Single-chip Type with built-in FET Switching Regulator Series

Simple Step-down Switching Regulators with Built-in Power MOSFET

BD9859EFJ

No.10027EAT43

●Summary

Output 3.0A and below High Efficiency Rate Step-down Switching Regulator Power MOSFET Internal Type BD9859EFJ mainly used as secondary side Power supply, for example from fixed Power supply of 9V, 12V etc, Step-down Output of 1.2V/1.8V/3.3V/5V, etc, can be produced.

This IC has external Coil/Capacitor down-sizing through 750kHz High Frequency operation, inside Nch-FET SW for 15V "withstand-pressure" commutation and also, High Speed Load Response through Current Mode Control is a simple external setting Phase compensation System, through a wide range external constant, a compact Power supply can be produced easily.

●Features

1) Internal 100 mΩ Nch MOSFET
2) Output Current 3A
3) Oscillation Frequency 750kHz
4) Feedback Voltage 1.0V±1.0%
5) Internal Soft Start Function
6) Internal Over Current Protect Circuit, Low Input Error Prevention Circuit, Heat Protect Circuit
7) ON/OFF Control through EN Pin (Standby Current 0μA Typ.)
8) Package :HTSOP-J8 Package

●Uses

For Household machines in general that have 9V/12V Lines, etc.

●Operating Conditions (Ta=25℃)

Item	Symbol	Voltage Range	Unit
Power supply Voltage	VCC	5.0～14	V
Output Voltage	VOUT	1.0	V

●Absolute Maximum Rating

Item	Symbol	Rating	Unit
Maximum Application Power supply Voltage	VCC	15	V
Between BST – GND	VBST	22	V
Between BST – Lx	⊿VBST	7	V
Between EN – GND	VEN	15	V
Between Lx – GND	VLx	15	V
Between FB – GND	VFB	7	V
Between VC – GND	VC	7	V
Highside NchFET Drain Current	IDH	3	A
Power Dissipation	Pd	3.76	W
Operating Temperature Range	Topr	-40 ~ +85	℃
Storage Temperature Range	Tstg	-55 ~ +150	℃
Junction Temperature	Tjmax	150	℃

(*1)During mounting of 70×70×1.6t mm 4layer board (Copper area：70mm×70mm).Reduce by 30.08mW for every 1℃ increase. (Above 25℃)

●Electrical Characteristics
(Unless otherwise specified, Ta=25℃, VCC=12V, Vo=5V,EN=3V)

Item		Symbol	Rating Value			Unit	Conditions
			Min	Typ	Max		
【Circuit Current】							
Circuit Current during Standby		Ist	―	0	10	uA	VEN=0V
Circuit Current during Operation		Icc	―	2.8	5.6	mA	FB=1.2V
【Low Voltage Input Error Prevention Circuit】							
Detect Threshold Voltage		Vuv	4.2	4.4	4.6	V	
Hysteresis Width		Vuvhy	-	200	400	mV	
【Oscillator】							
Oscillation Frequency		fosc	675	750	825	kHz	
Max Duty Cycle		Dmax	75	85	95	%	
【Error Amp】							
FB Pin Threshold Voltage		VFB	0.990	1.000	1.010	V	
FB Pin Input Current		IFB	-1.0	0	1.0	uA	VFB=0V
Mutual Conductance		Gm	70	140	280	uA/V	IVC=±10uA,VC=1.5V
Soft Start Time		Tsoft	2.0	4.0	6.0	ms	
【Output-part】							
High Side Nch FET ON Resistance		RonH	―	100	200	mΩ	
Nch FET ON Resistance for Pre-Charge		RonL	―	5	10	Ω	
Over Current Detect Current		Iocp	3.5	5.5	―	A	
【CTL】							
EN Pin Threshold Voltage	ON	VENON	2.0	―	14	V	
	OFF	VENOFF	-0.3	―	0.3	V	
EN Pin Input Current		REN	2.5	7.5	15	uA	VEN=3V

◎Not designed to withstand radiation.

