Application Note

Chopper Type Switching Regulator IC

SI-8000FDL Series

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SANKEN ELECTRIC CO., LTD.

——— Content ———

1. General Description

The SI-8001FDL is a chopper type switching regulator IC which is provided with various functions required for the buck switching regulator and protection functions. By using six external components, a highly efficient switching regulator can be composed.

● 1-1 Features

- Compact size and large output current of 3.5A
  The maximum output current of 3.5 A for the outline of TO263-5 class
- High efficiency of 83% (V_{IN} = 15V/I_O = 2A)
  Heat dissipation is small due to high efficiency to allow for the downsizing of a heat sink.
- Six external components
  The regulator can be composed of input / output capacitor, diode, coil and resistors of Vout setting.
- 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
  A current limiting type protection circuit against overcurrent and overheat is built in.
  (automatic restoration type)
- ON/OFF function that turns the output ON and OFF.
  Voltage is inputted from outside to enable ON/OFF function.
  Active Low of ON at Low (ON at Open)
  When the voltage of ON/OFF terminal (Vc terminal) falls below the threshold, the output is turned on (active low). The ON/OFF terminal (Vo terminal) is open.
- 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

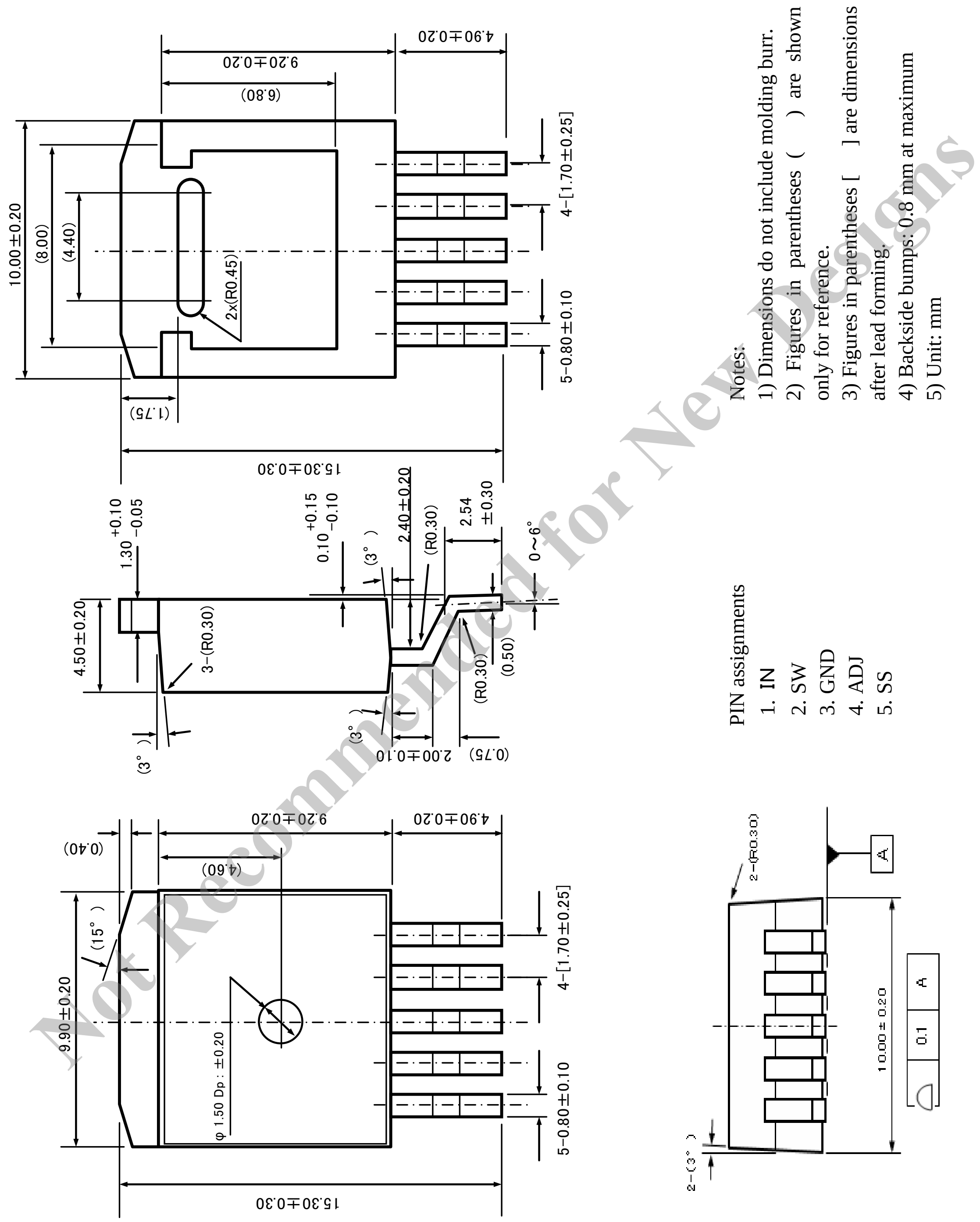
● 1-3 Type

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

2. Specification

Unit: mm

●2-1 Package Information



Products Weight: Approx.1.48g

2-2 Ratings

2-2-1 Absolute Maximum Ratings

Parameter	Symbol	Rating	Unit
Input Voltage	V_{IN}	43 *1	V
Allowable Power Dissipation	Pd	3 *2	W
Junction Temperature	Tjmax	150 *1	°C
Storage Temperature	Tstg	-40 -+150	°C

*1 Since the thermal shutdown is provided, it may be operated at Tj > 130°C.

*2 Glass epoxy single side board 40 × 40 mm (when copper foil area is 100%)

2-2-2 Recommended Conditions

Parameter	Symbol	SI-8001FDL	Unit
DC Input Voltage	V_{IN}	Vo+3v - 40*3	V
Output Current	I_O	0 - 3.5 *4	A
Junction Temperature in Operation	Tjop	-30 - ＋125	°C

*3 V_{IN} = 4.5V or Vout +3V, whichever higher value is recommended.

*4 It should be used within the temperature range which does not exceed Tjmax.

2-2-3 Electrical Characteristics

(Ta=25°C, Vo=5V, R1=4.2kΩ, R2=0.8kΩ)

Parameter		Symbol	Limits MIN	Limits TYP	Limits MAX	Unit	Test Conditions
Reference Voltage		V_{ADJ}	0.784	0.800	0.816	V	V_{IN}=15V, I_O=0.2A
Reference Voltage Temperature Coefficient		$\Delta V_{ADJ}/\Delta T$		±0.1		mV/°C	V_{IN}=15V I_O=0.2A, T_C=0 - 100℃
Efficiency *6		η		83		%	V_{IN}=15V, I_O=2A
Operating Frequency		f_O	270	300	330	kHz	V_{IN}=15V, I_O=2A
Line Regulation		V_{Line}			80	mV	V_{IN}=10 - 30V, I_O=2A
Load Regulation		V_{Load}			50	mV	V_{IN}=15V, I_O=0.2 - 3.5A
Overcurrent Defection		I_S	3.6			A	V_{IN}=15V
Quiescent Current 1		Iq		6		mA	V_{IN}=15V, I_O=0A
ON/OFF Terminal *7	V_C Terminal Control Voltage (ON)	$V_{C, IH}$			0.8	V	
	V_C Terminal Control Voltage (OFF)	$V_{C, IL}$	2.0			V	
	ON/OFF Control Current at ON	$I_{C, IH}$		6	100	µA	V_C=2V
Quiescent Current 2		Iq(off)		30	200	µA	V_{IN}=15V, V_C=2V

*5 Electrical characteristics indicate specific limits, which are guaranteed when IC is operated under the test conditions shown above in the circuit diagram (refer to P.6).

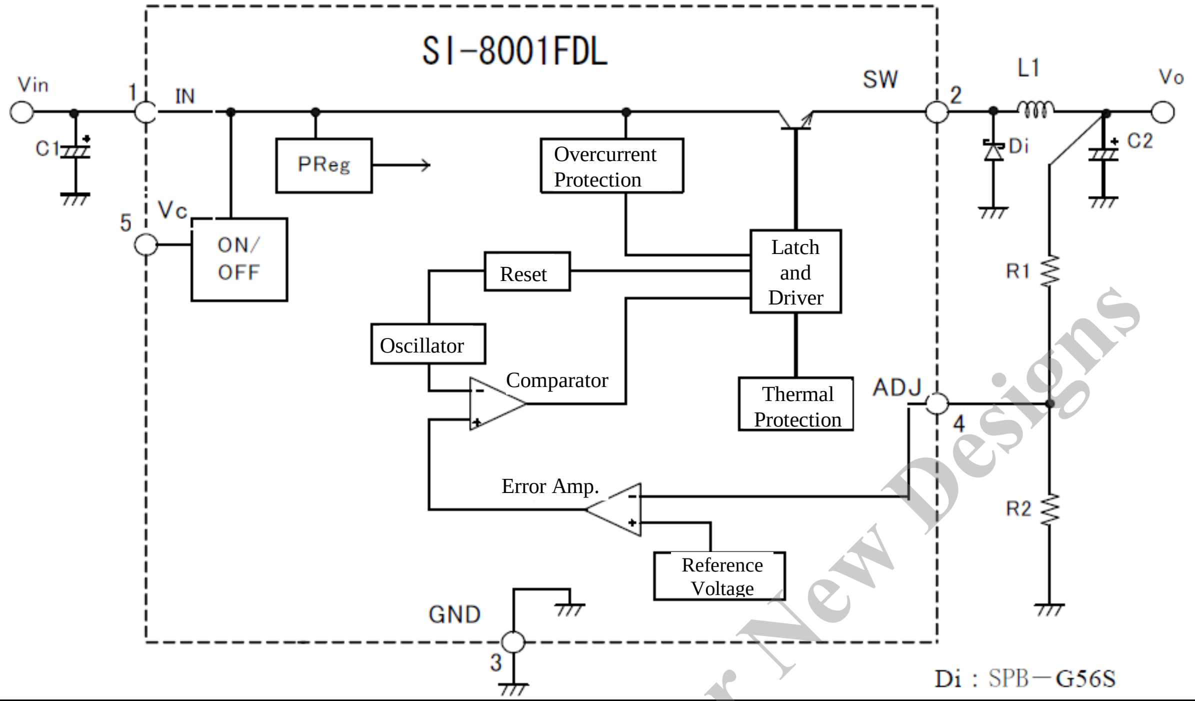
*6 Efficiency is calculated by the following equation.

