

# 12V to 76V input voltage range 3A output current 1ch Buck Converter Integrated FET

## BD9G341AEFJ

### General Description

The BD9G341AEFJ is a buck switching regulator with integrated 150mΩ power MOSFET. Current mode architecture provides fast transient response and a simple phase compensation setup. The operating frequency is programmable from 50kHz to 750kHz. Additional protection features are included such as Over Current Protection, Thermal shutdown and Under voltage lockout. The under voltage lockout and hysteresis can be set by external resistor.

### Features

- Wide input voltage range from 12V to 76V.
- Integrated 80V/3.5A/150mΩ NchFET.
- Current mode.
- Variable frequency from 50kHz to 750kHz.
- Accurate reference voltage. (1.0 V $\pm$ 1.5 %).
- Precision ENUVLO threshold ( $\pm$ 3%).
- Soft-start function
- 0uA Standby current
- Over Current Protection (OCP), Under Voltage Lockout(UVLO), Thermal-Shutdown(TSD), Over Voltage Protection (OVP)
- Thermally enhanced HTSOP-J8 package

### Applications

- Industrial distributed power applications.
- Battery powered equipment.

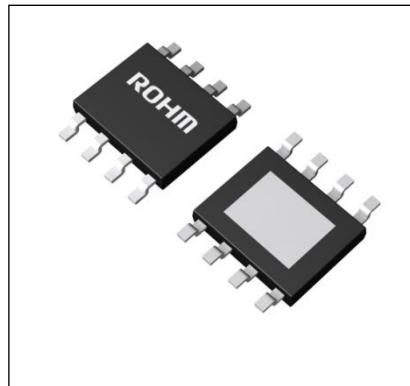
### Key specifications

■ Input voltage	12 to 76[V]
■ Ref voltage( $T_a=25^{\circ}\text{C}$ )	$\pm 1.5[\%]$
	( $T_a=-40$ to $85^{\circ}\text{C}$ ) $\pm 2.0[\%]$
■ Max output current	3 [A] (Max.)
■ Operating Temperature	-40° C to 85°C
■ Max junction temperature	150°C

### Package(s)

HTSOP-J8

4.90mm x 6.00mm x 1.00mm



### Typical Application Circuit

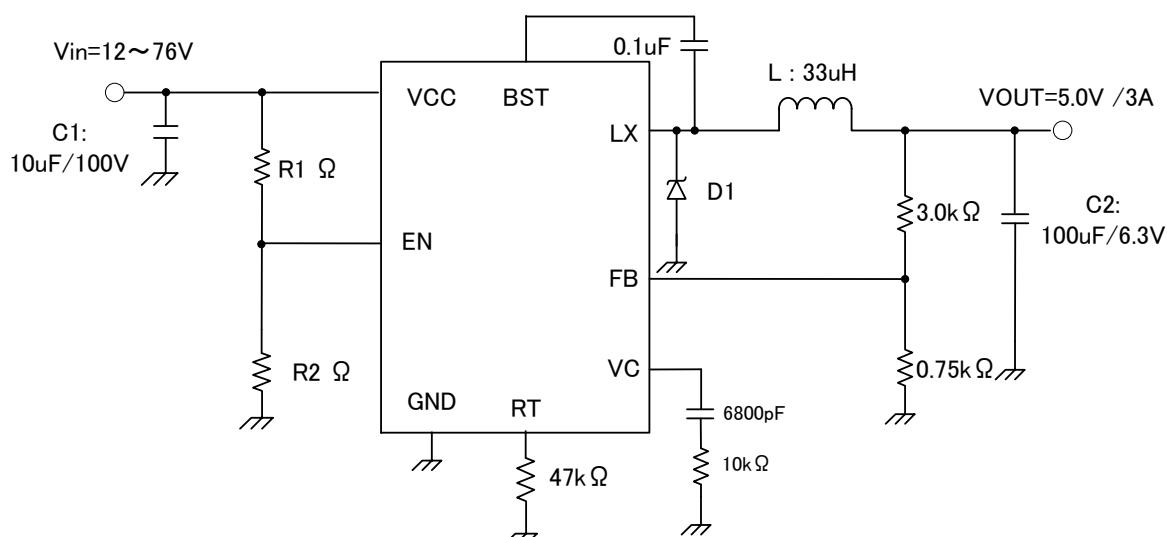


Figure 1. Typical Application Schematic

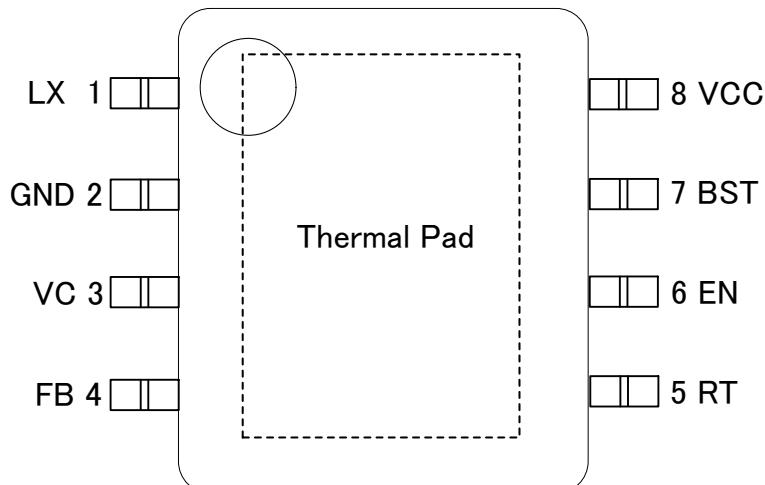
**Pin Configuration**

Figure 2. Pin Configuration (TOP VIEW)

**Pin Description**

Pin No.	Pin Name	Description
1	LX	Switching node. It should be connected as near as possible to the schottky barrier diode, and inductor.
2	GND	Ground pin. GND pattern is kept from the current line of input capacitor to output capacitor.
3	VC	The output of the internal error amplifier. The phase compensation implementation is connected between this pin to GND.
4	FB	Voltage feedback pin. This pin is the error-amp input with the DC voltage is set at 1.0V with feed-back operation.
5	RT	The internal oscillator frequency set pin. The internal oscillator is set with a single resistor connected between this pin and the GND pin. Recommended frequency range is 50kHz to 750kHz
6	EN	Shutdown pin. If the voltage of this pin is below 1.3V, the regulator will be in a low power state. If the voltage of this pin is between 1.3V and 2.4V. The IC will be in standby mode. If the voltage of this pin is above 2.6V, the regulator is operational. An external voltage divider can be used to set under voltage threshold. If this pin is left open circuit. when converter is operating. This pin output 10uA source current. If this pin is left open circuit, a 10uA pull up current source configures the regulator fully operational.
7	BST	Boost input for bootstrap capacitor The external capacitor is required between the BST and the Lx pin. A 0.1uF ceramic capacitor is recommended.
8	VCC	Input supply voltage pin.
-	Thermal Pad	Connect to GND.

## Block Diagram

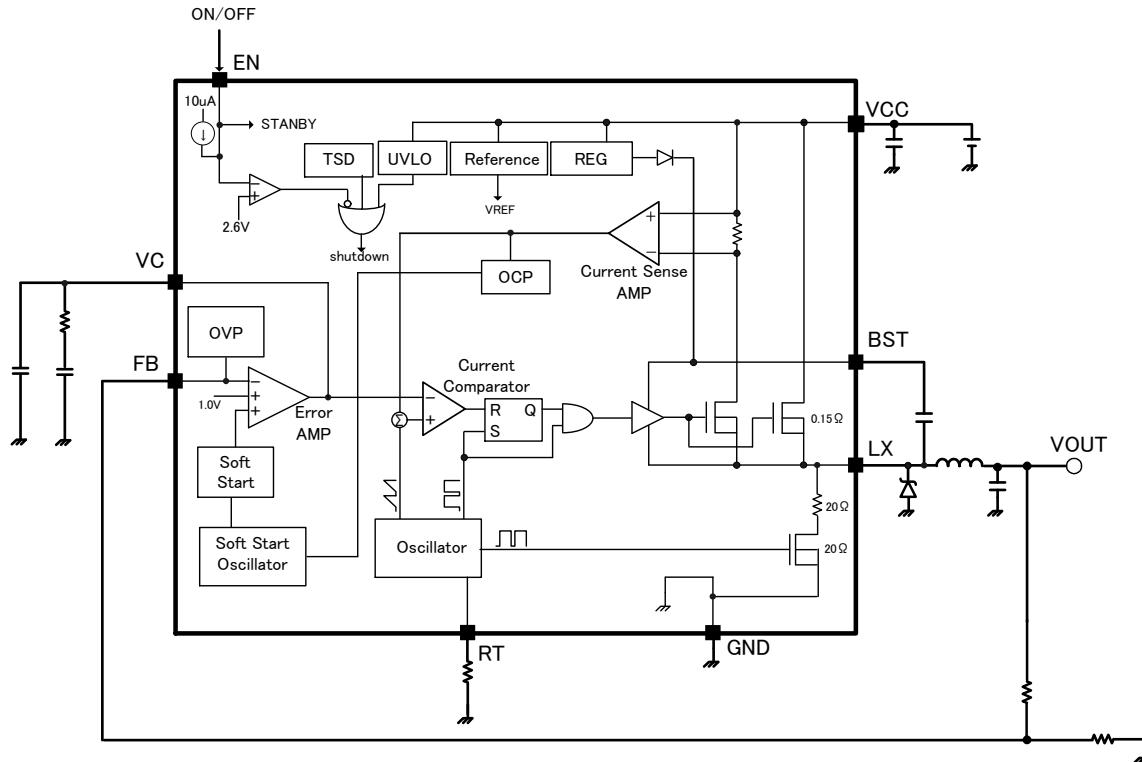


Figure 3. Block Diagram

## Description of Blocks

1. Reference  
This block generates inner reference voltage.
2. REG  
This block generates 8V reference voltage for bootstrap.
3. OSC  
This block generates inner CLK.  
The internal oscillator is set with a single resistor connected between this pin and the GND pin.  
Recommended frequency range is 50 kHz to 750 kHz. If RT pin connect to 47kohm, frequency is set 200 kHz.
4. Soft Start  
Soft Start of the output voltage of regulator prevents in-rush current during Start-up.  
Soft Start time is 20msec (typ)
5. ERROR AMP  
This is an error amplifier what detects output signal, and outputs PWM control signal.  
Internal reference voltage is set to 1.0V.
6. ICOMP  
This is a comparator that outputs PWM signal from current feed-back signal and error-amp output for current-mode.
7. Nch FET SW  
This is a 80V/150mΩ-Power Nch MOSFET SW that converts inductor current of DC/DC converter  
Since the current rating of this FET is 3.5A, it should be used within 3.5A including the DC current and ripple current of the coil.
8. UVLO  
This is a Low Voltage Error Prevention Circuit.  
This prevents internal circuit error during increase of Power Supply Voltage and during decline of Power supply Voltage.  
It monitors VCC Pin Voltage and internal REG Voltage, When VCC Voltage becomes 11V and below, UVLO turns OFF all Output FET and turns OFF the DC/DC Comparator Output, and the Soft Start Circuit resets.  
Now this Threshold has Hysteresis of 200mV.

