# Application Note

## Surface Mount, Synchronous Rectification Type Chopper Regulator IC

# NR885K



Jun. 2015 Rev 6.0

SANKEN ELECTRIC CO., LTD.

The contents of this application note are subject to change without any notice for further improvements.

# --- Contents ---

1. General Descriptions
1-1 Features ........ 3
1-2 Applications ........ 3
1-3 Type ........ 3
2. Product Specifications
2-1 Package Information ........ 4
2-2 Electrical Characteristics ........ 5
2-3 Circuit Diagram ........ 7
3. Terminal Descriptions
3-1 Terminal List ........ 8
3-2 Terminal Functions ........ 8
4. Operational Descriptions
4-1 PWM Output Control ........ 9
4-2 Overcurrent and Thermal Shutdown Protections ........ 10
5. Design Notes
5-1 External Components ........ 11
5-2 Pattern Designs ........ 16
5-3 Power Supply Stabilities ........ 19
6. Application Information
6-1 Soft Start ........ 20
6-2 Output ON / OFF Control ........ 21
6-3 Spike Noise Reduction ........ 21
6-4 Reverse Bias Protection ........ 23
6-5 External Bootstrap Diode for Low Input ........ 23
7. Technical Terms ........ 24

# 1. General Descriptions

The NR885K products are synchronous rectification type Step-Down regulator ICs incorporating a power MOSFET. By applying the current mode control system, ultra low ESR capacitors such as ceramic capacitors can be used. The products have protection functions such as over-current protection, under-voltage lockout and thermal shutdown. The built-in soft-start function, adjustable by an external capacitor, prevents the excessive inrush current to flow at start-up. In addition, the IC incorporates the integrated phase compensation circuit, which simplifies the design and reduces the number of external components. The ON/OFF pin allows deactivation of the regulator and helps to achieve low power consumption requirements. The NR885K is available in a compact and slim HSOP-8-pin package with an exposed thermal pad on the back side.



## ● 1-1 Features

- Output Current 3.0A
  Maximum output current: 3.0A
- High Efficiency
  Maximum efficiency: 94% (VIN = 8V / VO = 5V / IO = 0.8A)
- Variable Output Voltage: 0.8 - 14V
- Low ESR Output Capacitor
  Ceramic capacitors applicable
- Operation Frequency: 350kHz
- Incorporated Over-current and Thermal Shutdown Protections
  Drooping type over-current protection and thermal shutdown protection circuits (auto-restart type)
- Incorporated Phase Compensation Circuit
  No external phase compensation component
- Soft Start Function
  Controlled output voltage rising by an external capacitor during start-up
- ON / OFF Function
- Small Size Package
  HSOP-8-pin package with an exposed thermal pad

## ● 1-2 Applications

- On-board Local Power Supplies
- Stabilized Secondary Voltage Regulators
- OA Equipment Power Supplies
- Telecommunication Power Supplies

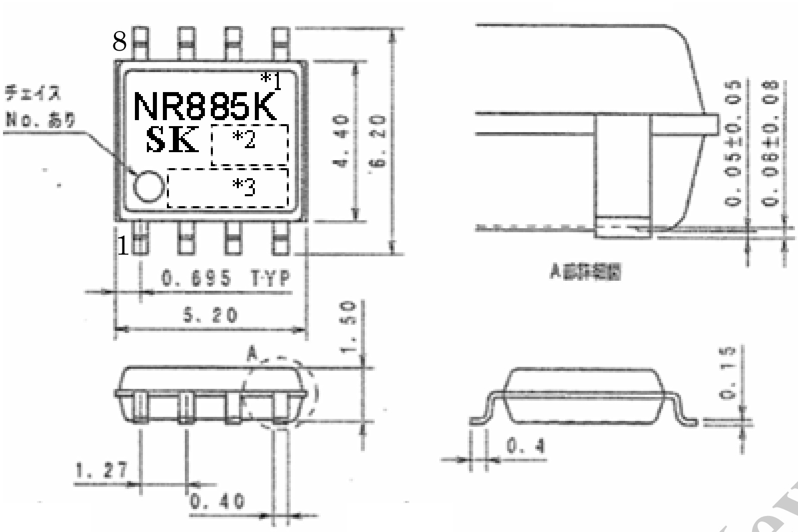
## ● 1-3 Type

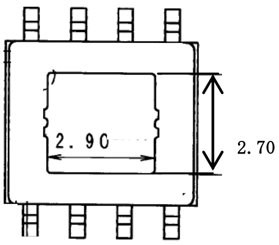
- Type: Semiconductor IC (Monolithic IC)
- Structure: Plastic Package (Transfer Mold)

# 2. Product Specifications

## ● 2-1 Package Information

Unit: mm




*1. Part number
*2. Lot number (three digits)
- 1st letter — Last digit of year
- 2nd letter — Month (1 to 9 for Jan to Sep, O for Oct, N for Nov, D for Dec)
- 3rd letter — Week 01~05: Arabic Numerical

*3. Control number (four digits)

## ● 2-2 Electrical Characteristics

Table 1 Absolute Maximum Rating

| Parameter | Symbol | Ratings | Unit | Conditions |
|---|---|---|---|---|
| Input Voltage $V_{IN}$ | $V_{IN}$ | 20 | V | |
| BS Voltage $V_{BS}$ | $V_{BS}$ | 25.5 | V | |
| SW Voltage $V_{SW}$ | $V_{SW}$ | 20 | V | |
| FB Voltage $V_{FB}$ | $V_{FB}$ | 5.5 | V | |
| EN Voltage $V_{EN}$ | $V_{EN}$ | 20 | V | |
| SS Voltage $V_{SS}$ | $V_{SS}$ | 5.5 | V | |
| Allowable Power Dissipation [1)] | Pd | 1.69 | W | |
| Junction Temperature | Tj | 150 | °C | |
| Storage Temperature | Tstg | -40 - 150 | °C | |
| Thermal Resistance (Junction - Case) [2)] | θj-c | 40 | °C/W | |
| Thermal Resistance (Junction - Air) [2)] | θj-a | 74 | °C/W | |

[1)] The incorporated thermal shutdown protection will trigger at Tj > 160°C.
[2)] Mounted on a glass epoxy PCB of 30.0mm × 30.0mm (copper foil area: 25.0mm × 25.0mm)

Table 2 Recommended Operating Conditions

| Parameter | Symbol | Ratings | Unit |
|---|---|---|---|
| DC Input Voltage [3)] | $V_{IN}$ | (4.5 or Vo+3v) - 18 | V |
| Output Current | $I_O$ | 0 - 3.0 | A |
| DC output voltage range | Vo | 0.8 - 14 | V |
| Operating Ambient Temperature | Top | -40 - +85 | °C |

[3)] The minimum value of input voltage range shall be either of 4.5V or $V_O$+3V, whichever is higher.

When $V_{IN}$ = $V_O$+1 – $V_O$+3V, $I_{OUT}$ = 2A MAX.