●Pin Description

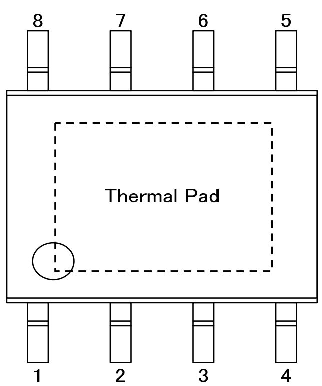


Fig.1 Pin Layout Diagram

Pin No.	Pin Name	Function
1	Lx	NMOSFET Source Pin
2	GND	Ground Pin
3	VC	Error Amp Output Pin
4	FB	Output Voltage Return Pin
5	EN	ON/OFF Control Pin
6	BST	Capacitor Connection Pin for Bootstrap
7	VCC	Power supply Voltage Pin
8	VCC	Power supply Voltage Pin

●Block Diagram

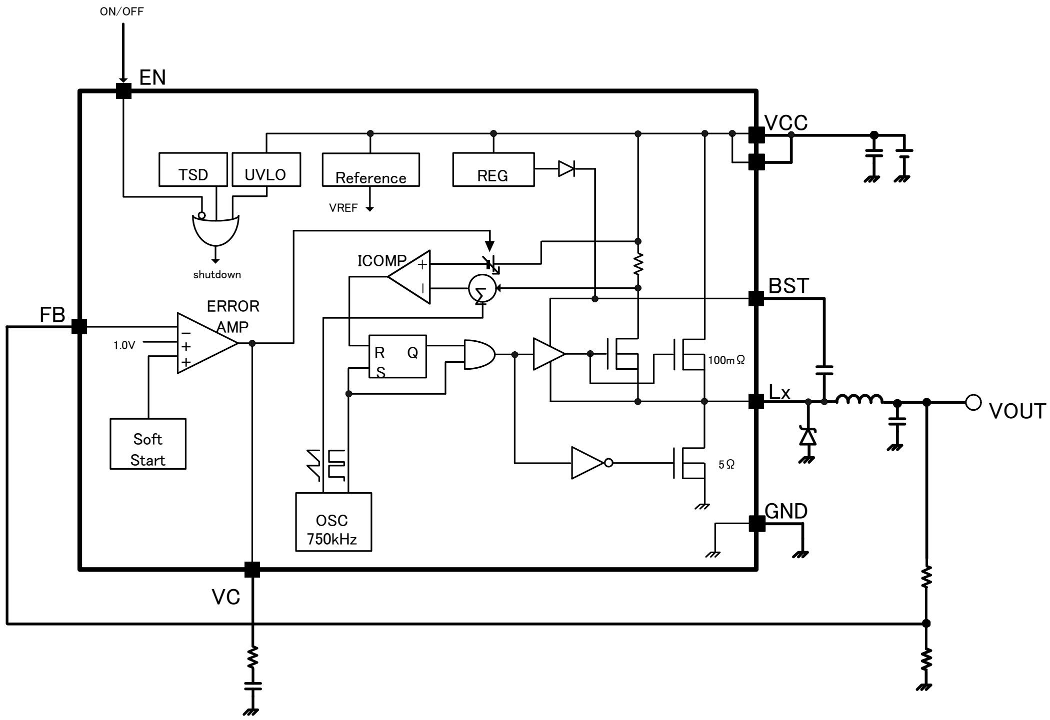


Fig.2 Block Diagram

●Block Description

1. Reference
This Block generates Error Amp Standard Voltage.
Standard Voltage is 1.0V.

2. REG
This is a Gate Drive Voltage Generator and 5VLow Saturation regulator for internal Circuit Power supply.

3. OSC
This is a precise wave Oscillation Circuit with Operation Frequency fixed to 750kHz fixed.

4. Soft Start
A Circuit that does Soft Start to the Output Voltage of DC / DC Comparator, and prevents Rush Current during Start-up. Soft Start Time is set at IC internal, after 4mSecs from starting-up EN Pin, Standard Voltage comes to 1.0V, and Output Voltage becomes set Voltage.

5. ERROR AMP
This is an Error amplifier what detects Output Signal, and outputs PWM Control Signal.
Internal Standard Voltage is set to 1.0V.
Also, C and R are connected between the Output (VC) Pin GND of Error Amp as Phase compensation elements. (See Page11)

6. ICOMP
This is a Voltage-Pulse Width Converter that controls Output Voltage in response to Input Voltage.
This compares the Voltage added to the internal SLOPE waveform in response to the FET WS Current with Error amplifier Output Voltage, controls the width of Output Pulse and outputs to Driver.

7. Nch FET SW
This is an internal commutation SW that converts Coil Current of DC/DC Comparator.
It contains 15V"withstand pressure" 100mΩSW.
Because the Current Rating of this FET is 3.0A, including Ripple Current of DC Current+Coil, please use at within 3.0A

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、And when VCC Voltage becomes 4.4V and below, it turns OFF all Output FET and turns OFF DC / DC Comparator Output, and Soft Start Circuit resets.
Now this Threshold has Hysteresis of 200mV.

9. TSD
This is a Heat Protect (Temperature Protect) Circuit.
When it detects an abnormal temperature exceeding Maximum Junction Temperature (Tj=150℃), it turns OFF all Output FET, and turns OFF DC/DC Comparator Output. When Temperature falls, it has/with Hysteresis and automatically returns.

