

# 7V to 28V Input, 1.5A Integrated MOSFET Single Synchronous Buck DC/DC Converter

**BD9E103FJ**

## General Description

BD9E103FJ is a single synchronous buck DC/DC converter with built-in low on-resistance power MOSFETs. The SLLM™ control provides excellent efficiency characteristics in light-load conditions which make the product ideal for equipment and devices that demand minimal standby power consumption. BD9E103FJ is a current mode control DC/DC converter and features high-speed transient response. Phase compensation can also be set easily.

## Features

- Single Synchronous Buck DC/DC Converter
- 5V Fixed Output Voltage
- SLLM™ (Simple Light Load Mode) Control
- Efficiency = 80% (@I<sub>OUT</sub>=10mA)
- Over Current Protection
- Short Circuit Protection
- Thermal Shutdown Protection
- Under Voltage Lockout Protection
- Over Voltage Protection
- Internal Soft Start
- Reduced External Diode
- SOP-J8 Package

## Applications

- Consumer Applications such as Home Appliance
- Secondary Power Supply and Adapter Equipment
- Telecommunication Devices

## Key Specifications

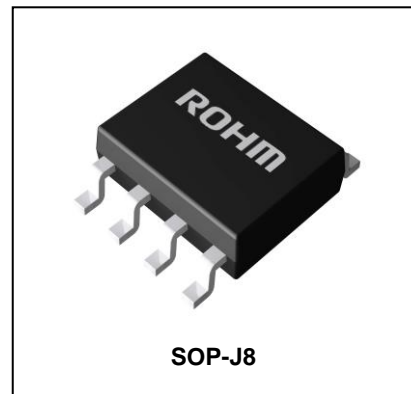
- |                                   |              |
|-----------------------------------|--------------|
| ■ Input Voltage Range:            | 7V to 28V    |
| ■ Fixed Output Voltage:           | 5.0V (Typ)   |
| ■ Output Current:                 | 1.5A (Max)   |
| ■ Switching Frequency:            | 330kHz (Typ) |
| ■ High-Side MOSFET ON-Resistance: | 250mΩ (Typ)  |
| ■ Low-Side MOSFET ON-Resistance:  | 200mΩ (Typ)  |

## Package

SOP-J8

**W (Typ) x D (Typ) x H (Max)**

4.90 mm x 6.00 mm x 1.65 mm



## Typical Application Circuit

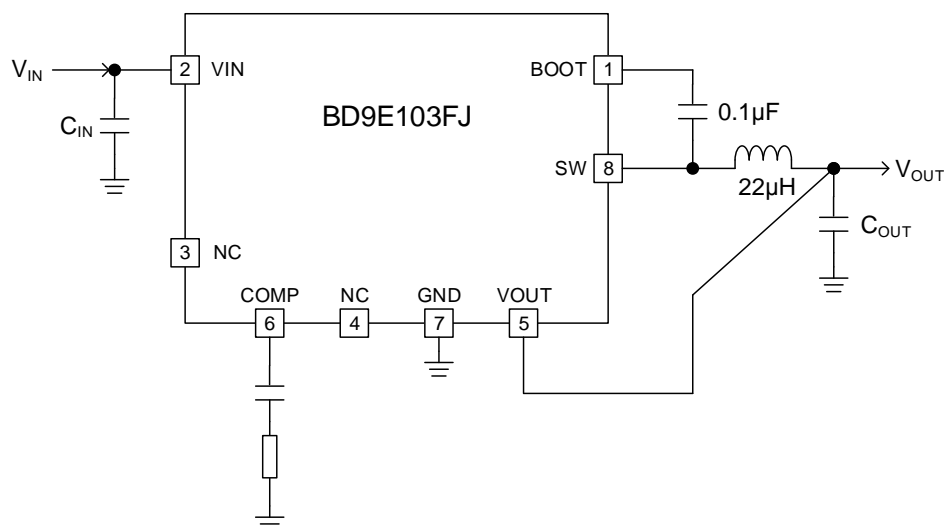
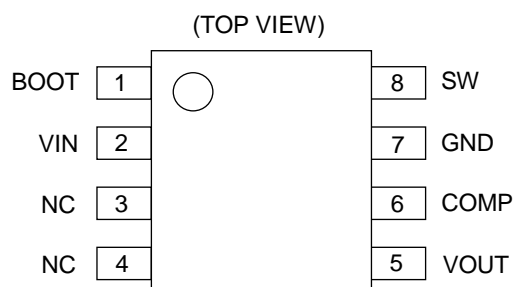


Figure 1. Application Circuit

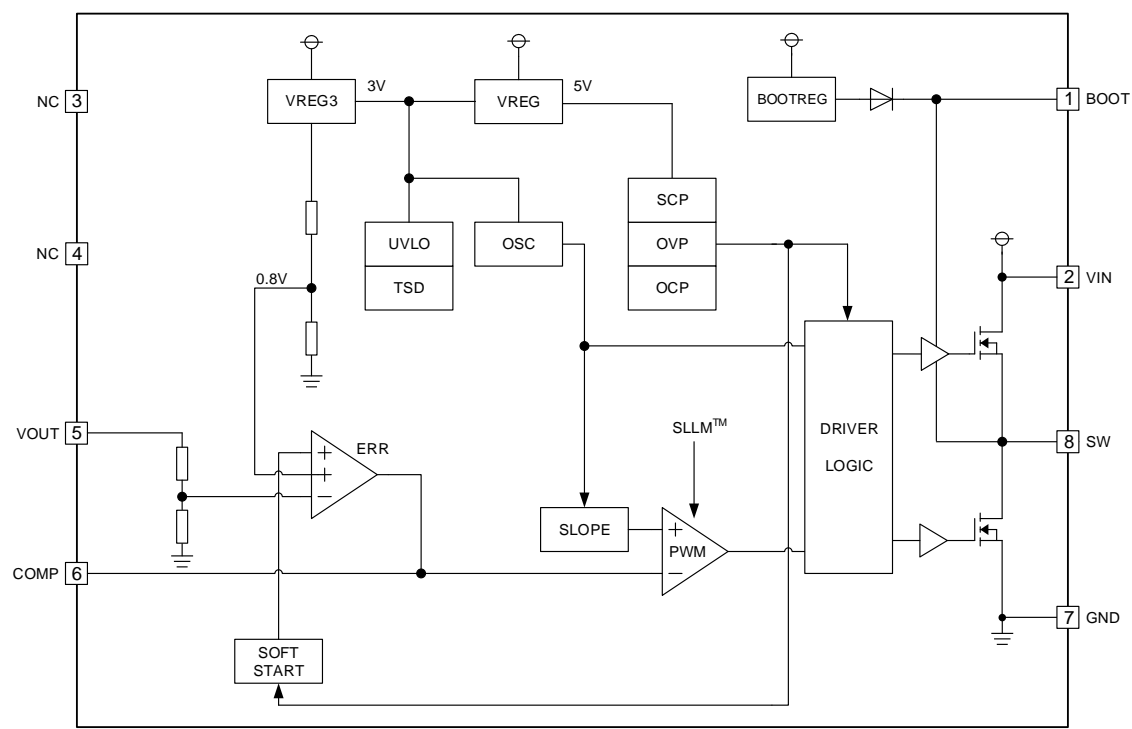
## Pin Configuration



## Pin Description

Pin No.	Pin Name	Description
1	BOOT	Connect a bootstrap capacitor of 0.1μF between BOOT terminal and SW terminal. The voltage of this capacitor is the gate drive voltage of the High-Side MOSFET.
2	VIN	Power supply terminal for the switching regulator and control circuit. Connecting a more than 10μF ceramic capacitor is recommended.
3	NC	No connection terminal.
4	NC	No connection terminal.
5	VOUT	Output voltage sense terminal.
6	COMP	Output terminal for the error amplifier and input terminal for PWM comparator. Connect phase compensation components to this terminal.
7	GND	Ground terminal for the control circuit and output stage of the switching regulator.
8	SW	Switch terminal. This terminal is connected to the source of the High-Side MOSFET and drain of the Low-Side MOSFET. Connect a bootstrap capacitor of 0.1μF between BOOT terminal and SW terminal. In addition, connect an inductor of 22μH considering the direct current superimposition characteristic.

Block Diagram



## Description of Blocks

1. VREG3  
The VREG3 block generates the 3V (Typ) internal reference voltage.
2. VREG  
The VREG block generates the 5V (Typ) internal power supply.
3. BOOTREG  
The BOOTREG block generates the gate drive voltage.
4. TSD  
The TSD block is for thermal protection. It shuts down the device when the internal temperature of IC rises to 175°C (Typ) or higher. Thermal protection circuit resets when the temperature falls. The circuit has a hysteresis of 25°C (Typ).
5. UVLO  
The UVLO block is for under voltage lockout protection. It shuts down the device when the  $V_{IN}$  falls to 6.4V (Typ) or lower. The UVLO threshold voltage has a hysteresis of 200mV (Typ).
6. ERR  
The ERR amplifier compares the reference voltage with the feedback voltage of the output voltage. The ERR amplifier output voltage (the COMP terminal voltage) determine the switching duty. Also, COMP terminal voltage is controlled by internal slope voltage due to soft start function during start-up.
7. OSC  
The OSC block generates the oscillating frequency.
8. SLOPE  
The SLOPE block synthesizes slope signal generated by OSC signal and current sense signal of High-Side MOSFET. This synthesized slope signal is sent to the PWM comparator.
9. PWM  
The PWM block compares the COMP terminal voltage and the slope signal voltage to determine the switching duty.
10. DRIVER LOGIC  
The DRIVER LOGIC block generates the DC/DC driver signals. A signal from PWM comparator is applied to drive the MOSFETs.
11. SOFT START  
The SOFT START circuit slows down the rise of output voltage during start-up and controls the current, which allows the prevention of output voltage overshoot and inrush current. The internal soft start time is set to 4ms (Typ).
12. OCP  
Current flowing in High-Side MOSFET is controlled every cycle of switching frequency when over current protection is detected.
13. SCP  
When the output voltage has fallen below 3.5V (Typ) and remained there for 0.8ms (Typ), SCP stops the operation for 25ms (Typ) and subsequently initiates a restart.
14. OVP  
When the output voltage exceeds 6.5V (Typ), it turns off the output MOSFETs. After the output voltage drops, it returns to normal operation with hysteresis.

