Single-chip built-in FET type Switching Regulator Series

Simple Step-down Switching Regulator with Integrated Compensation

BD9701FP/CP-V5/T/T-V5, BD9703FP/CP-V5/T/T-V5, BD9702CP-V5/T/T-V5

● Description

The BD9701/BD9703/BD9702 are single-channel step-down switching regulator capable of PWM operation.
The Pch MOS FET is built in for high efficiency in small load area.
Lower electricity consumption of operating current 4mA (Typ) and stand-by current 0uA(Typ) is realized by adopting Bi-CMOS process.

●Features

1. Maximum switching current: 1.5A(BD9701/BD9703),　3A(BD9702)
2. Built-in Pch FET ensures high efficiency
3. Output voltage adjustable via external resistors
4. High switching frequency: 100kHz (BD9701), 300kHz(BD9703), 110kHz(BD9702)
5. Overcurrent and thermal shutdown protection circuits built in
6. ON/OFF control via STBY pin
7. Small surface mount TO252-5 package (only BD9701FP, BD9703FP)

●Applications

TVs, printers, DVD players, projectors, gaming devices, PCs, car audio/navigation systems, ETCs, communication equipment, AV products, office equipment, industrial devices, and more.

●Line Up

	BD9701FP/CP-V5/T/T-V5	BD9703FP/CP-V5/T/T-V5	BD9702CP-V5/T/T-V5
Output Current	1.5A		3.0A
Input Voltage	8 or Vo+3 ～ 36V		
Switching Frequency	100kHz (fixed)	300kHz (fixed)	110kHz (fixed)
External Synchronization	×		
Stand-by Function	○		
Operating Temperature	-40 ～ +85℃		
Package	TO252-5/TO220CP-V5/TO220FP-5/TO220FP-5 (V5)		TO220CP-V5/TO220FP-5/TO220FP-5 (V5)

Apr.2008

●Absolute Maximum Ratings (Ta＝25℃)

Parameter		Symbol	Ratings	Unit
Supply Voltage (VCC−GND)		Vcc	36	V
STBY−GND		V_{STBY}	36	V
OUT−GND		V_O	36	V
INV−GND		V_{INV}	10	V
Maximum Switching Current	BD9701/BD9703	Iout	1.5	A
	BD9702		3	
Power Dissipation	TO252	Pd	0.8 (*1)	W
	TO220		2(*2)	
Operating Temperature		Topr	−40～+85	℃
Storage Temperature		Tstg	−55～+150	℃

※1 Without external heat sink, the power dissipation reduces by 6.4mW/℃ over 25℃.

※2 Without external heat sink, the power dissipation reduces by 16.0mW/℃ over 25℃.
Reduced by 160mW/℃, when mounted on Infinity size heatsink.

●Operating Conditions(Ta=−40～+85℃)

Parameter	Symbol	Limit MIN	Limit TYP	Limit MAX	Unit
Input Voltage	Vcc	8.0 or Vo+3 (*3)	−	35.0	V
Output Voltage	Vo	1.0	−	32	V

※3The minimum value of an input voltage is the higher either 8.0V or Vo+3

●Electrical Characteristics

○BD9701FP/CP−V5/T/T−V5 (Unless otherwise noted, Ta=25℃,Vcc=12V,Vo=5V,STBY=3V)

Parameter		Symbol	Limit MIN	Limit TYP	Limit MAX	Unit	Conditions
Output ON Resistance		Ron	−	1.0	1.5	Ω	design guarantee
Efficiency		η	−	86	−	%	Io＝0.5A design guarantee
Switching Frequency		fosc	80	100	120	kHz	
Load Regulation		ΔVOLOAD	−	10	40	mV	Vcc=20V, Io=0.5～1.5A
Line Regulation		ΔVOLINE	−	40	100	mV	Vcc=10～30V, Io=1.0A
Over Current Protection Limit		Iocp	1.6	−	−	A	
INV Pin Threshold Voltage		VINV	0.98	1.00	1.02	V	
INV Pin Threshold Voltage Thermal Variation		ΔVINV	−	±0.5	−	%	Tj=0～85℃ design guarantee
INV Pin Input Current		IINV	−	1	−	μA	VINV=1.0V
STBY Pin Threshold Voltage	ON	VSTBYON	2.0	−	36	V	
	OFF	VSTBYOFF	−0.3	−	0.3	V	
STBY Pin Input Current		Istby	5	25	50	μA	STBY=3V
Circuit Current		Icc	−	4	12	mA	
Stand-by Current		Ist	−	0	5	μA	STBY＝0V

This product is not designed to be resistant to radiation.

●Electrical Characteristics

○BD9703FP/CP-V5/T/T-V5 (Unless otherwise noted, Ta=25℃,Vcc=12V,Vo=5V,STBY=3V)

Parameter		Symbol	Limit			Unit	Conditions
			MIN	TYP	MAX		
Output ON Resistance		Ron	–	1.0	1.5	Ω	design guarantee
Efficiency		η	–	86	–	%	Io＝0.5A design guarantee
Switching Frequency		fosc	270	300	330	kHz	
Load Regulation		ΔVOLOAD	–	10	40	mV	Vcc=20V, Io=0.5～1.5A
Line Regulation		ΔVOLINE	–	40	100	mV	Vcc=10～30V, Io=1.0A
Over Current Protection Limit		Iocp	1.6	–	–	A	
INV Pin Threshold Voltage		VINV	0.98	1.00	1.02	V	
INV Pin Threshold Voltage Thermal Variation		ΔVINV	–	±0.5	–	%	Tj=0～85℃ design guarantee
INV Pin Input Current		IINV	–	1	–	μA	VINV=1.0V
STBY Pin Threshold Voltage	ON	VSTBYON	2.0	–	36	V	
	OFF	VSTBYOFF	-0.3	–	0.3	V	
STBY Pin Input Current		Istby	5	25	50	μA	STBY=3V
Circuit Current		Icc	–	5	12	mA	
Stand-by Current		Ist	–	0	5	μA	STBY＝0V

●Electrical Characteristics

○BD9702FP/CP-V5/T/T-V5 (Unless otherwise noted, Ta=25℃,Vcc=12V,Vo=5V,STBY=3V)

Parameter		Symbol	Limit			Unit	Conditions
			MIN	TYP	MAX		
Output ON Resistance		Ron	–	0.5	1.5	Ω	design guarantee
Efficiency		η	–	86	–	%	Io＝1A design guarantee
Switching Frequency		fosc	88	110	132	kHz	
Load Regulation		ΔVOLOAD	–	10	40	mV	Vcc=20V, Io=1～3A
Line Regulation		ΔVOLINE	–	40	100	mV	Vcc=10～30V, Io=1.0A
Over Current Protection Limit		Iocp	3.2	–	–	A	
INV Pin Threshold Voltage		VINV	0.98	1.00	1.02	V	
INV Pin Threshold Voltage Thermal Variation		ΔVINV	–	±0.5	–	%	Tj=0～85℃ design guarantee
INV Pin Input Current		IINV	–	1	–	μA	VINV=1.0V
STBY Pin Threshold Voltage	ON	VSTBYON	2.0	–	36	V	
	OFF	VSTBYOFF	-0.3	–	0.3	V	
STBY Pin Input Current		Istby	5	25	50	μA	STBY=3V
Circuit Current		Icc	–	4	12	mA	
Stand-by Current		Ist	–	0	5	μA	STBY＝0V

