1 Channel Compact High Side Switch ICs

1.3A Current Limit High Side Switch ICs

BD2232G   BD2233G

General Description

BD2232G and BD2233G are low ON-Resistance N-Channel MOSFET high-side power switches, optimized for Universal Serial Bus (USB) applications. BD2232G and BD2233G are equipped with the function of over-current detection, thermal shutdown, under-voltage lockout and soft-start.

Features

- Built-in Low ON-Resistance (Typ 110mΩ) N-Channel MOSFET
- Over-Current Detection
- Thermal Shutdown
- Open-Drain Fault Flag Output
- Flag Output Delay
- Under-Voltage Lockout
- Soft-Start Circuit
- Output Discharge Function
- Control Input Logic
  - ➢ Active-High: BD2232G
  - ➢ Active-Low: BD2233G

Applications

USB Hub in Consumer Appliances, PC, PC Peripheral Equipment, and so forth

Key Specifications

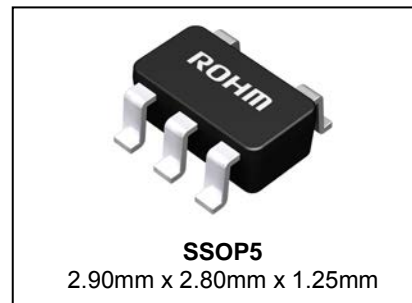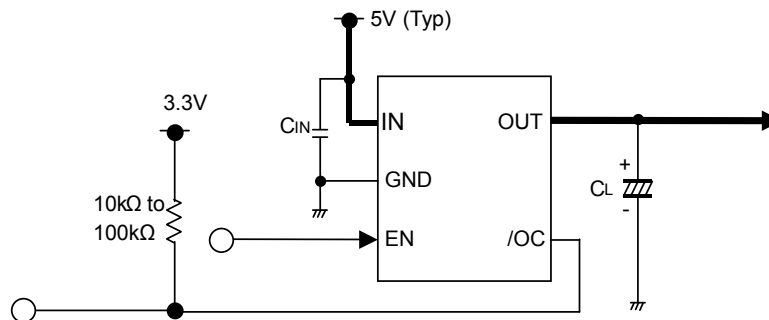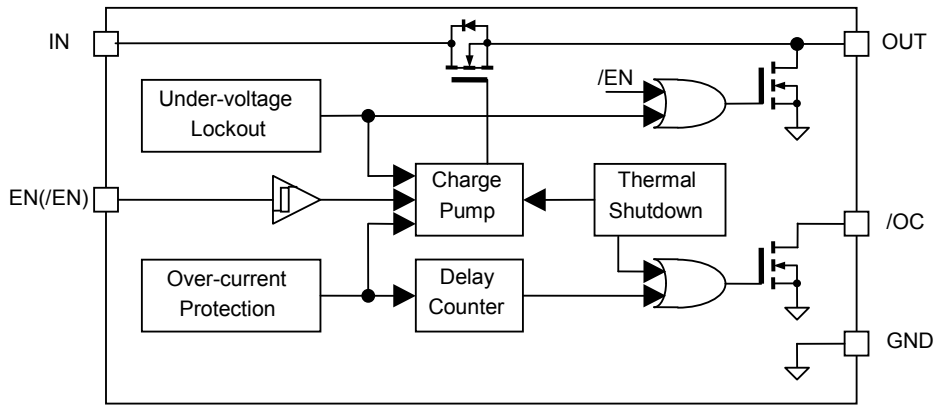- Input Voltage Range: 2.7V to 5.5V
- ON-Resistance: 100mΩ(Typ)
- Over-Current Threshold: 1.15A (Min), 1.4A (Max)
- Standby Current: 0.01μA (Typ)
- Operating Temperature Range: -40°C to +85°C

Package   W(Typ)   D(Typ)   H (Max)

SSOP5
2.90mm x 2.80mm x 1.25mm

Typical Application Circuit

Lineup

Over-Current Detection			Control Input Logic	Package		Orderable Part Number
Min	Typ	Max				
1150mA	1275mA	1400mA	High	SSOP5	Reel of 3000	BD2232G-GTR
1150mA	1275mA	1400mA	Low	SSOP5	Reel of 3000	BD2233G-GTR

○Product structure : Silicon monolithic integrated circuit   ○This product has not designed protection against radioactive rays

Block Diagram

Pin Configurations
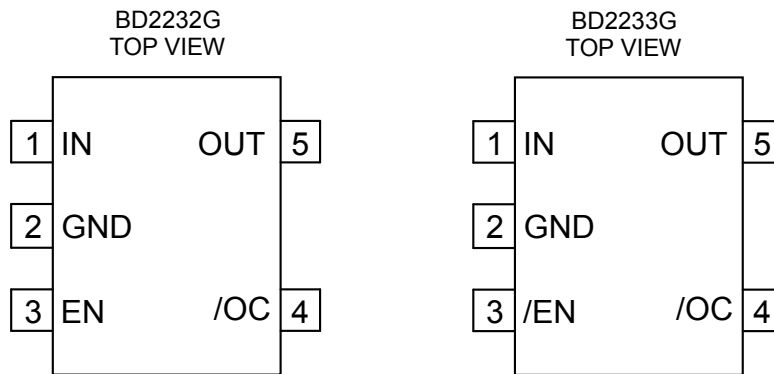
Pin Description

Pin No.	Symbol	I/O	Function
1	IN	-	Switch input and the supply voltage for the IC
2	GND	-	Ground
3	EN, /EN	I	Enable input EN: High level input turns on the switch. (BD2232G) /EN: Low level input turns on the switch. (BD2233G)
4	/OC	O	Over-current detection terminal. Low level output during over-current or over-temperature condition Open-drain fault flag output
5	OUT	O	Switch output

Absolute Maximum Ratings (Ta=25°C)

Parameter	Symbol	Rating	Unit
IN Supply Voltage	V_{IN}	-0.3 to +6.0	V
EN(/EN) Input Voltage	V_{EN}, $V_{/EN}$	-0.3 to +6.0	V
/OC Voltage	$V_{/OC}$	-0.3 to +6.0	V
/OC Sink Current	$I_{/OC}$	5	mA
OUT Voltage	V_{OUT}	-0.3 to V_{IN} + 0.3	V
Storage Temperature	Tstg	-55 to +150	°C
Power Dissipation	Pd	0.67 [(Note 1)]	W

(Note 1)   Mounted on 70mm x 70mm x 1.6mm glass epoxy board. Reduce 5.4mW per 1°C above 25°C
Caution: 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.

Recommended Operating Conditions

Parameter	Symbol	Rating			Unit
		Min	Typ	Max	
IN Operating Voltage	V_{IN}	2.7	5.0	5.5	V
Operating Temperature	Topr	-40	-	+85	°C

Electrical Characteristics

BD2232G   (V_{IN}= 5V, Ta= 25°C, unless otherwise specified.)
DC Characteristics

Parameter	Symbol	Limit			Unit	Conditions
		Min	Typ	Max		
Operating Current	I_{DD}	-	110	160	µA	V_{EN} = 5V, V_{OUT} = open
Standby Current	I_{STB}	-	0.01	5	µA	V_{EN} = 0V, V_{OUT} = open
EN Input Voltage	V_{ENH}	2.0	-	-	V	High Input
	V_{ENL}	-	-	0.8	V	Low Input
EN Input Leakage	I_{EN}	-1	+0.01	+1	µA	V_{EN} = 0V or 5V
ON-Resistance	R_{ON}	-	100	145	mΩ	I_{OUT} = 500mA
Over-Current Threshold	I_{TH}	1150	1275	1400	mA	
Short Circuit Output Current	I_{SC}	500	-	-	mA	V_{OUT} = 0V, RMS
Output Discharge Resistance	R_{DISC}	30	60	120	Ω	I_{DISC} = 1mA
/OC Output Low Voltage	$V_{/OC}$	-	-	0.4	V	$I_{/OC}$ = 0.5mA
UVLO Threshold	V_{TUVH}	2.1	2.3	2.5	V	V_{IN} Increasing
	V_{TUVL}	2.0	2.2	2.4	V	V_{IN} Decreasing

AC Characteristics

Parameter	Symbol	Limit			Unit	Conditions
		Min	Typ	Max		
Output Rise Time	t_{ON1}	-	1	6	ms	R_L = 100Ω
Output Turn ON Time	t_{ON2}	-	1.5	10	ms	R_L = 100Ω
Output Fall Time	t_{OFF1}	-	1	20	µs	R_L = 100Ω
Output Turn OFF Time	t_{OFF2}	-	3	40	µs	R_L = 100Ω
/OC Delay Time	$t_{/OC}$	10	15	20	ms	

Electrical Characteristics - continued

BD2233G   (V$_{IN}$= 5V, Ta= 25°C, unless otherwise specified.)

DC Characteristics

Parameter	Symbol	Limit			Unit	Conditions
		Min	Typ	Max		
Operating Current	I$_{DD}$	-	110	160	µA	V$_{/EN}$ = 0V, V$_{OUT}$ = open
Standby Current	I$_{STB}$	-	0.01	5	µA	V$_{/EN}$ = 5V, V$_{OUT}$ = open
/EN Input Voltage	V$_{/ENH}$	2.0	-	-	V	High Input
	V$_{/ENL}$	-	-	0.8	V	Low Input
/EN Input Leakage	I$_{/EN}$	-1	+0.01	+1	µA	V$_{/EN}$ = 0V or 5V
ON-Resistance	R$_{ON}$	-	100	145	mΩ	I$_{OUT}$ = 500mA
Over-Current Threshold	I$_{TH}$	1150	1275	1400	mA	
Short Circuit Output Current	I$_{SC}$	500	-	-	mA	V$_{OUT}$ = 0V, RMS
Output Discharge Resistance	R$_{DISC}$	30	60	120	Ω	I$_{DISC}$ = 1mA
/OC Output Low Voltage	V$_{/OC}$	-	-	0.4	V	I$_{/OC}$ = 0.5mA
UVLO Threshold	V$_{TUVH}$	2.1	2.3	2.5	V	V$_{IN}$ Increasing
	V$_{TUVL}$	2.0	2.2	2.4	V	V$_{IN}$ Decreasing

