I_{OUT} = 3 A, V_{IN} = 10 V Linear Regulator IC

SI-3011ZD

Data Sheet

Description

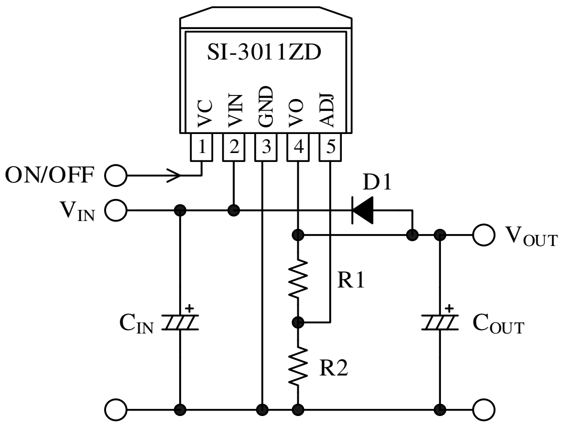
The SI-3011ZD is a linear regulator IC whose maximum output current is 3 A. Output voltage is adjusted by external resistors.

The IC has a built-in low saturation PNP bipolar transistor and can operate with a low input/output voltage difference. The IC has various functions including the Output On/Off Function, the Overcurrent Protection and the Thermal Shutdown, and achieves a linear regulator circuit with few external components.

Features

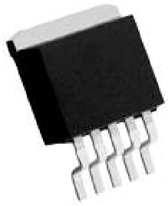
- Adjustable Output Voltage (V_{OUT} = 1.2 V to 5.0 V)
- Low Dropout Voltage, $\Delta V_{DIF} \leq 0.6$ V (I_{OUT} = 3 A)
- Output On/Off Function
- Protections
  Overcurrent Protection (OCP): Fold-back
  Thermal Shutdown (TSD) with Hysteresis: Auto-restart

Typical Application



Packages

TO263-5L



Not to scale

Specifications

- Recomended Input Voltage, V_{IN} = 2.4 V to 6.0 V
- Reference Voltage, V_{REF} = 1.1 V ± 2%
- Output Current, I_{OUT} = 3.0 A
- Dropout Voltage, $\Delta V_{DIF} \leq 0.6$ V (I_{OUT} = 3 A)

Applications

- Audio Visual Equipment
- Office Automation Equipment
- White Goods

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Contents

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1. Absolute Maximum Ratings

Unless otherwise specified, $T_A = 25$ °C.

Parameter	Symbol	Conditions	Rating	Unit
VIN Pin Voltage	V_{IN}		10	V
VC Pin Voltage	V_C	$V_C \leq V_{IN}$	6	V
Output Current	I_{OUT}		3	A
Power Dissipation	P_D	Mounted on the board [(1)]	3	W
Junction Temperature [(2)]	T_J		−30 to 125	°C
Operating Ambient Temperature [(2)]	T_{OP}		−30 to 85	°C
Storage Temperature	T_{STG}		−40 to 125	°C

[(1)] Glass-epoxy board (40 mm × 40 mm), copper area 100%
[(2)] When the junction temperature increases to 135 °C or more, the thermal shutdown is activated.

2. Thermal Resistance Characteristics

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Thermal Resistance between Junction and Ambient	$\theta_{J\text{-}A}$	[(1)]	—	—	33.3	°C/W
Thermal Resistance between Junction and Case[(2)]	$\theta_{J\text{-}C}$		—	—	3	°C/W

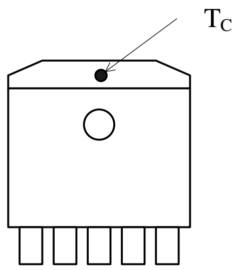

Figure 2-1. Case Temperature Measurement Point

[(1)] The IC is mounted on the glass-epoxy board (40 mm × 40 mm) with copper area 100%.
[(2)] The case temperature (°C) is measured at the point defined in Figure 2-1.

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3. Recommended Operating Range

Parameter	Symbol	Min.	Max.	Unit
VIN Pin Voltage	V_{IN}	(3)	6(4)	V
Output Current	I_{OUT}	0	3(2)	A
Output Voltage	V_{OUT}	1.2	5	V
Operating Ambient Temperature	$T_{OP(A)}$	−20	85	°C
Operating Junction Temperature	$T_{OP(J)}$	−20	100	°C

(3) When setting the output voltage to 2.0 V or lower, set the input voltage to 2.4 V or higher.

