

## SPM Series

### Energy-Saving Power Module Series (3W Class)

Rev.2.0  
Dec, 2023

#### Outline

The SPM Energy-Saving Power Module Series is a series of energy-saving switching power modules with built-in switching transformers, control ICs, control circuits and switching elements (FET).

Attaching the input noise filter, the input rectifier diode and the output smoothing capacitor externally enables the easy creation of power switching with high-efficiency, low-standby power.

#### Features

- Operations using both frequency reduction and bursts for generation of low-standby power.
- Supports worldwide input and PFC output voltages.
- Reinforced insulation between Primary and Secondary.
- Resin filling is available to reduce audible noise.
- Compliant with all required safety standards for information equipment, AV equipment, industrial equipment, and home appliance equipment.
- Various built-in protection functions (overcurrent protection).

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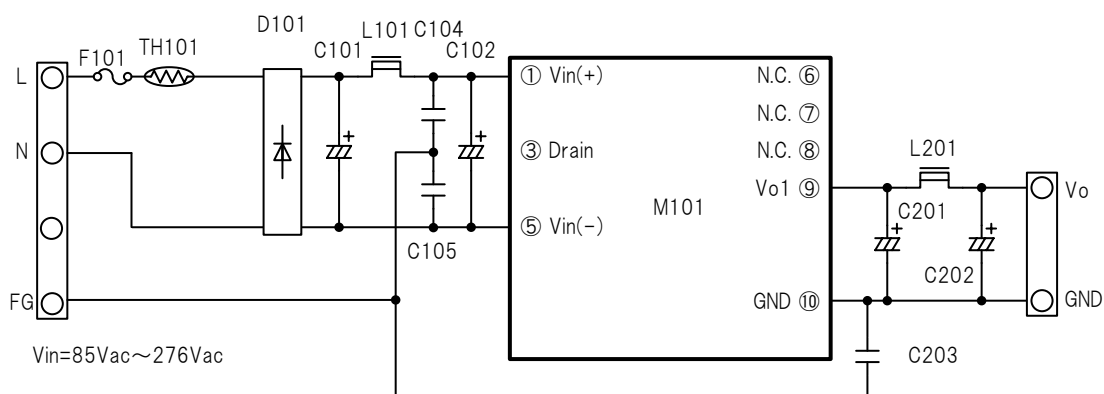
## 1. Selecting Externally Connected Equipment

The example of application circuits and parts value which are indicated to this application note aim at assistance of a design. Therefore, external parts variation or user operating conditions are not fully taken into consideration.

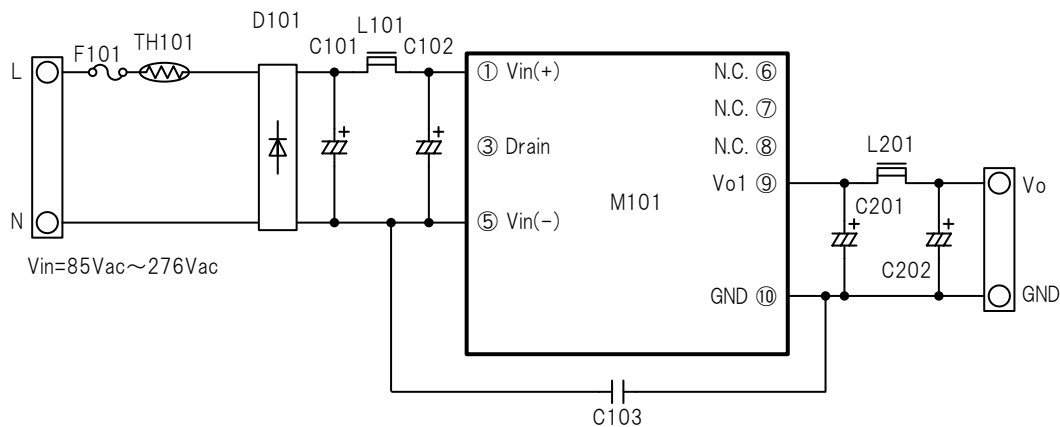
Please take parts variation, operating conditions into consideration when designing.

### 1.1 Application Circuits

#### ● With FG (Class I Power Supply)



#### ● Without FG (Class II Power Supply)



## 1.2 Parts example

部品	出力仕様			
	3.3V 0.7A	5.0V 0.66A	12V 0.28A	15V 0.22A
M101	SPM0307SJ	SPM0507SJ	SPM1203SJ	SPM1502SJ
F101	250V 2.0A タイムラグ*	250V 2.0A タイムラグ*	250V 2.0A タイムラグ*	250V 2.0A タイムラグ*
TH101	5Ω~20Ω	5Ω~20Ω	5Ω~20Ω	5Ω~20Ω
L101	4.7mH~22mH/ 0.2A	4.7mH~22mH/ 0.2A	4.7mH~22mH/ 0.2A	4.7mH~22mH/ 0.2A
L201	2.2uH~10uH / 1.4A	2.2uH~10uH / 1.4A	2.2uH~10uH / 0.6A	2.2uH~10uH / 0.3A
C101	0.1uH~0.22uH / 250V	0.1uH~0.22uH / 250V	0.1uH~0.22uH / 250V	0.1uH~0.22uH / 250V
C102	450V 22uF	450V 22uF	450V 22uF	450V 22uF
C103	100pF~2200pF クラス II	100pF~2200pF クラス II	100pF~2200pF クラス II	100pF~2200pF クラス II
C105、C106	470pF~2200pF クラス I	470pF~2200pF クラス I	470pF~2200pF クラス I	470pF~2200pF クラス I
C201	10V 1200uF	10V 1200uF	25V 100uF	25V 220uF
C202	10V 1200uF	25V 100uF	25V 100uF	25V 47uF
C203	1kV 0.022uF	1kV 0.022uF	1kV 0.022uF	1kV 0.022uF
R101	3.3MΩ 500V	3.3MΩ 500V	3.3MΩ 500V	3.3MΩ 500V

※C102 assuming the rated output power as the maximum power.

※Depending on the capacity of the Xcapacitor (C101), a discharge resistor (R101) is required.

Please see section 1.6 for details.

### 1.3 AC input DC output

When using an AC input connector and DC output connector, pay attention to the rated voltage and rated current of the connector. Consider the input voltage, withstand voltage and safety standard demanded values and provide a clearance between AC input connector pins.