**9. EN**

Shutdown function. If the voltage of this pin is below 1.3V, the regulator will be in a low power state. If the voltage of this pin is between 1.3V and 2.4V will be standby mode. If the voltage of this pin is above 2.6V, the regulator is operational. An external voltage divider can be used to set under voltage threshold. If this pin is left open circuit, when converter is operating. This pin output 10uA source current. If this pin is left open circuit, a 10uA pull up current source configures the regulator fully operational. When IC turn off, EN pin is pulled down by pull down resistor that sink above 10uA.

**10. OCP**

Over current protection

If the current of power MOSFET is over 6.0A (typ), this function reduces duty pulse –by- pulse and restricts the over current. If IC detects OCP 2 times sequentially, the device will stop and after 20 msec restart.

**11. TSD**

This is Thermal Shutdown Detection

When it detects an abnormal temperature exceeding Maximum Junction Temperature ( $T_j=150^{\circ}\text{C}$ ), it turns OFF all Output FETs, and turns OFF the DC/DC Comparator Output. When Temperature falls, and the IC automatically returns

**12. OVP**

Over voltage protection.

Output voltage is monitored with FB terminal, and output FET is turned off when it becomes 120% of set-point voltage.

**Absolute Maximum Ratings**

Item	Symbol	Ratings	Unit
Maximum input voltage	VCC	80	V
BST to GND	VBST	85	V
Maximum input current	I <sub>max</sub>	3.5	A
BST to LX	ΔVBST	15	V
EN to GND	VEN	80	V
LX to GND	VLX	80	V
VC to GNF	VVC	7	V
FB to GND	VFB	7	V
RT to GND	VRT	7	V
Operating Temperature	Topr	-40 to +85	°C
Storage Temperature	T <sub>stg</sub>	-55 to +150	°C
Junction Temperature	T <sub>jmax</sub>	150	°C

**Caution1:** 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 with thermal resistance 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>	
HTSOP-J8				
Junction to Ambient	θ <sub>JA</sub>	125.3	27.6	°C/W
Junction to Top Characterization Parameter <sup>(Note 2)</sup>	Ψ <sub>JT</sub>	21	13	°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.

(Note 4) Using a PCB board based on JESD51-5, 7.

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	

Layer Number of Measurement Board	Material	Board Size	Thermal Via <sup>(Note 5)</sup>	
			Pitch	Diameter
4 Layers	FR-4	114.3mm x 76.2mm x 1.6mm	1.20mm	Φ0.30mm
Top		2 Internal Layers		Bottom
Copper Pattern	Thickness	Copper Pattern	Thickness	Copper Pattern
Footprints and Traces	70μm	74.2mm x 74.2mm	35μm	74.2mm x 74.2mm
				70μm

(Note 5) This thermal via connects with the copper pattern of all layers.

**Recommended Operating Ratings(Ta=25°C)**

Item	Symbol	Rating			Unit
		Min	Typ	Max	
Power Supply Voltage	VCC	12	—	76	V
Output voltage	V <sub>OUT</sub>	1.0 <sup>(Note 6)</sup>	—	VCC <sup>(Note 7)</sup>	V
Output current	I <sub>OUT</sub>	-	—	3.0	A
Oscillator frequency	F <sub>osc</sub>	50	—	750	kHz

(Note 6) Restricted by minduty=f × MinOn Time ( f :frequency)

If the voltage of Vcc × minduty [V] lower than 1V, this value is minimum output.

(Note 7) Restricted by maxduty =1-f × forced off time

The maximum output is (Vcc - Iout \* Ron) × maxduty

**Electrical Characteristics (Unless otherwise specified Ta=25°C, VCC=48V, Vo=5V, EN=3V, RT=47kΩ )**

Parameter	Symbol	Limit			Unit	Condition
		Min	Typ	Max		
<b>【Circuit Current】</b>						
Stand-by current of VCC	Ist	—	0	10	μA	VEN=0V
Circuit current of VCC	Icc	—	1.5	2.0	mA	FB=1.5V
<b>【Under Voltage Lock Out (UVLO)】</b>						
Detect Voltage	Vccuv	10.4	11	11.6	V	
Hysteresis width	Vuvhy	—	200	300	mV	
<b>【Error Amp】</b>						
FB threshold voltage	VFBN	0.985	1.000	1.015	V	Ta=25°C
	VFBA	0.980	1.000	1.020	V	Ta=-40 to 85°C
FB Input bias current	IFB	-1	0	1	uA	VFB=2.0V
VC source current	Isource	15	40	65	uA	
VC sink current	Isink	-65	-40	-15	uA	
Soft start time	Tsoft	15	20	25	msec	
Error amplifier DC gain	AVEA	—	10000	—	V/V	
Trans conductance	GEA	—	300	—	μA/V	
<b>【Current Sense Amp】</b>						
VC to switch current trans conductance	Gcs	—	10	—	A/V	
<b>【OCP】</b>						
Detect current	Iocp	3.5	6.0	—	A	
OCP latch count	NOCP	—	2	—	count	
OCP latch hold time	TOCP	15	20	25	msec	
<b>【Output】</b>						
Lx NMOS ON resistance	RonH	—	150	—	mΩ	
<b>【CTL】</b>						
EN Pin inner REG on voltage	ON	VENON	1.3	—	2.4	V
EN Pin IC output on threshold	Venuv	2.52	2.6	2.68	V	IC on or off threshold
EN pin	IEN	9.0	10.0	11.0	μA	VEN=3V
<b>【Oscillator】</b>						
Oscillator frequency	Fosc	180	200	220	kHz	RTR=47kΩ
Forced off time	Toff	—	—	500	nsec	

**Typical Performance Characteristics**

(Unless otherwise specified, Ta=25°C, VCC=24V, VOUT=5V)

