Application Note

Dual Output Surface Mounted type Switching Regulator IC

SPI-8000TW Series

2nd Edition June 2006

SANKEN ELECTRIC CO., LTD

――― Contents ―――

1. General Description

The SPI-8000TW series (SPI-8001TW, SPI-8002TW and SPI-8003TW) are a regulator IC provided with various functions required for the buck regulator as well as protection functions against overcurrent and overheat. Two of 1.5A variable outputs are provided in a package for surface mounting to realize a small and highly efficient switching regulator.

● 1-1 Features

- Small package, high output current 1.5A

  HSOP – 16-pin surface mounting package with the maximum output current of 1.5A for each output
- High efficiency

  80% TYP (SPI-8001TW, V_{IN} = 15V / Io = 0.5A)

  78% TYP (SPI-8002TW, V_{IN} = 15V / Io = 0.5A)

  78% TYP (SPI-8003TW, V_{IN} = 14V / Io = 0.5A)
- Variable output voltage

  1 – 16V (SPI-8001TW), 1 – 24V (SPI-8002TW and SPI-8003TW)
- Low voltage/high precision reference voltage

  1V ±1% and low voltage/high precision
- Operational frequency

  Choke coil can be downsized by means of 250kHz fixed (SPI-8001TW and SPI-8002TW), 200 – 400 kHz variable (SPI-8003TW) and high operating frequency.
- Low power consumption

  1μA or less at output off. Low power consumption can be realized during standby operation.
- Built-in functions

  The foldback type overcurrent protection and thermal shutdown circuit
- Built-in control function

  Output ON/OFF control function (applicable for each channel), soft start function

● 1-2 Applications

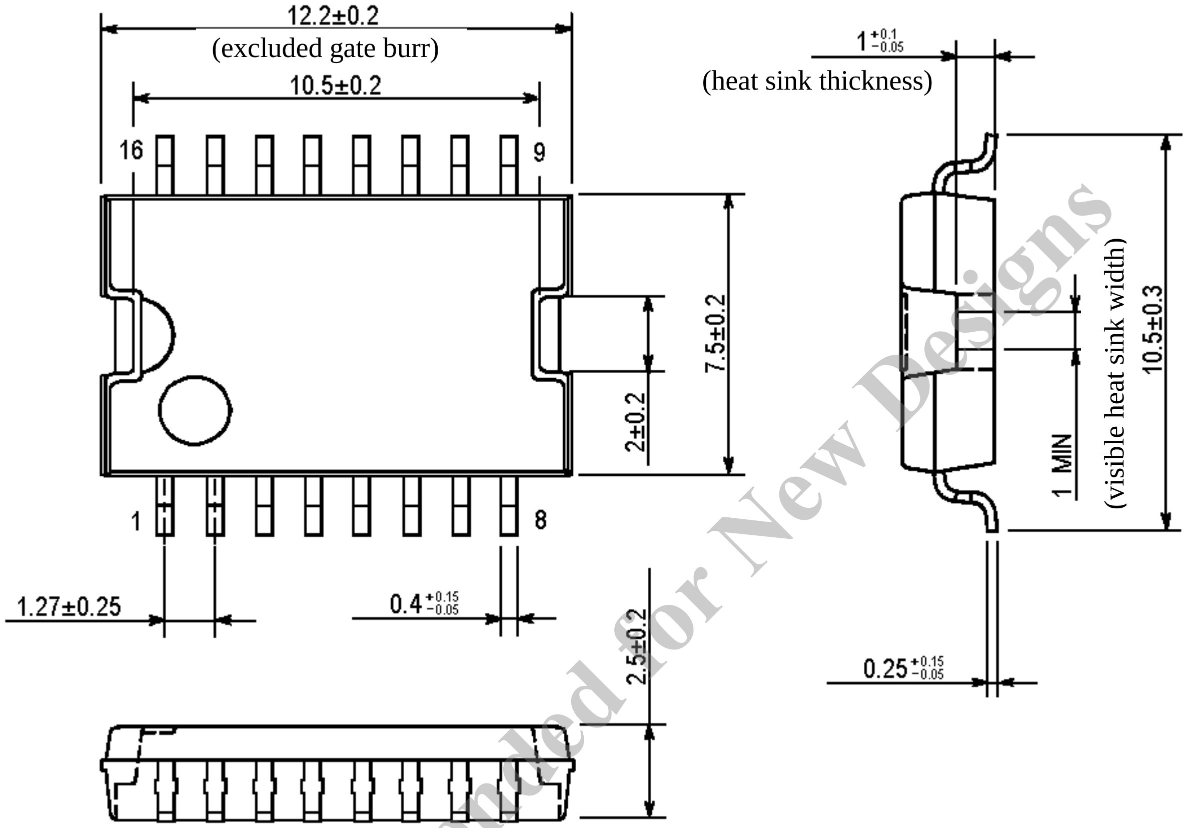
For on-board local power supplies, power supplies for OA equipment and stabilization of secondary output voltage of regulator.

● 1-3 Types

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

2. Specification

● **2-1 Package Information**



● 2-2 Ratings

Absolute Maximum Rating *1

<table>
<tr><th>Parameter</th><th>Symbol</th><th>Rating</th><th>Unit</th><th>Condition</th></tr>
<tr><td>Input Voltage V_{IN}</td><td>VIN</td><td rowspan="2">21</td><td>V</td><td rowspan="2">(8001TW)</td></tr>
<tr><td rowspan="2">Input Voltage V_{CC}</td><td rowspan="2">VCC</td><td rowspan="2">V</td></tr>
<tr><td rowspan="2">40</td><td rowspan="2">(8002TW,8003TW)</td></tr>
<tr><td>Input Voltage $V_{C/E}$</td><td>VC/E</td><td>V</td></tr>
<tr><td>Power Dissipation *2</td><td>Pd</td><td>3.0</td><td>W</td><td>Glass epoxy board: 70.0cm^2
(Copper foil area: 30.8cm^2)</td></tr>
<tr><td rowspan="2">Junction Temperature</td><td rowspan="2">Tj</td><td>135</td><td rowspan="2">°C</td><td>(8001TW,8002TW)</td></tr>
<tr><td>150</td><td>(8003TW)</td></tr>
<tr><td rowspan="2">Storage Temperature</td><td rowspan="2">Tstg</td><td>-40 - 135</td><td rowspan="2">°C</td><td>(8001TW,8002TW)</td></tr>
<tr><td>-40 - 150</td><td>(8003TW)</td></tr>
<tr><td>Thermal Resistance
(Junction and case)</td><td>θj-c</td><td>9.0</td><td>°C /W</td><td>Glass epoxy board: 70.0cm^2
(Copper foil area: 30.8cm^2)</td></tr>
<tr><td>Thermal Resistance
(Junction and ambient)</td><td>θj-a</td><td>35.8</td><td>°C /W</td><td>Glass epoxy board: 70.0cm^2
(Copper foil area: 30.8cm^2)</td></tr>
</table>

*1 Absolute Maximum Ratings 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.