### 1.4 Fuse (F101)

Since a fuse is not built into the module (M101), always install a fuse at the Live side to ensure safety. Select the fuse by considering the normal current, in-rush current, ambient temperature, and other conditions. (Discharge the capacitors in the circuit fully and consider the conditions at which the circuit impedance is lowest when there is a thermistor or other element whose resistance value changes with temperature.)

- ① Select a rated current of 2 or more times the normal current.
- ② Consider the rated current rate of change by ambient temperature. (At high temperature: Rated voltage drops)
- ③ Check that the in-rush current and normal current are within the blowout characteristic curve of the fuse.
- ④ Select a fuse so that in-rush current and normal current can take sufficient margin to a fuse permission  $I^2t$  curve. A required margin is subject to the influence by temperature conditions, and the influence of the number of times of incoming current which occurs in an expected life. We recommend you to ask a fuse maker a proper margin.

In order to share an input line and an input electrolytic capacitor with another converter, when selecting a fuse with the high fusing current characteristic, and a high-capacity electrolytic capacitor, there is a case which a fuse does not blow out at the time of abnormalities. Please perform a safety check enough in such a case.

### 1.5 Noise filter

#### 1.5.1 C101:X capacitor (Across-the-line capacitor)

- Select the rated voltage matched to the input voltage specifications.
- Use a safety standard approved product of each country.

#### 1.5.2 C103,C105,C106,C203: Y capacitor (Line bypass capacitor)

- Use a safety standard approved product of each country.
- Be careful of the leakage current specified by each safety standard.
- With a Class II power supply, when connecting directly between the primary and secondary, use a reinforced insulation product (Y1 class approved).
- The Y capacitor comes to have a lot of effect to the noise by making the pattern short.
- C203 does not require a safety standard approved product, but since the withstand test voltage applied between the primary and secondary is divided and applied according to the overall capacitance of C105 and C106 and the capacitance of C203, pay careful attention to the rated voltage.
- Depending on the applicable safety standards, you may be required to use two or more Y1 capacitors. (Example IEC60335-1)

### 1.5.3 L101:Common mode choke coil

- Be careful to confirm the rated temperature specified by the wire type and the bobbin insulation used in the common choke coil.
- When the input/output pattern of the common mode choke coil is close, there is a possibility that the effect to the noise reduces, so please be careful about routing technique.

## 1.6 X capacitor discharge resistance (R101)

The voltage immediately before cutoff is charged in the X capacitor even when the input line is in cutoff status. With a device at which parts of the same voltage as the X capacitor may be touched, a discharge resistor is necessary according to the capacity of the X capacitor.

Example) IEC62368-1: The voltage of the X capacitor 2 seconds after cutting off the input line must be within the specified value.

Select the discharge resistance R so that the discharge time t is 2 seconds or less using the formula below, and check that there are no problems.

$$t = - C \times R \times \ln(V_t/V_{in})$$

V<sub>t</sub>: X capacitor voltage t seconds from input cutoff

V<sub>in</sub>: Effective input voltage  $\times \sqrt{2}$

C: X capacitor capacitance

R: Discharge resistor value

## 1.7 Rectifying diode(D101)

Always perform full-wave rectification using a bridge diode or general rectifying diodes (use 4 diodes).

When selecting parts, pay attention to the rated voltage, rated current, and temperature rise.

Check that the in-rush current does not exceed the peak surge current and I<sup>2</sup>t specification of the rectifying diode.

(Discharge the capacitors in the circuit fully and consider the conditions at which the circuit impedance is lowest when there is a thermistor or other element whose resistance value changes with temperature.)

## 1.8 Surge current prevention(TH101)

When input power is applied, an in-rush current which charges the input smoothing electrolytic capacitor flows. An in-rush current that is too large will cause the power supply voltage to become unstable and may affect the devices which share the power supply. The fuse and rectifying diodes used may also be damaged.

When using a power thermistor to suppress the surge current, select it by paying attention to the following:

- ① Be sure that the temperature is within the operating temperature range of the thermistor.
- ② Since the characteristic is such that a rated current drop accompanies a temperature rise, check the highest temperature of the thermistor and that the load current (power supply input current) is the rated current or less at the highest temperature.
- ③ With a power thermistor, the relationship between the maximum value of the usable input voltage (rms) and the capacitance of the input smoothing electrolytic capacitor are set. Check that the relationship between the input voltage (rms) and input smoothing electrolytic capacitor is not a problem with the thermistor used.
- ④ Since a power thermistor has a large thermal time constant and its resistance value remains low after the input is tripped, when the input is repeatedly turned on and off, the surge current cannot be controlled. When using under this condition, check that the effect, etc. on the fuse, bridge diode, and input power supply are no problem.

The surge current calculation expression is:

As the calculation result is only a reference, conduct a thorough check using actual equipment.

· AC input :

$$\text{Inrush Current(peak value)} : V_{in}(\text{rms}) \cdot \sqrt{2} / (R_{TH101} + R_L)$$

$$I^2 t : V_{in}(\text{rms})^2 \cdot C102 / (R_{TH101} + R_L)$$

· DC input

$$\text{Inrush Current(peak value)} : V_{in}(\text{dc}) / (R_{TH101} + R_L)$$

$$I^2 t : V_{in}(\text{dc})^2 \cdot C102 / 2(R_{TH101} + R_L)$$

$R_L$ : Line impedance ( $\Omega$ )

$R_{TH101}$ : Thermistor resistance ( $\Omega$ ) at 25°C

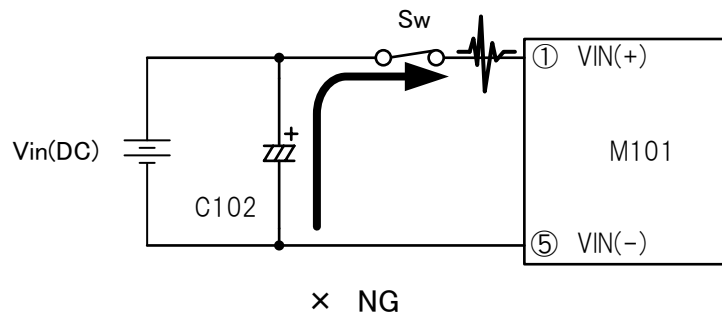
C102: electrolytic capacitor (F)

## 1.9 Input smoothing electrolytic capacitor(C102)

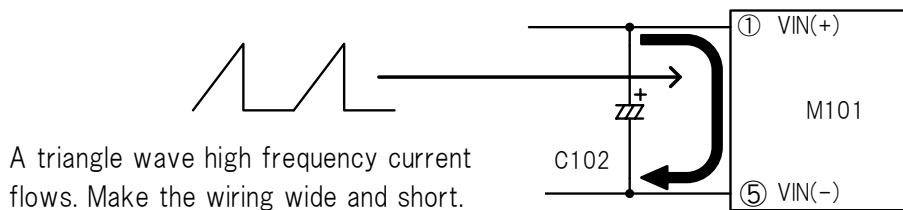
The input smoothing electrolytic capacitor has a large effect on the characteristics and life of the product. Select the capacitor by paying attention to the following.