$$\eta(\%) = \frac{V_O \cdot I_O}{V_{IN} \cdot I_{IN}} \times 100$$

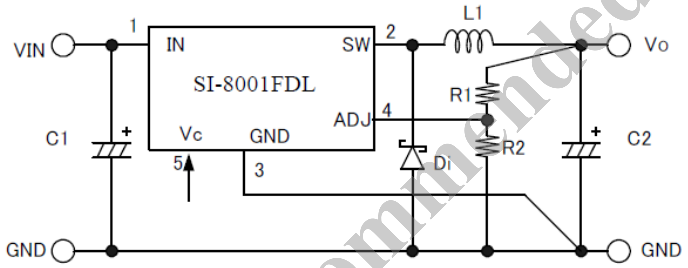
*7 If V_C terminal is OPEN, output will be ON state. As input level is equivalent to LS-TTL direct drive by LS-TTL is possible.

● 2-3 Circuit Diagram

2-3-1 Internal Equivalent Circuit



2-3-2 Typical Connection Diagram



C1: 470µF

C2: 680µF

L1: 47µH

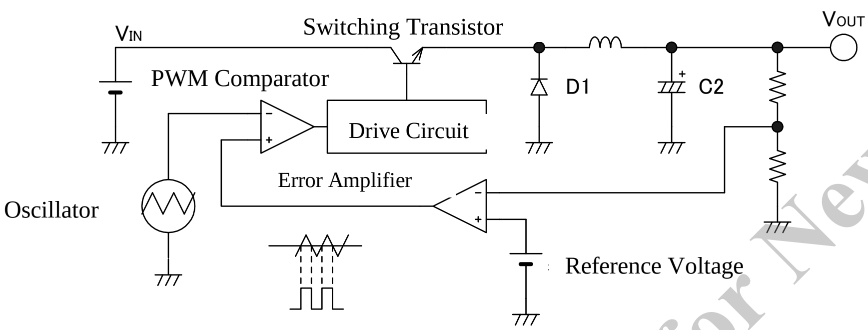
Di: SPB-G56S (Sanken Product)

3. Operational Description

● 3-1 PWM Output Voltage Control

The SI-8000FDL series controls the output voltage by the PWM system and comprises PWM comparator, oscillator, error amplifier, reference voltage, output transistor drive circuit etc. For the input of the PWM comparator, the triangular wave output (≈300KHz) from the oscillator and the output of the error amplifier are given. The PWM comparator compares the oscillator output with the error amplifier output to control to turn on the switching transistor at the time when the error amplifier exceeds the error amplifier output.

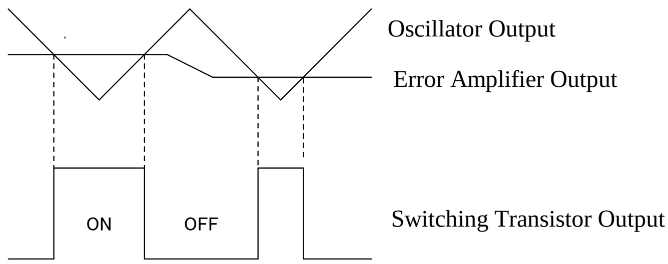
PWM Control Chopper Type Regulator Basic Configuration



The error amplifier output and oscillator output are compared by the PWM comparator to generate the rectangular wave signal and this signal is inputted into the drive circuit to drive the switching transistor.

On the assumption that the output voltage commences to rise, the output of the error amplifier will drop, because the error amplifier is of inverting type. As the output of the error amplifier falls down, the time period during which 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 at a certain level. As described above, the output voltage is controlled by varying the ON time of the switching transistor, while fixing the switching frequency.
(the higher is Vin, the larger is the ON time of the switching transistor.)

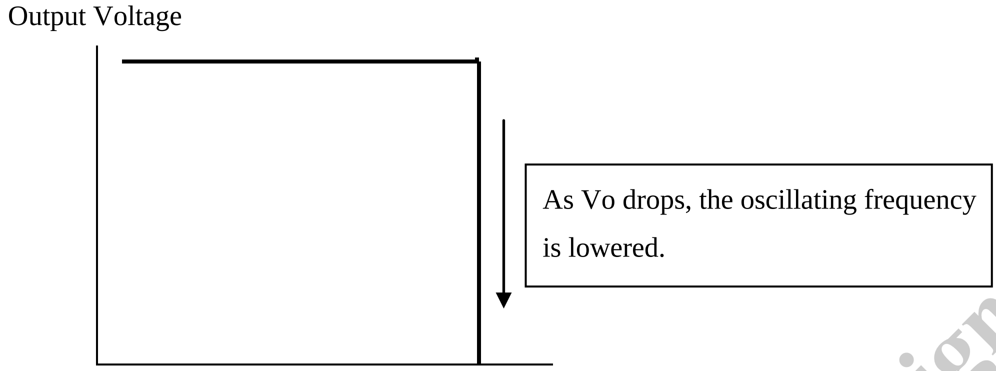
PWM Comparator Operation



The rectangular wave output of the switching transistor is smoothed by the LC low pass filter of a choke coil and capacitor to supply stabilized DC voltage to the load.

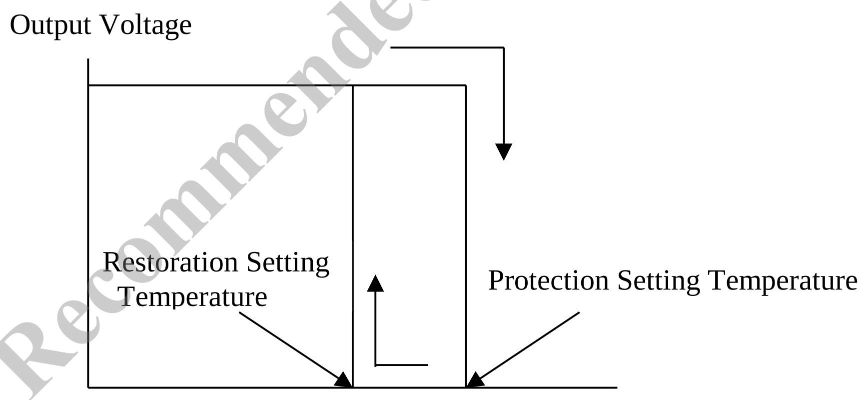
● 3-2 Overcurrent Protection / Thermal Shutdown

Output Voltage Characteristics in Overcurrent



The SI-8000FDL 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. In addition, when the output voltage is lowered, the increase of current at low output voltage is prevented by dropping linearly the switching frequency to about 25 KHz. 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 (around 150°C), 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 15°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

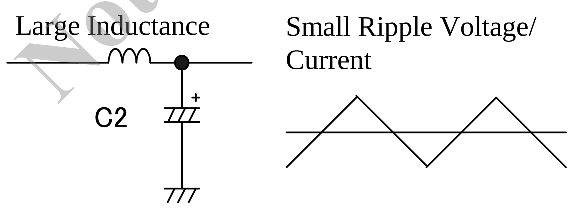
4-1-1 Choke coil L1

The choke coil L1 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.

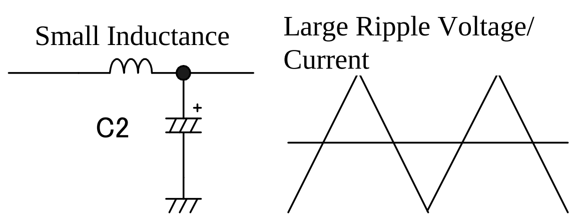
a) The choke coil should be fit for the switching regulator.
The coil for a noise filter should not be used because of large loss and generated heat.

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.
When the ripple voltage of the output voltage becomes too high, the operation is likely to be unstable and waveform skipping or jitter may be generated.
It is recommended that the ripple voltage of the output voltage should be 1% or less of the set output voltage.
The ripple voltage of the output voltage is determined as the product of ΔIL and ESR (equivalent series resistance) of the output capacitor, therefore when the ESR is too large, a problem may happen. The ESR should also be taken into account as well as the selection of the output capacitor.

Vout ripple = ΔIL x ESR of output capacitor



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



The smaller is the inductance, the larger will be the ripple current/voltage.
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 equation (1).

However, it should be noted that the ripple value should also be adjusted to be appropriate.

ΔIL 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 (3.5A) of the SI-8000FDL: output current × 0.1 or so

・In the case that the output current to be used is approximately 2A or less: output current × 0.3 – 0.4

$$L1 = \frac{(VIN - VOUT) \cdot VOUT}{\Delta IL \cdot VIN \cdot f} \qquad --- (1)$$

For example, where V_{IN} = 25V, V_{OUT} = 5V, ΔIL = 0.5A, frequency = 300 KHz,

$$L1 = \frac{(25-5)\times 5}{0.5\times 25\times 300\times 10^3} \fallingdotseq 26.7uH$$

As shown above, the coil of about 27μH may be selected.