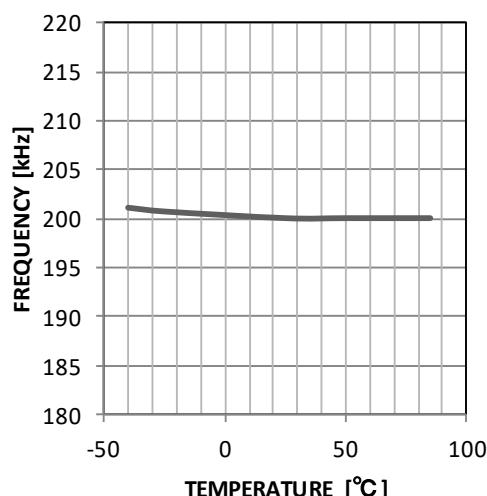


Fig.4 Oscillator Frequency - Temperature

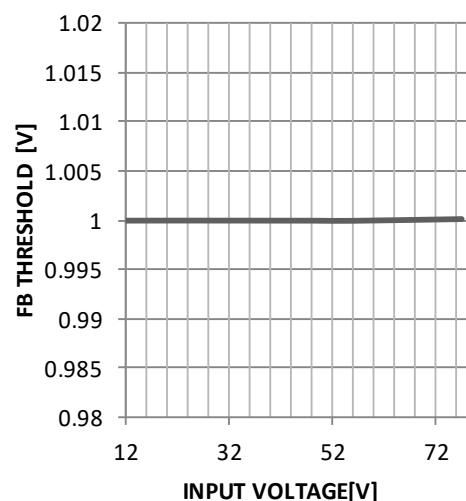


Fig.5 FB Threshold Voltage- Input Voltage

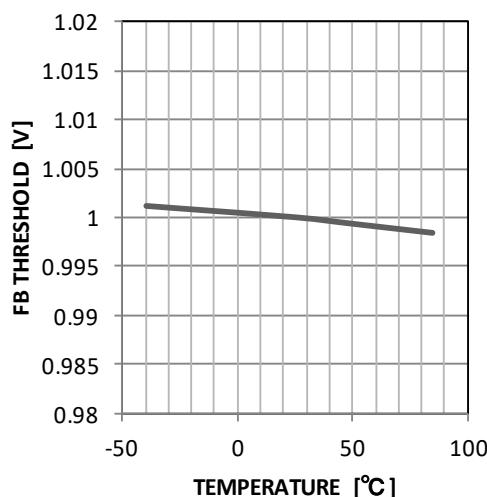


Fig.6 FB Threshold Voltage - Temperature

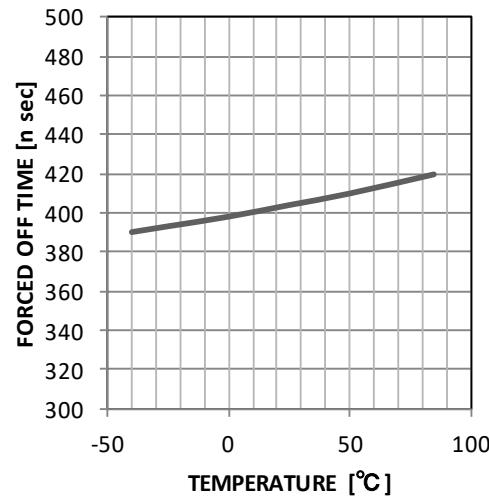


Fig.7 Forced off time - Temperature

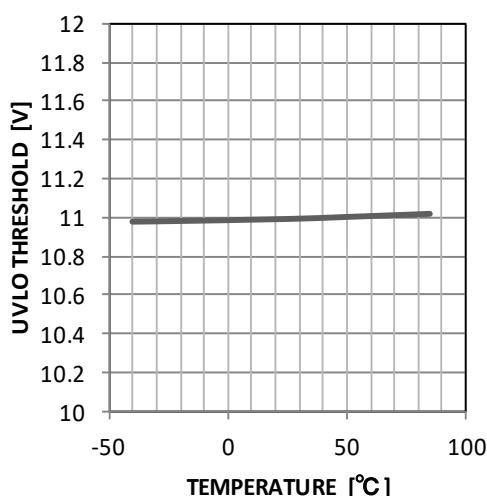


Fig.8 UVLO Threshold Voltage - Temperature

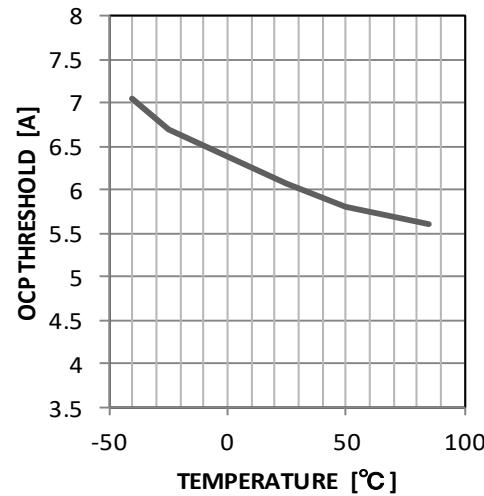


Fig.9 OCP Detect Current - Temperature

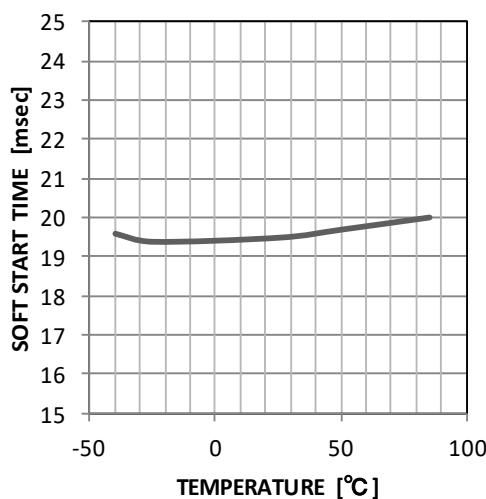


Fig.10 Soft Start Time - Temperature

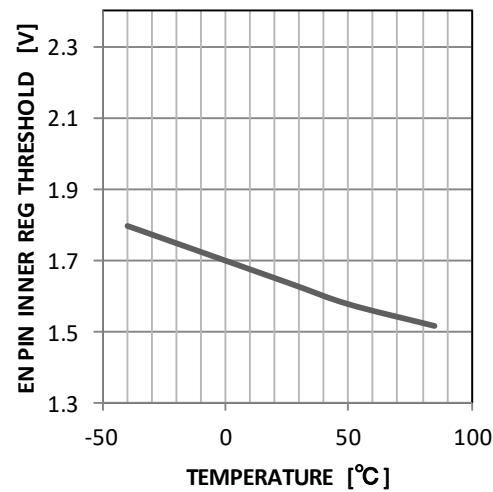


Fig.11 EN Pin Inner REG ON Threshold - Temperature

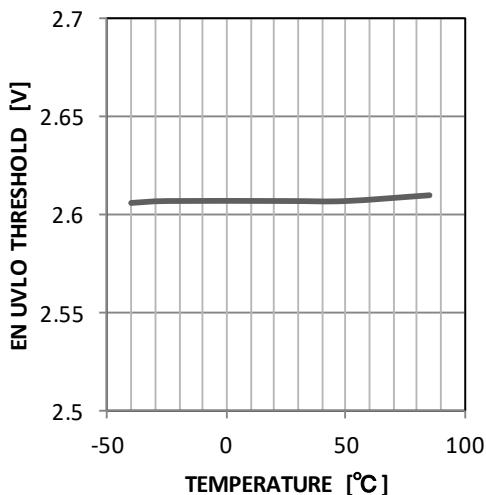


Fig.12 ENUVLO Threshold - Temperature

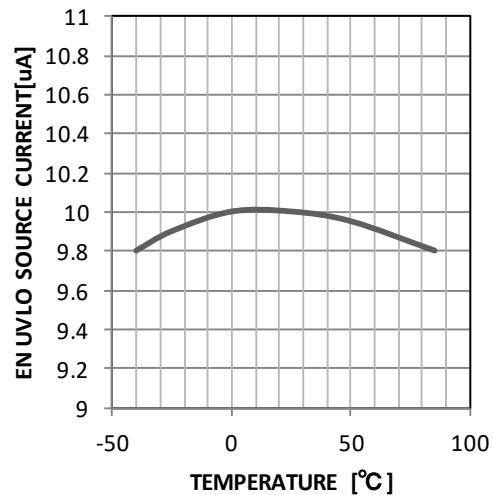


Fig.13 EN Source Current - Temperature

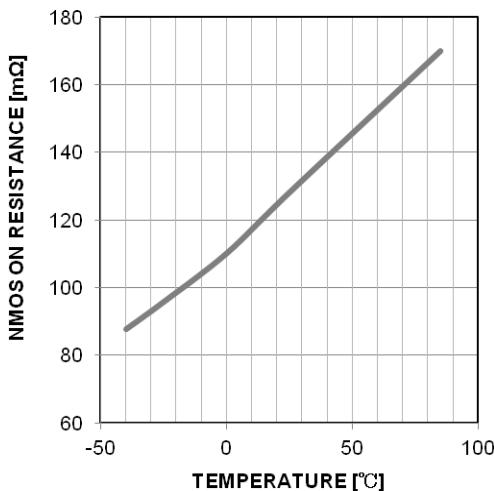
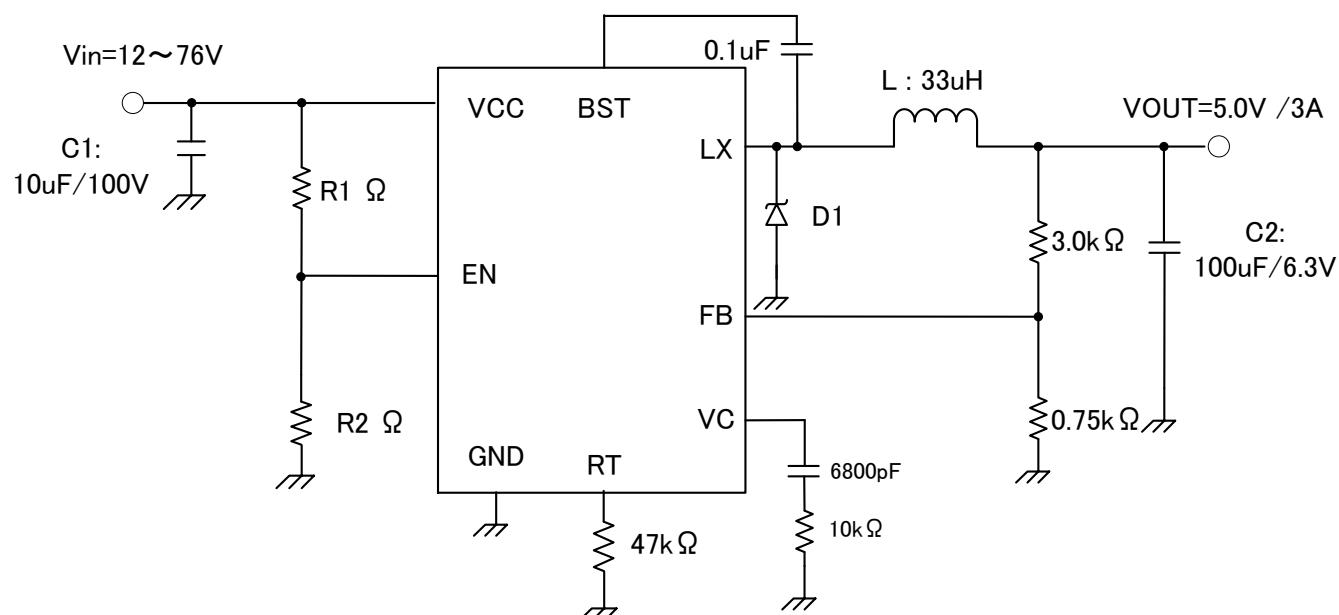


Fig.14 NMOS ON Resistance - Temperature

## Reference Characteristics of Typical Application Circuits

Vout=5V, f=200kHz

(All the external components can be substituted by equivalents)



Parts : L	: SUMIDA	CDRH129HF	33μH
C1	: TDK	C5750X7S2A106K	10μF/100V
C2	: TDK	C4532X5R0J107M	100μF/6.3V
D1	: Rohm	RB095BGE-90TL	