When VIN < 6V, it is recommended to place a diode between VIN and BS, or to connect a diode and apply an external voltage to the BS terminal.

Table 3 Electrical Characteristics (Ta = 25°C, when Vo = 3.3V, R1 = 5kΩ, R2 = 1.6kΩ)

| Parameter | | Symbol | Ratings | | | Unit | Conditions |
|---|---|---|---|---|---|---|---|
| | | | MIN | TYP | MAX | | |
| Set-up Reference Voltage [4] | | VREF | 0.784 | 0.800 | 0.816 | V | VIN = 12V,Io = 1.0A |
| Output Voltage Temperature Coefficient | | ΔVREF/ΔT | | ±0.05 | | mV/°C | VIN = 12V,Io = 1.0A<br>Ta = -40°C - +85°C |
| Efficiency [6] | | η | | 90 | | % | VIN = 12V, Io = 1A |
| Operation Frequency [5] | | fo | 280 | 350 | 420 | kHz | VIN = 12V, Io = 1A |
| Line Regulation [7] | | VLine | | 50 | | mV | VIN = 6.3 - 18V, Io = 1A |
| Load Regulation [7] | | VLoad | | 50 | | mV | VIN = 12V, Io = 0.1 - 3.0A |
| Overcurrent Protection Start Current | | IS | 3.1 | | 6.0 | A | VIN = 12V |
| Quiescent Current 1 | | IIN | | 6 | | mA | VIN = 12V, Io = 0A,<br>VEN = 10kΩ pull up to VIN |
| Quiescent Current 2 | | IIN(off) | | | 10 | μA | VIN = 12V, Io = 0A,<br>VEN = 0V |
| SS Terminal *9 | Source Current at Low Level | ISS1 | 6 | 10 | 14 | μA | VSS = 0V, VIN = 12V |
| | Open Voltage | VssH | 2.7 | 3.0 | 3.3 | V | VIN = 12V |
| EN Terminal | Sink Current | $I_{EN}$ | | 50 | 100 | μA | VEN = 10V |
| | ON Threshold Voltage | $V_{C/EH}$ | 0.7 | 1.4 | 2.1 | V | VIN = 12V |
| Maximum On Duty [7] | | DMAX | 85 | 90 | 95 | % | |
| Minimum On Time [7] | | DMIN | | 150 8) | | nsec | |
| Thermal Shutdown Start Temperature [7] | | TSD | 151 | 165 | | °C | |
| Thermal Shutdown Restart Hysteresis [7] | | TSD_hys | | 20 | | °C | |

4) MIN / MAX: Preliminary

5) MIN / MAX: Preliminary

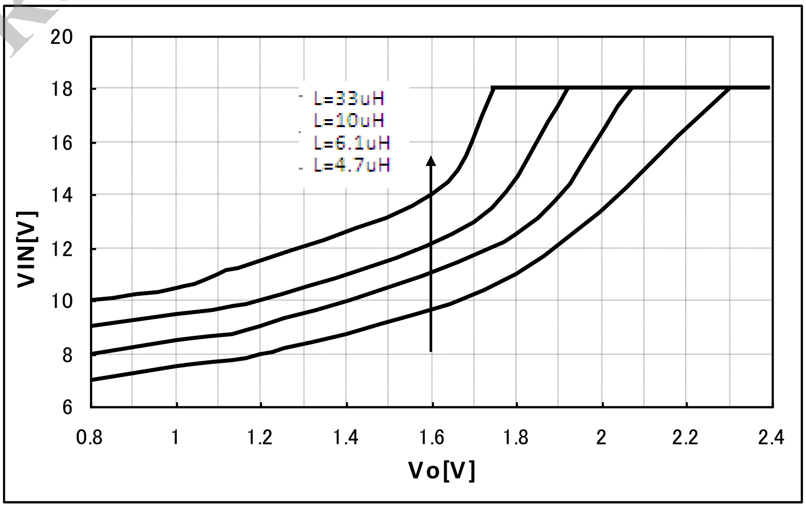
6) The efficiency is calculated using the following equation.

$$\eta\ (\%) = \frac{V_O \cdot I_O}{V_{IN} \cdot I_{IN}} \times 100 \quad \text{------ (1)}$$

7) Design guaranteed value

8) The I/O characteristic graph of the figure below shows the I/O condition limited by the DMIN

Be effective only if output current is less than 100mA.



## ● 2-3 Circuit Diagram

### 2-3-1 Functional Block Diagram

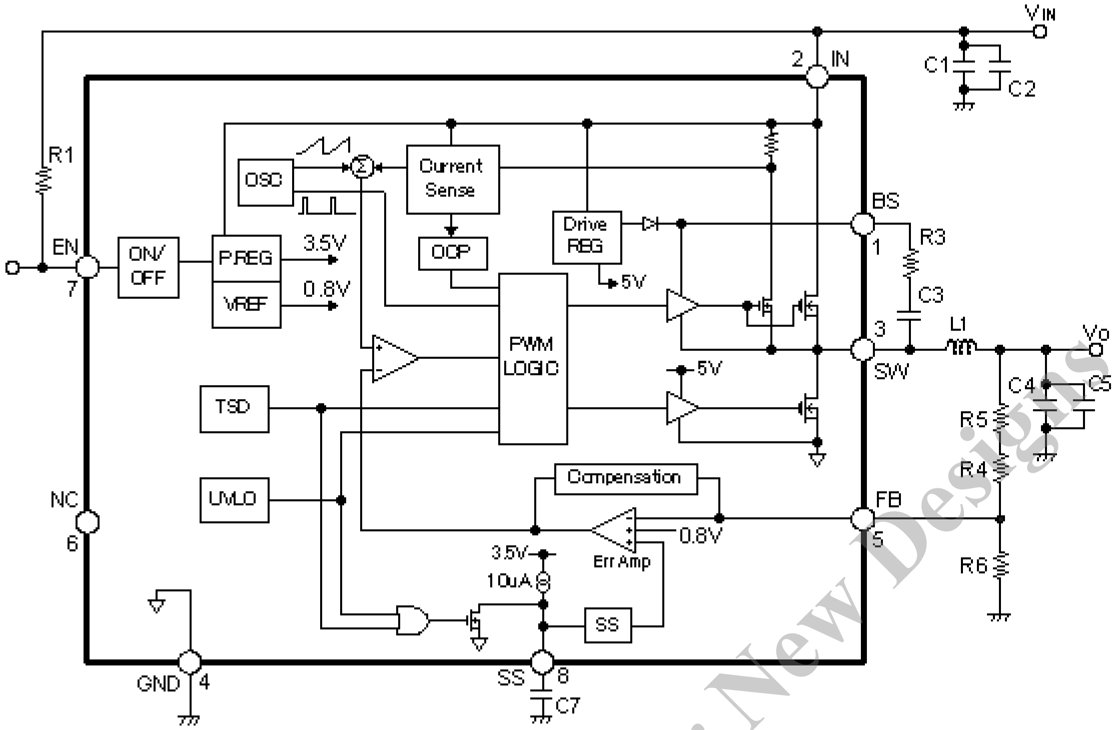
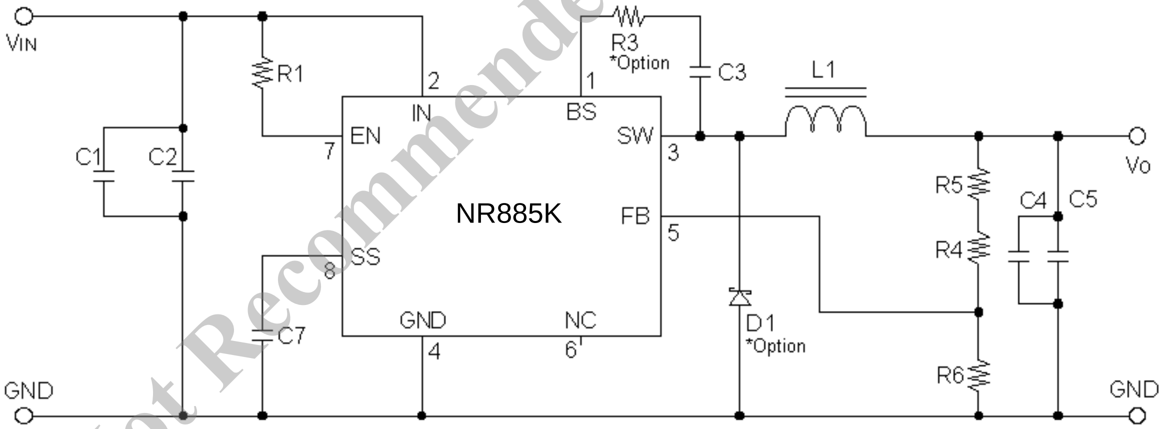