●Characteristic Data

○BD9701FP/CP-V5/T/T-V5

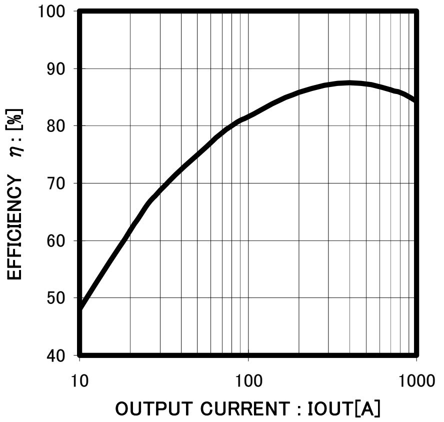


Fig.1

EFFICIENCY－LOAD CURRENT

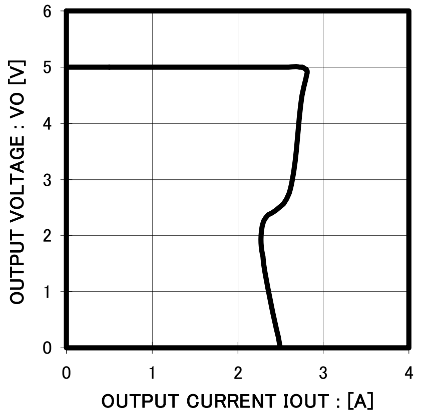


Fig.2

OCP VCC=20V

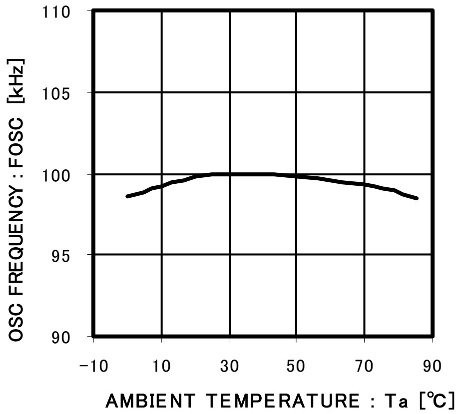


Fig.3

fosc－Ta

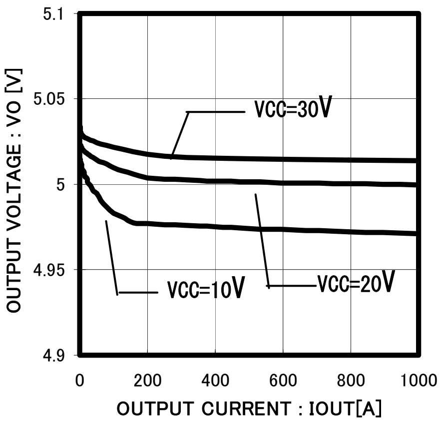


Fig.4

OUTPUT VOLTAGE－LOAD CURRENT

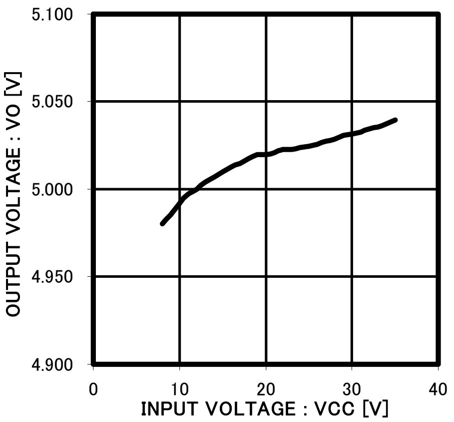


Fig.5

OUTPUT VOLTAGE－INPUT VOLTAGE

(Vo=5V, Ro=5ohm)