10. EN
With the Voltage applied to EN Pin(5pin), IC ON / OFF can be controlled.
When a Voltage of 2.0V or more is applied, it turns ON, at Open or 0V application, it turns OFF.
About 400kΩ Pull-down Resistance is contained within the Pin.

●Reference Data

(Unless otherwise specified, Ta=25℃ , VCC=12V, Vo=5V,EN=3V)

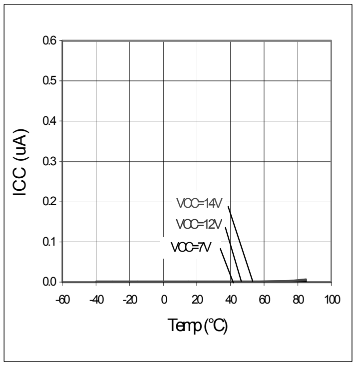


Fig.3. Standby Current Temperature Characteristics

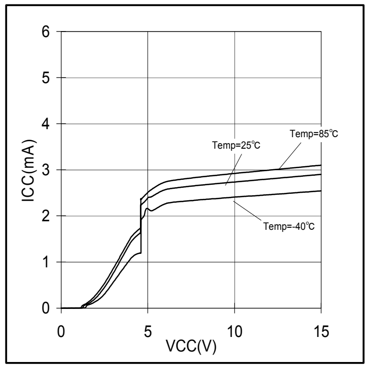


Fig.4. Circuit Current Power supply Voltage Characteristics

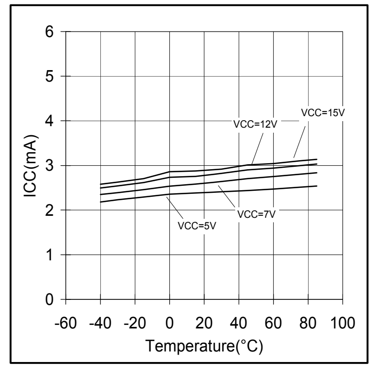


Fig.5. Circuit Current Temperature Characteristics

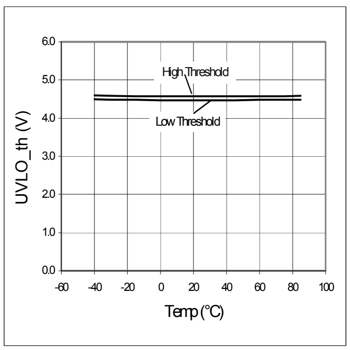


Fig.6. UVLO Threshold Temperature Characteristics

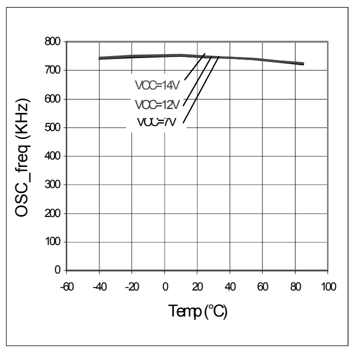


Fig.7. Oscillation Frequency Temperature Characteristics

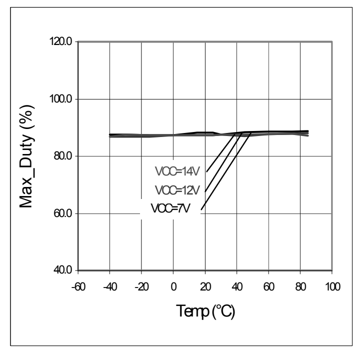


Fig.8. Max Duty Temperature Characteristics