AC Characteristics

Parameter	Symbol	Limit			Unit	Conditions
		Min	Typ	Max		
Output Rise Time	t$_{ON1}$	-	1	6	ms	R$_{L}$ = 100Ω
Output Turn ON Time	t$_{ON2}$	-	1.5	10	ms	R$_{L}$ = 100Ω
Output Fall Time	t$_{OFF1}$	-	1	20	µs	R$_{L}$ = 100Ω
Output Turn OFF Time	t$_{OFF2}$	-	3	40	µs	R$_{L}$ = 100Ω
/OC Delay Time	t$_{/OC}$	10	15	20	ms	

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Measurement Circuit

A.   Operating Current

B.   EN, /EN Input Voltage, Output Rise / Fall Time

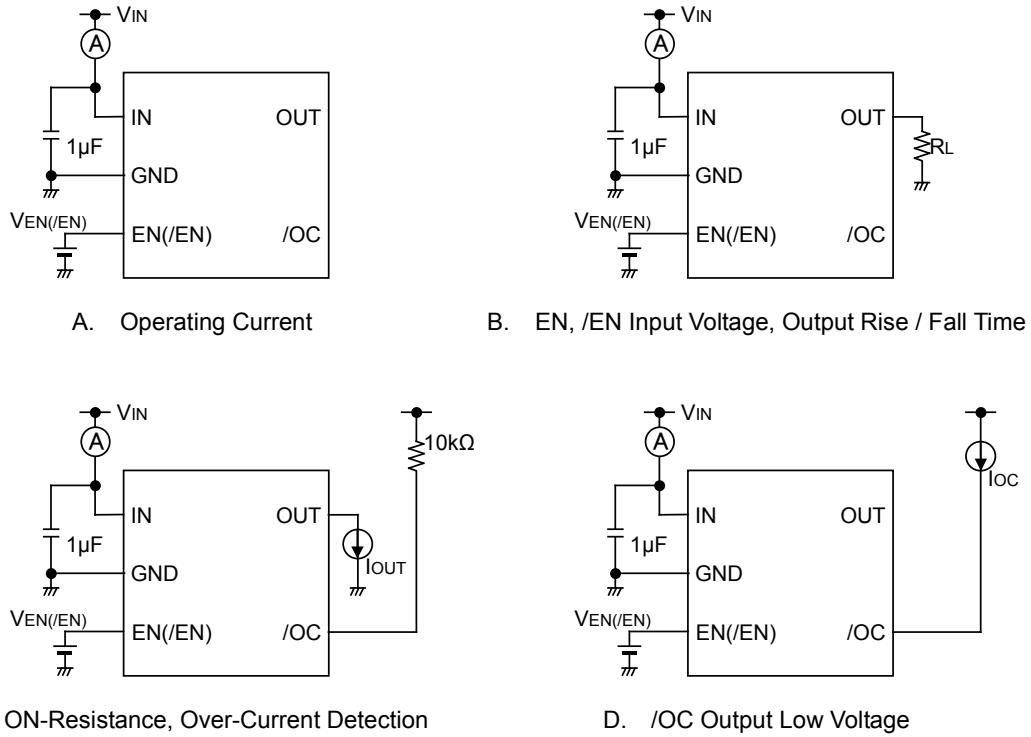C.   ON-Resistance, Over-Current Detection

D.   /OC Output Low Voltage

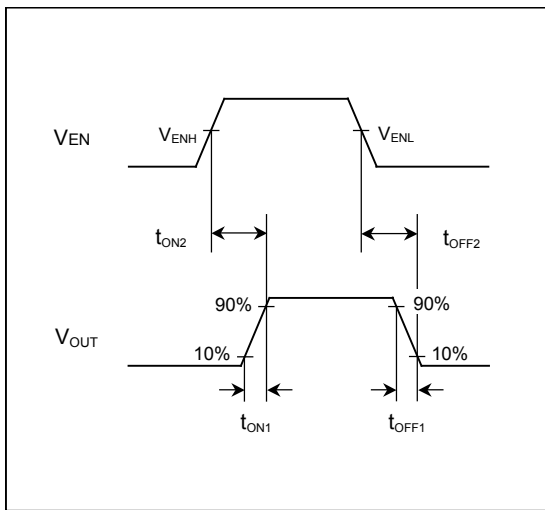Figure 1. Measurement Circuit

Timing Diagram

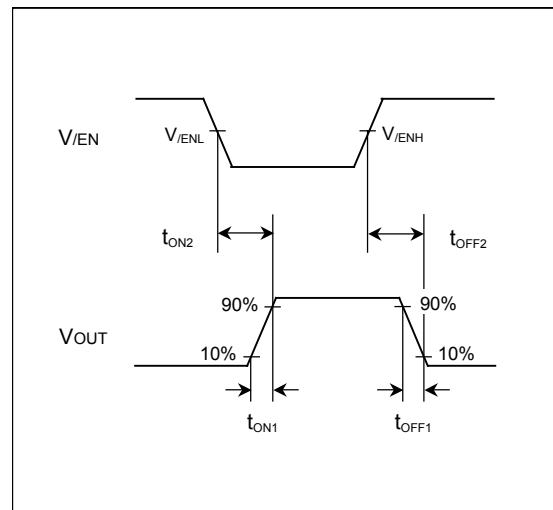Figure 2. Output Rise / Fall Time
(BD2232G)

Figure 3. Output Rise / Fall Time
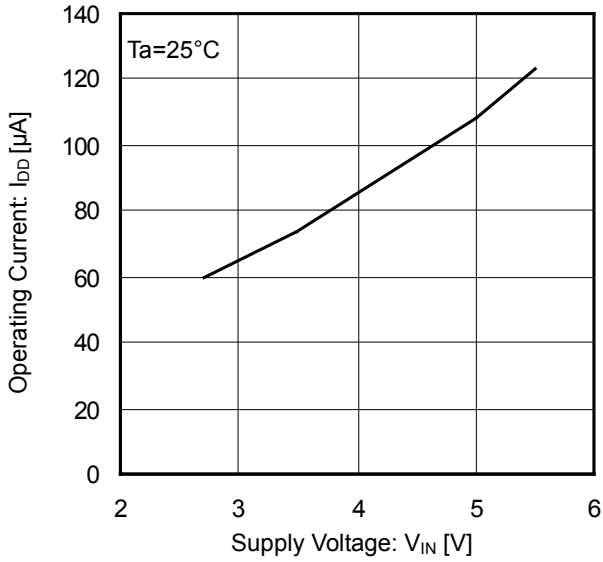(BD2233G)

Typical Performance Curves

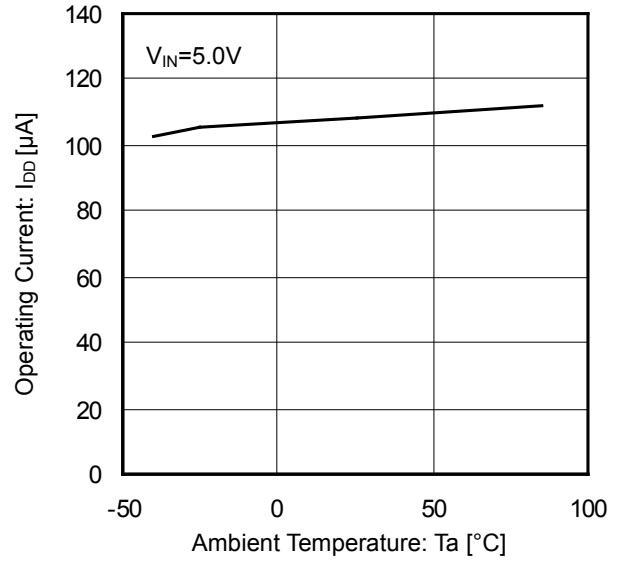Figure 4. Operating Current vs Supply Voltage
(EN, /EN Enable)

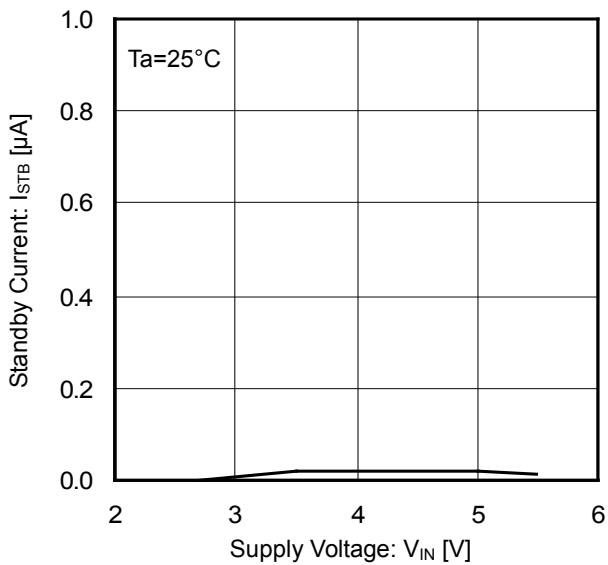Figure 5. Operating Current vs Ambient Temperature
(EN, /EN Enable)

Figure 6. Standby Current vs Supply Voltage
(EN, /EN Disable)
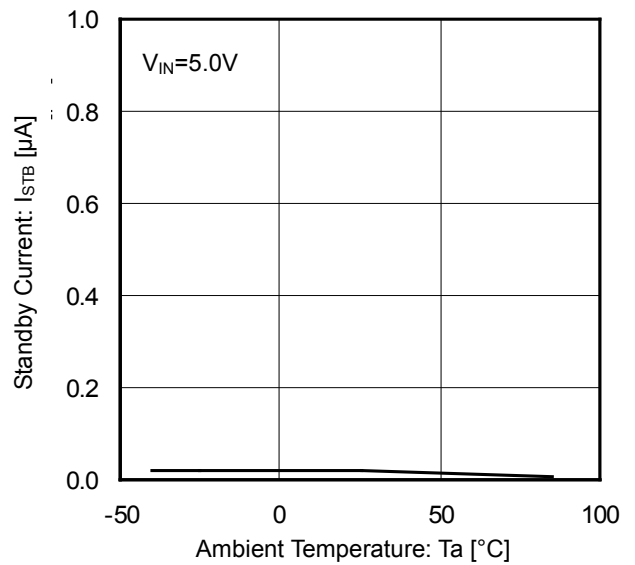
Figure 7. Standby Current vs Ambient Temperature
(EN, /EN Disable)

