

Application Note

Surface Molding Chopper type Switching Regulator IC

SI-8000W Series

Not Recommended for New Designs

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SANKEN ELECTRIC CO., LTD.

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1. General Description

The SI-8000W is a chopper type switching regulator IC which is provided with various functions required for the buck switching regulator and protection functions. By using four external components, a highly efficient switching regulator can be composed.

● 1-1 Features

- Compact size package, output current of 0.6A
 - The maximum output current of 0.6A for the outline of SOP8
- High efficiency of 82% (SI-8050W $V_{in} = 20V / I_o = 0.3A$)
 - Heat dissipation is small due to high efficiency to allow for the downsizing of a heat sink.
- Four external components
 - The regulator can be composed of input / output capacitor, diode and coil.
- Internal adjustment of output voltage and phase compensation having been done in production
 - Troublesome adjustment of output voltage and phase compensation by means of external components is no longer required.
- Reference oscillation by a built-in timing capacitor
 - No external capacitor for setting the oscillation frequency is required.
- Built-in functions for overcurrent and thermal shutdown
 - The foldback type overcurrent protection and thermal shutdown circuit are built in.
(automatic recovery type)
- Output ON / OFF function (rise time delay setting can be made.)
 - The ON / OFF control function of output is also possible. Current consumption is decreased at OFF time. It is possible to delay the rising speed of output voltage at start-up by adding external capacitors.
- No insulation plate required
 - No insulation plate is required, when it is fitted to the heat sink, because it is of full molding type.

● 1-2 Applications

For on-board local power supplies, power supplies for OA equipment, stabilization of secondary output voltage of regulator and power supply for communication equipment

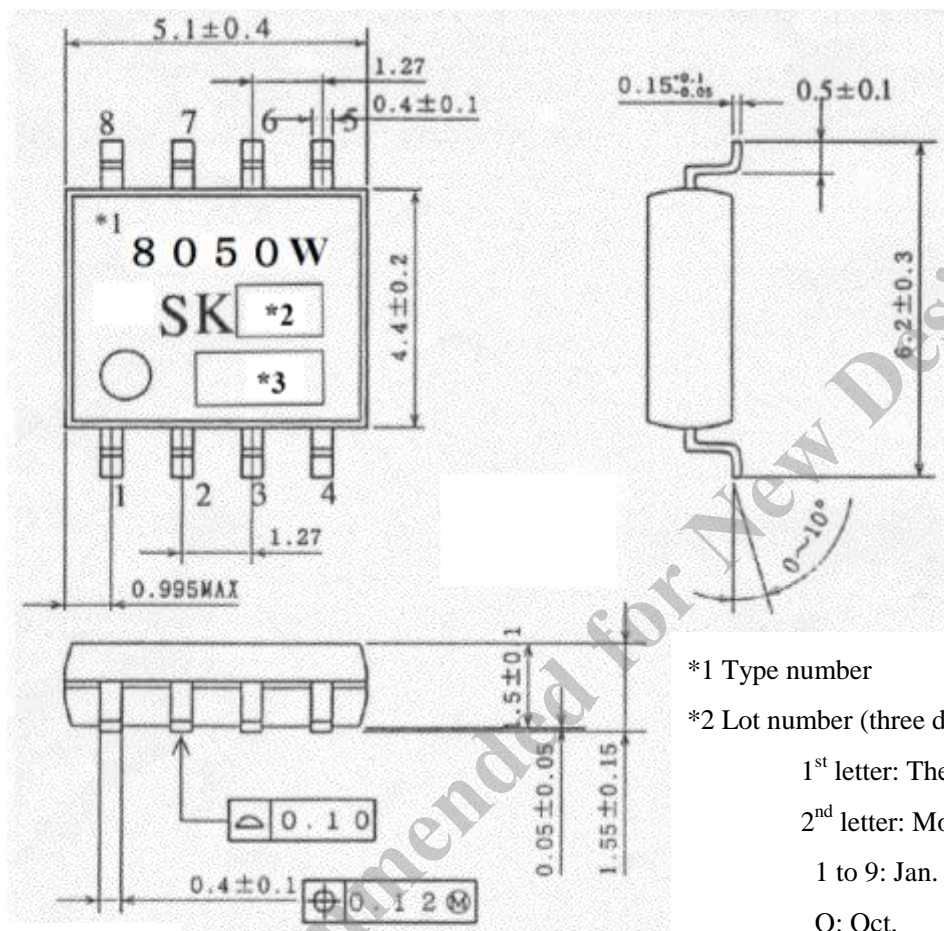
● 1-3 Type

- Type: Semiconductor integrated circuits (monolithic IC)
- Structure: Resin molding type (transfer molding)

2. Specification

● 2-1 Package Information

Unit: mm



*1 Type number

*2 Lot number (three digit)

1st letter: The last digit of year2nd letter: Month

1 to 9: Jan. to Sept.

O: Oct.

N: Nov.

D: Dec.

3rd letter: Week

Arabic Numerical

*3 Control number (four digit)

PIN Assignment

Products Weight: Approx. 0.1g

1. VIN
2. N.C.
3. SW
4. VOS
- 5-8. GND

● 2-2 Ratings

Line up

Product Name	Vout(V)
SI-8033W	3.3
SI-8050W	5.0

Absolute Maximum Ratings

Parameter	Symbol	Rating	Unit
Input Voltage	VIN	35	V
Junction Temperature	Tj	125	°C
Storage Temperature	Tstg	-40 - 125	°C

Recommended Conditions

Parameter	Symbol	SI-8033W	SI-8050W	Unit
DC Input Voltage	Vin	5.3 - 28	7 - 33	V
Output Current	Io	0 - 0.6		A
Junction Temperature in Operation	TjOp	-30 - 125		°C

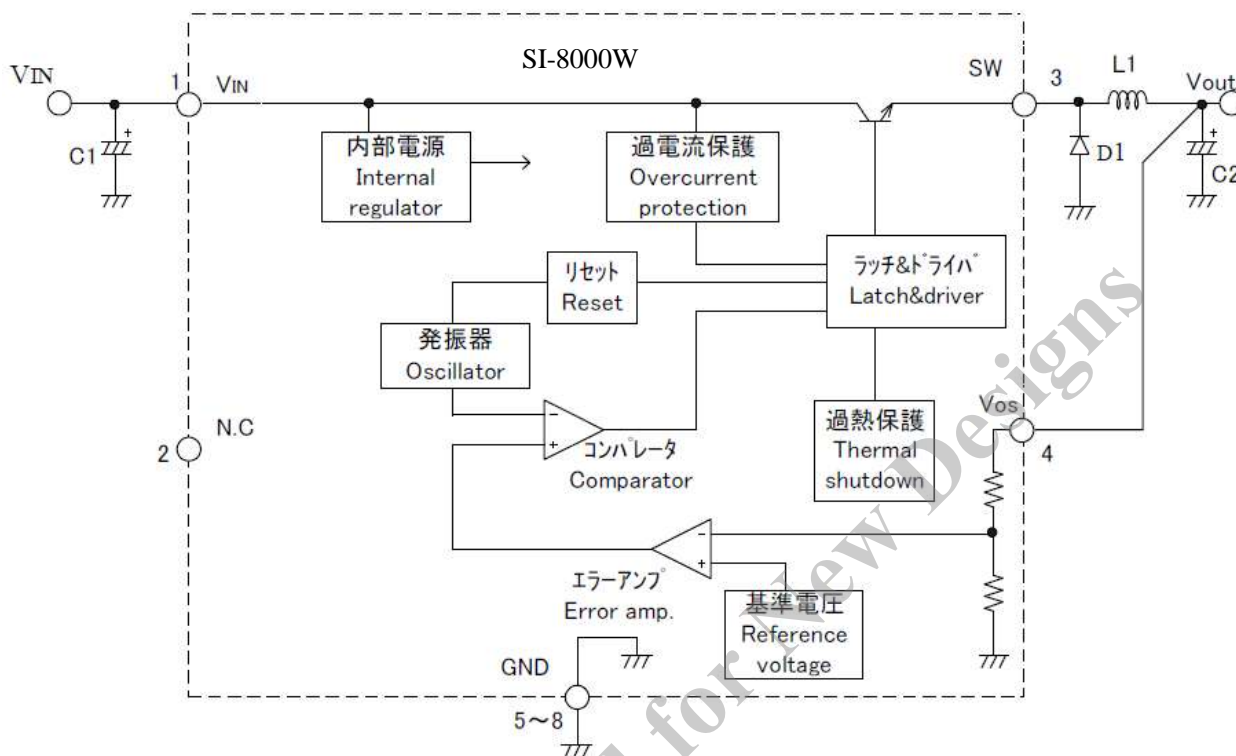
Electrical Characteristics

(Ta = 25°C)