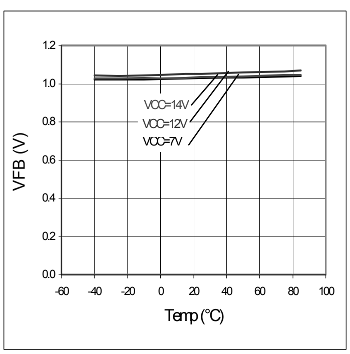


Fig.9. FB Threshold Voltage Temperature Characteristics

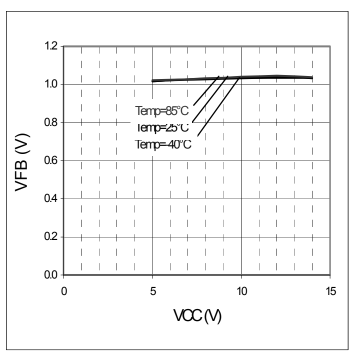


Fig.10. FB Threshold Power supply Characteristics

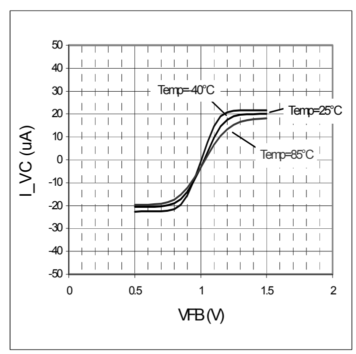


Fig.11. FB Voltage - IVC Current Characteristics

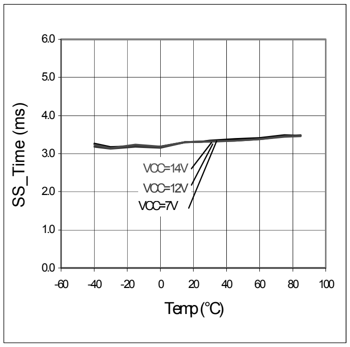


Fig.12. Soft Start Time Temperature Characteristics

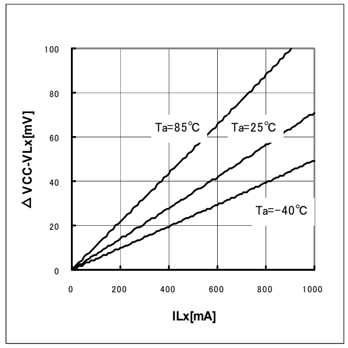


Fig.13. Nch FET ON Resistance Temperature Characteristics

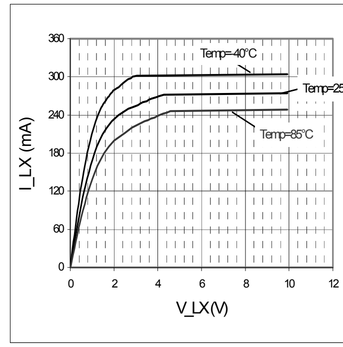


Fig.14. Pre-charge FET ON Resistance Temperature Characteristics

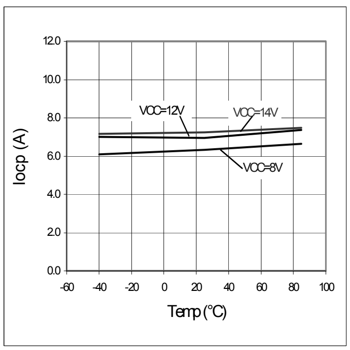


Fig.15 OCP Detect Current Temperature Characteristics

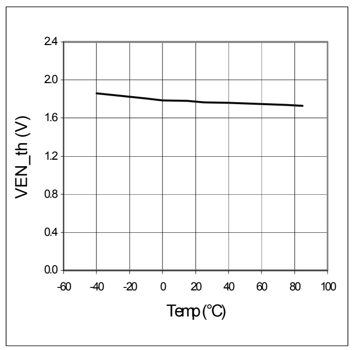


Fig.16. EN Threshold Temperature Characteristics

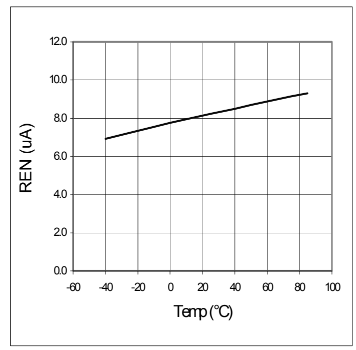
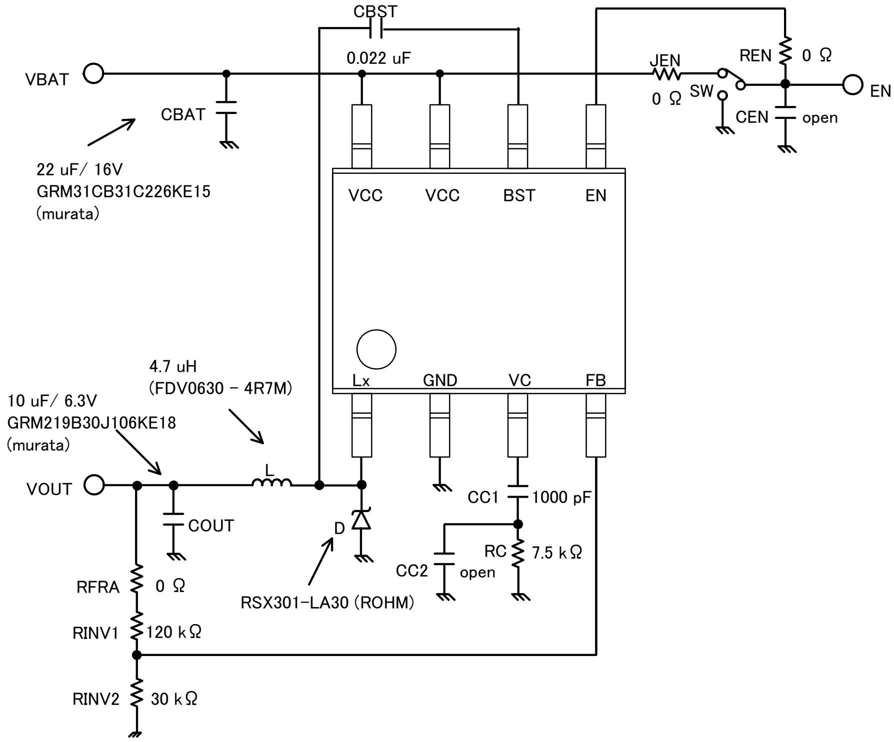