fig.1

### 2-3-2 Typical Application Circuit




C1/C2: 10uF / 25V ×2
C3: 0.1uF
L1: 10uH
R3: 22Ω (Option)
R5: 4.3kΩ

C4/C5: 22uF / 6.3V ×2
C7: 0.1uF
R1: 100kΩ
R4: 8.2 kΩ
R6: 3.9kΩ(Vo=3.3V)
D1:*Option

fig.2

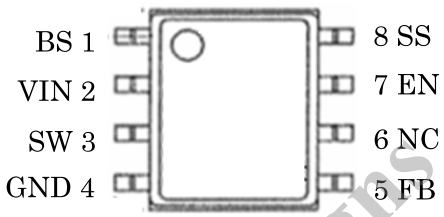
# 3. Terminal Descriptions

## ● 3-1 Terminal List

Table 4 Terminal List

| Terminal No. | NR885K | |
|---|---|---|
| | Symbol | Name |
| 1 | BS | High-side Boost Terminal |
| 2 | VIN | Input Terminal |
| 3 | SW | Switching Output Terminal |
| 4 | GND | Ground Terminal |
| 5 | FB | Reference Voltage Terminal |
| 6 | NC | No Connection |
| 7 | EN | ON / OFF Terminal |
| 8 | SS | Soft Start Terminal |

NR885K




## ● 3-2 Terminal Functions

- BS (Terminal No.1):

  The internal power supply for the gate drive of high-side switch Nch-MOSFET

  The high-side Nch-MOSFET is driven by connecting a capacitor (10uF or higher) between SW terminal and BS terminal.

- VIN (Terminal No.2):

  The IC input voltage

- SW (Terminal No.3):

  The switching output terminal supplying the output power

- GND (Terminal No.4):

  Ground terminal

- FB (Terminal No.5):

  Terminal for the output voltage setting

  The output voltage is set with R1and R2.

- NC (Terminal No.6):

  No connection terminal (Connection to GND is recommended)

- EN (Terminal No.7):

  Terminal for turning the IC ON and OFF

- SS (Terminal No.8):

  Terminal for enabling the output voltage soft start function by connecting a capacitor

# 4. Operational Descriptions

## ● 4-1 PWM Output Control

The NR885K consists of total three blocks; two feedback loop systems (current control and voltage control) and one slope compensation. For the voltage control feedback, the loop makes the output voltage feedback to the PWM control. In NR885K, the error amplifier compares the output voltage divided by resistors with the reference voltage VREF = 0.8V. For the current control feedback, the loop makes the inductor current feedback to the PWM control. The inductor current that is branched by using sense MOSFET is detected with the current sense amplifier. In terms of current control method characteristics, the slope compensation is made for current control slope, to prevent subharmonic oscillations. For NR885K, the PWM control is achieved with current control method, by calculating the voltage control feedback, the current control feedback and the slope compensation signals. (Refer to Fig.3)

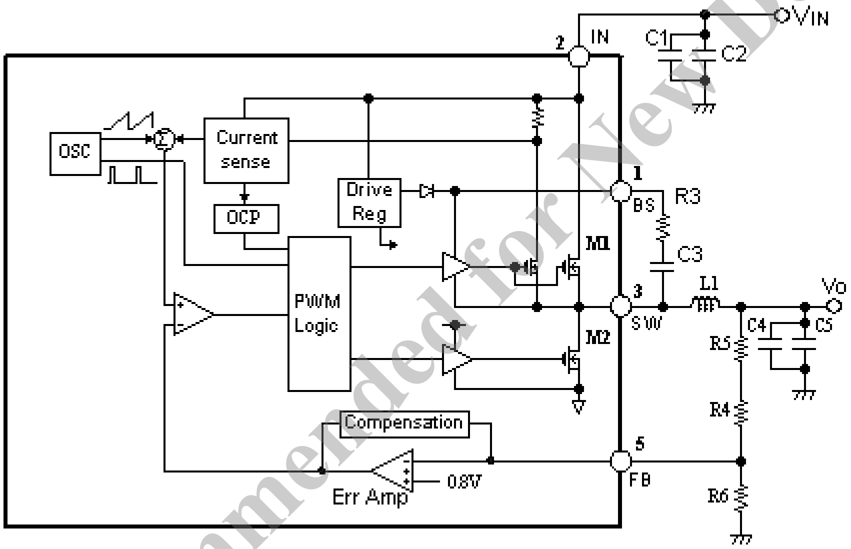


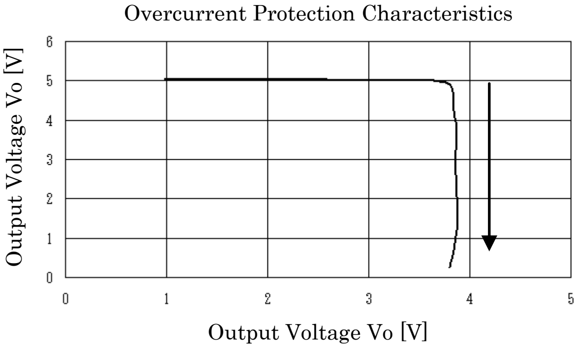

fig.3 Basic Structure of Chopper Type Regulator with PWM Control by Current Control

The NR885K starts the switching operation when UVLO is released, or EN or SS terminal voltage exceeds the threshold. Initially, it operates switching with minimum ON duty or maximum ON duty. The high-side switch (M1) is the switching MOSFET that supplies output power. At first, the low-side switch (M2) turns ON and charges the boost capacitor C3 that drives M1. When M1 is ON, as the inductor current is increased by applying voltage to SW terminal and the inductor, the output of inductor current sense amplifier is also increased. Sum of the current sense amplifier output and slope compensation signal is compared with the error amplifier output. When the summed signal exceeds the error amplifier (Error Amp.) output voltage, the current comparator output becomes “H” and the RS flip-flop is reset. When M1 turns OFF and M2 turns ON, the regenerative current flows through M2. If an external SBD (D1) is connected, the current also flows through D1.

