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

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

BD9870FPS

No.09027EAT26

● Description

The BD9870FPS single-channel step-down switching regulator incorporates a Pch MOSFET capable of PWM operation at 900kHz, enabling use of a smaller coil, as well as circuitry that eliminates the need for external compensation – only a diode, coil, and ceramic capacitor are required – reducing board size significantly.

●Features

1) Maximum switching current: 1.5A
2) 2. Built-in Pch FET ensures high efficiency
3) Output voltage adjustable via external resistors
4) High switching frequency: 900kHz (fixed)
5) Soft start time: 5ms (fixed)
6) Overcurrent and thermal shutdown protection circuits built in
7) ON/OFF control via STBY pin
8) Ceramic output capacitor compatibility
9) Small surface mount TO252S-5 package

●Applications

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

●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_{OUT}	36	V
INV-GND	V_{INV}	5	V
Maximum Switching Current	Iout	1.5(*1)	A
Power Dissipation	Pd	800(*2)	mW
Operating Temperature	Topr	-40 to +85	℃
Storage Temperature	Tstg	-55 to +150	℃

(*1) Do not exceed Pd, ASO, and Tjmax=150℃
(*2) Derated at 6.4mW/°C over Ta=25℃

●Operating Conditions(Ta=-40 to +85℃)

Parameter	Symbol	Limit		Unit
		MIN	MAX	
Input Voltage	V_{CC}	8.0	35.0	V
Output Voltage	Vo	1.0	0.8×(Vcc-Io×Ron)	V

●Electrical Characteristics（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	
Efficiency		η	80	88	-	%	Io＝0.5A
Switching Frequency		fosc	810	900	990	kHz	
Load Regulation		ΔVOLOAD	-	5	40	mV	Vcc=20V, Io=0.5 to 1.5A
Line Regulation		ΔVOLINE	-	5	25	mV	Vcc=10 to 30V, Io=1.0A
Over Current ProtectionLimit		Iocp	1.6	-	-	A	
INV Pin Threshold Voltage		VINV	0.99	1.00	1.01	V	
INV Pin Input Current		IINV	-	1	2	μA	VINV=1.0V
STBY Pin Threshold Voltage	ON	VSTBYON	2.0	-	36	V	
	OFF	VSTBYOFF	-0.3	-	0.3	V	
STBYPin Input Current		Istby	5	15	30	μA	STBY=3V
Circuit Current		Icc	-	5	12	mA	INV=2V
Stand-by Current		Ist	-	0	5	μA	STBY＝0V
Soft Start Time		Tss	1	4	10	ms	

* This product is not designed to be resistant to radiation.

●Block Diagram

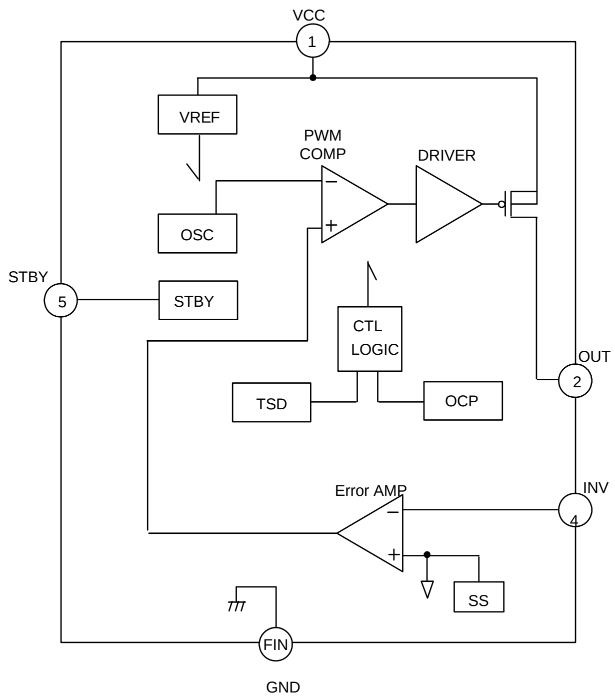
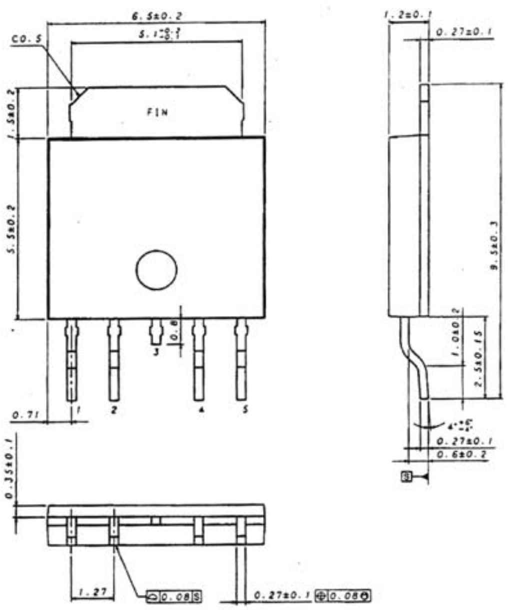