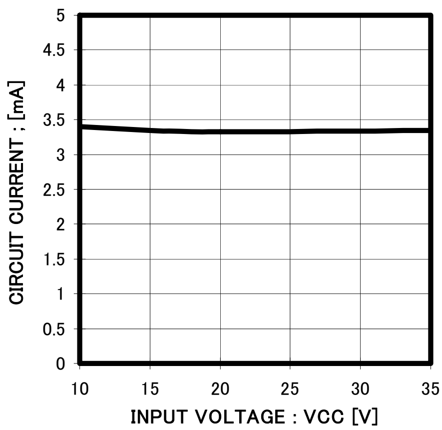


Fig.6

CIRCUIT CURRENT－INPUT VOLTAGE

NO LOAD

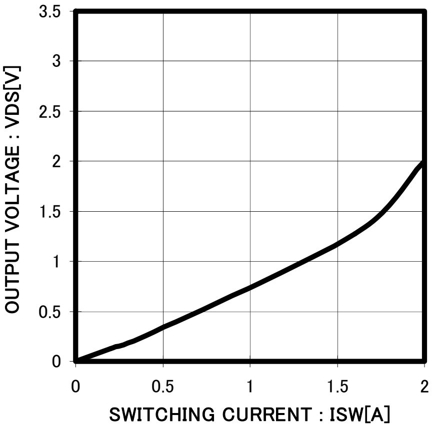


Fig.7

VOUT～OUT VOLTAGE－DRAIN CURRENT

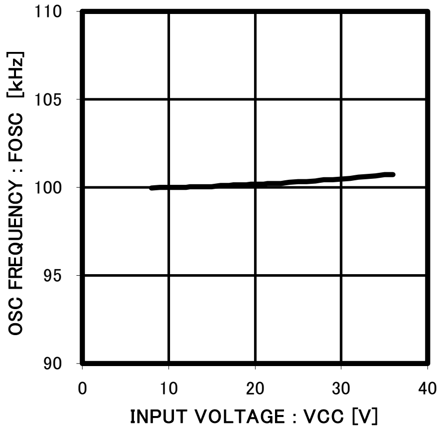


Fig.8

fosc－INPUT VOLTAGE

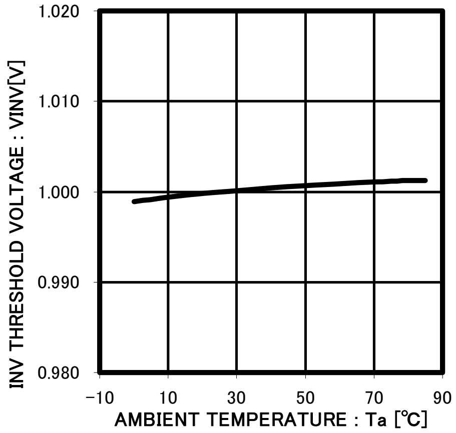


Fig.9

INV THRESHOLD VOLTAGE－Ta

●Characteristic Data

○BD9702FP/CP-V5/T/T-V5

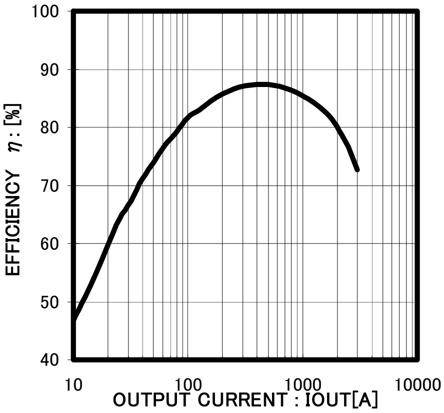


Fig. 10

EFFICIENCY—LOAD CURRENT

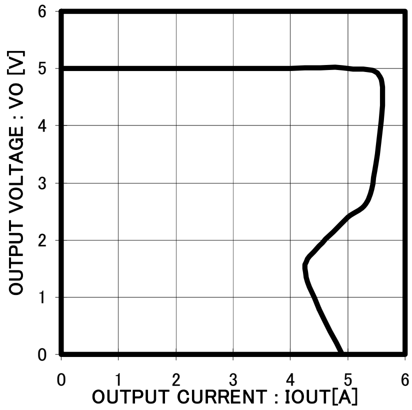


Fig. 11

OCP VCC=20V

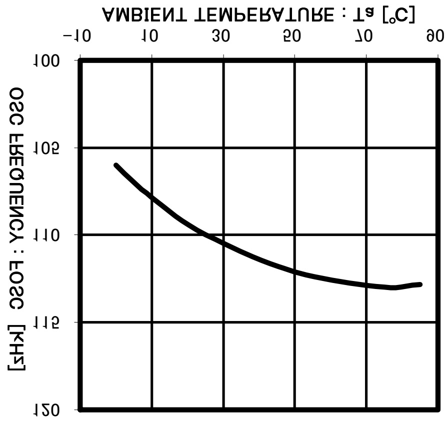


Fig. 12

fosc—Ta

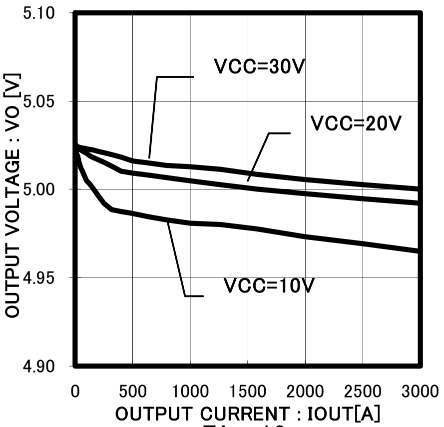


Fig. 13

OUTPUT VOLTAGE—LOAD CURRENT

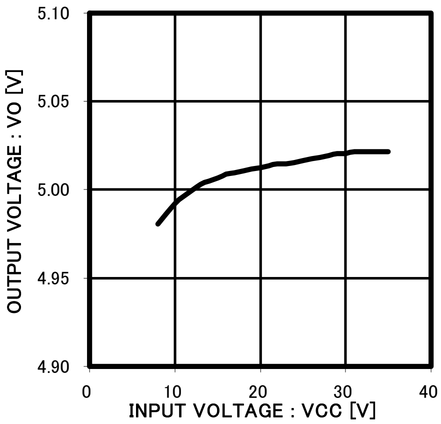


Fig. 14

OUTPUT VOLTAGE—INPUT VOLTAGE

(Vo=5V, Ro=5ohm)

