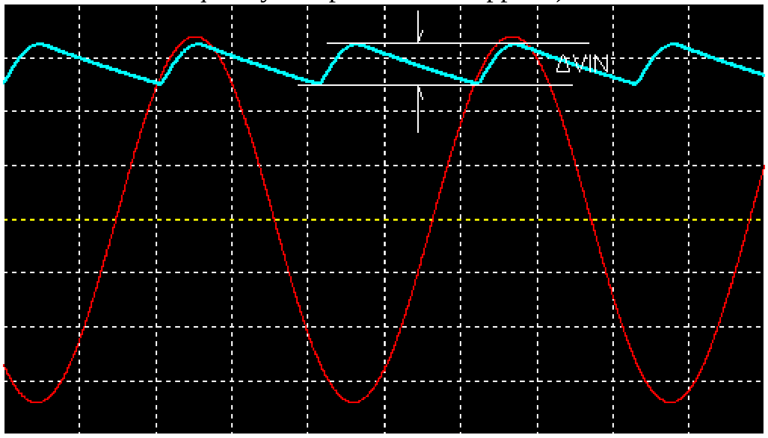
It is required to select the input smoothing capacitor which has the specifications of being able to flow the above ripple current .

Please select a capacitor which has the capacity of being able to flow ripple current by consulting the catalogs of suppliers of capacitors.

2)Setting of commercial power ripple voltage ΔVIN of VIN voltage for the amusement equipment etc.

The full-wave rectified frequency fr = 100Hz. This ripple voltage ΔVIN is set.

In the case that with AC24V x $\sqrt{2}$ ≒33V as a peak, the bottom point of voltage drop caused from discharging supplied by the smoothing capacitor to the load is set at the ripple voltage of −20% = 6. 6V : (*20% is at your discretion. If this is made larger, the capacity may be calculated to be smaller, but please take note that large commercial frequency components will appear.).



Blue: VIN ripple 10V/Div
Cin = 1000μF
*Peak ≒33V
Bottom point ≒26. 4V
Example of the load after smoothing rectification corresponds with 33W.
Red: AC24V 50Hz
10V/Div

Fig.12 VIN ripple voltage by all wave rectifier smoothing of commercial frequency

$$Cin \fallingdotseq \frac{Io \times D \times (1 - D)}{fr \times \Delta VIN}$$

···equation 10

From the Equation 10, when the duty D at VIN 33V and Vo = 12V is set to

D = 12 (V)/33(V) = 0.3636, the equation is as follows.

$$Cin \fallingdotseq \frac{3(A) \times 0.3636 \times (1 - 0.3636)}{100(Hz) \times 6.6(V)}$$

≒1051(μF)

and the smoothing capacitor Cin will require the capacitance of 1051μF or more.

Similarly, when the AC24V is bridge-rectified, the capacitance of the smoothing capacitor will be determined subject the voltage of ripple of commercial frequency at the bottom point..

In addition, in the case that the power supply source is a stabilized DC24V, such capacity is not required, but a capacitor which can flow ripple current calculated at ①should be inserted between VIN and GND.

Furthermore, this smoothing capacitor Cin has a function of so called "pascon" (bypass

condenser) with respect to the avoidance of wrong operation, therefore it is not recommendable not to insert any capacitor.

3)Rated Voltage Range.

In the case of the all-wave smoothing rectification of AC 24V, the withstand voltage of 35V is insufficient in term of margin, therefore 50V or higher withstand voltage should be chosen.

As stated above, the specifications of the input smoothing capacitor Cin should be determined in consideration of the following:

① It should have "allowable ripple current" performance which allows for sufficient margin to the calculated ripple current,

②It should calculate the capacitance in accordance with the valley voltage of the commercial frequency ripple voltage (for amusement apparatus etc.)

③ It should have higher withstand voltage than the maximum value of VIN voltage.

The capacitor should be chosen from the capacitor supplier's catalog for switch mode power supplies.

Selection of output voltage /ripple smoothing capacitor Co (common to MPM01/MPM04)

This module does not build in a smoothing capacitor in the package and the mounting conditions and smoothing capacitors to be used are determined by users.

Consequently, no description of specifications is found in this paragraph.

1)Setting of ripple voltage.

When the output ripple voltage is theoretically calculated on the desk, it is determined by the critical current of inductor Δ IL and ESR (equivalent series resistance) which is equivalent to the performance of smoothing capacitor.