Fig.1

●Package Dimensions



TO252S-5（Unit：mm）

Fig.2

●Pin Description

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

※Normally OPEN

●Block Function Explanations

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

・OSC
Generates the triangular wave oscillation frequency (900kHz) 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 (175°C). Hysteresis is built in (15°C) 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).

・Soft Start (SS)
This block conducts soft start operations. When STBY is High and the IC starts up the internal capacitor begins charging. The soft start time is fixed at 5ms.

●Notes for PCB layout

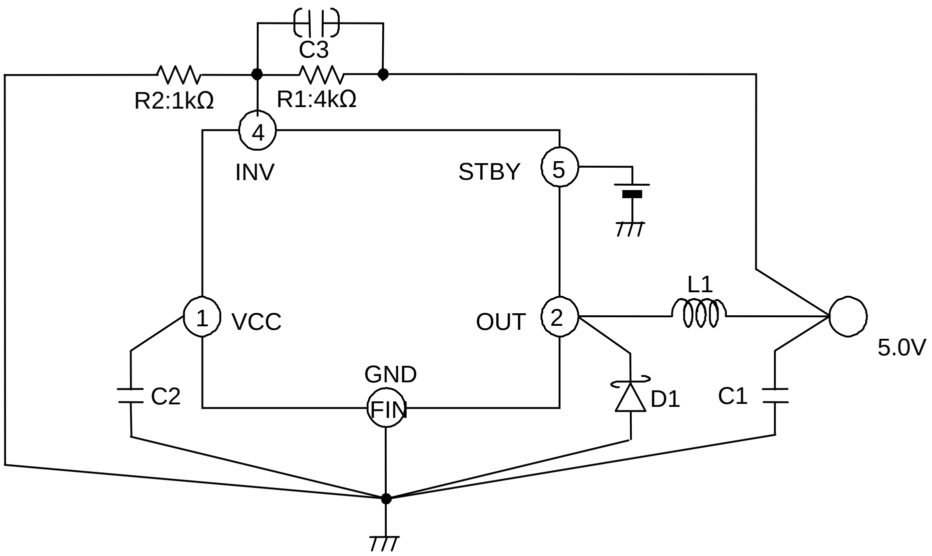


Fig.3

- 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.

（If the patterning is longer or thin, it’s possible to cause ringing or waveform crack.）

● Application component selection and settings

Inductor L1

A large inductor series impedance will result in deterioration of efficiency. OCP operation greater than 1.6A may cause inductor overheating, possibly leading to overload or output short.
Note that the current rating for the coil should be higher than I_{OUT}(MAX)＋⊿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
If you make a point of efficiency, we will recommend C10-H5R(mitsumi).The efficiency will improve about 1-2%.

Schottky Diode 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 (⊿I_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

Output Capacitor C1

A suitable output capacitor should satisfy the following formula for ESR:
ESR≦⊿VL/⊿IL
⊿VL : permissible ripple voltage, ⊿IL : coil ripple current
Another factor that must be considered is the permissible ripple current. Select a capacitor with sufficient margin, governed by the following formula:
IRMS =⊿IL/2√3
IRMS: effective value of ripple current to the output capacitor, ⊿IL : coil ripple current
Use ceramic capacitor over B characteristic of temperature. Except that, it is possible to cause abnormal movement of IC. It’s depends on ambient temperature or output voltage setting
Also it is possible to use Al electronic capacitor, but use it by enough confirmation.

