# Application Note

**Full Mold Type Chopper Type Switching Regulator IC**

# SI-8000E Series



October 2013 Rev.4.0

SANKEN ELECTRIC CO., LTD.

# ――― Contents ―――

# 1. General Description

The SI-8000E 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 configured.

## ●1-1 Features

- Compact package, output current 0.6A

  The maximum output current of 0.6A for the outline of TO220
- High efficiency of 80% (SI-8050E Vin=20V/Io=0.3A)

  Heat dissipation is small due to high efficiency to contribute to the downsizing of a heat sink.
- Four external components

  The regulator can be configured by 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 external components is no longer required.
- Reference oscillation by a built-in timing capacitor

  No external capacitor for the oscillation frequency setting is required.
- Built-in functions for overcurrent and thermal shutdown

  A current limiting type overcurrent protection circuit and overheat protection are built in.
  (automatic restoration type)
- 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

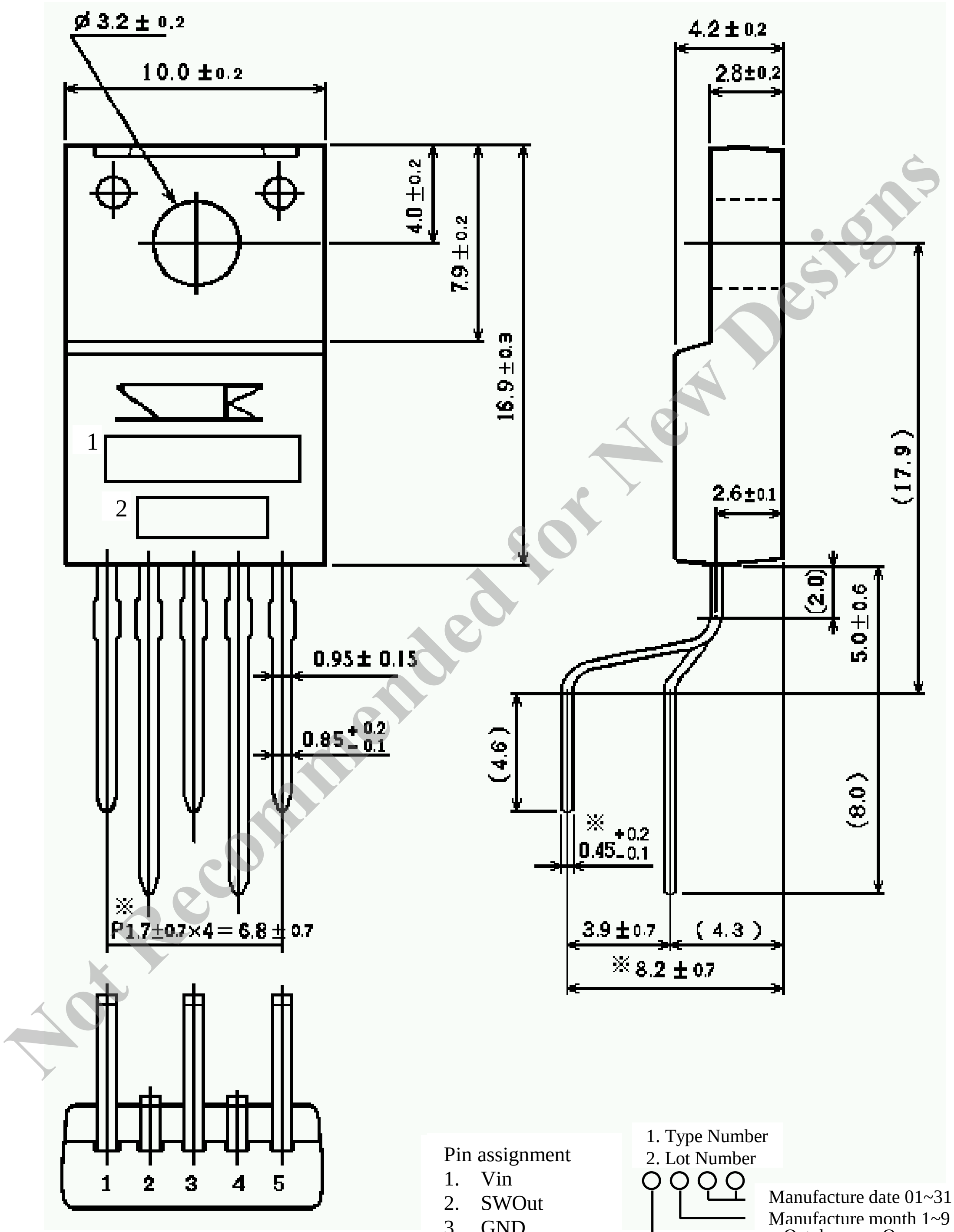
## ●1-3 Type

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

# 2. Specification

## ●2-1 Package Information (lead forming No.: LF1101)

Dimensions in mm






Pin assignment

1. Vin
2. SWOut
3. GND
4. Vos
5. N.C.

1. Type Number
2. Lot Number

Manufacture date 01~31

Manufacture month 1~9

| | |
|---|---|
| October | O |
| November | N |
| December | D |

Manufacture year Last digit of year

## ●2-2 Ratings

Lineup

| Product Name | Vout(V) |
|---|---|
| SI-8050E | 5 |

**Absolute Maximum Ratings**

| Parameter | Symbol | Rating | Unit |
|---|---|---|---|
| Input Voltage | Vin | 43 | V |
| Allowable Power Dissipation in Infinite Radiation | Pd1 | 14 | W |
| Allowable Power Dissipation without Heat sink | Pd2 | 1.5 | W |
| Junction Temperature | Tj | 125 | °C |
| Storage Temperature | Tstg | -40 - +125 | °C |