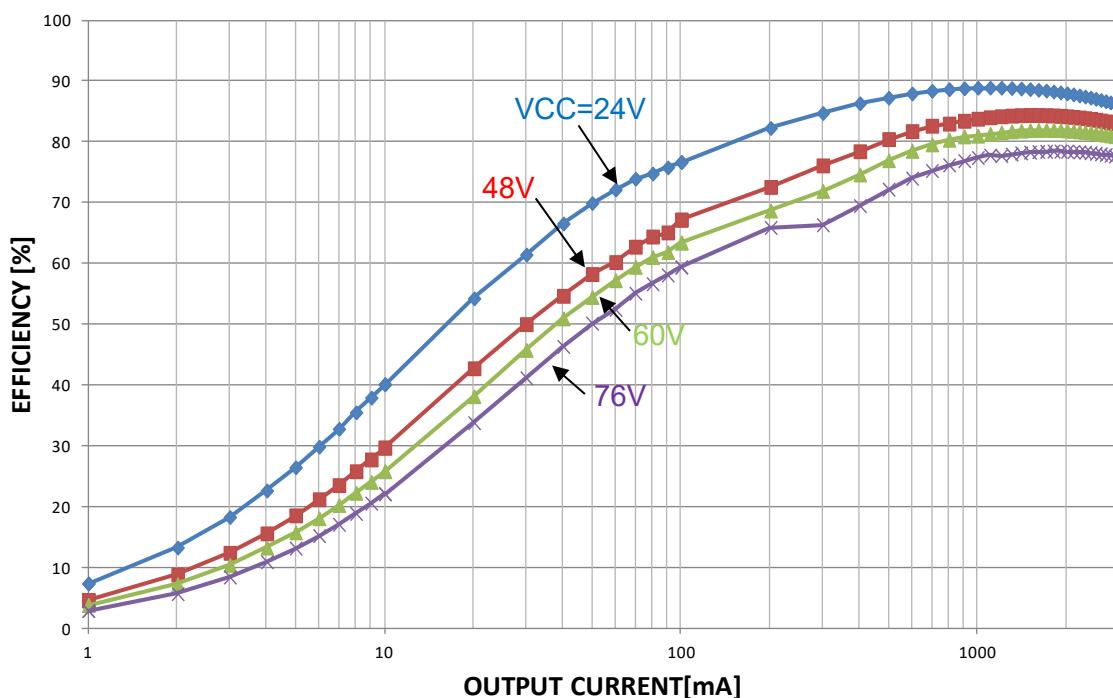


Fig. 15 Efficiency – Output Current

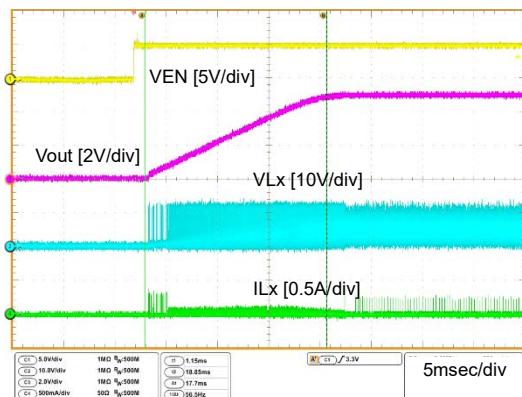
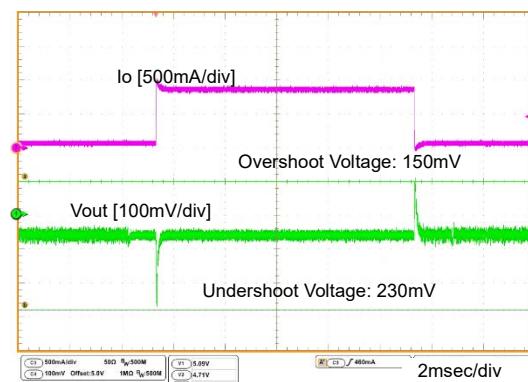
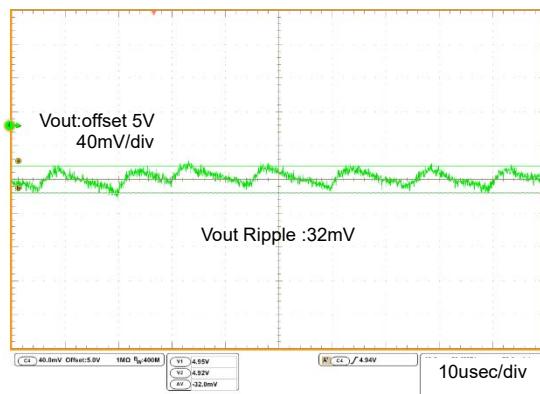
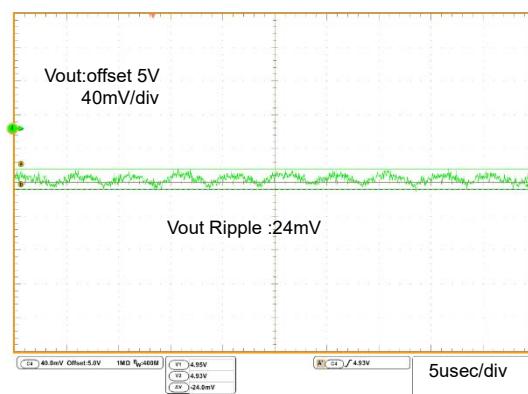
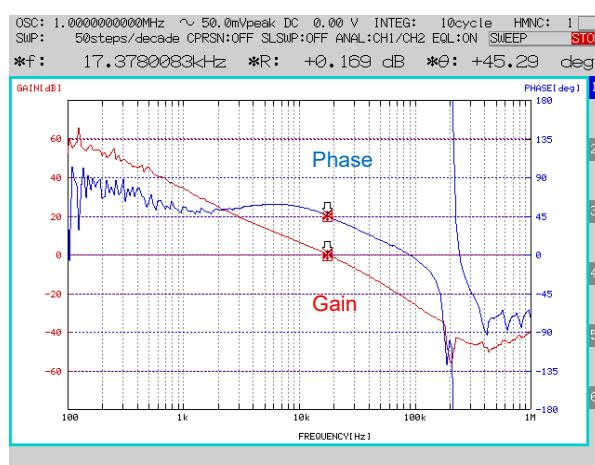
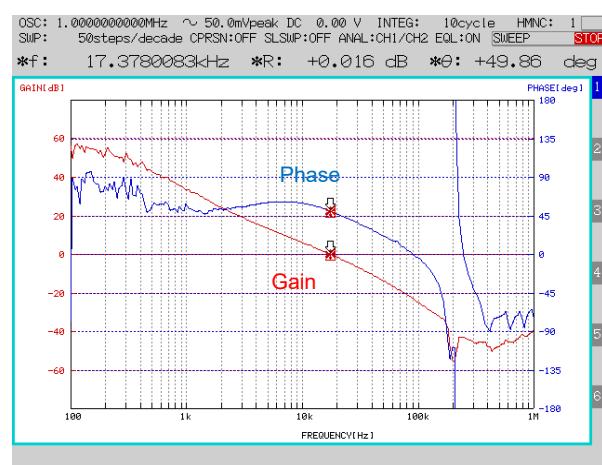


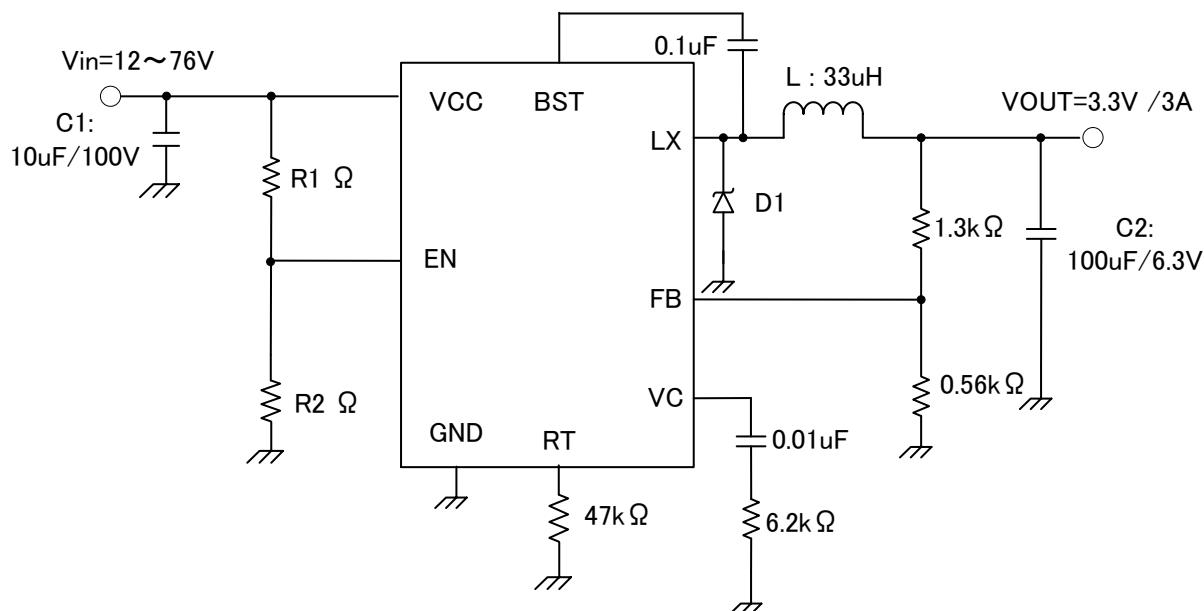
Fig.16 Start-up Characteristics

Fig.17 Load Response  
Iout:100mA  $\leftrightarrow$  1AFig.18 Lx Switching/Vout Ripple  
Io = 100mAFig.19 Lx Switching/Vout Ripple  
Io=1AFig.20 Frequency Response  
Io=100mAFig.21 Frequency Response  
Io=3.0A

## Reference Characteristics of Typical Application Circuits

Vout=3.3V, f=200kHz

(All the external components can be substituted by equivalents)



Parts :	L	: SUMIDA	CDRH129HF	33μH
C1	: TDK	C5750X7S2A106K	10μF/100V	
C2	: TDK	C4532X5R0J107M	100μF/6.3V	
D1	: Rohm	RB095BGE-90TL		