Vripple=ΔIL×ESR･･･equation 11

From the equation 4, ΔIL = 2. 637A is obtained and when this value is multiplied by the ESR of the smoothing capacitor, the output ripple voltage is obtained.

(An example of calculation)

-Conditions

VIN=24(V)､Vo=12(V)､Io=3(A)､Frequency =250(kHz)→cycle T=4(μs)､

D=12(V)／24(V)=0.5(Ton=2μs)､Built-in inductor/inductance value =9.1(μH)

In the case that the ESR of a smoothing capacitor at low temperature is provisionally 20 Ω, ΔIL = 2. 637 (A) from the equation 4 and Vripple = 2. 637 (A) x 20 (mΩ) = 52. 7mVp-p. will be obtained

When the equation 11 is modified, it will be as follows:

$$ESR = \frac{Vripple}{\Delta IL}$$

･･･equation 12

When the ripple voltage is made to be 100mVp-p, it will be as follows from the equation 12:

$$ESR = \frac{100(mV)}{2.637(A)}$$

=37.9mΩ

At any event, it will be necessary to connect an electrolytic capacitor which has 37.9 mΩ or lower even at low temperature.

* Phase-lead compensation circuit

In a MPM00 series,as the output capacitor, the aluminum electrolytic capacitor is used for output capacitance with the premise,the phase compensation circuit fitted to aluminum electrolytic capacitor is built in.By the performance improvement, the product of small-size, big-capacity, super-low-ESR are in the market. Even if it is aluminum electrolytic capacitor, there is a product of an ESR character which is nearly equal to the character of the ceramics capacitor.
In this case, a un-stable movement sometimes occurs, because AC-gain of control loop declines. In this case, as the fig 13, connect a phase-lead-compensation circuit (R_{FF} & C_{FF}) between the OUT terminal and FB terminals, and avoid a un-stable movement .

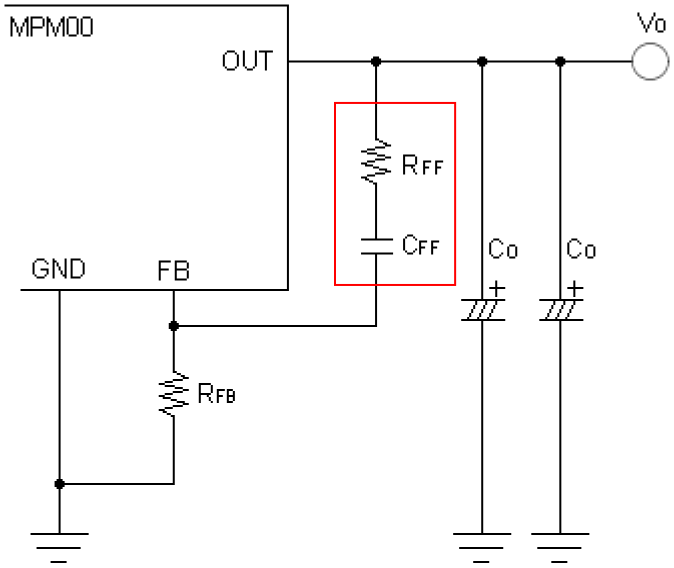


Fig.13 The connection of phase-lead-compensation

*Setup example (Input and output conditions：VIN=33V DC, Vo=12V, Io=1A～3A)
Co：1000µF／25V , ESR=14mΩ／20℃(a single kind of article)･･･It is almost 7mΩ in case of a parallel connection (2pcs).

R_{FF}：0Ω～100Ω
C_{FF}：100pF～1000pF

It is a standard persistently. And, the ESR character of aluminum electrolytic capacitor has temperature dependence. Therefore, adjust R_{FF} & C_{FF} after you confirm the movement of MPM00 under both environments of the low temperature/high temperature.

2)Ripple current of output smoothing capacitor.

Then, the ripple current which flows across the output smoothing capacitor Co is given by the equation 13.

$$Ico(ripple) = \frac{\Delta IL}{2\sqrt{3}} \quad \cdots \text{equation 13}$$

(Example of calculation)

-Conditions

VIN=24(V)、Vo=12(V)、Io=3(A)、frequency =250(kHz)→Cycle T=4(μs)、

D=12(V)／24(V)=0.5(Ton=2μs)、built-in inductor/inductance value =9.1(μH)

$$\Delta IL = \frac{\{24(V) - 12(V)\} \times 2(\mu s)}{9.1(\mu H)} = 2.637(A)$$

Then, from the equation 13, it will be as follows:

$$Ico(ripple) = \frac{2.637(A)}{2\sqrt{3}}$$

=0.761(Arms)

To 0. 761(Arms), please select a capacitor having the specifications of sufficient margin to the calculated ripple current for the tolerated ripple current from the catalog of capacitor suppliers.