Input Capacitor C2

The input capacitor is the source of current flow to the coil via the built-in Pch FET when the FET is ON. When selecting the input capacitor sufficient margin must be provided to accommodate capacitor voltage and permissible ripple current. The expression below defines the effective value of the ripple current to the input capacitor. It should be used in determining the suitability of the capacitor in providing sufficient margin for the permissible ripple current.

$$IRMS = IOUT \times \sqrt{(1 - VOUT / VCC) \times VOUT / VCC}$$

IRMS : effective value of the ripple current to the input capacitor
IOUT : output load current, VOUT: output voltage, VCC: input voltage

Capacitor C3

This capacitor is utilized to stabilize the frequency characteristics, but is seldom used. However, if the phase margin is insufficient and oscillation is likely, connecting this capacitor may improve frequency stability.

Resistor R1,R2

These resistors determine the output voltage:
VOUT＝1.0V×(1 + R1/R2)
Select resistors less than 10kΩ.

＜Recommended Components (Example)＞

Inductor	L1＝10μH	: C6-K3LA (MITSUMI)
Schottky Diode	D1	: RB050LA-30（ROHM）… use when VCC is less than 30V
	D2	: RB050LA-40（ROHM）… use when VCC is greater than 30V
Capacitor	C1＝10μF(25V)	: ceramic cap GRM31CB31E106KA75L(murata)
	C2＝4.7μF(50V)	: ceramic cap GRM32EB31H475KA87L(murata)
	C3＝OPEN	

＜Recommended Components example 2＞…when the Duty ratio of output/input voltage is less than 10%

Inductor	L1＝10μH	: C6-K3LA (MITSUMI)
Schottky Diode	D1	: RB050LA-30（ROHM）… use when VCC is less than 30V
	D2	: RB050LA-40（ROHM）… use when VCC is more than 30V
Capacitor	C1＝100μF(25V)	: Al electric capacitor UHD1E101MED(nichicon)
	C2＝4.7μF(50V)	: ceramic cap GRM32EB31H475KA87L(murata)
	C3＝OPEN	

●Test Circuit

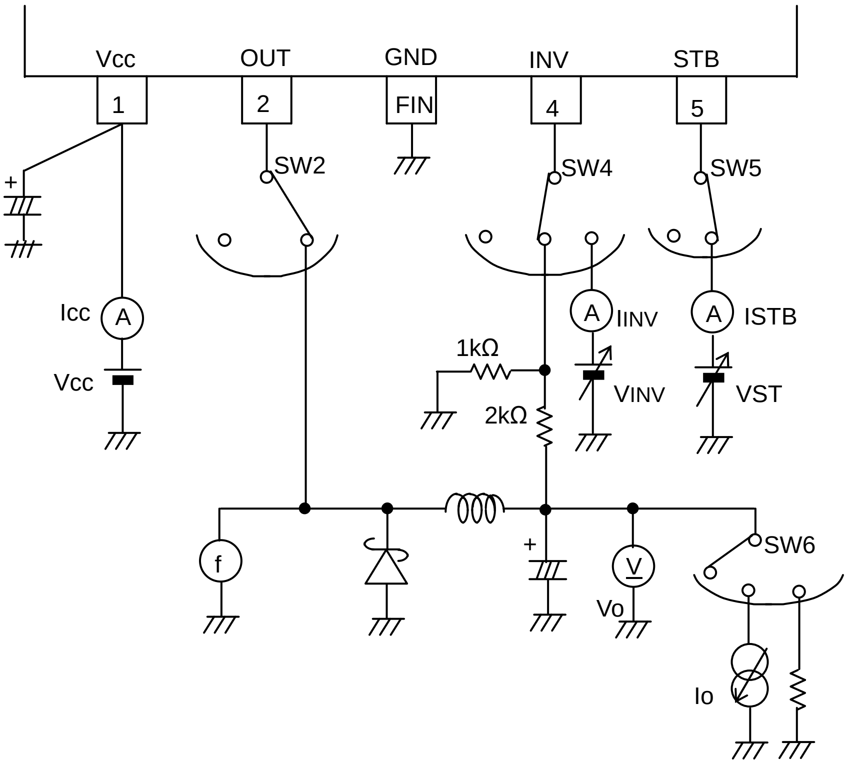


Fig.4

●Typical Performance Characteristics（Unless otherwise noted, Ta=25℃,Vcc=12V,Vo=5V,STBY=3V）