**Absolute Maximum Ratings (Ta = 25°C)**

Parameter	Symbol	Rating	Unit
Input Voltage	V <sub>IN</sub>	-0.3 to +30	V
Voltage from GND to BOOT	V <sub>BOOT</sub>	-0.3 to +35	V
Voltage from SW to BOOT	ΔV <sub>BOOT</sub>	-0.3 to +7	V
VOUT Terminal Voltage	V <sub>OUT</sub>	-0.3 to +7	V
COMP Terminal Voltage	V <sub>COMP</sub>	-0.3 to +7	V
SW Terminal Voltage	V <sub>SW</sub>	-0.5 to +30	V
Maximum Junction Temperature	T <sub>jmax</sub>	150	°C
Storage Temperature Range	T <sub>stg</sub>	-55 to +150	°C

**Caution 1:** Operating the IC over the absolute maximum ratings may damage the IC. The damage can either be a short circuit between pins or an open circuit between pins and the internal circuitry. Therefore, it is important to consider circuit protection measures, such as adding a fuse, in case the IC is operated over the absolute maximum ratings.

**Caution 2:** Should by any chance the maximum junction temperature rating be exceeded the rise in temperature of the chip may result in deterioration of the properties of the chip. In case of exceeding this absolute maximum rating, design a PCB boards with power dissipation taken into consideration by increasing board size and copper area so as not to exceed the maximum junction temperature rating.

**Thermal Resistance (Note 1)**

Parameter	Symbol	Thermal Resistance (Typ)		Unit
		1s <sup>(Note 3)</sup>	2s2p <sup>(Note 4)</sup>	
SOP-J8				
Junction to Ambient	θ <sub>JA</sub>	149.3	76.9	°C/W
Junction to Top Characterization Parameter <sup>(Note 2)</sup>	Ψ <sub>JT</sub>	18	11	°C/W

(Note 1) Based on JESD51-2A(Still-Air).

(Note 2) The thermal characterization parameter to report the difference between junction temperature and the temperature at the top center of the outside surface of the component package.

(Note 3) Using a PCB board based on JESD51-3.

Layer Number of Measurement Board	Material	Board Size
Single	FR-4	114.3mm x 76.2mm x 1.57mm
Top		
Copper Pattern	Thickness	
Footprints and Traces	70μm	

(Note 4) Using a PCB board based on JESD51-7.

Layer Number of Measurement Board	Material	Board Size			
4 Layers	FR-4	114.3mm x 76.2mm x 1.6mm			
Top		2 Internal Layers		Bottom	
Copper Pattern	Thickness	Copper Pattern	Thickness	Copper Pattern	Thickness
Footprints and Traces	70μm	74.2mm x 74.2mm	35μm	74.2mm x 74.2mm	70μm

## Recommended Operating Conditions

Parameter	Symbol	Rating			Unit
		Min	Typ	Max	
Input Voltage	$V_{IN}$	7	-	28	V
Output Current	$I_{OUT}$	-	-	1.5	A
Operating Temperature	$T_{opr}$	-40	-	+85	°C

Electrical Characteristics (Unless otherwise specified  $T_a = 25^{\circ}\text{C}$ ,  $V_{IN} = 12\text{V}$ )

Parameter	Symbol	Limit			Unit	Conditions
		Min	Typ	Max		
Operating Supply Current	$I_{OPR}$	-	270	500	$\mu\text{A}$	$V_{OUT} = 5.62\text{V}$
Output Voltage	$V_{OUT}$	4.9	5.0	5.1	V	
Switching Frequency	$f_{OSC}$	280	330	380	kHz	
Maximum Duty Ratio	Maxduty	88	93	98	%	
High-side MOSFET ON-Resistance	$R_{ONH}$	-	250	-	$\text{m}\Omega$	$I_{SW} = 100\text{mA}$
Low-side MOSFET ON-Resistance	$R_{ONL}$	-	200	-	$\text{m}\Omega$	$I_{SW} = 100\text{mA}$
Over Current Limit (Note 1)	$I_{LIMIT}$	2.1	2.5	2.9	A	
UVLO Detection Voltage	$V_{UVLO}$	6.1	6.4	6.7	V	$V_{IN}$ falling
UVLO Hysteresis Voltage	$V_{UVLOHYS}$	100	200	300	mV	
Soft Start Time	$t_{ss}$	2	4	8	ms	

(Note 1) No tested on outgoing inspection.

Typical Performance Curves

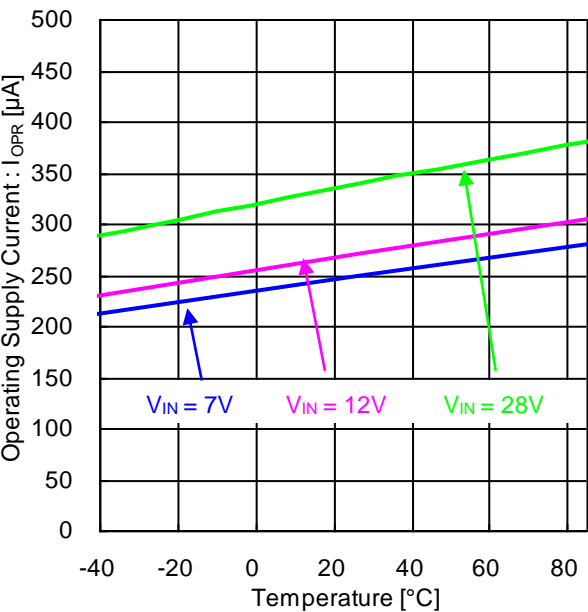


Figure 2. Operating Supply Current vs Temperature

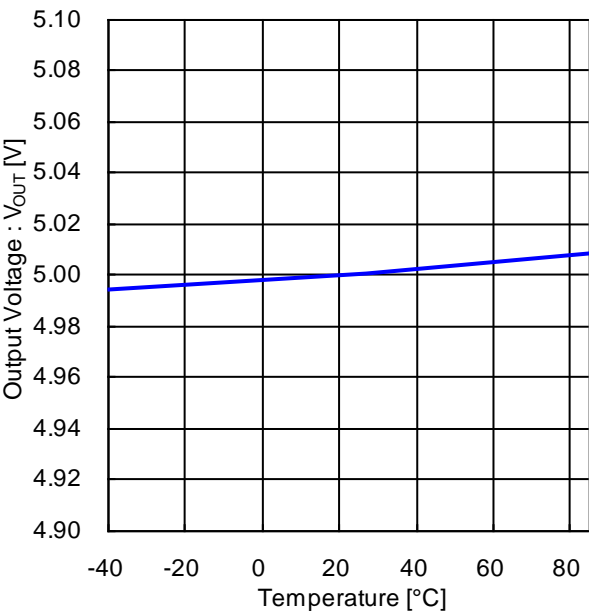


Figure 3. Output Voltage vs Temperature  
( $V_{IN}=12V$ )

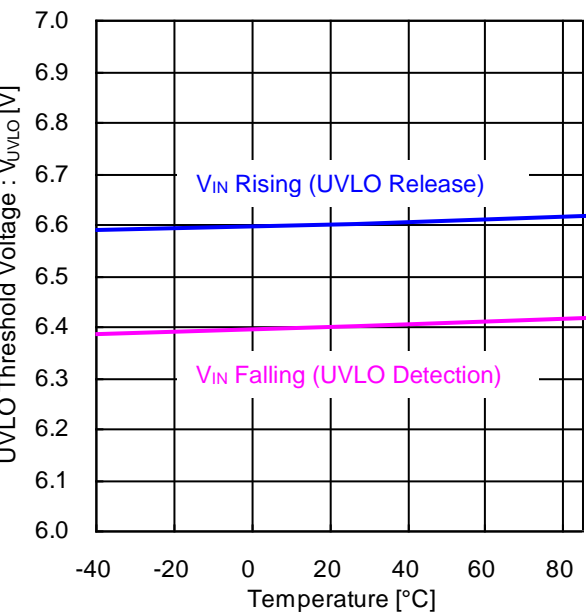


Figure 4. UVLO Threshold Voltage vs Temperature

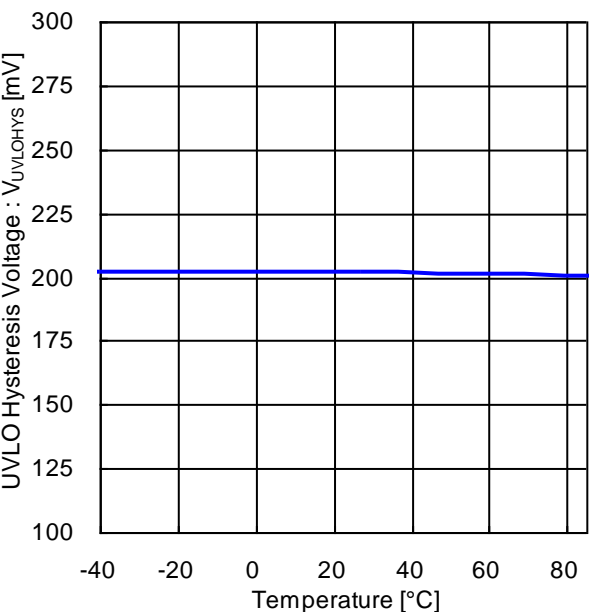


Figure 5. UVLO Hysteresis Voltage vs Temperature

Typical Performance Curves - continued

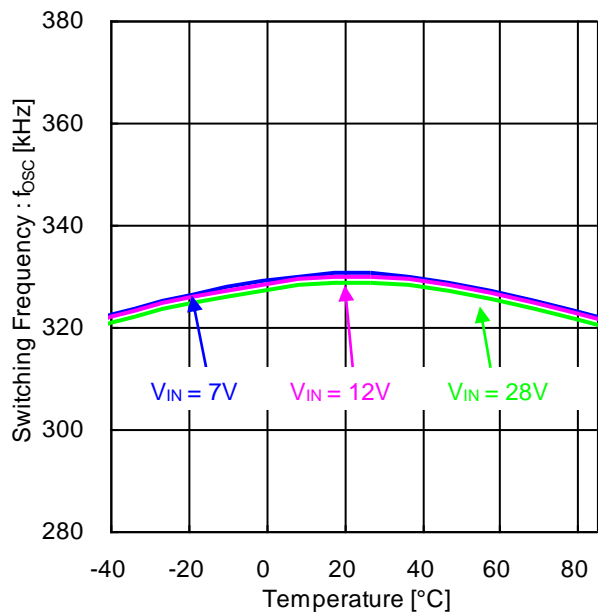


Figure 6. Switching Frequency vs Temperature

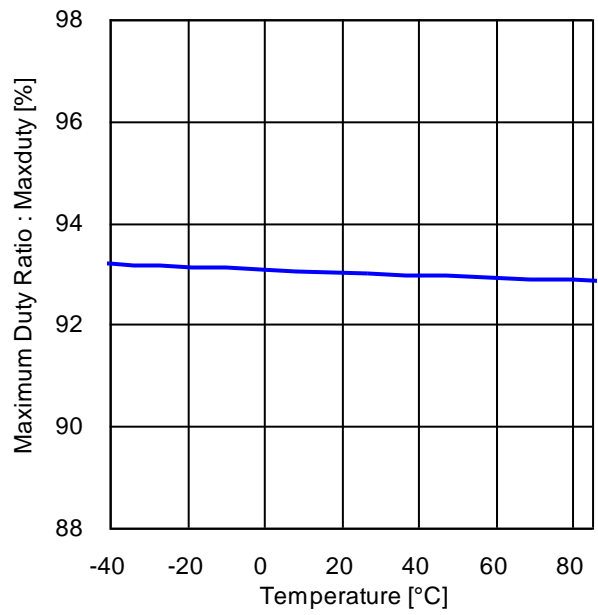


Figure 7. Maximum Duty Ratio vs Temperature  
(VIN = 12V)

