Data Sheet

Surface Mounted synchronized rectifier type Chopper Regulator IC

SI-8205NHD

Mar. 04, 2020 Rev.6.0

SANKEN ELECTRIC CO., LTD.

― ― ― Contents ― ― ―

1. General Description
- 1-1 Features ― ― ― ― ― ― ― ― ― ― ― 3
- 1-2 Applications ― ― ― ― ― ― ― ― ― ― ― 3
- 1-3 Type ― ― ― ― ― ― ― ― ― ― ― 3

2. Specification
- 2-1 Package Information ― ― ― ― ― ― ― ― ― ― ― 4
- 2-2 Ratings ― ― ― ― ― ― ― ― ― ― ― 5
- 2-3 Circuit Diagram ― ― ― ― ― ― ― ― ― ― ― 7

3. Terminal Description
- 3-1 Terminal List ― ― ― ― ― ― ― ― ― ― ― 8
- 3-2 Functional Description of Terminal ― ― ― ― ― ― ― ― ― ― ― 8

4. Operational Description
- 4-1 PWM Output Voltage Control ― ― ― ― ― ― ― ― ― ― ― 9
- 4-2 Overcurrent Protection / Thermal Shutdown ― ― ― ― ― ― ― ― ― ― ― 10

5. Design Notes
- 5-1 External Components ― ― ― ― ― ― ― ― ― ― ― 11
- 5-2 Pattern Design Notes ― ― ― ― ― ― ― ― ― ― ― 17
- 5-3 Power Supply Stability ― ― ― ― ― ― ― ― ― ― ― 19

6. Applications
- 6-1 Soft Start ― ― ― ― ― ― ― ― ― ― ― 20
- 6-2 Output ON / OFF Control ― ― ― ― ― ― ― ― ― ― ― 21
- 6-3 Spike Noise Reduction ― ― ― ― ― ― ― ― ― ― ― 21
- 6-4 Reverse Bias Protection ― ― ― ― ― ― ― ― ― ― ― 22
- 6-5 Operational Frequency ― ― ― ― ― ― ― ― ― ― ― 22
- 6-6 Synchronous, non-synchronous automatic selection function ― ― ― ― ― ― ― ― ― ― ― 24
- 6-7 About the operational -frequency when the output is light-load or no-load ― ― ― ― ― ― ― ― ― ― ― 25
- 6-8 About the movement mode in the light-load condition ― ― ― ― ― ― ― ― ― ― ― 26

6-9 About the dispersion of resistance "RonH and RonL"with the internal-MOSFET
－－－－－－－－－－－ 26
7. Terminology －－－－－－－－－－－ 27

1. General Description

The SI-8205NHD is a synchronized rectifier type chopper regulator IC with a built-in power MOS. Due to a current control system, it is applicable to such a super low ESR capacitor as a ceramic capacitor. It is provided with various protection functions such as overcurrent protection, low input prohibition, overheat protection etc. In order to protect the IC against in-rush current at start-up, the soft start function is provided. The soft start time can be set by connecting external capacitors. And the frequency can be set by connecting an external capacitor. This device is supplied in a compact and thin HOSP 8-pin package with heat slug on the back side.

● 1-1 Features

- Output current 3.0A

  The output current of each output is maximum 3.0A in the HSOP 8-pin surface mounting package.

- High efficiency

  Maximum efficiency 94%

- Output voltage variable

  0.5 - 24V

- Low ESR capacitor for output

  The ceramic capacitor can be used.

- Operating frequency

  200k – 1MHz

- Built-in functions for overcurrent and thermal shutdown

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

- Soft start function (capable of ON/OFF output)

  By adding an external capacitor, it is possible to delay the rise speed of the output voltage. ON/OFF control of the output is also possible.

- Small package (SI-8205NHD)

  HSOP8 pin package with small heat slug

● 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

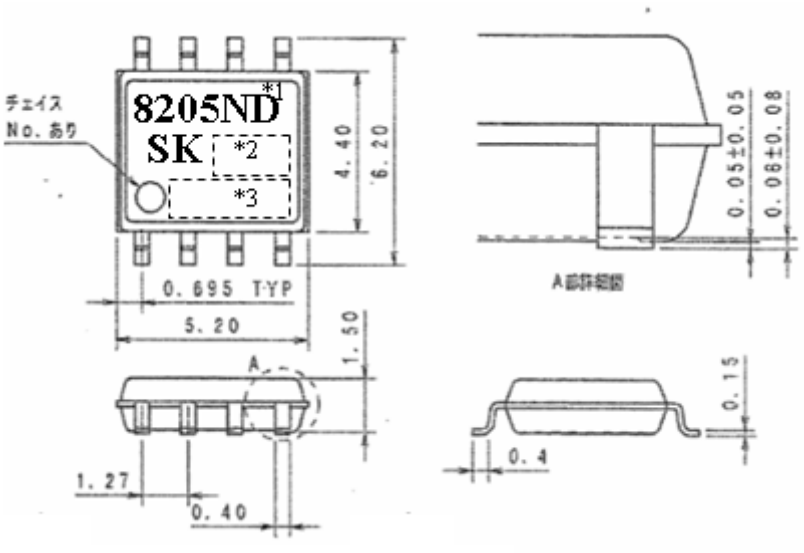
- Type: Semiconductor integrated circuits (monolithic IC)
- Structure: Resin molding type (transfer molding)

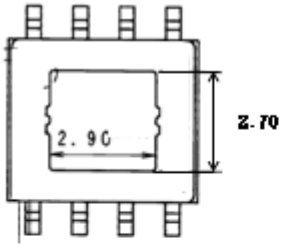
2. Specification

● 2-1 Package Information

2-1-2 SI-8205NHD

Unit: mm





*1 Type number

*2 Lot number (three digit)

1st letter: The last digit of year

2nd letter: Month

1 to 9 for Jan. to Sep.

O for Oct.

N for Nov.

D for Dec.

3rd and 4th letter: week

*3 Control number (four digit)

Pin Assignment

1. GND
2. EN/SS
3. VIN
4. FSET
5. COMP
6. FB
7. BS
8. SW

External Terminal Processing: Sn-2.5Ag plating

● 2-2 Ratings

Table 1 Absolute Maximum Rating

Parameter	Symbol	Rating	Unit	Condition
Input Voltage VIN	VIN	46	V	
BS Pin voltage	V_{BS}	52	V	
BS Pin-SW Pin voltage	V_{BS-SW}	6	V	
SW Pin voltage	V_{SW}	46	V	
FB Pin voltage	V_{FB}	6	V	
EN/SS Pin voltage	$V_{EN/SS}$	6	V	
FSET Pin voltage	V_{FSET}	6	V	
COMP Pin voltage	V_{COMP}	6	V	
Allowable Power Dissipation *1	Pd	1.35	W	
Junction Temperature	Tj	150	°C	
Storage Temperature	Tstg	-40 - 150	°C	
Thermal Resistance (Junction and Case) *2	θj-c	40	°C /W	
Thermal Resistance (Junction and Ambient) *2	θj-a	74	°C /W	

*1: Since the thermal shutdown is provided, it may be operated at Tj >140°C. Designing should be made at Tj <125°C.

*2: Glass epoxy board: 30.0mm × 30.0mm (copper foil area: 25.0mm × 25.0mm)

Table 2 Recommended Conditions

Parameter	Symbol	SI-8205NHD	Unit
DC Input Voltage	VIN	Vo+3 - 43 *3	V
Output Voltage	IO	0 - 3.0	A
Junction Temperature in Operation	Tjop	-30 - 125	°C
Temperature in Operation	Top	-30 - 85	°C

*3: The minimum value of input voltage range is 8V or V_O + 3V whichever higher.

In the case of V_{IN} = Vo +2 – Vo +3, I_{OUT} is 2A at maximum.