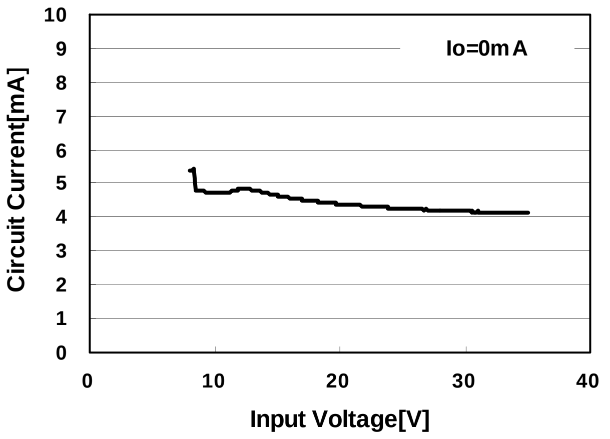


Fig.5 Circuit Current vs. Supply Voltage：no load

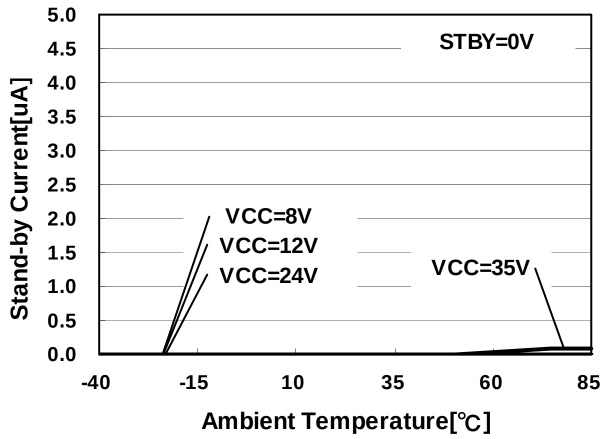


Fig.6 Stand-by Current vs. Ambient temperature

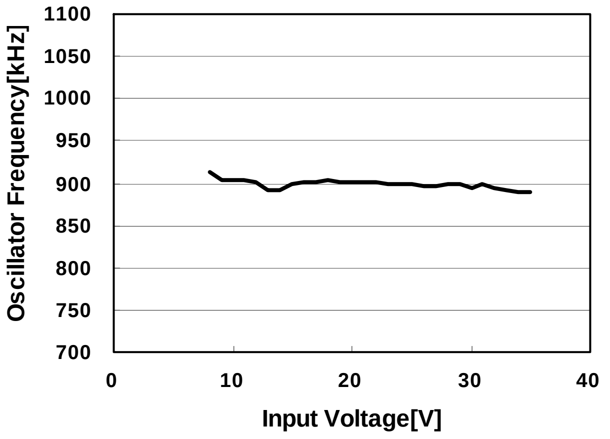


Fig.7 Oscillator Frequency vs. Supply Voltage

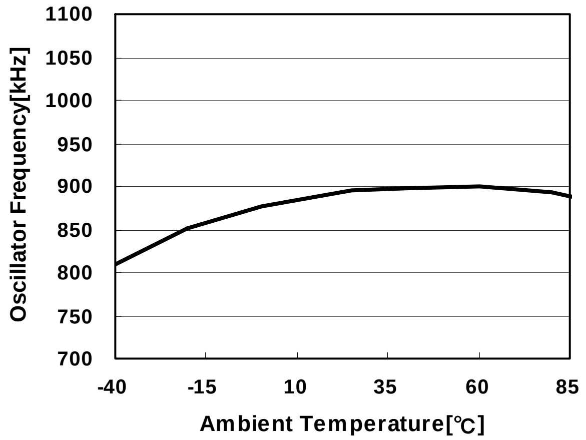


Fig.8 Oscillator Frequency vs. Supply Voltage

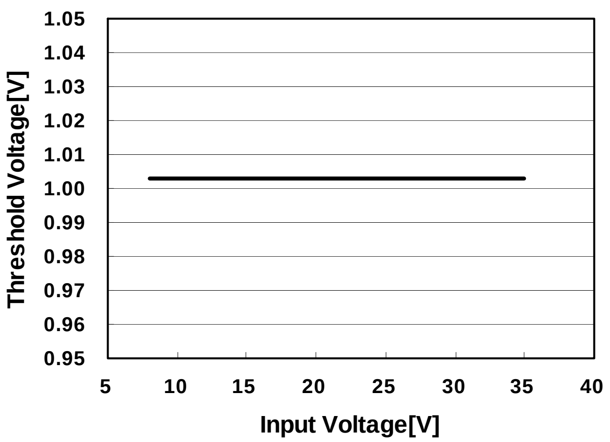


Fig.9 ErrorAmp Threshold Voltage vs. Supply Voltage

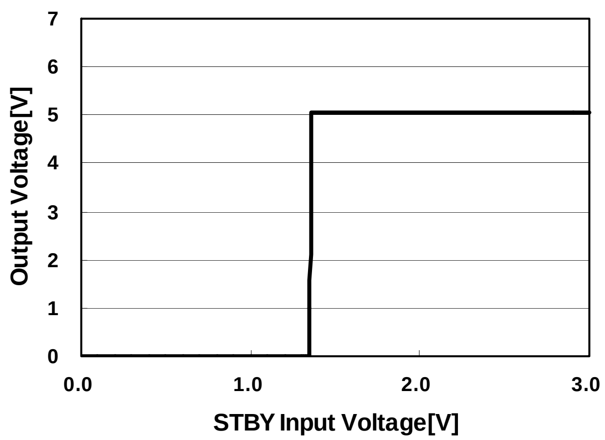


Fig.10 Output Voltage vs. STBY Pin Voltage