Typical Performance Curves - continued
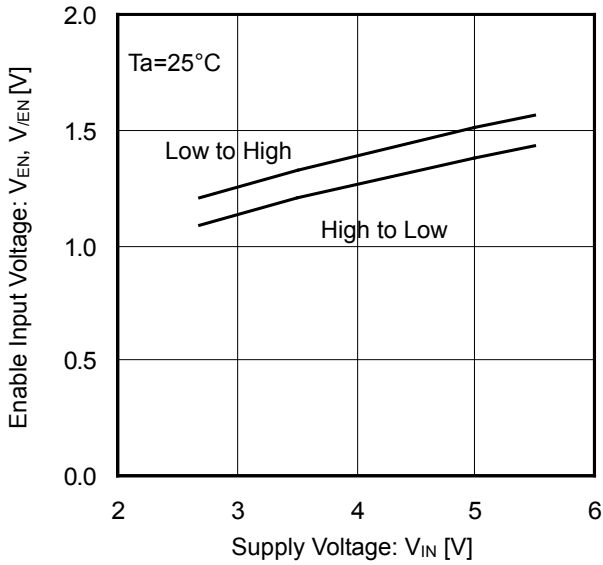
Figure 8. EN, /EN Input Voltage vs
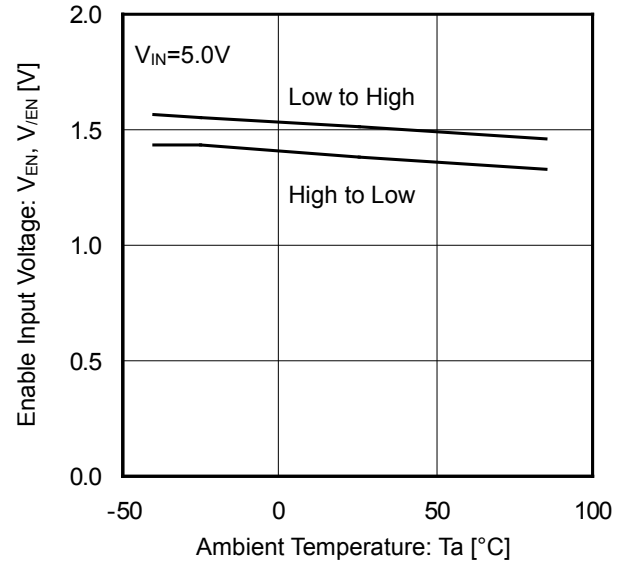Supply Voltage
(V_{ENH}, V_{ENL}, $V_{/ENH}$, $V_{/ENL}$)

Figure 9. EN, /EN Input Voltage vs
Ambient Temperature
(V_{ENH}, V_{ENL}, $V_{/ENH}$, $V_{/ENL}$)
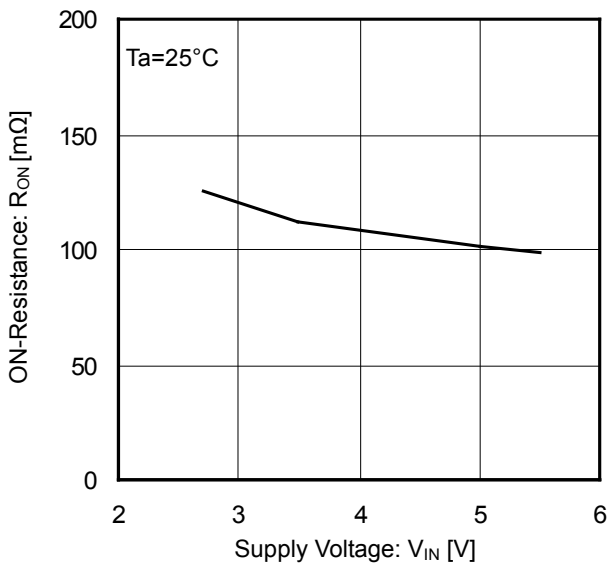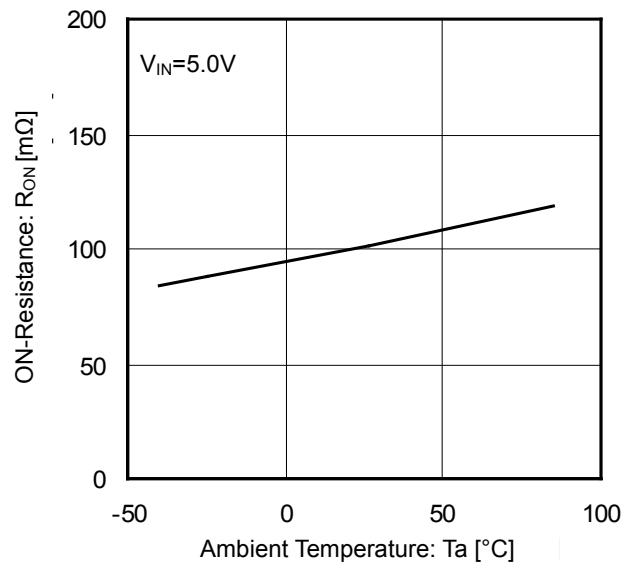

Figure 10. ON-Resistance vs Supply Voltage

Figure 11. ON-Resistance vs Ambient Temperature

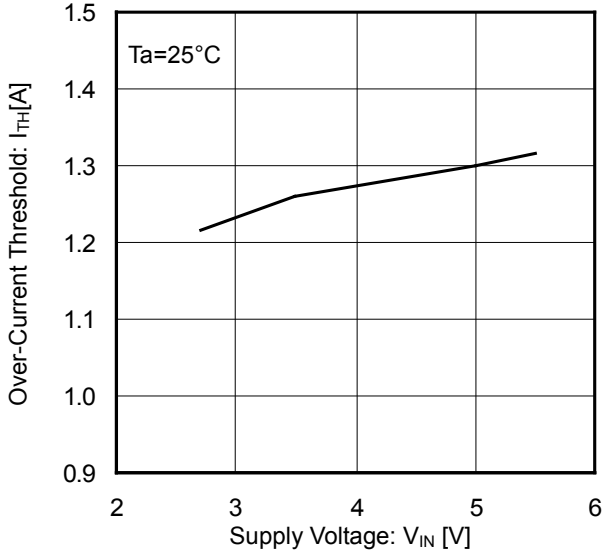## Typical Performance Curves - continued

Figure 12. Over-Current Threshold vs
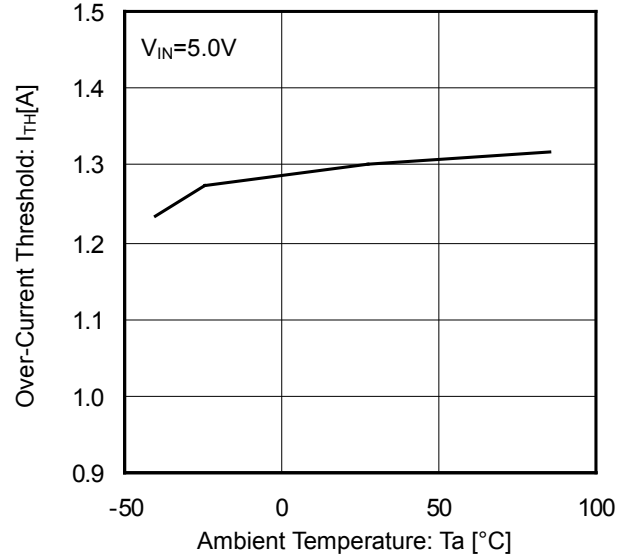Supply Voltage
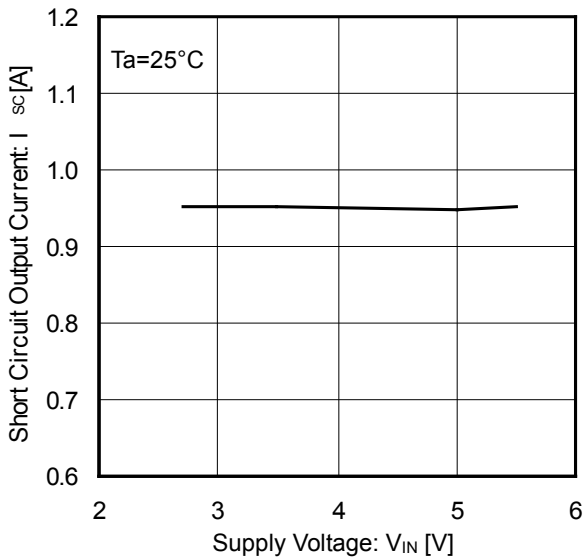

Figure 13. Over-Current Threshold vs
Ambient Temperature

Figure 14. Short Circuit Output Current
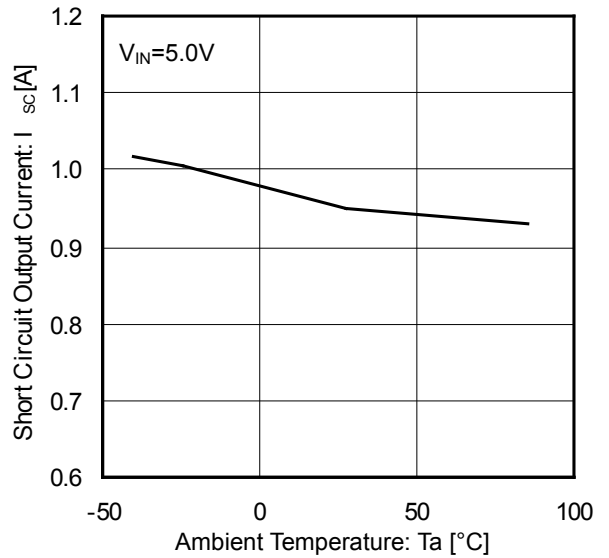vs Supply Voltage