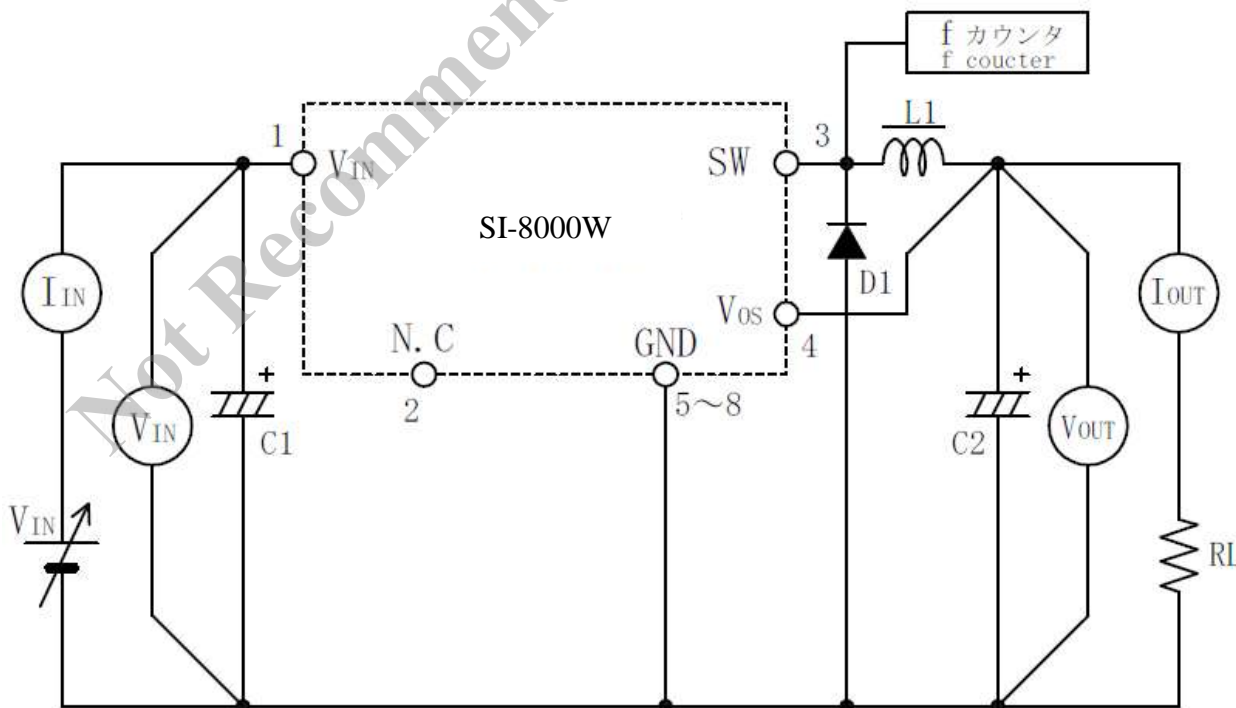
Parameter	Symbol	SI-8050W			SI-8033W			Unit
		min	typ	max	Min	Typ	Max	
Set output Voltage	Vin	4.80	5.00	5.20	3.17	3.30	3.43	V
	Condition	Vin=20V/Io=0.3A			Vin=15V/Io=0.3A			
Efficiency	η		80			75		%
	Condition	Vin=20V/Io=0.3A			Vin=15V/Io=0.3A			
Switching Frequency	f		60			60		kHz
	Condition	Vin=20V/Io=0.3A			Vin=15V/Io=0.3A			
Input Voltage – Output Voltage (Iout = 0.3A)	ΔVLine		80	100		60	80	mV
	Condition	Vin=10~30V			Vin=8~28V			
Output Current – Output Voltage (Iout = 0.1 - 0.4A)	ΔVLoad		30	40		20	30	mV
	Condition	Vin=20V			Vin=15V			
Overcurrent Protection Start Current	Is	0.61			0.61			A
	Condition	Vin=20V			Vin=15V			
Output Voltage Temperature Variation	ΔVo/ΔT		±0.5			±0.5		mV/°C

● **2-3 Circuit Diagram**

2-3-1 Internal Equivalent Circuit



2-3-2 Typical Connection Diagram



C1: 100 μ F/50V

C2: 330 μ F/35V

L1: 200 μ H

D1: SFPB-54 (サンケン製)
(made by Sanken)

3. Operational Description

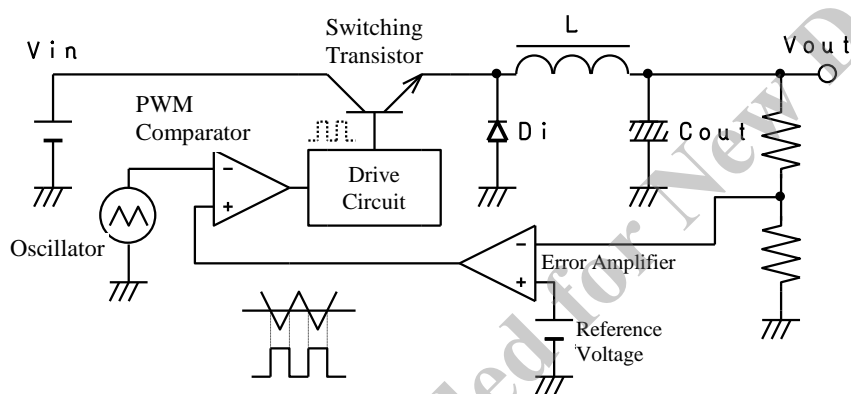
● 3-1 PWM Output Voltage Control

In the SI-8000W series, the output voltage is controlled by the PWM system and the IC incorporates the PWM comparator, oscillator, error amplifier, reference voltage, output transistor drive circuit etc.

The triangular wave output ($\approx 60\text{KHz}$) from the oscillator and the output of the error amplifier are given to the input of the PWM comparator.

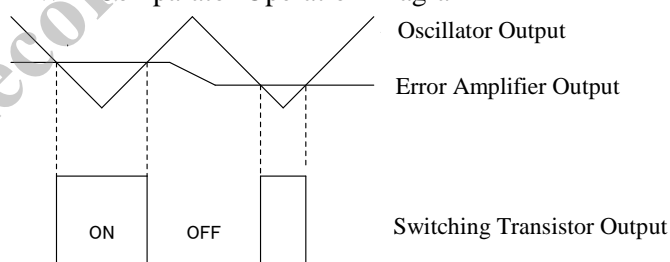
The PWM comparator compares the oscillator output with the error amplifier output to turn on the switching transistor for a time period when the output of the error amplifier exceeds the oscillator output.

PWM Control Chopper Type Regulator Basic Configuration



The error amplifier output and the oscillator output are compared by the PWM comparator to generate the drive signal of rectangular wave and to drive the switching transistor.

PWM Comparator Operation Diagram



On the assumption that the output voltage attempts to rise, the output of the error amplifier is lowered, because the error amplifier is of inverting type. As the output of the error amplifier is lowered, the time period where it falls below the triangular wave level of the oscillator is increased to shorten the ON time of the switching transistor and as a result, the output voltage is maintained constant.

As described above, the output voltage is controlled by varying the ON time of the switching transistor with the switching frequency fixed (the higher is V_{IN} , the shorter is the ON time of the switching transistor.)