Table 3 Electrical Characteristics (Ta = 25°C, Vo = 5V, R1 = 9kΩ, R2 = 1kΩ)

Parameter		Symbol	Ratings			Unit	Test Condition
			MIN	MIN	MIN		
Setting Reference Voltage		VREF	0.495	0.500	0.505	V	V_{IN} = 12V, Io = 1.0A
Output Voltage Temperature Coefficient		ΔVREF /ΔT		±0.05		mV/°C	V_{IN} = 12V. Io = 1.0A Ta = -40°C to 85°C
Efficiency *4		η		90		%	V_{IN} = 12V, Io = 1A
Operation Frequency		fo	425	500	575	kHz	V_{IN} = 12V, Io = 1A Rfset = 150kΩ
Line Regulation *5		VLine		50		mV	V_{IN} = 8 - 43V, Io = 1A
Load Regulation *5		VLoad		50		mV	V_{IN} = 12V, Io = 0.1 - 3.0A , f=500kHz
Overcurrent Protection Start Current		IS	3.1		6.0	A	V_{IN} = 12V
Circuit Current in Non-operation 1		IIN		18		mA	V_{IN} = 12V, Io = 0A, V_{EN} = open
Circuit Current in Non-operation 2		IIN(off)		10	30	μA	V_{IN} = 12V, Io = 0A, V_{EN} = 0V
EN/SS terminal	Flow-out Current at Low Level Voltage	IEN/SS		5		μA	$V_{EN/SS}$ = 0V, V_{IN} = 12V
	Open-ciruit Voltage	VSSH	3.0	4.5	6.0	V	V_{IN} = 12V
	ON Threshold Voltage	VC/EH	0.6	1.3	2.0	V	V_{IN} = 12V
Slope Compensation		Kc		0.55		A/ μsec	
Error Amplifier Voltage Gain		AEA		800		V/V	
Error Amplifier Trans-conductance		GEA		800		μA /V	
Current Sense Amplifier Impedance		GCS		3.33		A/V	
Maximum ON Duty		DMAX		90		%	
Minimum ON Duty		DMIN		150		nsec	
High-side Switching ON resistance		RonH		150		mΩ	V_{IN} = 12V
Low-side Switching ON resistance		RonL		150		mΩ	V_{IN} = 12V

*4: Efficiency should be calculated by using the following equation: $\eta(\%) = \frac{(Vo \cdot Io)}{V_{IN} \cdot I_{IN}} \times 100$

*5: This is a design assurance value.

● 2-3 Circuit Diagram

2-3-1 Internal Equivalent Circuit

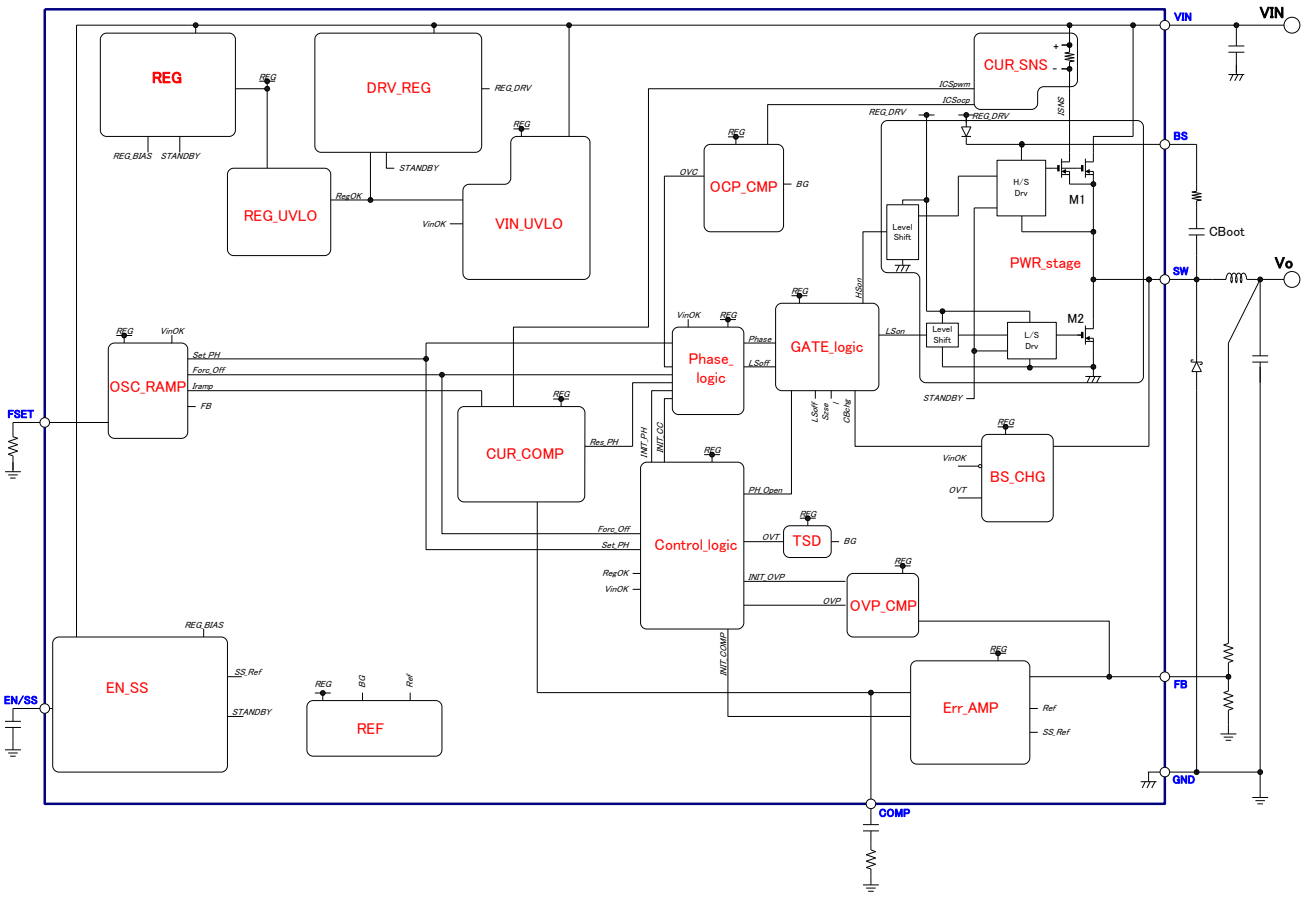
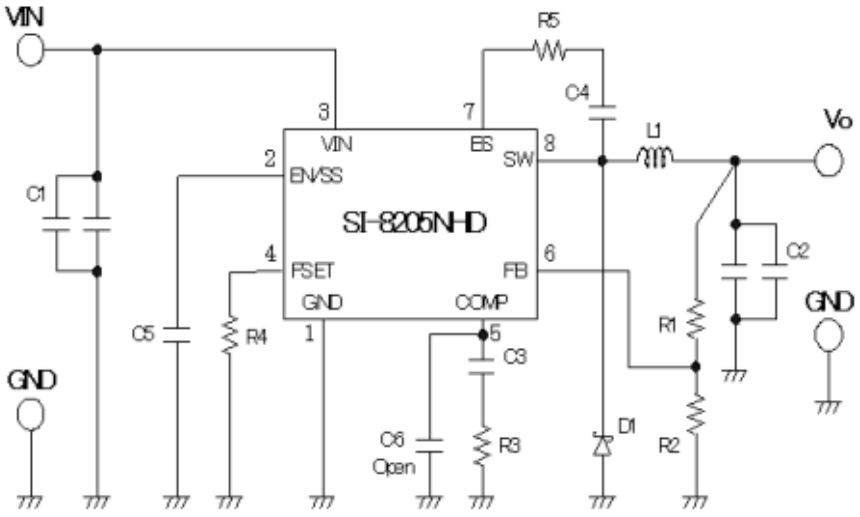


Fig. 1

2-3-2 Typical Connection Diagram



C1: 10µF / 50V ×2
C2: 22µF / 16V ×2
C3: 270pF
C4: 0.1µF
C5: 1µF
A ceramics capacitor should be a good temperature character.
L1: 10µH
D1: SJPB-L6 (Sanken)
R1: 9kΩ (at Vo=5V)
R2: 1kΩ
R3: 51kΩ
R4: 150kΩ
R5=47Ω

Fig. 2

3. Terminal Description

● 3-1 Terminal List

Table 4

Terminal	SI-8205NHD	
	Symbol	Description
1	GND	Ground Terminal
2	EN/SS	Soft Start Terminal (ON/OFF Terminal)
3	VIN	Input Terminal
4	FSET	Setting Frequency Terminal
5	COMP	Phase Compensation Terminal
6	FB	Feedback Voltage Terminal
7	BS	High side Boost Terminal
8	SW	Switching Output Terminal

● 3-2 Functional Description of Terminal

- GND (terminal No. 1)

  It is a ground terminal.