Never arrange the mechanical switches between the input electrolytic capacitor and the module.

When the mechanical switch turned on, surge voltage by the energy which collected on an electrolytic condenser is impressed on a module, and there is a fear that a module is destroyed by a pressure-resistant over.



① Install the capacitor very close to the module (M101) and use a wide pattern to connect M101.

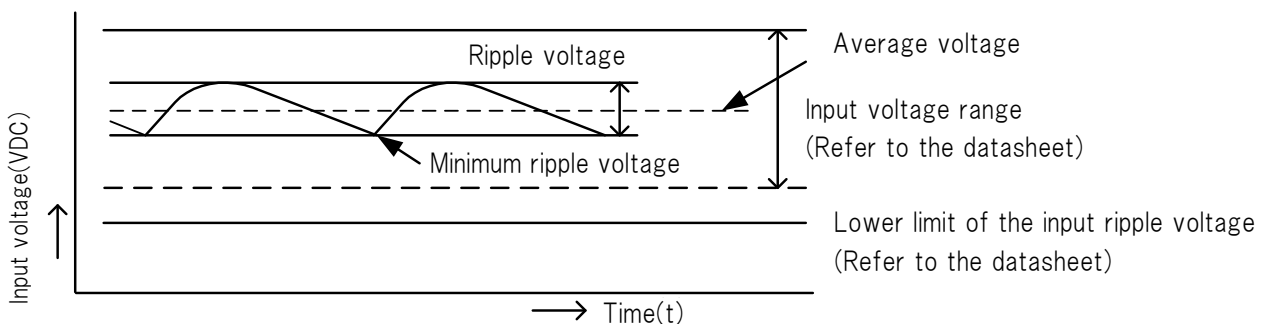


② Follow the instructions below to determine the capacitance of the electrolytic capacitors according to the input voltage to be used.

### 1) AC 100 V input, worldwide input

Determine the capacitance of the electrolytic capacitors so that the average voltage is equal to or higher than the lower limit of the input voltage, and so that the minimum ripple voltage is equal to or higher than the lower limit of the input ripple voltage.

Make sure that the peak voltage of the ripple voltage does not exceed the input voltage range. Take the variation in capacitance and the capacitance reduction due to aging into consideration when selecting the capacitance.



Datasheet...「<http://www.tamura-ss.co.jp/electronics/en/powermodule/>」

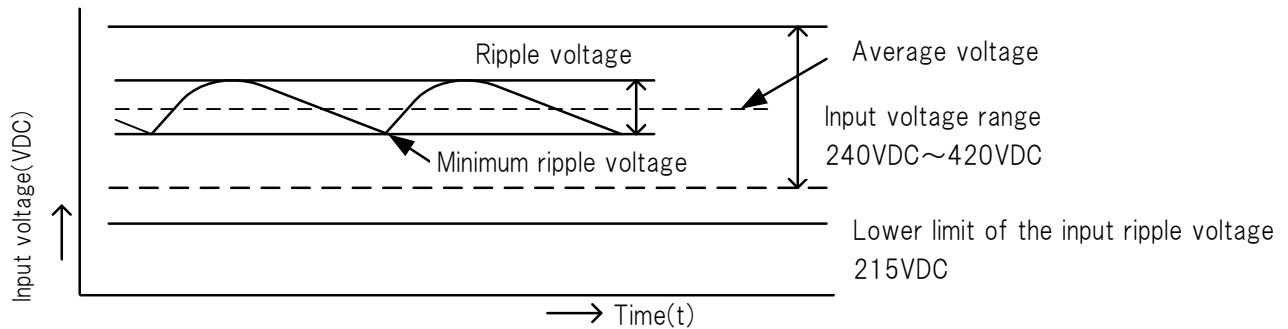


## 2) AC 200 V input

Determine the capacitance of the electrolytic capacitors so that the average voltage is equal to or higher than 240 V, and so that the minimum ripple voltage is equal to or higher than 215 V.

Make sure that the peak voltage of the ripple voltage does not exceed the input voltage range.

Take the variation in capacitance and the capacitance reduction due to aging into consideration when selecting the capacitance.



The capacitance of the electrolytic capacitors can be estimated using the formulae below.

The value calculated using the formulae is the minimum required capacitance. Take into consideration variations in the capacitance of the electrolytic capacitors to be used and reductions in the capacitance due to aging.

As the calculation result is only a reference, conduct a thorough check using actual equipment.

$$100\text{V}/\text{WW input} \quad \dots C_{102}(\text{min}) \geq 4 \cdot K \cdot I_o(\text{max}) / (5 \cdot f \cdot (2 \cdot V_{in \text{ min}}(\text{rms})^2 - 85^2))$$

(reference for the minimum ripple voltage)

$$\text{And } C_{102}(\text{min}) \geq K \cdot I_o(\text{max}) / (5 \cdot f \cdot 100 \cdot (\sqrt{2} \cdot V_{in \text{ min}}(\text{rms}) - 100))$$

(reference for the average voltage)

$$200\text{V input} \quad \dots C_{102}(\text{min}) \geq 4 \cdot K \cdot I_o(\text{max}) / (5 \cdot f \cdot (2 \cdot V_{in \text{ min}}(\text{rms})^2 - 215^2))$$

(reference for the minimum ripple voltage)

$$\text{And } C_{102}(\text{min}) \geq K \cdot I_o(\text{max}) / (5 \cdot f \cdot 240 \cdot (\sqrt{2} \cdot V_{in \text{ min}}(\text{rms}) - 240))$$

(reference for the average voltage)

$V_{in \text{ min}}(\text{rms})$ : Minimum effective input voltage (Vrms)

$f$ : Commercial power frequency (Hz)

$I_o(\text{max})$ : Maximum output current in use (A)

$K$ : Coefficient (varies depending on model. Refer to the following.)