Figure 15. Short Circuit Output Current
vs Ambient Temperature

Typical Performance Curves - continued
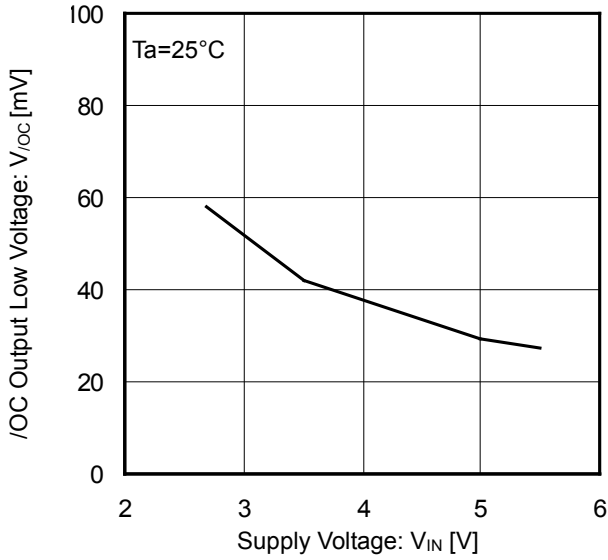

Figure 16. /OC Output Low Voltage vs Supply Voltage
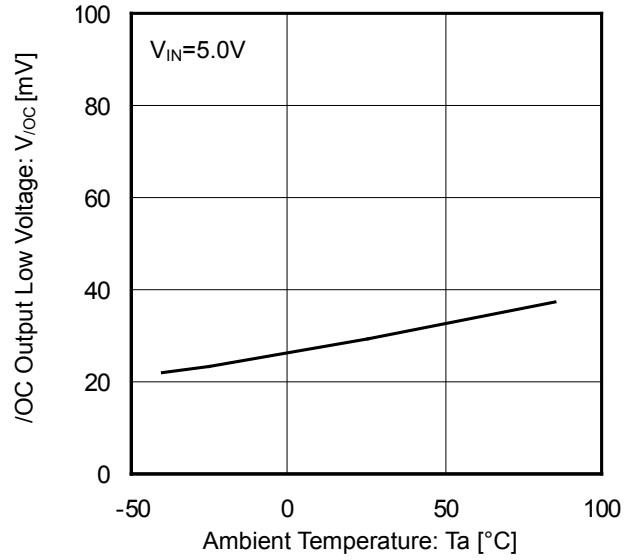

Figure 17. /OC Output Low Voltage vs Ambient Temperature
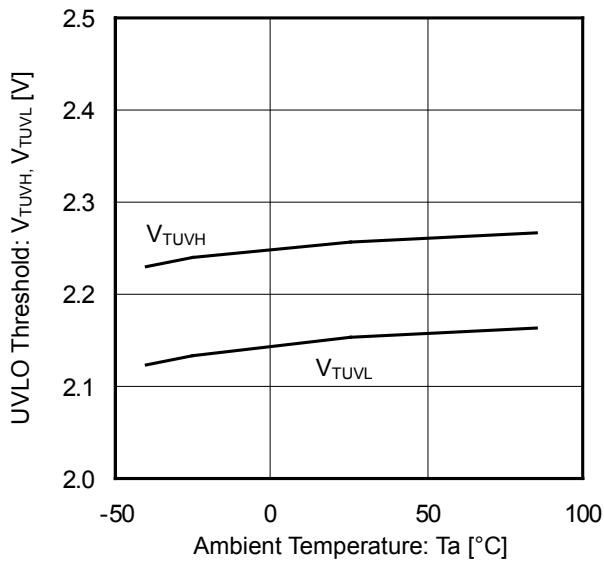
Figure 18. UVLO Threshold Voltage vs Ambient Temperature
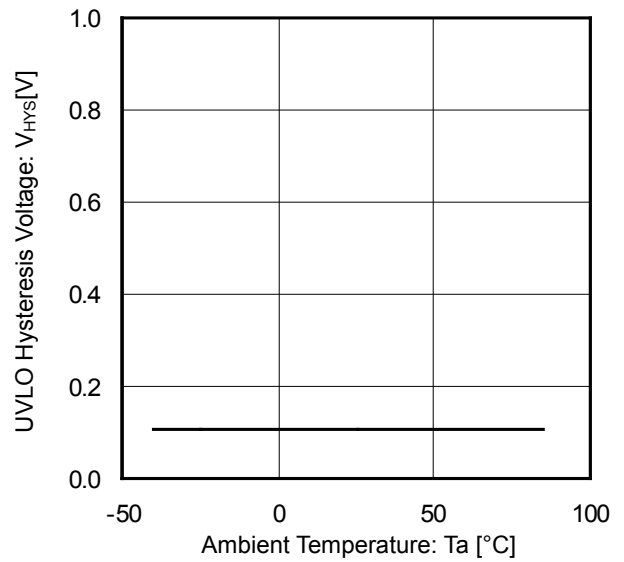
Figure 19. UVLO Hysteresis Voltage vs Ambient Temperature

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Typical Performance Curves - continued
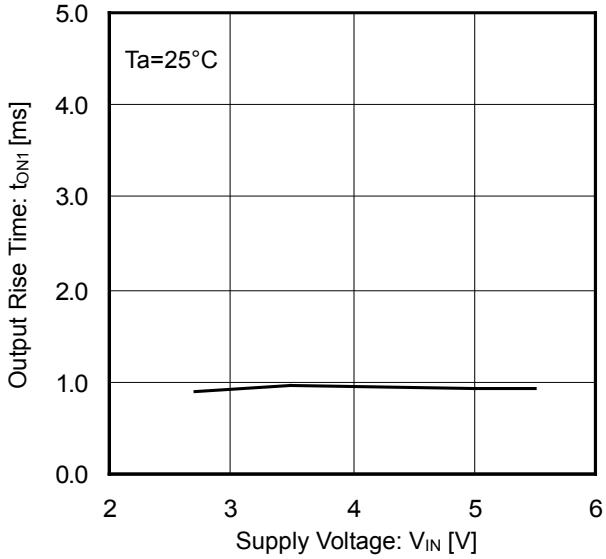
Figure 20. Output Rise Time vs
Supply Voltage
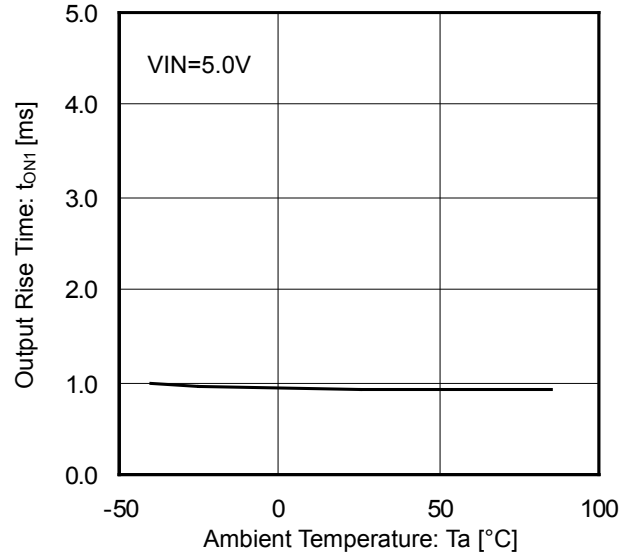
Figure 21. Output Rise Time vs
Ambient Temperature

Figure 22. Output Turn ON Time vs
Supply Voltage

Figure 23. Output Turn ON Time vs
Ambient Temperature

Typical Performance Curves - continued

Figure 24. Output Fall Time vs
Supply Voltage
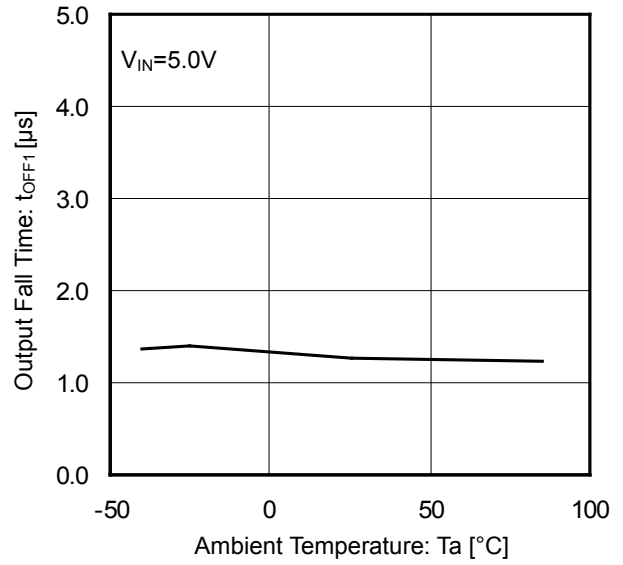
Figure 25. Output Fall Time vs
Ambient Temperature
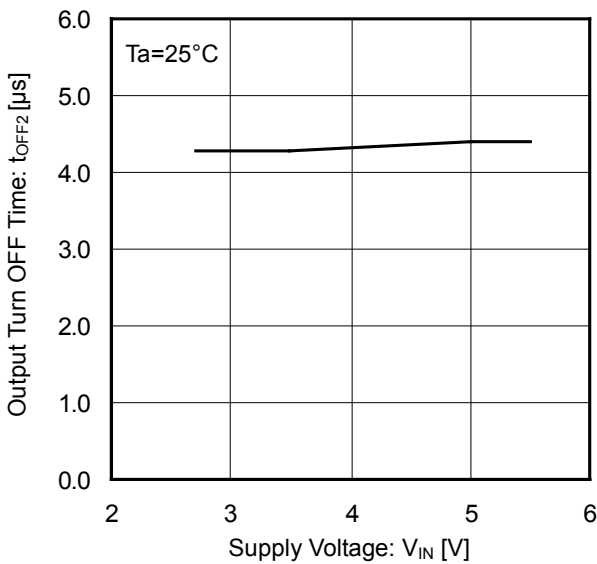
Figure 26. Output Turn OFF Time
vs Supply Voltage
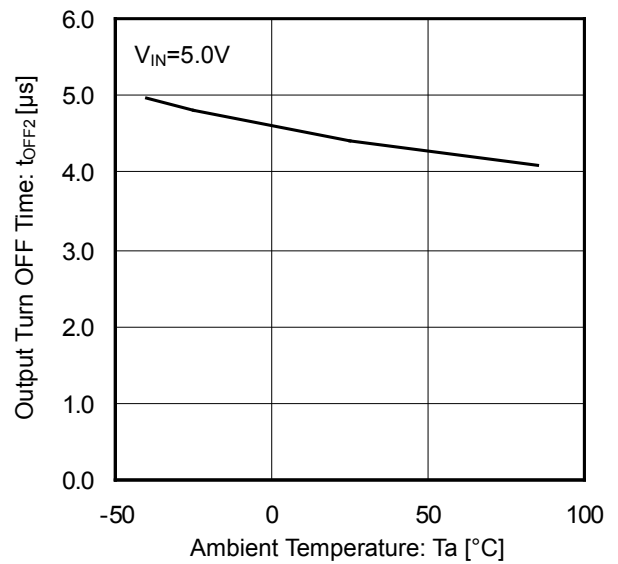
Figure 27. Output Turn OFF Time
vs Ambient Temperature