The rectangular wave output of the switching transistor is smoothed by the LC low pass filter composed of a

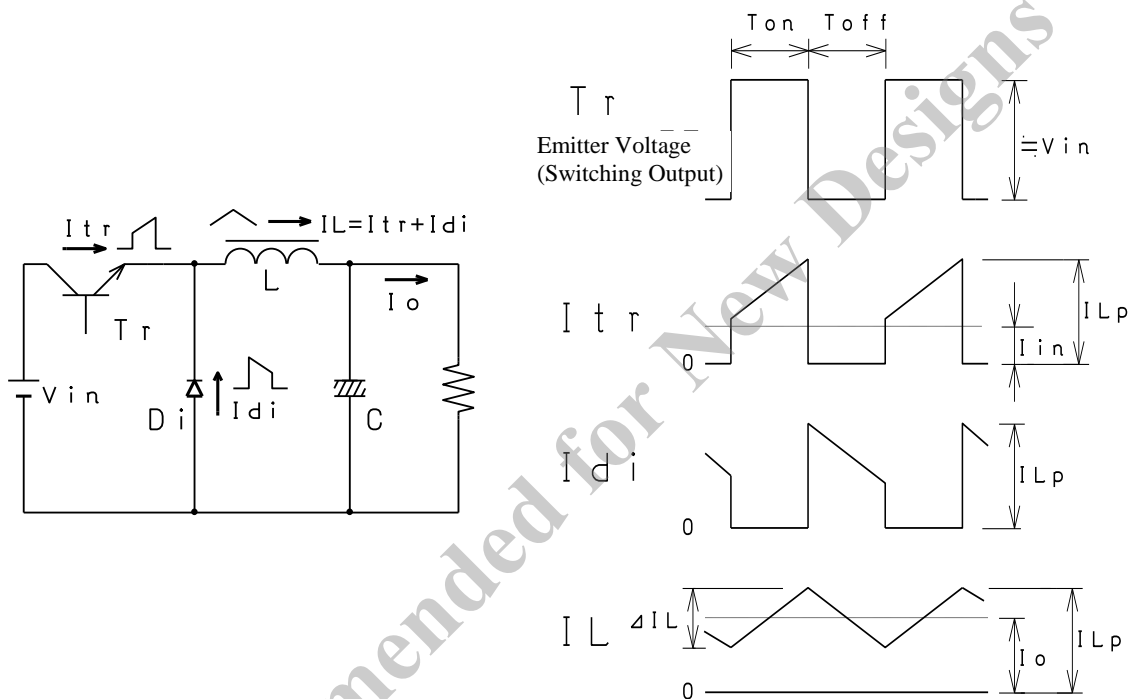
choke coil and a capacitor to supply stabilized DC voltage to the load.

● 3-2 Input/ Output Current and Choke Coil Current

The rectangular output which is produced by the switching transistor of the SI-8000W is converted into DC output voltage by being smoothed by the LC filter composed of a choke coil and an output capacitor.

The operation of this LC filter significantly affects the stable operation of the chopper type regulator.

The relation between the choke coil and the current and the relation between the current and the ripple voltage are shown below.



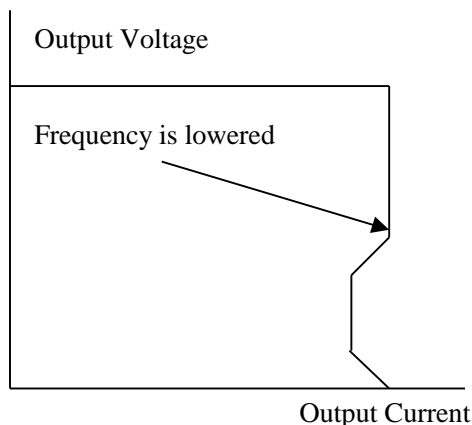
The current I_L flowing across the choke coil is of triangular wave shape. This triangular wave is composed of two kinds of current components, I_{tr} and I_{di} . The current I_{tr} is supplied from the input side through the transistor when the transistor is ON and its average value is input current I_{in} . The current I_{di} is the current that the energy stored in the choke coil is commutated via the flywheel diode D_i when the transistor is OFF.

The total of I_{tr} and I_{di} is the current I_L of choke coil.

In addition, the average value of I_L is the DC output current I_o since the triangular wave component superimposed on the I_L is smoothed by charging and discharging of the capacitor C .

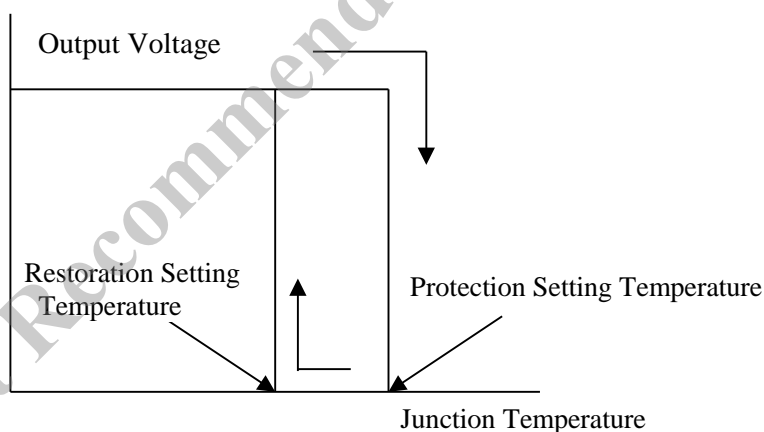
● 3-3 Overcurrent Protection / Thermal Shutdown

Output Voltage Characteristics in Overcurrent



The SI-8000W series integrates a current limiting type overcurrent protection circuit. The overcurrent protection circuit detects the peak current of a switching transistor and when the peak current exceeds the set value, the ON time of the transistor is compulsorily shortened to limit the current by lowering the output voltage. When the output voltage further drops to about 50% of the rated value, the switching frequency is lowered to about 25KHz to prevent the current increase at low output voltage. When the overcurrent condition is released, the output voltage will be automatically restored.

Output Voltage Characteristics in Thermal Shutdown



The thermal shutdown circuit detects the semiconductor junction temperature of the IC and when the junction temperature exceeds the set value, the output transistor is stopped and the output is turned OFF. When the junction temperature drops from the set value for overheat protection by around 10°C, the output transistor is automatically restored.

* Note for thermal shutdown characteristic

This circuit protects the IC against overheat resulting from the instantaneous short circuit, but it should be noted that this function does not assure the operation including reliability in the state that overheat continues due to long time short circuit.

4. Cautions

● 4-1 External Components

4-1-1 Choke coil L

The choke coil L supplies current to the load side when the switching transistor is OFF. And the coil is one of the most important components in the chopper type switching regulator. In order to maintain the stable operation of the regulator, such dangerous state of operation as saturation state and operation at high temperature due to heat generation must be avoided.

The following points should be taken into consideration for the selection of the choke coil.

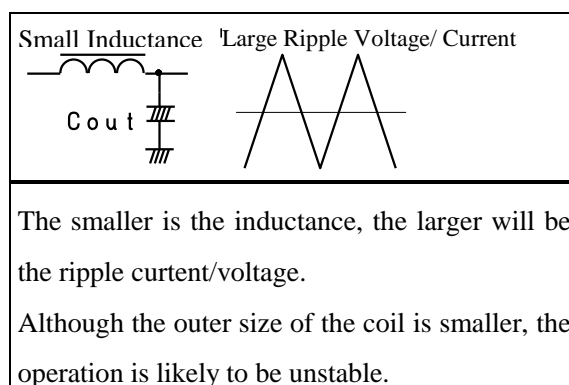
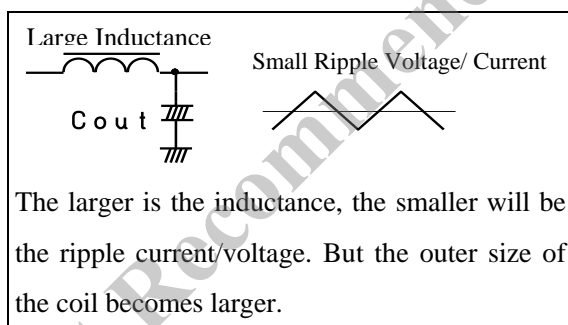
a) The choke coil should be fit for the switching regulator.