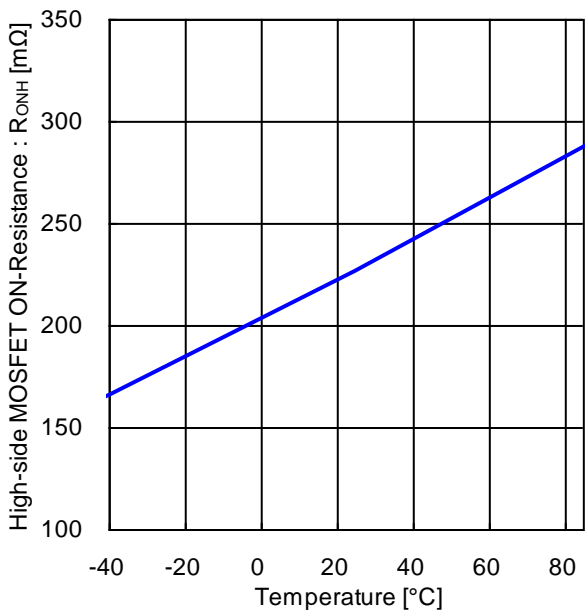


Figure 8. High-side MOSFET ON-Resistance vs Temperature  
(VIN = 12V)

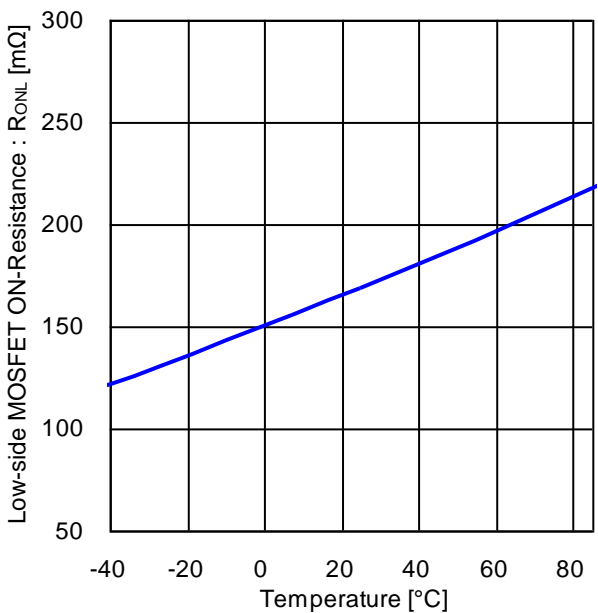


Figure 9. Low-side MOSFET ON-Resistance vs Temperature  
(VIN = 12V)



Typical Performance Curves - continued

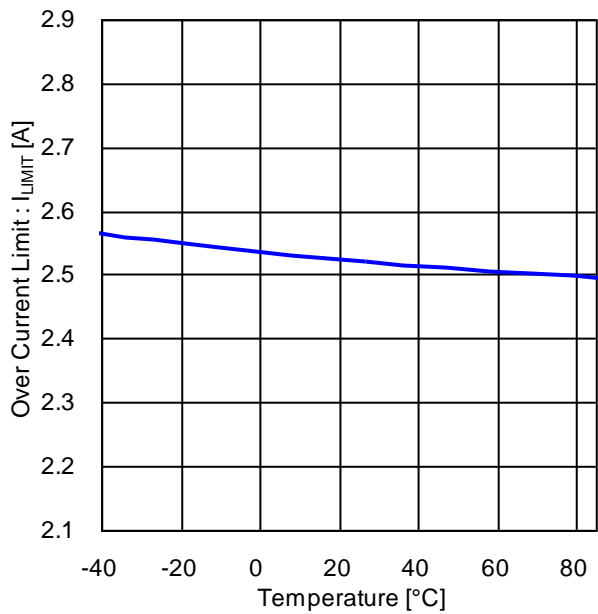


Figure 10. Over Current Limit vs Temperature  
( $V_{IN} = 12V$ )

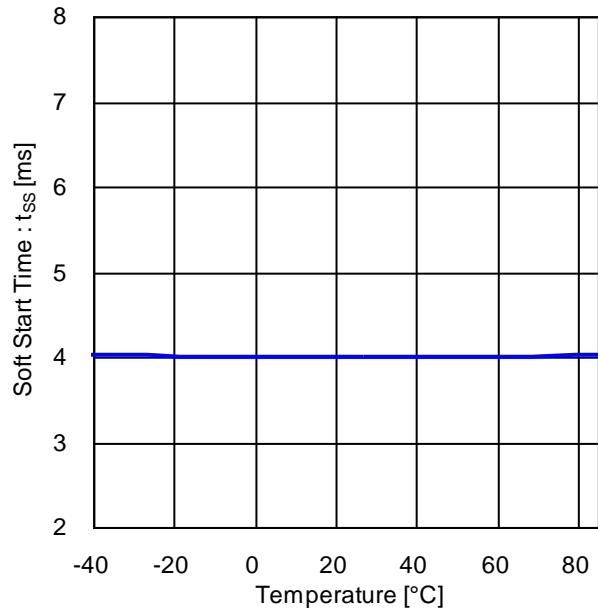


Figure 11. Soft Start Time vs Temperature  
( $V_{IN} = 12V$ )

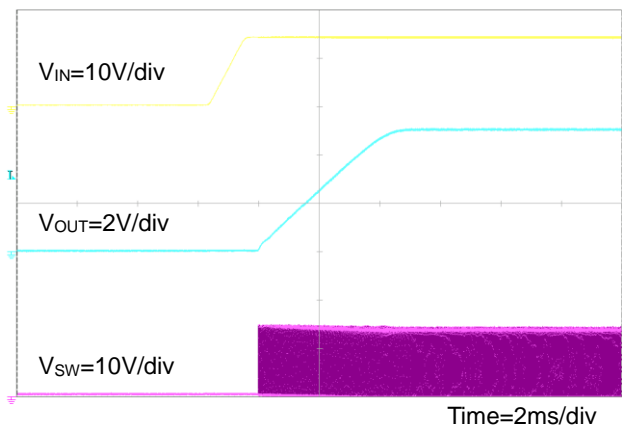


Figure 12. Start-up Waveform  
( $V_{IN} = 0V$  to  $12V$ )

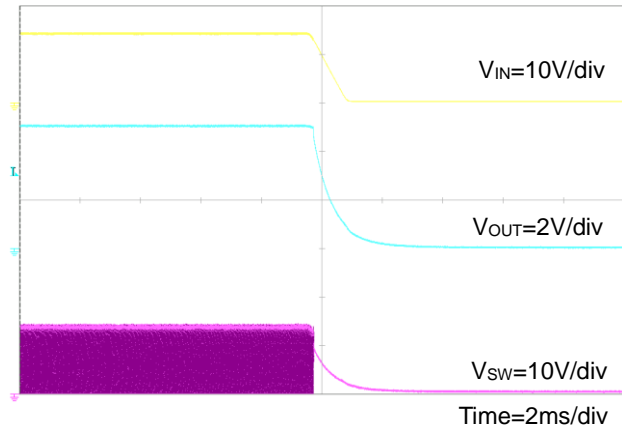


Figure 13. Shutdown Waveform  
( $V_{IN} = 12V$  to  $0V$ )

Typical Performance Curves - continued

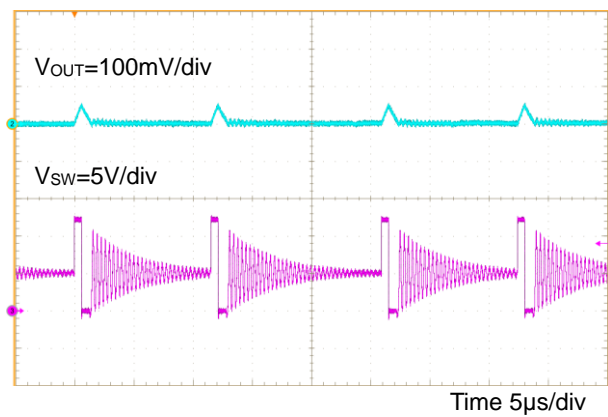


Figure 14. V<sub>OUT</sub> Ripple (V<sub>IN</sub> = 12V, I<sub>OUT</sub> = 10mA)

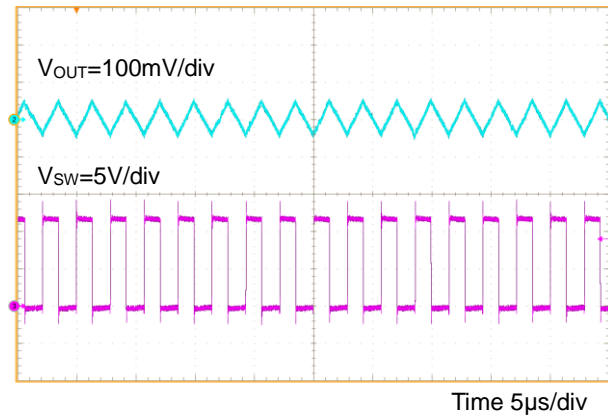


Figure 15. V<sub>OUT</sub> Ripple (V<sub>IN</sub> = 12V, I<sub>OUT</sub> = 1.5A)