3)Rated Voltage Range.

In the above calculation example, Vo = 12V condition is applied, but the withstand voltage of a smoothing capacitor is required to be 16V or higher.

As stated above, in the output smoothing capacitor Co,

① The ESR characteristic at low temperature is determined subject to the output ripple voltage Vp-p.

②There should be the “allowable ripple current” performance which has sufficient margin to the calculated ripple current.

③The specifications should be determined on the condition that the withstand voltage should be higher with enough margin than the set output voltage Vo.

Please select a suitable capacitor for the switch mode power supply from the catalog of capacitor manufacturers.

(Reference) Impedance and temperature characteristics of aluminum electrolytic capacitors

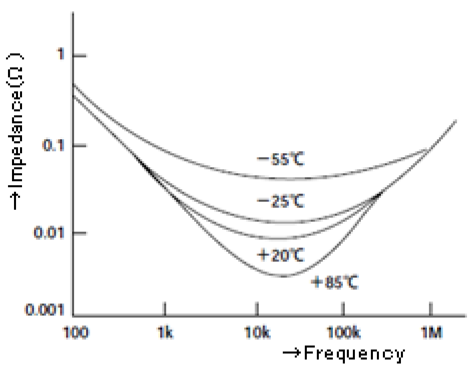


Fig.14

In the aluminum electrolytic capacitor, as the temperature rises, the impedance changes with the equivalent series resistance ESR as the lowest point, as shown in the fig 14.
This is because the resistive component in the electrolyte changes subject to the temperature and in the low temperature, the impedance will rise.
Please be careful, as this characteristic may affect the increase of ripple voltage.
The impedance specifications of electrolytic capacitors are specified at 20℃ and 100kHz, but please refer to the catalogs or technical brochures of each capacitor manufacturer for detailed ESR in the low temperature.

Demonstration board for MPM00 series

(Demonstration board for evaluation and reference static characteristics)

The preproduction of an evaluation board for the evaluation of actual operation of the MPM series has been completed. Please contact Sanken's sales department for further information.