The coil for a noise filter should not be used because of large loss and generated heat.

b) The inductance value should be appropriate.

The larger is the inductance of the choke coil, the less is the ripple current flowing across the choke coil, and the output ripple voltage drops and as a result, the overall size of the coil becomes larger.

On the other hand, if the inductance is small, the peak current flowing across the switching transistor and diode is increased to make the ripple voltage higher and this operation state is not favorable for maintaining the stable operation.



The inductance value shown in the specifications should be considered as a reference value for the stable operation and the appropriate inductance value can be calculated by the following equation.

ΔI_L shows the ripple current value of the choke coil and the lower limit of inductance is set as described in the following.

- In the case that the output current to be used is nearly equal to the maximum rating (0.6A) of the SI-8000W: output current \times 0.5 - 0.6
- In the case that the output current to be used is approximately 0.3A or less: output current \times 0.8 - 1.0

$$L = \frac{(V_{in} - V_{out}) \cdot V_{out}}{\Delta I_L \cdot V_{in} \cdot f} \quad \text{--- (1)}$$

For example, where $V_{IN} = 25V$, $V_{Out} = 5V$, $\Delta I_L = 0.3A$, frequency = 60KHz,

$$L = \frac{(25-5) \times 5}{0.2 \times 25 \times 60 \times 10^3} \doteq 222\mu H$$

As shown above, the coil of about 220 μ H may be selected.

c) The rated current shall be met.

The rated current of the choke coil must be higher than the maximum load current to be used. When the load current exceeds the rated current of the coil, the inductance is sharply decreased to the extent that it causes saturation state at last. Please note that overcurrent may flow since the high frequency impedance becomes low.

d) Noise shall be low.

In the open magnetic circuit core which is of drum shape, since magnetic flux passes outside the coil, the peripheral circuit may be damaged by noise. It is recommended to use the toroidal type, EI type or EE type coil which has a closed magnetic circuit type core as much as possible.

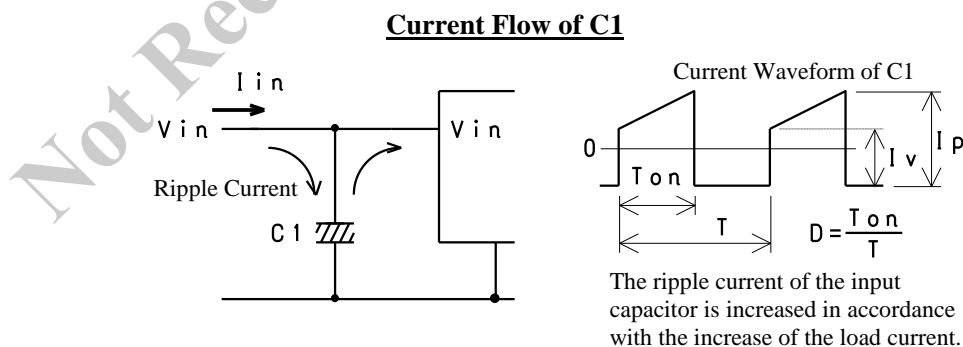
4-1-2 Input Capacitor C1

The input capacitor is operated as a bypass capacitor of the input circuit to supply steep current to the regulator during switching and to compensate the voltage drop of the input side. Therefore, the input capacitor should be connected as close as to the regulator IC.

In addition, in the case that the smoothing capacitor of the AC rectifier circuit is located in the input circuit, the input capacitor may be also used as a smoothing capacitor, but similar attention should be paid.

The selection of C1 shall be made in consideration of the following points:

- The requirement of withstand voltage shall be met.
- The requirement of the allowable ripple voltage shall be met.



If the withstanding voltages or allowable ripple voltages are exceeded or used without derating, it is in danger of causing not only the decreasing the capacitor lifetime (burst, capacitance decrease, equivalent impedance increase, etc) but also the abnormal oscillations of regulator.

Therefore, the selection with sufficient margin is needed.

The effective value of ripple current flowing across the input capacitor can be obtained by the following equation:

$$I_{rms} \approx 1.2 \times \frac{V_o}{V_{in}} \times I_{out} \quad \text{--- (2)}$$

For instance, where $I_o=0.6A$, $V_{IN}=20V$, $V_o=5V$,

$$I_{rms} \approx 1.2 \times \frac{5}{20} \times 0.6 = 0.18A$$

Therefore, it is necessary to select the capacitor with the allowable ripple current of 0.18A or higher.

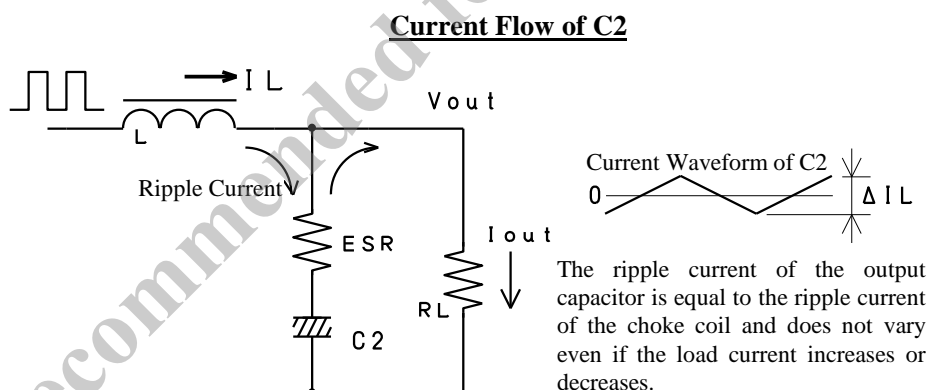
4-1-3 Output Capacitor C2

The output capacitor C2 composes a LC low pass filter together with a choke coil L and functions as a rectifying capacitor of switching output.

The current equivalent to the pulse current ΔI_L of the choke coil current is charged and discharged in the output capacitor.

Therefore, it is necessary to meet the requirements of withstand voltage and allowable ripple current with sufficient margin like the input capacitor. Additional points to be checked are DC equivalent series resistance (ESR) and capacitance.

The following points should be taken into consideration.



- Allowable Ripple Current

The ripple current effective value of the output capacitor is calculated by the equation.

$$I_{rms} = \frac{\Delta I_L}{2\sqrt{3}} \quad \text{--- (3)}$$

When $\Delta I_L = 0.3A$,

$$I_{rms} = \frac{0.3}{2\sqrt{3}} \doteq 0.09A$$

Therefore a capacitor having the allowable ripple current of 0.09A or higher is required.

- DC equivalent series resistance (ESR)

It is necessary for the stable operation to select the ESR properly. When the ESR is too large or too small, abnormal oscillation due to increase of ripple voltage or insufficient phase margin occurs respectively.

The output ripple voltage is determined by a product of the pulse current ΔI_L (=C2 discharge and charge current) of the choke coil current and the ESR, and the output ripple voltage which is 0.5 - 2% of the output voltage (for example, where 0.5% at $V_{out} = 5V$, 25mV) is good for the stable operation. Please refer to the equations (4) and (5) to obtain the output ripple voltage. It should be noted that the ESR is changeable subject to temperature and it is especially lowered at high temperature.

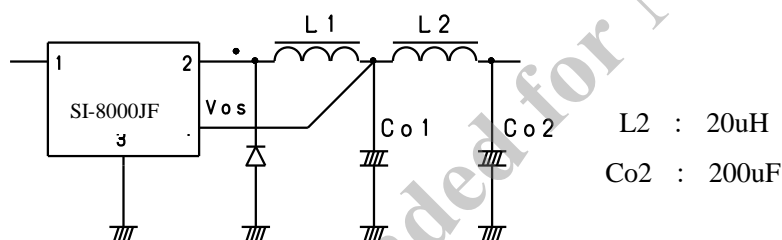
$$V_{rip} \approx \frac{(V_{in} - V_{out})V_{out}}{L \cdot V_{in} \cdot f} ESR \quad \text{--- (4)}$$

$$V_{rip} \approx \Delta I_L \cdot ESR \quad \text{--- (5)}$$

When the ESR is too low (approx. 10 - 20 Ω or lower), the phase delay becomes larger, resulting in abnormal oscillation.