**Recommended Conditions**

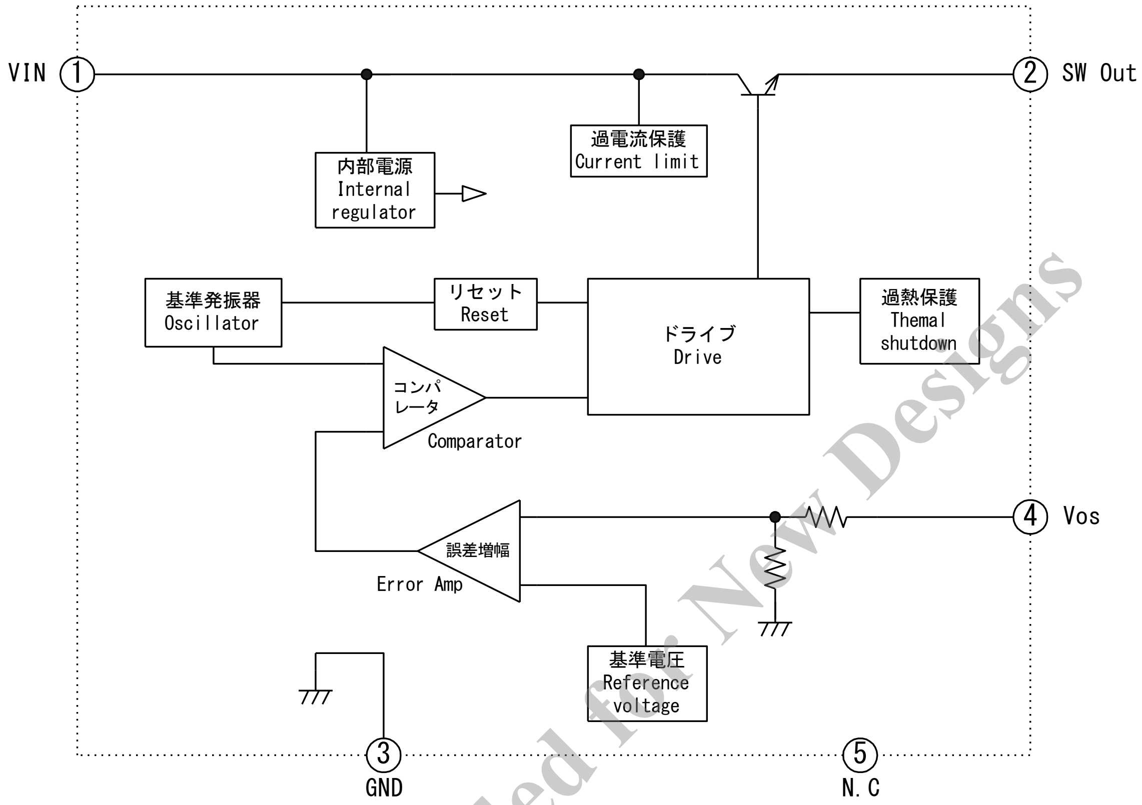
| Parameter | Symbol | SI-8050E | Unit |
|---|---|---|---|
| DC Input Voltage | Vin | 7 - 40 | V |
| Output Current | Io | 0 - 0.6 | A |
| Junction Temperature in Operation | TjOp | -30 - +125 | °C |

**Electrical Characteristics** (Ta=25°C)

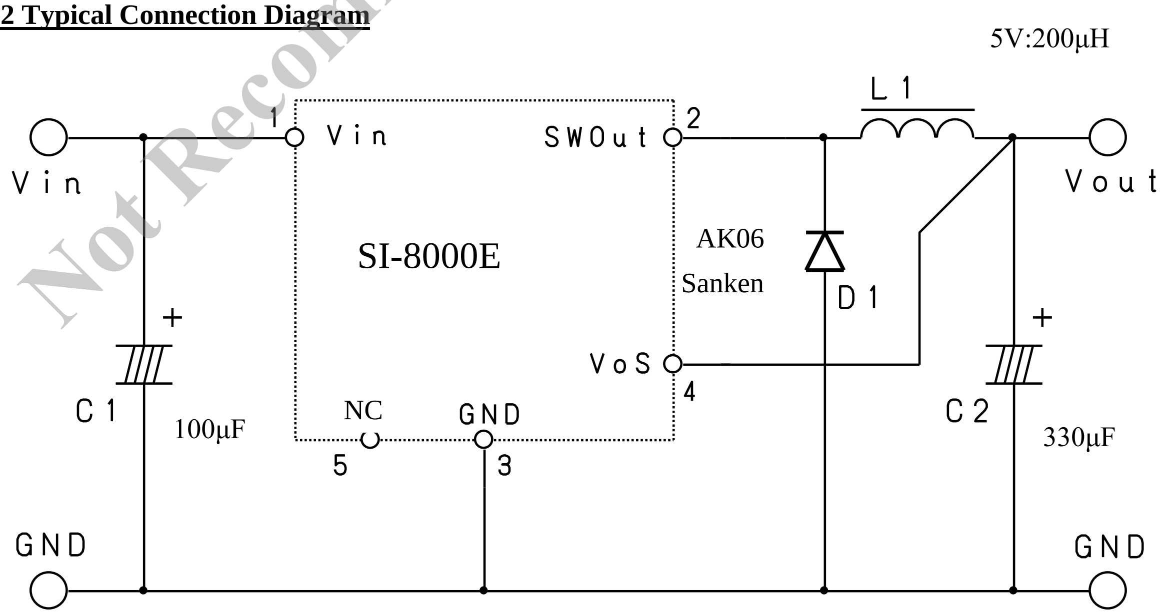
| Parameter | Symbol | SI-8050E | | | Unit |
|---|---|---|---|---|---|
| | | min | typ | max | |
| Set Output Voltage | Vin | 4.80 | 5.00 | 5.20 | V |
| | conditions | Vin=20V/Io=0.3A | | | |
| Efficiency | η | | 80 | | % |
| | conditions | Vin=20V/Io=0.3A | | | |
| Switching Frequency | f | | 60 | | kHz |
| | conditions | Vin=20V/Io=0.3A | | | |
| Input Voltage – Output Voltage | ⊿VLi | | 80 | 100 | mV |
| | conditions | Vin=10 - 30V, Iout=0.3A | | | |
| Output Current - Output Voltage | ⊿VLo | | 30 | 40 | mV |
| | conditions | Vin=20V, Iout=0.1 - 0.4A | | | |
| Overcurrent Protection Start Current | Is | 0.61 | | | A |
| | conditions | Vin=10V | | | |
| Output Voltage Temperature Variation | Kt | | ±0.5 | | mV/°C |