*2 Absolute Maximum Ratings are restricted by thermal shutdown.

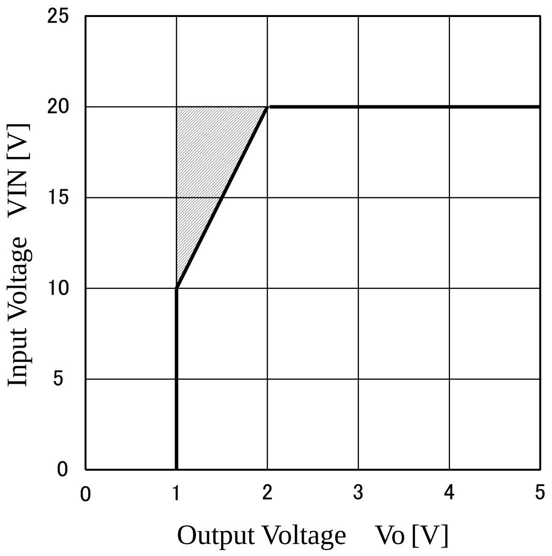
Recommended Condition *3

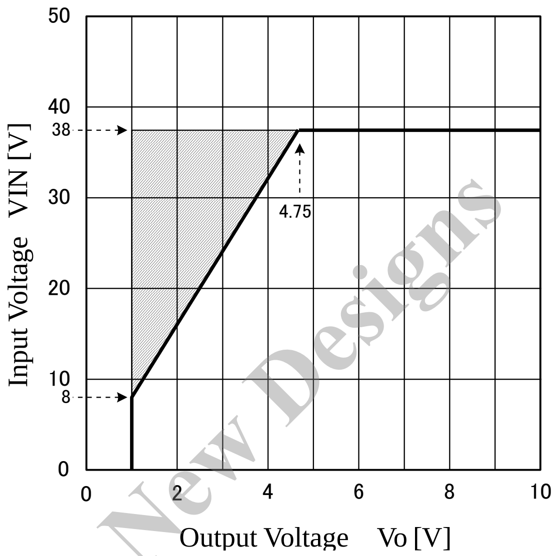
<table>
<tr><th rowspan="2">Parameter</th><th rowspan="2">Symbol</th><th colspan="2">Rating</th><th rowspan="2">Unit</th></tr>
<tr><th>MIN</th><th>MAX</th></tr>
<tr><td>Input Voltage VIN *4</td><td>VIN</td><td>VO+3</td><td rowspan="3">20 (8001TW)
38 (8002/3TW)</td><td>V</td></tr>
<tr><td>Input Voltage VCC</td><td>VCC</td><td>4.5</td><td>V</td></tr>
<tr><td>Input Voltage VC/E</td><td>VC/E</td><td></td><td>V</td></tr>
<tr><td>Output Voltage</td><td>Vo</td><td>1</td><td>16 (8001TW)
24 (8002/3TW)</td><td>V</td></tr>
<tr><td>Output Current</td><td>IOUT</td><td></td><td>1.5</td><td>A</td></tr>
<tr><td>Junction Temperature in Operation</td><td>Tjop</td><td>-30</td><td>135(8001/2TW)
125(8003TW)</td><td>°C</td></tr>
<tr><td>Temperature in Operation</td><td>Top</td><td>-30</td><td>135(8001/2TW)
85(8003TW)</td><td>°C</td></tr>
</table>

*3 Recommended Conditions shows the operation conditions required for maintaining normal circuit functions that are shown in electrical characteristics. It is required to meet the conditions in actual operations.

*4 Please refer to figures below for maximum input voltage.

Input Voltage Range (8001TW, 8002TW and 8003TW)





- In the output voltage of 2 – 16V of SPI-8001TW, the input voltage range is Vo +3 – 20V.
- In the output voltage of 4. 75 – 24V of SPI-8002TW and SPI-8003TW, the input voltage range is Vo +3 – 38V.
- Under the conditions of use of shaded area, oscillation may become unstable due to the degradation of phase margin and the decrease of ON width, therefore the capacity of choke coil L and output capacitor C2 and C3 should be made large.

Electrical Characteristics (SPI-8001TW and SPI-8002TW) *5 (Ta=25°C)

Parameter		Symbol	Rating MIN	Rating TYP	Rating MAX	Unit	Condition
Setting Reference Voltage		VREF	0.996	1.006	1.016	V	VIN=10V, Vo=1V, IO=0.1A
Output Voltage Temperature Coefficient		ΔVREF/ ΔT		±0.1		mV/°C	VIN=10V, Vo=1V, IO=0.1A, Ta=-30 - 135°C
Efficiency1 *6		Eff1		80/78		%	VIN=VCC=15V,VO=5V, Io=0.5A
Efficiency2 *6		Eff2		83/81		%	VIN=15V, VO=5V, Io=0.5A, VCC=5V
Operational frequency		fosc		250		kHz	VIN=VCC=15V,VO=5V, Io=0.5A
Line Regulation		VLine		30	60	mV	VIN=VCC=10 - 20V, Vo=5V, IO=1A
Load Regulation		VLoad		10	40	mV	VIN= VCC=15V, Vo=5V, IO=0.2 - 1.5A
Overcurrent Protection Start Current		IS	1.6			A	VIN= VCC=15V
Circuit Current in Non-operation 1		IIN		4		mA	VIN= 15V, VCC=5V, IO=0A, VO≤ 12V
Circuit Current in Non-operation 2		ICC		8.5		mA	VCC=15V, IO=0A
Circuit Current in Non-operation 3		IIN(off)			1	μA	VIN=15V, VC/E=0V or Open
Circuit Current in Non-operation 4		ICC(off)			1	μA	VCC=15V, VC/E=0V or Open
C/E Terminal	High level Voltage	VC/EH	2.0			V	VIN=VCC=15V
	Low level Voltage	VC/EL			0.8	V	VIN=VCC=15V
	Flow-out Current at High level	IC/EH		95		μA	VC/E=20V
SS Terminal *7	Low level Voltage	VSSL			0.5	V	VIN= VCC=15V
	Flow-out Current at Low level	ISSL		60	80	μA	VSSL=0V, VIN= VCC=15V

* The left side and right side of columns of efficiency rating values show that of SPI-8001TW and SPI-8002TW respectively.