Therefore, it is not appropriate that a tantalum capacitor or a laminated ceramic capacitor is used for the output capacitor as an independent component. However, connecting a tantalum capacitor or a laminated ceramic capacitor in parallel with an electrolytic capacitor is effective in reducing the output ripple voltage only when it is used at low temperature (< 0°C).

In addition, in order to further decrease the ripple voltage, as shown below, it is also effective to add one stage of the LC filter to form the π type filter.



It should be noted that the operating stability is more influenced by the ESR than the capacitance as described above if the requirements of withstand voltage and allowable ripple current are met.

With respect to the layout of the output capacitor, if it is located far from the IC, it will give same effect as the increase of ESR due to wiring resistance etc., therefore it is recommended to connect it near the IC.

4-1-4 Flywheel Diode Di

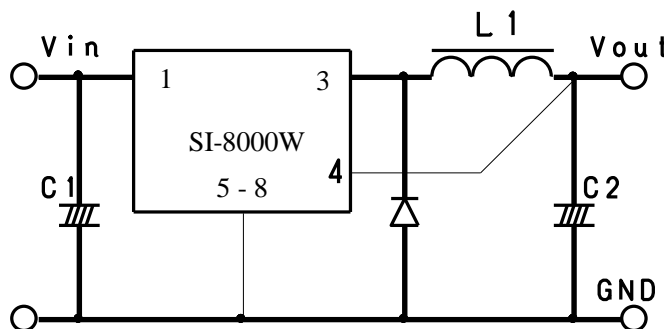
The flywheel diode Di is to discharge the energy which is stored in the choke coil at switching OFF.

For the flywheel diode, the Schottky barrier diode must be used. If a general rectifying diode or fast recovery diode is used, the IC may be destroyed by applying reverse voltage due to the recovery and ON voltage.

● 4-2 Pattern Design Notes

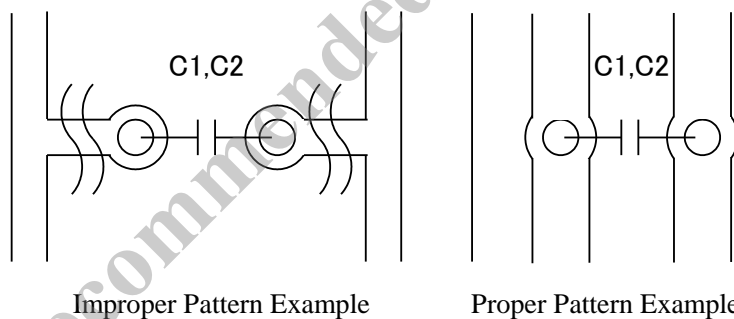
4-2-1 High Current Line

Since high current flows in the bold lines in the connection diagram, the pattern should be as wide and short as possible.



4-2-2 Input/ Output Capacitor

The input capacitor C1 and the output capacitor C2 should be connected to the IC as close as possible. If the rectifying capacitor for AC rectifier circuit is on the input side, it can be used as an input capacitor. However, if it is not close to the IC, the input capacitor should be connected in addition to the rectifying capacitor. Since high current is discharged and charged through the leads of input/output capacitor at high speed, the leads should be as short as possible. A similar care should be taken for the patterning of the capacitor.



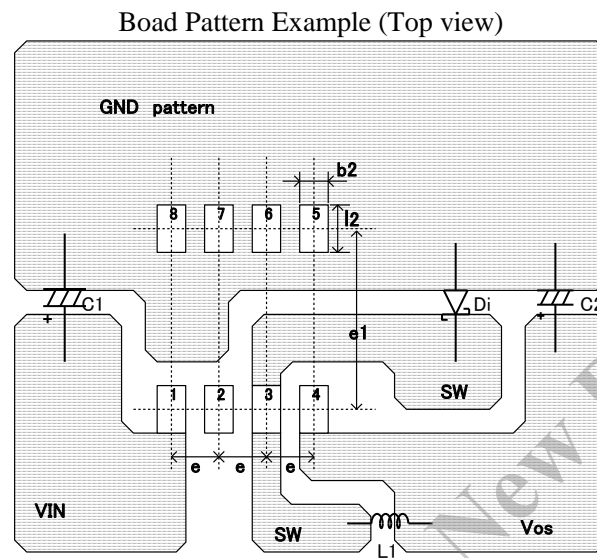
Improper Pattern Example

Proper Pattern Example

4-2-3 Sensing Terminal

The output voltage sensing terminal V_{os} shall be connected near the output capacitor $C2$ as much as possible.

(V_{os} terminal flow-in current is approx. 0.5mA.)



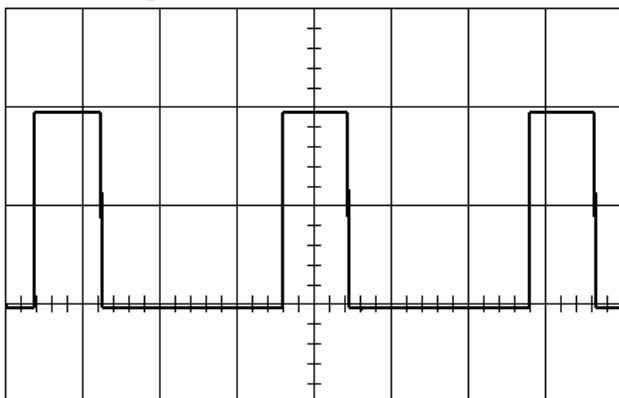
Not Recommended for New Designs

● 4-3 Operation Waveform Check

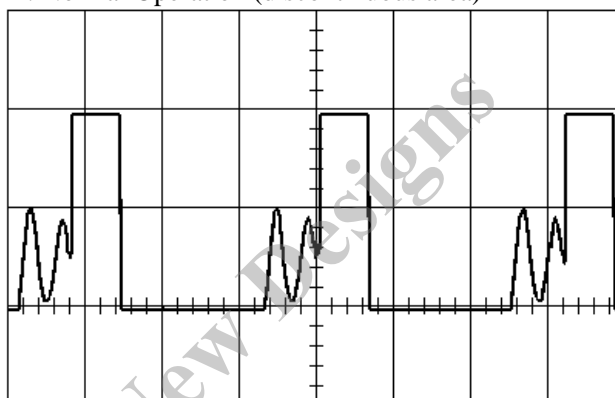
It can be checked by the waveform between the pin 3 to 5 (SWOut waveform) (Pin 5 to 8 are shorted) of the SI-8000W whether the switching operation is normal or not.

The examples of waveforms at normal and abnormal operations are shown below:

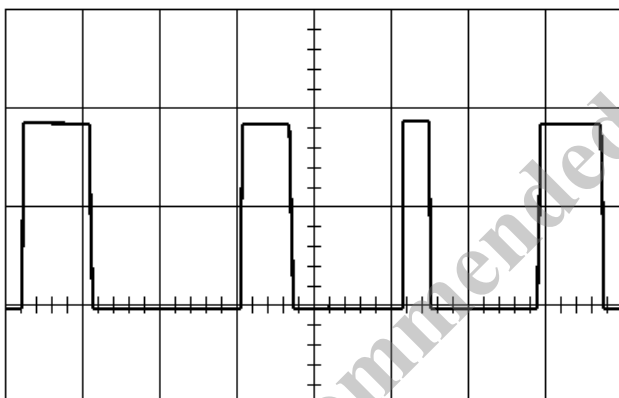
1. Normal Operation (continuous area)



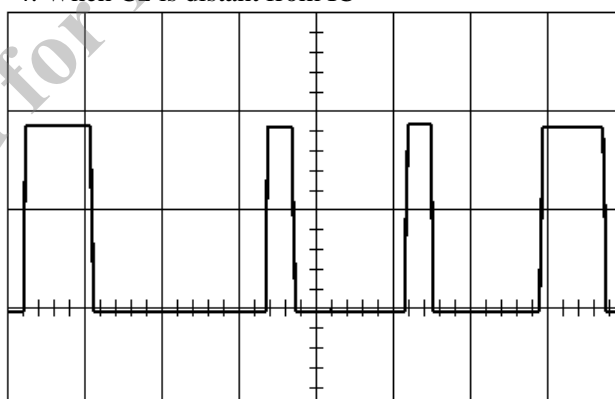
2. Normal Operation (discontinuous area)



3. When C1 is distant from IC



4. When C2 is distant from IC



The continuous area is an area where the DC component of the triangular wave is superimposed on the current flowing across the choke coil and the discontinuous area is an area where the current flowing across the choke coil is intermittent (a period of zero current may happen.) because the current flowing across the choke coil is low.