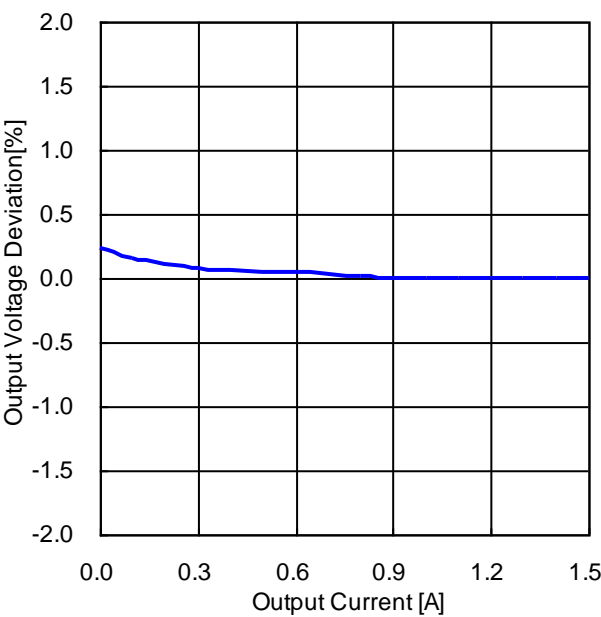


Figure 16. Load Regulation (V<sub>IN</sub> = 12V)

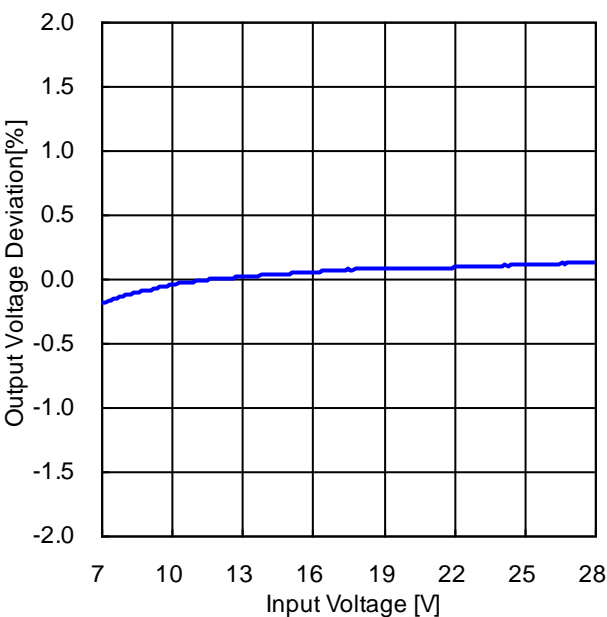


Figure 17. Line Regulation (I<sub>OUT</sub> = 1.5A)

## Function Description

### 1. DC/DC Converter Operation

BD9E103FJ is a synchronous rectifying step-down switching regulator that achieves faster transient response by employing current mode PWM control system. It utilizes switching operation in PWM (Pulse Width Modulation) mode for heavier load, while it utilizes SLLM (Simple Light Load Mode) control for lighter load to improve efficiency.

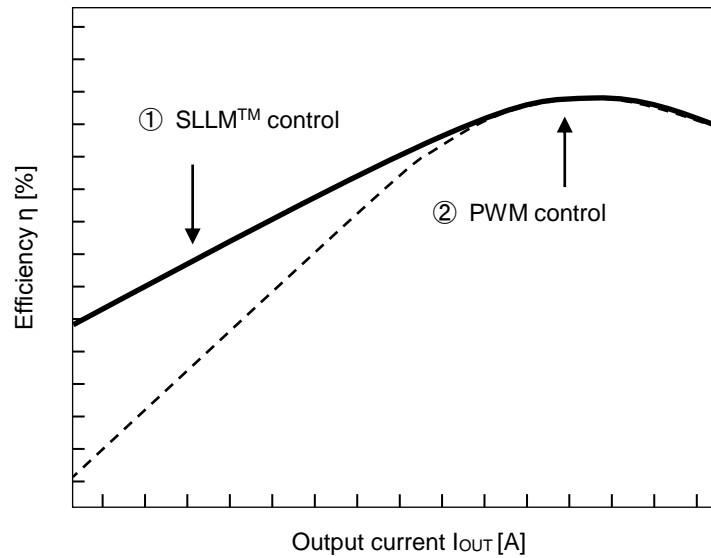


Figure 18. Efficiency (SLLM™ control and PWM control)

① SLLM™ Control

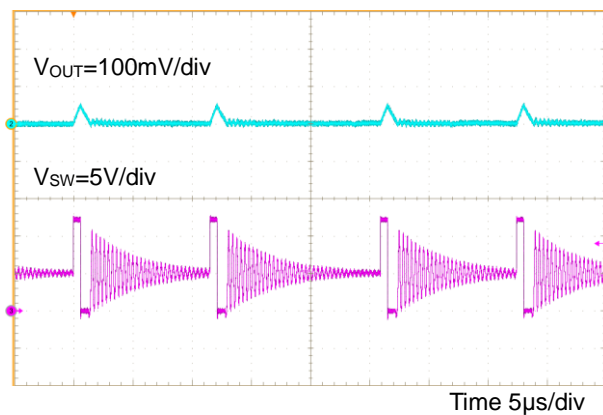


Figure 19. SW Waveform at SLLM™ Control  
( $V_{IN} = 12V$ ,  $I_{OUT} = 10mA$ )

② PWM Control

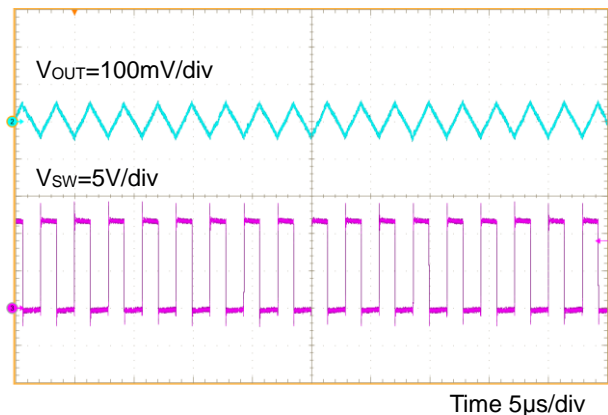


Figure 20. SW Waveform at PWM Control  
( $V_{IN} = 12V$ ,  $I_{OUT} = 1.5A$ )

## Function Description – continued

## 2. Soft Start

When  $V_{IN}$  reaches 6.6V (Typ), Soft Start function operates and the output voltage  $V_{OUT}$  gradually rises. With the Soft Start function, output voltage overshoot and in-rush current can be prevented. The rising time of output voltage is 4ms (Typ).

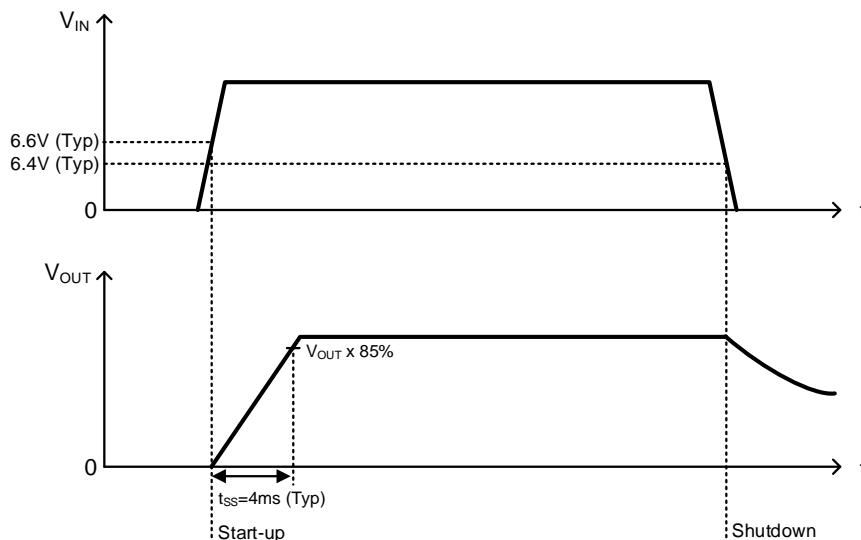


Figure 21. Soft Start Timing Chart

## 3. Protection

The protective circuits are intended for prevention of damage caused by unexpected accidents. Do not use them for continuous protective operation.

## (1) Short Circuit Protection (SCP)

The short circuit protection block compares the output voltage of  $V_{OUT}$  terminal with the internal reference voltage. When the  $V_{OUT}$  terminal voltage has fallen below 3.5V (Typ) and remained there for 0.8ms (Typ), SCP function stops the IC operation for 25ms (Typ) and subsequently initiates a restart.

Table 1. Short Circuit Protection Function

VIN terminal	VOUT terminal	Short Circuit Protection	Short Circuit Protection Operation
6.6V or higher (UVLO Release)	< 3.5V (Typ)	Enabled	ON
	> 3.5V (Typ)		OFF
6.4V or lower (UVLO Detect)	-	Disabled	OFF

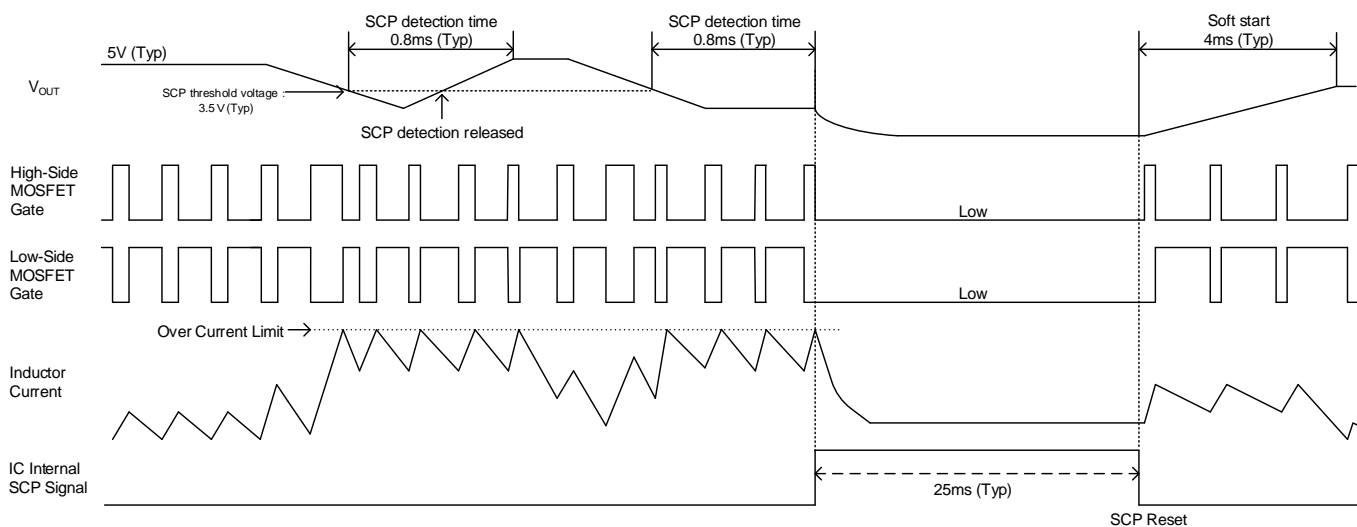


Figure 22. Short Circuit Protection (SCP) Timing Chart

## Function Description - continued

**(2) Under Voltage Lockout Protection (UVLO)**

The under voltage lockout protection circuit monitors the VIN terminal voltage.