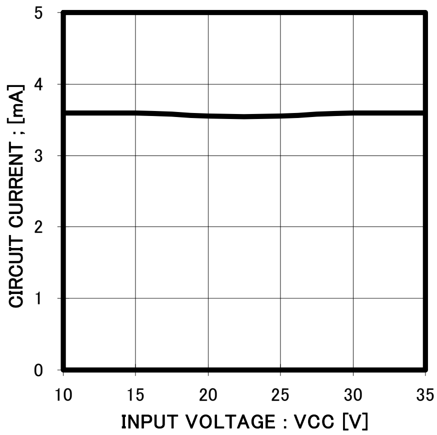


Fig. 15

CIRCUIT CURRENT—INPUT VOLTAGE

NO LOAD

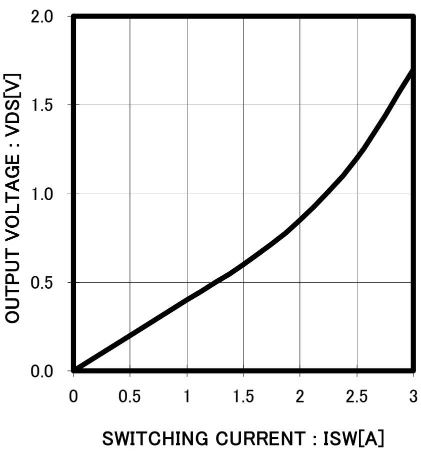


Fig. 16

VOUT～OUT VOLTAGE—DRAIN CURRENT

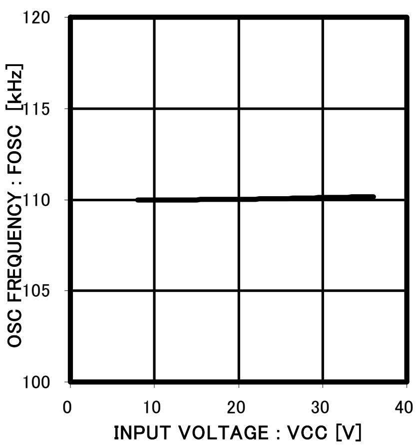


Fig. 17

fosc—INPUT VOLTAGE

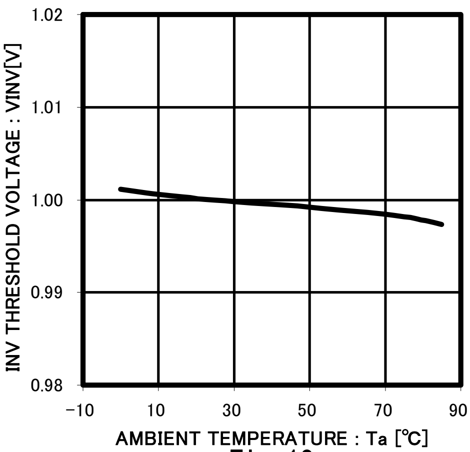


Fig. 18

INV THRESHOLD VOLTAGE—Ta

●Characteristic Data

○BD9703FP/CP-V5/T/T-V5

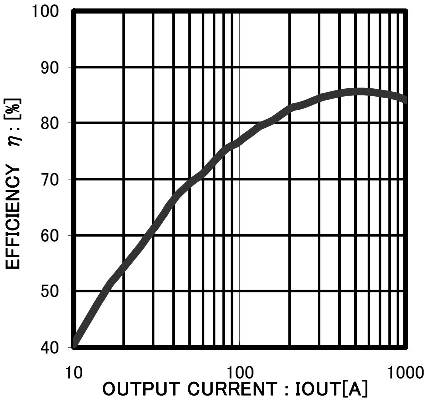


Fig. 19

EFFICIENCY－LOAD CURRENT

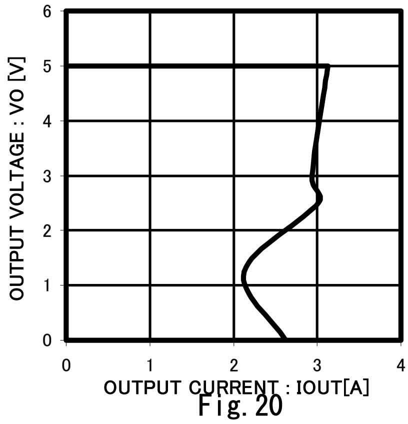


Fig. 20

OCP VCC=20V

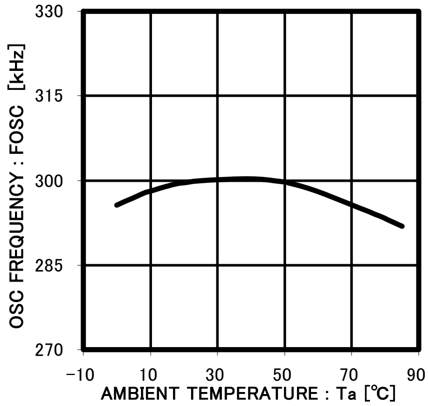


Fig. 21

fosc－Ta

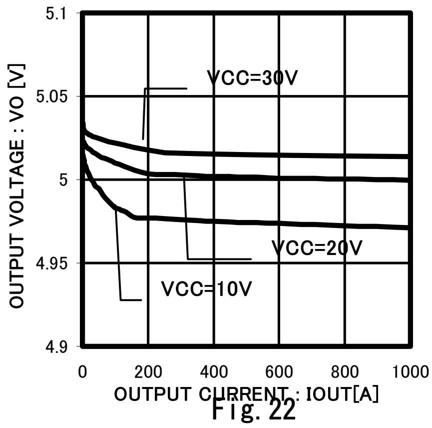


Fig. 22

OUTPUT VOLTAGE－LOAD CURRENT

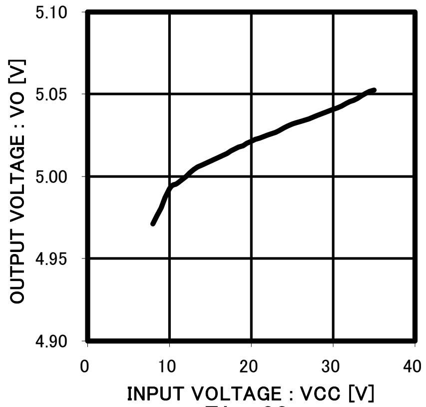


Fig. 23

OUTPUT VOLTAGE－INPUT VOLTAGE

(Vo=5V, Ro=5ohm)

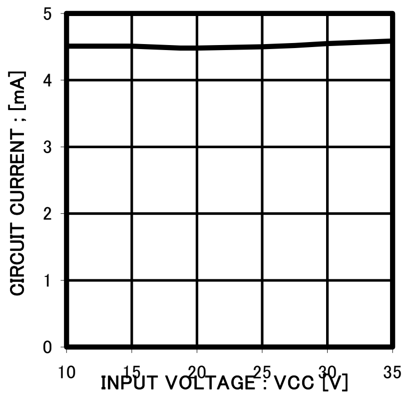


Fig. 24

CIRCUIT CURRENT－INPUT VOLTAGE

NO LOAD

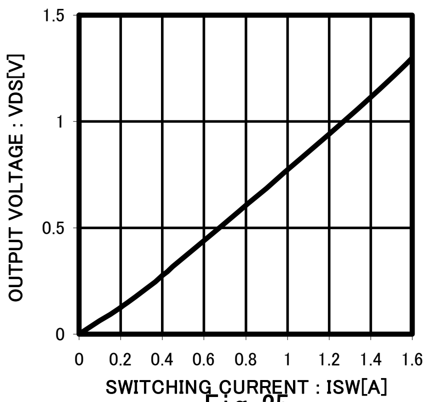


Fig. 25

VOUT～OUT VOLTAGE－DRAIN CURRENT

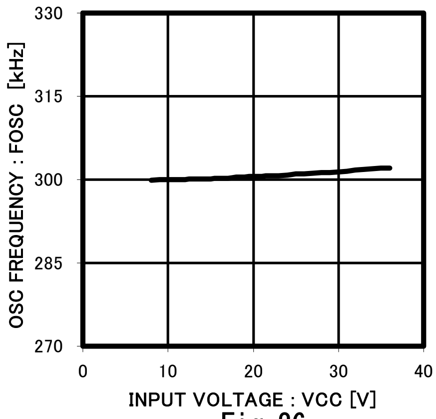


Fig. 26

fosc－INPUT VOLTAGE

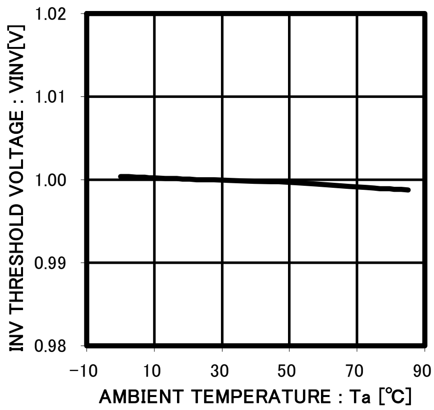


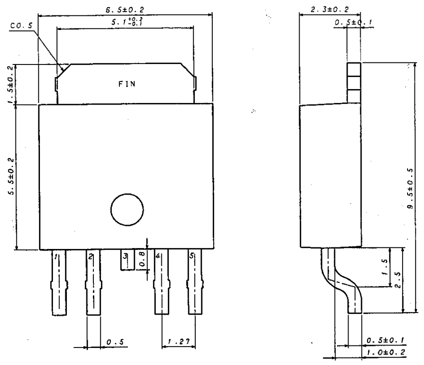
Fig. 27

INV THRESHOLD VOLTAGE－Ta

●Block Diagram

BD9701FP/CP-V5/T/T-V5, BD9703FP/CP-V5/T-V5, BD9702CP-V5/T/T-V5

TO252-5 Package Dimensions (mm)



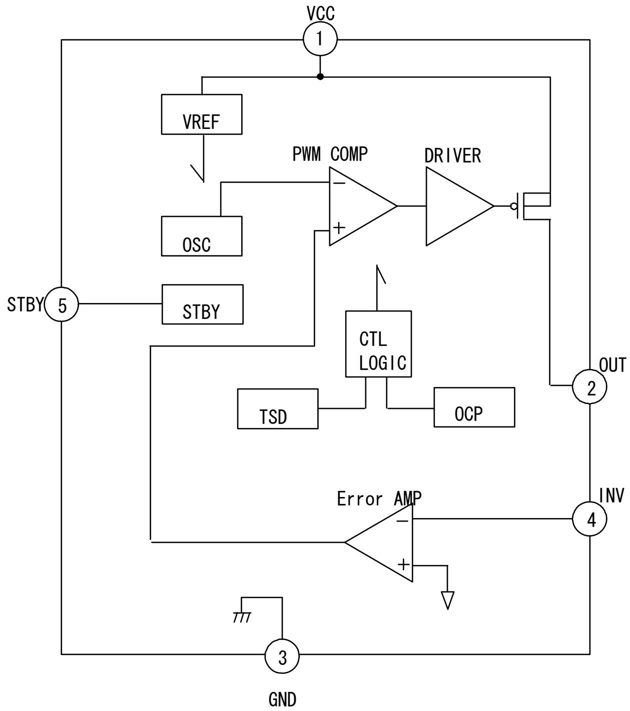
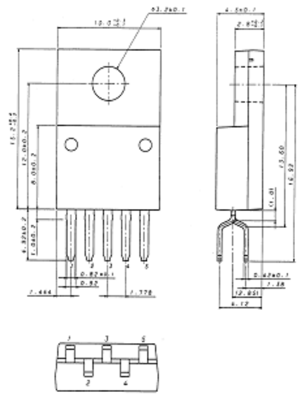


Fig.28
Block Diagram

TO220CP-V5 Package Dimensions (mm)