Therefore, when the load current is high, the area is a continuous area and when the same current is low, the area is a discontinuous area.

In the continuous area, the switching waveform is formed in the normal rectangular waveform (waveform 1) and in the discontinuous area, damped oscillation is caused in the switching waveform (waveform 2), but this is a normal operation without any problem.

In the meantime, when the IC is far from C1 and C2, jitter which disturbs the ON – OFF time of switching will happen as shown in the waveforms (3, 4). As described above, C1 and C2 should be connected close to the IC.

● **4-4 Thermal Design**

The relation among the power dissipation Pd of regulator, junction temperature Tj, case temperature Tc, and ambient temperature Ta is as follows:

$$P_D = \frac{T_j - T_c}{\theta_{j-c}} \quad \text{---(6)} \qquad P_D = \frac{T_j - T_a}{\theta_{j-a}} \quad \text{---(7)}$$

The TjMAX is an inherent value for each product, therefore it must be strictly observed.

For this purpose, it is required to design the copper foil area with PdMAX, TaMAX. The thermal derating chart illustrates graphically these factors. The design of copper foil area is made in the following procedure:

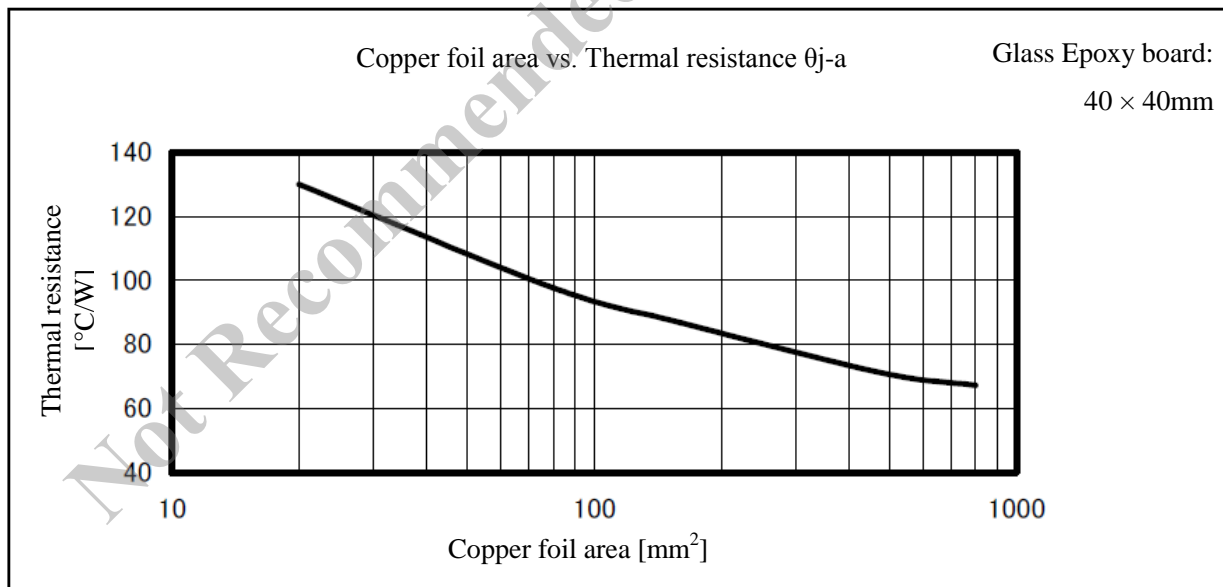
- 1) The maximum ambient temperature Ta MAX in the set is obtained.
- 2) The maximum power dissipation PdMAX is obtained.

$$P_D = V_o \cdot I_o \left(\frac{100}{\eta x} - 1 \right) - V_f \cdot I_o \left(1 - \frac{V_o}{V_{IN}} \right) \quad \text{---(8)}$$

* ηx= efficiency (%), Vf= diode forward voltage (SFPB-54: 0.4V)

- 3) The copper foil area is determined by intersection points of thermal derating.

The copper foil area size can be obtained from the copper foil area on the glass epoxy board vs. thermal resistance between junction and ambient temperature (but the maximum ambient temperature TaMAX must be confirmed.)



In general, 10 - 20% of derating is used. In reality, thermal dissipation effect is significantly variable because of difference of part mounting. Therefore, the ambient temperature or case temperature (refer to 7 – 1 for measurement points of case temperature) in the state of parts being mounted need to be confirmed.

*It shows the thermal resistance change ratio, assuming 6kg cm as 100%.

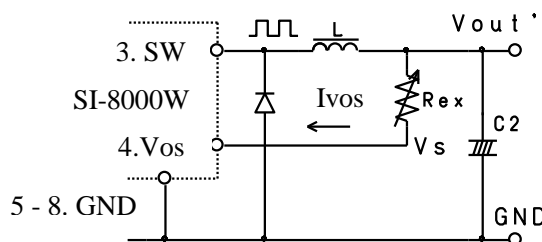
*G746 is used for silicon grease.

5. Applications

● 5-1 Controllable Output Voltage

The output voltage can be increased by adding a resistor to the Vos terminal (pin 4) (not applicable for voltage fall)

5-1-1 Variable Output Voltage by One External Resistor



The output voltage adjustment resistance R_{ex} is calculated by the following equation.

$$R_{ex} = \frac{V_{out'} - V_{os}}{I_{vos}} \quad (9)$$

V_{os} : Set output voltage for product

$V_{out'}$: Variable output voltage

I_{vos} : Vos terminal in-flow current, about 1mA

* Since no temperature compensation is made for R_{ex} , the temperature characteristic of output voltage is lowered. I_{vos} is variable at maximum $\pm 20\%$ depending on each IC product. Therefore, as the variation range of the output voltage becomes wider, the semi-fixed type resistor is required for the adjustment of accurate output voltage.

The variation range of the output voltage including the variation of R_{ex} , I_{vos} and V_{os} is shown as follows:

- Maximum output voltage ($V_{out' MAX}$)

$$V_{out' MAX} = V_{os MAX} + R_{ex MAX} \times I_{vos MAX}$$

$V_{os MAX}$: The maximum value of set output voltage. The MAX value of the set output voltage should be put, shown in the electrical characteristics of the specifications.

$R_{ex MAX}$: The maximum value of R_{ex} . It is obtained from the allowable tolerance.

$I_{vos MAX}$: The maximum in-flow current of Vos terminal, 1.2mA

- The minimum output voltage ($V_{out' MIN}$)

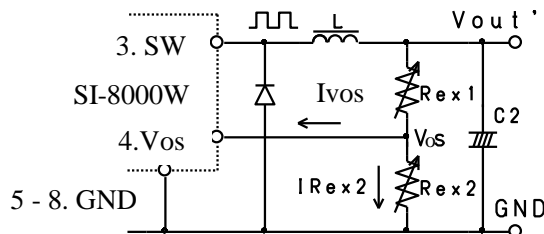
$$V_{out' MIN} = V_{os MIN} + R_{ex MIN} \times I_{vos MIN}$$

$V_{os MIN}$: The minimum value of set output voltage. The MIN value of the set output voltage should be put, shown in the electrical characteristics of the specifications.

RexMAX: The minimum value of Rex. It is obtained from the allowable tolerance of resistance.