The operation enters standby when the VIN terminal voltage is 6.4V (Typ) or lower.

The operation starts when the VIN terminal voltage is 6.6V (Typ) or higher.

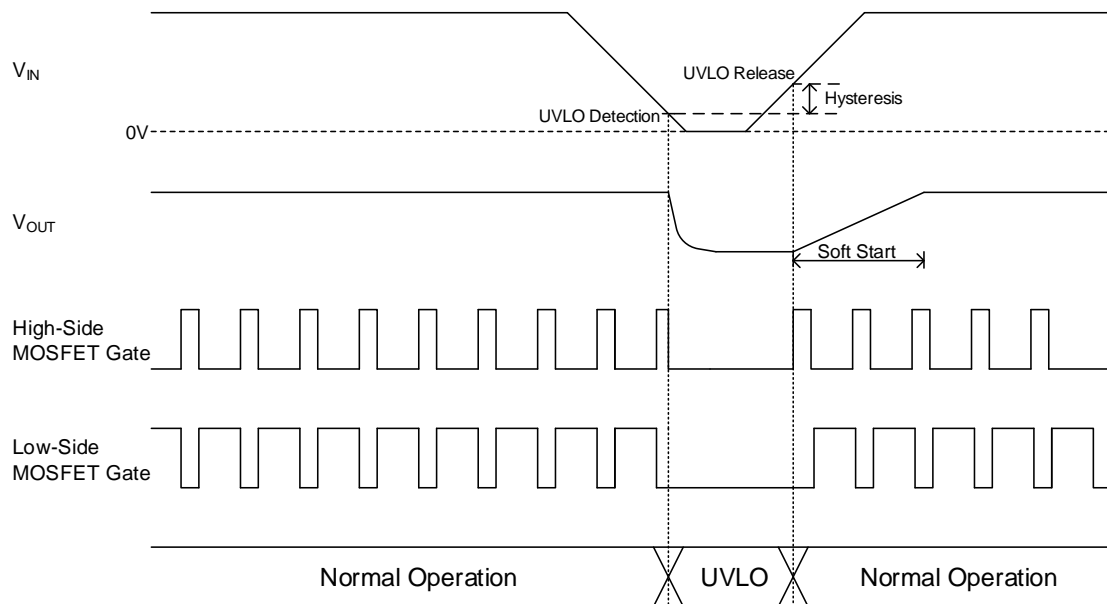


Figure 23. UVLO Timing Chart

**(3) Thermal Shutdown (TSD)**

When the chip temperature exceeds  $T_j=175^{\circ}\text{C}$  (Typ), the DC/DC converter output is stopped. Thermal protection circuit resets and the output voltage returns to the normal operation level when the temperature falls. The circuit has a hysteresis of  $25^{\circ}\text{C}$  (Typ). The thermal shutdown circuit is intended for shutting down the IC from thermal runaway in an abnormal state with the temperature exceeding  $T_{j\text{max}}=150^{\circ}\text{C}$ . It is not meant to protect or guarantee the reliability of the application. Do not use this function of the circuit for application protection design.

**(4) Over Current Protection (OCP)**

The Over Current Protection function is realized by using the current mode control to limit the current that flows through the High-Side MOSFET at each cycle of the switching frequency. The designed over current limit value is 2.5A (Typ).

**(5) Over Voltage Protection (OVP)**

Over Voltage Protection function compares VOUT terminal voltage with internal reference voltage and when the VOUT terminal voltage exceeds 6.5V (Typ), the OVP function turns off the output MOSFETs. When the output voltage drops, the device returns to normal operation with hysteresis.

## Application Example

Parameter	Symbol	Value
Input Voltage	$V_{IN}$	12V
Output Voltage	$V_{OUT}$	5V
Switching Frequency	$f_{osc}$	330kHz (Typ)
Maximum Output Current	$I_{OUTMAX}$	1.5A
Operating Temperature Range	$T_{opr}$	-40°C to +85°C

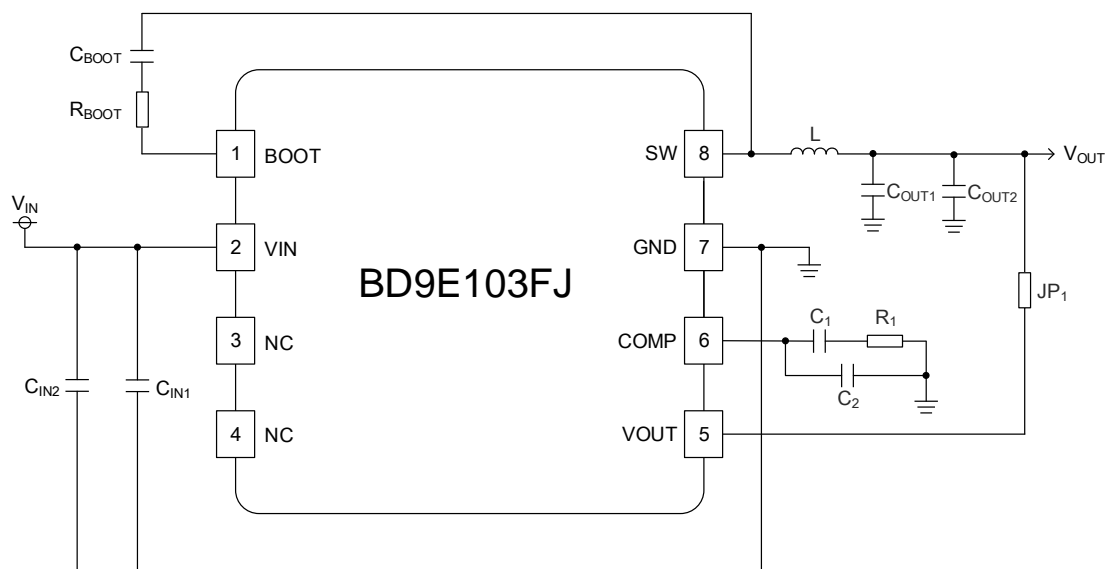


Figure 24. Application Circuit

Table 2. Recommended Component Values

Part No.	Value
$C_{IN1}$ (Note 1)	0.1 $\mu$ F
$C_{IN2}$ (Note 2)	470 $\mu$ F
$C_{BOOT}$ (Note 3)	0.1 $\mu$ F
$R_{BOOT}$ (Note 4)	Short
L	22 $\mu$ H
$C_{OUT1}$ (Note 5)	0.1 $\mu$ F
$C_{OUT2}$ (Note 5)	220 $\mu$ F
$R_1$	30k $\Omega$
$C_1$	2200pF
$C_2$	100pF
$JP_1$ (Note 6)	Short

(Note 1) In order to reduce the influence of high frequency noise, connect a 0.1 $\mu$ F ceramic capacitor as close as possible to the VIN terminal and the GND terminal.

(Note 2) For the capacitance of input capacitor, take temperature characteristics, DC bias characteristics, etc. into consideration and set to a minimum value of no less than 10 $\mu$ F.

(Note 3) For the capacitance of bootstrap capacitor, take temperature characteristics, DC bias characteristics, etc. into consideration to set minimum value to no less than 0.047 $\mu$ F.

(Note 4) Avoid short-circuiting between VIN terminal and VOUT terminal or SW terminal. Short-circuiting between these terminals may result in damage to the IC or smoke generation. In a case that has been applied  $V_{IN} = 20V$  or more, when there is a possibility the BOOT terminal and SW terminal is short-circuited, please insert a  $R_{BOOT}$  resistor of 10 $\Omega$  between the bootstrap capacitor 0.1 $\mu$ F and BOOT terminal. Short-circuiting without inserting this resistance may result in damage to the IC or smoke generation.

(Note 5) In case capacitance value fluctuates due to temperature characteristics, DC bias characteristics, etc. of output capacitor, Loop Response may oscillate. Please confirm on actual equipment. When selecting a capacitor, confirm the characteristics of the capacitor in its datasheet.

(Note 6)  $JP_1$  is an option, used for feedback's frequency response measurement. By inserting a resistor at  $JP_1$ , it is possible to measure the frequency response (phase margin) using a FRA. However, the resistor will not be used in actual application, please use this resistor pattern in short-circuit mode.