In NR885K, the set signal is generated in each cycle and RS flip-flop is set. If the summed signal does not exceed the error amplifier (Error Amp.) output voltage, RS flip-flop is reset without fail by the signal from

OFF duty circuit.

## ● 4-2 Overcurrent and Thermal Shutdown Protections




The oscillation frequency decreases as VO decreases.

fig.4 Output Voltage Characteristics at Overcurrent

The NR885K incorporates the drooping type over-current protection circuit. The circuit detects the peak current of switching transistor. When the peak current exceeds the rated value, the over-current protection limits the current by forcibly shortening the ON time of transistor and decreasing the output voltage. It prevents the current from increasing at low output voltage by decreasing the switching frequency, if the output voltage drops lower. When the over-current state is released, the output voltage automatically returns.

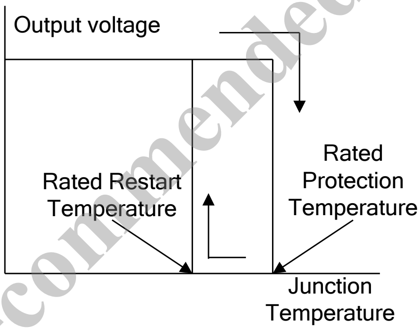



fig.5 Output Voltage Characteristics at Thermal Shutdown

The thermal shutdown circuit detects the IC junction temperature. When the junction temperature exceeds the rated value (around 160°C), it shuts-down the output transistor and turns the output OFF. If the junction temperature falls below the thermal shutdown rated value by around 20°C, the operation returns automatically.

* (Thermal Shutdown Characteristics) Notes

The circuit protects the IC against temporary heat generation (e.g. momentary short circuit). It does not guarantee the operation including reliabilities under the continuous heat generation conditions, such as short circuit for a long time.

# 5. Design Notes

## ● 5-1 External Components

### 5-1-1 Choke Coil L1

The choke coil L1 plays a central role of chopper type switching regulators. In order to maintain the stabilized regulator operation, the coil should be carefully selected so it must not enter saturation or over heat excessively at any conditions. The selection points of choke coil are as follows:

a) Only switching regulator type coil should be used.
It is recommended not to use a coil for noise filer since it causes high heat generation due to high power dissipation.

b) The subharmonic oscillations should be prevented.
Under the peak detection current control, the inductor current may fluctuate at a frequency that is an integer multiple of switching operation frequency. This phenomenon is the known as subharmonic oscillation and this phenomenon theoretically occurs in the peak detection current control mode. Therefore, in order to stabilize the operation, the inductor current compensation is made internally. The proper inductor value corresponding to the output voltage should be selected.

Fig.6 shows the selection range of inductance L value to prevent the subharmonic oscillations. As for the upper limit of inductance L, the value is for reference, because it may vary depending on input/output conditions and load current.

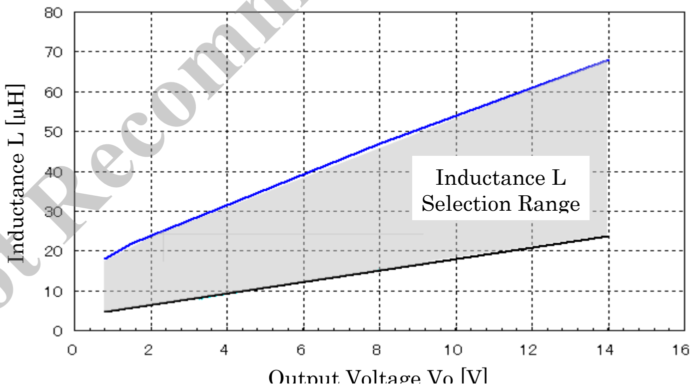



fig.6 NR885K(f=350kHz) Inductance L Value Selection Range

The ripple portion of choke coil current ΔIL and the peak current ILp are calculated from the following equations:

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

$$ILp = \frac{\Delta IL}{2} + Iout \qquad \text{------ (B)}$$

According to the equations, the smaller the choke coil inductance L is, the bigger the ΔIL and ILp are. Therefore, if the inductance is too low, the regulator operation may be unstable because the choke coil current fluctuates largely. It is necessary to take care of the choke coil inductance decrease due to the magnetic saturation such as in overload and load shortage.

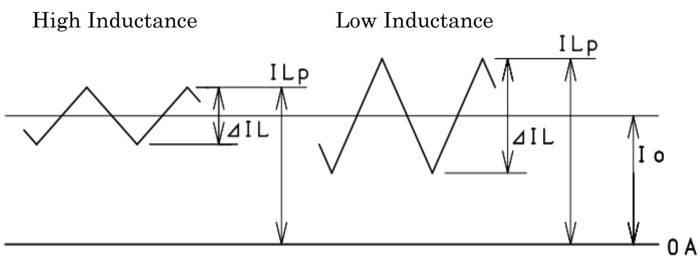



fig.7

c) The coil should be of proper rated current.

The rated current should be higher than the maximum load current used. If the load current exceeds the rated current of coil, the inductance decreases drastically and eventually enters into the saturation state. In this status, it is necessary to take care because the high-frequency impedance decreases and the excess current runs.

d) The magnetic noise should be minimized.

The open magnetic circuit type core like a drum type may generate noise in peripheral circuit due to the magnetic flux passing outside of coil. Coils of closed magnetic circuit type core, such as toroidal type, EI type and EE type are preferable.

### 5-1-2 Input Capacitor $C_{IN}$

The input capacitor operates as a bypass capacitor of input circuit. It supplies the short current pulses to the regulator during switching and compensates the input voltage drop. Therefore, it should be placed as close as possible to the regulator IC. Even if the rectifying capacitor of AC rectifier circuit is in input circuit, the input capacitor cannot be used as a rectifying capacitor unless it is placed near NR880K.

*$C_{IN}$ is C1/C2 in the typical application circuit.