Electrical Characteristics (SPI-8003TW) *5 (Ta=25°C)

Parameter		Symbol	Rating			Unit	Condition
			MIN	TYP	MAX		
Setting Reference Voltage		VREF	0.996	1.006	1.016	V	VIN=14V, IO=0.1A
Output Voltage Temperature Coefficient		ΔVREF/ ΔT		±0.1		mV/ °C	VIN=14V, IO=0.1A, Ta=-30 - 125°C
Efficiency1 *6		Eff1		78		%	VIN=VCC=14V,VO=5V,Io=0.5A
Efficiency2 *6		Eff2		81		%	VIN=14V,VO=5V,Io=0.5A, VCC=5V
Operational frequency		Fosc	200		400	kHz	VIN=14V,IO=0.1A,Cosc=100pF
Line Regulation		VLine		30	60	mV	VIN=VCC=9 - 18V, Vo=5V, IO=1A
Load Regulation		VLoad		10	40	mV	VIN= VCC=14V, Vo=5V, IO=0.2 - 1.5A
Overcurrent Protection Start Current		IS	1.6			A	VIN= VCC=14V
Circuit Current in Non-operation 1		IIN		4		mA	VIN= 14V, VCC=5V, IO=0A, VO≦12V
Circuit Current in Non-operation 2		ICC		8.5		mA	VCC=14V, IO=0A
Circuit Current in Non-operation 3		IIN(off)			1	μA	VIN=14V, VC/E: Low or Open
Circuit Current in Non-operation 4		ICC(off)			1	μA	VCC=14V, VC/E: Low or Open
Circuit Current in Non-operation 5		IIN(SS0V)		4		mA	VIN= 14V, VCC=5V, IO=0A, SS1=SS2=0V
Circuit Current in Non-operation 6		ICC(SS0V)		8.5		mA	VCC=14V, IO=0A, SS1=SS2=0V
C/E Terminal	High level Voltage	VC/EH	2.0			V	VIN=VCC=14V
	Low level Voltage	VC/EL			0.8	V	VIN=VCC=14V
	Flow-out Current at High level	IC/EH		95		μA	VC/E=20V
SS Terminal *7	Low level Voltage	VSSL			0.5	V	VIN= VCC=14V
	Flow-out Current at Low level	ISSL		60	80	μA	VSSL=0V, VIN= VCC=14V

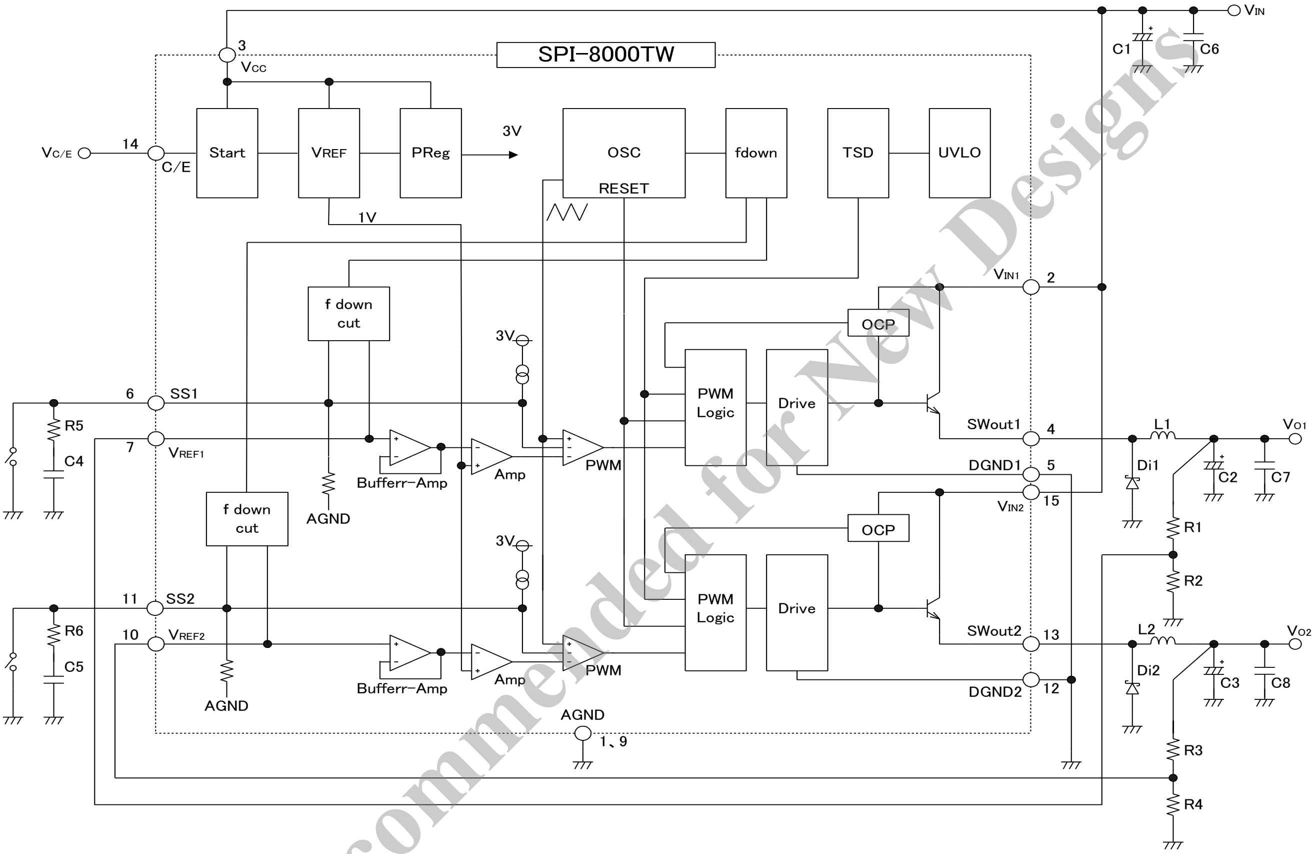
*5 The electrical characteristics shall mean the rated characteristic values assured in the case that the IC is operated under the measurement conditions of each column of the above table.

*6 Efficiency can be calculated by following equation. $\eta(\%) = \frac{Vo \times Io}{V_{IN} \times I_{IN}} \times 100$