Fig.17. EN Pin Influx Current

●Example of Reference Application Circuit (Input 12V, Output 5.0V/ 2.5A)



●Reference Application Data (Example of Reference Application Circuit)

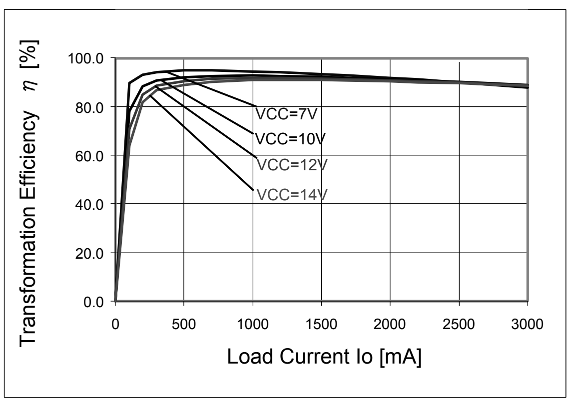


Fig.19 Electric Power Conversion

●Reference Application Data (Example of Reference Application Circuit)

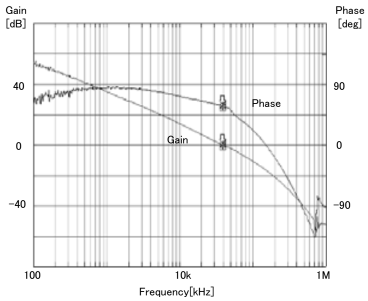


Fig.20 Frequency Response Characteristics（Io=1.5A）

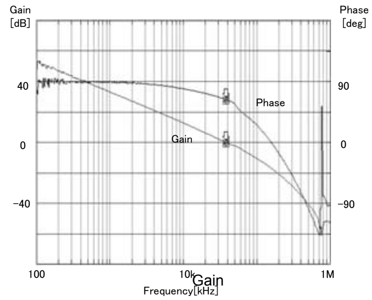


Fig.21 Frequency Response Characteristics （Io=3.0A）

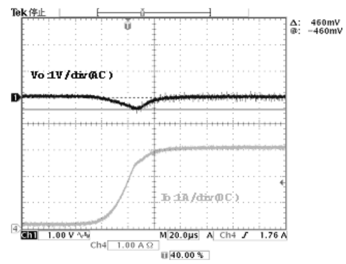


Fig.22 Load Response Characteristics（Io=0A→3A）

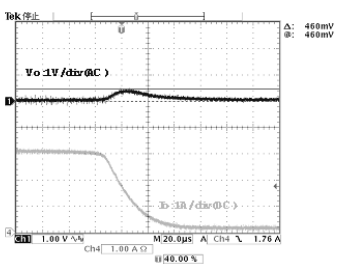


Fig.23 Load Response Characteristics（Io=3A→0A）

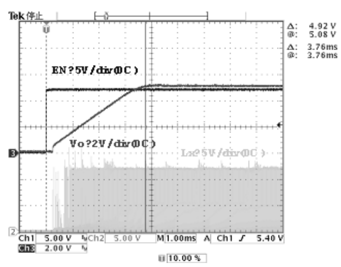


Fig.24 Operation Waveform

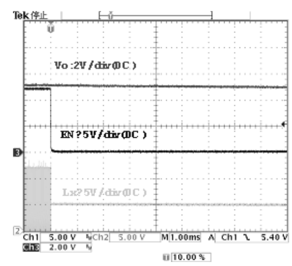


Fig.25 Stop Waveform

●Evaluation Board Pattern (Reference)