Model	SPM0307SJ	SPM0507SJ	SPM1203SJ	SPM1502SJ
K	4.71	6.58	15.0	18.0

## ③ Calculate the guaranteed life of the electrolytic capacitor and check that there is no problem.

Since the life calculation expression is different depending on the capacitor manufacturer and type, requesting life calculation by the manufacturer of the capacitor used is recommended.

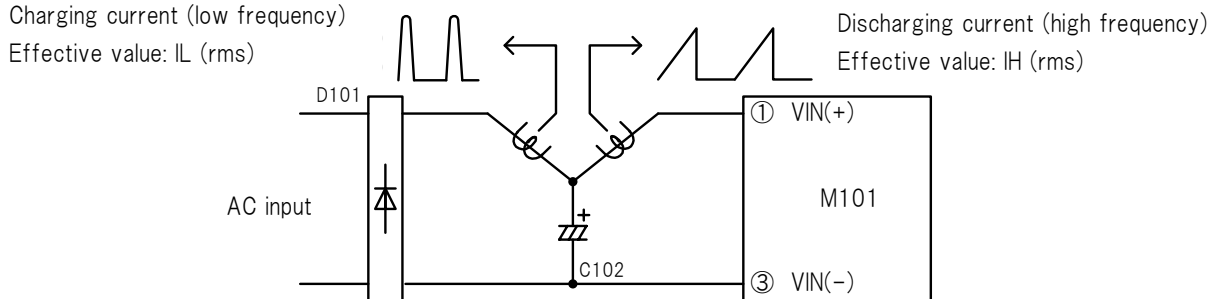
Generally, life can be calculated by using the temperature and ripple current of the electrolytic capacitor.

### 1) Electrolytic capacitor temperature

The temperature at which the temperature on the body of the electrolytic capacitor is maximum is measured and is made a life calculation parameter.

## 2) Ripple current

For AC input, a charging current ( $I_L$ ) and discharging current ( $I_H$ ) flow in the input smoothing electrolytic capacitor. These currents are measured individually and frequency correction is performed on  $I_H$  and it is made a life calculation parameter as 120Hz ripple current.

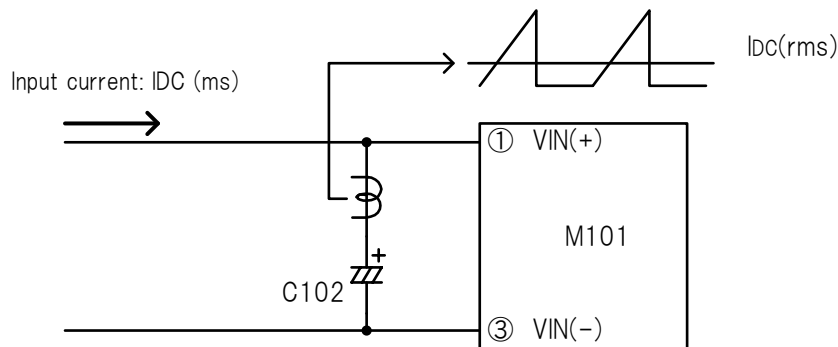


The ripple current ( $I_{120}$ ) frequency corrected to 120Hz is calculated from the following expression:

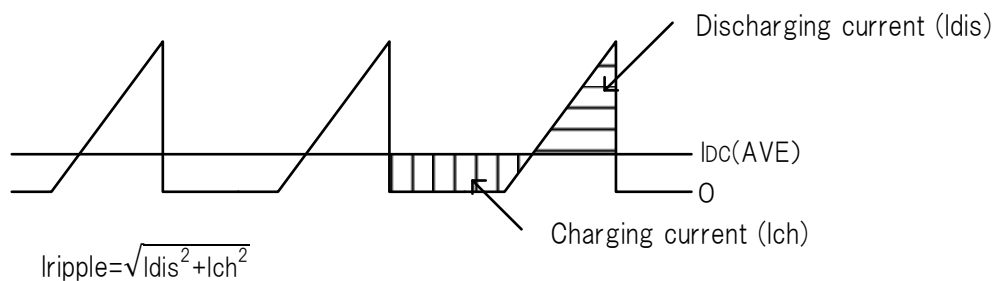
$$I_{120}(\text{rms}) = \sqrt{I_L(\text{rms})^2 + (I_H(\text{rms}) \cdot f_c)^2}$$

$f_c$ : Frequency correction coefficient (Refer to the electrolytic capacitor catalog.)

For stable DC input, the ripple current by high frequency charging/discharging current is assumed for input electrolytic capacitor.



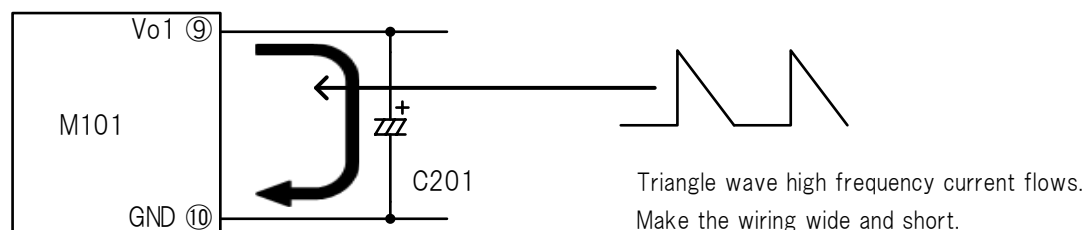
The ripple current of an electrolytic capacitor is a triangle wave high frequency current with the input current (DC current) made the average value. Ripple current is calculated as follows:



## 1.10 Output smoothing electrolytic capacitor (C201)

The output smoothing electrolytic capacitor has a large effect on the characteristics and life of the product. Select the electrolytic capacitor by paying attention to the following:

- ① Install the capacitor very close to the module (M101) and use a wide pattern to connect M101.



- ② Use an electrolytic capacitor with good frequency characteristics and low impedance. Output ripple and noise and rise time may be affected depending on the ESR and ESL and wiring impedance of the capacitor.
- ③ If the capacitance is too large, the overcurrent protection function may operate and the rise may be faulty at startup. A recommended value is shown in the following table. Please ask us, when the capacity more than the following table is required.