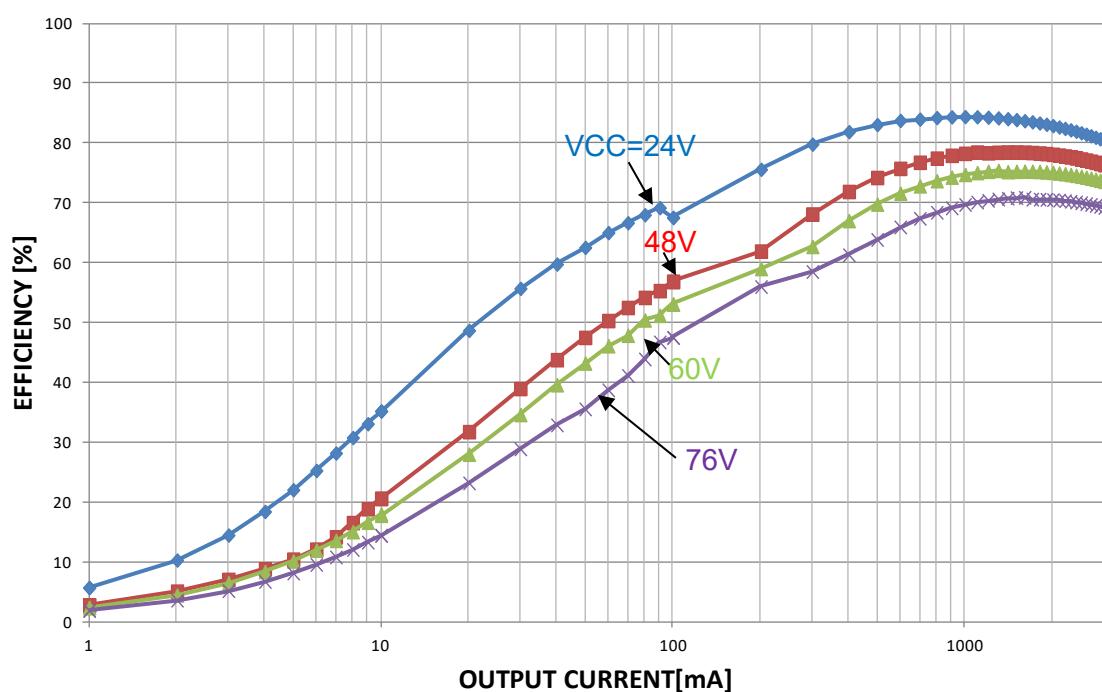


Fig.22 Efficiency – Output Current

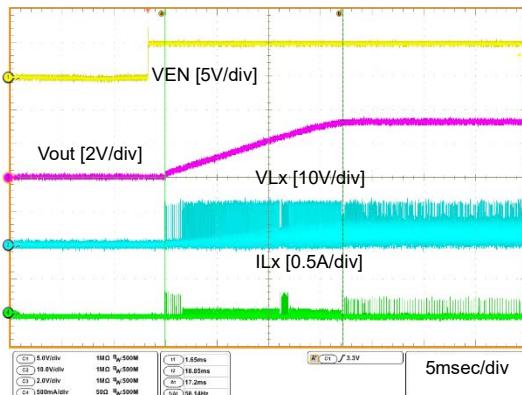
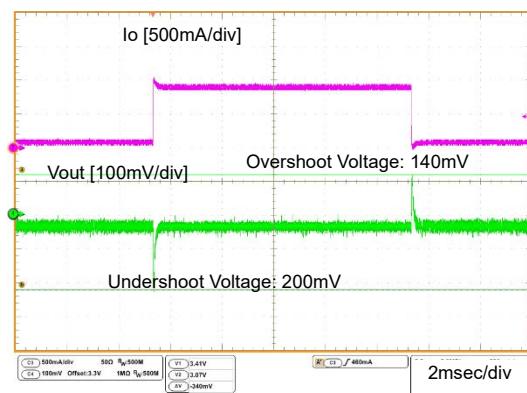
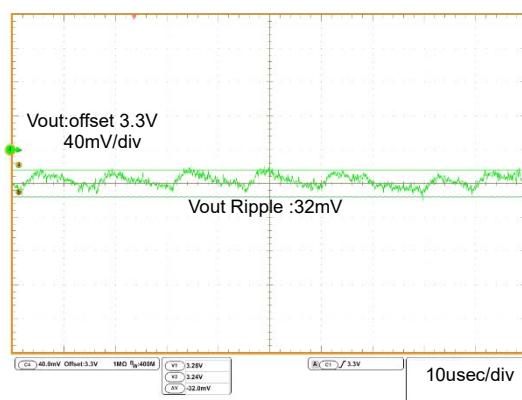
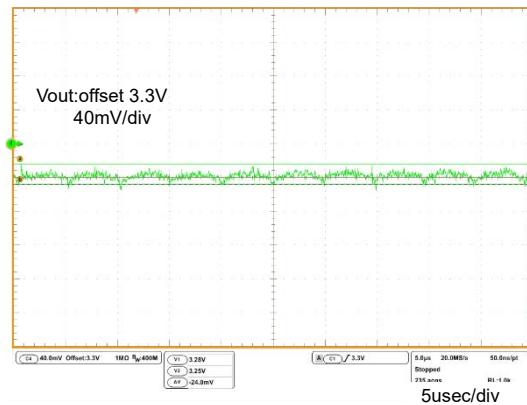
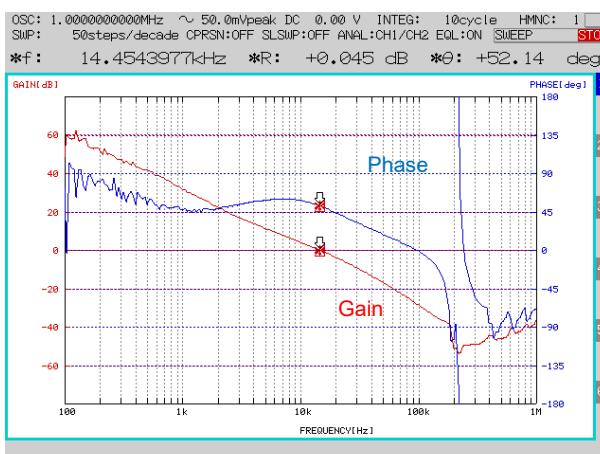
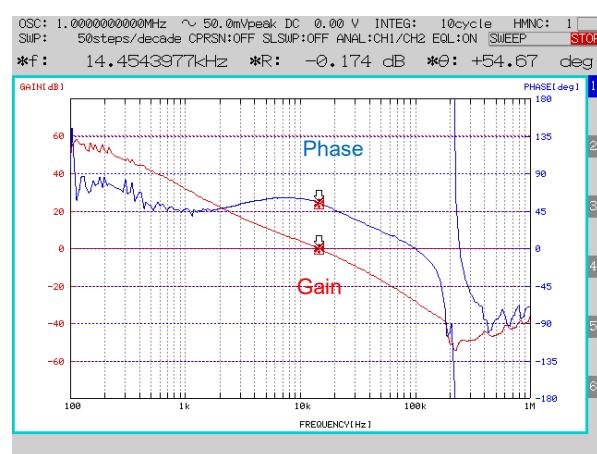


Fig.23 Start-up Characteristics

Fig.24 Load Response  
Iout:100mA ⇌ 1AFig.25 Lx Switching/Vout Ripple  
Io = 100mAFig.26 Lx Switching/Vout Ripple  
Io=1AFig.27 Frequency Response  
Io=100mAFig.28 Frequency Response  
Io=3A

## Detailed Description

### ◊Frequency setting

Arbitrary internal oscillator frequency setup is possible by connecting RT resistance. Recommended frequency range is 50 kHz to 750 kHz.

For setting frequency  $f$  [Hz] , RT resistance is looked for using the following formula.

$$RT = \frac{\frac{1}{f} - 400 \times 10^{-9}}{96.48 \times 10^{-12}} [\Omega]$$

If setting frequency is 200kHz, RT is 47kΩ.

RT resistance is related to frequency as shown in Figure 26.

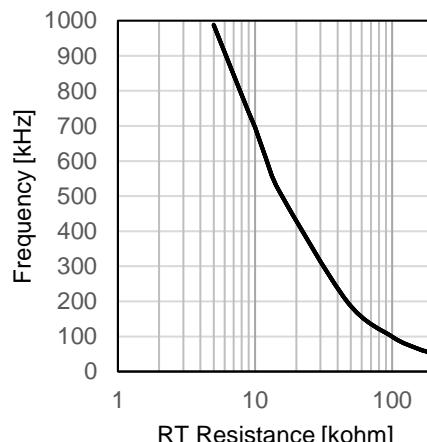


Fig.29 Oscillator Frequency - RT resistance

### ◊External UVLO threshold

The high precision reset function is built in EN terminal of BD9G341AEFJ, and arbitrary low-voltage malfunction prevention setup is possible by connecting EN pin to resistance division of input voltage.

When you use, please set R1 and R2 to arbitrary voltage of IC turned on ( $V_{UV}$ ) and hysteresis ( $V_{UVHYS}$ ) like below.

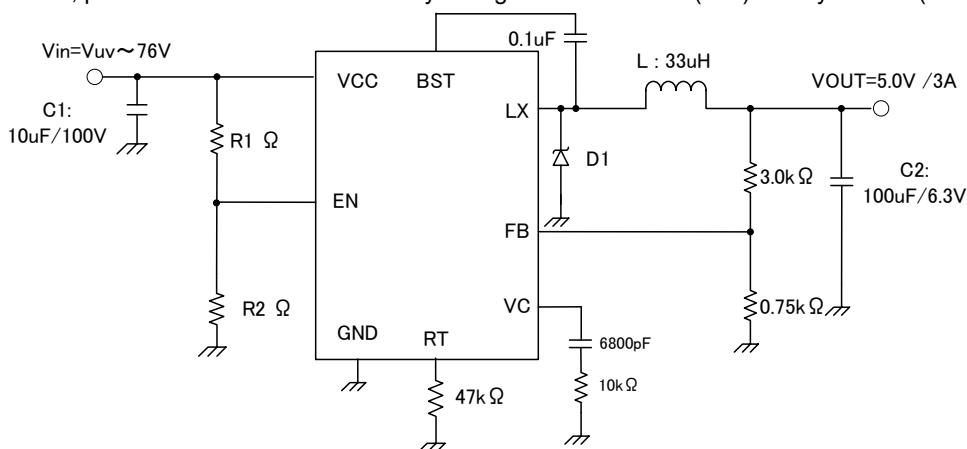


Fig.30 External UVLO setup

$$R1 = \frac{V_{UVHYS}}{IEN} \quad [\text{ohm}]$$

$$R2 = \frac{V_{EN} \times R1}{V_{UV} - V_{EN}} \quad [\text{ohm}]$$

IEN: EN pin source current 10uA(typ) VEN: EN pin output on threshold 2.6V(typ)

As an example in typical sample, When Vcc voltage which IC turned on 15V, Hysteresis width 1V, The resistance divider set to R1=100kΩ, R2=20kΩ.