## ●2-3 Circuit Diagram

### 2-3-1 Internal Equivalent Circuit




### 2-3-2 Typical Connection Diagram

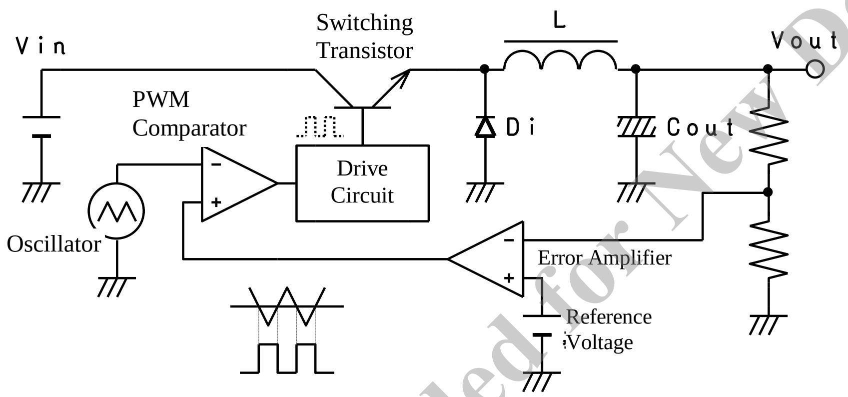


# 3. Operational Description

## ●3-1 PWM Output Voltage Control

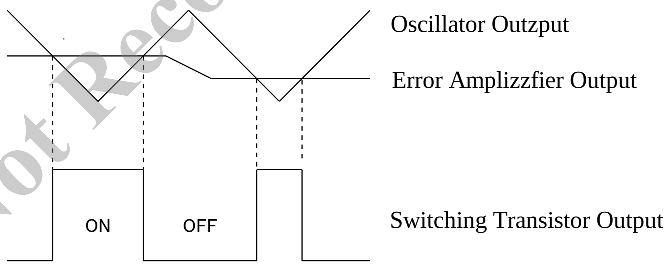
In the SI-8000E series, the output voltage is controlled by the PWM system and the IC incorporates the PWM comparator, oscillator, error amplifier, reference voltage, output transistor drive circuit etc. The triangular wave output (≒60KHz) from the oscillator and the output of the error amplifier are 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

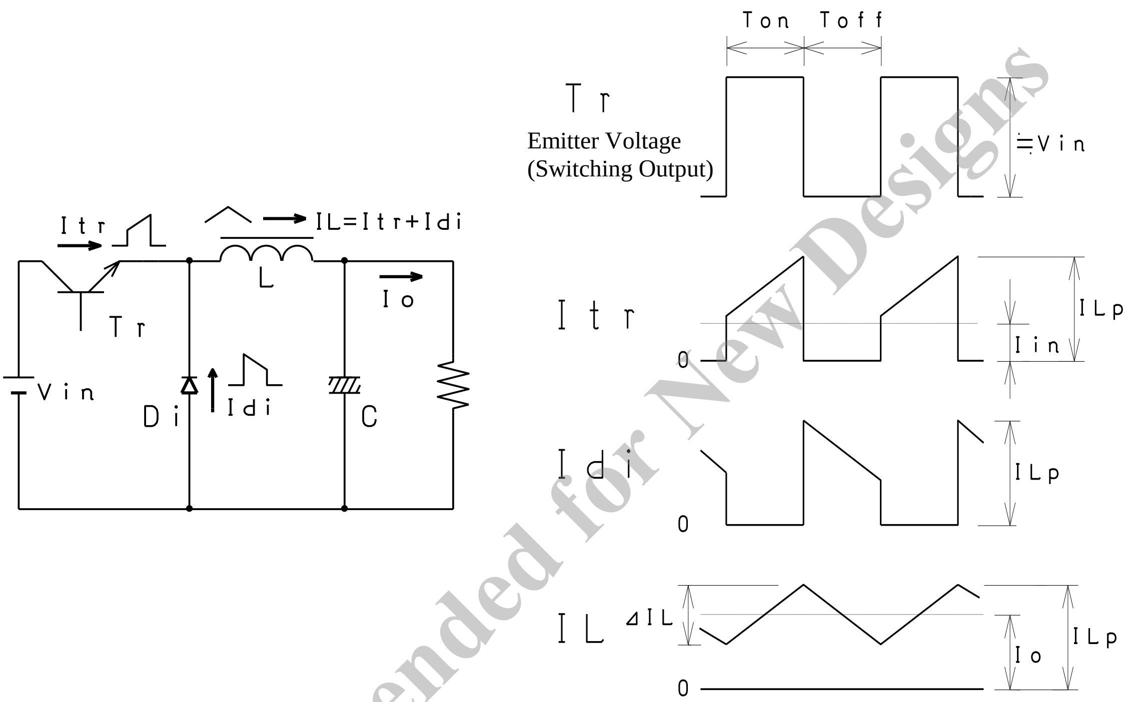



On the assumption that the output voltage attempts to rise, the output of the error amplifier is lowered, because the error amplifier is inverting type. As the error amplifier output is lowered, the time period where it falls below the triangular wave level of the oscillator is increased to shorten the 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 $V_{IN}$ is, the shorter the ON time of the switching transistor is.)

The rectangular wave output of the switching transistor is smoothed by the LC low pass filter configured by a choke coil and a capacitor, and the stabilized DC voltage is supplied 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-8000E is converted into DC output voltage by being smoothed by the LC filter configured by 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.

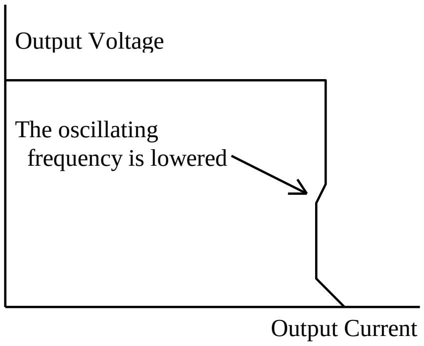





The current IL flowing in the choke coil is of triangular wave shape. This triangular wave is configured by two kinds of current components, Itr and Idi. The current Itr is supplied from the input side through the transistor when the transistor is ON and its average value is input current Iin. The current Idi is the current that the energy stored in the choke coil is commutated via the flywheel diode Di when the transistor is OFF. The total of Itr and Idi is the current IL of choke coil. In addition, the average value of IL is the DC output current Io since the triangular wave component superimposed on the IL is smoothed by charging and discharging of the capacitor C.

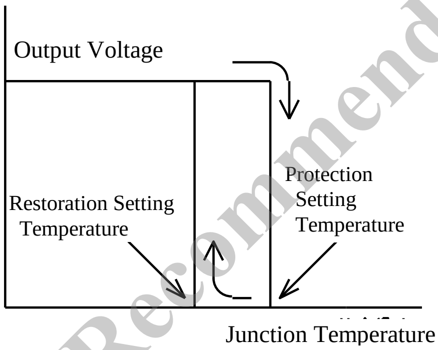
## ●3-3 Overcurrent Protection / Thermal Shutdown

### Output voltage characteristics in overcurrent protection




The SI-8000E incorporates 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. In addition, when the output voltage is lowered up to the 50% of the rated value, the increase of current at low output voltage is prevented by dropping the switching frequency to about 25kHz. 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 around 10°C from the set value for overheat protection, 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 this function does not assure the operation including reliability in the state of continuous overheat 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. It is a key component of 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.

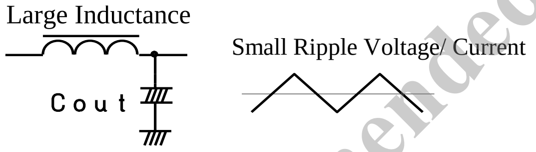
a) The choke coil should be fit for the switching regulator.

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

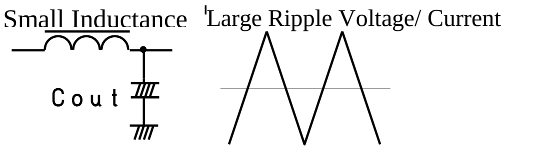
b) The inductance value should be appropriate.