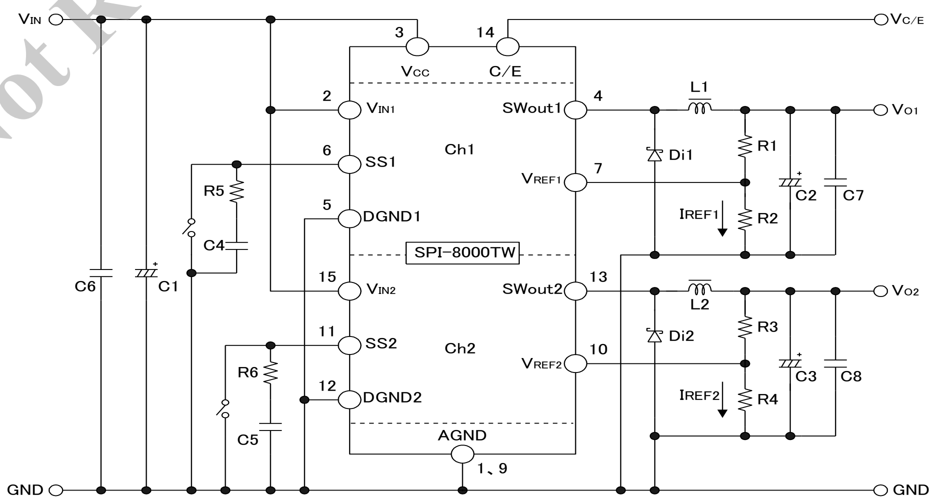
*7 No. 6 and 11 terminals are a SS terminal and soft start can be made by connecting a capacitor. In addition, it is possible to turn on and off the output by using the SS terminal. The output is stopped by lowering the SS terminal voltage below Vsst. The switch-over of potential of SS terminal can be made by open collector driving of the transistor etc. In the case that both soft start and ON-OFF of transistor are used, since the discharge current of C4 and C5 flows across the transistor for ON-OFF, protection for limiting current etc. should be made, if the capacitance of capacitors is large. Because the SS terminal is pulled up to the internal power supply of the IC, voltage cannot be applied from outside.

● 2-3 Circuit Diagram

Internal Equivalent Circuit (SPI-8001TW and SPI-8002TW)



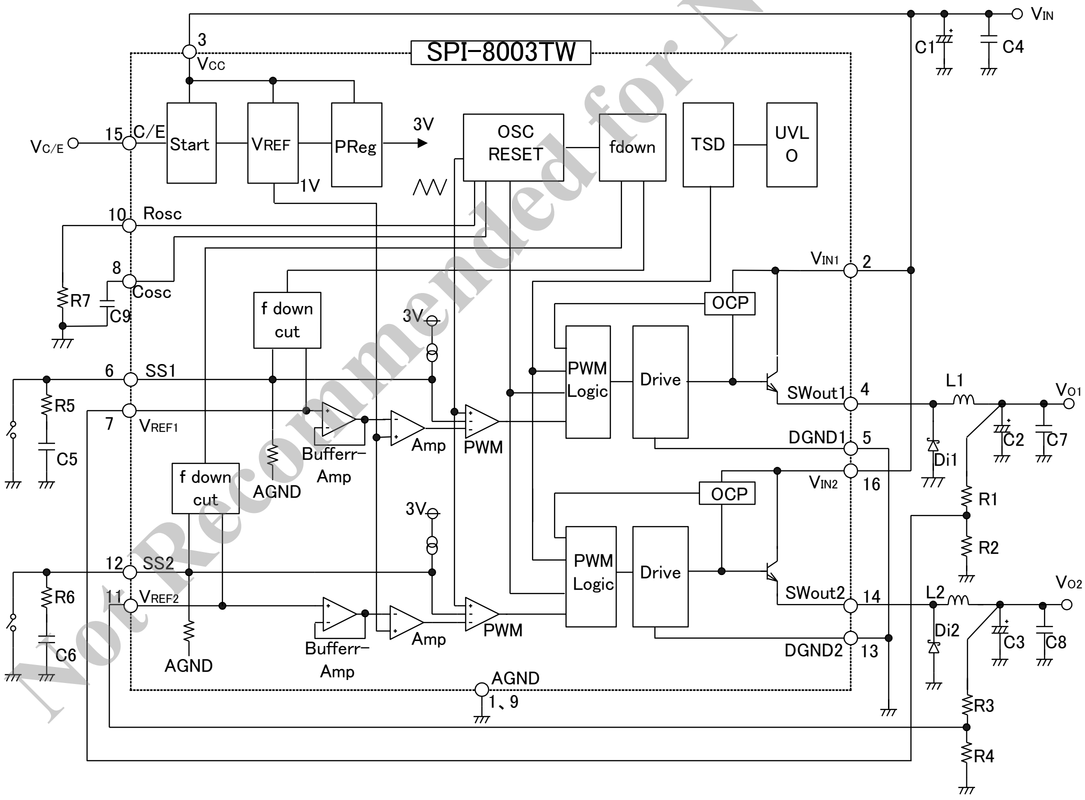
Typical Connection Diagram



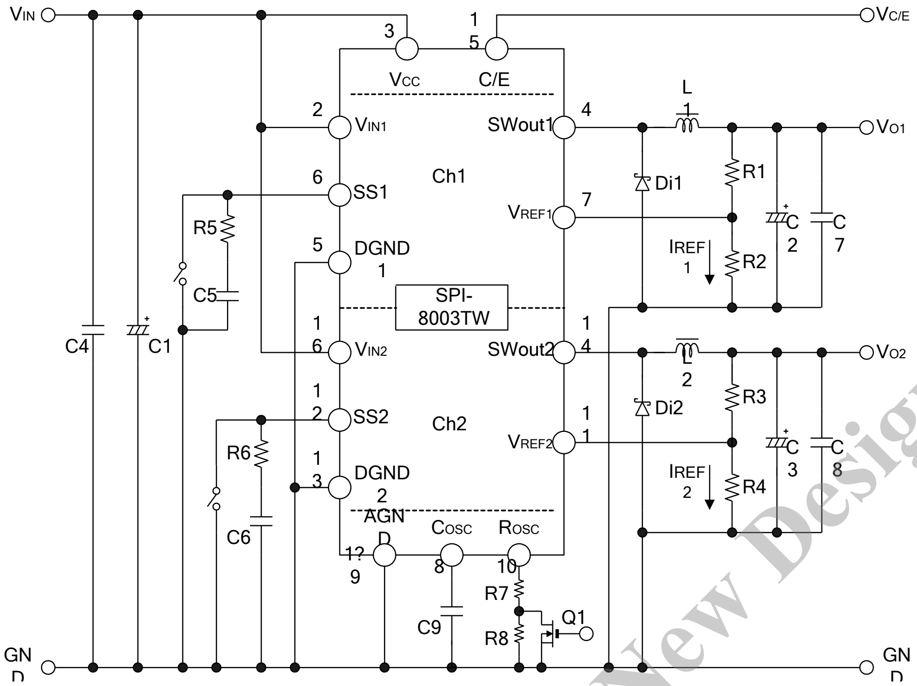
Component List

Component	Rating		Recommended Device
C1	220µF/50V	Electrolytic Capacitor	UUD1H221MNR1GS (nichicon)
C2, C3	470µF/25V	Electrolytic Capacitor	UUD1E471MNR1GS (nichicon)
C4, C5	1µF/10V	Ceramic Capacitor	GRM21BR11A105MA01B (MURATA)
C6, C7, C8	0.1µF/50V	Ceramic Capacitor	GRM21BR11H104MA01B (MURATA)
L1, L2	47µH	Inductor	SLF12575T-470M2R7 (TDK)
D1, D2	2A/60V	Schottky Barrier Diode	SFPB-66 (Sanken)
R1, R3	4kΩ (VO=5V)		-
R2, R4	1kΩ		-