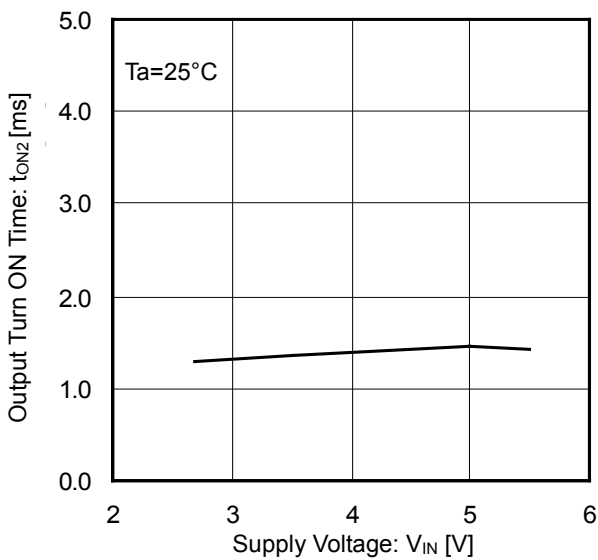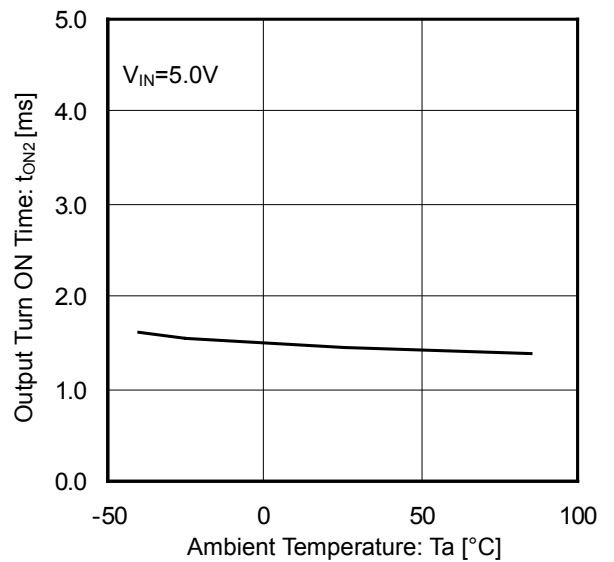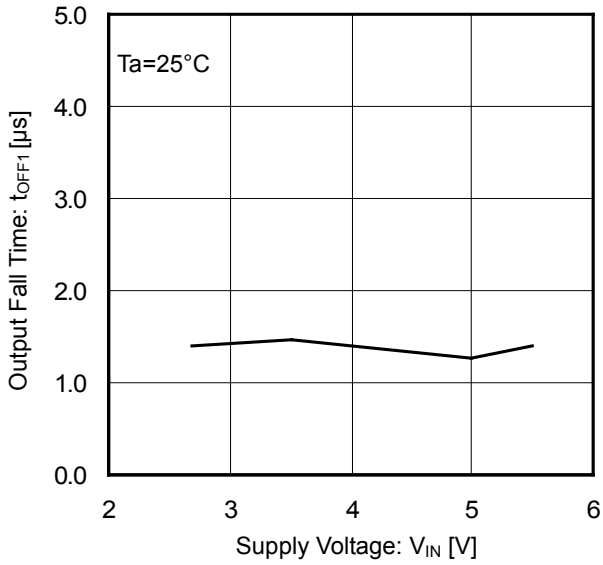**Typical Performance Curves - continued**
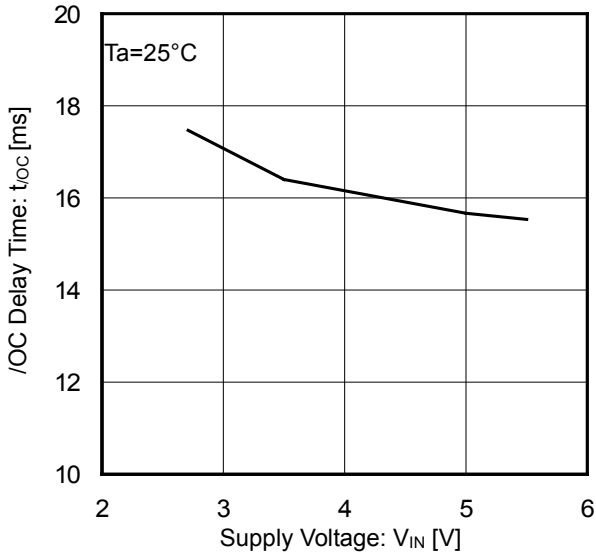
Figure 28. /OC Delay Time vs
Supply Voltage
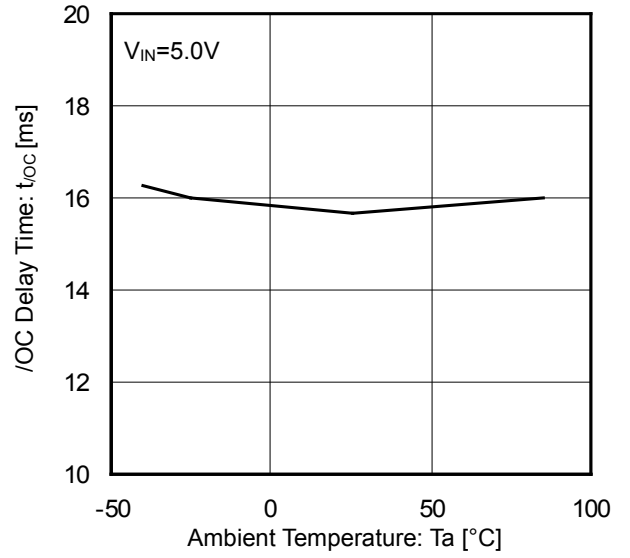
Figure 29. /OC Delay Time vs
Ambient Temperature
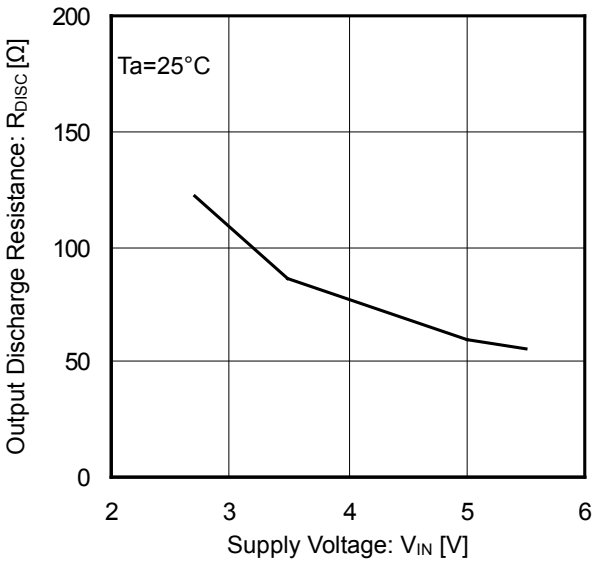
Figure 30. Output Discharge Resistance
vs Supply Voltage
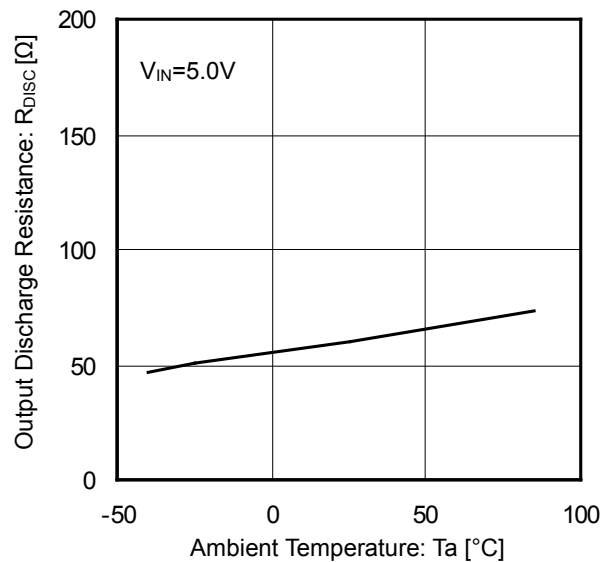
Figure 31. Output Discharge Resistance
vs Ambient Temperature

Typical Wave Forms
(BD2232G)

V_{EN}
(5V/div.)

$V_{/OC}$
(5V/div.)

V_{OUT}
(5V/div.)

V_{IN}=5V

R_L=20Ω

I_{OUT}
(0.5A/div

TIME(1ms/div.)
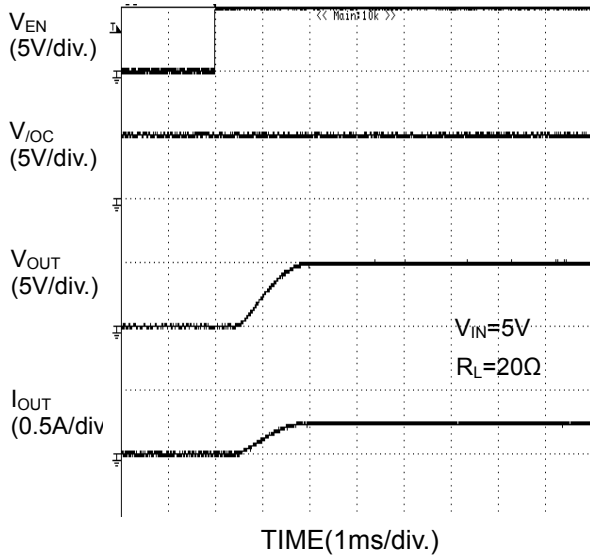
Figure 32. Output Rise Characteristic

V_{EN}
(5V/div.)

$V_{/OC}$
(5V/div.)

V_{OUT}
(5V/div.)

V_{IN}=5V

R_L=20Ω

I_{OUT}
(0.5A/div.)

TIME(1μs/div.)
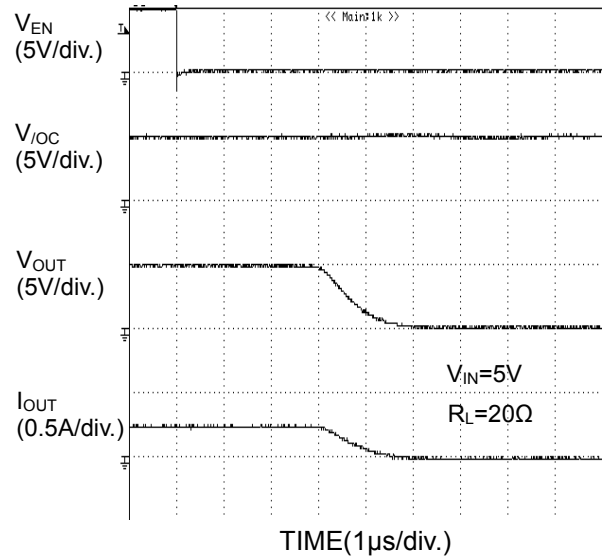
Figure 33. Output Fall Characteristic

V_{EN}
(5V/div.)