IvosMIN: The minimum in-flow current of Vos terminal, 0.8mA

5-1-2 Variable Output Voltage by Two External Resistors



The output voltage adjustment resistors Rex1 and 2 are calculated by the following equation.

$$Rex1 = \frac{Vout' - Vos}{S \cdot Ivos} \quad \text{--- (10)}$$

$$Rex2 = \frac{Vos}{(S - 1) \cdot Ivos} \quad \text{--- (11)}$$

S: Stability coefficient

The tolerance of temperature characteristics and output voltage is improved more by bypassing the current to Rex2 than the method 5-1-1.

Stability coefficient S means the ratio of Rex 2 to the Vos terminal in-flow current Ivos. The larger is S, the more is the variation of temperature characteristic and output voltage improved. (Normally, about 5 - 10)

The tolerance of the output voltage including variation of Rex 1, Rex 2, Ivos, Vos is shown below.

- Maximum output voltage (Vout MAX)

$$Vout' MAX = VosMAX + Rex1 MAX \left(\frac{VosMAX}{Rex2MIN} + IvosMAX \right) \quad \text{--- (12)}$$

VosMAX: The maximum value of set output voltage. The MAX value of set output voltage should be put, shown in the electrical characteristics of the specifications.

Rex1MAX: The maximum value of Rex1. It is obtained from the tolerance of the resistor.

Rex2 MIN: The minimum value of Rex2. It is obtained from the tolerance of the resistor.

IvosMAX: The maximum in-flow current of Vos terminal, 1.2mA

- The minimum output voltage (VoutMIN)

$$Vout' MIN = VosMIN + Rex1 MIN \left(\frac{VosMIN}{Rex2MAX} + IvosMIN \right) \quad \text{--- (13)}$$

VosMIN: The minimum value of the set output voltage. Please fill in the MIN value of the set output voltage which is shown in the electrical characteristics of the specifications.

Rex1 MIN: The minimum value of Rex1. It is obtained from the tolerance of the resistor.

Rex2MAX: The maximum value of Rex2. It is obtained from the tolerance of the resistor.

IvosMIN: The minimum in-flow current of Vos terminal, 0.8mA

5-1-3 Cautions for variation of output voltages

The degradation of regulation and the increase in the output voltage temperature coefficient are assumed when the output voltage is varied.

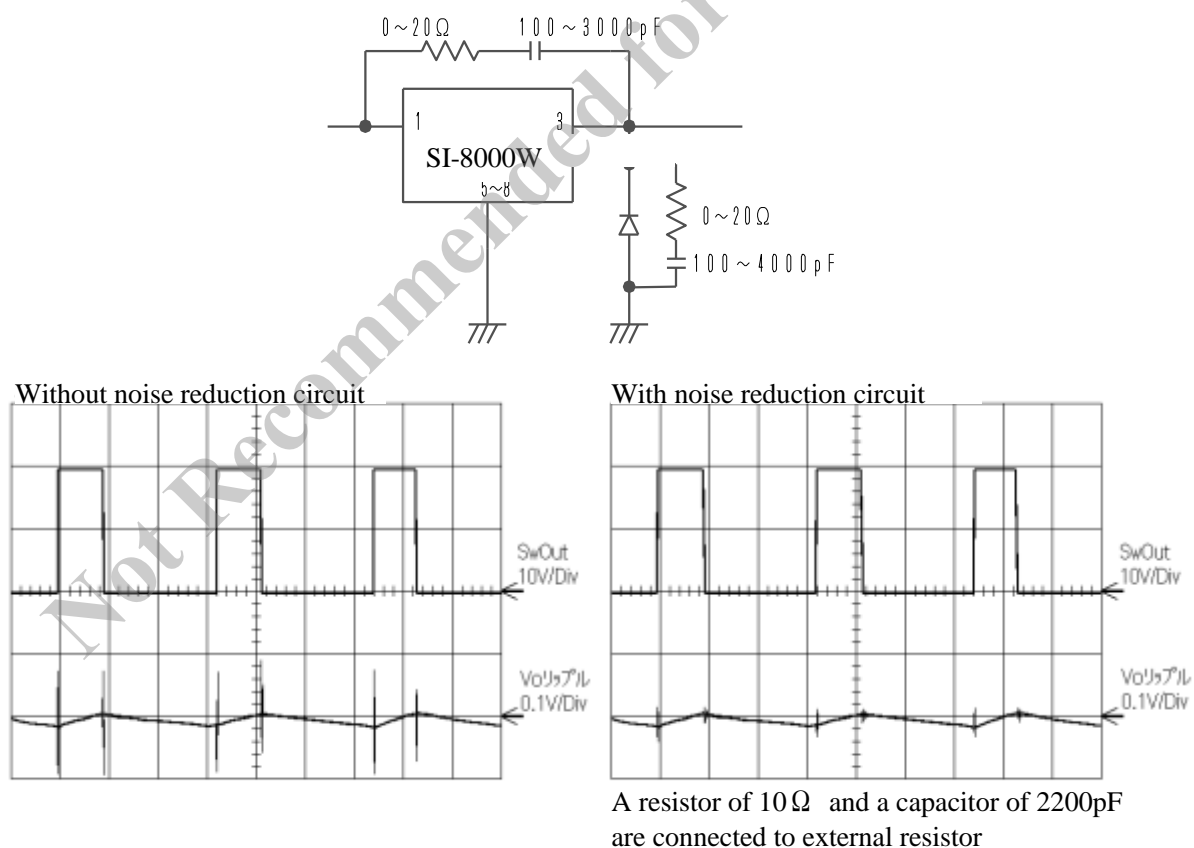
If it is varied drastically, the increase of coil capacitance value may be required since the overcurrent protection current is assumed to be lowered due to the increase in coil current.

Therefore, the use within the set output voltage +5V is recommended as for the upper limit of output voltage variation.

In addition, the MAX value of the set output voltage is recommended as for the lower limit of output voltage variation.

● 5-2 Spike Noise Reduction

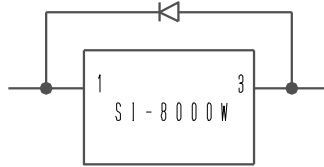
In order to reduce the spike noise, it is possible to compensate the output waveform of the SI-8000W and the recovery time of the diode by a capacitor, but it should be noted that the efficiency is also slightly reduced.



*When the spike noise is observed with an oscilloscope, the lead wire may function as an antenna and the spike noise may be observed extremely higher than usual if the probe GND lead wire is too long. In the observation of spike noise, the probe lead wire should be as short as possible and be connected with the root of the output capacitor.

● 5-3 Reverse Bias Protection

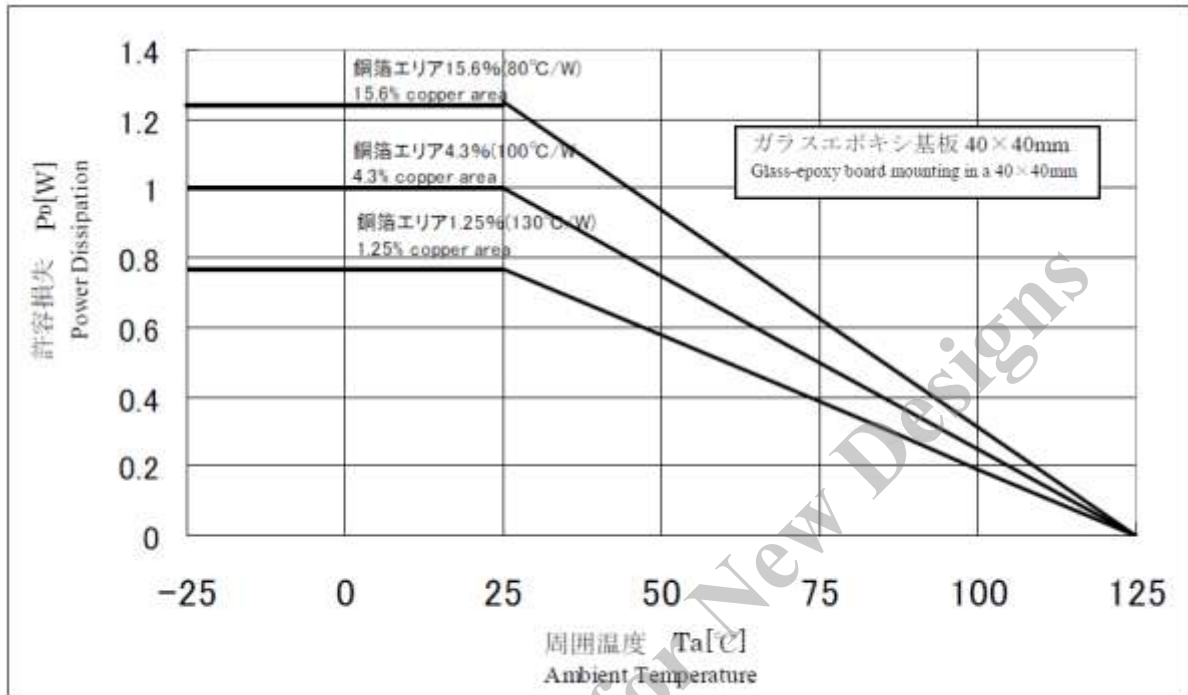
A diode for reverse bias protection is required between input and output when the output voltage is higher than the input terminal voltage, such as in battery chargers.