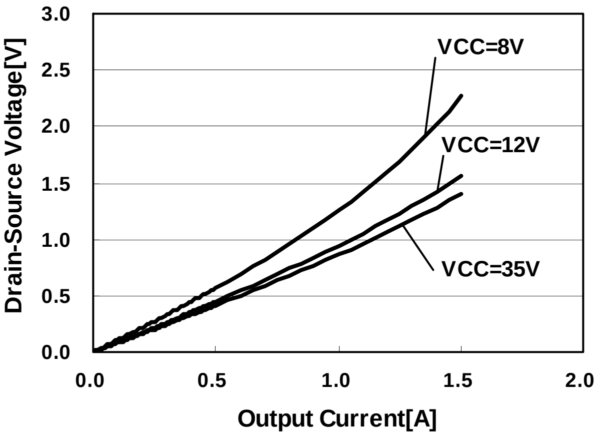


Fig.11 Driver Drain-Source Voltage vs. Output Current

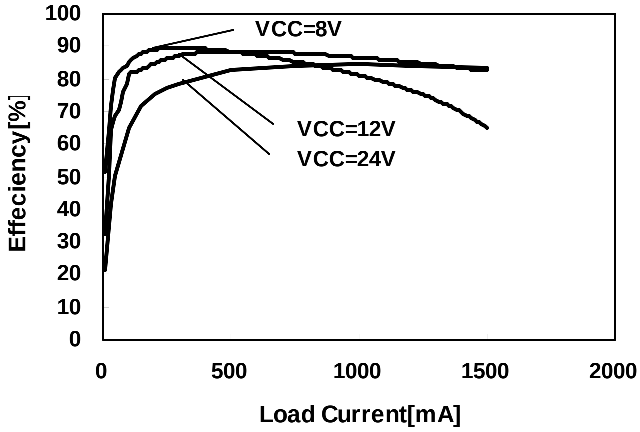


Fig.12 Efficiency vs. Load Current

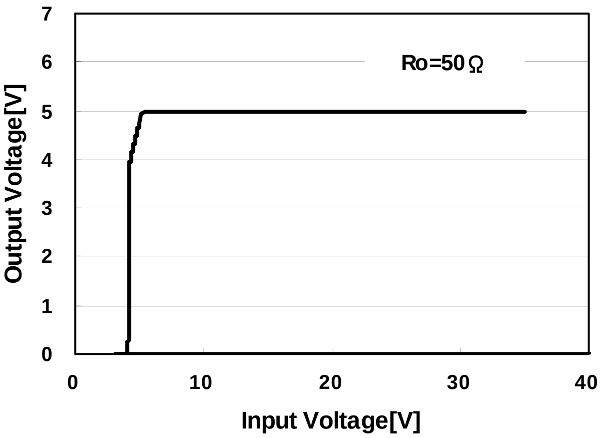


Fig.13 Output Voltage vs. Supply Voltage

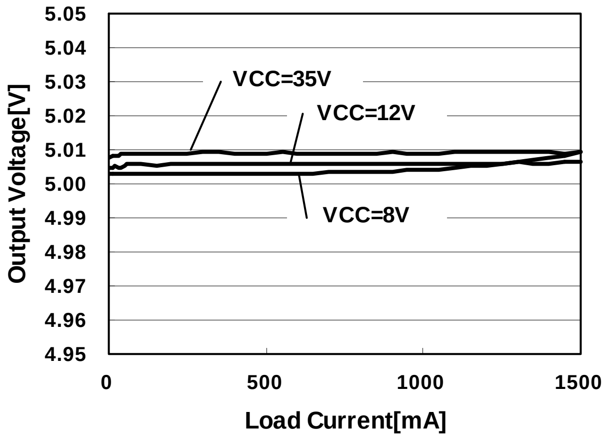


Fig.14 Output Voltage vs. Load Current

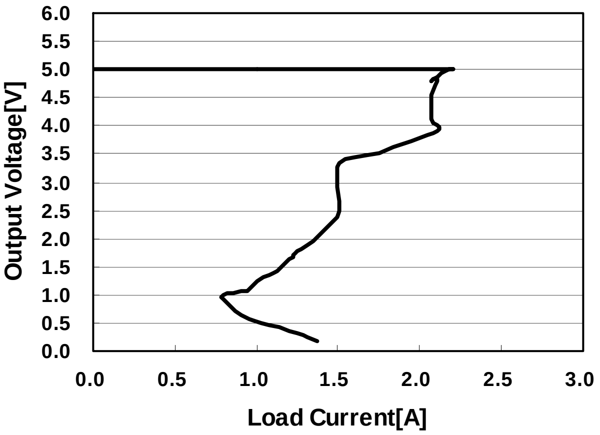


Fig.15 Over Current Protection Characteristics

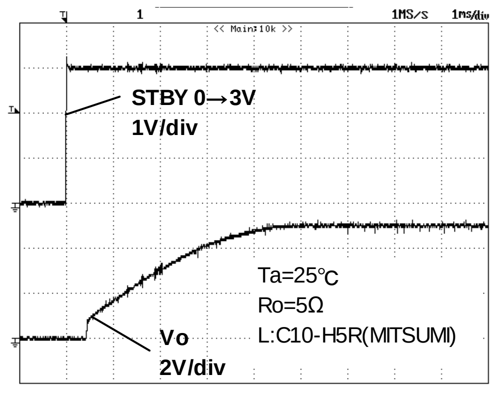
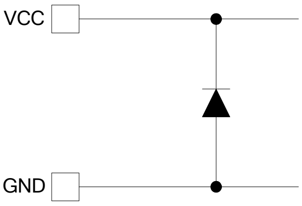
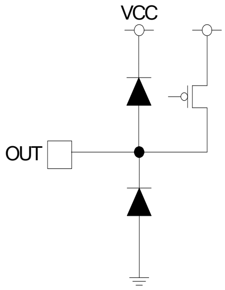
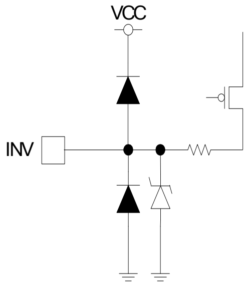
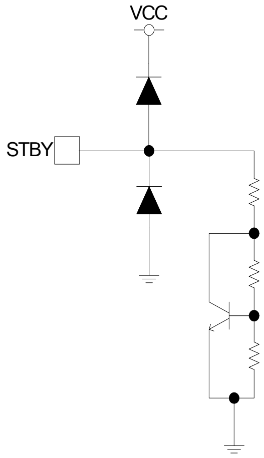


Fig.16 Output Start-up Characteristics

●I/O Equivalent Circuit

Pin 1 (Vcc, GND)	Pin 2 (OUT)	Pin 4 (INV)	Pin 5 (STBY)
			

●Operation Notes

1. Absolute Maximum Ratings
   Exceeding the absolute maximum ratings (i.e. supply voltage, temperature) may cause damage to the device and make it impossible to determine the failure mode (short/open). Therefore, when conditions exceeding the maximum ratings are anticipated, consideration should be given to preventive countermeasures (e.g. fuses).