The selection points of $C_{IN}$ are as follows:

a) The capacitor should be of proper breakdown voltage rating

b) The capacitor should have sufficient allowable ripple current rating

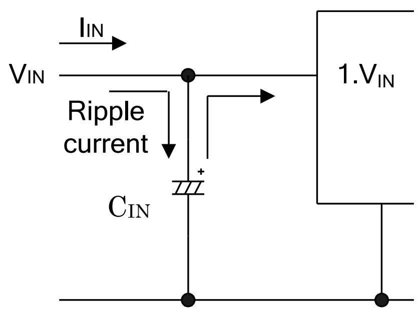
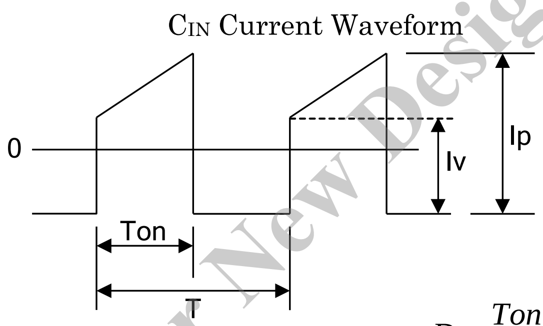



fig.8 $C_{IN}$ Current Flow




$$D = \frac{Ton}{T}$$

The ripple current of input capacitor increases according to the load current increase.

fig.9 $C_{IN}$ Current Waveform

If the input capacitor is working under the conditions of excessive breakdown voltage or allowable ripple current, or without derating, the regulator may become unstable and the capacitor's lifetime may be greatly reduced. This may result in capacitance decrease, equivalent series impedance increase or even capacitor bursting. Therefore, the selection with sufficient margins is needed. The effective value of ripple current Irms that flows across the input capacitor is calculated from the equation (2):

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

For instance, where $V_{IN}$ = 20V, $I_O$ = 3A, $V_O$ = 5V,

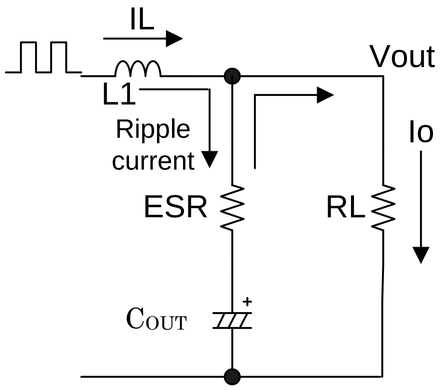
$$Irms \approx 1.2 \times \frac{5}{20} \times 3 = 0.9A$$

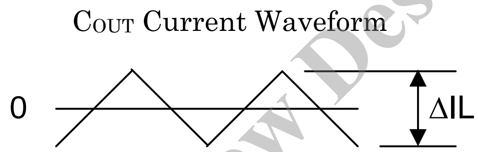
Therefore, it is necessary to select the capacitor with the allowable ripple current of 0.9A or higher.

### 5-1-3 Output Capacitor $C_{OUT}$

In the current control method, the feedback loop which detects the inductor current is added to the voltage control method. The stable operation is achieved by adding inductor current to the feedback loop without considering the effect of secondary delay factor of LC filter. Therefore, it is possible to reduce the capacitance C of LC filter that is needed to make compensations for the secondary delay, and the stable operation is achieved even by using the low ESR capacitor (ceramic capacitor).

The output capacitor $C_{OUT}$ comprises the LC low-pass filter with choke coil L1 and works as the rectifying capacitor of switching output. The current equal to ripple portion ΔIL of choke coil current charges and discharges the output capacitor. Therefore, in the same way as the input capacitor, the breakdown voltage and the allowable ripple current should be met with sufficient margins.




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

fig.10 $C_{OUT}$ Current Flow

The ripple current effective value of output capacitor is calculated from the equation (3):

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

When ΔIL = 0.5A,

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

Therefore a capacitor with the allowable ripple current of 0.14A or higher is needed.

The output ripple voltage of regulator Vrip is determined by the product of choke current ripple portion ΔIL (= $C_{OUT}$ discharge and charge current) and output capacitor $C_{OUT}$ equivalent series resistance ESR.

$$Vrip = \Delta IL \cdot Cout \cdot ESR \quad \text{------ (4)}$$

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 products of higher capacitance with same breakdown voltage, or of higher breakdown voltage with same capacitance.

When ΔIL = 0.5A, Vrip = 40mV,

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

A capacitor with ESR of 80mΩ or lower should be selected. 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 every capacitor series. *$C_{OUT}$ is C4/C5 in the typical application circuit.

**5-1-4 Flywheel Diode D1**

By connecting a flywheel diode externally, the higher efficiency is available.

The flywheel diode D1 is for releasing the energy stored in the choke coil at switching OFF. It is strongly recommended to use a Schottky barrier diode for flywheel diode. If a general rectifying diode or a fast recovery diode is used, the IC may be destroyed by applying reverse voltage due to the recovery and ON voltage. Since the output voltage from the SW terminal (pin 3) of NR885K is almost equal to the input voltage, it is necessary to use the flywheel diode with the reverse breakdown voltage of equal or higher than the input voltage.

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

**5-1-5 Output Voltage Vo and Output Capacitor $C_{OUT}$**

Table 5 shows the comparison of output voltage and output capacitor, for maintaining the NR885K stable operations, for reference.

Regarding the inductance L, it is recommended to select it according to **5-1-1 Choke Coil L1.** (Refer to fig.6 Inductance L Value Selection Range)

Table 5 NR885K (fo=350kHz) Vo and Co Comparison Table

| VO(V) | $C_{OUT}$(μF) | |
|---|---|---|
| | Ceramic Capacitor | Electrolytic Capacitor (ESR: around 100mΩ) |
| 1.2 | 33 - 100 | 47 - 330 |
| 1.8 | 22 - 100 | 47 - 470 |
| 3.3 | 10 - 68 | 20 - 180 |
| 5 | 4.7 - 47 | 4.7 - 100 |
| 9 | 3.3 - 22 | 2.2 - 47 |
| 12 | 3.3 - 22 | 2.2 - 33 |
| 14 | 2.2 - 22 | 2.2 - 33 |

## ● 5-2 Pattern Designs

### 5-2-1 High Current Line

High current runs in certain paths in the circuit and these paths are marked as bold lines in the circuit diagram below. These paths should be as wide and short as possible.

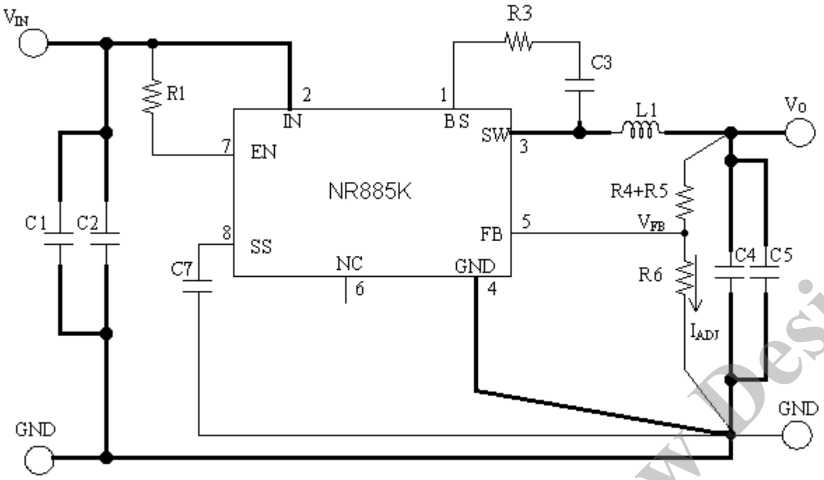



fig.11 Circuit Diagram

### 5-2-2 Input / Output Capacitors

The input capacitor C1/C2 and the output capacitor C4/C5 should be placed as close as possible to the IC. If the rectifying capacitor for AC rectifier circuit is in the input side, it can be also used as an input capacitor. However, if it is not close to the IC, the input capacitor needs to be connected in addition to the rectifying capacitor. A similar care should be taken when designing pattern for other capacitors.