Internal Equivalent Circuit (SPI-8003TW)



Typical Connection Diagram



Component List

Component	Rating		Recommended Device
C1	220µF/50V	Electrolytic Capacitor	UUD1H221MNR1GS (nichicon)
C2, C3	470µF/25V	Electrolytic Capacitor	UUD1E471MNR1GS (nichicon)
C5, C6	1µF/10V	Ceramic Capacitor	GRM21BR11A105MA01B (MURATA)
C4, C7, C8	0.1µF/50V	Ceramic Capacitor	GRM21BR11H104MA01B (MRATA)
C9	100pF/10V	Ceramic Capacitor	GRM21BR11H101MA01B (MURATA)
L1, L2	47µH	Inductor	SLF12575T-470M2R7 (TDK)
D1, D2	2A/60V	Schottky Barrier Diode	SFPB-66 (Sanken)
R1, R3	4kΩ (VO=5V		-
R2, R4	1kΩ		-
R7	30kΩ		-
R8	9.1kΩ		-

The operating frequency can be set by a capacitor added between the C_{OSC} and GND and a resistor added between R_{OSC} and GND. In addition, as shown in the above application circuit, it is possible to add and turn on and off the Q1 to modify the operating frequency.

In the above example, when Q1 turns on, only R7 (30kΩ) is added, then the operating frequency is about 300kHz. When Q1 turns off, the synthetic resistance of R7 (30kΩ) and R8 (9. 1kΩ) is added, then the operating frequency is about 250kHz.

This is recommended for such applications as AM radio receivers, TV sets, audio equipment etc that are susceptible to switching noise.

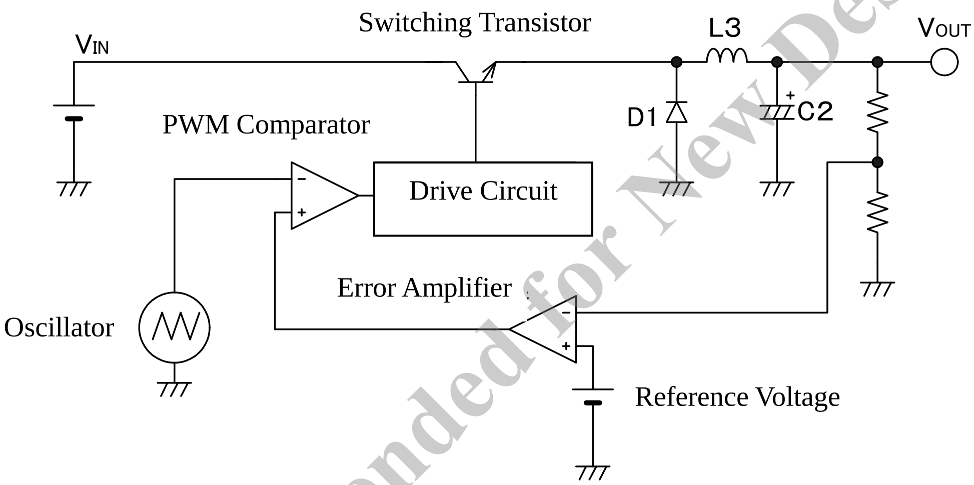
3. Operational Description

● 3-1 PWM Output Voltage Control

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

The triangular wave output (SPI-8001/2TW: 250kHz, SPI-8003TW: 200 – 400kHz) 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



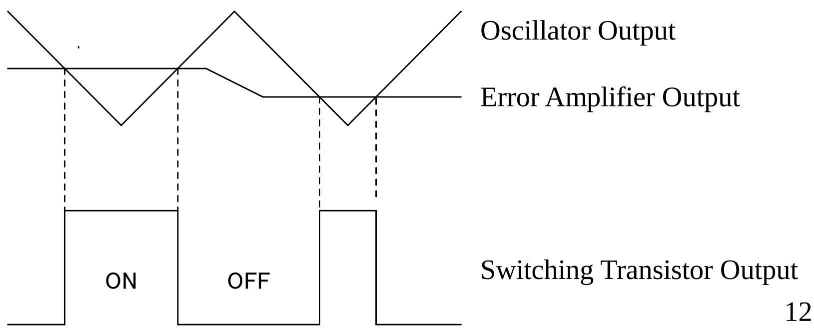
The error amplifier output and the oscillator output are compared by the PWM comparator to generate the drive signal of rectangular wave and to drive the switching transistor.

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.)

PWM Comparator Operation Diagram

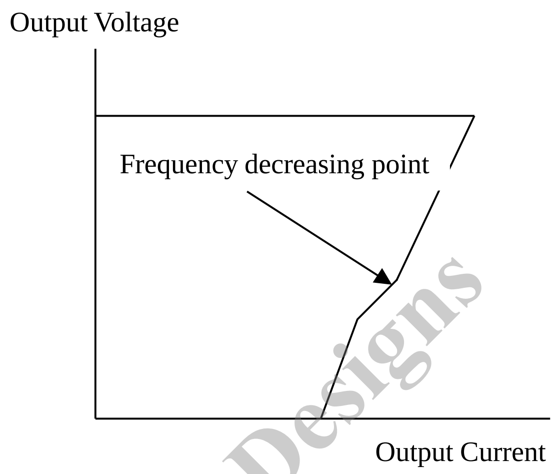
The rectangular wave output of the switching transistor is smoothed by the LC low pass filter composed of a choke coil and a capacitor to supply stabilized DC voltage to the load.



● 3-2 Overcurrent Protection / Thermal shutdown

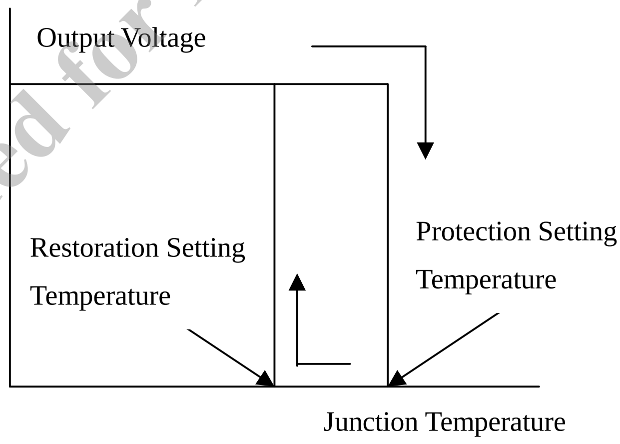
In the SPI – 8000TW, in order to suppress the current at short circuited load, the foldback type overcurrent protection circuit is built in. The overcurrent protection circuit detects the peak current of a switching transistor and when the peak current exceeds the set value, the ON time of the transistor is compulsorily shortened to limit the current by lowering the output voltage. When the overcurrent condition is released, the output voltage will be automatically restored.

Output Voltage Characteristic on Overcurrent



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 15°C, the output transistor is automatically restored.