- EN/SS (terminal No. 2)

  It is a terminal for turning ON/OFF the IC. The soft start of output voltage can be made by connecting a capacitor to this terminal also.

- VIN (terminal No. 2)

  It is an input voltage of IC.

- FSET (terminal No. 4)

  This is a terminal to make the frequency variable.

- Comp (terminal No. 5)

  It is a phase compensation terminal for controlling the loop stably.

- FB (terminal No. 6)

  It is a terminal for setting the output voltage. The output voltage is set by R1 and R2.

- BS (terminal No. 7)

  It is an internal power supply for driving the gate of high side switch Nch - MOS. A capacitor of 10 nF or more is connected between the SW terminal and BS terminal to drive the high side Nch - MOS.

- SW (terminal No. 8)

  It is a switching output terminal which supplies power to the output.

4. Operational Description

● 4-1 PWM Output Voltage Control

The SI-8205NHD consists of 2 systems of feedback loops of current control and voltage control and 3 blocks which compensate slope and, in the voltage control feedback, the output voltage is fed back for PWM control loop and the SI-8205NHD is composed of an error amplifier which compares the division of resistance with the reference voltage of 0.5V. The current control feedback is a loop which feeds back the inductor current for PWM control and the inductor current shunted by using a sense MOS is detected by a current sense amplifier. With respect to the slope compensation, in consideration of current control system, in order to avoid the sub harmonic oscillation, slope compensation is made for the current control slope. As shown in Fig.5, in the SI-8205NHD, by means of voltage control feedback, current control feedback and calculation of slope compensation, the PWM control by current control system is made.

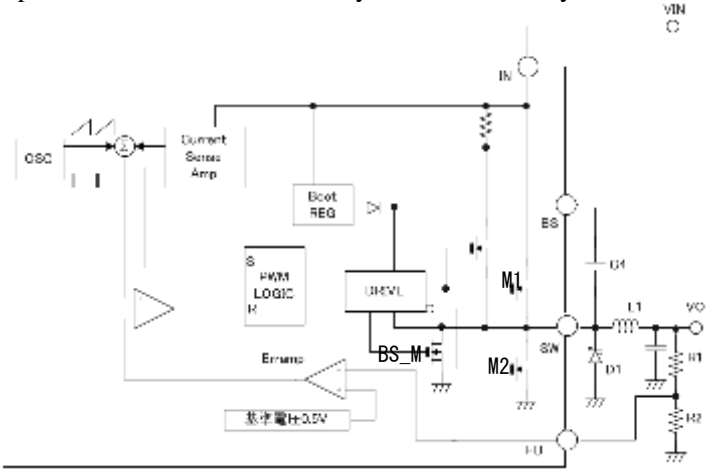


Fig.3 Current Control PWM Chopper Regulator Basic Configuration

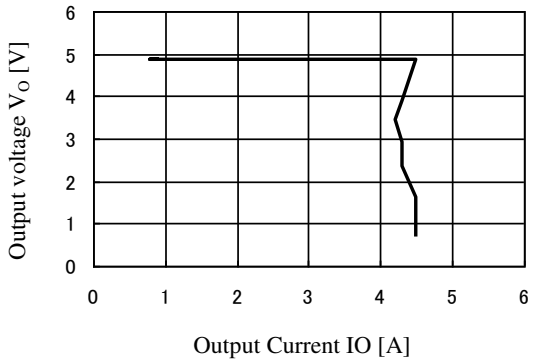
Since the SI-8205NHD is a current control regulator, the COMP terminal voltage is proportional to the peak value of the inductor current. When the ULVO is released or current of the EN/SS terminal exceeds the threshold value, the switching operation is made. At first, switching operation is made by MIN ON duty or MAX ON duty. The high side switch (hereinafter called as M1) is a switching MOS which supplies power to the output and a switch for charging the BS capacitor (hereinafter called as BS M) charges the capacitor C4 to drive M1.

At M1: ON, inductor current is increased by applying voltage to the SW switch and inductor, and the output of the current detection amplifier which detects it also rises. The signal to which the output of this current detection amplifier and the Ramp compensation signal are added is compared with the output of the error amplifier by the current comparator (CUR COMP). When the added signal exceeds the output of the error amplifier (COMP terminal voltage), the output of the current comparator becomes “H” to reset the RS flip-flop. Then, M1 turns off and M2 turns on. Thereby, the regenerated current flows through M2 and the external SBD (D1).

In the SI-8205NHD, the reset signal is generated at each cycle to reset the RS flip-flop. In the case the

added signal does not exceed the COMP terminal voltage, the RS flip-flop is reset without fail by the signal of the 10% OFF Duty circuit.

● 4-2 Overcurrent Protection / Thermal Shutdown



As Vo drops, the oscillating frequency is lowered.

Fig.4 Output Voltage Characteristics in Overcurrent

The SI-8205NHD 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 the switching frequency. When the overcurrent condition is released, the output voltage will be automatically restored.

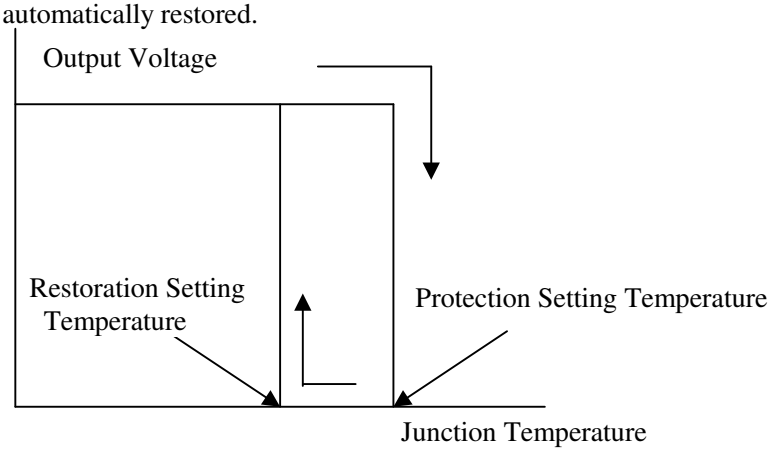


Fig.5 Output Voltage Characteristics in Thermal Shutdown

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 10°C, the output transistor is automatically restored.

* Note for thermal shutdown characteristic

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

5. Cautions

● 5-1 External Components

5-1-1 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) For the peak detection current control, the inductance current may fluctuate at the cycle of integral multiple of switching operation frequency.

Such phenomenon is called as sub harmonic oscillation and it may theoretically occur in the peak detection current control mode.

Therefore, in order to assure stable operation, the inductance current is compensated inside the IC, and it is required to select a proper inductance value to the output voltage.

The upper limit of inductance L is variable subject to the input/output conditions, load current etc., therefore please regard it as a reference in the Fig. 6 below.