2. 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.

3. Operating conditions
   Proper operation is guaranteed under the recommended conditions/specifications.

4. GND voltage
   Ensure that the GND fin is connected and is at the lowest potential under any operating conditions, including transients.

5. Input supply voltage
   Ensure that the Vcc pin is connected to the supply voltage.

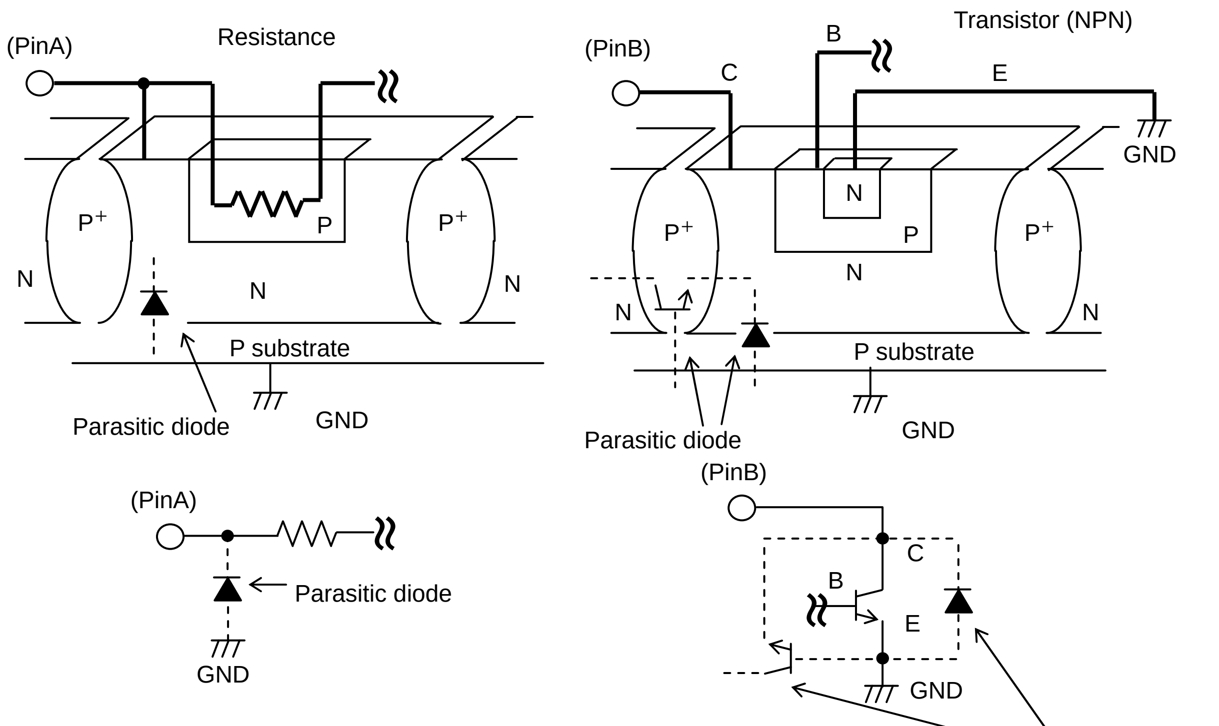
6. Thermal design
   Thermal designs should allow for sufficient margin for power dissipation under actual use.

7. Soldering
   During mounting ensure that the OUT, Vcc, and GND pins are not shorted with one another. Carefully note IC orientation.