$V_{/OC}$
(5V/div.)

C_L=220μF

C_L=100μF

I_{OUT}
(0.2A/div.)

C_L=47μF

V_{IN}=5V

R_L=20Ω

TIME (1ms/div.)
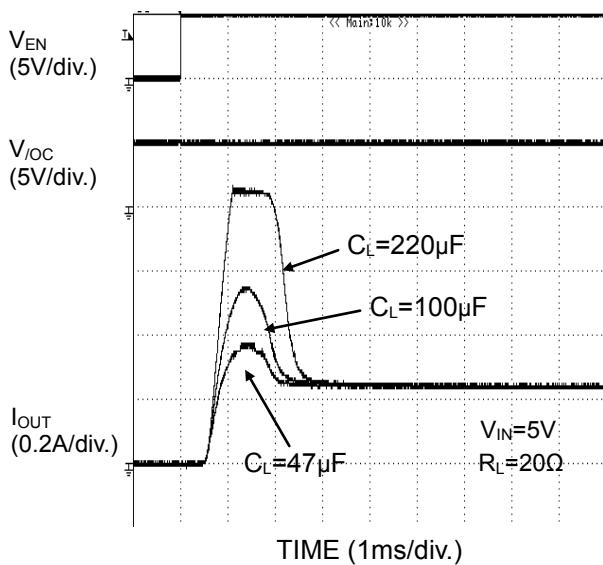
Figure 34. Inrush Current Response

$V_{/OC}$
(5V/div.)

V_{OUT}
(5V/div.)

I_{OUT}
(0.5A/div.)

V_{IN}=5V

TIME (5ms/div.)
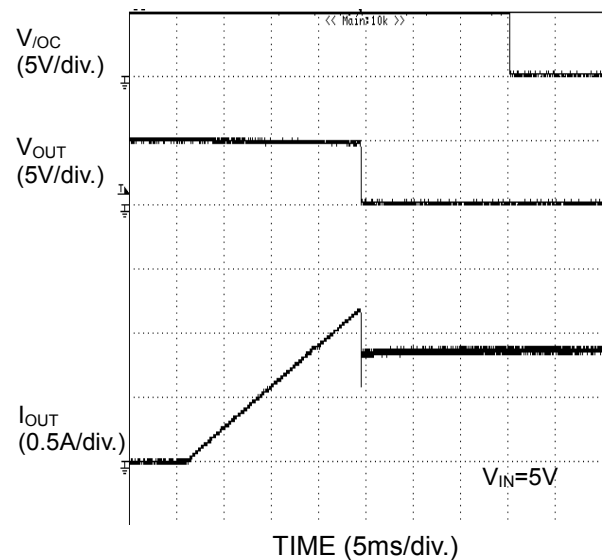
Figure 35. Over-Current Response
Ramped Load

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Typical Wave Forms - continued

Figure 36. Over-Current Response
Enable to Short Circuit
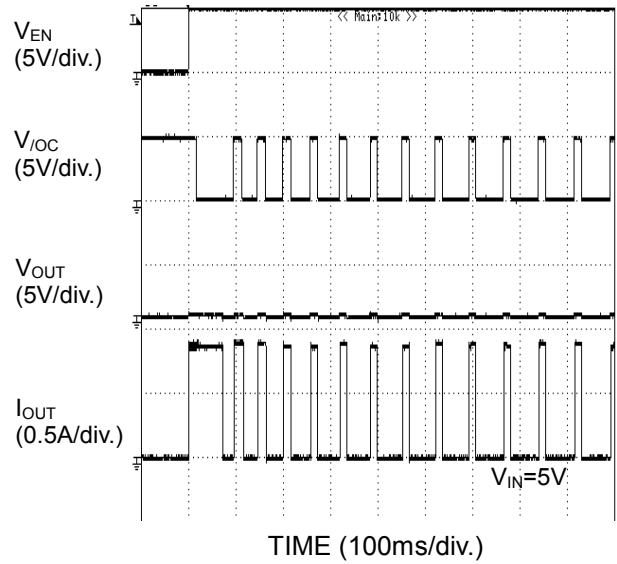
Figure 37. Over-Current Response
Enable to Short Circuit
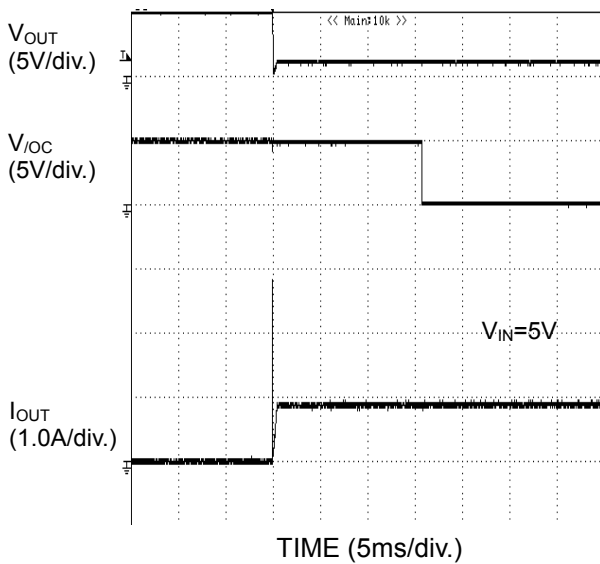
Figure 38. Over-Current Response
1ΩLoad Connected at EN
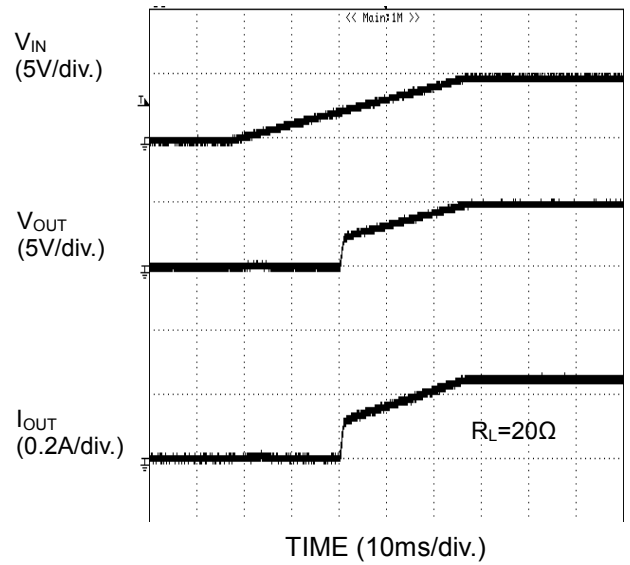
Figure 39. UVLO Response when
Increasing V_{IN}

Typical Wave Forms - continued

V_{IN}
(5V/div.)

V_{OUT}
(5V/div.)

I_{OUT}
(0.2A/div.)

$R_L = 20\Omega$

TIME (10ms/div.)
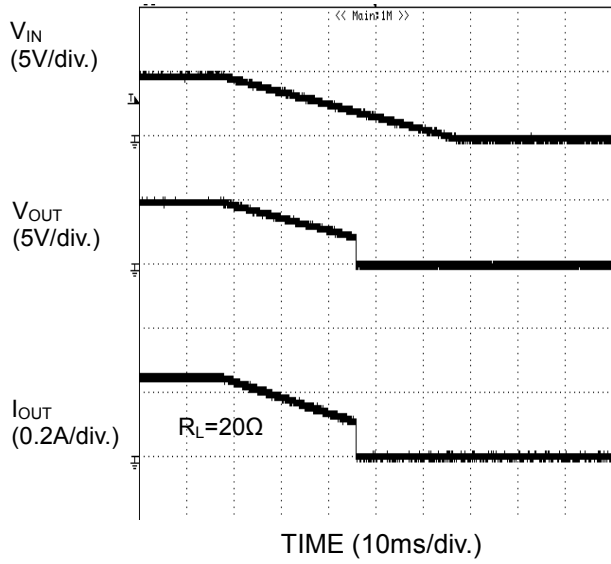
Figure 40. UVLO Response when
Decreasing V_{IN}

Typical Application Circuit
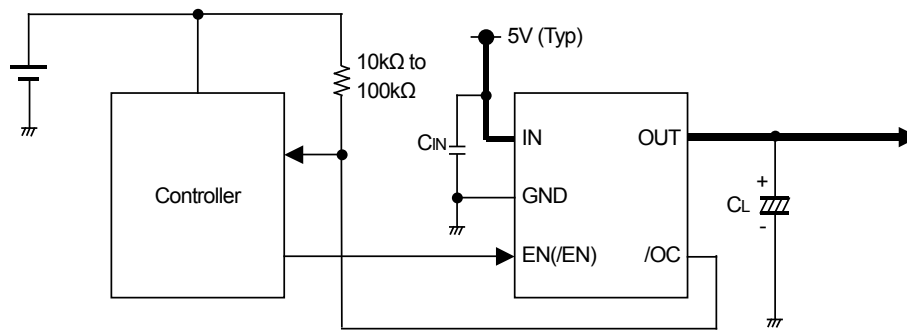
Application Information

When excessive current flows due to output short-circuit or so, ringing occurs because of inductance between power source line to IC, and may cause bad influences on IC operations. In order to avoid this case, connect a bypass capacitor across IN terminal and GND terminal of IC. 1µF or higher is recommended. In order to decrease voltage fluctuations from power source line to IC, connect a low ESR capacitor in parallel with C_{IN}. 10µF to 100µF or higher is effective.

Pull up /OC output by 10kΩ to 100kΩ resistance.
Set up value which satisfies the application as C_L.
This application circuit does not guarantee its operation.
When using the circuit with changes to the external circuit constants, make sure to leave an adequate margin for external components including AC/DC characteristics as well as dispersion of the IC.

Functional Description

1. Switch Operation

   IN terminal and OUT terminal are connected to the drain and the source of switch MOSFET respectively. And the IN terminal is used also as power source input to internal control circuit.