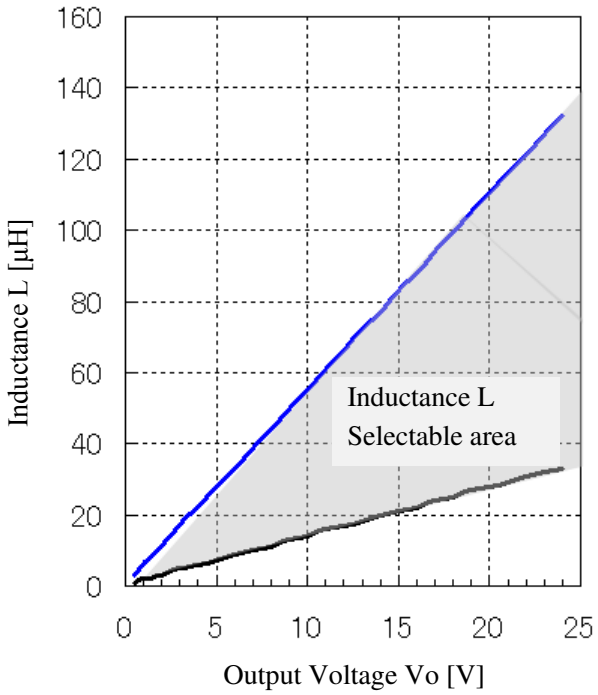


Fig. 6 shows the selection range of the inductance L value to avoid the sub harmonic oscillation.

The pulse current of choke coil ΔIL and the peak current ILp are expressed by the following equation:

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

$$ILp = \frac{\Delta IL}{2} + Iout \quad ---(2)$$

From this equation, you will see that as the inductance L of choke coil is decreased, ΔIL and ILP are increased. In the event that the inductance is too little, the fluctuation of choke coil current is larger, resulting in unstable operation of the regulator.

Care should be taken of decrease of inductance of choke coil due to magnetic saturation of overload, load short circuit etc.

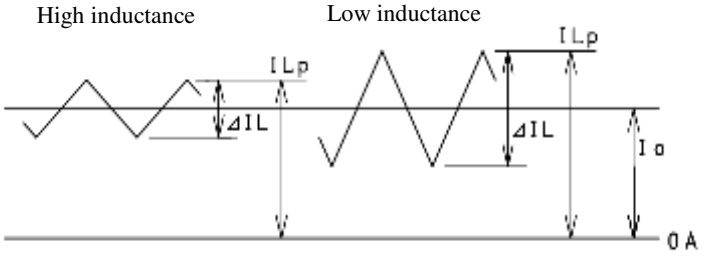


Fig.7 Relation between Ripple current I_{LP} and Output Current I_O

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

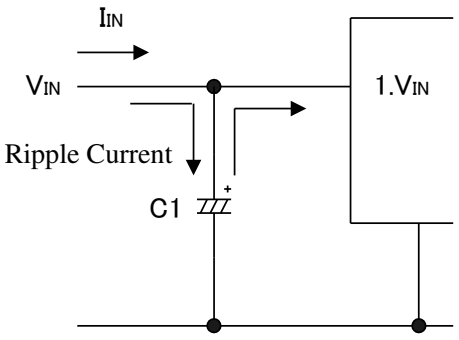
The input capacitor is operated as a bypass capacitor of the input circuit to supply steep current to the regulator during switching and to compensate the voltage drop of the input side. Therefore, the input capacitor should be placed as close as to the regulator IC.

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 placed near the SI-8205NHD.

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.



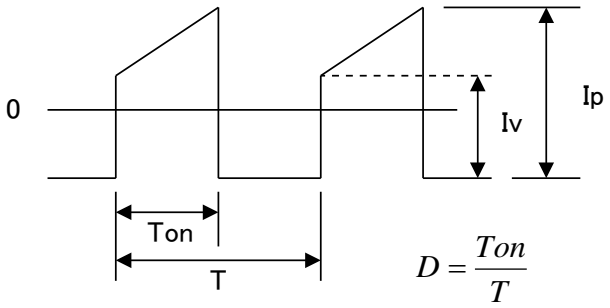


Fig.8 Current Flow of C1 Fig. 9 Current Waveform of C1

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 (3):

$$Irms \approx 1.2 \times \frac{Vo}{Vin} \times Io \quad --(3)$$

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.

5-1-3 Output Capacitor C2

The current control system is a voltage control system to which a loop which detects and feeds back the inductance current is added. By adding inductor current to the feedback loop, stable operation is realized without taking into consideration the influence of secondary delay of the LC filter. Therefore, the capacitance C of the LC filter which is required to compensate the secondary delay can be decreased and furthermore, stable operation can be obtained, even if the low ESR capacitor (ceramic capacitor) is used.

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.

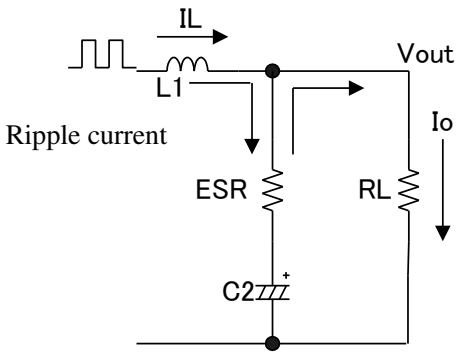


Fig.10 C2 current flow

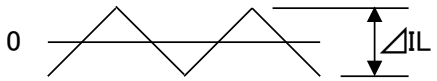


Fig.11 C2 current curve

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 (4).

$$Irms = \frac{\Delta IL}{2\sqrt{3}} \qquad ---(4)$$

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.

$$Vrip = \Delta IL \cdot C2ESR \qquad ---(5)$$

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.

5-1-4 Flywheel Diode D1

The SI-8205NHD has a switch-over function between synchronous rectification and asynchronous one subject to input/output conditions, load conditions etc.. Since asynchronous operation is made as well, it is recommended to connect a fly wheel diode D1 externally.

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 8) of the SI-8205NHD 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 to use the ferrite bead for the flywheel diode.

5-1-5 Phase compensation elements C3, C6, R3

The stability and responsiveness of the loop are controlled through the COMP terminal.

The COMP terminal is an output of the internal trans-conductance amplifier.

The series combination of a capacitor and resistor sets the combination of pole and zero which determines characteristics of the control system. The DC gain of voltage feedback loop can be calculated by the following equation:

$$Adc = Rl \times \mathrm{Gcs} \times \mathrm{A_{EA}} \times \frac{\mathrm{V_{FB}}}{\mathrm{Vout}}$$

Here, VFB is feedback voltage (0.5V). AEA is the voltage gain of error amplifier, G_{CS} trans-inductance of current detection and R1 a load resistance value. There are 2 important poles. One is produced by a phase compensation capacitor (C3) and an output resistor of the error amplifier.

Another one is produced by a output capacitor and a load resistor. These poles appear at the following frequencies:

$$fp1 = \frac{G_{EA}}{2\pi \times C3 \times A_{EA}}$$

$$fp2 = \frac{1}{2\pi \times C2 \times Rl}$$

Here, G_{EA} is the trans-conductance of error amplifier. In this system, one zero is important. This zero is produced by phase compensation capacitor C3 and phase compensation resistance R3. This zero appears in the following frequencies:

$$fz1 = \frac{1}{2\pi \times C3 \times R3}$$

If the output capacitor is large and/or ESR is large, this system may have another important zero. This zero is produced by the ESR and capacitance of the output capacitor. And it exists in the following frequencies:

$$fESR = \frac{1}{2\pi \times C2 \times RESR}$$

In this case, the third pole which is set by the phase compensation capacitor (C6) and phase compensation resistor (R3) is used to compensate the effect of ESR zero on the loop gain.

This pole exists in the following frequencies:

$$p3 = \frac{1}{2\pi \times C6 \times R3}$$

The objective of design of phase compensation is to form the converter transfer function to obtain the desired loop gain. The system crossover frequency where the feedback loop has a single gain is important.