However, it is to be noted that the peak current of the switching transistor is increased depending on the calculated inductance value.

Therefore, the peak current detection system is adopted for overcurrent detection and in this case, the overcurrent detection point may become lower.

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 possible to the regulator IC.

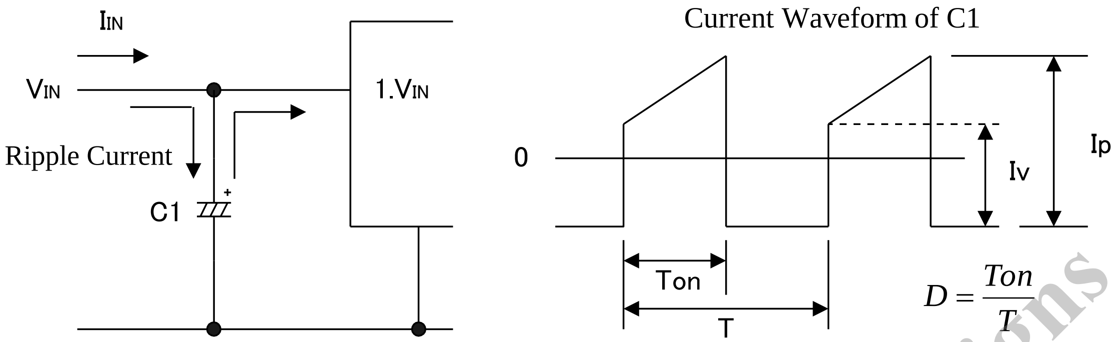
Even in the case that the rectifying capacitor of the AC rectifier circuit is located in the input circuit, the input capacitor cannot play a role of the rectifying capacitor unless it is connected close to the SI-8000FDL.

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 voltage shall be met.

Current Flow of C1



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

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 calculated by the following equation (2):

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

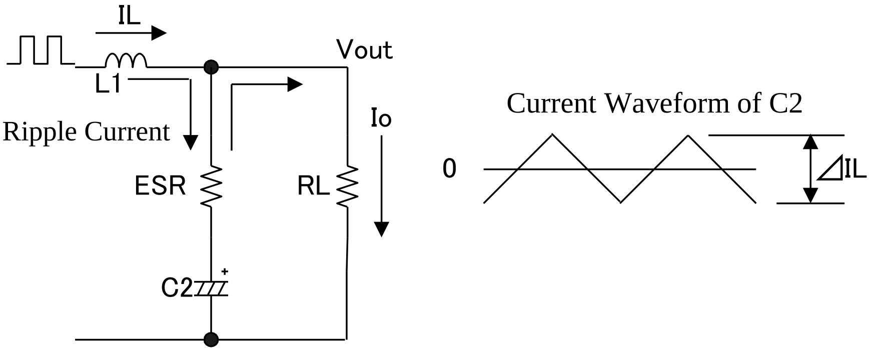
For instance, where V_{IN} = 20V, Io = 3A and Vo= 5V,

$$Irms \approx 1.2 \times \frac{5}{20} \times 3 = 0.9A$$

Therefore, it is necessary to select the capacitor with the allowable ripple current of 0.9A or higher.

4-1-3 Output Capacitor C2

The output capacitor C2 composes a LC low pass filter together with a choke coil L1 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.



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.

The ripple current effective value of the output capacitor is calculated by the equation (3).

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

When ΔIL = 0.5A,

$$Irms = \frac{0.5}{2\sqrt{3}} \fallingdotseq 0.14A$$

Therefore a capacitor having the allowable ripple current of 0.14A or higher is required.

In addition, the output ripple voltage Vrip of the regulator is determined by a product of the pulse current ΔIL of the choke coil current (= C2 charging/discharging current) and the equivalent series resistance ESR of the output capacitor.

$$Vrip = \Delta IL \cdot C2ESR \qquad ---(4)$$

It is therefore necessary to select a capacitor with low equivalent series resistance ESR in order to lower the output ripple voltage. As for general electrolytic capacitors of same product series, the ESR shall be lower, for the products of higher capacitance with same withstand voltage, or with higher withstand voltage (almost proportional to larger externals) with same capacitance.

When ΔIL = 0.5A, Vrip = 40mV,

$$C2esr = 40 \div 0.5 = 80m\Omega$$

As shown above, a capacitor with the ESR of 80mΩ or lower should be selected. In addition, since the ESR varies with temperature and increases at low temperature, it is required to examine the ESR at the actual operating temperatures. It is recommended to contact capacitor manufacturers for the ESR value since it is peculiar to capacitors.

However, if the ESR of the output capacitor is too low (10 - 30mΩ or lower), the phase margin within the feedback loop of the regulator will be short to make the operation unstable. 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).

4-1-4 Flywheel Diode D1

The flywheel diode D1 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 damaged by applying reverse voltage due to the recovery and ON voltage.

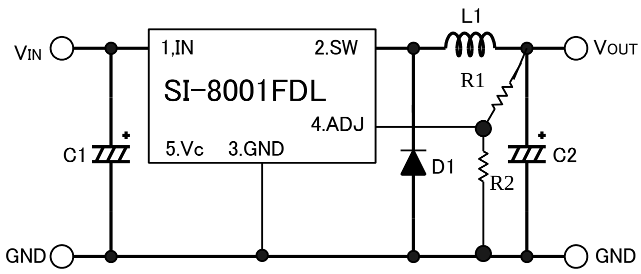
In addition, since the output voltage from the SW terminal (pin 2) of the SI-8000FD series is almost equivalent to the input voltage, the flywheel diode with the reverse withstand voltage of the input voltage or higher should be used.

It is recommended not use the ferrite beads for the flywheel diode.

● 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.

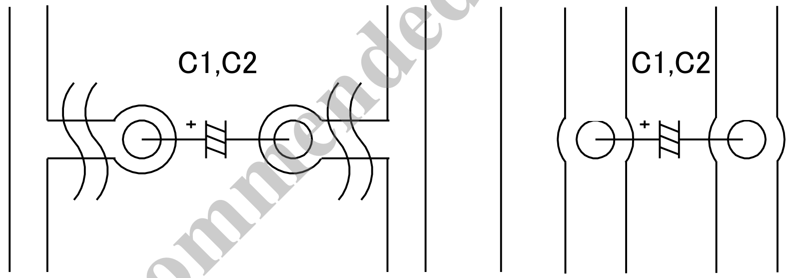


4-2-2 Input / Output Capacitor

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 ADJ Terminal (Output Voltage Set-up)

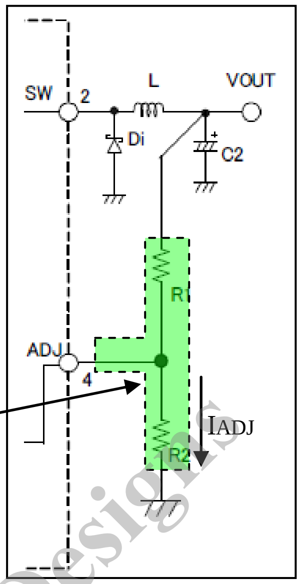
The ADJ terminal is a feedback detection terminal for controlling the output voltage. It is recommended to connect it as close as possible to the output capacitor C2. When they are not close, the abnormal oscillation may be caused due to the poor regulation and increase of switching ripple. The output voltage set-up is achieved by connecting R1 and R2. (The I_{ADJ} lower limit is 0.8mA, and the upper limit is not defined. However, it is necessary to consider that the consumption current shall increase according to the I_{ADJ} value, resulting in lower efficiency.)

R1, R2 and output voltage are calculated from the following equations:

$I_{ADJ} = V_{ADJ} / R2$ *$V_{ADJ} = 0.8v \pm 2\%$

$R1 = (Vo - V_{ADJ}) / I_{ADJ}$ $R2 = V_{ADJ} / I_{ADJ}$

$Vout = R1 \times (V_{ADJ} / R2) + V_{ADJ}$



The layout of voltage detection line should be made in compact form for stable operation in order to avoid the effect of switching noise.

R2 should be connected for the stable operation when set to Vo = 0.8V.

It is recommended to set the output voltage to 8% or higher of the input voltage.

Constants and variation range are shown in the following table in the case that the output voltage is set for the output voltage setting resistors R1 and R2 by the resistance constants of existing accuracy of 1% and 0.5%.