## ◊OCP operation

The device has over current protection for protecting the FET from over current.  
To detect OCP 2 times sequentially, the device will stop and after 20msec restart.

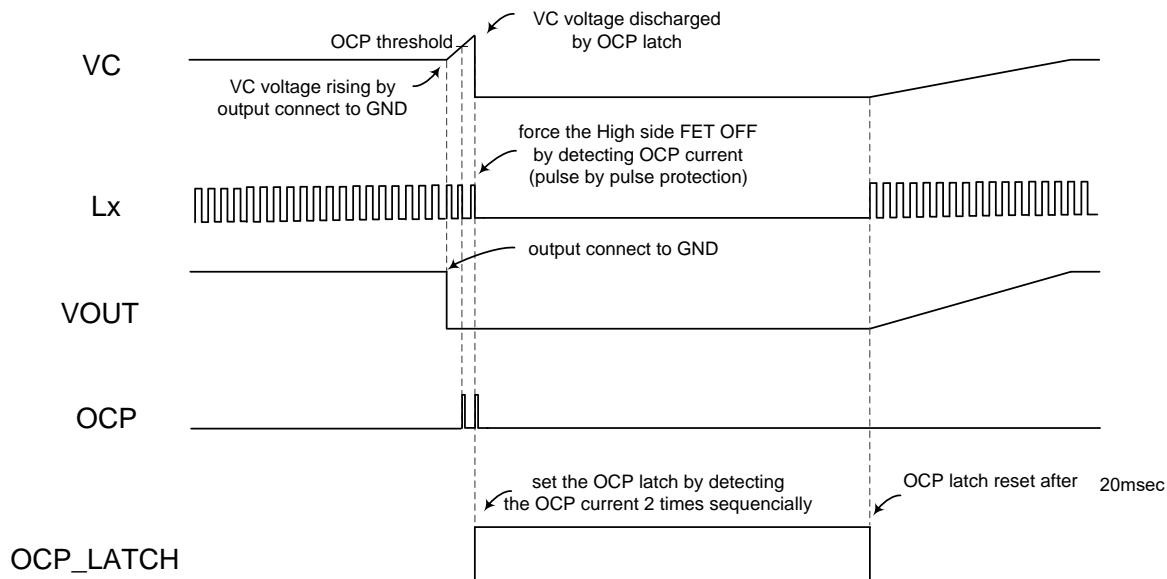
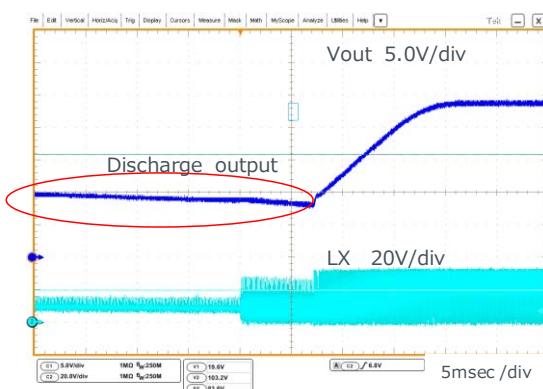


Fig.31 Timing chart at OCP operation

## ◊start up with output pre-bias voltage

It starts in the state that the voltage remains in the output , in the cases that big capacitor is connected to output , IC discharge output voltage min 7.5V by FET ON 300nsec in period to charge bootstrap capacitor between BST to LX. When it is necessary to make a startup sequence, please forcibly discharge the output voltage.

Figure 32. pre-bias start up waveform  
VCC=48V, Vout=24V

◇Restriction of output Bias application

The application that output connects to the other power supply is not recommended because the output voltage is not discharged in startup.

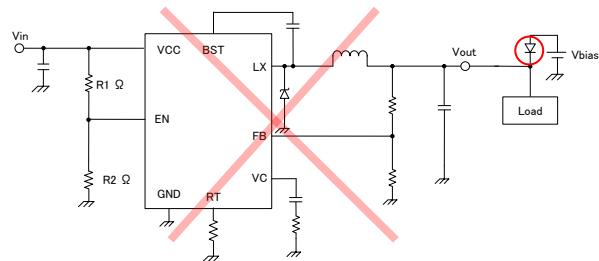


Figure 33. Output Bias NG application

When output connect to voltage supply, please insert a diode to the IC output side.

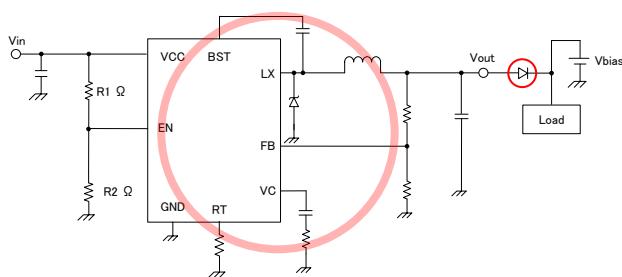


Figure 34. Output Bias OK application

## Application Components Selection Method

### (1) Inductors

Something of the shield type that fulfills the current rating (Current value Ipeak below), with low DCR is recommended. Value of Inductance influences Inductor Ripple Current and becomes the cause of Output Ripple. In the same way as the formula below, this Ripple Current can be made small for as big as the L value of Coil or as high as the Switching Frequency.

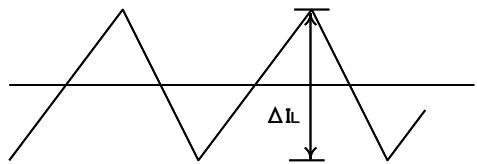


Fig.35 inductor Current

$$I_{peak} = I_{OUT} + \frac{\Delta IL}{2} \quad \dots \quad (1)$$

$$\Delta IL = \frac{V_{CC} - V_{OUT}}{L} \times \frac{V_{OUT}}{V_{CC}} \times \frac{1}{f} \quad \dots \quad (2)$$

(ΔIL: Output Ripple Current, VCC: Input Voltage, VOUT: Output Voltage, f: Switching Frequency)

For design value of Inductor Ripple Current, please carry out design tentatively with about 20% to 50% of Maximum Output Current.

In the BD9G341AEFJ, it is recommended the below series of 4.7μH to 33μH inductance value.

Recommended Inductor: SUMIDA CDRH129HF Series

### (2) Output Capacitor

In order for capacitor to be used in output to reduce output ripple, Low ceramic capacitor of ESR is recommended.

Also, for capacitor rating, on top of putting into consideration DC Bias characteristics, please use something whose maximum rating has sufficient margin with respect to the Output Voltage.

Output ripple voltage is looked for using the following formula.

$$V_{PP} = \Delta IL \times \frac{1}{2\pi \times f \times C_{OUT}} + \Delta IL \times R_{ESR} \quad \dots \quad (3)$$

Please design in a way that it is held within Capacity Ripple Voltage.

In the BD9G341AEFJ, it is recommended a ceramic capacitor over 10μF.

The maximum value of the output capacitor is limited by Start Up Rush current

The rush current is expressed by the following

$$(Rush Current) = (\text{Current of the error amplifier reply delay}) + \frac{C_{out} \times V_{out}}{T_{softstart\_min}} + \text{Ripple Current} + \text{Output Current}$$

↑  
(Output Capacitor Charge current)

Current of the error amplifier reply delay depend on the phase compensation element and output capacitor.

As output capacitor big, Rush Current grows big.

Please verify actual equipment that the Rush Current become smaller than OCP Threshold(min3.5A).

## (3) Output voltage setting

The internal reference voltage of ERROR AMP is 1.0V.  
Output voltage is determined like (4) types.

$$V_{OUT} = \frac{R1 + R2}{R2} \quad \dots \quad (4)$$

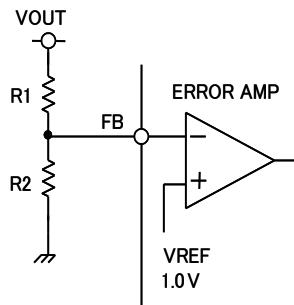


Fig.36 Output voltage setting

## (4) Bootstrap Capacitor

Please connect from 0.1uF (Laminate Ceramic Capacitor) between BST Pin and Lx Pins.

## (5) Catch Diode

BD9G341AEFJ should be taken to connect external catch diode between Lx Pin and GND Pin. The diode require adherence to absolute maximum Ratings of application. Opposite direction voltage should be higher than maximum voltage of Lx Pin (VCCMAX + 0.5V). The peak current is required to be higher than IOUTMAX + ΔIL.

## (6) Input Capacitor

BD9G341AEFJ needs an input decoupling capacitor. It is recommended a low ceramic capacitor ESR over 4.7μF. Additionally, it should be located as close as possible.

Capacitor should be selected by maximum input voltage with input ripple voltage.

Input ripple voltage is calculated by using the following formula.

$$\Delta V_{CC} = \frac{I_{OUT}}{f \times C_{VCC}} \times \frac{V_{OUT}}{V_{CC}} \times \left[ 1 - \frac{V_{OUT}}{V_{CC}} \right] \quad \dots \quad (5)$$

CVCC: Input capacitor

RMS ripple current is calculated by using the following formula.

$$I_{CVCC} = I_{OUT} \times \sqrt{\frac{V_{OUT}}{V_{CC}} \times \left( 1 - \frac{V_{OUT}}{V_{CC}} \right)} \quad \dots \quad (6)$$

If VCC=2VOUT, RMS ripple current is maximum. That is determined by (9).

$$I_{CVCC\_max} = \frac{I_{OUT}}{2} \quad \dots \quad (7)$$

## (7) About Adjustment of DC/DC Comparator Frequency Characteristics

Role of Phase compensation element C1, C2, R3

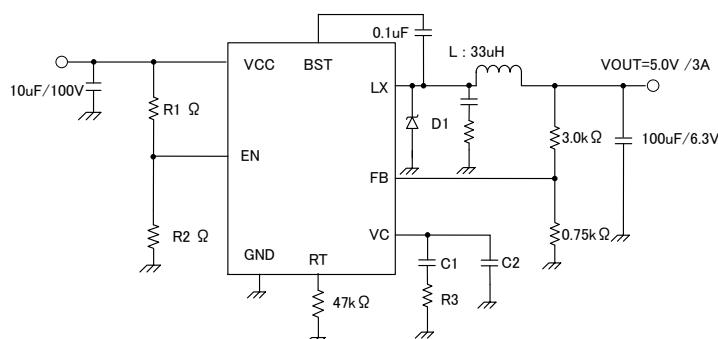


Fig.37 Feedback voltage resistance setting method

Stability and Responsiveness of Loop are controlled through VC Pin which is the output of Error Amp. The combination of zero and pole that determines Stability and Responsiveness is adjusted by the combination of resistor and capacitor that are connected in series to the VC Pin.