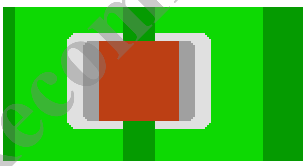


fig.12 Proper Pattern Example

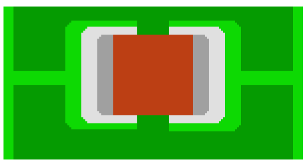


fig. 13 Improper Pattern Example

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

The FB is the feedback detection terminal that controls the output voltage. It is recommended to connect it as close as possible to the output capacitor $C_{OUT}$. If they are not close, cares should be necessary because the abnormal oscillations may be caused by the poor regulation and the increased switching ripple.

The output voltage setting is achieved by connecting R4,R5 and R6.

Setting the $I_{FB}$ to around 0.5mA is recommended.

(The target of $I_{FB}$ lower limit is 0.5mA, and the upper limit is not defined. However, it is necessary to consider that the circuit current shall increase according to the $I_{FB}$ value.)

R4, R5 and R6 the output voltage are calculated from the following equations:

$I_{FB}=V_{FB}/R6$ *$V_{FB}=0.8v\pm2\%$

$R4+R5= (Vo-V_{FB})/I_{FB}$ $R6=V_{FB}/I_{FB}$

$V_{OUT}=(R4+R5)\times(V_{FB}/R6) +V_{FB}$

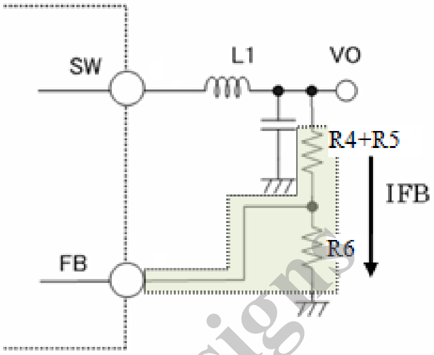



fig.14

- R6 needs to be connected for the stable operation when set to Vo = 0.8V.
- Regarding the relation of input / output voltages, the setting making the SW terminal ON width to be around 200nsec or wider is recommended.

● The PCB circuit traces of FB terminal, R4,R5 and R6 that run parallel to the flywheel diode should be avoided. The switching noise may affect the detection voltage and the abnormal oscillation may be caused. Especially, it is recommended to design the circuit trace short from FB terminal to R6.

● Mounting Board Pattern Example (Demo-board Pattern)

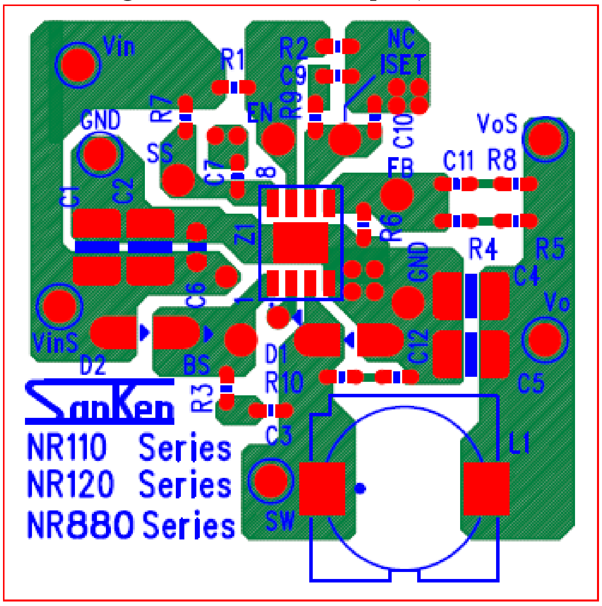



fig.15 Front Side: Component Side (double sided board)

fig.16 Back Side: GND Side (double sided board)

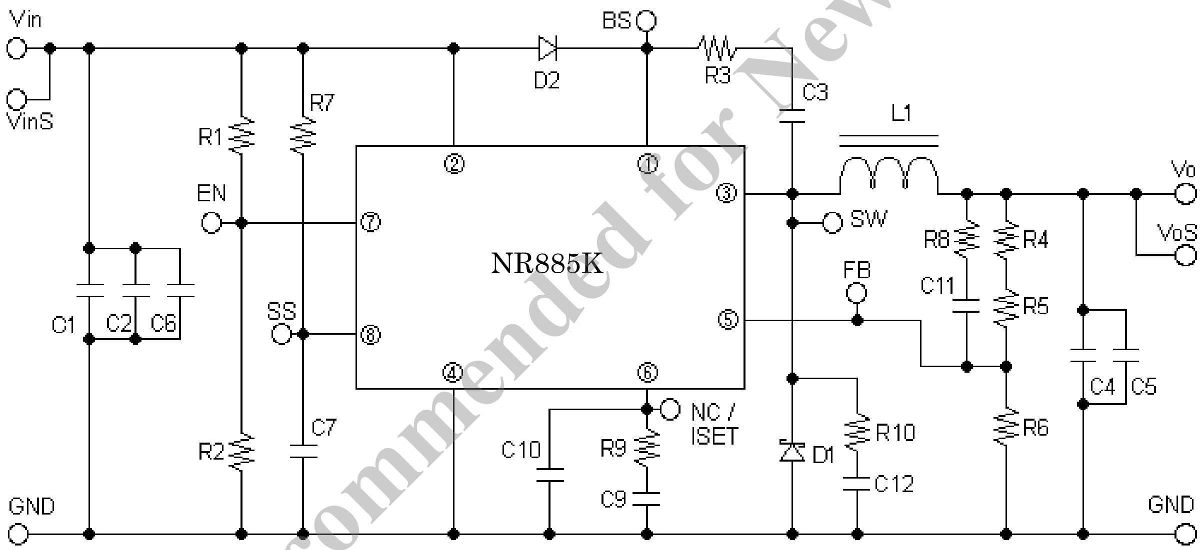



fig.17 Demo-board circuit-diagram

As for the part number of the demonstration board "circuit-diagram", a circuit board concerned doesn't partly fit each other with the above application circuit example and so on for NR110, NR120 and the NR880 series common use. Approve it in advance. C9, R9 and C10 aren't used in the NR880 series. And, D1, D2, R3, R8,R10, C11 and C12 are options.