   When the switch is turned on from EN, /EN control input, IN terminal and OUT terminal are connected by a 100mΩ(Typ) switch. At on state, the switch is bidirectional, therefore, when the potential of OUT terminal is higher than that of IN terminal, current flows from OUT terminal to IN terminal.

2. Thermal Shutdown Circuit (TSD)

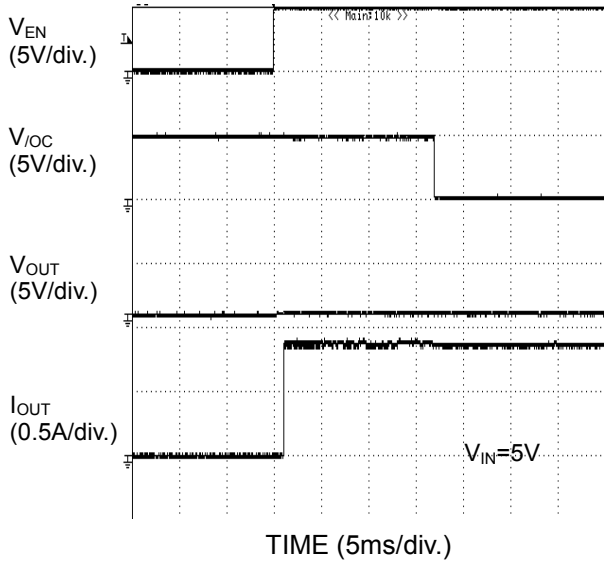   If over-current would continue, the temperature of the IC would increase drastically. If the junction temperature is beyond 135°C (Typ) in the condition of over-current detection, thermal shutdown circuit operates and makes power switch turn off and outputs fault flag (/OC). Then, when the junction temperature decreases lower than 115°C (Typ), power switch is turned on and fault flag (/OC) is cancelled. Unless the increasing of the chip's temperature is removed or the output of power switch is turned off, this operation repeats.
   The thermal shutdown circuit operates when the switch is on (EN, /EN signal is active).

3. Over-Current Detection (OCD)

   The over-current detection circuit limits current (I_{SC}) and outputs fault flag (/OC) when current flowing in each switch MOSFET exceeds a specified value. The over-current detection circuit works when the switch is on (EN, /EN signal is active). There are three types of response against over-current.

   (1) When the switch is turned on while the output is in shortcircuit status
       When the switch is turned on while the output is in shortcircuit status or so, the switch gets in current limit status immediately.

   (2) When the output shortcircuits while the switch is on
       When the output shortcircuits or high-current load is connected while the switch is on, very large current will flow until the over-current limit circuit reacts. When the current detection and limit circuit works, current limitation is carried out.

   (3) When the output current increases gradually
       When the output current increases gradually, current limitation does not work until the output current exceeds the over-current detection value. When it exceeds the detection value, current limitation is carried out.

4. Under-Voltage Lockout (UVLO)

   UVLO circuit prevents the switch from turning on until the V_{IN} exceeds 2.3V(Typ). If the V_{IN} drops below 2.2V(Typ) while the switch turns on, then UVLO shuts off the power switch. UVLO has hysteresis of 100mV(Typ). Under-voltage lockout circuit works when the switch is on (EN, /EN signal is active).

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5. Fault Flag (/OC) Output
   Fault flag output is an N-MOS open drain output. At detection of over-current or thermal shutdown, output is low-level.
   Over-current detection has delay filter. This delay filter prevents instantaneous current detection such as inrush current at
   switch on, hot plug from being informed to outside. . If fault flag output is unused, /OC pin should be connected to open
   or ground line.

6. Output Discharge Function
   When the switch is turned off from disable control input or UVLO function, the 60Ω(Typ.) discharge circuit between OUT
   and GND turns on. By turning on this switch, electric charge at capacitive load is discharged. But when the voltage of IN
   declines extremely, then the OUT pin becomes Hi-Z without UVLO function.
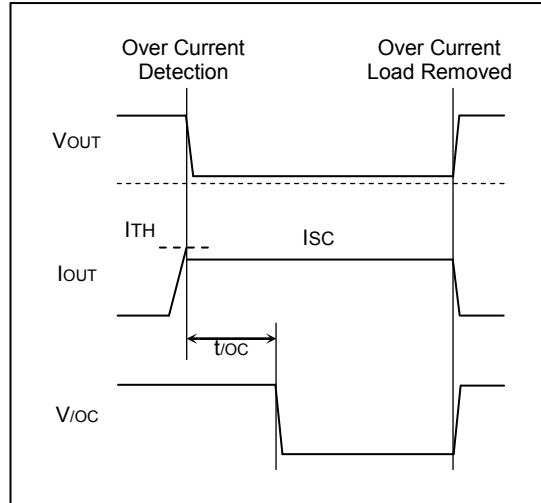
Figure 41. Over-Current Detection
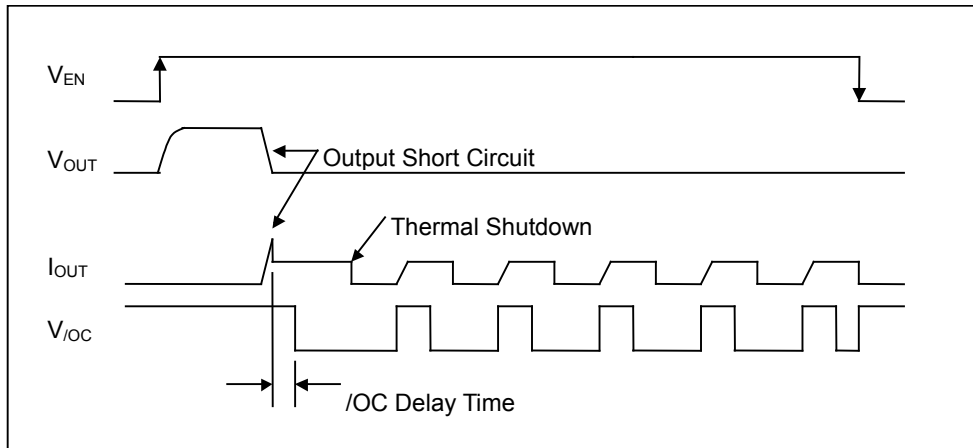
Figure 42. Over-Current Detection, Thermal Shutdown Timing (BD2232G)
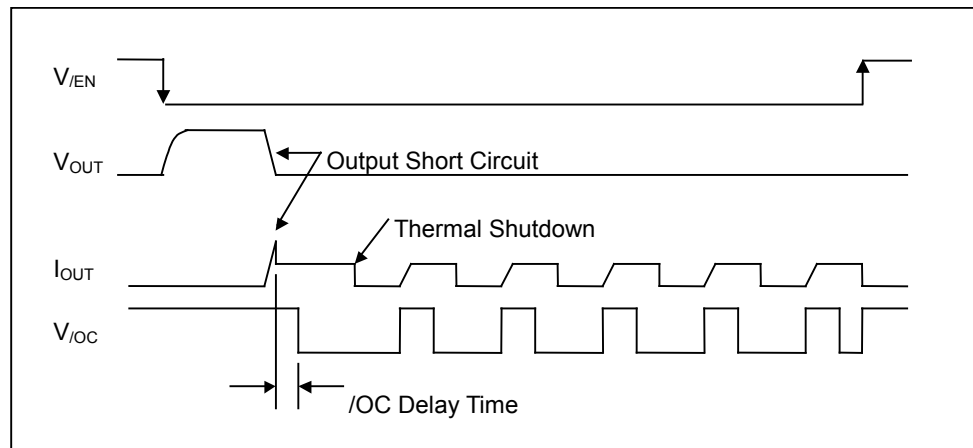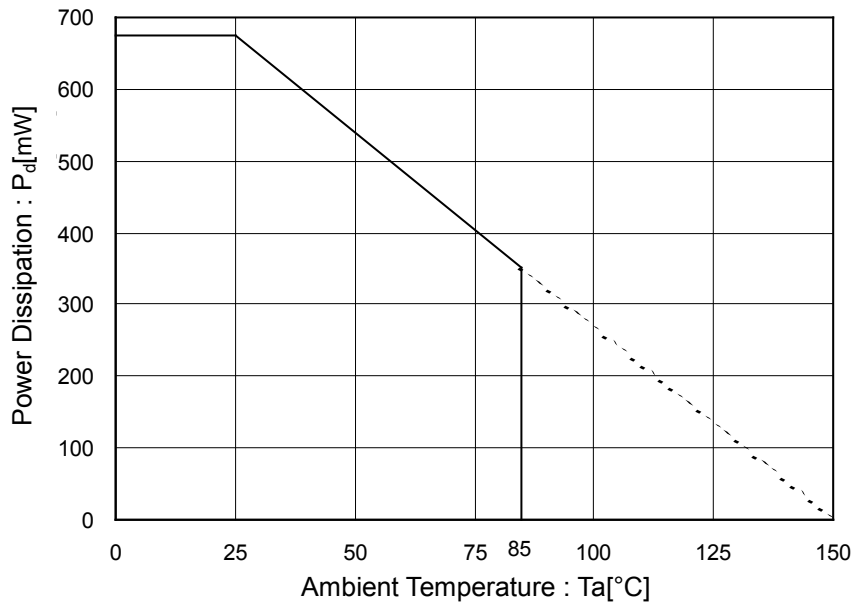

Figure 43. Over-Current Detection, Thermal Shutdown Timing (BD2233G)

Power Dissipation

(SSOP5 package)

70mm x 70mm x 1.6mm Glass Epoxy Board

Figure 44. Power Dissipation Curve (Pd-Ta Curve)

I/O Equivalence Circuit

Symbol	Pin No.	Equivalence Circuit
EN (/EN)	3	
OUT	5	
/OC	4	

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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. **Thermal Consideration**
   Should by any chance the power dissipation rating be exceeded the rise in temperature of the chip may result in deterioration of the properties of the chip. The absolute maximum rating of the Pd stated in this specification is when the IC is mounted on a 70mm x 70mm x 1.6mm glass epoxy board. In case of exceeding this absolute maximum rating, increase the board size and copper area to prevent exceeding the Pd rating.

6. **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.

7. **In rush 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.

8. **Operation Under Strong Electromagnetic Field**
   Operating the IC in the presence of a strong electromagnetic field may cause the IC to malfunction.

9. **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.

10. **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.

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Operational Notes - continued

11. 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.