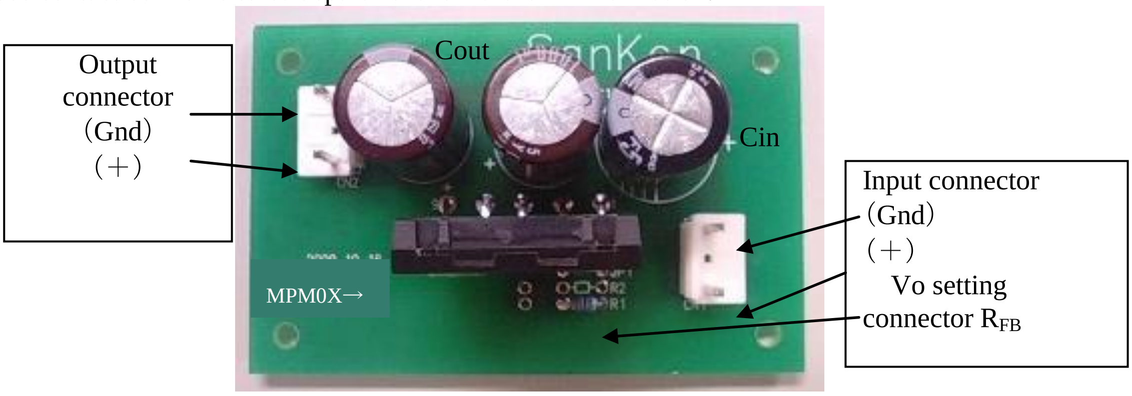


Photo1

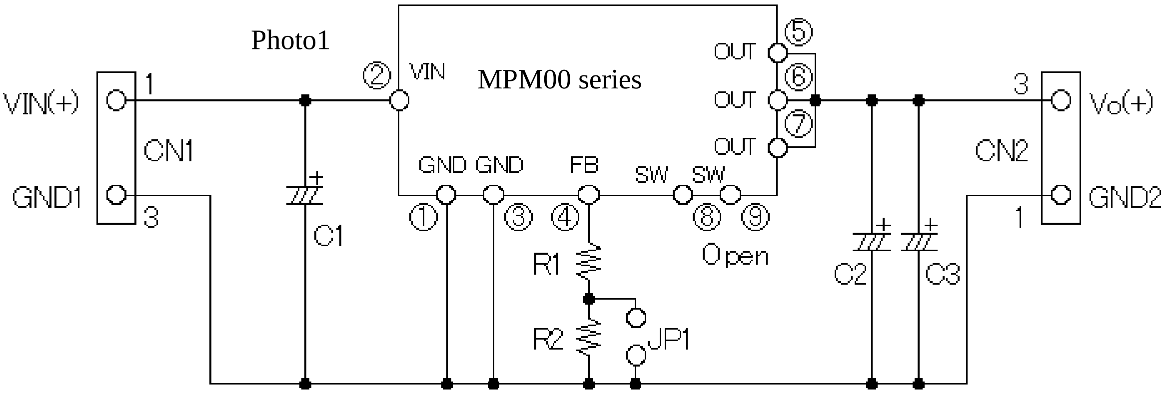


Fig.15 Circuit diagram of demonstration board

Table 7

Parts	Part No.	Part names	Manufacturers
Printed circuit board	PCB	CEM3 single side	–
Connector	CN1, CN2	B2P3 - VH	JST
DC/DC module	IC1	MPM01	Sanken
Aluminum electrolytic capacitor	C1	ZLH50V/1000μF	Rubicon
Aluminum electrolytic capacitor	C2	ZLH25V/1000μF	Rubicon
Aluminum electrolytic capacitor	C3	ZLH25V/1000μF	Rubicon
Carbon resistor	R1	1/4W 510Ω	–
Carbon resistor	R2	Open	–
Jumper wire	JP1	ϕ 0. 5 Sn plated wire	–

*Demonstration board part list (an example of input voltage VIN = 33V, output voltage Vo = 5V setting).

This part list is just for reference. Customers are requested to perform the verification test by replacing these listed parts by their own standard parts.

6.Example of static characteristics

Examples of our own measurements of MPM01/04 are shown below:

1. Efficiency (Ta = 25℃) *these are reference values in our measurement environments.

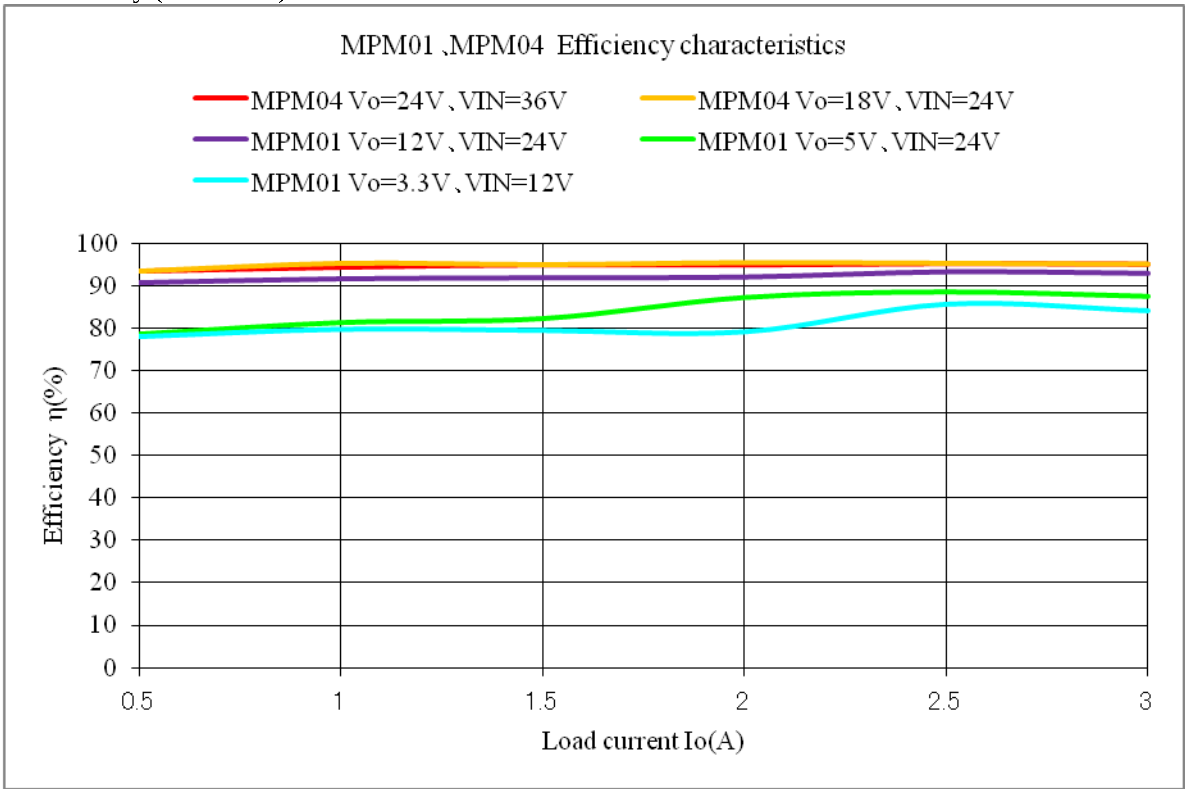


Fig.16

2) Load regulation (Ta = 25℃) *These are reference values in our measurement environments.