Model	CR mode
SPM0307SJ	$\leq 2400\mu\text{F}$
SPM0507SJ	$\leq 1300\mu\text{F}$
SPM1203SJ	$\leq 200\mu\text{F}$
SPM1502SJ	$\leq 270\mu\text{F}$

- ④ Since abnormal oscillation may occur by large phase delay if a capacitor with a very small ESR such as a tantalum capacitor or multilayer ceramic capacitor is used, use an electrolytic capacitor.
- ⑤ The following rated voltage is recommended.

Model	Rated voltage
SPM0307SJ	$\geq 10\text{V}$
SPM0507SJ	$\geq 10\text{V}$
SPM1203SJ	$\geq 25\text{V}$
SPM1502SJ	$\geq 25\text{V}$

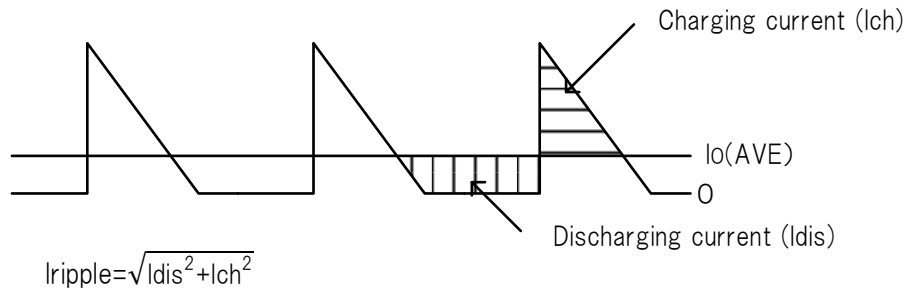
- ⑥ Calculate the guaranteed life of the electrolytic capacitor and check that there is no problem. Since the life calculation expression is different depending on the capacitor manufacturer and type, requesting life calculation by the manufacturer of the capacitor used is recommended. Life can be calculated by using the temperature and ripple current of the electrolytic capacitor, the same as the input smoothing electrolytic capacitor.

### 1) Electrolytic capacitor temperature

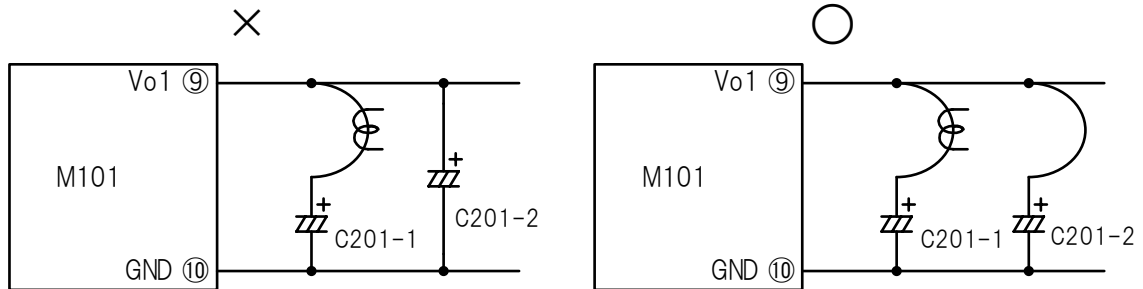
The temperature at which the temperature on the body of the electrolytic capacitor is maximum is measured and is made a life calculation parameter.

## 2) Ripple current

A high frequency ripple current by charging/discharging current flows in the input electrolytic capacitor. The ripple current is calculated by splitting it into the top (charging current) and bottom (discharging current) of output current ( $I_o$ ).



⑧ When planning to split the ripple current by using multiple electrolytic capacitors, be sure that ripple current measurement does not cause an unbalance.



When current measurement leads, etc. are installed Only to the capacitor to be measured, the impedance is unbalanced and accurate measurement is not possible.

When the capacitor whose current is not to be measured has the same impedance as the capacitor to be measured, accurate measurement is possible.

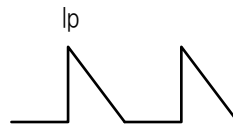
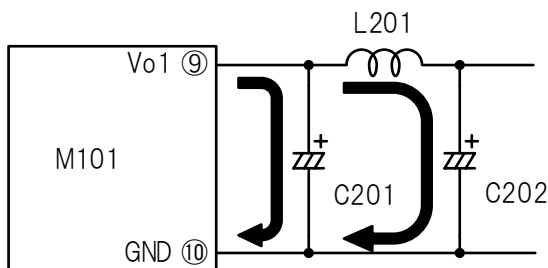
### 1.11 LC $\pi$ type filter(L201,C202)

Output ripple voltage reduction is possible to a certain degree by using a low impedance electrolytic capacitor at C201. However, the addition of a one-stage LC $\pi$  type filter is effective in lowering the output ripple voltage more.

① Since a ripple current equivalent to C201 may flow depending on the impedance of L201, check the ripple current, temperature rise, and life of C202 also.

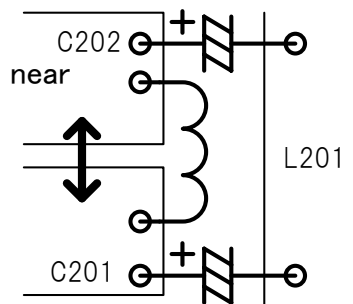
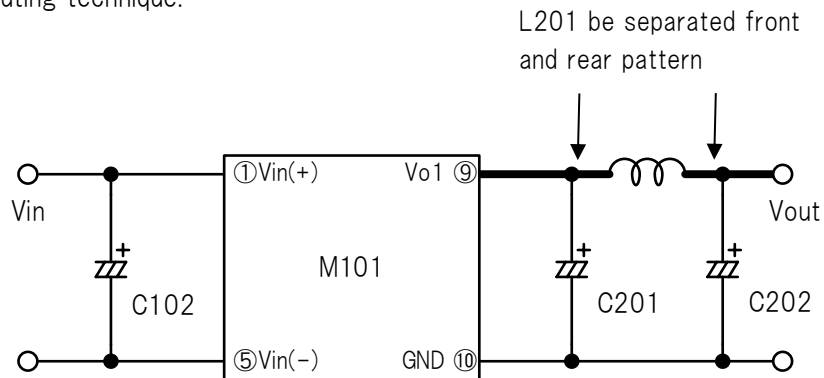
② Triangle wave high frequency current also flows in L201. Check that L201 is not saturated at the peak current.

In addition, consider the DC resistance of L201 and check that there is no problem with temperature rise.