Output Voltage Characteristic on Thermal Shutdown



* 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. Terminal Description

● 4-1 Terminal List

Terminal	SPI-8001TW / SPI-8002TW		SPI-8003TW	
	Symbol	Description	Symbol	Description
1	AGND	Ground Terminal	AGND	Ground Terminal
2	VIN1	Power Input Terminal (ch1)	VIN1	Power Input Terminal (ch1)
3	VCC	Controller Input Voltage	VCC	Controller Input Voltage
4	SWout1	Switching Output Terminal (ch1)	SWout1	Switching Output Terminal (ch1)
5	DGND1	Drive Ground Terminal (ch1)	DGND1	Drive Ground Terminal (ch1)
6	SS1	Soft Start ON/OFF Terminal (ch1)	SS1	Soft Start ON/OFF Terminal (ch1)
7	VREF1	Reference Voltage Terminal (ch1)	VREF1	Reference Voltage Terminal (ch1)
8	N/C	Non-connected Terminal	Cosc	Frequency Setting Terminal (for Capacitor)
9	AGND	Ground Terminal	AGND	Ground Terminal
10	VREF2	Reference Voltage Terminal (ch2)	Rosc	Frequency Setting Terminal (for Resistor)
11	SS2	Soft Start ON/OFF Terminal (ch2)	VREF2	Reference Voltage Terminal (ch2)
12	DGND2	Drive Ground Terminal (ch2)	SS2	Soft Start ON/OFF Terminal (ch2)
13	SWout2	Switching Output Terminal (ch2)	DGND2	Drive Ground Terminal (ch2)
14	C/E	Chip Enable Terminal	SWout2	Switching Output Terminal (ch2)
15	VIN2	Power Input Terminal (ch2)	C/E	Chip Enable Terminal
16	N/C	Non-connected Terminal	VIN2	Power Input Terminal (ch2)

● 4-2 Functional Description of Terminal

- AGND (terminal No.1 and No.9 for SPI-8001/2/3TW)

  It is a ground terminal for analogue.

- DGND 1, 2 (terminal No.5 and No.12 for SPI-8001/2TW, terminal No.5 and No.13 for SPI-8003TW)

  It is a ground terminal for power

- VIN 1, 2 (terminal No.2 and No.15 for SPI-8001/2TW, terminal No.2 and No.16 for SPI-8003TW)

  These are input terminals for external main voltage. VIN1 and VIN2 can be connected separately.

- VCC (terminal No.3 for SPI-8001/2/3TW)

  This is a terminal for internal power supply. It should be connected to VIN (No.2, 16 terminals: SPI-8001/2TW, No.2, 16 terminals: SPI-8003TW) or voltage within the recommended operation should be applied. Lower voltage can make less power consumption.

- SWOUT 1, 2 (terminal No.4 and No.13 for SPI-8001/2TW, terminal No.4 and No.14 for SPI-8003TW)

It is a switching output terminal.

- SS 1, 2 (terminal No.6 and No.11 for SPI-8001/2TW, terminal No.6 and No.12 for SPI-8003TW)

  This is a terminal for soft start. From connected capacitors C4 and C5, the output voltage can be soft started. It is possible to turn on or off the transistor for each channel by making the voltage of SS terminal 0.5V or lower. Please refer to 6-1 Soft Start of page 21 for details. R5 and R6 are for discharge protection, when an open collector is used for ON/OFF. Without ON/OFF, neither R5 nor R6 is required.

- VREF 1, 2 (terminal No.7 and No.10 for SPI-8001/2TW, terminal No.7 and No.11 for SPI-8003TW)

  This is a terminal for setting the output voltage. The output voltage of Ch1 is set by R1 and R2 and that of Ch2 by R3 and R4. Please refer to 6-3 Output Voltage Setting of page 21 for the method of setting the output voltage. The variable ranges of output voltage are 1 – 16V (SPI-8001TW) and 1 – 24V (SPI-8002/3TW).

- C/E (terminal No.14 for SPI-8001/2TW, terminal No.15 for SPI-8003TW)

  This is a ON/OFF terminal. The output is OFF at 0.8V or lower and ON at 2V or higher. In the case of ON/OFF by using the C/E terminal, both Ch1 and Ch2 are ON/OFF. In the case of OFF at the CE terminal, inflowing current of VIN and VCC is 1 μ A or less respectively. If the C/E terminal is not used, it should be pulled up to VIN.

- COSC, ROSC (terminal No.8 and No.10 for SPI-8003TW)

  These are terminals for setting the oscillating frequency. The oscillating frequency is set by C9 and R7 (R8). For the method of setting the oscillating frequency, please refer to the operational frequency characteristics of page 22. The variable operation range of oscillating frequency is 200kHz – 400kHz (SPI-8003TW).

- N/C (terminal No.8 and No.16 for SPI-8001/2TW)

  As the N/C terminal is not connected to the internal circuit, it should be open. In order to avoid influence of noise, it should not be used for the repeating pad etc..

5. Cautions

● 5-1 External Components

5-1-1 Choke coil L1, L2

The choke coil L supplies current to the load side when the switching transistor is OFF. And the L 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.

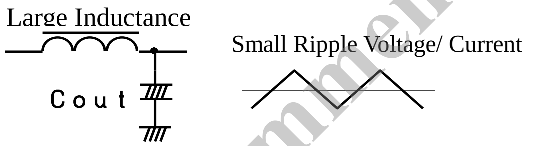
a) The choke coil should be fit for the switching regulator.

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

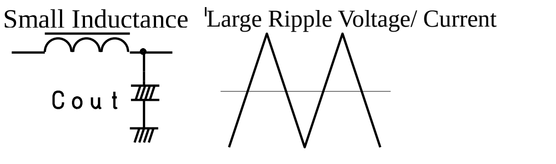
b) The inductance value should be appropriate.

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 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 curtent/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 following equation.

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 (1.5A) of the SI-8000TW: output current × 0.2 - 0.3
- In the case that the output current to be used is approximately 0.5A or less: output current × 0.5 – 0.6

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

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 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.

5-1-2 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 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.

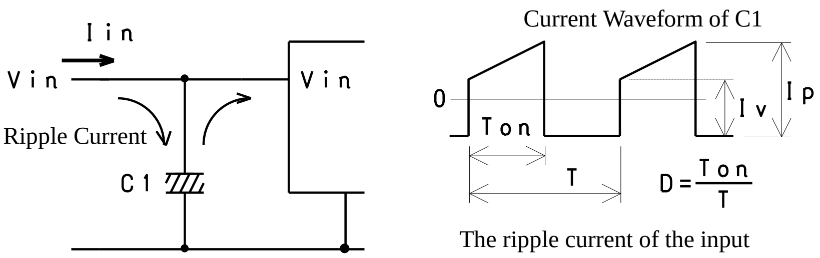
The selection of C1 shall be made in consideration of the following points:

a) The requirement of withstand voltage shall be met.