DC Gain of Voltage Return Loop can be calculated for using the following formula.

$$Adc = Rl \times G_{CS} \times A_{VEA} \times \frac{VFB}{VOUT} \quad \dots \quad (8)$$

Here, VFB is Feedback Voltage (1.0V).A<sub>EA</sub> is Voltage Gain of Error amplifier (typ: 80dB), G<sub>CS</sub> is the Trans-conductance of Current Detect (typ: 10A/V), and R<sub>l</sub> is the Output Load Resistance value.

There are 2 important poles in the Control Loop of this DC/DC.

The first occurs with/ through the output resistance of Phase compensation Capacitor (C1) and Error amplifier.

The other one occurs with/through the Output Capacitor and Load Resistor.

These poles appear in the frequency written below.

$$fp1 = \frac{G_{EA}}{2\pi \times C1 \times A_{VEA}} \quad \dots \quad (9)$$

$$fp2 = \frac{1}{2\pi \times COUT \times Rl} \quad \dots \quad (10)$$

Here, G<sub>EA</sub> is the trans-conductance of Error amplifier (typ: 300  $\mu$ A/V).

Here, in this Control Loop, one zero becomes important. With the zero which occurs because of Phase compensation Capacitor C1 and Phase compensation Resistor R3, the Frequency below appears.

$$fz1 = \frac{1}{2\pi \times C1 \times R3} \quad \dots \quad (11)$$

Also, if Output Capacitor is big, and that ESR (RESR) is big, in this Control Loop, there are cases when it has an important, separate zero (ESR zero).

This ESR zero occurs due to ESR of Output Capacitor and Capacitance, and exists in the Frequency below.

$$fz_{ESR} = \frac{1}{2\pi \times COUT \times RESR} \quad \dots \quad (12) \quad (\text{ESR zero})$$

In this case, the 3<sup>rd</sup> pole determined with the 2<sup>nd</sup> Phase compensation Capacitor (C2) and Phase Correction Resistor (R3) is used in order to correct the ESR zero results in Loop Gain.

This pole exists in the frequency shown below.

$$fp3 = \frac{1}{2\pi \times C2 \times R3} \quad \dots \quad (13) \quad (\text{Pole that corrects ESR zero})$$

The target of Phase compensation design is to create a communication function in order to acquire necessary band and Phase margin.

Cross-over Frequency (band) at which Loop gain of Return Loop becomes "0" is important.

When Cross-over Frequency becomes low, Power supply Fluctuation Response, Load Response etc. worsens.

On the other hand, when Cross-over Frequency is too high, instability of the Loop can occur.

Tentatively, Cross-over Frequency is targeted to be made 1/20 or below of Switching Frequency.

Selection method of Phase Compensation constant is shown below.

- Phase Compensation Resistor (R3) is selected in order to set to the desired Cross-over Frequency. Calculation of RC is done using the formula below.

$$R3 = \frac{2\pi \times C_{OUT} \times f_c}{G_{EA} \times G_{CS}} \times \frac{V_{OUT}}{V_{FB}} \quad \dots \quad (14)$$

Here,  $f_c$  is the desired Cross-over Frequency. It is made about 1/20 and below of the Normal Switching Frequency ( $f_s$ ).

- Phase compensation Capacitor (C1) is selected in order to achieve the desired phase margin.

In an application that has a representative Inductance value (about several 4.7µH to 33µH), by matching zero of compensation to 1/4 and below of the Cross-over Frequency, sufficient Phase margin can be acquired. C1 can be calculated using the following formula.

$$C1 > \frac{4}{2\pi \times R3 \times f_c} \quad \dots \quad (15)$$

- Examination whether the second Phase compensation Capacitor C2 is necessary or not is done.

If the ESR zero of Output Capacitor exists in a place that is smaller than half of the Switching Frequency, a second Phase compensation Capacitor is necessary. In other words, it is the case wherein the formula below happens.

$$\frac{1}{2\pi \times C_{OUT} \times RESR} < \frac{f_s}{2} \quad \dots \quad (16)$$

In this case, add the second Phase compensation Capacitor C2, and match the frequency of the third pole to the Frequency  $f_{p3}$  of ESR zero.

$$C2 = \frac{C_{OUT} \times RESR}{R3} \quad \dots \quad (17)$$

## PCB Layout

Layout is a critical portion of good power supply design. There are several signals paths that conduct fast changing currents or voltages that can interact with stray inductance or parasitic capacitance to generate noise or degrade the power supplies performance. To help eliminate these problems, the VCC pin should be bypassed to ground with a low ESR ceramic bypass capacitor with B dielectric. Care should be taken to minimize the loop area formed by the bypass capacitor connections, the VCC pin, and the anode of the catch diode. See Fig.28 for a PCB layout example. The GND pin should be tied directly to the thermal pad under the IC and the thermal pad. In order to reduce the influence of the impedance and L of the parasitic, the high current line is thick and short.

Input decoupling capacitor should be located as close to the VCC pins

In order to minimize the parasitic capacitor and impedance of pattern, catch diode and inductance should be located as close to the LX pin.

The thermal pad should be connected to any internal PCB ground planes using multiple VIAs directly under the IC.

GND feedback resistor, phase compensation element and RT resistor don't give the common impedance resistor against high current line.

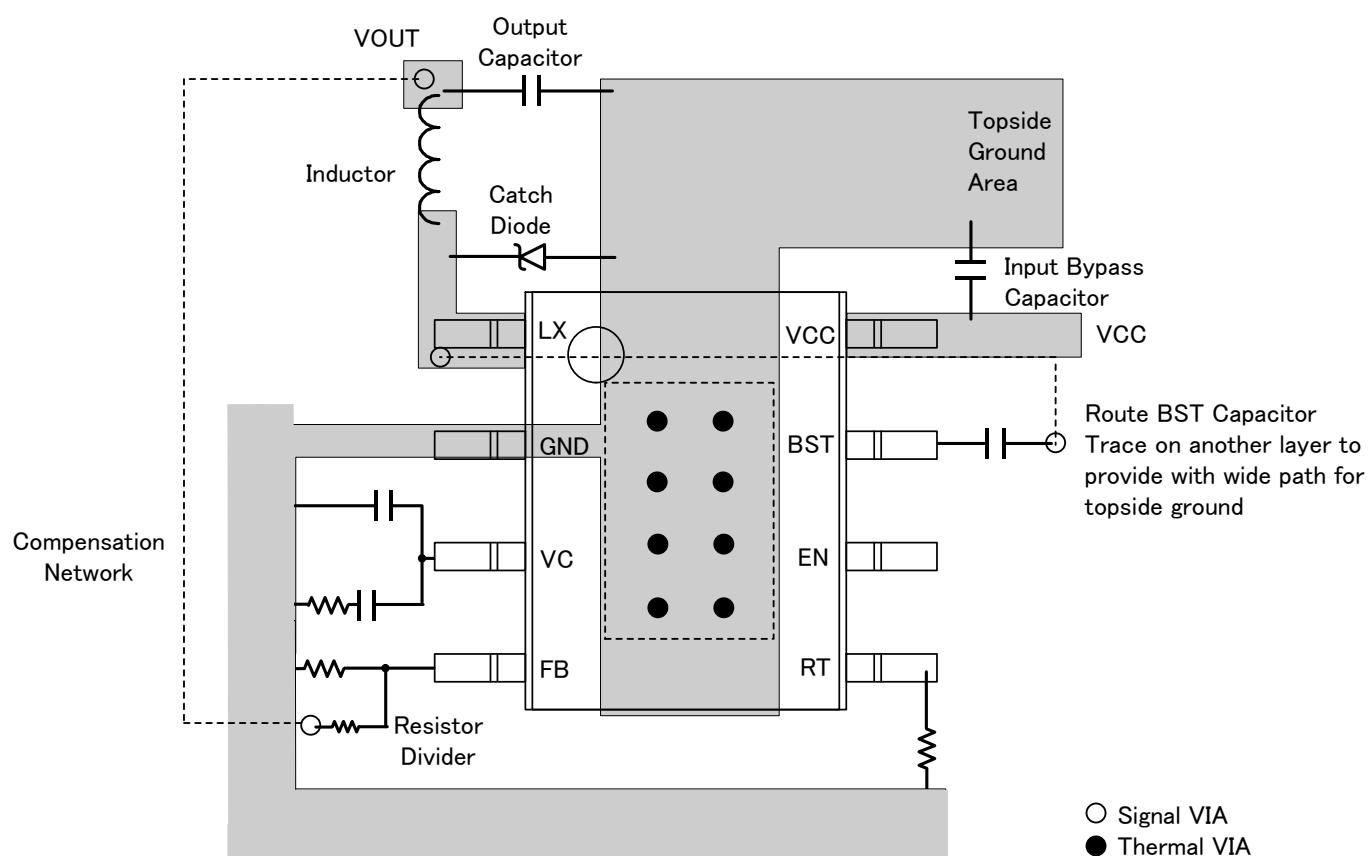


Figure 38. Evaluation Board Pattern

## Power Dissipation Estimate

The following formulas show how to estimate the device power dissipation under continuous mode operations. They should not be used if the device is working in the discontinuous conduction mode.