The larger the inductance of the choke coil is, the less the ripple current flowing in the choke coil is, 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 in the switching transistor and diode is increased and the ripple voltage becomes higher and this operation state is not favorable for maintaining the stable operation.




The larger the inductance is, the smaller the ripple current/voltage is. But the outer size of the coil becomes larger.




The smaller the inductance is, the larger the ripple current/voltage is.

Although the outer size of the coil is smaller, the operation is likely to be unstable.

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 obtained by the following equation.

ΔIL shows the ripple current value of the choke coil and the inductance value 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-8000E: Output current × 0.5- 0.6
- In the case that the output current to be used is approximately 1.5A or less: Output current × 0.8 - 1.0

$$L = \frac{(Vin - Vout) \cdot Vout}{\Delta IL \cdot Vin \cdot f} \qquad ---(1)$$

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

$$L = \frac{(25-5)\times 5}{0.2\times 25\times 60\times 10^{3}} \fallingdotseq 222uH$$

As shown above, the coil of about 220μH 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 like drum shape type, since magnetic flux passes outside the coil, the peripheral circuit may be affected 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.



**<u>4-1-2 Input Capacitor C1</u>**

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 placed as close as to the regulator IC.

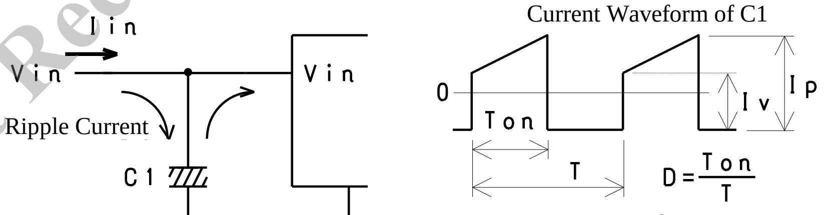
In addition, in the case that the smoothing capacitor of the AC rectifier circuit is located in the input circuit, the input capacitor may be also used as a smoothing capacitor, but similar attention should be paid.

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

a) The requirement of withstand voltage shall be met.

b) The requirement of the allowable ripple current shall be met.

**<u>Current Flow of C1</u>**




The ripple current of the input capacitor is increased in accordance with the increase of the load current.

If the withstanding voltage and allowable ripple current 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:

$$Irms \approx 1.2 \times \frac{Vo}{Vin} \times Io \qquad --(2)$$

For instance, where Iout=0.6A, Vin=20V, Vo=5V,

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

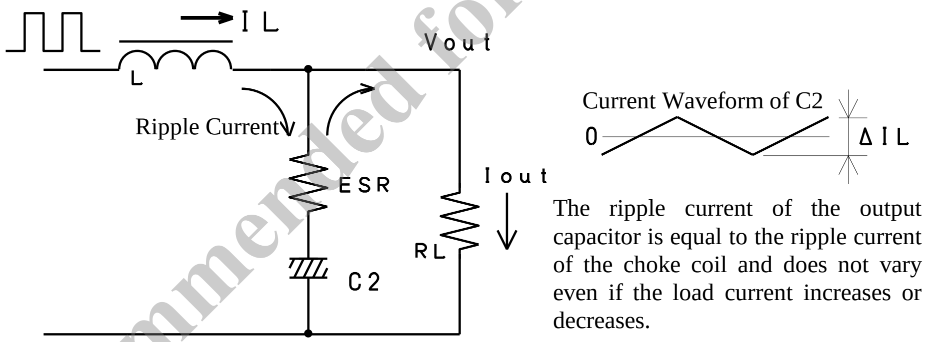
Therefore, it is necessary to select the capacitor with the allowable ripple current of 0.18A or higher.

**<u>4-1-3 Output Capacitor C2</u>**

The output capacitor C2 configures an 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 ΔIL 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.

**<u>Current Flow of C2</u>**




The ripple current of the output capacitor is equal to the ripple current of the choke coil and does not vary even if the load current increases or decreases.

- Allowable Ripple Current

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

$$Irms = \frac{\Delta IL}{2\sqrt{3}} \qquad ---(3)$$

When ΔIL = 0.3A,

$$Irms = \frac{0.3}{2\sqrt{3}} \fallingdotseq 0.09A$$

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 ΔIL (=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 Vout = 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.

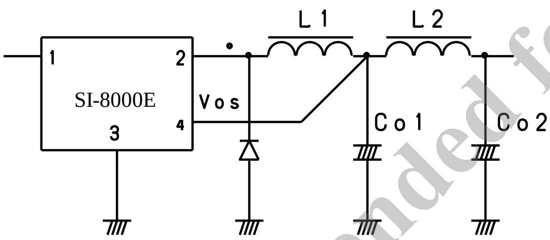
$$Vrip \approx \frac{(Vin - Vout)Vout}{L \cdot Vin \cdot f} ESR \quad --- (4)$$

$$Vrip \approx \Delta IL \cdot ESR \quad --- (5)$$

When the ESR is too low (approx. 10 – 20mΩ 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.




L2 : 20uH

Co2 : 200uF

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 place it near the IC.

**4-1-4 Flywheel Diode Di**

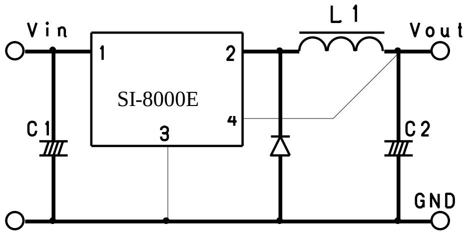
The flywheel diode Di is to discharge the energy which is stored in the choke coil at switching OFF.

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.

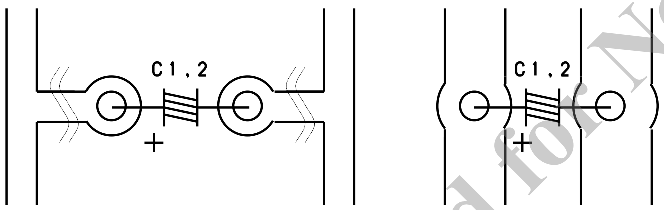



### 4-2-2 Input/ Output Capacitor

The input capacitor C1 and the output capacitor C2 should be placed 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.