The lower crossover frequency will produce the slower line and load transient. In the meantime, the higher crossover frequency may cause instability of the system. The selection of the most suitable phase compensation element is described below.

1. A phase compensation resistor (R3) is selected to set the resistor at the desired crossover frequency.

The calculation of R3 is made by the following equation:

$$R3 = \frac{2\pi \times C2 \times fc}{GEA \times GCS} \times \frac{Vout}{VFB} < \frac{2\pi \times C2 \times 0.1 \times fs}{GEA \times GCS} \times \frac{Vout}{V_{FB}}$$

Here, fc is a desired crossover frequency. It should be one tenth or lower of the normal switching frequency (fs).

2. In order to achieve the desired phase margin, a phase compensation capacitor (C3) is selected.

For the application having a representative inductance value, adequate phase margin is provided by setting the zero compensation of one fourth or lower of the crossover frequency.

C3 is calculated by the following equation.

$$C3 > \frac{4}{2\pi \times R3 \times fc}$$

R3 is a phase compensation resistor.

3. It is required to judge whether the second compensation capacitor C6 is necessary or not.

It will be necessary, when the ESR zero of the output capacitor is located at a frequency which is lower than the half of the switching frequency.

Namely, it is necessary, when the following equation is applicable.

$$\frac{1}{2\pi \times C2 \times RESR} < \frac{fs}{2}$$

In this case, the second compensation capacitor C6 is added and the frequency fp3 of ESR zero is set.

C6 is calculated from the following equation.

$$C6 = \frac{C2 \times RESR}{R3}$$

The constants for each output setting voltage in the case that ceramic capacitors or aluminum electrolytic capacitors are used are shown in the following table.

The inductor L should be selected by reference to the choke coil L1 of 5-1-1. (Refer to Fig. 6 Scope of

selection of inductance L value)

Table 5 Output setting voltage (use ceramic capacitors)

Vout [V]	L [uH]	Cout [uF] (ceramic capacitor)	fc = 50kHz			fc = 20kHz		
			R3 [kΩ]	C3 [pF]	C6 [pF]	R3 [kΩ]	C3 [pF]	C6 [pF]
1.2	2.0 - 10	22 × 2	12	1000	No	4.7	6800	No
1.8	3.0 - 10	22 × 2	18	680	No	7.3	4700	No
3.3	6.8 - 16	22 × 2	33	330	No	13	3300	No
5	8.2 - 22	22 × 2	51	220	No	20	1800	No
12	22 - 68	22 × 2	124	100	No	47	680	No

Table 6 Output setting voltage (use aluminum electrolytic capacitors)

Vout [V]	L [uH]	Cout[uF]/ ESR[mΩ] (aluminum electrolytic capacitor)	fc = 50kHz			fc =2 0kHz		
			R3 [kΩ]	C3 [pF]	C6 [pF]	R3 [kΩ]	C3 [pF]	C6 [pF]
1.2	2.0 - 10	220/100	62	220	470	24	1500	1000
1.8	3.0 - 10	220/100	91	180	330	36	1000	680
3.3	6.8 - 16	220/100	160	100	180	68	470	330
5	8.2 - 22	220/100	240	100	100	100	330	220
12	22 - 68	220/100	620	100	100	240	150	100

● 5-2 Pattern Design Notes

5-2-1 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.

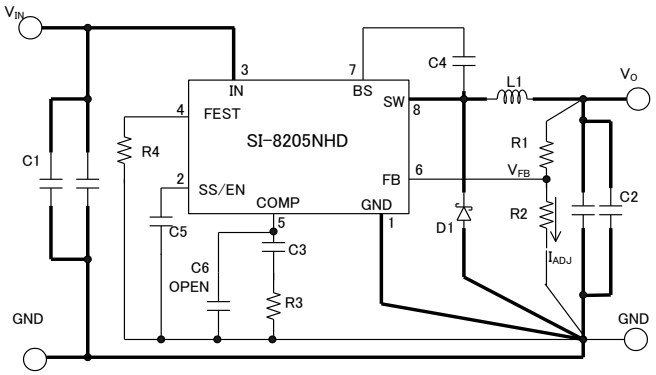


Fig. 12 Circuit Diagram

5-2-2 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.

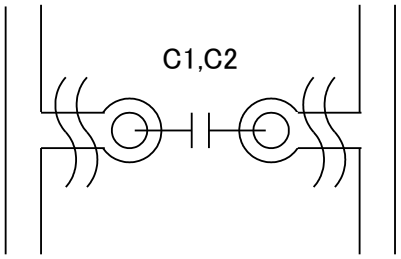


Fig. 13 Improper Pattern Example

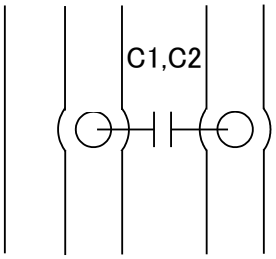


Fig. 14 Proper Pattern Example

5-2-3 FB Terminal (Output Voltage Set-up)

The FB 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. I_{FB} should be set to be around 0.5mA.

(The I_{FB} lower limit is 0.5mA, and the upper limit is not defined. However, it is necessary to consider that the consumption current shall increase according to the I_{FB} value, resulting in lower efficiency.)

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

$I_{FB} = V_{FB} / R2 \ *V_{FB} = 0.5V \pm 1\%$

$R1 = (Vo - VFB) / I_{FB} \quad R2 = V_{FB} / I_{FB}$

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

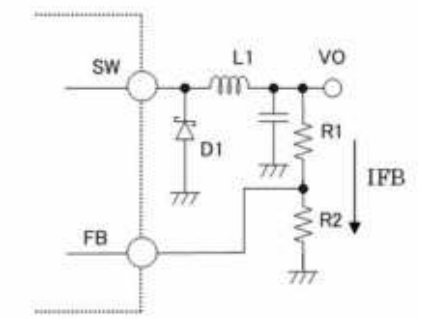


Fig. 15

- R2 should be connected for the stable operation when set to Vo = 0.5V.
- As to the relationship with the input/output voltage, it is recommended to set the ON width of SW terminal to be 200 nsec or longer.

The wiring of COMP terminal, FB 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 FB terminal to R2 as short as possible.

- Mounting Board Pattern Example

Component Insertion Type (SI-8205NHD)