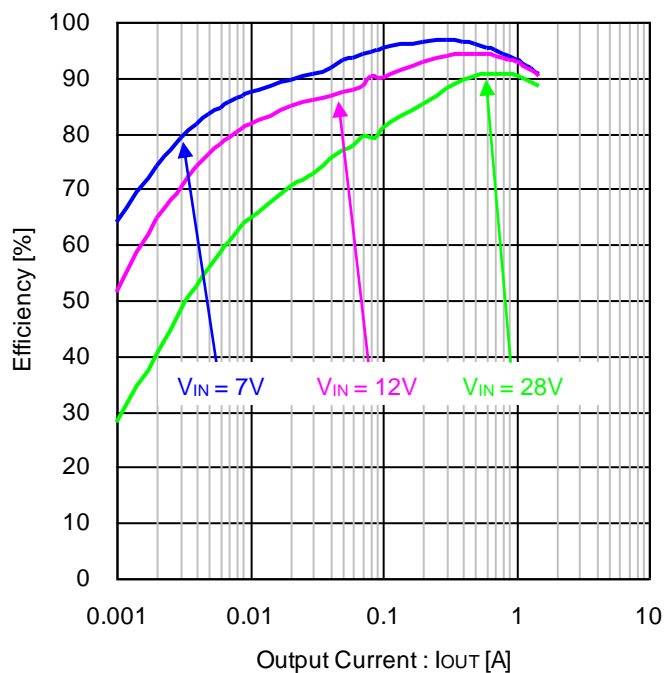
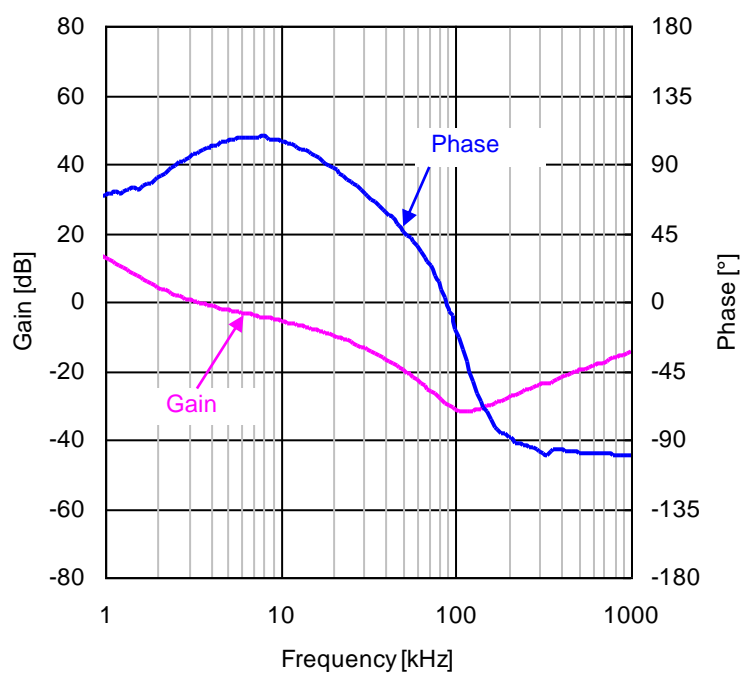
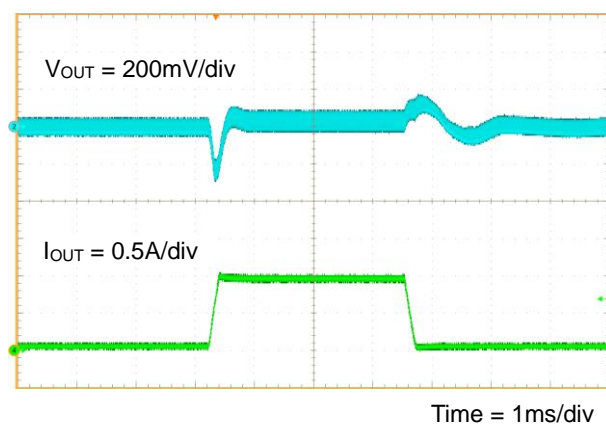
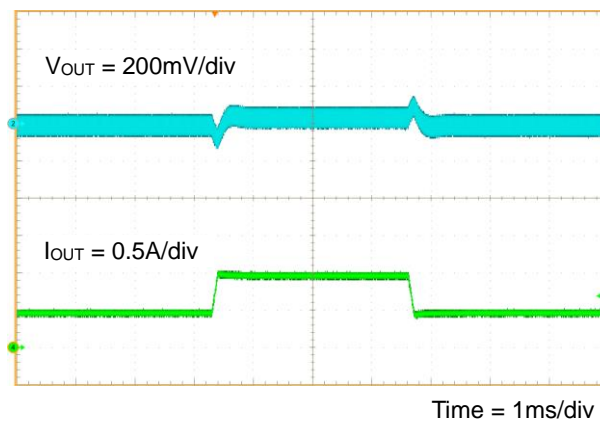


Figure 25. Efficiency vs Output Current

Figure 26. Closed Loop Response  $I_{OUT} = 1.5A$   
( $V_{IN} = 12V$ ,  $L = 22\mu H$ ,  $C_{OUT} = \text{Ceramic}0.1\mu F$  and  $\text{Electrolytic}220\mu F$ )Figure 27. Load Transient Response  
 $I_{OUT} = 0.1A - 1.0A$   
( $V_{IN} = 12V$ ,  $L = 22\mu H$ ,  $C_{OUT} = \text{Ceramic}0.1\mu F$  and  $\text{Electrolytic}220\mu F$ )Figure 28. Load Transient Response  
 $I_{OUT} = 0.5A - 1.0A$   
( $V_{IN} = 12V$ ,  $L = 22\mu H$ ,  $C_{OUT} = \text{Ceramic}0.1\mu F$  and  $\text{Electrolytic}220\mu F$ )

## Selection of Components Externally Connected

About the application except the recommendation, please contact us.

### 1. Output LC Filter

The DC/DC converter requires an LC filter for smoothing the output voltage in order to supply a continuous current to the load.  $I_L$  ripple current flowing through the inductor is returned to the device for SLLM™ control. It is recommended to use 22μH inductor since the feedback current has the best behavior in the specified inductance value.

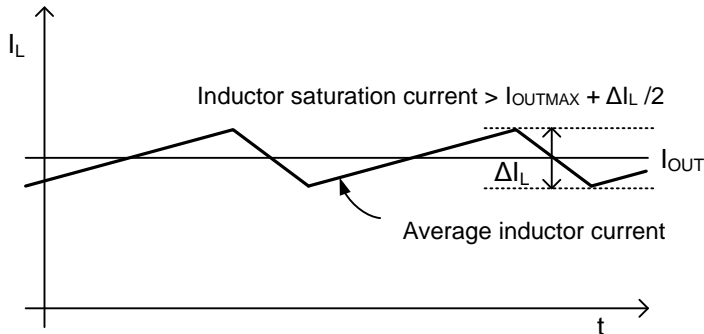


Figure 29. Waveform of Current through Inductor

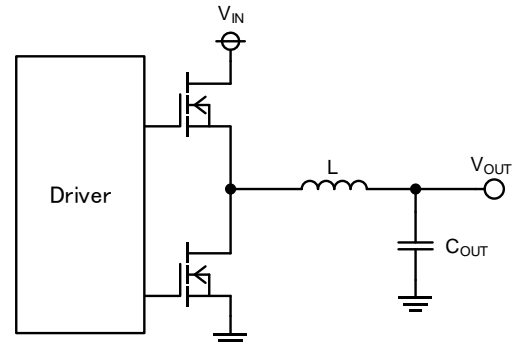


Figure 30. Output LC Filter Circuit

Calculation with  $V_{IN} = 12V$ ,  $V_{OUT} = 5V$ ,  $L = 22\mu H$ , and switching frequency  $f_{OSC} = 330kHz$  is expressed as below.

Inductor ripple current  $\Delta I_L$ ,

$$\Delta I_L = V_{OUT} \times (V_{IN} - V_{OUT}) \times \frac{1}{V_{IN} \times f_{OSC} \times L} = 402 \text{ [mA]}$$

The saturation current of the inductor must be larger than the sum of the maximum output current and one-half (1/2) of the inductor ripple current  $\Delta I_L$ .

The output capacitor  $C_{OUT}$  affects the output ripple voltage characteristics. The output capacitor  $C_{OUT}$  must satisfy the required ripple voltage characteristics.

The output ripple voltage can be represented by the following equation.

$$\Delta V_{RPL} = \Delta I_L \times (R_{ESR} + \frac{1}{8 \times C_{OUT} \times f_{OSC}})$$

$R_{ESR}$  is the Equivalent Series Resistance (ESR) of the output capacitor.

With  $C_{OUT} = 220\mu F$ ,  $R_{ESR} = 100m\Omega$  the output ripple voltage is calculated as below.

$$\Delta V_{RPL} = 0.402 \times (100m + \frac{1}{8 \times 220\mu \times 330k}) = 41 \text{ [mV]}$$

Be careful of the total capacitance value when additional capacitor  $C_{LOAD}$  is connected to the output capacitor  $C_{OUT}$ . Use maximum additional capacitor  $C_{LOAD}$  (Max) condition which satisfies the following method.

$$\text{Maximum starting inductor ripple current } I_{LSTART} < \text{Over Current Limit } 2.1A \text{ (Min)}$$

Maximum starting inductor ripple current  $I_{LSTART}$  can be expressed in the following method.

$$I_{LSTART} = \text{Maximum starting output current (} I_{OUTMAX} \text{)} + \text{Charge current to output capacitor (} I_{CAP} \text{)} + \frac{\Delta I_L}{2}$$

Charge current to output capacitor  $I_{CAP}$  can be expressed in the following method

$$I_{CAP} = \frac{(C_{OUT} + C_{LOAD}) \times V_{OUT}}{t_{SS}}$$



Calculation with  $V_{IN} = 12V$ ,  $V_{OUT} = 5V$ ,  $L = 22\mu H$ ,  $I_{OUTMAX} = 1.5A$ , switching frequency  $f_{OSC} = 330kHz$  (Typ), Output capacitor  $C_{OUT} = 220\mu F$ , Soft Start time  $t_{SS} = 4ms$  (Typ), the method is as below.

$$C_{LOAD}(Max) \leq \frac{(2.1 - I_{OUTMAX} - \frac{\Delta I_L}{2}) \times t_{SS}}{V_{OUT}} - C_{OUT} = 99.2 [\mu F]$$

\*  $C_{LOAD}$  has an effect on the stability of the DC/DC converter. To ensure the stability of the DC/DC converter, make sure that a sufficient phase margin is provided.

## 2. Phase Compensation

A current mode control buck DC/DC converter is a two-pole, one-zero system two poles formed by an error amplifier and load and one zero point added by phase compensation. The phase compensation resistor  $R_{CMP}$  determines the crossover frequency  $f_{CRS}$  where the total loop gain of the DC/DC converter is 0 dB. High value for this crossover frequency  $f_{CRS}$  provides a good load transient response characteristic but inferior stability. Conversely, specifying a low value for the crossover frequency  $f_{CRS}$  greatly stabilizes the characteristics but the load transient response characteristic is impaired.

### (1) Selection of Phase Compensation Resistor $R_{CMP}$ ( $R_1$ )

The phase compensation resistance  $R_{CMP}$  can be determined by using the following equation.

$$R_{CMP} = \frac{2\pi \times V_{OUT} \times f_{CRS} \times C_{OUT}}{V_{FB} \times G_{MP} \times G_{MA}}$$

Where:

$V_{OUT}$  is the output voltage (5V (Typ))

$f_{CRS}$  is the crossover frequency [Hz]

$C_{OUT}$  is the output capacitance [F]

$V_{FB}$  is the feedback reference voltage (0.8V (Typ))

$G_{MP}$  is the current sense gain (7 A/V (Typ))

$G_{MA}$  is the error amplifier transconductance (82  $\mu A/V$  (Typ))

### (2) Selection of Phase Compensation Capacitance $C_{CMP}$ ( $C_1$ )

For stable operation of the DC/DC converter, inserting a zero point at 1/6 of the zero crossover frequency cancels the phase delay due to the pole formed by the load often provides favorable characteristics.

The phase compensation capacitance  $C_{CMP}$  can be determined by using the following equation.

$$C_{CMP} = \frac{1}{2\pi \times R_{CMP} \times f_z}$$

Where:

$f_z$  is Zero point inserted

### (3) Loop Stability

In order to ensure stability of DC/DC converter, confirm there is enough phase margin on actual equipment. Under the worst condition, it is recommended to ensure phase margin is 45° or more. In fact, the characteristics may variable due to PCB layout, routing of wiring, types of used components and operating environments (temperature etc.). Use gain-phase analyzer or FRA to confirm frequency characteristics on actual equipment. Contact the manufacturer of each equipment to check its measuring method, etc.