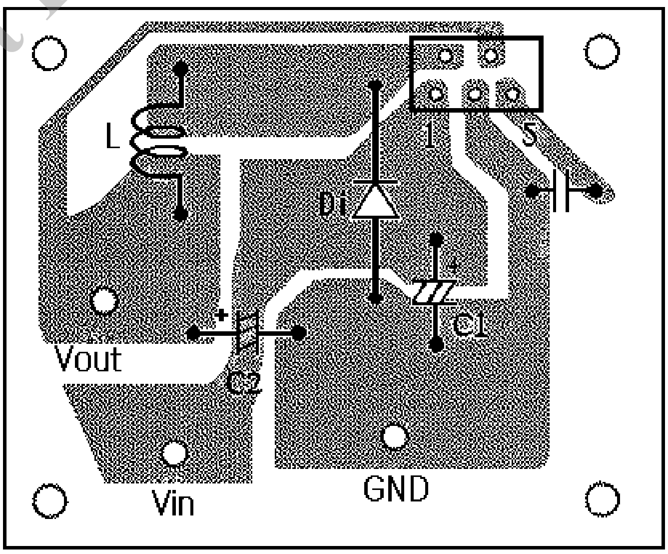



Improper Pattern Example    Proper Pattern Example

### 4-2-3 Sensing Terminal

The output voltage sensing terminal Vos shall be connected near the output capacitor C2 as much as possible. (Vos terminal flow-in current is approx. 1mA.)

**SI-8000E**




**Board Pattern Example**

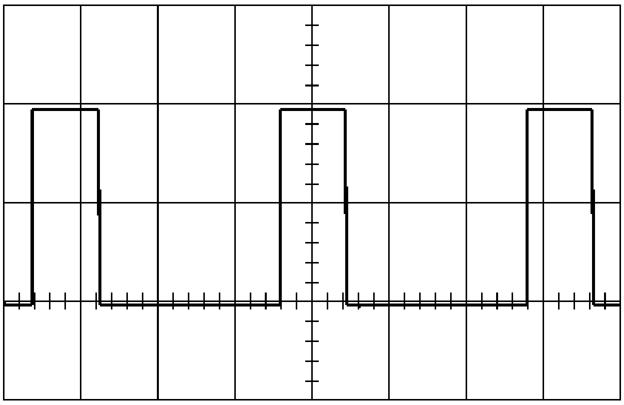
TopView

## ●4-3 Operation Waveform Check

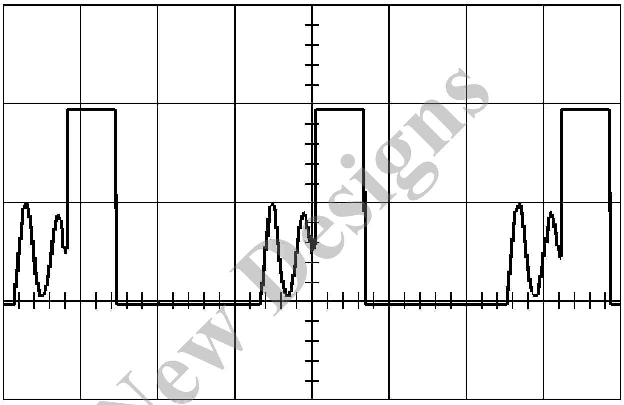
It can be checked by the waveform between the pin 2 and 3 (SWOut waveform) of the SI-8000E whether the switching operation is normal or not.

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

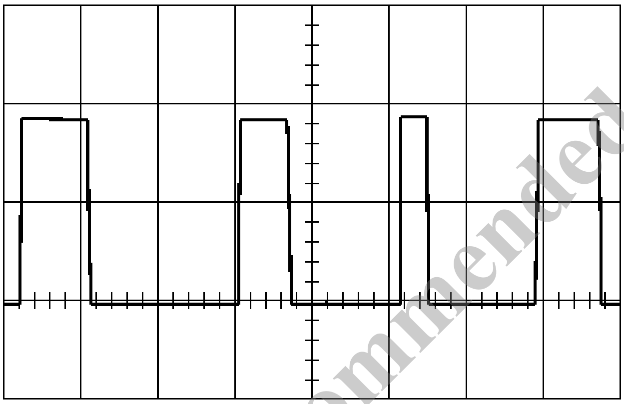
1. Normal Operation (continuous area)



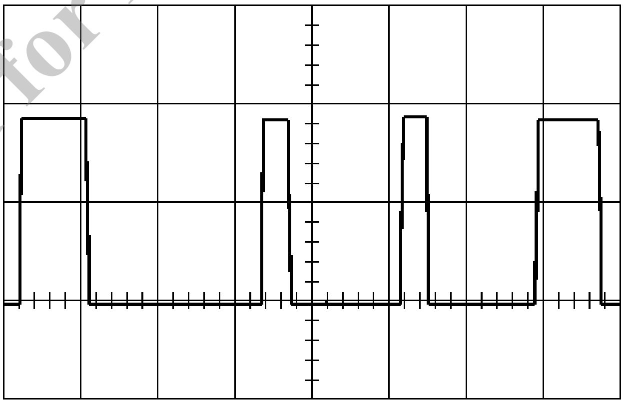
2. Normal Operation (discontinuous area)



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.

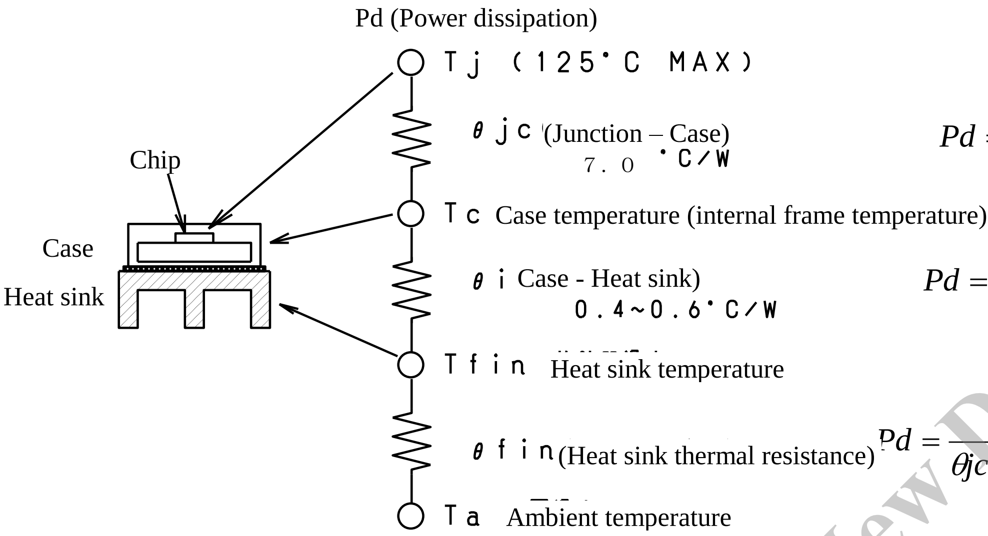
In the continuous area, the switching waveform is formed in the normal rectangular waveform (waveform 1) and in the discontinuous area, damped oscillation is caused in the switching waveform (waveform 2), but this is a normal operation without any problem.