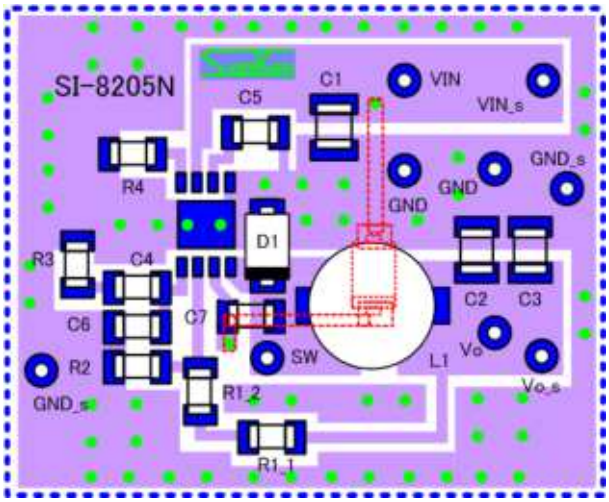


Fig. 16 Front side: materials on this side

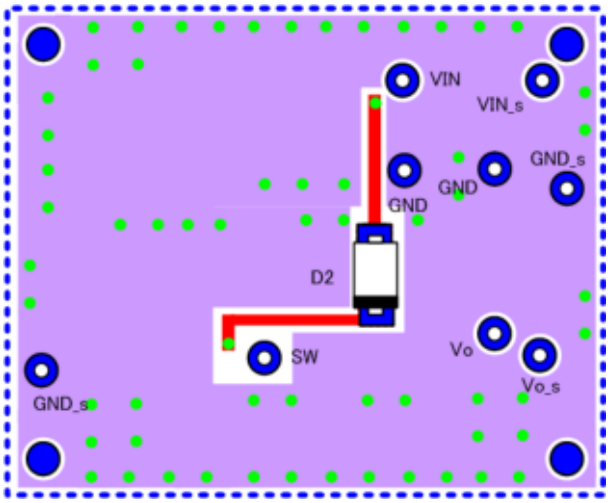


Fig. 17 Back side: GND side

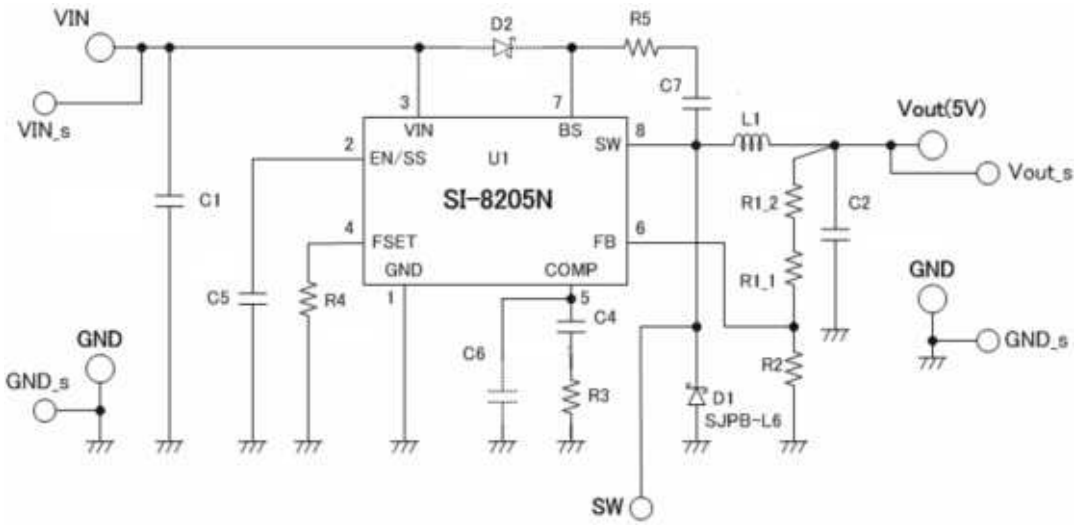


Fig. 18 Pattern Circuit Diagram

● 5-3 Power Supply Stability

The phase characteristics of the chopper type regulator are synthesized by the phase characteristics inside the regulator IC and that of output capacitor Cout and the load resistor Rout. 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, external parts such as resistors and capacitors should be connected outside the IC for phase compensation.

Please refer to phase compensation elements C3, C6 and R3 of 5-1-5.

6. Applications

● 6-1 Soft Start

When a capacitor is connected to terminal 2, the soft start is activated when the input voltage is applied.

Vout rises in relation with the charging voltage of Css. Therefore, the rough estimation is done by the time constant calculation of Css charging.

The capacitor Css controls the rise time by controlling the OFF period of PWM control. The rise time tss and the delay time t_delay are obtained approximately by the following equation:

It is the delay time t_delay when voltage of EN/SS terminal <1.6V.

It is the rise time tss when 1.6V< voltage of EN/SS <2.1V

$$t_delay = C_{EN/SS} \times V_{EN/SS-1} / I_{EN/SS} = 0.1\mu F \times 1.6V / 5\mu A = 32msec$$

$$tss = C_{EN/SS} \times (V_{EN/SS-2} - V_{EN/SS-1}) / I_{EN/SS} = 0.1\mu F \times 0.5V / 5\mu A = 10msec$$

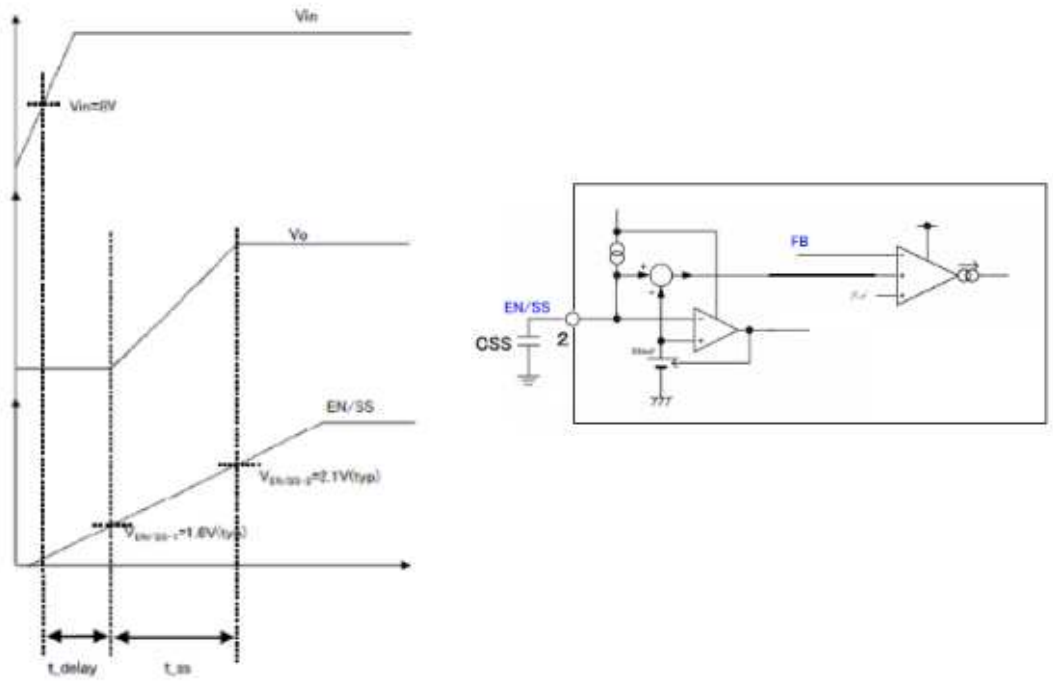


Fig. 19 Characteristic on Soft Start

Since the EN/SS terminal is pulled up (4.5V TYP) with the internal power supply of IC, the external voltage can not be applied.

If there is no Css or it is extremely low, Vout rises at the time constants charging the output capacitor with the output current restricted by the overcurrent protection Is.

Time constants at output capacitor start-up

$$t = (Co \times Vo) / Is \text{ (at no load)}$$

*The amount of load current is deducted from the Is value at load.

● 6-2 Output ON / OFF Control

The output ON-Off control is possible using the EN/SS terminal (No.2). The output is turned OFF when the terminal 5 voltage falls below $V_{C/EH}$ (1.6V TYP) by such as open collector. It is possible to use the soft start together. Since the soft start terminal has been already pulled up (4.5V TYP), no voltage shall be applied from the external side.

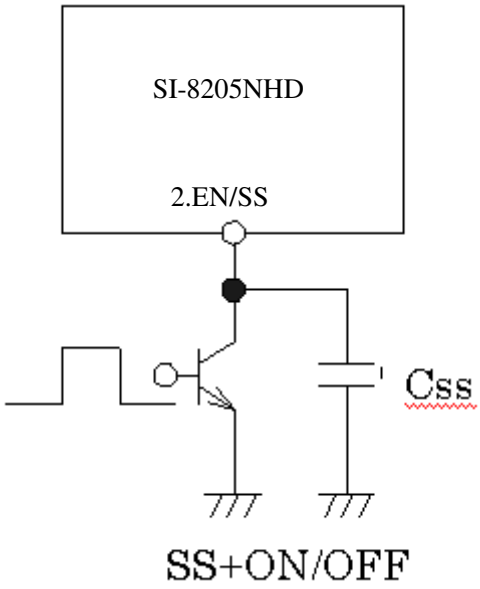


Fig. 20 ON / OFF Control

In the case that the transistor Q1 for ON/OFF control is not connected, the discharge of Css is made from the IN terminal, when the Vin falls. In the case of the restart (rise of Vin), after fall of Vin and drop of Vo, and prior to the complete fall of Vin, the discharge of Css may not be made without applying soft start.
Such an incident may be solved by connecting a discharge circuit as shown in Fig. 21.