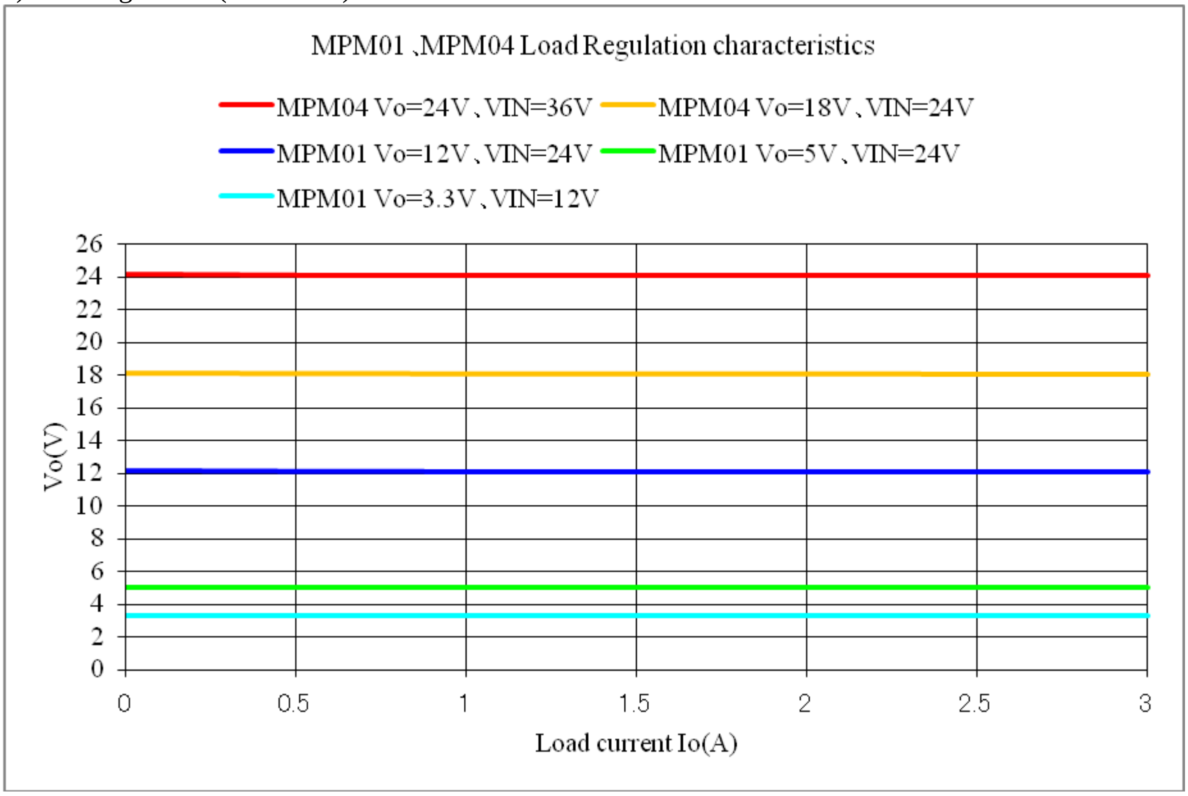


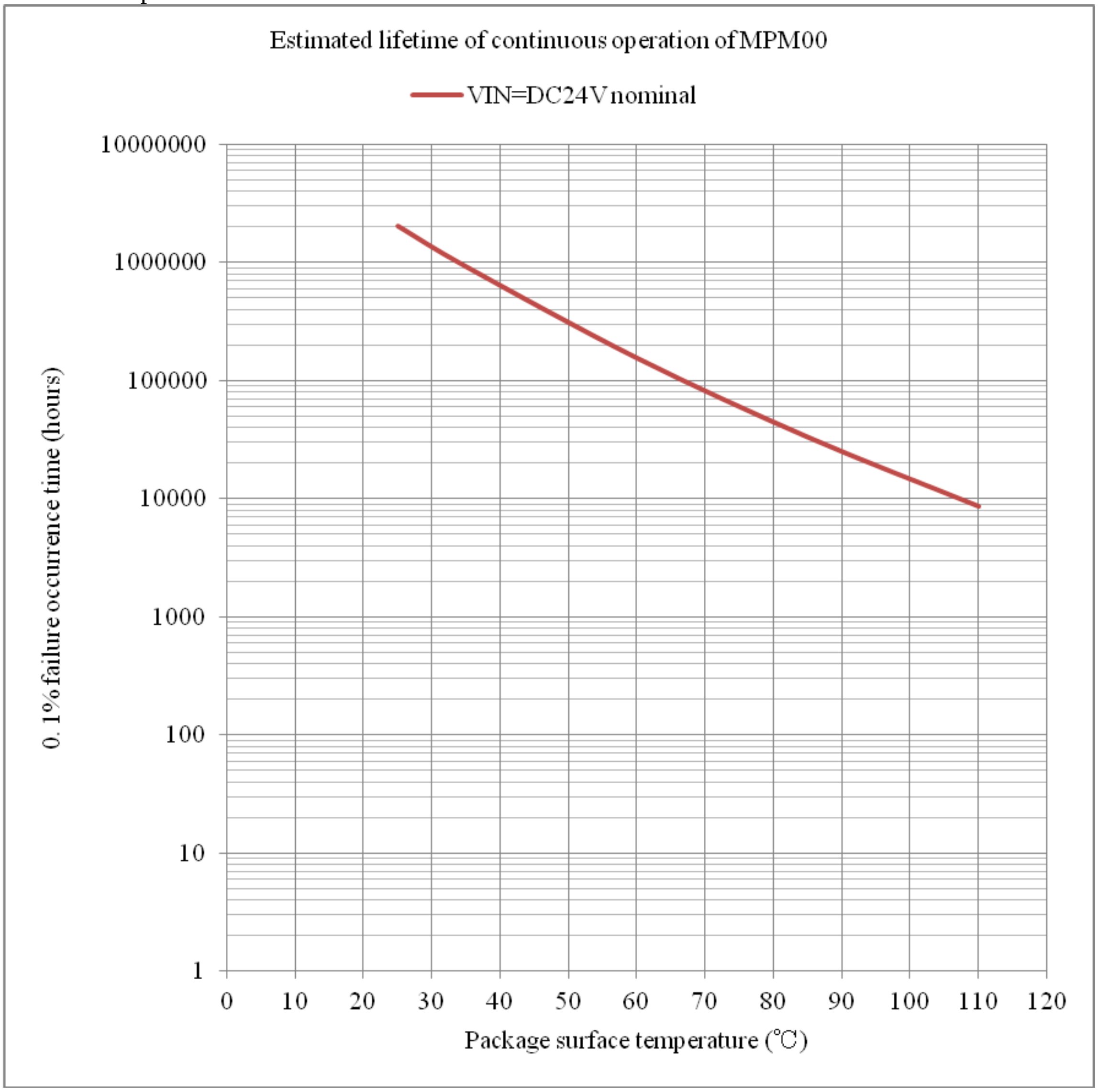
Fig.17

7. Estimated lifetime curve (common to MPM01 and MPM04)

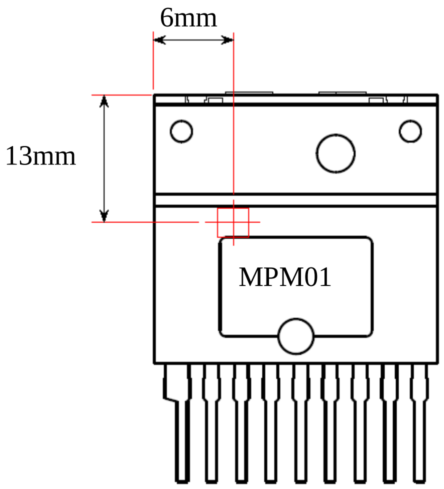
The lifetime of electronic parts is generally shorter in higher temperature.For long time use, it is most effective to use them in lower temperature.