## PCB Layout Design

PCB layout design for DC/DC converter power supply IC is as important as the circuit design. Appropriate layout can avoid various problems caused by power supply circuit. Figure 31-a to 31-c show the current path in a buck converter circuit. The Loop1 in Figure 31-a is a current path when H-side switch is ON and L-side switch is OFF, the Loop2 in Figure 31-b is when H-side switch is OFF and L-side switch is ON. The thick line in Figure 31-c shows the difference between Loop1 and Loop2. The current in thick line changes sharply each time the switching element H-side and L-side switch change from OFF to ON, and vice versa. These sharp changes induce several harmonics in the waveform. Therefore, the loop area of thick line that is consisted by input capacitor and IC should be as small as possible to minimize noise. For more detail, refer to application note of switching regulator series "PCB Layout Techniques of Buck Converter".

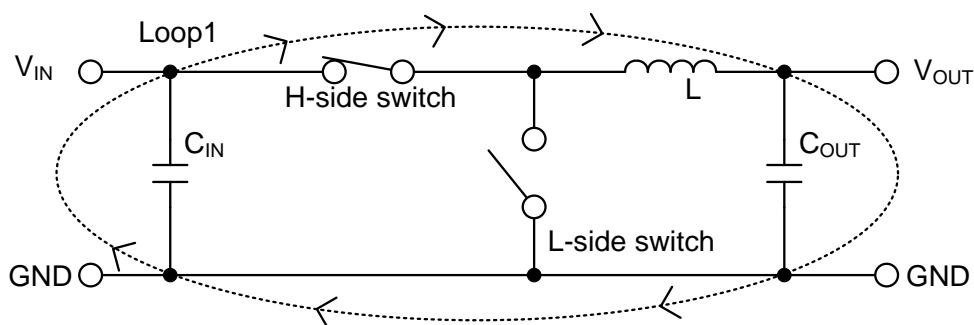


Figure 31-a. Current path when H-side switch = ON, L-side switch = OFF

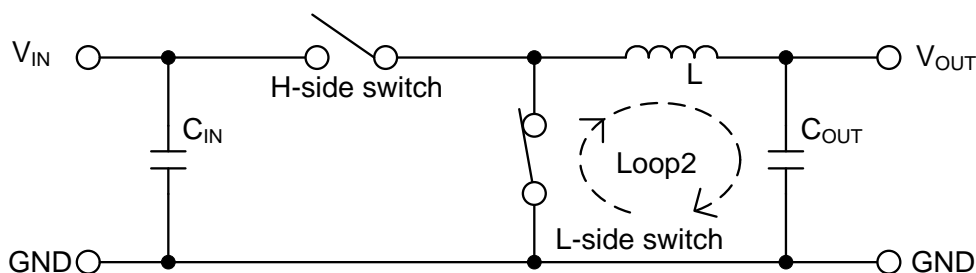


Figure 31-b. Current path when H-side switch = OFF, L-side switch = ON

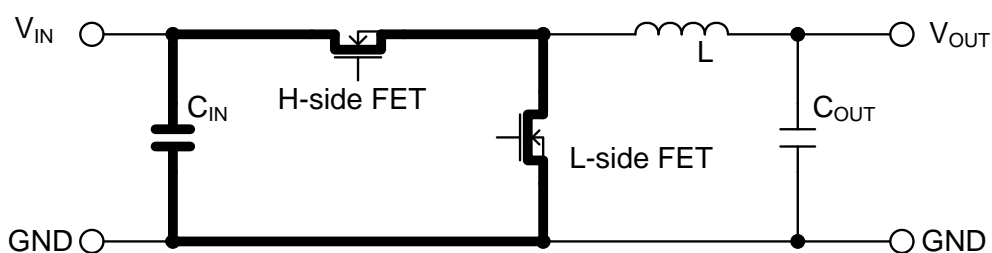


Figure 31-c. Difference of current and critical area in layout

## PCB Layout Design - continued

When designing the PCB layout, please pay extra attention to the following points:

- Place input capacitor on the same PCB surface as the IC and as close as possible to the IC's VIN terminal.
- Switching nodes should be traced as thick and short as possible to the inductor, because they may induce the noise to the other nodes due to AC coupling.
- Please keep the lines connected to VOUT sense away from the SW node as far as possible.
- Please place output capacitor away from input capacitor to avoid harmonics noise from the input.

## I/O Equivalence Circuits

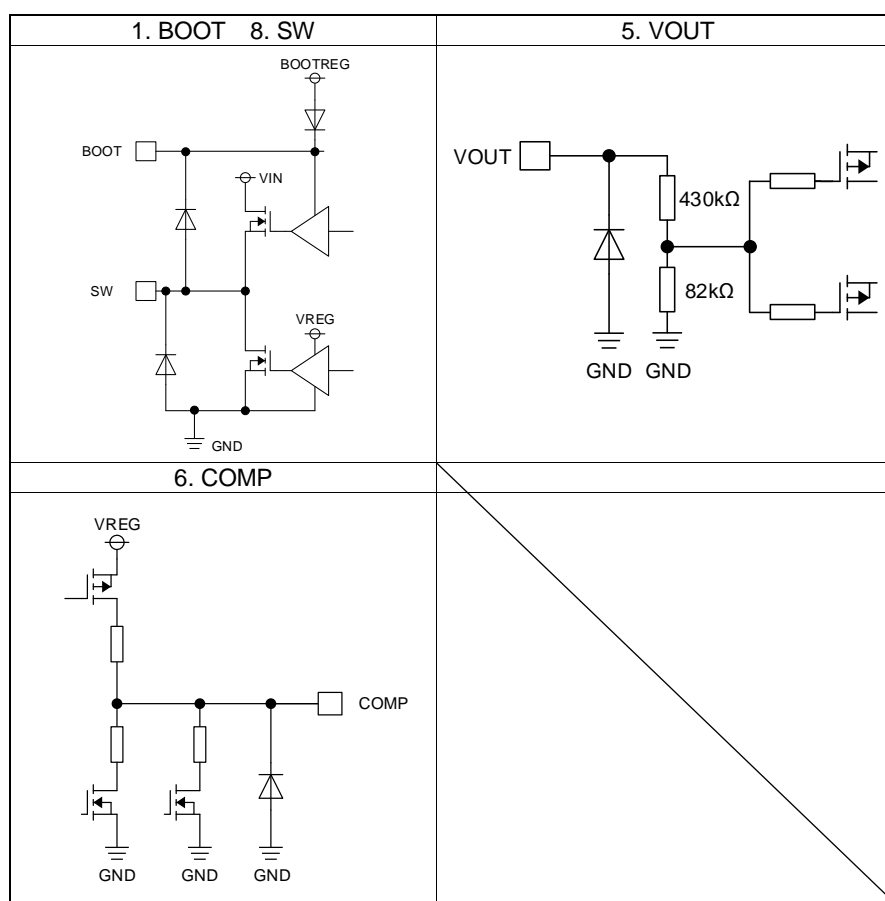


Figure 32. I/O Equivalence Circuits

## Operational Notes

### 1. Reverse Connection of Power Supply

Connecting the power supply in reverse polarity can damage the IC. Take precautions against reverse polarity when connecting the power supply, such as mounting an external diode between the power supply and the IC's power supply pins.

### 2. Power Supply Lines

Design the PCB layout pattern to provide low impedance supply lines. Separate the ground and supply lines of the digital and analog blocks to prevent noise in the ground and supply lines of the digital block from affecting the analog block. Furthermore, connect a capacitor to ground at all power supply pins. Consider the effect of temperature and aging on the capacitance value when using electrolytic capacitors.

### 3. Ground Voltage

Ensure that no pins are at a voltage below that of the ground pin at any time, even during transient condition. However, pins that drive inductive loads (e.g. motor driver outputs, DC-DC converter outputs) may inevitably go below ground due to back EMF or electromotive force. In such cases, the user should make sure that such voltages going below ground will not cause the IC and the system to malfunction by examining carefully all relevant factors and conditions such as motor characteristics, supply voltage, operating frequency and PCB wiring to name a few.

### 4. Ground Wiring Pattern

When using both small-signal and large-current ground traces, the two ground traces should be routed separately but connected to a single ground at the reference point of the application board to avoid fluctuations in the small-signal ground caused by large currents. Also ensure that the ground traces of external components do not cause variations on the ground voltage. The ground lines must be as short and thick as possible to reduce line impedance.

### 5. Recommended Operating Conditions

The function and operation of the IC are guaranteed within the range specified by the recommended operating conditions. The characteristic values are guaranteed only under the conditions of each item specified by the electrical characteristics.

### 6. Inrush Current

When power is first supplied to the IC, it is possible that the internal logic may be unstable and inrush current may flow instantaneously due to the internal powering sequence and delays, especially if the IC has more than one power supply. Therefore, give special consideration to power coupling capacitance, power wiring, width of ground wiring, and routing of connections.

### 7. Operation Under Strong Electromagnetic Field

Operating the IC in the presence of a strong electromagnetic field may cause the IC to malfunction.

### 8. Testing on Application Boards

When testing the IC on an application board, connecting a capacitor directly to a low-impedance output pin may subject the IC to stress. Always discharge capacitors completely after each process or step. The IC's power supply should always be turned off completely before connecting or removing it from the test setup during the inspection process. To prevent damage from static discharge, ground the IC during assembly and use similar precautions during transport and storage.

### 9. Inter-pin Short and Mounting Errors

Ensure that the direction and position are correct when mounting the IC on the PCB. Incorrect mounting may result in damaging the IC. Avoid nearby pins being shorted to each other especially to ground, power supply and output pin. Inter-pin shorts could be due to many reasons such as metal particles, water droplets (in very humid environment) and unintentional solder bridge deposited in between pins during assembly to name a few.

### 10. Unused Input Pins

Input pins of an IC are often connected to the gate of a MOS transistor. The gate has extremely high impedance and extremely low capacitance. If left unconnected, the electric field from the outside can easily charge it. The small charge acquired in this way is enough to produce a significant effect on the conduction through the transistor and cause unexpected operation of the IC. So unless otherwise specified, unused input pins should be connected to the power supply or ground line.

## Operational Notes – continued

**11. Regarding the Input Pin of the IC**

This monolithic IC contains P<sup>+</sup> isolation and P substrate layers between adjacent elements in order to keep them isolated. P-N junctions are formed at the intersection of the P layers with the N layers of other elements, creating a parasitic diode or transistor. For example (refer to figure below):

When GND > Pin A and GND > Pin B, the P-N junction operates as a parasitic diode.

When GND > Pin B, the P-N junction operates as a parasitic transistor.