## 5-3 Power Supply Stability

The phase characteristics of chopper type regulator are the synthesis of the internal phase characteristics of regulator IC, and the combination of output capacitor Cout and load resistance Rout. The internal phase characteristics of regulator IC are generally determined by the delay time of control block and the phase characteristics of output error amplifier. Among these, the phase delay due to the delay time of control block rarely causes problems in actual use. As the phase compensation for output error amplifier is incorporated, refer to **5-1-5 Output Voltage VO and Output Capacitor CO** for the setting of output voltage and output capacitor, in order to ensure stable operation.

# 6. Application Information

## ● 6-1 Soft Start

By connecting a capacitor to the terminal 8, the soft start is activated at applying the input voltage. The Vout rises according to the charging voltage of Css. Therefore, the rough estimation is made using the time constant calculation of Css charge.

The capacitor Css controls the rise time by controlling the PWM OFF period. The rise time t_ss and the delay time t_delay are roughly calculated from the equations in Fig.18.

The terminal 8 shall be open, when the soft start function is not used.

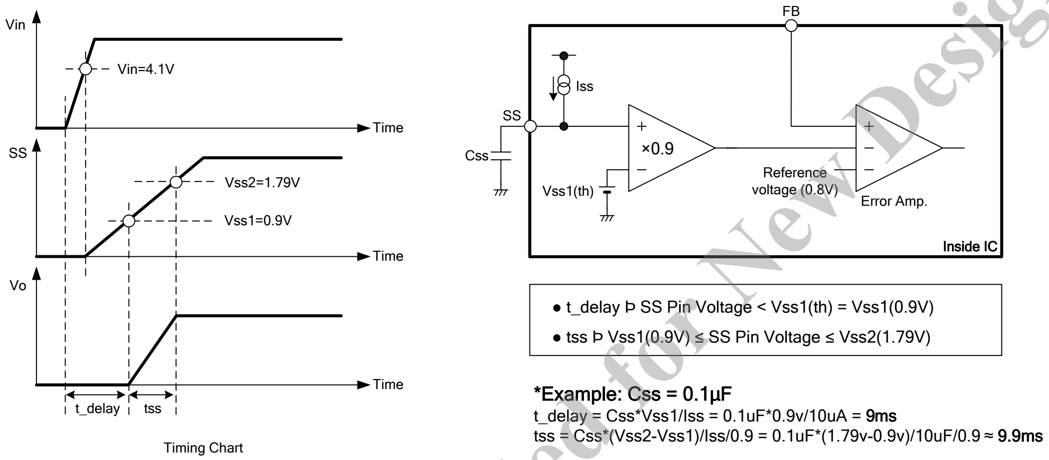
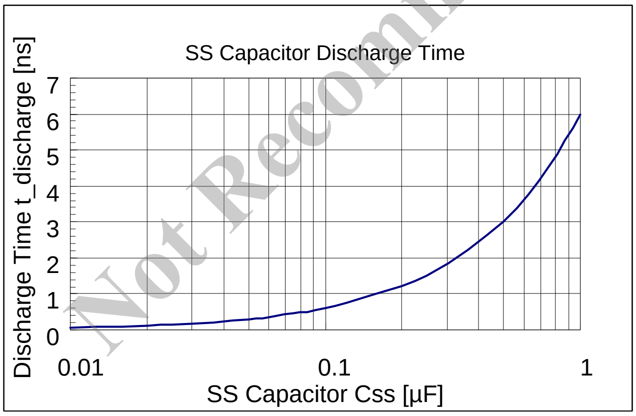



fig.18 Soft Start Characteristics




SS Open Voltage: 3V

SS Discharge Capability: 500μA

The left graph shows the SS terminal voltage changing time from 3V to 0V.



If there is no Css or it is extremely low, the Vout raises with the time constant that charges the output capacitor with output current limited by over-current protection Is.

The time constant at output capacitor start-up t = (Co × Vo) / Is ------- (at no load)

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

## ● 6-2 Output ON and OFF Control

EN Pin (Pin No.7) turns the regulator ON or OFF. When drive EN under 1.4V ($V_{ENL}$), output is turned OFF (fig.19). 1.4V ($V_{ENL}$) can be achieved by connecting a bipolar transistor in an open collector configuration.
When the external ON/OFF function isn't used, connect only Pull-up resistor of 100kΩ between IN and EN, and use it as the fig20.It starts when a $V_{IN}$ voltage is inputted.

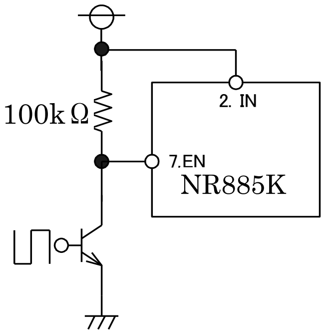



fig. 19 ON / OFF Control 1

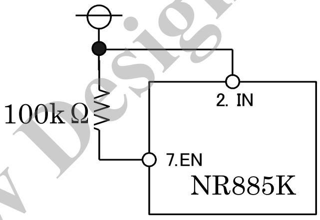



fig. 20 ON / OFF Control 2

## ● 6-3 Spike Noise Reduction

6.3.1 The addition of the BS serial resistor

The "turn-on switching speed" of the internal Power-MOSFET can be slowed down by inserting $R_{BS}$ (option) of the fig21.It is tendency that Spike noise becomes small by reducing the switching-speed. Set up 22-ohm as an upper limit when you use $R_{BS}$.

*Attention

1) When the resistance value of $R_{BS}$ is enlarged by mistake too much, the internal power-MOSFET becomes an under-drive, it may be damaged worst.
2) The "defective starting-up" is caused when the resistance value of $R_{BS}$ is too big.

*The BS serial resistor $R_{BS}$ is R3 in the Demonstration Board.

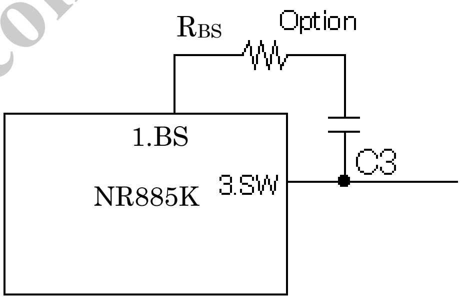



fig.21. The addition of the BS serial resistor

6.3.2 The addition of the Snubber circuit

In order to reduce the spike noise, it is possible to compensate the output waveform and the recovery time of diode by connecting a capacitor and resistor parallel to the freewheel diode (snubber method). This method however may slightly reduce the efficiency.

* For observing the spike noise with an oscilloscope the probe lead (GND) should be as short as possible and connected to the root of output capacitor. If the probe GND lead is too long, the lead may act like an antenna and the observed spike noise may be much higher and may not show the real values.

*The snubber circuit parts are C12 and R10.