The device power dissipation includes:

- 1) Conduction loss :  $P_{con} = I_{OUT}^2 \times RonH \times V_{OUT}/V_{CC}$
- 2) Switching loss :  $P_{sw} = 16n \times V_{CC} \times I_{OUT} \times f_{sw}$
- 3) Gate charge loss :  $P_{gc} = 500p \times 7 \times 7 \times f_{sw}$
- 4) Quiescent current loss :  $P_q = 1.5m \times V_{CC}$

Where:

$I_{OUT}$  is the output current (A) ,  $RonH$  is the on-resistance of the high-side MOSFET ( $\Omega$ ) ,  $V_{OUT}$  is the output voltage (V).

$V_{CC}$  is the input voltage (V)  $f_{sw}$  is the switching frequency (Hz).

Therefore

Power dissipation of IC is the sum of above dissipation.

$$P_d = P_{con} + P_{sw} + P_{gc} + P_q$$

For given  $T_j$ ,  $T_j = T_a + \theta_{ja} \times P_d$

Where:

$P_d$  is the total device power dissipation (W),  $T_a$  is the ambient temperature ( $^{\circ}C$ )

$T_j$  is the junction temperature ( $^{\circ}C$ ),  $\theta_{ja}$  is the thermal resistance of the package ( $^{\circ}C$ )

## I/O Equivalent Schematic

Pin. No	Pin. Name	Pin Equivalent Schematic	Pin. No	Pin. Name	Pin Equivalent Schematic
1 2 7 8	Lx GND BST VCC		5	RT	
3	VC		6	EN	
4	FB				

## 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.

### 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

These conditions represent a range within which the expected characteristics of the IC can be approximately obtained. The electrical characteristics are guaranteed under the conditions of each parameter.

### 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.

## 11. Regarding the Input Pin of the IC

This monolithic IC contains P+ 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.

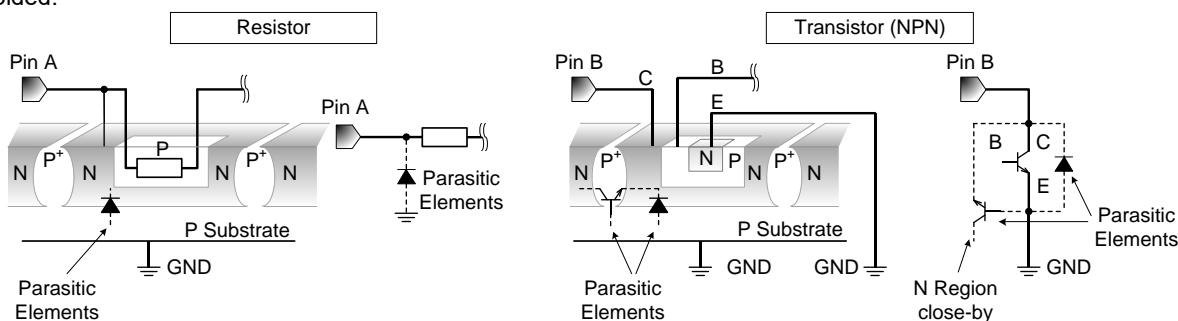


Figure 39. Example of monolithic IC structure

## 12. Ceramic Capacitor

When using a ceramic capacitor, determine the dielectric constant 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 power dissipation 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 power dissipation 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 all output pins. When the  $T_j$  falls below the TSD threshold, the circuits are automatically restored to normal operation.

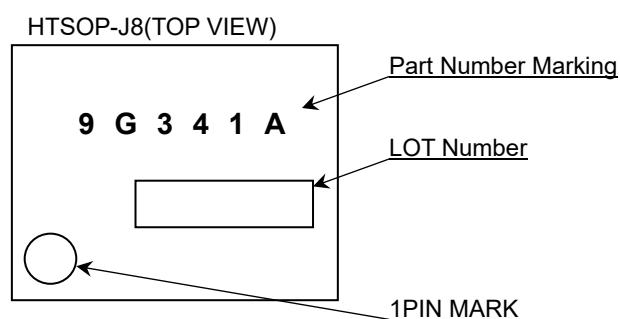
Note that the TSD circuit operates in a situation that exceeds the absolute maximum ratings and therefore, under no circumstances, should the TSD circuit be used in a set design or for any purpose other than protecting the IC from heat damage.

## 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.

**Ordering Information**

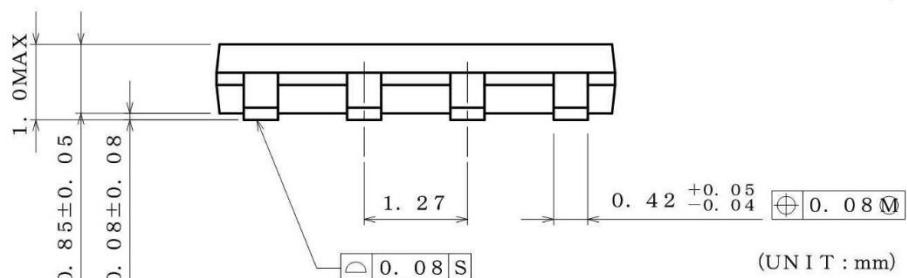
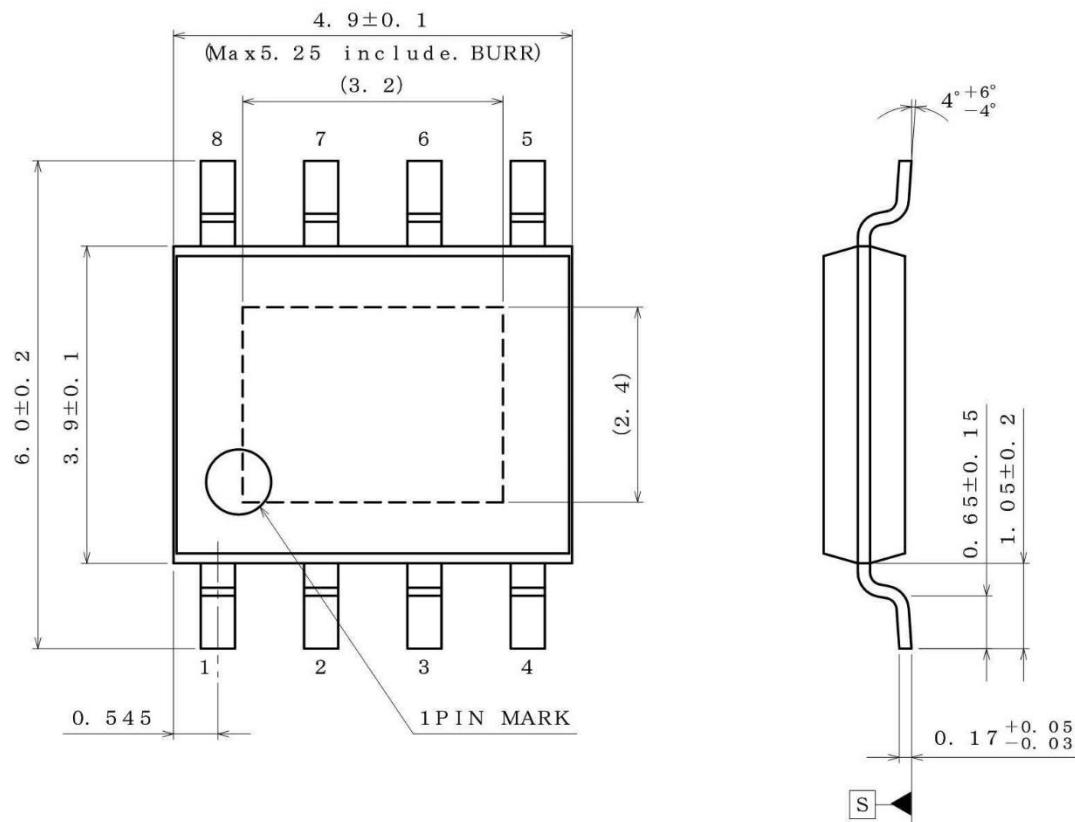
B D 9 G 3 4 1 A E F J	-	E2
Part Number	Package EFJ: HTSOP-J8	Packaging and forming specification: Embossed tape and reel

**Marking Diagrams**

## Physical Dimension, Tape and Reel Information

Package Name

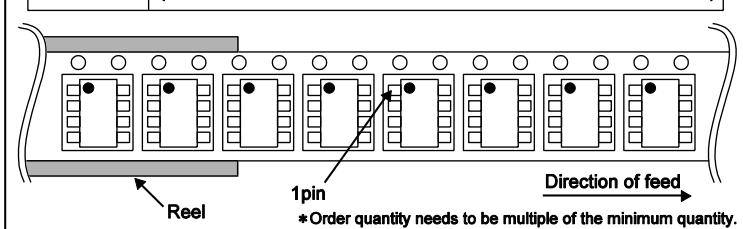
HTSOP-J8



PKG : HTSOP - J 8  
Drawing No. EX169-5002-2

## &lt;Tape and Reel information&gt;

Tape	Embossed carrier tape
Quantity	2500pcs
Direction of feed	E2 (The direction is the 1pin of product is at the upper left when you hold reel on the left hand and you pull out the tape on the right hand)



## Revision History

Date	Revision	Changes
15.Jun.2015	001	New Release
06.Oct.2015	002	P16 Correct error in writing
16.Dec.2015	003	P13 start up with output pre-bias voltage P14 Restriction of output Bias application P15 Output Capacitor maximum value
28.Sep.2016	004	Correct error in writing P20 Fig39 P20 calculation of Gate charge loss $P_{gc} = 500p \times 7 \times f_{sw}$ $\Rightarrow P_{gc} = 500p \times 7 \times 7 \times f_{sw}$
24.Dec.2020	005	P5 Removed power dissipation in absolute maximum ratings Added thermal resistance based on JEDEC standard. Added VC-GND and RT-GND absolute maximum ratings. Added Caution under the absolute maximum ratings. P9, 11 Added the comment "All the external components can be substituted by equivalents" P13 Fig.29 Modified the horizontal axis. P16 (1)Inductors I.9 Corrected error in writing ("Maximum Input Current" $\Rightarrow$ "Maximum Output Current"). P20 Removed power dissipation characteristic. P22 Modified I/O Equivalent Schematic of Pin No.1, 2, 7, 8. P23 Deleted 5. Thermal Consideration in Operational notes P25 Fixed Marking Diagram

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  - Use of the Products in places subject to dew condensation
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