Parasitic diodes inevitably occur in the structure of the IC. The operation of parasitic diodes can result in mutual interference among circuits, operational faults, or physical damage. Therefore, conditions that cause these diodes to operate, such as applying a voltage lower than the GND voltage to an input pin (and thus to the P substrate) should be avoided.

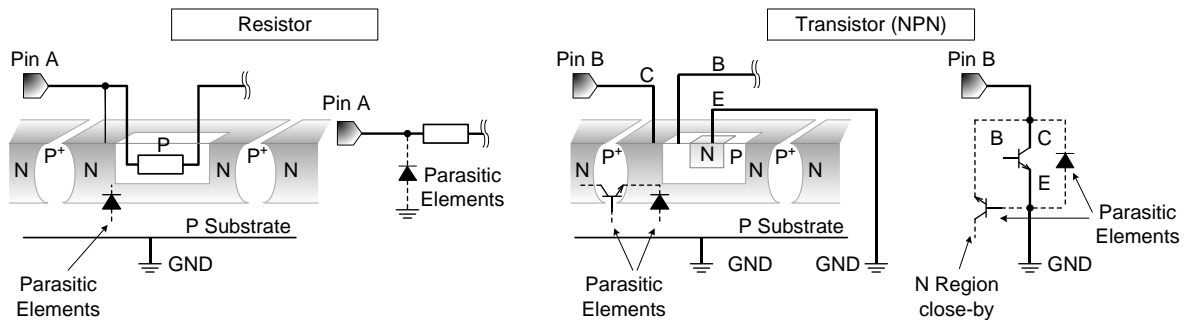


Figure 33. Example of monolithic IC structure

**12. Ceramic Capacitor**

When using a ceramic capacitor, determine a capacitance value considering the change of capacitance with temperature and the decrease in nominal capacitance due to DC bias and others.

**13. Area of Safe Operation (ASO)**

Operate the IC such that the output voltage, output current, and the maximum junction temperature rating are all within the Area of Safe Operation (ASO).

**14. Thermal Shutdown Circuit(TSD)**

This IC has a built-in thermal shutdown circuit that prevents heat damage to the IC. Normal operation should always be within the IC's maximum junction temperature rating. If however the rating is exceeded for a continued period, the junction temperature ( $T_j$ ) will rise which will activate the TSD circuit that will turn OFF power output pins. When the  $T_j$  falls below the TSD threshold, the circuits are automatically restored to normal operation.

Note that the TSD circuit operates in a situation that exceeds the absolute maximum ratings and therefore, under no circumstances, should the TSD circuit be used in a set design or for any purpose other than protecting the IC from heat damage.

**15. Over Current Protection Circuit (OCP)**

This IC incorporates an integrated overcurrent protection circuit that is activated when the load is shorted. This protection circuit is effective in preventing damage due to sudden and unexpected incidents. However, the IC should not be used in applications characterized by continuous operation or transitioning of the protection circuit.

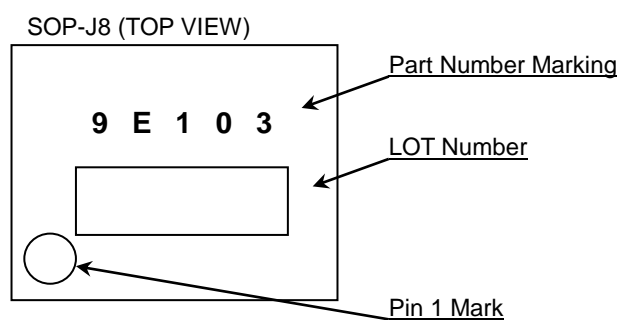
**16. Disturbance Light**

In a device where a portion of silicon is exposed to light such as in a WL-CSP and chip products, IC characteristics may be affected due to photoelectric effect. For this reason, it is recommended to come up with countermeasures that will prevent the chip from being exposed to light.

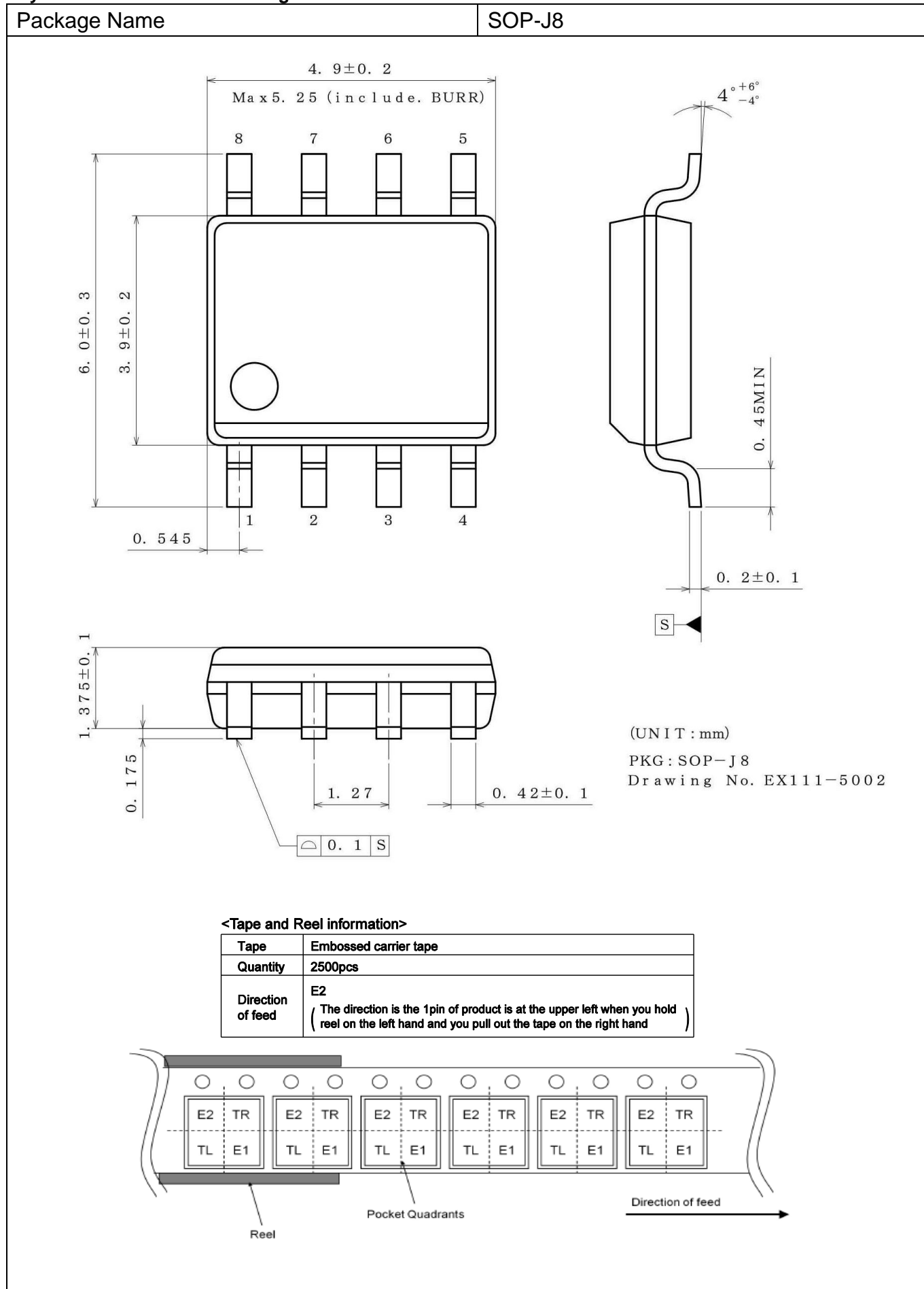
## Ordering Information

B D 9 E 1 0 3 F J									-	E 2	
Part Number									Package FJ: SOP-J8	Packaging and forming specification E2: Embossed tape and reel	

## Marking Diagram



## Physical Dimension and Packing Information



## Revision History

Date	Revision	Changes
25. Sep. 2017	001	New Release



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(Note1) Medical Equipment Classification of the Specific Applications

JAPAN	USA	EU	CHINA
CLASS III	CLASS III	CLASS II b	CLASS III
CLASS IV		CLASS III	

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  - Use of our Products in places where the Products are exposed to static electricity or electromagnetic waves
  - Use of our Products in proximity to heat-producing components, plastic cords, or other flammable items
  - Sealing or coating our Products with resin or other coating materials
  - Use of our Products without cleaning residue of flux (even if you use no-clean type fluxes, cleaning residue of flux is recommended); or Washing our Products by using water or water-soluble cleaning agents for cleaning residue after soldering
  - Use of the Products in places subject to dew condensation
- The Products are not subject to radiation-proof design.
- Please verify and confirm characteristics of the final or mounted products in using the Products.
- In particular, if a transient load (a large amount of load applied in a short period of time, such as pulse. is applied, confirmation of performance characteristics after on-board mounting is strongly recommended. Avoid applying power exceeding normal rated power; exceeding the power rating under steady-state loading condition may negatively affect product performance and reliability.
- De-rate Power Dissipation depending on ambient temperature. When used in sealed area, confirm that it is the use in the range that does not exceed the maximum junction temperature.
- Confirm that operation temperature is within the specified range described in the product specification.
- ROHM shall not be in any way responsible or liable for failure induced under deviant condition from what is defined in this document.

## Precaution for Mounting / Circuit board design

- When a highly active halogenous (chlorine, bromine, etc.) flux is used, the residue of flux may negatively affect product performance and reliability.
- In principle, the reflow soldering method must be used on a surface-mount products, the flow soldering method must be used on a through hole mount products. If the flow soldering method is preferred on a surface-mount products, please consult with the ROHM representative in advance.

For details, please refer to ROHM Mounting specification

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## Precaution for Electrostatic

This Product is electrostatic sensitive product, which may be damaged due to electrostatic discharge. Please take proper caution in your manufacturing process and storage so that voltage exceeding the Products maximum rating will not be applied to Products. Please take special care under dry condition (e.g. Grounding of human body / equipment / solder iron, isolation from charged objects, setting of ionizer, friction prevention and temperature / humidity control).

## Precaution for Storage / Transportation

1. Product performance and soldered connections may deteriorate if the Products are stored in the places where:
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  - [b] the temperature or humidity exceeds those recommended by ROHM
  - [c] the Products are exposed to direct sunshine or condensation
  - [d] the Products are exposed to high Electrostatic
2. Even under ROHM recommended storage condition, solderability of products out of recommended storage time period may be degraded. It is strongly recommended to confirm solderability before using Products of which storage time is exceeding the recommended storage time period.
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4. Use Products within the specified time after opening a humidity barrier bag. Baking is required before using Products of which storage time is exceeding the recommended storage time period.

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Minimum Package Quantity	2500
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Constitution Materials List	inquiry
RoHS	Yes