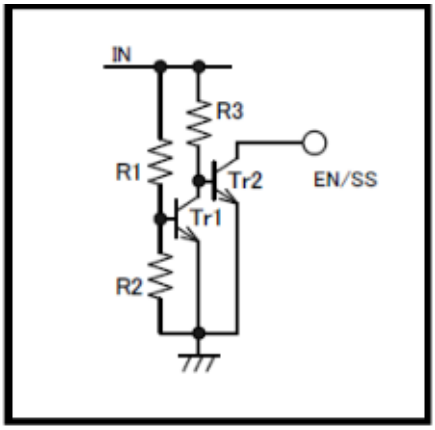


Fig. 21 Css Discharge Circuit diagram

● 6-3 Spike Noise Reduction

In order to reduce the spike noise, it is possible to compensate the output waveform of the SI-8205NHD and the recovery time of the diode by a capacitor (snubber), but it should be noted that the efficiency is also

slightly reduced.

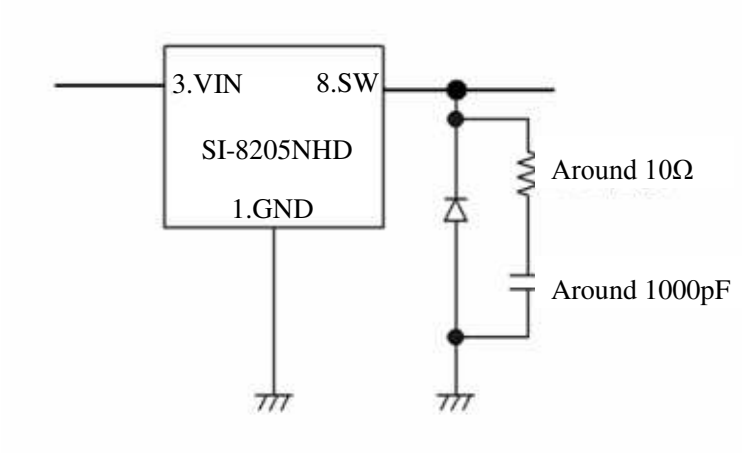


Fig. 22 Example of Snubber

* 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.

● 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, such as in battery chargers.

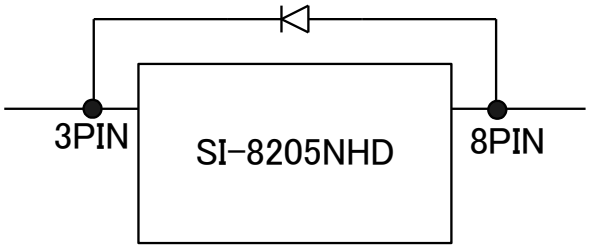
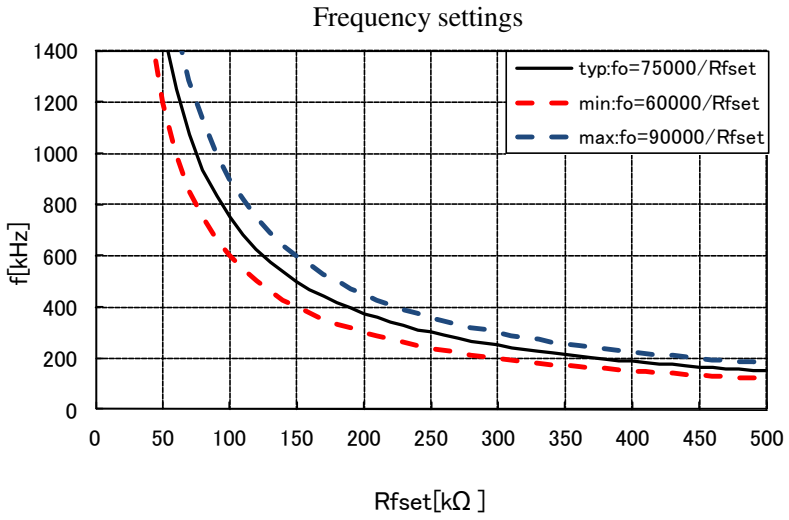


Fig. 23 Diode for Reverse Bias Protection

● 6-5 Operational Frequency

When a resistor is connected to No. 4 terminal (FSET terminal), it is possible to set the operating frequency to 200 – 1000kHz (TYP). Fig. 24 shows the relation between the connected resistor and the operating frequency.



・Typ value:

fo[kHz]=75000／Rfset[kΩ]・・・・1

・min value:

fo[kHz]=60000／Rfset[kΩ] ・・・・2

・max value:

fo[kHz]=90000／Rfset[kΩ] ・・・・3

Rfset is resistor of "Frequency settings", connect it between Pin-4 (FSET) and Pin-1(GND).

Fig. 24 Characteristic of Operational Frequency

● 6-6 Synchronous, non-synchronous automatic selection function

In the SI-8205NHD, The automatic selection function of the synchronous rectification / non-synchronous rectification is being given by the relations between the VIN voltage and Ip current (peak current of the inductor). The changeover characteristic (VIN-Ip characteristic) of the synchronous rectification / non-synchronous rectification is shown by the fig.23. In case of the synchronous mode, when the internal-Lowside-MOSFET is turned on, the recirculating-current flows via the internal-Lowside-MOSFET. In case of a non-synchronous mode, the internal-Lowside-MOSFET is turned off, the recirculating-current flows via the parasitic diode with Lowside-MOSFET.

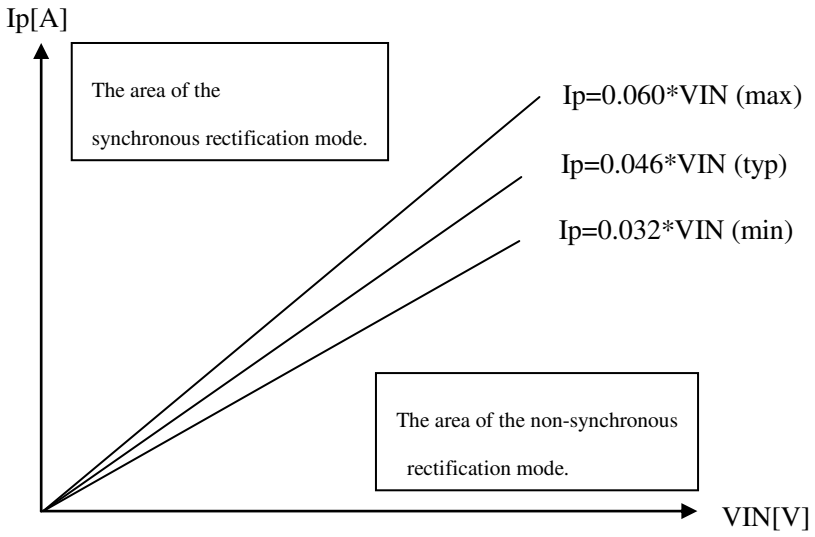


Fig.25

The changeover characteristic (VIN-Ip characteristic)

of the synchronous rectification / non-synchronous rectification.

And, it becomes the following equation when the inductor-peak-current Ip is converted into the output-current Io.