① Continuous operation lifetime

The continuous operation time and estimated lifetime are shown in Fig. 17.The horizontal axis shows the package surface temperature and the vertical axis the 0. 1% failure occurrence time.



*The data may be variable subject to the input voltage.



As shown below on the front side of printed measurement point of package temperature.

Fig.18

Input DC24V nominal estimated lifetime curve and package temperature measurement point.

② Estimated lifetime by repeated temperature cycles

In the temperature cycle mode of repetition of temperature rise and fall due to switched ON and OFF, the estimated lifetime can be obtained as shown below:

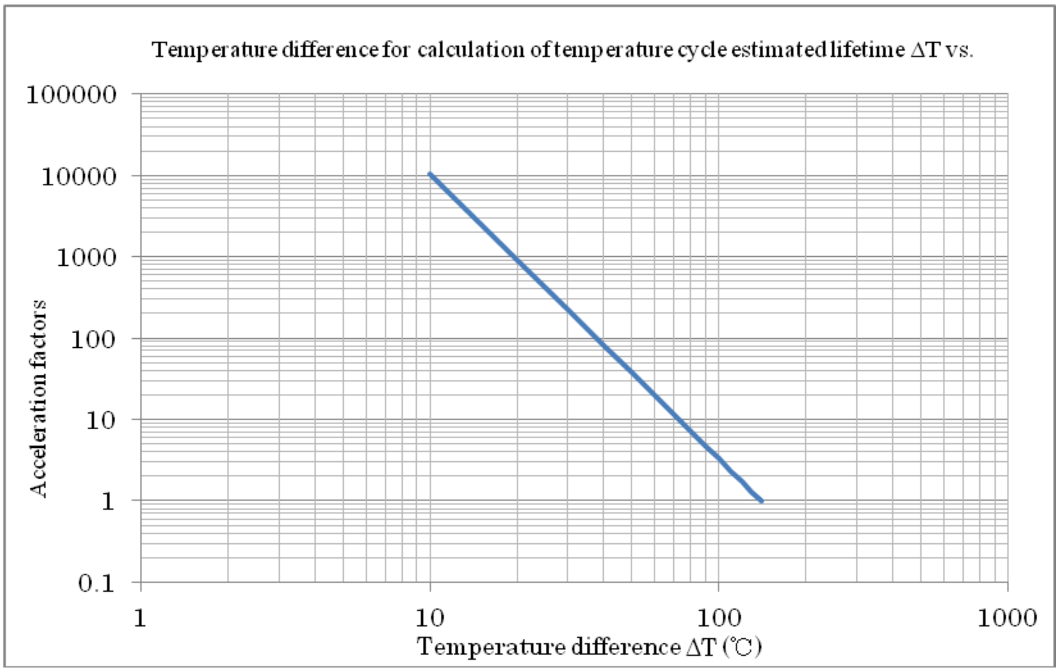


Fig.19 Temperature difference for calculation of temperature cycle estimated lifetime vs. acceleration factors

ΔT at package temperature measuring point of 1) is obtained.

Then, the estimated lifetime L1 is calculated on the acceleration condition as follows:

L1 ≒ L0 x acceleration factor ････equation 14

On the assumption that the temperature difference is ΔT = 60℃ in 25 – 85℃, as the acceleration factor can be read off as about 20 times from the graph of Figure 17, the temperature cycle estimated life time can be obtained as follows from the equation 14:

L1 ≒ 100 x 20 ≒2000 (cycles)

By means of derating the output current, the package temperature can be lowered, but in order to obtain the desired expected lifetime, please use the cooling system appropriately. (Example: forced air cooling by using a heatsink.)

In addition, it is required to connect electrolytic capacitors to the input/output of this product, therefore the lifetime of these capacitors should be also considered.Please implement the maintenance work of capacitors in accordance with the application of capacitor manufacturers.

In order to improve constantly our products, we may change the specifications etc. of our products without any advance notice to our customers and your understanding and acknowledgement to the above would be appreciated.