8. Operation in strong electromagnetic field
   Operation in a strong electromagnetic field may cause malfunction.

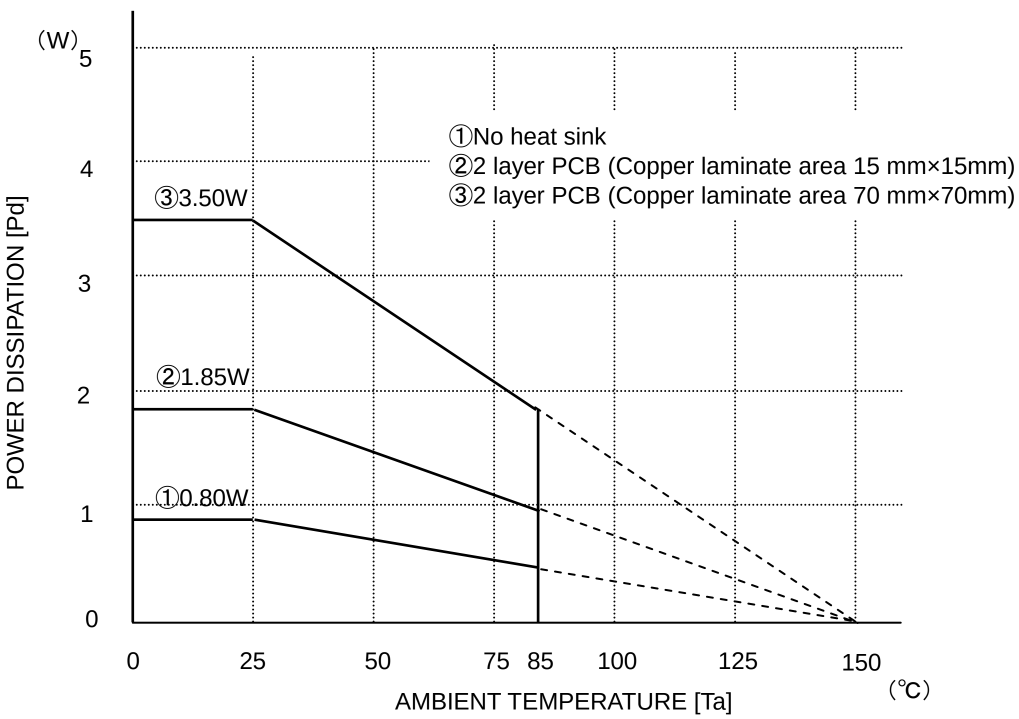
9. Operation
   The IC will turn ON when the voltage at the STBY pin is greater than 2.0V and will switch OFF if under 0.3V.
   Therefore, do not input voltages between 0.3V and 2.0V. Malfunctions and/or physical damage may occur..

10.This IC is a monolithic IC which (as below) has P+ substrate and between the 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 operationfaults and physical damage. Accordingly, you must not use methods by which parasitic diodesoperate, such as applying a voltage that is lower than the GND(P substrate)voltage toan input pin.



Simplified structure of a Bipolar IC
Other adjacent components

●Power Dissipation



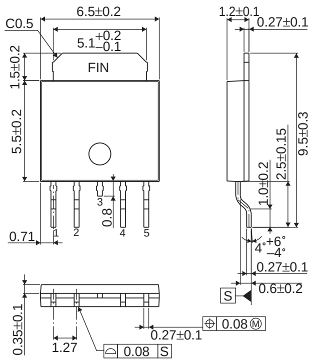
*When mounted on a 70mmx70mmx1.6mm board

●Ordering part number

B	D		9	8	7	0		F	P	S	-	E	2

- B D: Part No.
- 9 8 7 0: Part No.
- F P S: Package
  FPS = TO252S-5
- E 2: Packaging and forming specification
  E2: Embossed tape and reel
  (TO252S-5)

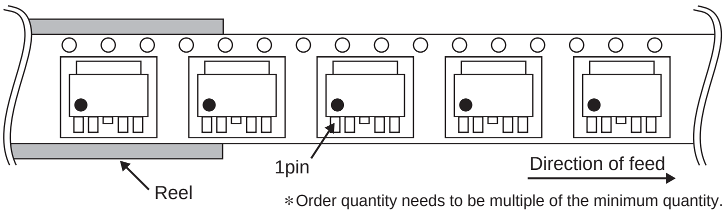
TO252S-5



(Unit : mm)

<Tape and Reel information>

Tape	Embossed carrier tape
Quantity	2000pcs
Direction of feed	E2 (The direction is the 1pin of product is at the lower left 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.

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