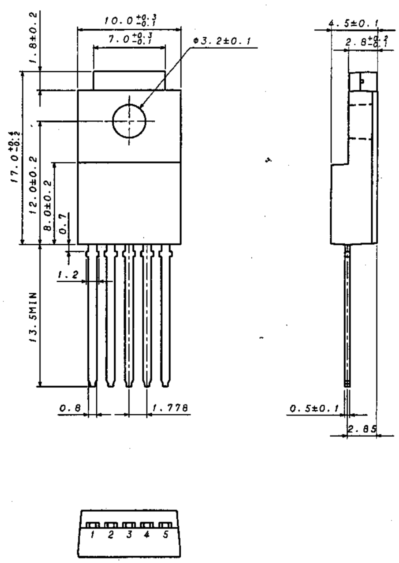


●Pin Description

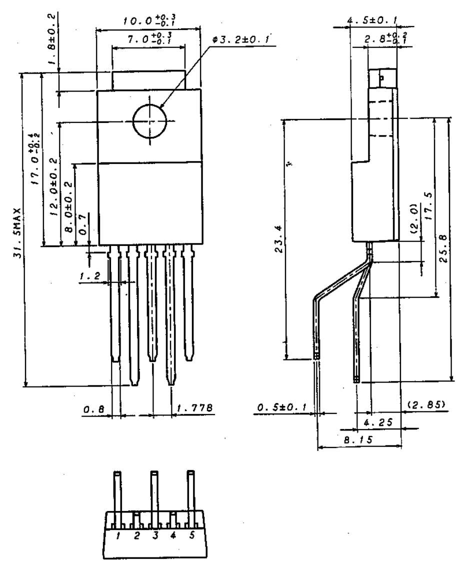
Pin No.	Pin Name	Function
1	VCC	Input Power Supply Pin
2	OUT	Internal Pch FET Drain Pin
3,FIN(*2)	GND	Ground
4	INV	Output Voltage Feedback Pin
5	STBY	ON/OFF Control Pin

(*2)FIN is assigned in the case of TO252-5.

TO220FP-5 Package Dimensions (mm)



TO220FP-5(V5) Package Dimensions (mm)



●Block Function Explanations

- VREF
  Generates the regulated voltage from Vcc input, compensated for temperature.

- OSC
  Generates the triangular wave oscillation frequency using an internal resistors and capacitor. Used for PWM comparator input.

- Error AMP
  This block, via the INV pin, detects the resistor-divided output voltage, compares this with the reference voltage, then amplifies and outputs the difference.

- PWM COMP
  Outputs PWM signals to the Driver block, which converts the error amp output voltage to PWM form.

- DRIVER
  This push-pull FET driver powers the internal Pch MOSFET, which accepts direct PWM input.

- STBY
  Controls ON/OFF operation via the STBY pin. The output is ON when STBY is High.

- Thermal Shutdown (TSD)
  This circuit protects the IC against thermal runaway and damage due to excessive heat. A thermal sensor detects the junction temperature and switches the output OFF once the temperature exceeds a threshold value (175deg). Hysteresis is built in (15deg) in order to prevent malfunctions due to temperature fluctuations.

- Over Current Protection (OCP)
  The OCP circuit detects the voltage difference between Vcc and OUT by measuring the current through the internal Pch MOSFET and switches the output OFF once the voltage reaches the threshold value. The OCP block is a self-recovery type (not latch).

●Timing Chart

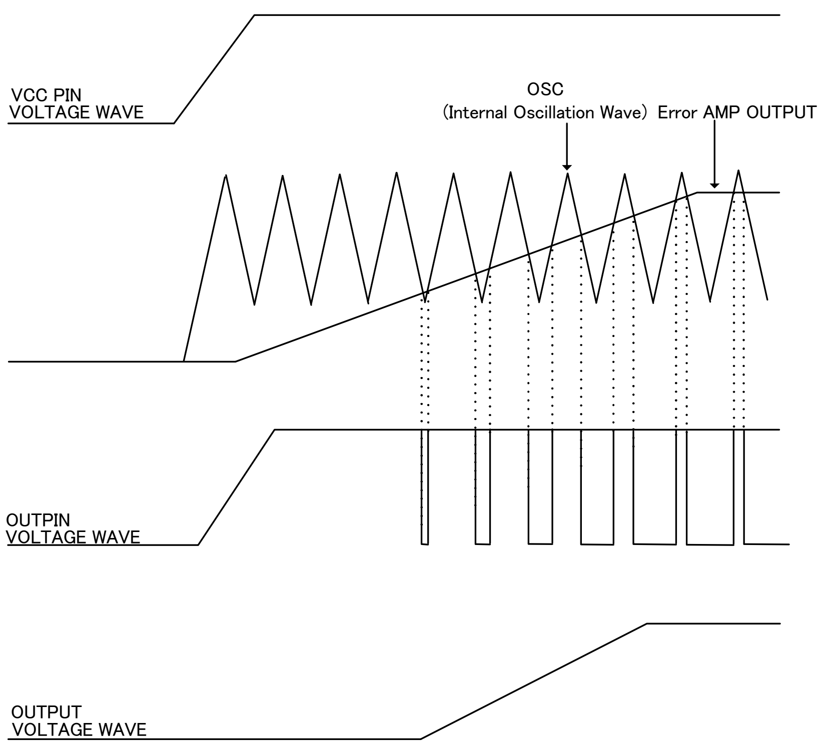


Fig.29
Timing Chart

●Notes for PCB layout

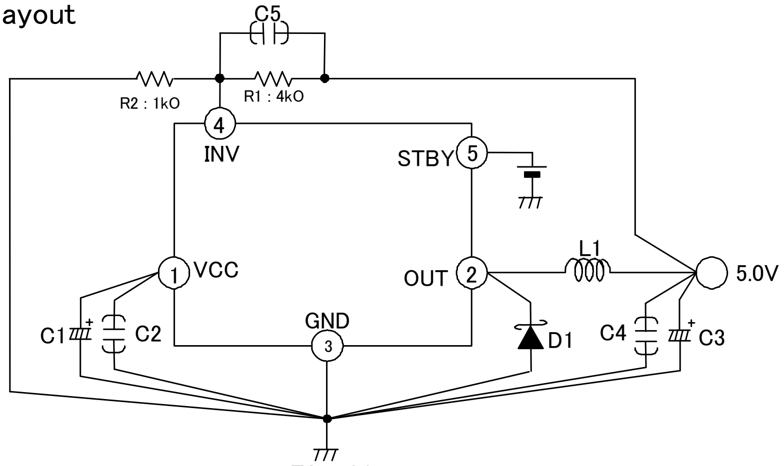


Fig.30

Layout

・Place capacitors between Vcc and Ground, and the Schottky diode as close as possible to the IC to reduce noise and maximize efficiency.

・Connect resistors between INV and Ground, and the output capacitor filter at the same Ground potential in order to stabilize the output voltage.

●Application component selection and settings

Inductor L1

If the winding resistance of the choke coil is too high, the efficiency may deteriorate.
As the overcurrent protection operates over minimum 1.6A (BD9701FP/CP-V5/T/T-V5, BD9703FP/CP-V5/T-V5) or 3.2A minimum (BD9701CP-V5/T/T-V5), attention must be paid to the heating of the inductor due to overload of short-circulated load.

Note that the current rating for the coil should be higher than $I_{OUT}(MAX)+\Delta IL$. Iout (MAX): maximum load current

If you flow more than maximum current rating, coil will become overload, and cause magnetic saturation, and those account for efficiency deterioration. Select from enough current rating of coil which doesn't over peak current.

$$\Delta IL = \frac{(VCC-VOUT)}{L1} \times \frac{VOUT}{VCC} \times \frac{1}{fosc}$$

L1:inductor value, VCC:maximum input voltage, VOUT:output voltage, ⊿IL:coil ripple current value, fosc:oscillation frequency

Shottky Barrier Diodes D1

A Schottky diode with extremely low forward voltage should be used. Selection should be based on the following guidelines regarding maximum forward current, reverse voltage, and power dissipation:

・The maximum current rating is higher than the combined maximum load current and coil ripple current (ΔI_L).