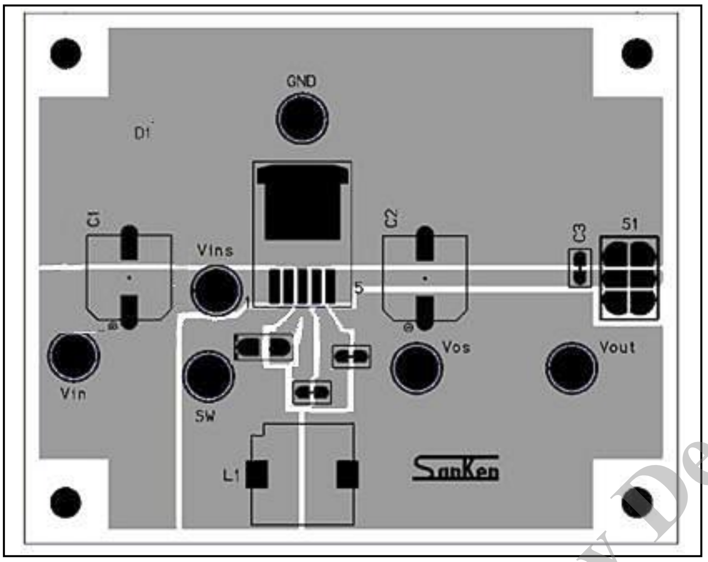
Table of constants for R1/R2 Vo setting

Target Vout (V)	Resistance Constants of Accuracy of 1%			Resistance Constants of Accuracy of 0.5%		
	R1 (Ω)	R2(Ω)	Calculated Accuracy (%)	R1 (Ω)	R2(Ω)	Calculated Accuracy (%)
1.2	402	806	+2.61 / −2.73	402	806	+2.26 / −2.41
1.8	1000	806	+2.72 / −3.48	1010	806	+2.72 / −2.41
2.5	1690	787	+4.15 / −2.64	1690	796	+2.64 / −2.73
3.3	2490	806	+2.67 / −4.31	2490	796	+2.86 / −2.67
5	4220	806	+3.50 / −3.85	4170	796	+2.68 / −3.00
9	8250	806	+3.75 / −3.89	8160	796	+2.95 / −2.88
12	11000	787	+3.77 / −3.96	11100	796	+2.58 / −3.27
24	23200	806	+3.25 / −4.57	23400	806	+3.11 / −2.84

The wiring of ADJ terminal, R1 and R2 that run parallel to the flywheel diode should be avoided, because switching noise may interfere with the detection voltage to cause abnormal oscillation. It is recommended to implement the wiring from the ADJ terminal to R2 as short as possible.

Mounting Board Pattern Example

Surface Mount Type (SI-8001FDL)

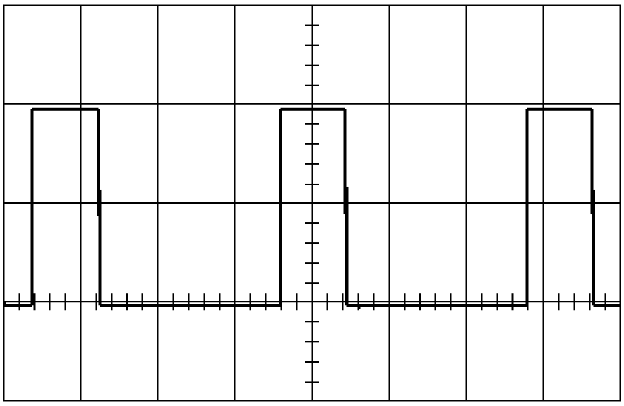


● 4-3 Operation Waveform Check

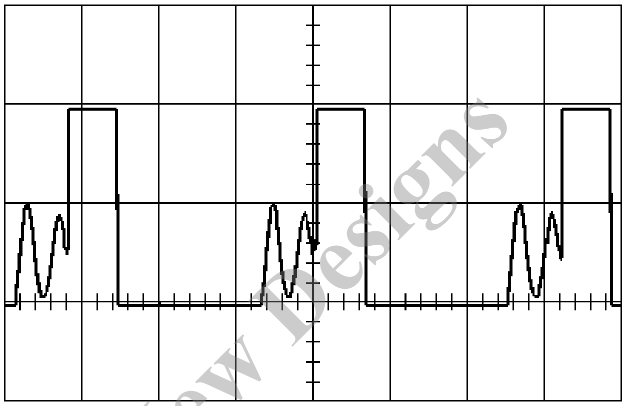
It can be checked by the waveform between the pin 2 and 3 (SW - GND) of the SI-8000FDL whether the switching operation is normal or not.

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

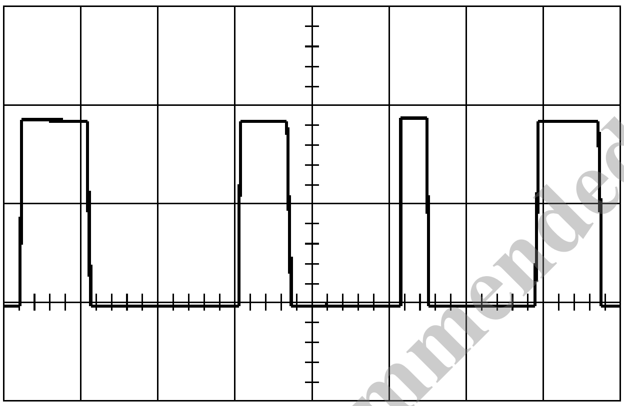
1. Normal Operation (continuous area)



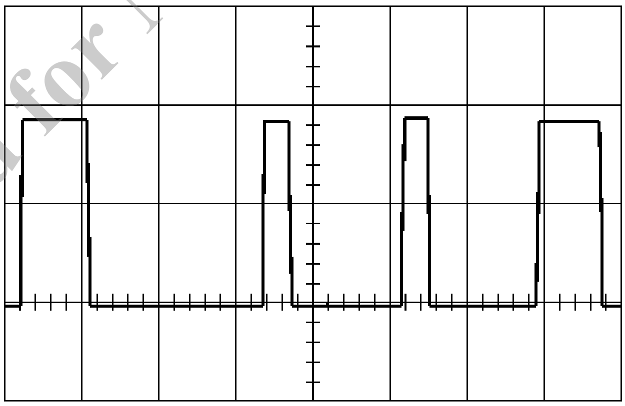
2. Normal Operation (discontinuous area)



3. When C1 and C4 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.

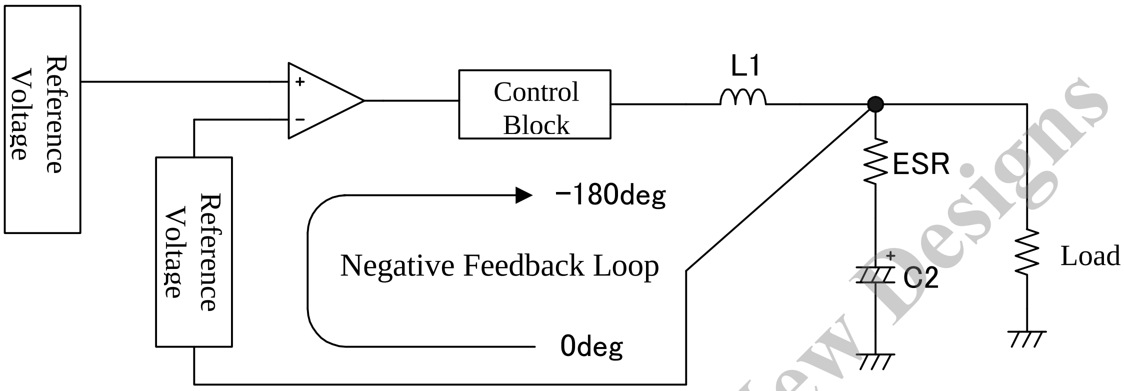
In the continuous area, the switching waveform is formed in the normal rectangular waveform (waveform 1) and in the discontinuous area, damped oscillation is caused in the switching waveform (waveform 2), but this is a normal operation without any problem.

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 Power Supply Stability

4-4-1 Phase Margin

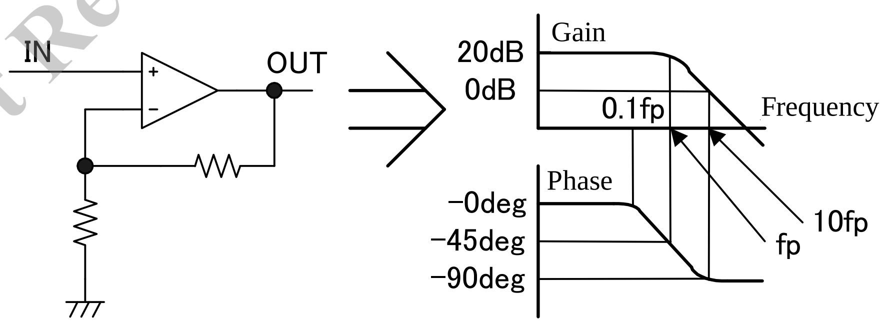
This block diagram shows that the chopper type regulator is a negative feedback amplifier which controls the output voltage by constantly comparing with the output voltage and the reference voltage which is set in advance. Therefore, it has a negative feedback loop to control the output by detecting the variation of output voltage with the error amplifier.



The phase within the negative feedback loop is displaced by 180° to negate the variation of the output voltage, but in the event that the phase is further delayed by 180° in the state that the amplification degree (gain) is 1 or more, the total phase delay amounts to 360° to deviate from the stable operation zone to cause abnormal oscillation. This is called Barkhausen oscillation conditions. Therefore, the oscillation conditions should not be accrued in the actual stabilized power supply.

It is possible to judge whether the Barkhausen oscillation conditions are accrued or not by means of frequency and gain/phase characteristics of the negative feedback loop. The frequency-gain/phase characteristics are called Bode diagram.