OPERATING PRECAUTIONS

In the case that you use Sanken products or design your products by using Sanken products, the reliability largely depends on the degree of derating to be made to the rated values. Derating may be interpreted as a case that an operation range is set by derating the load from each rated value or surge voltage or noise is considered for derating in order to assure or improve the reliability. In general, derating factors include electric stresses such as electric voltage, electric current, electric power etc., environmental stresses such as ambient temperature, humidity etc. and thermal stress caused due to self-heating of semiconductor products. For these stresses, instantaneous values, maximum values and minimum values must be taken into consideration. In addition, it should be noted that since power devices or IC's including power devices have large self-heating value, the degree of derating of junction temperature affects the reliability significantly.

Because reliability can be affected adversely by improper storage environments and handling methods, please observe the following cautions.

Cautions for Storage

- Ensure that storage conditions comply with the standard temperature (5 to 35°C) and the standard relative humidity (around 40 to 75%); avoid storage locations that experience extreme changes in temperature or humidity.
- Avoid locations where dust or harmful gases are present and avoid direct sunlight.
- Reinspect for rust on leads and solderability of the products that have been stored for a long time.

Cautions for Testing and Handling

When tests are carried out during inspection testing and other standard test periods, protect the products from power surges from the testing device, shorts between the product pins, and wrong connections. Ensure all test parameters are within the ratings specified by Sanken for the products.

Remarks About Using Thermal Silicone Grease

- When thermal silicone grease is used, it shall be applied evenly and thinly. If more silicone grease than required is applied, it may produce excess stress.
- The thermal silicone grease that has been stored for a long period of time may cause cracks of the greases, and it cause low radiation performance. In addition, the old grease may cause cracks in the resin mold when screwing the products to a heatsink.
- Fully consider preventing foreign materials from entering into the thermal silicone grease. When foreign material is immixed, radiation performance may be degraded or an insulation failure may occur due to a damaged insulating plate.
- The thermal silicon greases that are recommended for the resin molded semiconductor should be used.
  Our recommended thermal silicone grease is the following, and equivalent of these.

Type	Suppliers
G746	Shin-Etsu Chemical Co., Ltd.
YG6260	Momentive Performance Materials Japan LLC
SC102	Dow Corning Toray Co., Ltd.

Cautions for Mounting to a Heatsink

- When the flatness around the screw hole is insufficient, such as when mounting the products to a heatsink that has an extruded (burred) screw hole, the products can be damaged, even with a lower than recommended screw torque. For mounting the products, the mounting surface flatness should be 0.05mm or less.
- Please select suitable screws for the product shape. Do not use a flat-head machine screw because of the stress to the products. Self-tapping screws are not recommended. When using self-tapping screws, the screw may enter the hole diagonally, not vertically, depending on the conditions of hole before threading or the work situation. That may stress the products and may cause failures.

- Recommended screw torque: 0.588 to 0.785 N･m (6 to 8 kgf･cm).
- For tightening screws, if a tightening tool (such as a driver) hits the products, the package may crack, and internal stress fractures may occur, which shorten the lifetime of the electrical elements and can cause catastrophic failure. Tightening with an air driver makes a substantial impact. In addition, a screw torque higher than the set torque can be applied and the package may be damaged. Therefore, an electric driver is recommended.
  When the package is tightened at two or more places, first pre-tighten with a lower torque at all places, then tighten with the specified torque. When using a power driver, torque control is mandatory.

Soldering

- When soldering the products, please be sure to minimize the working time, within the following limits:
  - 260 ± 5 °C 10 ± 1 s (Flow, 2 times)
  - 380 ± 10 °C 3.5 ± 0.5 s (Soldering iron, 1 time)
- Soldering should be at a distance of at least 1.5 mm from the body of the products.

When soldering the products, please be sure to minimize the working time, within the following limits:

･Reflow Preheat ; 180 °C / 90 ± 30 s

Solder heating ; 250 °C / 10 ± 1s (260 °C peak, 2 times)

･Soldering iron ; 380 ± 10 °C / 3.5 ± 0.5s (1 time)

Electrostatic Discharge

- When handling the products, the operator must be grounded. Grounded wrist straps worn should have at least 1MΩ of resistance from the operator to ground to prevent shock hazard, and it should be placed near the operator.
- Workbenches where the products are handled should be grounded and be provided with conductive table and floor mats.
- When using measuring equipment such as a curve tracer, the equipment should be grounded.
- When soldering the products, the head of soldering irons or the solder bath must be grounded in order to prevent leak voltages generated by them from being applied to the products.
- The products should always be stored and transported in Sanken shipping containers or conductive containers, or be wrapped in aluminum foil.

IMPORTANT NOTES

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