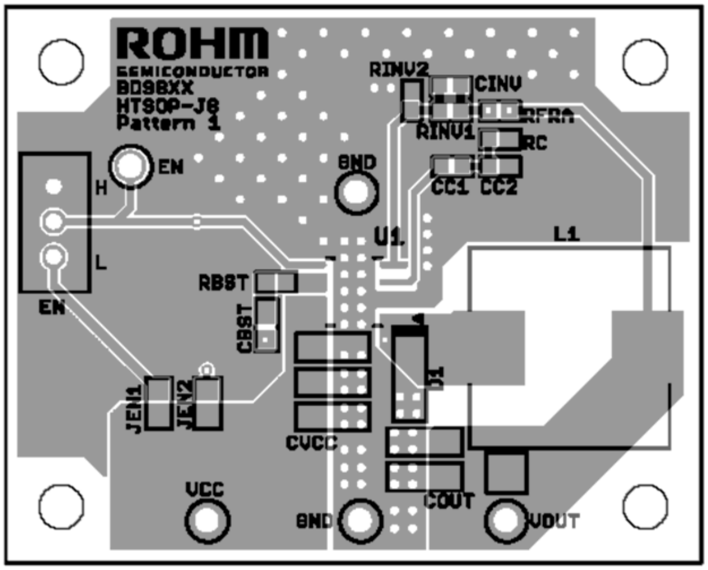


Fig.26 Evaluation Board Pattern

- Please make the Heat radiation plate of the Bottom layer to a plane of Low Impedance.
- Because large currents low into the lines of VCC, Lx, PGND, please make the patterns as thick as much as possible.

●Application Components Selection Method

(1)Inductor

Something of the shield Type that Fulfills the Current Rating (Current value Ipecac below), with low DCR (Direct Current Resistance element) is recommended.

Value of Inductor 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.

$$I_{peak} = I_{out} + \Delta I_L/2 \text{ [A]} \quad (1)$$

$$\Delta I_L = \frac{V_{in}-V_{out}}{L} \times \frac{V_{out}}{V_{in}} \times \frac{1}{f} \text{ [A]} \quad (2)$$

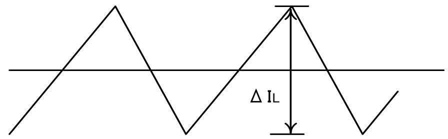


Fig.27 Inductor Current

(η : Efficiency、ΔI_L : Output Ripple Current、f : Switching Frequency)

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

※When current that exceeds Coil rating flows to the coil, the Coil causes a Magnetic Saturation, and there are cases wherein a decline in efficiency, oscillation of output happens. Please have sufficient margin and select so that Peak Current does not exceed Rating Current of Coil.

(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.

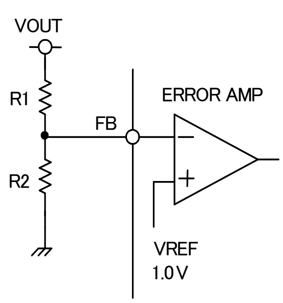
Output Ripple Voltage is looked for using the following formula.

$$V_{pp} = \Delta I_L \times \frac{1}{2\pi \times f \times C_o} + \Delta I_L \times R_{ESR} \text{ [V]} \quad \cdots (3)$$

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

(3)Output Voltage Setting

ERROR AMP internal Standard Voltage is 1.0V.Output Voltage is determined as seen in (4) formula.



$$V_o = \frac{(R1+R2)}{R2} \times 1.0 \text{ [V]} \quad \cdots (4)$$

Fig.28 Voltage Return Resistance Setting Method

(4)Boost Capacitor

Please connect CBST=0.022uF(Laminate Ceramic Capacitor) between BST Pin - Lx Pins as Output capacitors of Gate Drive Voltage Generator REG(5V).

(5)About Adjustment of DC/DC Comparator Frequency Characteristics
Role of Phase compensation element CC1、CC2,RC (See P.7Example of Reference Application Circuit)

Stability and Responsiveness of Loop are controlled through VC Pin which is the output of Error Amp.
The combination of zero and ball 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.

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

Here, VFB is Feedback Voltage(1.0V).A_{EA} is Voltage Gain of Error amplifier(typ : 60dB),
Gcs is the Trans-conductance of Current Detect(typ : 6A/V), and Rl is the Output Load Resistance value.

There are 2 important balls in the Control Loop of this DC/DC.
The first occurs with/ through the output resistance of Phase compensation Capacitor (CC1) and Error amplifier.
The other one occurs with/through the Output Capacitor and Load Resistor.
These balls appear in the frequency written below.

$$fp1 = \frac{G_{EA}}{2\pi \times CC1 \times A_{EA}}$$

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

Here、G_{EA} is the trans-conductance of Error amplifier(typ : 140uA/V).