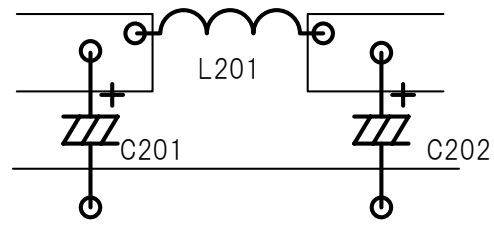


High frequency current also flows in L201 and C202.  
Check that L201 is not saturated even at Ip.

③ When the input/output pattern of L201 is close, there is a possibility as the filter is not obtained sufficiently, be careful about routing technique.



× Example of a bad pattern

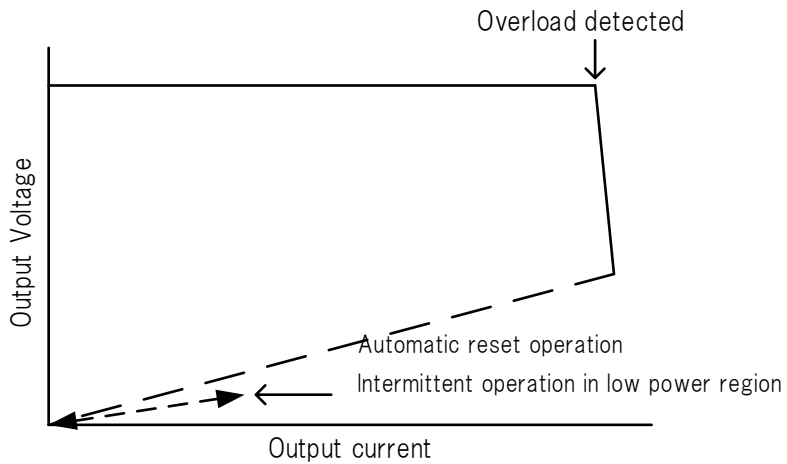


○ Example of a good pattern

## 2. Protection function

### 2.1 Overcurrent protection function

An overcurrent protection function is provided as protection when an output short circuit or overload occurs. The operation mode is automatic reset operation.



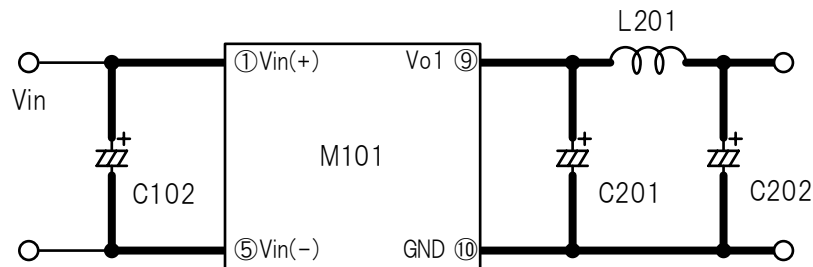
- Automatic reset operation

In the output short circuit and overload states, intermittent operation is performed in the low power region. Operation is automatically reset to normal operation when the short circuit or overload is removed.

### 3. Pattern design precautions

#### 3.1 Main current line

Since the input current, output current, and high frequency current flow in the bold line parts of the connection diagram (figure below), make the pattern wide and short.

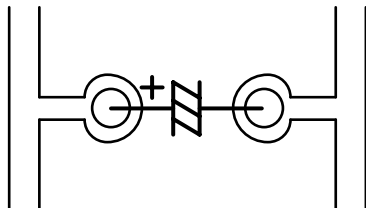


#### 3.2 Input and output capacitors

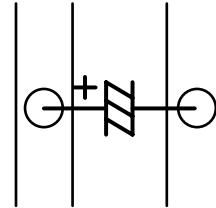
Install the input smoothing capacitor (C102) and output capacitor (C201) close to M101.

If more than one output capacitor is to be used, all the capacitors must be of the same type and be placed in the same location so that they are not affected by circuit patterns.

When there is a PFC output capacitor and a separate inverter smoothing capacitor, these capacitors can be shared. However, when the distance is long, the input smoothing capacitor only for M101 must be installed near M101. In addition, when the pattern from the output terminals and load of M101 is narrow and long, make the pattern wide thick and short because it had an effect on output accuracy.



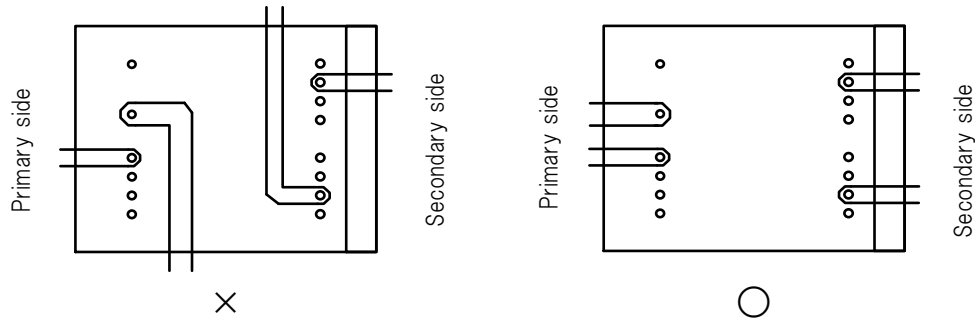
× Example of a bad pattern



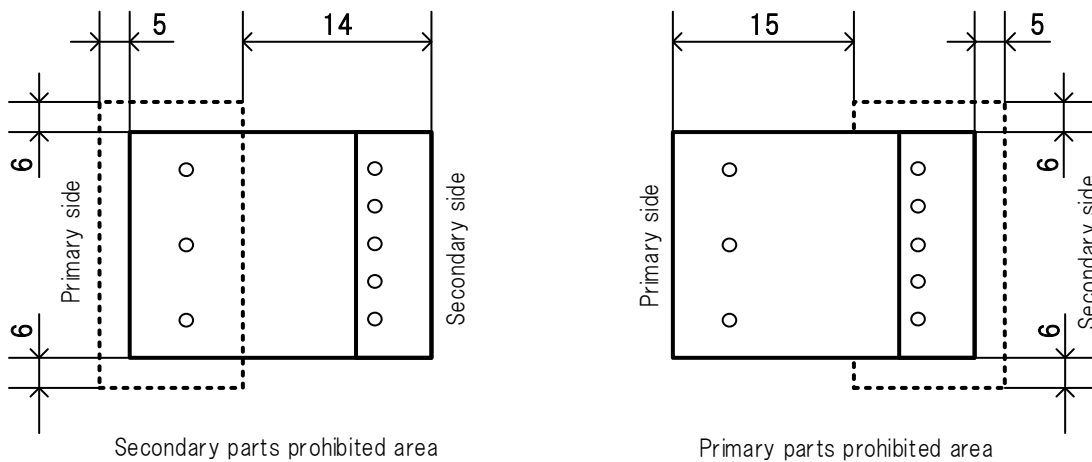
○ Example of a good pattern

### 3.3 Pattern prohibited area

When a double sided circuit board is used, do not provide a pattern directly below M101 of the parts side of the circuit board. If there is a pattern directly below M101 of the parts side, the insulation distance between the primary and secondary sides will not meet the specified value and safety cannot be ensured.