1-step Differential Amplifier　　　Bode Diagram Example

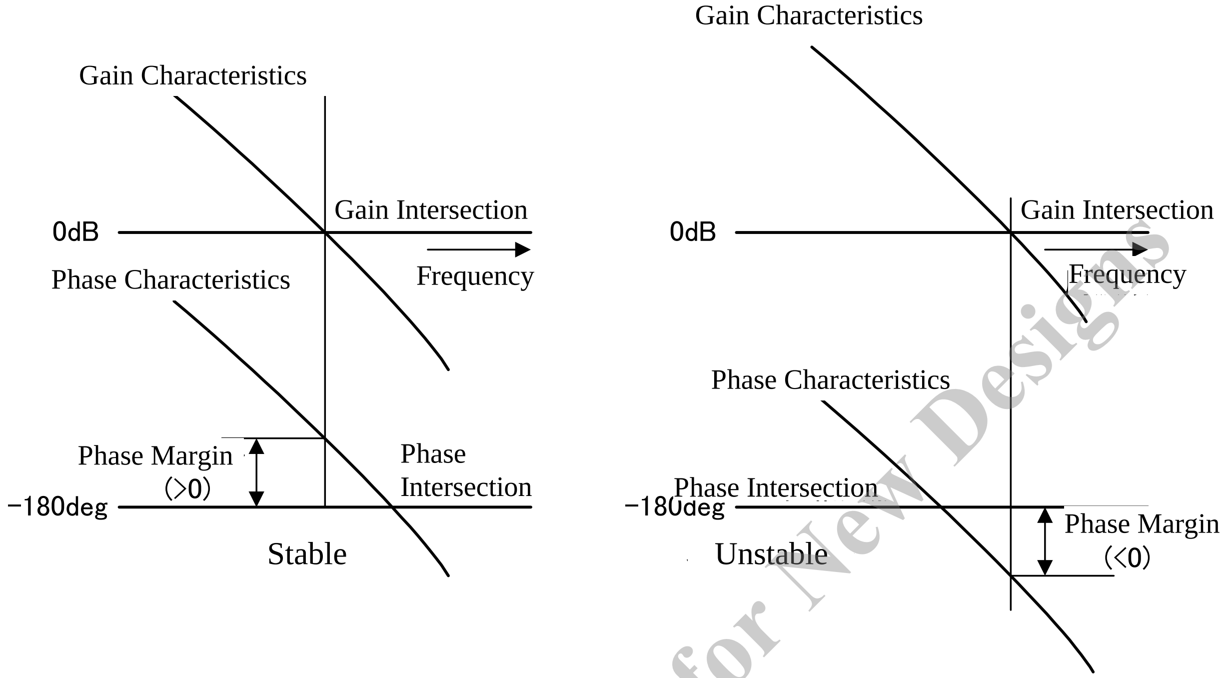


In the Bode diagram, the frequency at which the gain is 1 (0 dB) is called gain intersection and the frequency at which the phase of feedback loop is -180° is called phase intersection.

Unless the phase reaches -180° at the frequency of gain intersection, the oscillation conditions are not met.

In this respect, the phase at gain intersection - (-180°) is equal to the phase at gain intersection + 180° and this value is used as a margin to -180° which is called phase margin. The more the phase margin is, the less likely the abnormal oscillation is to occur against the variation of environmental conditions such as input/output conditions and temperature. Therefore, sufficient phase margin should be taken into consideration in order to maintain the stable operation.

Stability Judgment at Bode Diagram



4-4-2 Phase Characteristics of Regulator IC

The phase characteristics of the chopper type regulator are synthesized by the phase characteristics inside the regulator IC and that of the LC filter.

The phase characteristics inside the regulator IC are generally determined by the delay time of the control block and the phase characteristic of the output error amplifier.

Among these two factors, the phase delay due to the delay time of the control block rarely causes problems in actual use. Therefore, the phase characteristics of the error amplifier are important.

With respect to the compensation of phase characteristics of the output error amplifier, there are two types of regulator ICs. One is that compensation is made in the IC in advance, while another type is that external components such as resistors and capacitors are added to the IC for compensation.

In the former case, it is only a matter of selection of the LC filter, but in the latter case, appropriate phase compensation should be made in accordance with the application of the product.

4-4-3 Phase Characteristics of LC Filter

The phase margin of the chopper type regulator depends largely on the phase characteristics of the LC filter for output smoothing. The phase characteristic of the LC filter theoretically shows the characteristics of a secondary delay factor. Resonance is caused at a specific frequency due to the combination of inductance L1 of coil and of capacitance C2 of the capacitor and at frequency higher than the resonance point, the phase is delayed by 180°at a maximum.

The resonance frequency is expressed as shown in the equation (5):

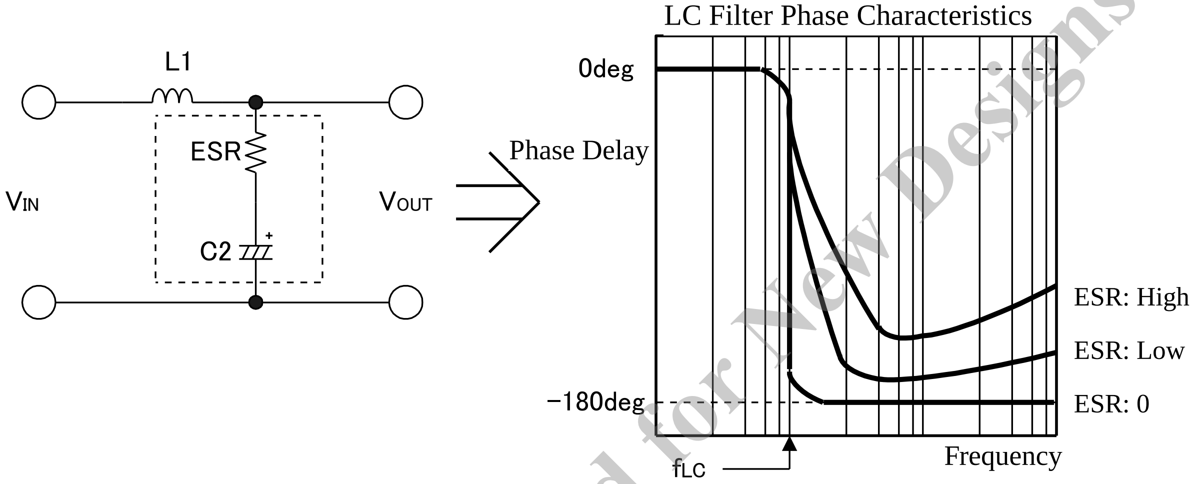
$$f_{LC} = \frac{1}{2\pi\sqrt{LC}} \qquad ---(5)$$

The phase characteristics are 0° if they are lower than the resonance frequency fLC.

The phase characteristics are 180° if they are higher than the resonance frequency fLC.

Accordingly, when the LC filter for output smoothing shows the theoretical phase characteristics, the phase delay reaches -180° in this filter portion and the phase margin will be zero for this regulator.

However, in the actual LC filter, the phase delay of the LC filter is less than 180°because of influence of the equivalent series resistance (ESR) of capacitor. Consequently, the phase margin can be secured for the regulator because of this phase compensation effect of the equivalent series resistance (ESR).



Generally speaking, when such capacitors as tantalum capacitors or laminated capacitors are used for the output LC filter, the phase delay of filters will be large.

Therefore, from the view point of securing the phase margin, use of the electrolytic capacitor is preferable.

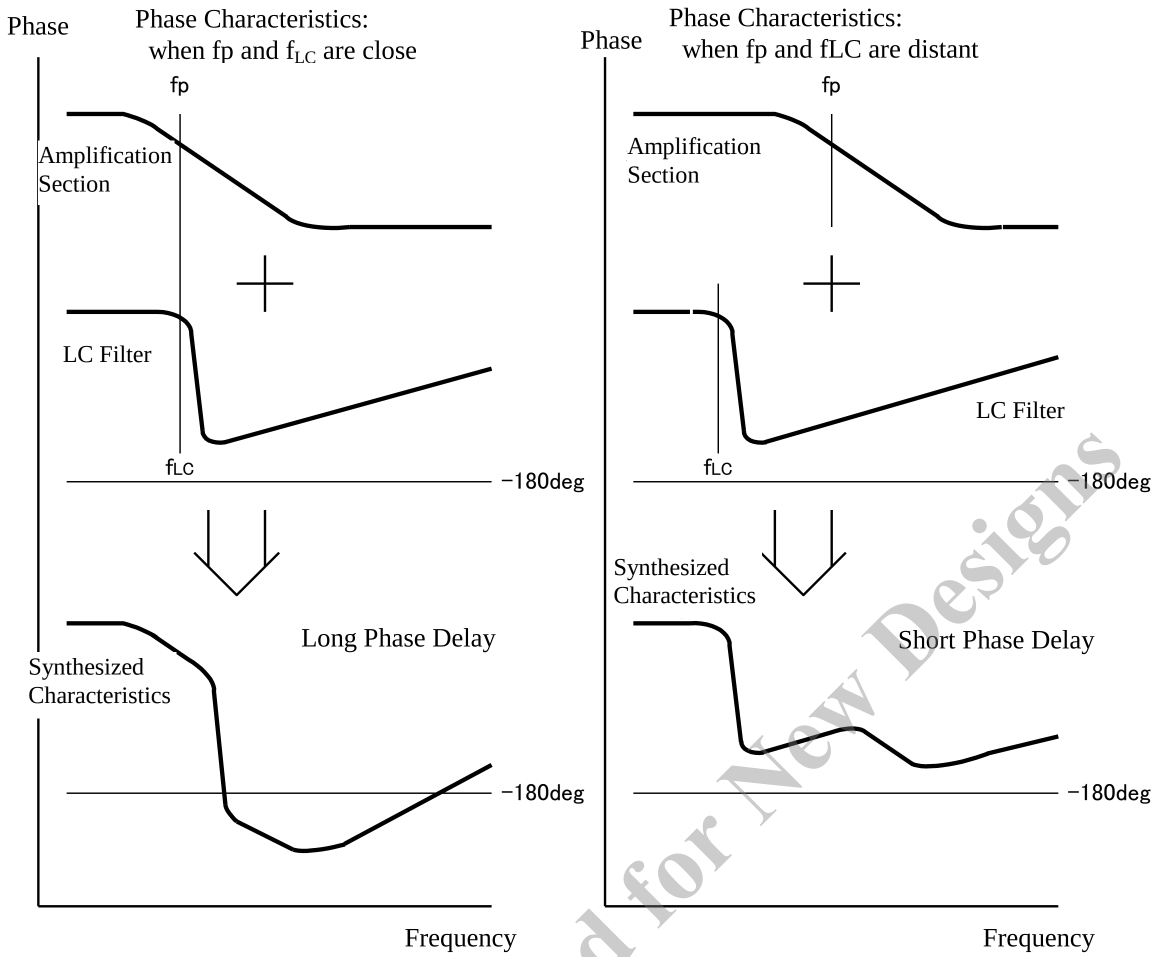
4-4-4 Relation of Phase Characteristics of Internal IC and LC Filter

As described above, the phase characteristics of the chopper type regulator is almost determined by the phase characteristics of the error amplifier and LC filter. In this respect, the relation between these two characteristics is important.