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

### 4-4-1 Calculation of Heat Dissipation

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




$$Pd = \frac{Tj - Tc}{\theta jc} \qquad --(6)$$

$$Pd = \frac{Tj - Tfin}{\theta jc + \theta i} \qquad --(7)$$

$$Pd = \frac{Tj - Ta}{\theta jc + \theta i + \theta fin} \qquad --(8)$$

The TjMAX is an inherent value for each product, therefore it must be strictly observed. For this purpose, it is required to design the heat sink in compliance with PdMAX, TaMAX (determination of θfin).

The designing of the heat sink is carried out by the following procedure:

1) The maximum ambient temperature Ta MAX in the set is obtained.

2) The maximum power dissipation PdMAX is obtained.

$$Pd = Vo \cdot Io\left(\frac{100}{\eta x} - 1\right) - Vf \cdot Io\left(1 - \frac{Vo}{Vin}\right) \qquad ---(9)$$

* ηx= efficiency (%), Vf= diode forward voltage

3) The required thermal resistance of the heat sink is calculated. The thermal resistance required for the heat sink is obtained by the following equation:

$$\theta i + \theta fin = \frac{Tj - Ta}{Pd} - \theta jc \qquad ---(10)$$

An example of heat calculation for using SI-8050E under the conditions of $V_{IN}$ = 10V, Iout = 0.6A and Ta = 85°C is shown below. Where efficiency η = 80% , Vf = 0.4V from the typical characteristics,

$$Pd = 5 \times 0.6 \times \left(\frac{100}{80} - 1\right) - 0.5 \times 0.6 \times \left(1 - \frac{5}{10}\right) = 0.63W$$

$$\theta i + \theta fin = \frac{125 - 85}{0.63} - 7.0 ≒ 56.5^{\circ} C / W$$

As a result, the heat sink with the thermal resistance of 56.5°C /W or less is required. As described above, the heat sink is determined, but the derating of 10 - 20% or more is used. Actually, heat dissipation effect significantly changes depending on the difference in component mounting. Therefore, heat sink temperature or case temperature should be checked with the heat sink mounted.

**4-4-2 Installation to Heat sink**

Selection of silicon grease

When the SI-8000E is installed to the heat sink, silicon grease should be thinly and evenly coated between the IC and heat sink. Without coating, thermal resistance θi is significantly increased because of contact failure due to micro concavity/convexity between the backside of the IC and the surface of the heat sink to accelerate the heating of the IC, resulting in shorter life of the IC. In some kind of silicon grease to be used, oil component may be separated to penetrate into the IC, resulting in the deformation of packages or the adverse effect on built-in elements. Any other silicon grease than one based on the modified silicon oil shall not be used.

The recommended silicon greases are as follows:

Sanken's recommended silicon greases:

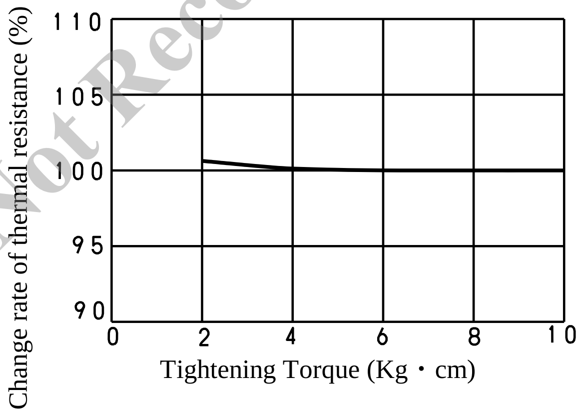
| Types | Suppliers |
|---|---|
| G746 | Shin-Etsu Chemical Co., Ltd. |
| SC102 | Toray Silicone Co., Ltd. |
| YG6260 | Momentive Performance Materials Inc. |

Tightening torque of fixing screws

In order to keep the thermal resistance between the IC and the heat sink at low level without damaging the IC package, it is necessary to control the torque of fixing screws in a proper way.

Even if silicon grease is coated, the thermal resistance θi increases if the tightening torque is not enough.

For the SI-8000E, 58.8 – 68.6N cm (6.0 – 7.0 kg cm) are recommended.




* 1. The change rate of thermal resistance in the case that 6Kg cm is expressed as 100% is shown above.

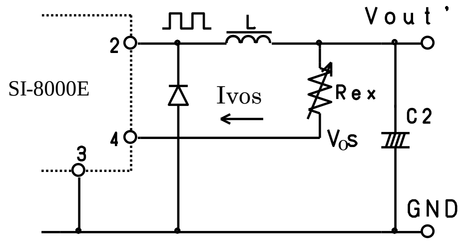
* 2. The silicon grease G746 shall be used.

# 5. Application

## ●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 Rex is obtained by the following equation.

$$Rex = \frac{Vout' - Vos}{IVos} \quad ---(13)$$

Vos: Set output voltage for product
Vout': Variable output voltage
Ivos : Vos terminal in-flow current≒1mA

* Since no temperature compensation is made for Rex, the temperature characteristic of output voltage is lowered. Ivos is variable at maximum ±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 Rex, Ivos and Vos is shown as follows:

- Maximum output voltage (Vout'MAX)

$$\text{Vout' MAX} = \text{VosMAX} + \text{RexMAX} \times \text{IvosMAX}$$

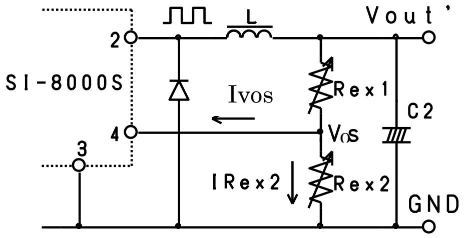
VosMAX: The maximum value of set output voltage. The MAX value of the set output voltage should be put, shown in the electrical characteristics in page 6.
RexMAX: The maximum value of Rex. It is obtained from the allowable tolerance.
IvosMAX : The maximum in-flow current of Vos terminal.1.2mA

- The minimum output voltage (Vout'MIN)

$$\text{Vout' MIN} = \text{VosMIN} + \text{RexMIN} \times \text{IvosMIN}$$

VosMIN: The minimum value of set output voltage. The MIN value of the set output voltage should be put, shown in the electrical characteristics in page 6.
RexMIN: 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 obtained by the following equation.

$$\mathrm{Re}\,x1 = \frac{Vout' - Vos}{S \cdot IVos} \qquad ---(14)$$

$$\mathrm{Re}\,x2 = \frac{Vos}{(S-1) \cdot IVos} \qquad ---(15)$$

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)

$$\mathrm{Vout'\,MAX} = \mathrm{VosMAX} + \mathrm{Rex1MAX}\left(\frac{\mathrm{VosMAX}}{\mathrm{Rex2MIN}} + \mathrm{IvosMAX}\right)$$

VosMAX: The maximum value of set output voltage. The MAX value of set output voltage should be put, shown in the electrical characteristics in page 6.