The installation prohibited area of primary parts and secondary parts is shown in the figure below. Do not install parts inside the dotted lines.



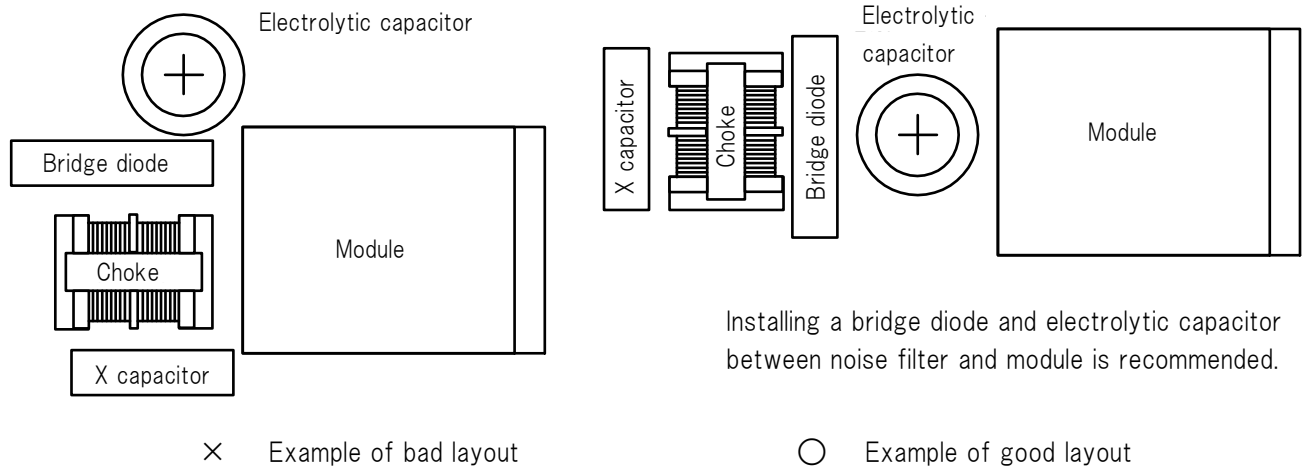
Unit : mm



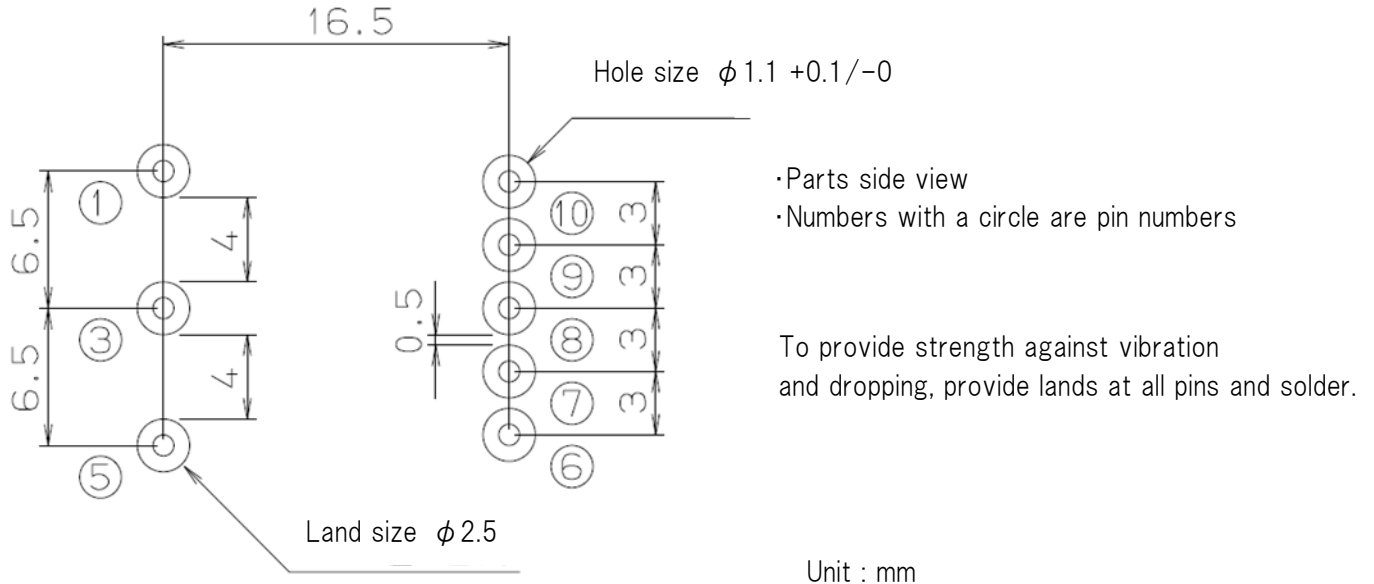
#### 4. Noise filter layout precautions

When a noise filter (X capacitor, choke) is located near the module, the original noise reduction effect may not be produced and noise reduction may become difficult.

Make the distance between noise filter and module long.