Here、in this Control Loop, one zero becomes important.
With the zero which occurs because of Phase compensation Capacitor CC1 and Phase compensation Resistor RC, the Frequency below appears.

$$fz1 = \frac{1}{2\pi \times CC1 \times RC}$$

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.

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

In this case, the 3rd ball determined with the 2nd Phase compensation Capacitor (CC2) and Phase Correction Resistor (RC) is used in order to correct the ESR zero results in Loop Gain.
This ball exists in the frequency shown below.

$$fp3 = \frac{1}{2\pi \times CC2 \times RC}$$ (Ball 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.

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

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

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

2. Phase compensation Capacitor (CC1) is selected in order to achieve the desired phase margin.
   In an application that has a representative Inductance value (about several uH ~ 20uH), by matching zero of compensation to 1/4 and below of the Cross-over Frequency, sufficient Phase margin can be acquired.CC1 can be calculated using the following formula.

$$CC1 > \frac{4}{2\pi \times RC \times fc}$$

RC is Phase compensation Resistor.

3. Examination whether the second Phase compensation Capacitor CC2 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.

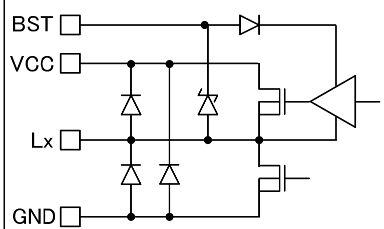
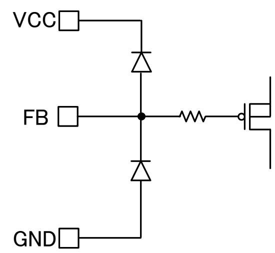
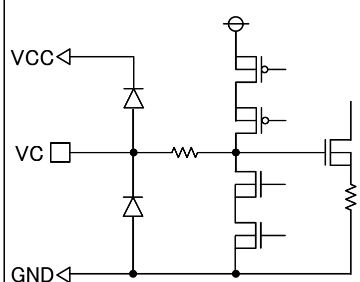
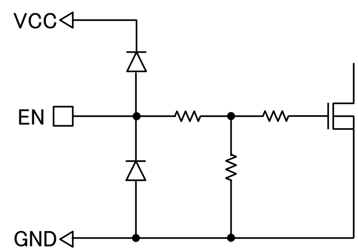
$$\frac{1}{2\pi \times COUT \times RESR} < \frac{fs}{2}$$

In this case, add the second Phase compensation Capacitor CC2, and match the frequency of the third ball to the Frequency fp3 of ESR zero.

CC2 is looked for using the following formula.

$$CC2 = \frac{COUT \times RESR}{RC}$$

● I/O Equivalent Schematic

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

●Cautions for Use

(1)About Absolute Maximum Rating

When the absolute maximum ratings of application voltage, operating temperature range, etc. was exceeded, there is possibility of deterioration and destruction. Also, the short Mode or open mode, etc. destruction condition cannot be assumed. When the special mode where absolute maximum rating is exceeded is assumed, please give consideration to the physical safety countermeasure for the fuse, etc.

(2)About GND Electric Potential

In every state, please make the electric potential of GND Pin into the minimum electrical potential. Also, include the actual excessive effect, and please do it such that the pins, excluding the GND Pin does not become the voltage below GND.

(3)About Heat Design

Consider the Power Dissipation (Pd) in actual state of use, and please make Heat Design with sufficient margin.

(4)About short circuit between pins and erroneous mounting

When installing to set board, please be mindful of the direction of the IC, phase difference, etc. If it is not installed correctly, there is a chance that the IC will be destroyed. Also, if a foreign object enters the middle of output, the middle of output and power supply GND, etc., even for the case where it is shorted, there is a change of destruction.

(5)About the operation inside a strong electro-magnetic field

When using inside a strong electro-magnetic field, there is a possibility of error, so please be careful.

(6)Temperature Protect Circuit (TSD Circuit)

Temperature Protect Circuit(TSD Circuit) is built-in in this IC. As for the Temperature Protect Circuit (TSD Circuit), because it a circuit that aims to block the IC from insistent careless runs, it is not aimed for protection and guarantee of IC. Therefore, please do not assume the continuing use after operation of this circuit and the Temperature Protect Circuit operation.

(7)About checking with Set boards

When doing examination with the set board, during connection of capacitor to the pin that has low impedance, there is a possibility of stress in the IC, so for every 1 process, please make sure to do electric discharge. As a countermeasure for static electricity, in the process of assembly, do grounding, and when transporting or storing please be careful. Also, when doing connection to the jig in the examination process, please make sure to turn off the power supply, then connect. After that, turn off the power supply then take it off.