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

c) The requirement of ESR shall be low type. The ESR type reduces the generation of spike noise.

Current Flow of C1



The ripple current of the input capacitor is increased in accordance

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. Vin should be the lowest input voltage.

$$Irms \approx 1.2 \times \frac{Vo1}{Vin} \times Iout1 + 1.2 \times \frac{Vo2}{Vin} \times Iout2 \qquad ---(2)$$

Vo1: output voltage of Ch1, Vo2: output voltage of Ch2, Io1: output current of Ch1, Io2: output current of Ch2.

5-1-3 Output Capacitor C2, C3

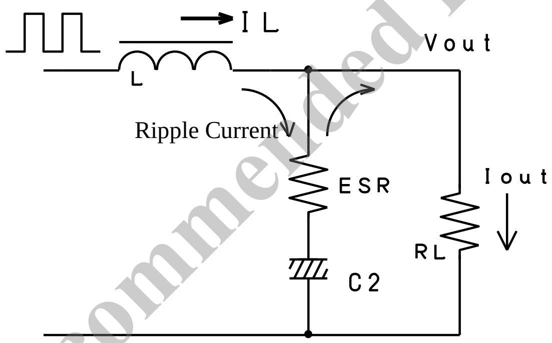
The output capacitor C2 composes a LC low pass filter together with a choke coil L and functions as a rectifying capacitor of switching output.

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

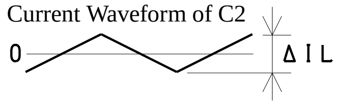
Therefore, it is necessary to meet the requirements of withstand voltage and allowable ripple current with sufficient margin like the input capacitor. Additional points to be checked are DC equivalent series resistance (ESR) and capacitance.

The following points should be taken into consideration.

Current Flow of C2



Current Waveform of C2



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.

a) Allowable Ripple Current

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

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

b) 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 - 1% 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.

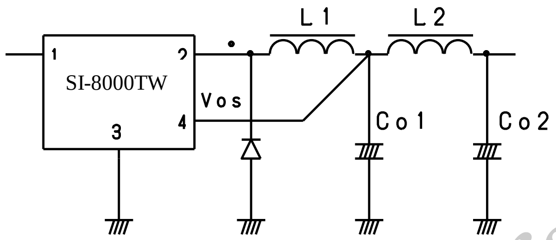
$$Vrip \approx \frac{(Vin - Vout)Vout}{L \cdot Vin \cdot f} ESR \qquad ---(4)$$

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

When the ESR is too low (approx. 10 - 20Ω 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.

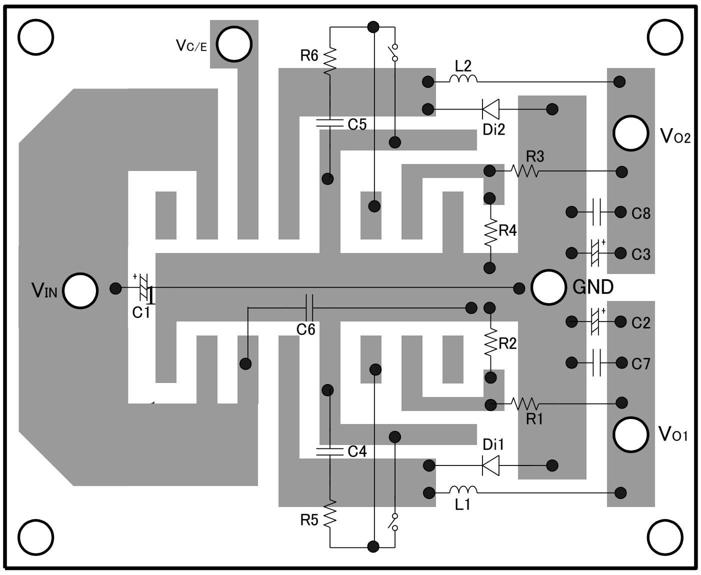
5-1-4 Flywheel Diode Di1, Di2

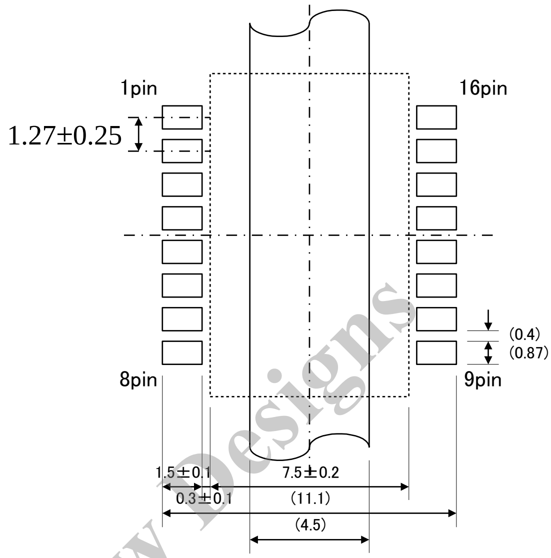
The flywheel diode Di is to discharge the energy which is stored in the choke coil at switching OFF.

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.

● 5-2 Pattern Design Notes

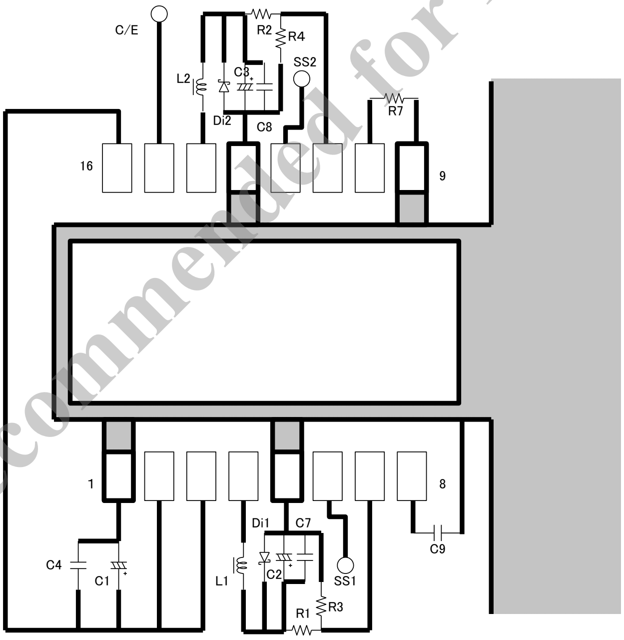
SPI-8001/2TW





Recommended Land Pattern

SPI-8003TW



Recommended Land Pattern

*In order to obtain the most suitable operating conditions, one-point GND wiring should be used for the GND line with No. 9 terminal as a center and it is required to lay out each part in the shortest distance.