## 5. Recommended hole diameter, land and pin pitch



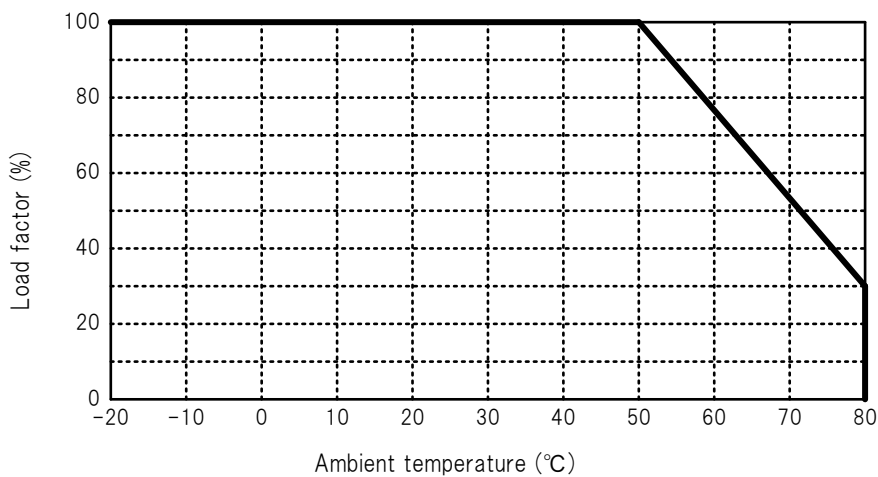
#### 6. Recommended soldering conditions (lead-free solder)

- ①Flow soldering: 255±3 °C    5 seconds or less    preheat end 110°C±10°C  
②Soldering iron: 350°C(MAX)    4 seconds or less

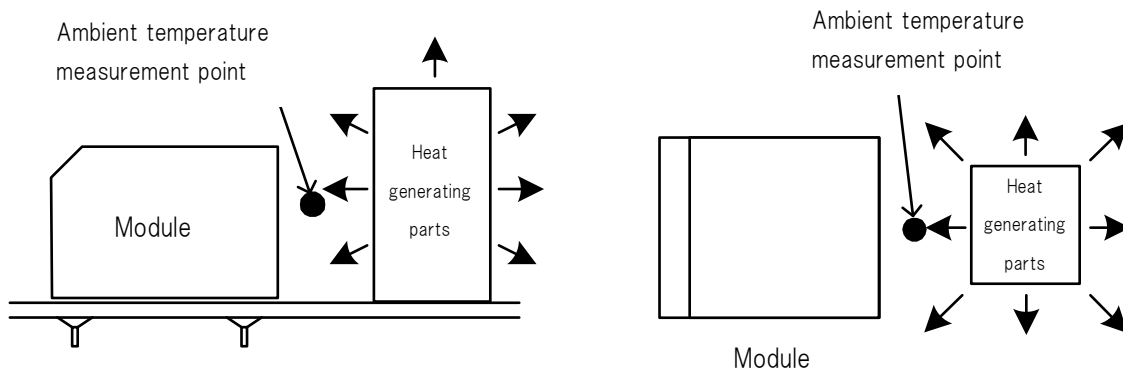
## 7. Output derating

When the ambient temperature exceeds +50°C, reduce the output power in accordance with the output derating chart below.

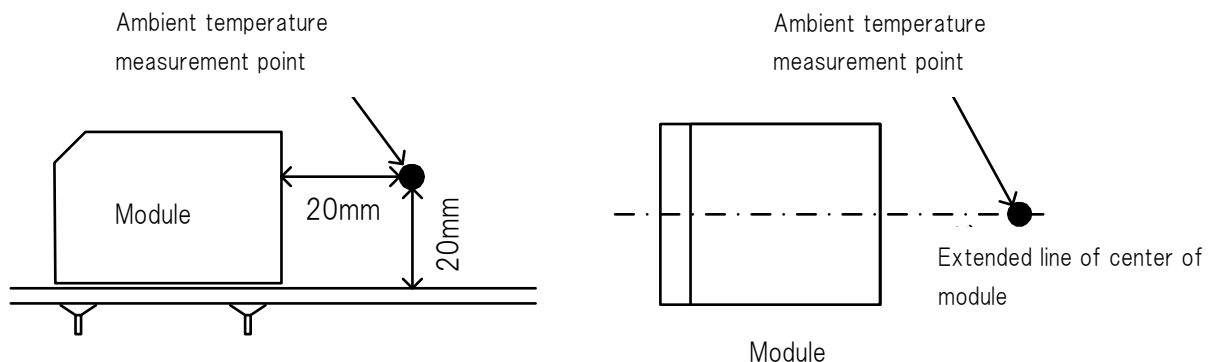
When the ambient temperature is affected by the heat generated by surrounding components, then the ambient temperature measurement point must be made in proximity to the heat generating components as shown below. When there are no heat generating parts nearby, make the temperature 20mm from the module and 20mm above the circuit board the ambient temperature.



Ambient temperature measurement point when there are heat generating parts nearby



Ambient temperature measurement point when there is no effect of heating generating part

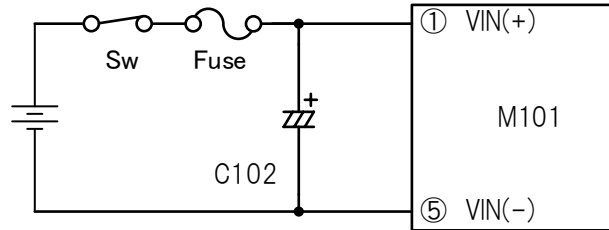


## 8. When a DC power supply is used as an input source

When using directly applied to the DC power supply as the input source, place the electrolytic capacitor near to the module.

Be sure to mount a fuse on an input line for safety securement.

When arranging the mechanical switch, Arrange a fuse in front of the electrolytic capacitor.



## Important notice

- The content of this manual is subject to change without prior notice for the purpose of improvements, etc. Ensure that you are in possession of the most up-to-date information when using this product.
- The operation examples and circuit examples shown in this manual are for reference purposes only, and Tamura Corporation disclaims all responsibility for any violations of industrial property rights, intellectual property rights and any other rights owned by Tamura Corporation or third parties that these may entail.
- The circuit examples and part constants listed in these specifications are provided as reference for the verification of characteristics. You are to perform design, verification, and judgment at your own responsibility, taking into account the various conditions.
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  - Use that involves exposure to direct sunlight, outdoor exposure, or dusty conditions
  - Use in locations where corrosive gases such as salt air, C12, H2S, NH3, SO2, or NO2, are present
  - Use in environments with strong static electricity or electromagnetic radiation
  - Use that involves placing inflammable material next to the product
  - Use of this product either sealed with a resin filling or coated with resin
  - Use of water or a water soluble detergent for flux cleaning
  - Use in locations where condensation is liable to occur
- This product is not designed to resist radiation.
- This product is not designed to be connected in series or parallel.  
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