・The reverse voltage rating is higher than the VIN value.

・Power dissipation for the selected diode must be within the rated level.

The power dissipation of the diode is expressed by the following formula:

Pdi=Iout(MAX)×Vf×(1-VOUT/VCC)

Iout (MAX): maximum load current, Vf: forward voltage, VOUT: output voltage, VCC: input voltage

Capacitor C1,C2,C3,C4,C5

As large ripple currents flow across C1 and C3 capacitors, high frequency and low impedance capacitor for a switching regulator must be used. The ceramic capacitor C2 must be connected. If not, noise may cause an abnormal operation. If the ripple voltage of input and output is large, C4 selected among ceramic , tantalum and OS capacitor with low ESR may decrease the ripple, however if the only low ESR capacitor is used, an oscillation or unstable operation may be caused.
C5 is the capacitor for phase compensation and normally not used. If you need to improve the stability of feedback network, connect C5 between INV and OUTPUT.

Feed back resistance R1,R2

The offset of output voltage is determined by both Feed back resistance and INV pin input current.
VOUT=(R1+R2) VINV/R2 (VINV pin Threshold Votage)
If Feed back resistance is high, the setting of output voltage will be move.
Recommended : Resistance between INV pin and GND = less than 10kΩ.

●Recommended Circuit

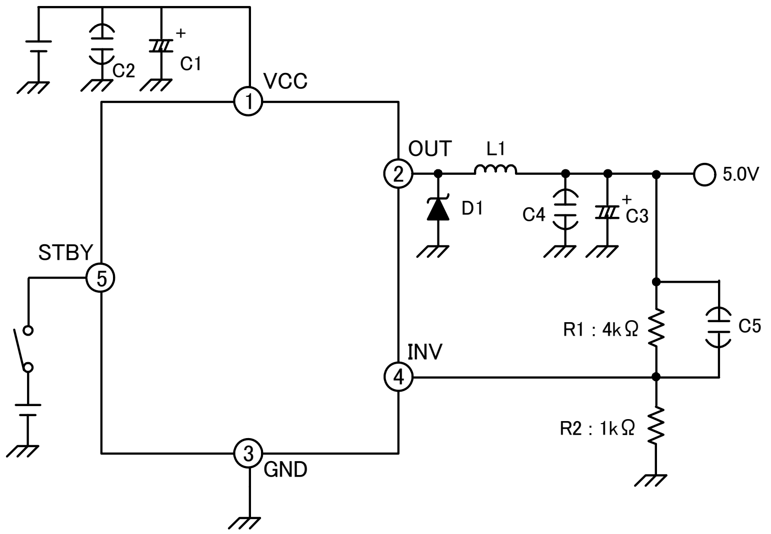


Fig. 31

Recommended Circuit

Output Voltage 5V : Application cicuit example

(BD9701FP/CP-V5/T/T-V5)

＜Recommended Components (Example)＞

Inductor	L1＝10μH	:CDRH127/LD (sumida)
Schottky Diode	D1	:RB050LA-40 (ROHM)
Capacitor	C1＝100μF(50V)	:Al electric capacitor UHD1H101MPT (nichicon)
	C2＝OPEN	
	C3＝220μF(25V)	:Al electric capacitor UHD1E221MPT (nichicon)
	C4＝OPEN	
	C5＝OPEN	

＜Recommended Components example 2＞

Inductor	L1＝100μH	:CDRH127/LD (sumida)
Schotky Diode	D1	:RB050LA-40 (ROHM)
Capacitor	C1＝220μF(25V)	:Al electric capacitor UVR1H221MPA (nichicon)
	C2＝1.0μF(50V)	:ceramic cap UMK212F105ZG (TAIYO YUDEN)
	C3＝470μF(16V)	:Al electric capacitor UVR1E471MPA (nichicon)
	C4＝150μF(20V)	:OS capacitor 20SVP150M (SANYO)
	C3＝OPEN	

＜Recommended Components＞

Inductor	L1＝47μH	:CDRH127/LD (sumida)
Schotky Diode	D1	:RB050LA-40 (ROHM)
Capacitor	C1＝100μF(50V)	:Al electric capacitor UHD1H101MPT (nichicon)
	C2＝2.2μF(50V)	:ceramic cap CM43X7R225K50A (KYOCERA)
	C3＝470μF(25V)	:Al electric capacitor UHD1E471MPT (nichicon)
	C4＝OPEN	
	C3＝OPEN	

(BD9702CP-V5/T/T-V5)

＜Recommended Components＞

Inductor	L1＝47μH	:CDRH127/LD (sumida)
Schotky Diode	D1	:RB050LA-40 (ROHM)
Capacitor	C1＝1000μF(50V)	:Al electric capacitor UHD1H102MPT (nichicon)
	C2＝OPEN	
	C3＝1000μF(25V)	:Al electric capacitor UHD1E102MPT (nichicon)
	C4＝OPEN	
	C3＝OPEN	