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

Rex2MIN: 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 (Vout'MIN)

$$\mathrm{Vout'\,MIN} = \mathrm{VosMIN} + \mathrm{Rex1MIN}\left(\frac{\mathrm{VosMIN}}{\mathrm{Rex2MAX}} + \mathrm{IvosMIN}\right)$$

VosMI: 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 in page 6.

Rex1MIN: 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.

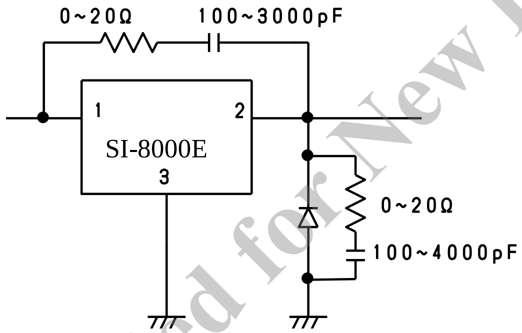
If it is varied drastically, the increase of coil capacitance value may be required since the overcurrent protection current is assumed to be lowered due to the increase in coil current.

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

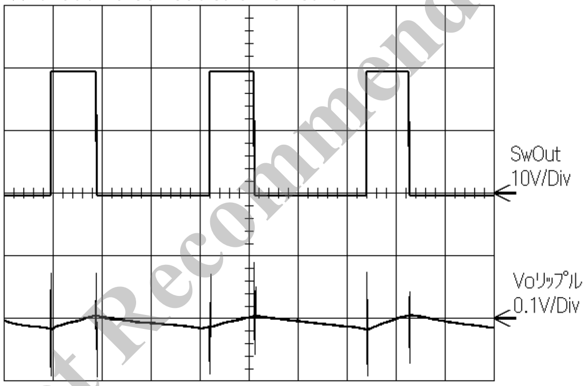
In addition, the MAX value of the set output voltage is recommended as for the lower limit of output voltage variation.

## ●5-2 Spike Noise Reduction

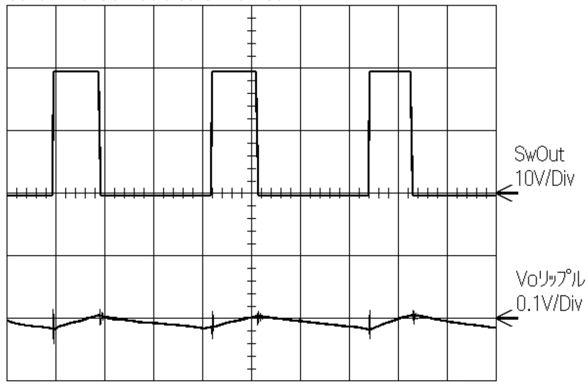
In order to reduce the spike noise, it is possible to compensate the output waveform of the SI-8000E and the recovery time of the diode by a capacitor, but it should be noted that the efficiency is also slightly reduced.




Without noise reduction circuit




With noise reduction circuit

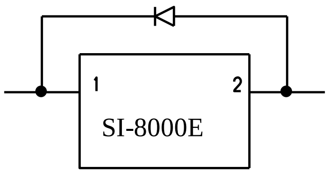



A resistor of 10Ω and a capacitor of 2200pF are connected to external resistor

*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 made as short as possible and be connected with the root of the output capacitor.

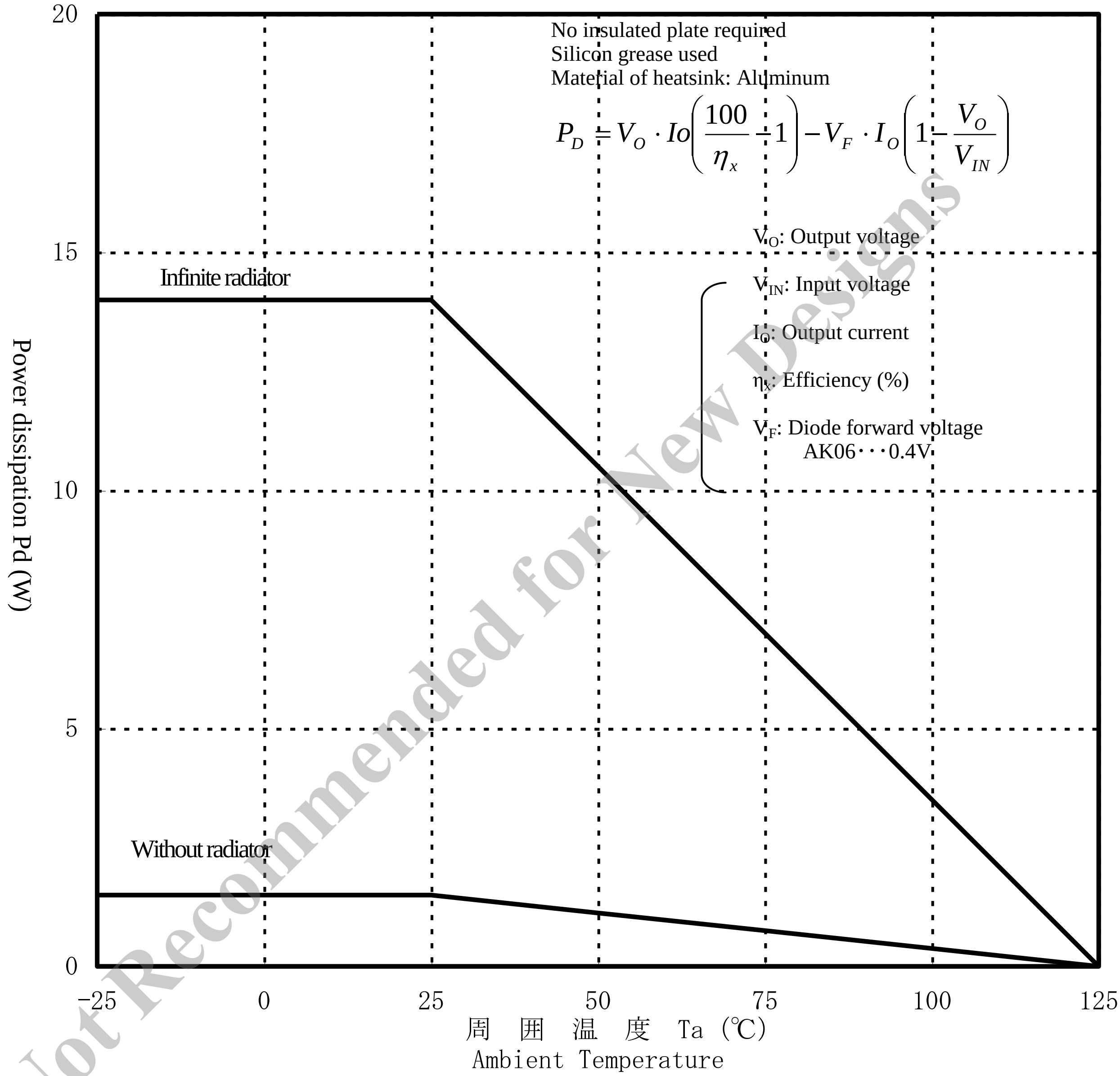
## ●5-3 Reverse Bias Protection

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.