● 5-3 Operation Notes

- It is not possible to operate the output of SPI-800TW in parallel.
- Since SPI-8000TW has common GND, it cannot used as a inverted chopper regulator.

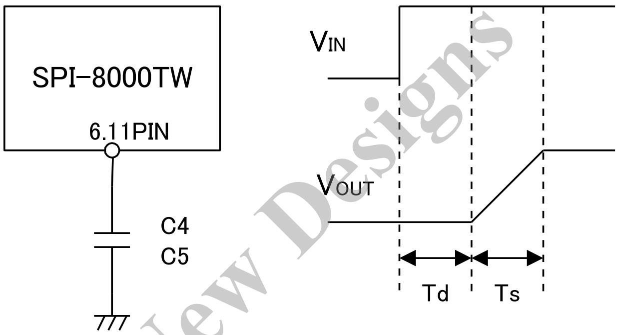
6. Applications

● 6-1 Soft Start

When a capacitor is connected to terminal 6 or 11, the soft start is activated when the input voltage is applied. The capacitor C4 and C5 controls the rise time by controlling the OFF period of PWM control. The delay time Td and the start time Ts are calculated approximately by the following equation. However, since in the actual equipment, the operation is affected by input power supply, initial rise of load etc., there may be some variation.

$$Td = \frac{C4}{60 \times 10^{-6}} \quad \text{(Sec)} \quad --(6)$$

$$Ts = \frac{C4 \times Vo}{Vin \times 60 \times 10^{-6}} \quad \text{(Sec)} --(7)$$



For example, in the case of VIN = 15V, Vo = 5V and C3 = 1 μ F, the calculation is as follows:

$$Td = \frac{1 \times 10^{-6}}{60 \times 10^{-6}} = 16.6(ms), \quad Ts = \frac{5 \times 1 \times 10^{-6}}{15 \times 60 \times 10^{-6}} \fallingdotseq 5.5(ms)$$

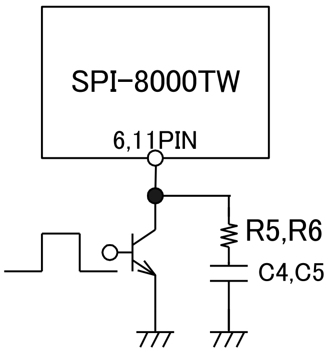
$$Td + Ts \fallingdotseq 22.1(ms)$$

Accordingly, after power-on and up to the rising of output voltage, it takes 22.1ms. But if C4 and C5 are made large, it takes time for discharging of C4 and C5 after Vin OFF. It is recommended to use C4 and C5 within the value of 7μF.

● 6-2 ON/OFF Control of Output by Using Soft Start

The output ON-Off control is possible using the SS terminal (No.6 and No.11). The output is turned OFF when the terminal 6 and 11 voltage falls to Lo level (1.5V or less) by such as open collector. It is possible to use the soft start together. Since the soft start terminal has been already pulled up, no voltage shall be applied from the external side.

R5 and R6 are used for protection during the discharging of C4 and C5.



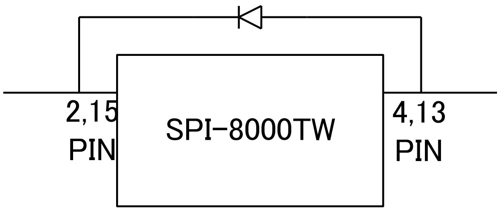
● 6-3 Output Voltage Setting

The output voltage of Ch1 is set by R1 and R2, while that of Ch2 by R3 and R4. When the output voltage is 5V, R1 is 4kΩ and R2 1kΩ.

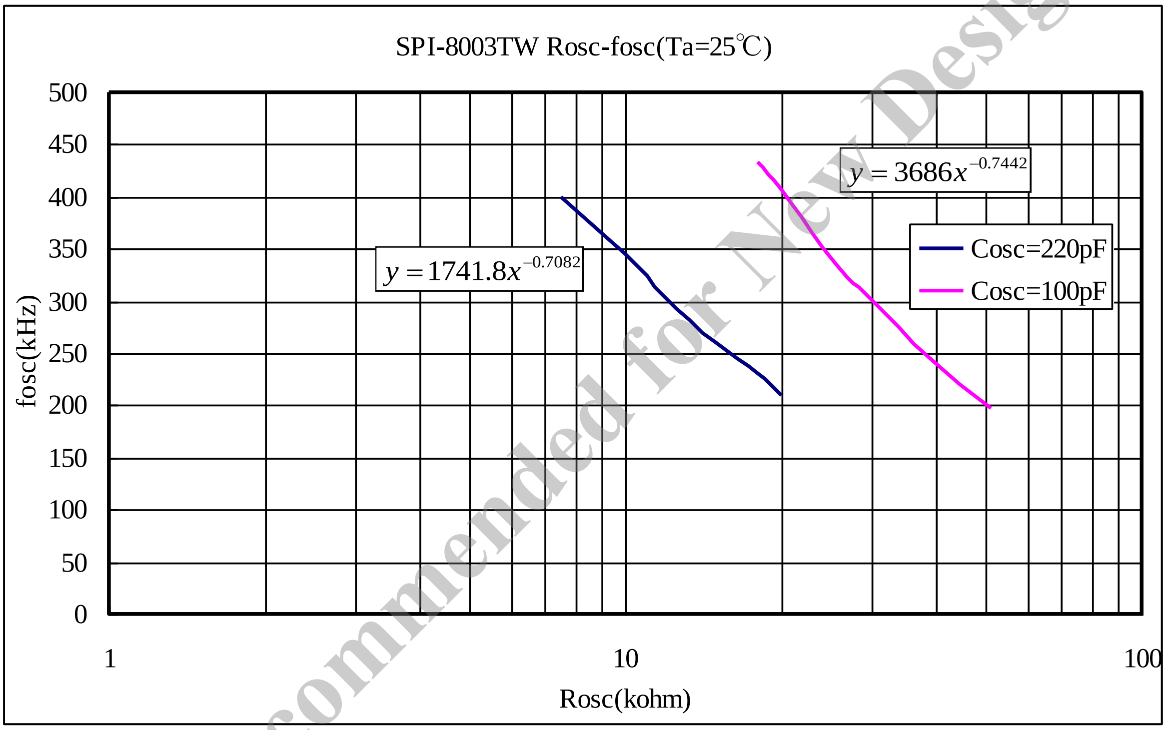
$$R1(R3) = \frac{(V_{O1} - V_{REF1})}{I_{REF1}} = \frac{(V_{O1} - 1)}{1 \times 10^{-3}} (\Omega), \quad R2(R4) = \frac{V_{REF1}}{I_{REF1}} = \frac{1}{1 \times 10^{-3}} \fallingdotseq 1(K\Omega) \quad \text{- - (8)}$$

● 6-4 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. SFPL52 (Sanken) is recommended for this diode.



● 6-5 Operational Frequency



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 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 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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