●Test Circuit

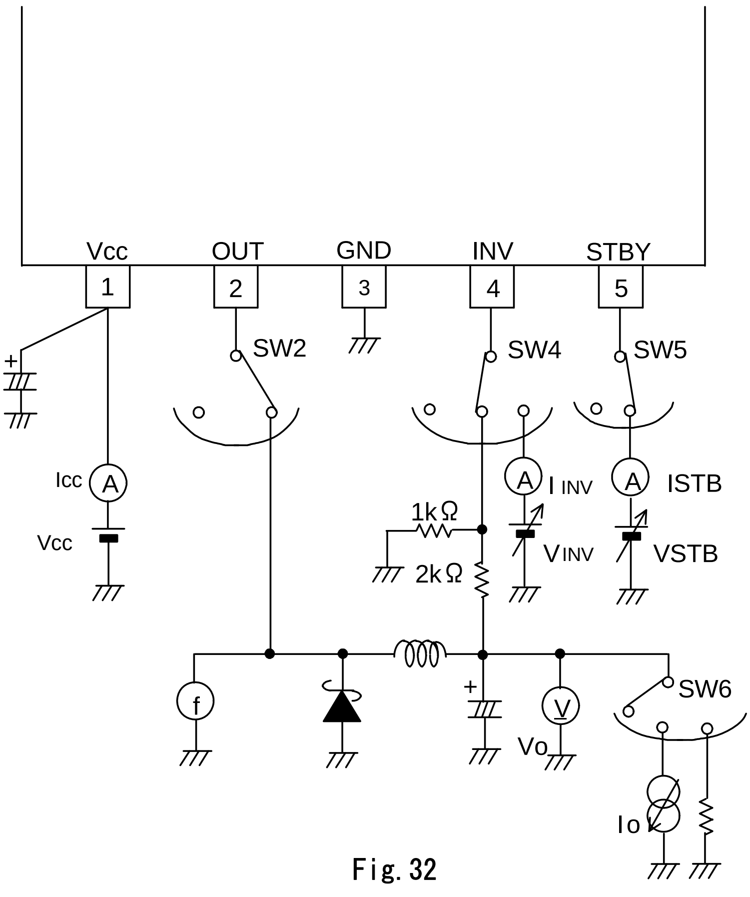


Fig. 32

Input Output Measurement Circuit

●I/O Equivalent Circuit

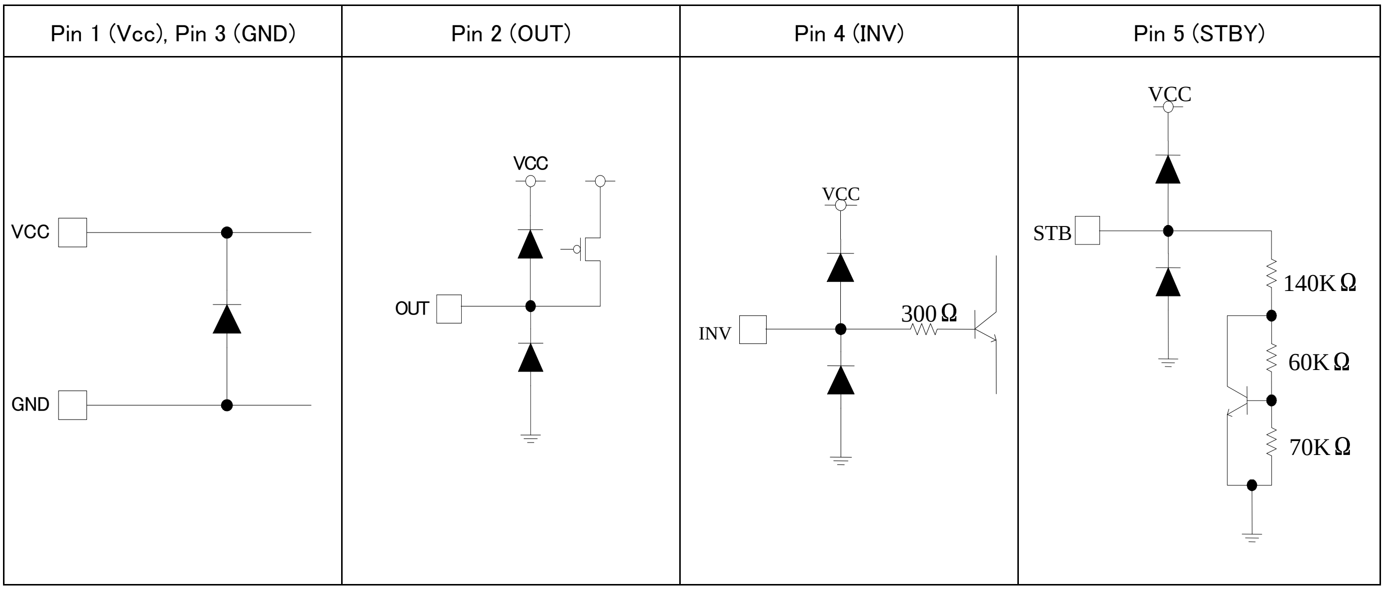


Fig. 33

Input Output Equivalent Circuit

●Operation Notes

1. Absolute Maximum Ratings

Use of the IC in excess of absolute maximum ratings such as the applied voltage or operating temperature range may result in IC deterioration or damage. Assumptions should not be made regarding the state of the IC (short mode or open mode) when such damage is suffered. A physical safety measure such as a fuse should be implemented when use of the IC in a special mode where the absolute maximum ratings may be exceeded is anticipated.

2. GND voltage

Ensure a minimum GND pin potential in all operating conditions. In addition, ensure that no pins other than the GND pin carry a voltage lower than or equal to the GND pin, including during actual transient phenomena.

3. Thermal design

Use a thermal design that allows for a sufficient margin in light of the power dissipation (Pd) in actual operating conditions.

4. Inter-pin shorts and mounting errors

Use caution when orienting and positioning the IC for mounting on printed circuit boards. Improper mounting may result in damage to the IC. Shorts between output pins or between output pins and the power supply and GND pin caused by the presence of a foreign object may result in damage to the IC.

5. Operation in strong electromagnetic field

Operation in a strong electromagnetic field may cause malfunction.

6. Thermal shutdown circuit (TSD circuit)

This IC incorporates a built-in thermal shutdown circuit (TSD circuit). The TSD circuit is designed only to shut the IC off to prevent runaway thermal operation. Do not continue to use the IC after operating this circuit or use the IC in an environment where the operation of the thermal shutdown circuit is assumed.

7. Testing on application boards

When testing the IC on an application board, connecting a capacitor to a pin with low impedance subjects the IC to stress. Always discharge capacitors after each process or step. Ground the IC during assembly steps as an antistatic measure, and use similar caution when transporting or storing the IC. Always turn the IC's power supply off before connecting it to or removing it from a jig or fixture during the inspection process.

8. IC pin input

This IC is a monolithic IC which (as below) has P+ substrate and betweenthe various pin. A P−N junction is formed from this P layer of each pin. For example the relation between each potential is as follows. (When GND > PinB and GND > PinA, the P−N junction operates as a parasitic diode.) Parasitic diodes can occur inevitably in the structure of the IC. The operation of parasitic diodes can result in mutual interference among circuits as well as operation faults and physical damage. Accordingly, you must not use methods by which parasitic diodes operate, such as applying a voltage that is lower than the GND(P substrate)voltage to an input pin.

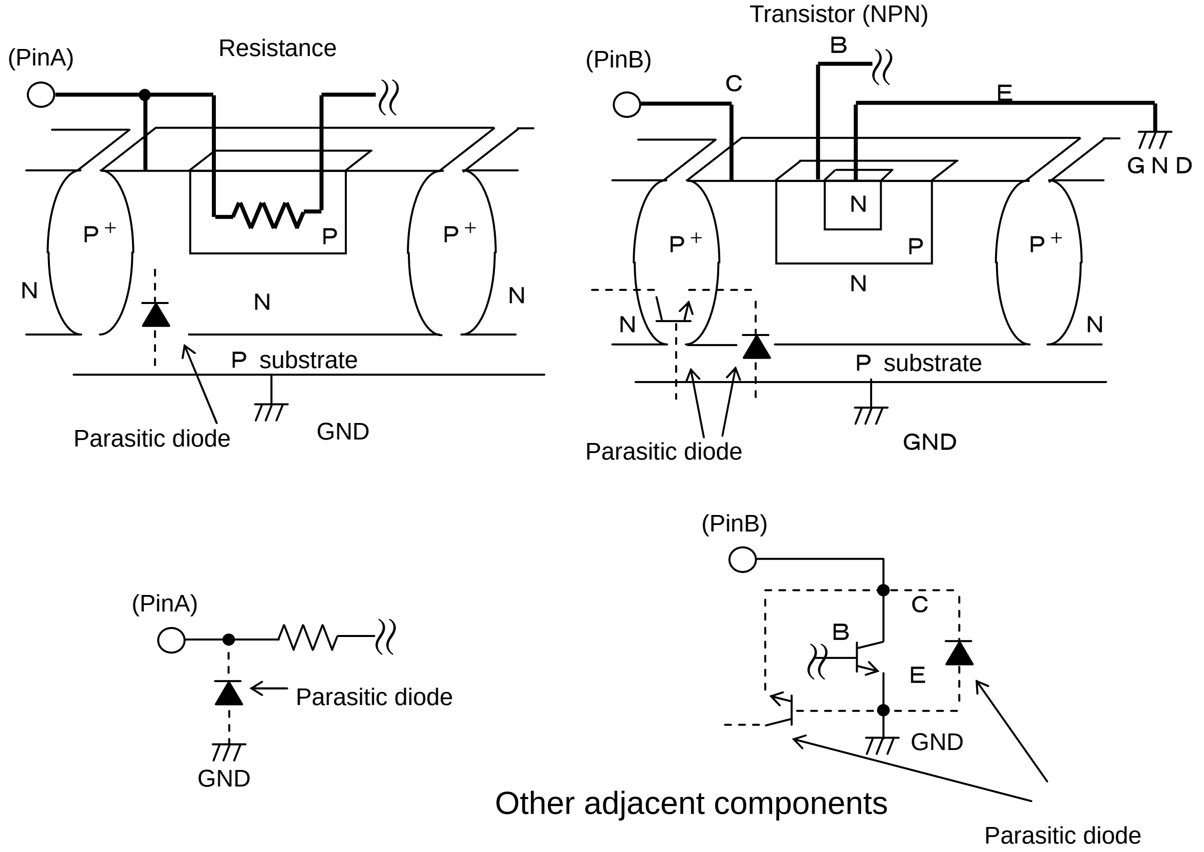


Fig. 34

Simplified structure of a Bipolar IC

9. Common impedance

Power supply and ground wiring should reflect consideration of the need to lower common impedance and minimize ripple as much as possible (by making wiring as short and thick as possible or rejecting ripple by incorporating inductance and capacitance).