When the gain lowering commencement frequency of the error amplifier, namely the first pole frequency fp and the resonant frequency of the LC filter f_{LC} are closer, the phase margin of the regulator is decreased because of concentrated phase delay. In this respect, the proper distribution of fp and fLC is important.

Normally, the phase delay of error amplifier commences from 0.1 times of the first pole frequency fp.

In order to avoid the concentration of phase delay, the resonant frequency of the LC filter f_{LC} should be kept to be less than 0.1 times of the first pole frequency fp of the error amplifier.

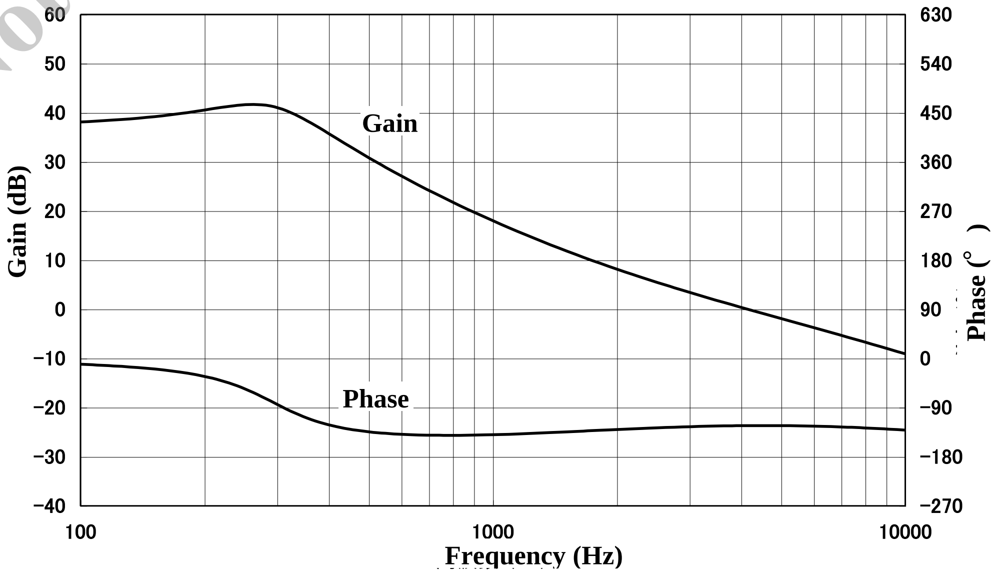


Generally, the frequency fp of the chopper type regulator IC is set from several KHz to higher than ten KHz.

With respect to the constants of LC filters described in the applications of each regulator IC, if the inductance of coil or capacitance of the capacitor is set to be less than the recommended values, the resonant frequency f_{LC} of the LC filter may rise to decrease the phase margin. Care should be taken to this phenomenon.

The constants of peripheral components should be properly selected according to the applications of each regulator I.C.

Typical Characteristics of Gain and Phase



● 4 - 5 Thermal Design

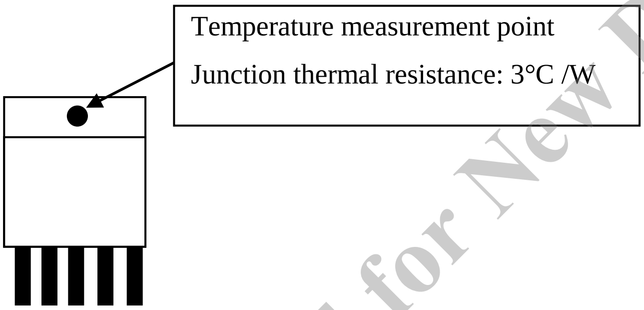
4-5-1 Calculation of Heat Dissipation for SI-8001FDL

In the case of the surface mounting type SI-8001FDL, the heat is dissipated toward the copper foil on the mounting board, therefore the thermal design should be made in consideration of copper foil area, board material and number of copper foil layers.

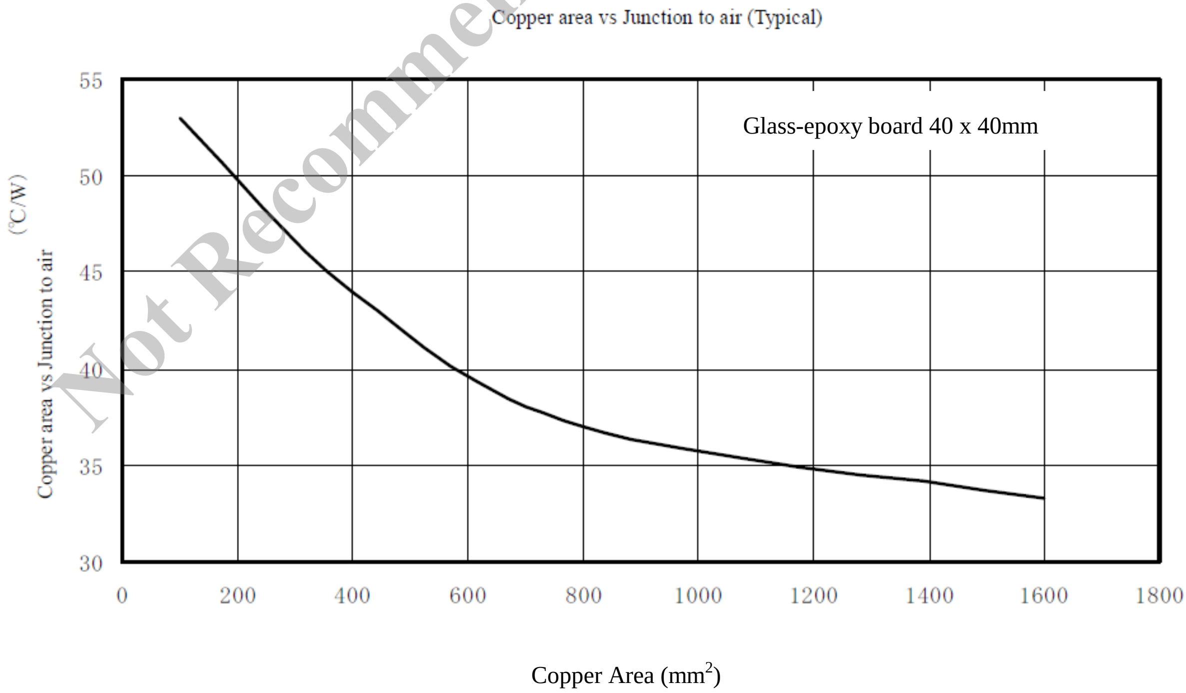
The stem part of the backside of the SI-8001FDL is connected with pin 3 (GND) by the inner frame and heat dissipation performance is improved by taking the larger GND pattern which is directly connected with the stem part.

In order to confirm the junction temperature, the temperature of the stem spot shown below should be measured to calculate the temperature by the following equation.

$T_j = T_c + P_d \times 3°C/W$ * T_c = Actually measured stem temperature



Reference data (Copper foil are vs Thermal resistance on single side copper foil board)



5. Application

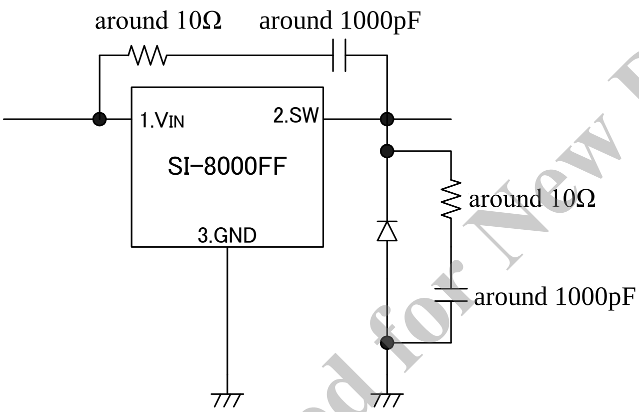
● 5-1 ON / OFF Control of Output

Voltage is directly applied to Vc terminal (pin 5) to enable the ON/OFF control of output.

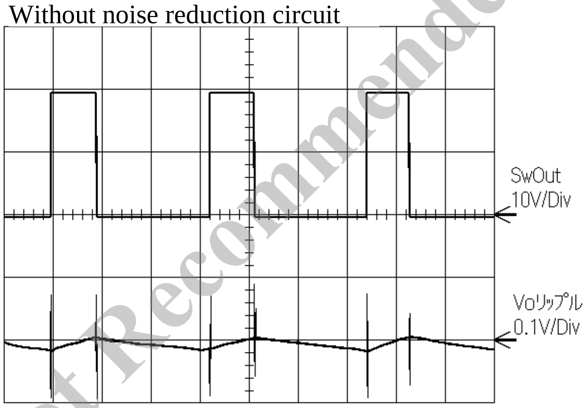
When the Vc terminal is open, the operation is in ON state.