(8)About common impedance

For the power supply and the wire of GND, lower the common impedance, then, as much as possible, make the ripple smaller (as much as possible make the wire thick and short、and lower the ripple from L・C), etc., then and please consider it sufficiently.

(9)In the application, when the mode where the VCC and each pin electrical potential becomes reversed exists, there is a possibility that the internal circuit will become damaged. For example、during cases wherein the condition when charge was given in the external capacitor、 and the VCC was shorted to GND, it is recommended to insert the bypass diode to the diode of the back current prevention in the VCC series or the middle of each Pin-VCC.

(10)About High-side NchFET

Please use within 3A containing ripple current, because the absolute maximum rating of high-side NchFET is 3A.

(11)About over current detection

The detecting current is the current flowing through high-side NchFET. Output current containing ripple current, therefore the detecting current is the current of the output current containing ripple current.

(12)About IC Pin Input

This IC is a Monolithic IC、and between each element, it has P^+ isolation for element separation and P board. With the N layer of each element and this , the P - N junction is formed、and the parasitic element of each type is composed.

For example、like the diagram below、when resistor and transistor is connected to Pin,

○When GND > (Pin A) in Resistor、 when GND > (Pin A)、when GND > (Pin B) in Transistor (NPN), the P - N junction will operate as a parasitic diode.

○Also, during GND > (Pin B) in the Transistor (NPN), through the N layer of the other elements connected to the above-mentioned parasitic diode , the parasitic NPN Transistor will operation.

On the composition of IC, depending on the electrical potential, the parasitic element will become necessary. Through the operation of the parasitic element interference of circuit operation will arouse, and error, therefore destruction can be caused. Therefore please be careful about the applying of voltage lower than the GND (P board) in I/O Pin, and the way of using when parasitic element operating.

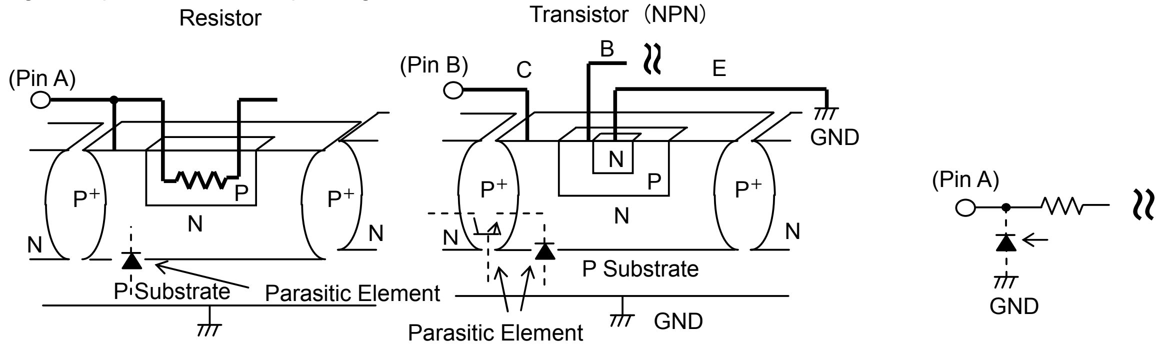


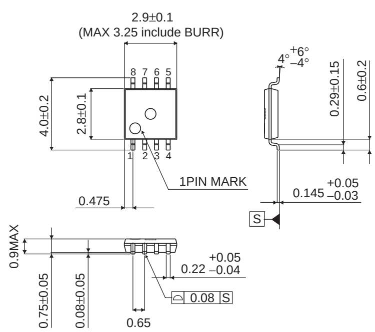
Fig.29 Example of simple structure of Bipolar IC

●ORDER MODEL NAME

B	D		9	8	5	9		E	F	J	-	E	2

- Device: BD
- Debice Name: 9859
- Package type: EFJ — HFN : HTSOP-J8
- Taping model name: E2 — E2: Reel-shape emboss taping

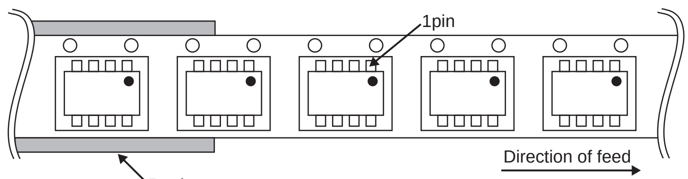
MSOP8



(Unit : mm)

<Tape and Reel information>

Tape	Embossed carrier tape
Quantity	3000pcs
Direction of feed	TR (The direction is the 1pin of product is at the upper right when you hold reel on the left hand and you pull out the tape on the right hand)



∗Order quantity needs to be multiple of the minimum quantity.

Notes

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