10. Pin short and mistake fitting

Do not short−circuit between OUT pin and VCC pin, OUT pin and GND pin, or VCC pin and GND pin. When soldering the IC on circuit board, please be unusually cautious about theorientation and the position of the IC.

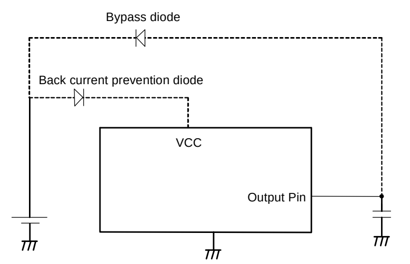


Fig.35

11. Application circuit

Although we can recommend the application circuits contained herein with a relatively high degree of confidence, we ask that you verify all characteristics and specifications of the circuit as well as performance under actual conditions. Please note that we cannot be held responsible for problems that may arise due to patent infringements or noncompliance with any and all applicable laws and regulations.

12. Operation

The IC will turn ON when the voltage at the STBY pin is greater than 2.0V and will switch OFF if under 0.3V. Therefore, do not input voltages between 0.3V and 2.0V. Malfunctions and/or physical damage may occur.

●Power Dissipation

TO252-S

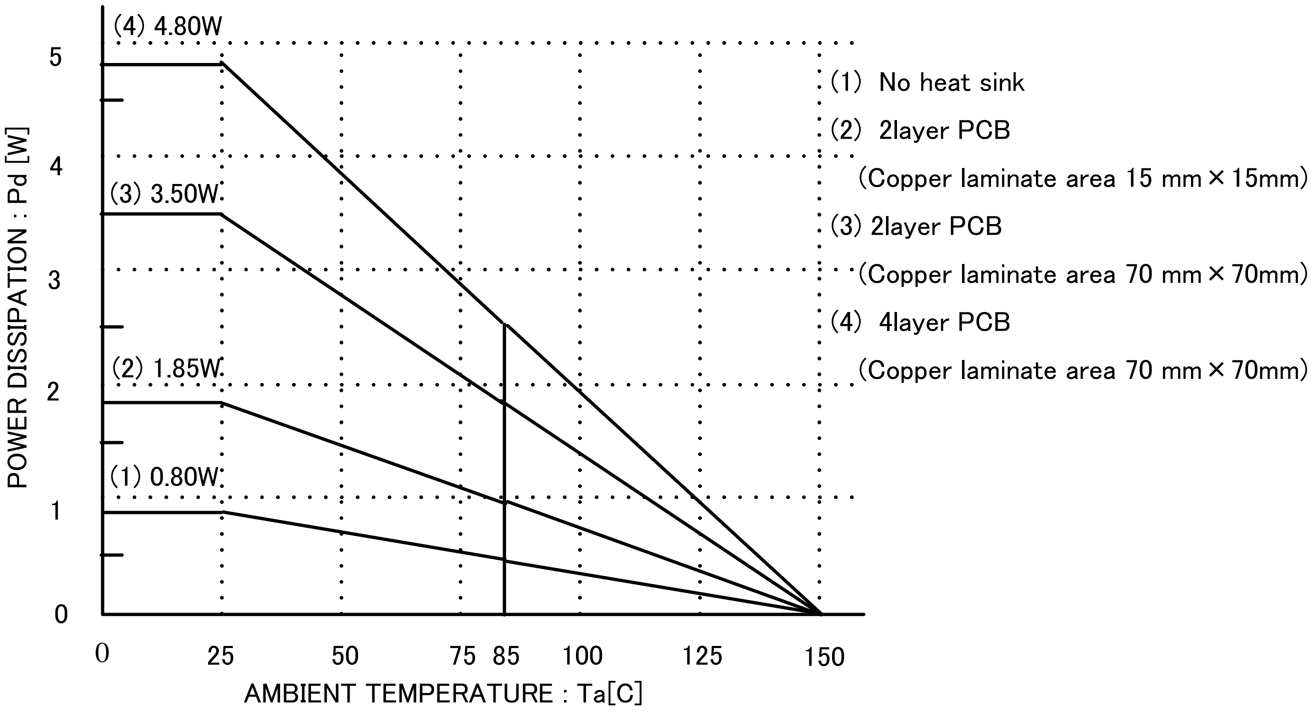


Fig.36

TO220

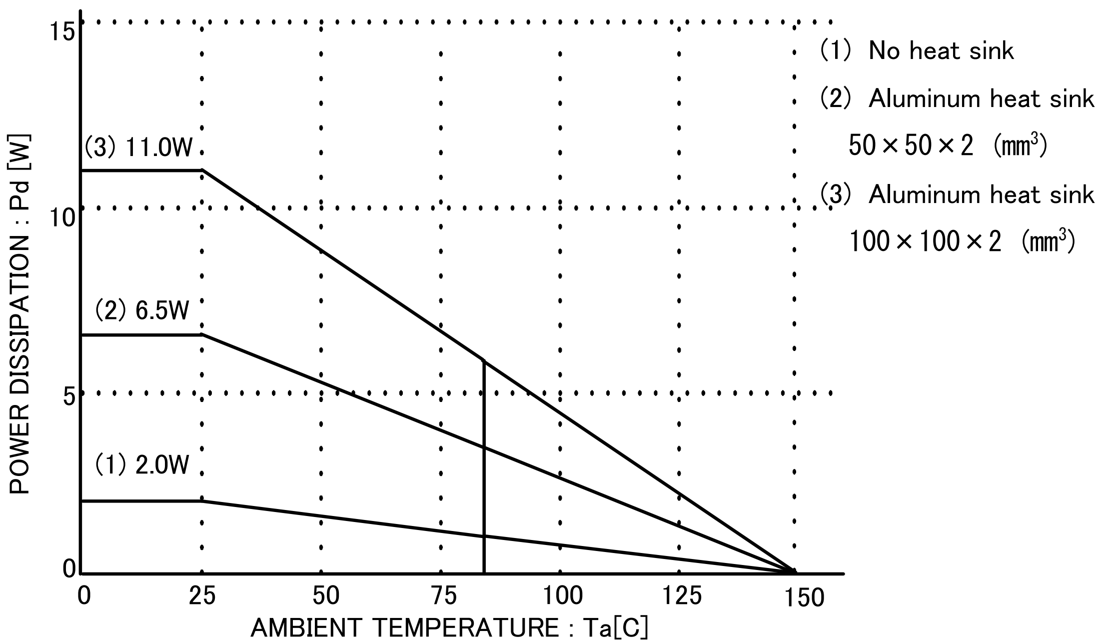


Fig.37

Notes

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