● 5-2 Spike Noise Reduction

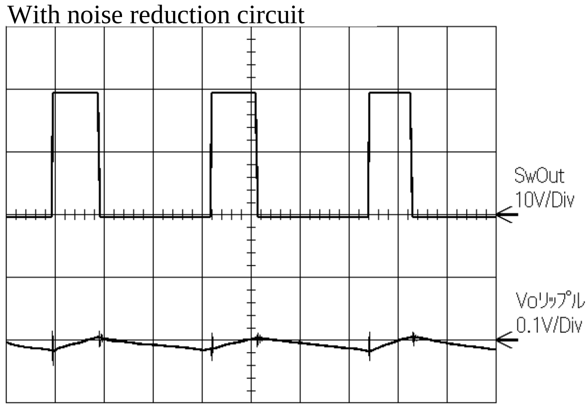
In order to reduce the spike noise, it is possible to compensate the output waveform of the SI-8000FD and the recovery time of the diode by a capacitor, but it should be noted that the efficiency is also slightly reduced.



Without noise reduction circuit



With noise reduction circuit

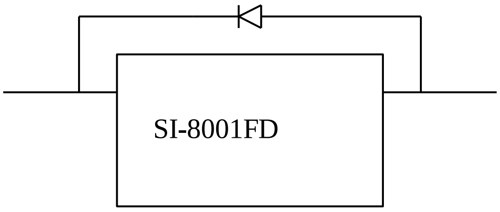


A resistor of 10 Ω and a capacitor of 2200pF are connected to external resistor

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

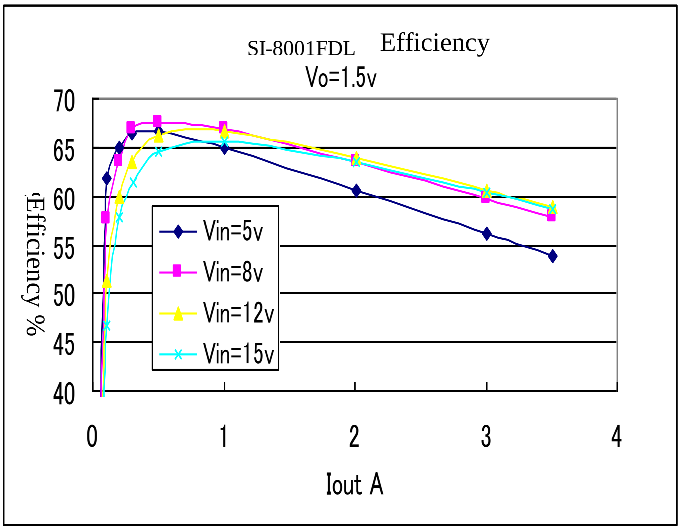
● 5-3 Reverse Bias Protection

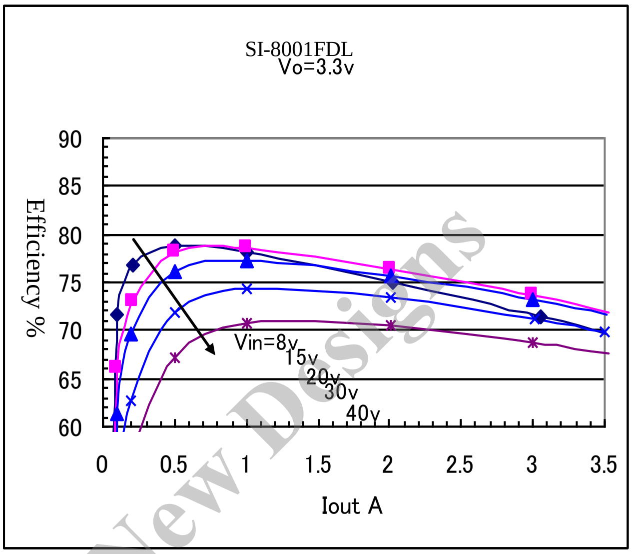
A diode for reverse bias protection will be required between input and output when the output voltage is higher than the input terminal voltage, such as in battery chargers.