# 6. Thermal Derating Curve

Allowable package power dissipation





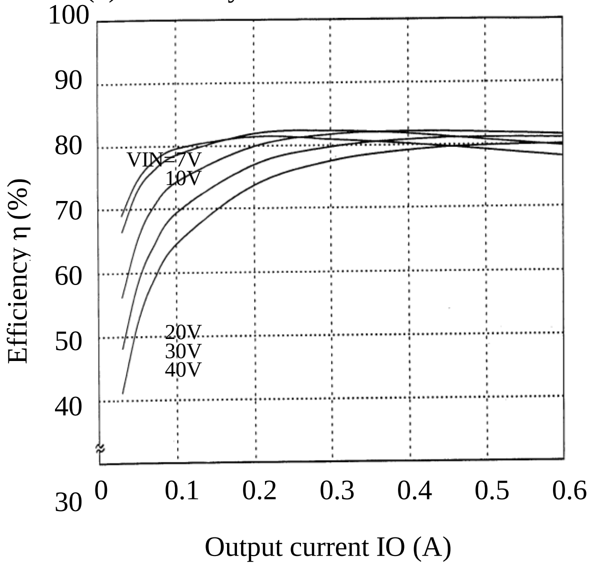

Note1: As the efficiency varies subject to the input voltage and output current, it shall be obtained from the efficiency curve in 4-2 and substituted in percent.

Note2: Thermal design for Di shall be made separately

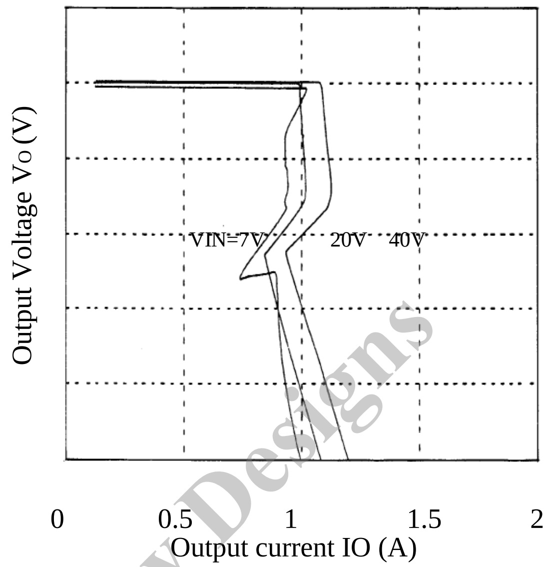
# 7. Typical Characteristics

**(Ta=25°C)**

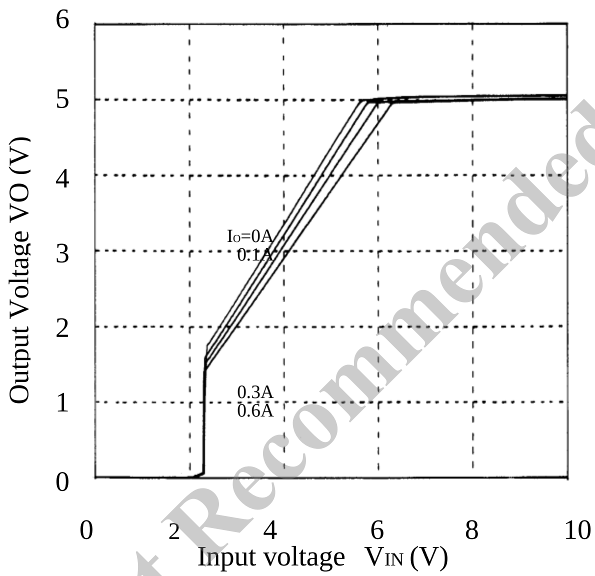
(1) Efficiency



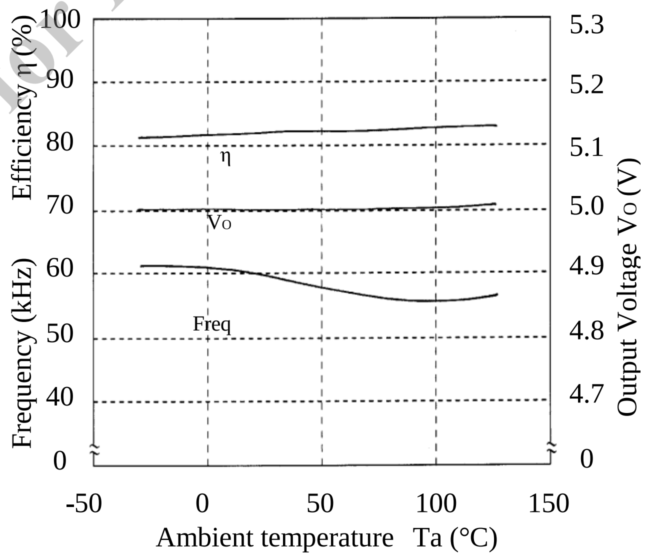

(4) Overcurrent protection characteristics



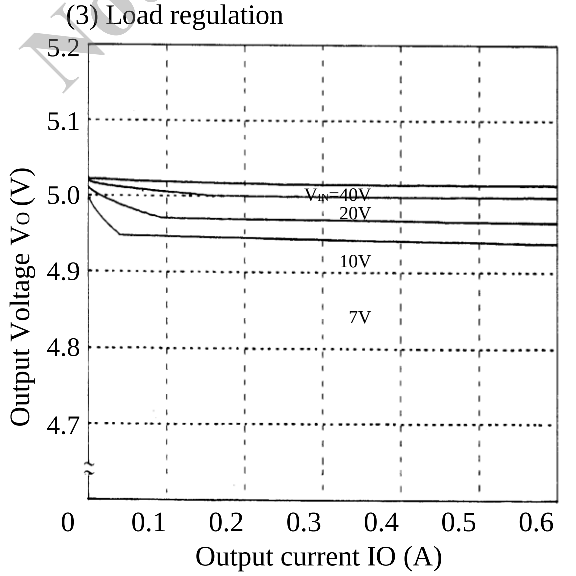

(2) Startup of output voltage * Load=C.R IO=0.3A




(5) Temperature characteristics VIN=20V, IO=0.3A




(3) Load regulation



# 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.