12. 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.
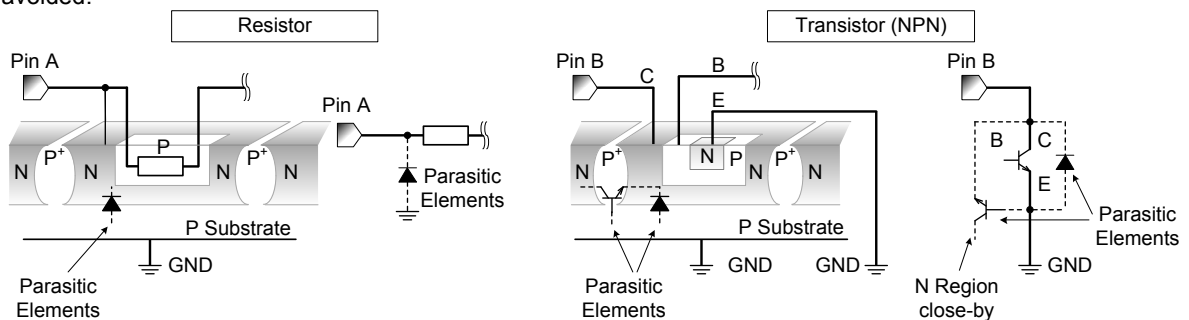
Figure 45. Example of monolithic IC structure

13. 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.

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 (Tj) will rise which will activate the TSD circuit that will turn OFF all output pins. When the Tj 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. Thermal design

Perform thermal design in which there are adequate margins by taking into account the power dissipation (Pd) in actual states of use.

Ordering Information

| B | D | 2 | 2 | 3 | 2 | G | - | G T R |

Part Number

Package
G: SSOP5

Packaging and forming specification
G: Halogen free Package
TR: Embossed tape and reel

| B | D | 2 | 2 | 3 | 3 | G | - | G T R |

Part Number

Package
G: SSOP5

Packaging and forming specification
G: Halogen free Package
TR: Embossed tape and reel

Marking Diagram

SSOP5 (TOP VIEW)

Part Number Marking
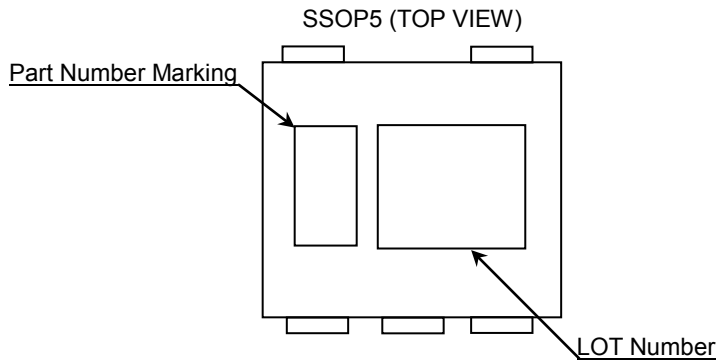
LOT Number

Part Number	Part Number Marking
BD2232G	J1
BD2233G	J7

Physical Dimension, Tape and Reel Information

Package Name	SSOP5

2.9±0.2

2.8±0.2

$1.6^{+0.2}_{-0.1}$

4°$^{+6°}_{-4°}$

0.2MIN

$0.13^{+0.05}_{-0.03}$

S

1.25MAX

$1.1±0.05$

$0.05±0.05$

0.95

$0.42^{+0.05}_{-0.04}$

⌓ 0.1 S

(UNIT:mm)
PKG:SSOP5
Drawing No. EX106-5001-2
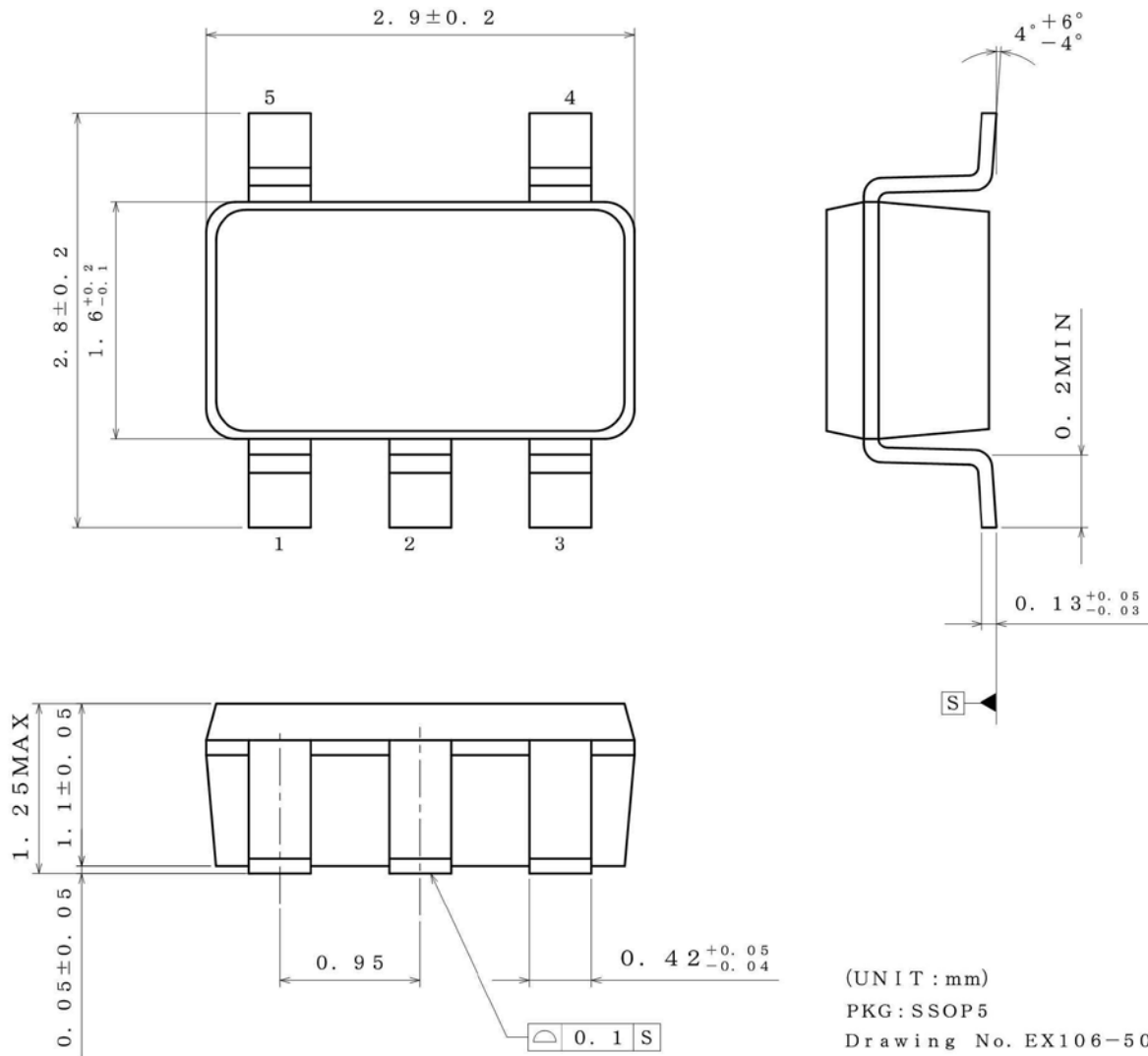
< Tape and Reel Information >

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

Pin 1

Reel

Direction of feed
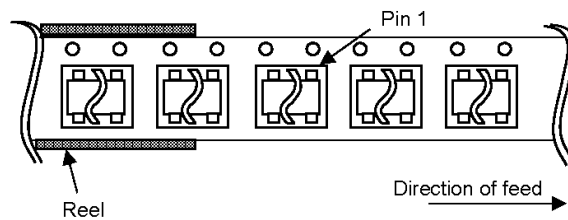
Revision History

Date	Revision	Changes
11.Mar.2013	001	New Release
25.Jun.2013	002	Modified Y-axis of figure 4. Ordering information is revised.
21.Aug.2014	003	Ordering information is revised. Applied the ROHM Standard Style and improved understandability. Improved Symbol name. Improved the spell of Y-axis in figure 26 and 27. Add Figure 14 and 15. Add Output Discharge Function explanation at page17.

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(Note1) Medical Equipment Classification of the Specific Applications

JAPAN	USA	EU	CHINA
CLASSⅢ	CLASSⅢ	CLASSⅡb	CLASSⅢ
CLASSⅣ		CLASSⅢ	

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    [b] Use of our Products outdoors or in places where the Products are exposed to direct sunlight or dust
    [c] Use of our Products in places where the Products are exposed to sea wind or corrosive gases, including Cl_2, H_2S, NH_3, SO_2, and NO_2
    [d] Use of our Products in places where the Products are exposed to static electricity or electromagnetic waves
    [e] Use of our Products in proximity to heat-producing components, plastic cords, or other flammable items
    [f] Sealing or coating our Products with resin or other coating materials
    [g] Use of our Products without cleaning residue of flux (even if you use no-clean type fluxes, cleaning residue of flux is recommended); or Washing our Products by using water or water-soluble cleaning agents for cleaning residue after soldering
    [h] Use of the Products in places subject to dew condensation

4. The Products are not subject to radiation-proof design.

5. Please verify and confirm characteristics of the final or mounted products in using the Products.

6. In particular, if a transient load (a large amount of load applied in a short period of time, such as pulse. is applied, confirmation of performance characteristics after on-board mounting is strongly recommended. Avoid applying power exceeding normal rated power; exceeding the power rating under steady-state loading condition may negatively affect product performance and reliability.

7. De-rate Power Dissipation (Pd) depending on Ambient temperature (Ta). When used in sealed area, confirm the actual ambient temperature.

8. Confirm that operation temperature is within the specified range described in the product specification.

9. ROHM shall not be in any way responsible or liable for failure induced under deviant condition from what is defined in this document.

Precaution for Mounting / Circuit board design

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2. In principle, the reflow soldering method must be used; if flow soldering method is preferred, please consult with the ROHM representative in advance.

For details, please refer to ROHM Mounting specification

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    [b] the temperature or humidity exceeds those recommended by ROHM
    [c] the Products are exposed to direct sunshine or condensation
    [d] the Products are exposed to high Electrostatic

2. Even under ROHM recommended storage condition, solderability of products out of recommended storage time period may be degraded. It is strongly recommended to confirm solderability before using Products of which storage time is exceeding the recommended storage time period.

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4. Use Products within the specified time after opening a humidity barrier bag. Baking is required before using Products of which storage time is exceeding the recommended storage time period.

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