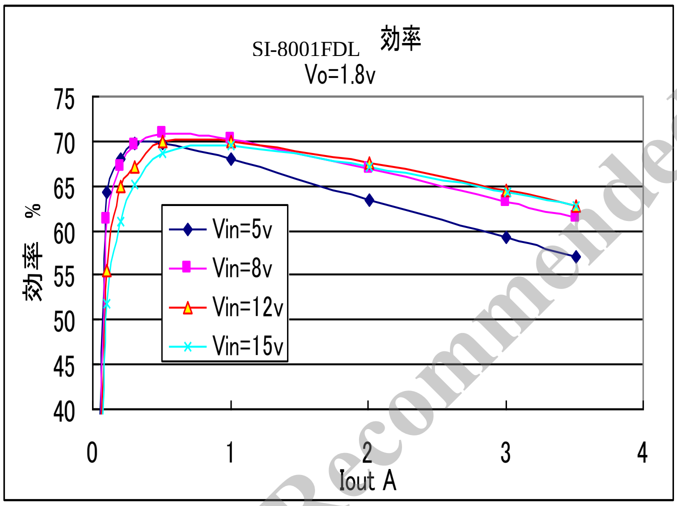


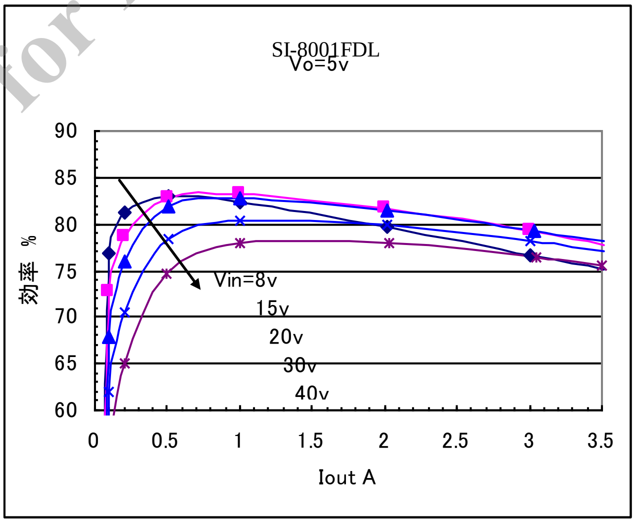
6. Typical Characteristics

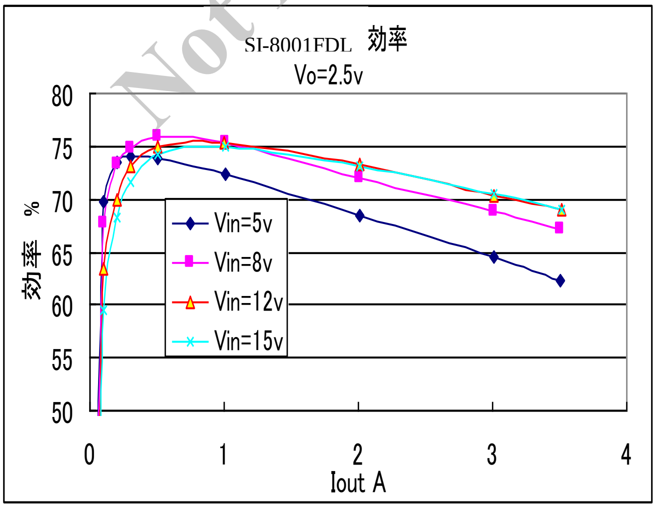
(1) Efficiency

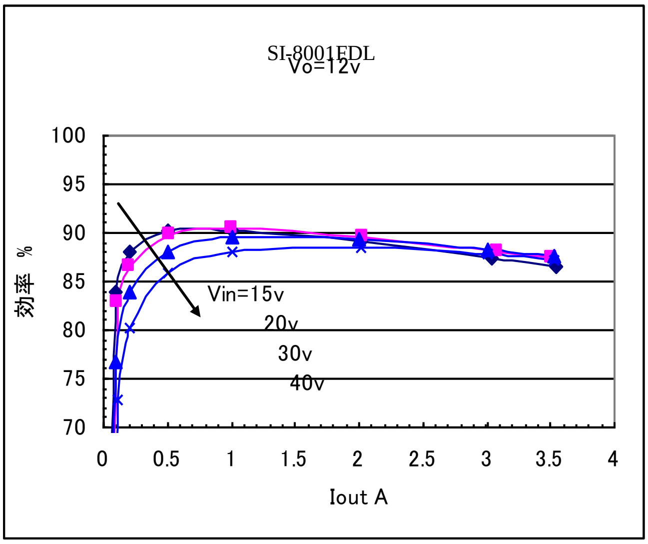


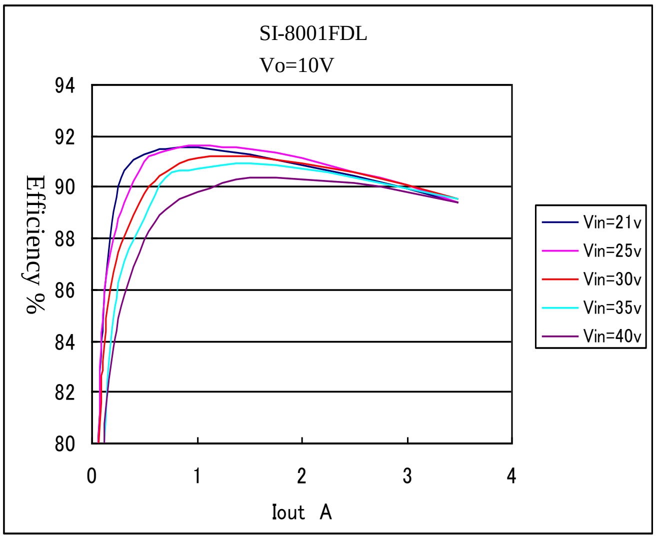




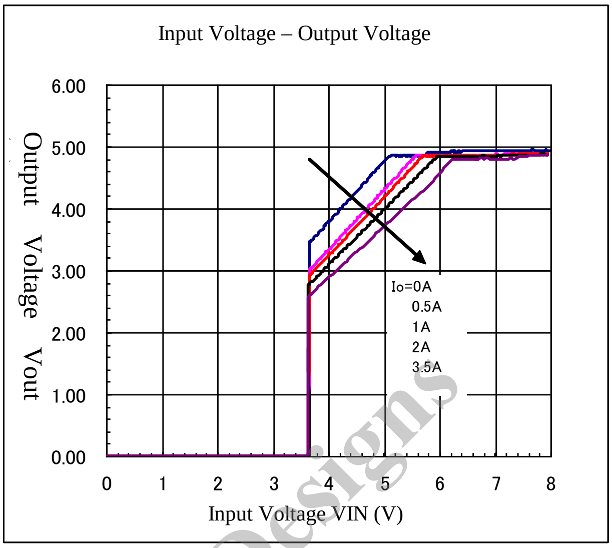


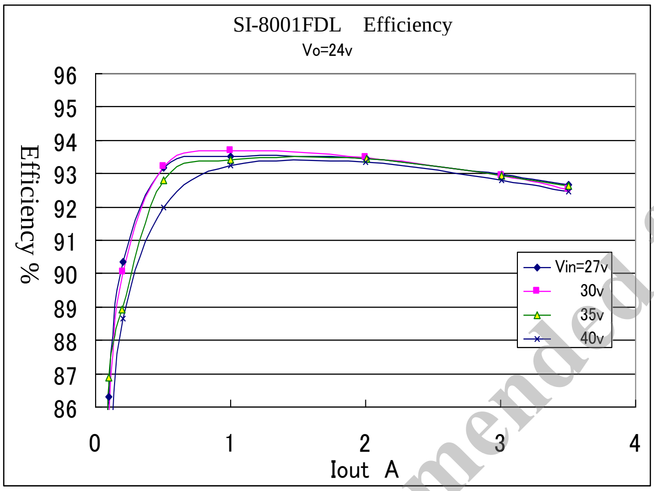




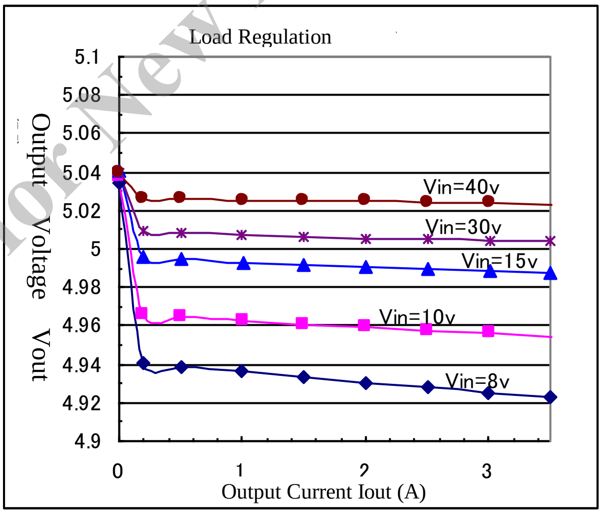


(2) Rising Characteristics

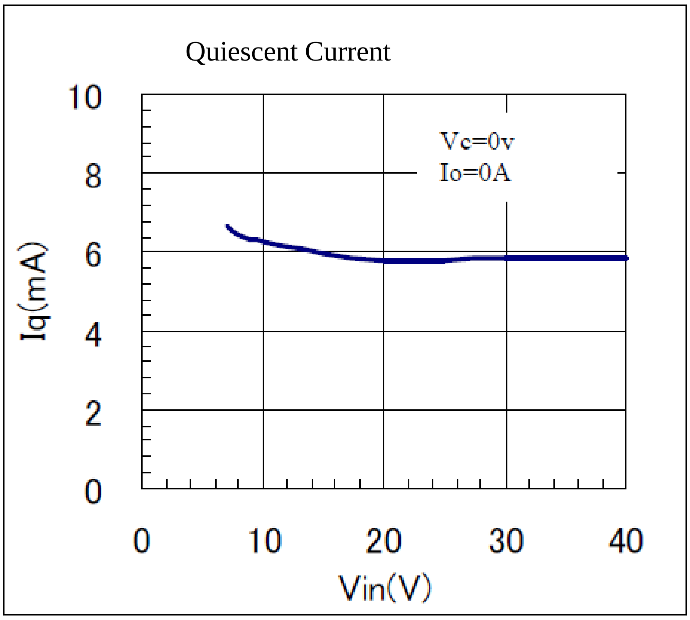




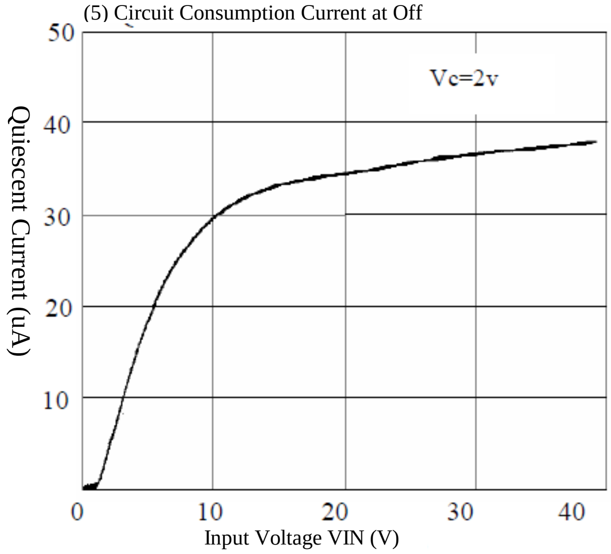
(3) Load Regulation



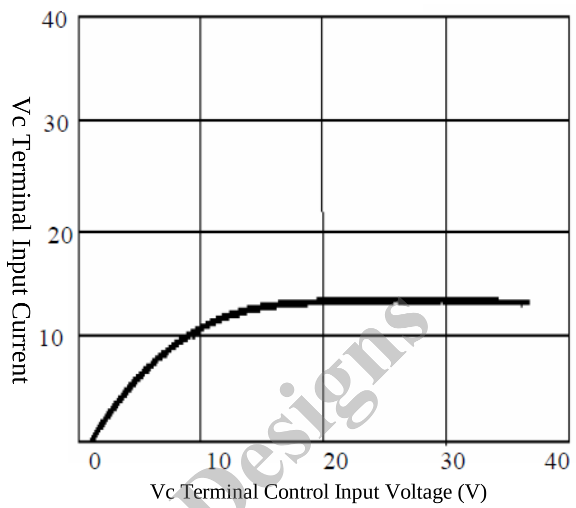
(4) Quiescent current



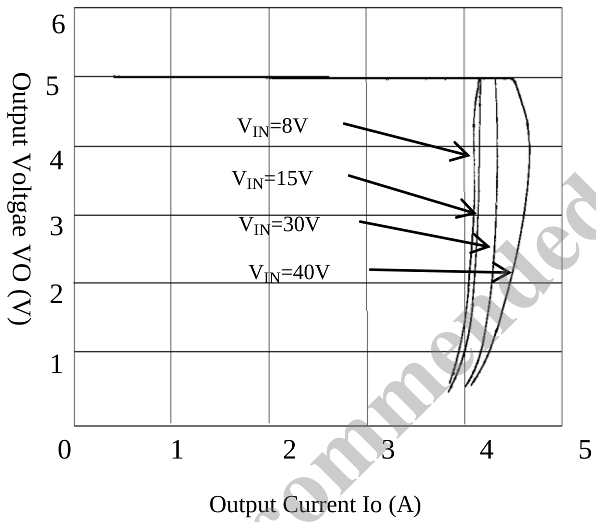
(5) Circuit Consumption Current at Off



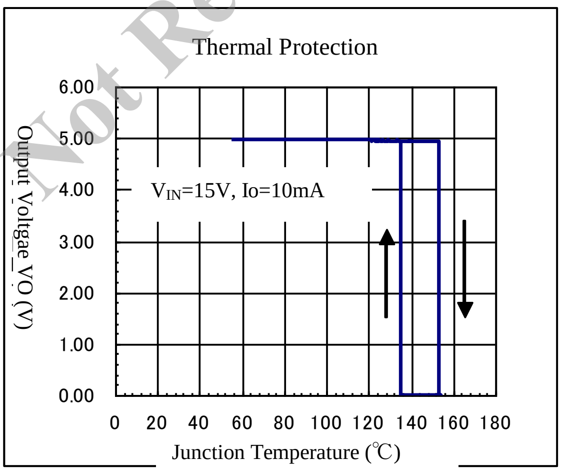
(8) Vc Terminal Control Input Current



(6) Over Current Protection



(7) Thermal Protection



7. 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 widthis 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 specified 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.

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