・Inductor ripple current ⊿IL

$$\cdots \quad \triangle IL = \frac{Vo}{L \times f} \times (1 - \frac{Vo}{V_{IN}})$$

・A critical condition (the inductor-current continuous mode and the boundary of the discontinuous mode) .

$$\cdots \text{Continuous mode :} \qquad Io \geqq \frac{\triangle IL}{2}$$

$$\cdots \text{Discontinuous mode :} \qquad Io < \frac{\triangle IL}{2}$$

・Output-current Io in case of the inductor-current continuous mode

$$\cdots \quad Io = Ip - \frac{\triangle IL}{2}$$

・Output-current Io in case of the inductor-current discontinuous mode

$$\cdots \quad Io = \frac{(V_{IN} \times L \times f)}{\{2 \times Vo \times (V_{IN} - Vo)\}} \times Ip^2 = \frac{1}{(2 \times \triangle IL)} \times Ip^2$$

● 6-7 About the operational -frequency when the output is light-load or no-load

In the non-synchronous mode (until it changes to the synchronous mode), In the SI-8205NHD, with a purpose of charging the BS-capacitor, the internal-MOSFET (It is called the "BS charge MOS") works at minimum-ON-time. This "BS charge MOS" works in half of the basic switching-frequency.
The fig.26 shows oscillating wave form of (the non-synchronous mode) in case of the light-load or no-load.

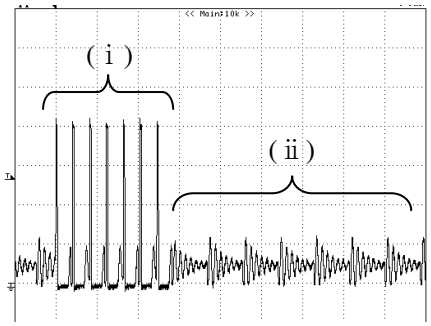


Fig.26 Oscillating wave form

In the part of (ⅰ), the high-side-MOSFET is turned on, and it is working in the basic oscillating-frequency.
In the part of (ⅱ),the high-side-MOSFET is turned off, and it is working only with "BS charge MOS". "BS charge MOS" works in half of the basic oscillating-frequency through (ⅰ) to (ⅱ), and it is understood that "BS charge MOS" works in the part of ⅱ .

（"BS charge MOS" works in half of the basic oscillating-frequency）

In the part of (ⅰ), there are relations of the "equation 1 - 3" that is described in the "6-5 operational-frequency".In the part of (ⅱ),the oscillating-frequency is a half of the "equation 1 - 3".

● 6-8 About the movement mode in the light-load condition

The movement mode in light-load condition changes to the synchronous mode / non-synchronous mode by the relations between the VIN voltage and peak electric current of the inductor. (Refer to "6-6 Synchronous, non-synchronous automatic selection function") . The oscillating wave form in the light-load condition, it becomes the "fig.26 of 6-7", however, the function which does the movement of the pulse-skip (intermittent oscillation) isn't contained in the SI-8205NHD.

● 6-9 About the dispersion of resistance "RonH and RonL"with the internal-MOSFET

High-side MOSFET RonH・・・ MIN：105mΩ TYP：150mΩ MAX：195mΩ

Low-side MOSFET RonL・・・ MIN：105mΩ TYP：150mΩ MAX：195mΩ

*Both MOSFET are n-channel type,the resistance is between the drain and the source.

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.

Important Notes

- All data, illustrations, graphs, tables and any other information included in this document (the "Information") as to Sanken's products listed herin (the "Sanken Products") are current as of the date this document is issued. The Information is subject to any change without notice due to improvement of the Sanken Products, etc. Please make sure to confirm with a Sanken sales representative that the contents set forth in this document reflect the latest revisions before use.
- The Sanken Products are intended for use as components of general purpose electronic equipment or apparatus (such as home appliances, office equipment, telecommunication equipment, measuring equipment, etc.). Prior to use of the Sanken Products, please put your signature, or affix your name and seal, on the specification documents of the Sanken Products and return them to Sanken. When considering use of the Sanken Products for any applications that require higher reliability (such as transportation equipment and its control systems, traffic signal control systems or equipment, disaster/crime alarm systems, various safety devices, etc.), you must contact a Sanken sales representative to discuss the suitability of such use and put your signature, or affix your name and seal, on the specification documents of the Sanken Products and return them to Sanken, prior to the use of the Sanken Products. The Sanken Products are not intended for use in any applications that require extremely high reliability such as: aerospace equipment; nuclear power control systems; and medical equipment or systems, whose failure or malfunction may result in death or serious injury to people, i.e., medical devices in Class III or a higher class as defined by relevant laws of Japan (collectively, the "Specific Applications"). Sanken assumes no liability or responsibility whatsoever for any and all damages and losses that may be suffered by you, users or any third party, resulting from the use of the Sanken Products in the Specific Applications or in manner not in compliance with the instructions set forth herein.
- In the event of using the Sanken Products by either (i) combining other products or materials or both therewith or (ii) physically, chemically or otherwise processing or treating or both the same, you must duly consider all possible risks that may result from all such uses in advance and proceed therewith at your own responsibility.
- Although Sanken is making efforts to enhance the quality and reliability of its products, it is impossible to completely avoid the occurrence of any failure or defect or both in semiconductor products at a certain rate. You must take, at your own responsibility, preventative measures including using a sufficient safety design and confirming safety of any equipment or systems in/for which the Sanken Products are used, upon due consideration of a failure occurrence rate and derating, etc., in order not to cause any human injury or death, fire accident or social harm which may result from any failure or malfunction of the Sanken Products. Please refer to the relevant specification documents and Sanken's official website in relation to derating.
- No anti-radioactive ray design has been adopted for the Sanken Products.
- The circuit constant, operation examples, circuit examples, pattern layout examples, design examples, recommended examples, all information and evaluation results based thereon, etc., described in this document are presented for the sole purpose of reference of use of the Sanken Products.
- Sanken assumes no responsibility whatsoever for any and all damages and losses that may be suffered by you, users or any third party, or any possible infringement of any and all property rights including intellectual property rights and any other rights of you, users or any third party, resulting from the Information.
- No information in this document can be transcribed or copied or both without Sanken's prior written consent.
- Regarding the Information, no license, express, implied or otherwise, is granted hereby under any intellectual property rights and any other rights of Sanken.
- Unless otherwise agreed in writing between Sanken and you, Sanken makes no warranty of any kind, whether express or implied, including, without limitation, any warranty (i) as to the quality or performance of the Sanken Products (such as implied warranty of merchantability, and implied warranty of fitness for a particular purpose or special environment), (ii) that any Sanken Product is delivered free of claims of third parties by way of infringement or the like, (iii) that may arise from course of performance, course of dealing or usage of trade, and (iv) as to the Information (including its accuracy, usefulness, and reliability).
- In the event of using the Sanken Products, you must use the same after carefully examining all applicable environmental laws and regulations that regulate the inclusion or use or both of any particular controlled substances, including, but not limited to, the EU RoHS Directive, so as to be in strict compliance with such applicable laws and regulations.
- You must not use the Sanken Products or the Information for the purpose of any military applications or use, including but not limited to the development of weapons of mass destruction. In the event of exporting the Sanken Products or the Information, or providing them for non-residents, you must comply with all applicable export control laws and regulations in each country including the U.S. Export Administration Regulations (EAR) and the Foreign Exchange and Foreign Trade Act of Japan, and follow the procedures required by such applicable laws and regulations.
- Sanken assumes no responsibility for any troubles, which may occur during the transportation of the Sanken Products including the falling thereof, out of Sanken's distribution network.
- Although Sanken has prepared this document with its due care to pursue the accuracy thereof, Sanken does not warrant that it is error free and Sanken assumes no liability whatsoever for any and all damages and losses which may be suffered by you resulting from any possible errors or omissions in connection with the Information.
- Please refer to our official website in relation to general instructions and directions for using the Sanken Products, and refer to the relevant specification documents in relation to particular precautions when using the Sanken Products.
- All rights and title in and to any specific trademark or tradename belong to Sanken and such original right holder(s).

DSGN-CEZ-16003