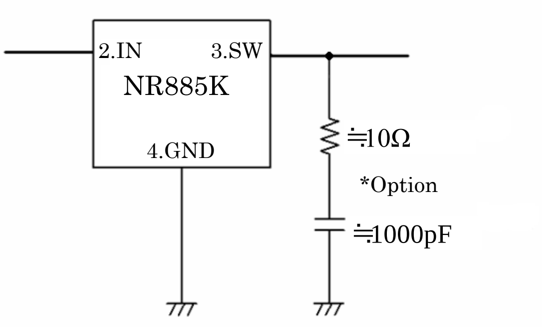



fig.22 The addition of the Snubber circuit

6.3.3 Attention about the insertion of the bead-core

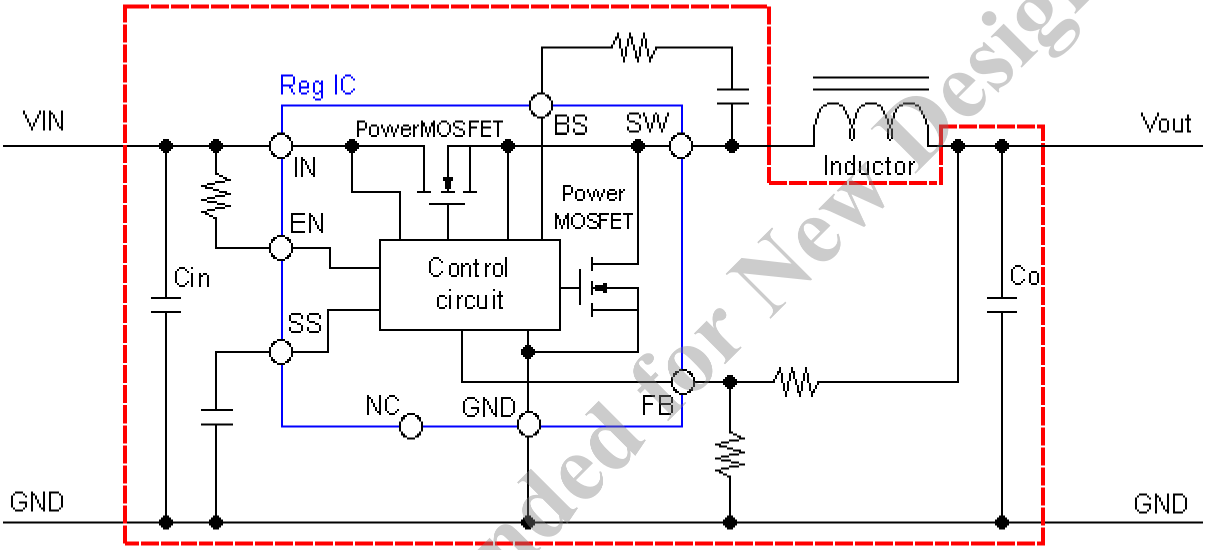



fig.23

In the area surrounded by the red dotted line within the fig23, don't insert the bead-core such as Ferrite-bead.
As for the pattern-design of printed-circuit-board, it is recommended that the parasitic-inductance of wiring-pattern is made small for the safety and the stability.
When bead-core was inserted, the inductance of the bead-core is added to parasitic-inductance of the wiring-pattern.
By this influence, the surge-voltage occurs often, or , GND of IC becomes unstable, and also, negative voltage occurs often.
Because of this, faulty operation occurs in the IC. The IC has the possibility of damage in the worst case.
About the Noise-reduction, fundamentally, Cope by "The addition of CR snubber circuit" and "The addition of BS serial resistor".

## ● 6-4 Reverse Bias Protection

A diode for reverse bias protection may be needed between input and output in case the output voltage is expected to be higher than the input terminal voltage (a common case in battery charger applications).

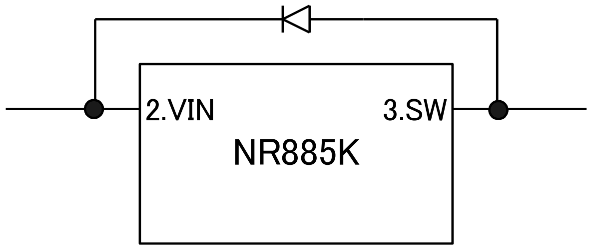



fig.24 Reverse Bias Protection Diode

## ● 6-5 External Bootstrap Diode for Low Input

Although the NR885K will work with input voltages lower than 6V, it is recommended to place a diode between VIN and BS in order to improve the efficiency (fig.25). Alternatively an external voltage source can be connected through a diode to the BS terminal (fig.26).

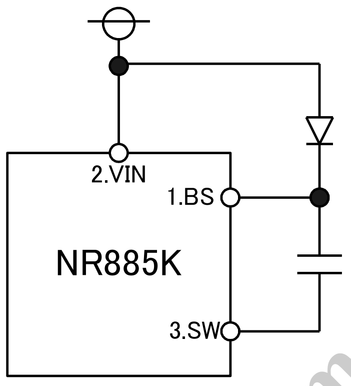



fig.25 External Bootstrap Diode Connection 1

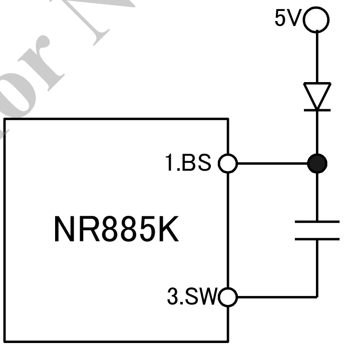



fig.26 External Bootstrap Diode Connection 2

## Technical Terms

*What is described in this document is subject to change without notice due to improvements in the performance, reliability and manufacturability of the product. Therefore, the user is cautioned to verify that the information in this publication is current before placing an order*

*Application and operation examples described in this document are quoted for the sole purpose of reference for the use of the products herein and Sanken can assume no responsibility for any infringement of industrial property rights, intellectual property rights or any other rights of Sanken or any third party which may result from its use.*

*When using the products herein, the applicability and suitability of such products for intended purpose object shall be reviewed at the user's responsibility.*

*Although Sanken undertakes to enhance the quality and reliability of its products, the occurrence of failure and defect of semiconductor products at a certain rate is inevitable. Users of Sanken products are requested to take, at their own risk preventative measures including safety design of the equipment or systems against any possible injury, death, fires or damages to the society due to device failure or malfunction.*

*Sanken products listed in this document are designed and intended for the use as components in general purpose electronic equipment or apparatus (home appliances, office equipment, telecommunication equipment, measuring equipment, etc.).*

*Whenever Sanken products are intended to be used in the applications where high reliability is required (transportation equipment and its control systems, traffic signal control systems or equipment, fire/crime alarm systems, various safety devices, etc.), and whenever long life expectancy is required even in general purpose electronic equipment or apparatus, please contact your nearest Sanken sales representative to discuss and obtain written consent of your specifications.*

*The use of Sanken products without the written consent of Sanken in the applications where extremely high reliability is required (aerospace equipment, nuclear power control systems, life support systems, etc.) is strictly prohibited.*