Not Recommended for New Designs

6. Heat Derating

Allowable Package Power Dissipation



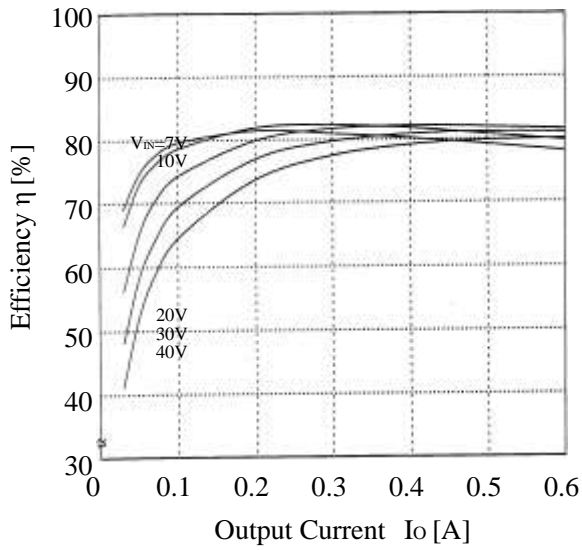
*1: Since the efficiency is subject to change depending on the input voltage and output current, it should be obtained from the efficiency curve in 7. Typical Characteristics, and be substituted in percent.

*2: The thermal design of Di should be made separately.

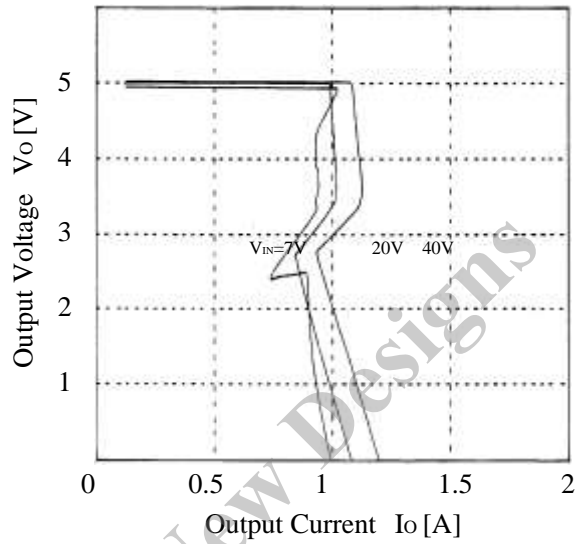
Not Recommended for New Designs

7. Typical Characteristics

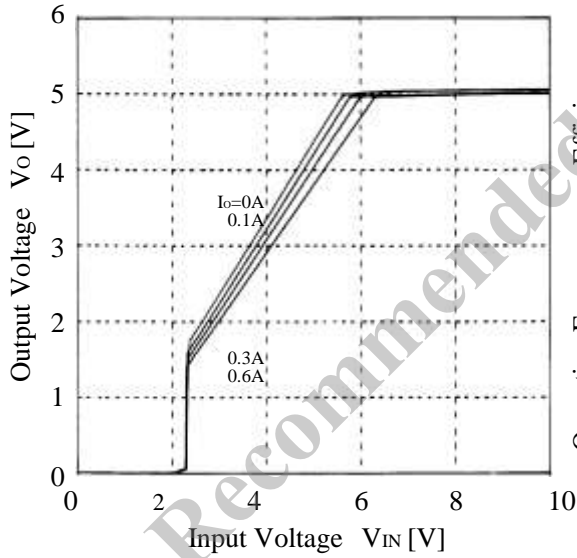
(1) Efficiency



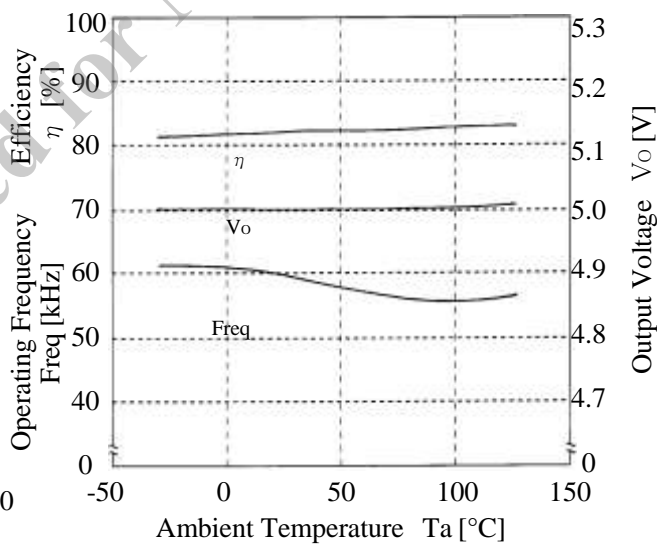
(4) Overcurrent Protection Characteristics



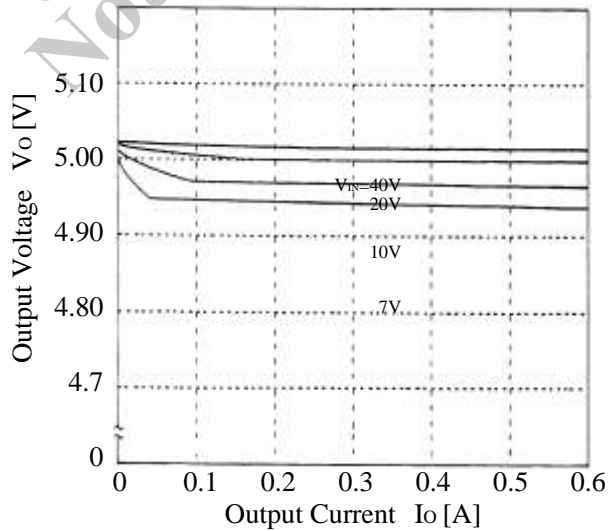
(2) Output Voltage Rising *Load=C.R



(5) Temperature Characteristics $V_{IN}=20V, I_o=0.3A$



(3) Output Voltage Variation



8. Terminology

- Jitter

It is a kind of abnormal switching operations and is a phenomenon that the switching pulse width varies in spite of the constant condition of input and output. The output ripple voltage peak width is increased when a jitter occurs.

- Recommended Conditions

It shows the operation conditions required for maintaining normal circuit functions. It is required to meet the conditions in actual operations.

- Absolute Maximum Ratings

It shows the destruction limits. It is required to take care so that even one item does not exceed the pacified value for a moment during instantaneous or normal operation.

- Electrical Characteristics

It is the specified characteristic value in the operation under the conditions shown in each item. If the operating conditions are different, it may be out of the specifications.

- PWM (Pulse Width Modulation)

It is a kind of pulse modulation systems. The modulation is achieved by changing the pulse width in accordance with the variation of modulation signal waveform (the output voltage for chopper type switching regulator).

- ESR (Equivalent Series Resistance)

It is the equivalent series resistance of a capacitor. It acts in a similar manner to the resistor series-connected to the capacitor.

Notice

- The contents of this description are subject to change without prior notice for improvement etc. Please make sure that any information to be used is the latest one.
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