(4) The following equation shows the relationship between V_{IN}, V_{OUT}, and I_{OUT}. Thus, Dropout Voltage ($V_{IN} - V_{OUT}$) and/or I_{OUT} may be limited in some conditions.

$$P_D = (V_{IN} - V_{OUT}) \times I_{OUT}$$

4. Electrical Characteristics

Current polarities are defined as follows: current going into the IC (sinking) is positive current (+); current coming out of the IC (sourcing) is negative current (−).

Unless otherwise specified, $T_A = 25$ °C.

Parameter	Symbol	Conditions (1)	Min	Typ.	Max	Unit
Reference Voltage	V_{REF}	$V_{IN} = V_{OUT} + 1$ V, $I_{OUT} = 10$ mA	1.078	1.100	1.122	V
Line Regulation	ΔV_{LINE}	$V_{IN} = 3.3$ V to 5 V, $I_{OUT} = 10$ mA, $V_{OUT} = 2.5$ V	—	—	10	mV
Load Regulation	ΔV_{LOAD}	$V_{IN} = 3.3$ V, $I_{OUT} = 0$ A to 10 mA, $V_{OUT} = 2.5$ V	—	—	40	mV
Dropout Voltage	ΔV_{DIF}	$I_{OUT} = 3$ A	—	—	0.6	V
Output Voltage Temperature Coefficient	$\Delta V_{OUT}/\Delta T_A$	$T_J = 0$ °C to 100 °C	—	±0.05	—	mV/°C
Ripple Rejection Ratio	R_{REJ}	$V_{IN} = V_{OUT} + 1$ V, f = 100 Hz to 120 Hz	—	60	—	DB
Overcurrent Protection Operating Current (2)	I_{S1}	$V_{IN} = V_{OUT} + 1$ V, $I_{OUT} = 10$ mA	3.2	—	—	A
Quiescent Current	I_Q	$V_{IN} = V_{OUT} + 1$ V, $I_{OUT} = 10$ mA, $V_C = 2$ V	—	1.0	1.5	mA
Circuit Current during Regulator Output Off	$I_{Q(OFF)}$	$V_{IN} = V_{OUT} + 1$ V, $V_C = 0$ V	—	—	1	µA
VC Pin Voltage (Output On)	V_{C_IH}		2	—	—	V
VC Pin Voltage (Output Off)	V_{C_IL}		—	—	0.8	V
VC Pin Current (Output On)	I_{C_IH}	$V_C = 2.7$ V	—	—	100	µA
VC Pin Current (Output Off)	I_{C_IL}	$V_C = 0$ V	−5	0	—	µA

(1) Following equation shows the relationship between V_{IN}, V_{OUT}, and I_{OUT}. Thus, Dropout Voltage ($V_{IN} - V_{OUT}$) or I_{OUT} may be limited in some conditions.

$$P_D = (V_{IN} - V_{OUT}) \times I_{OUT}$$

(2) After the Overcurrent Protection is activated, I_{S1} is measured when the output voltage decreases by 5% from the reference output voltage ($I_{OUT} = 10$ mA).

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5. Performance Curves

Unless otherwise specified, $T_A = 25$ °C.

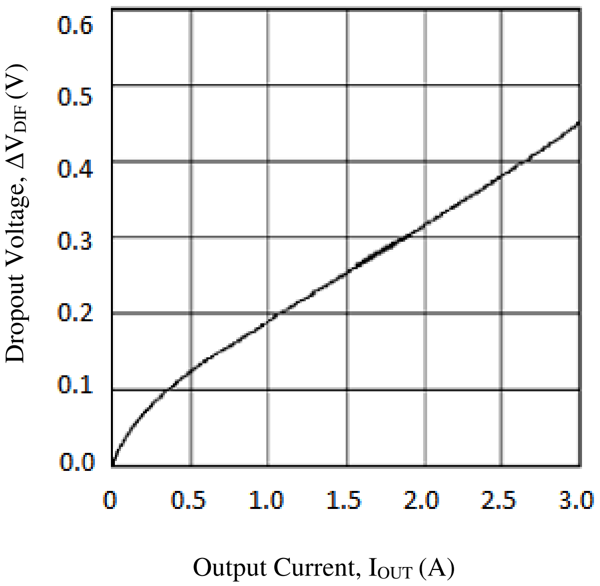

Figure 5-1. Dropout Voltage

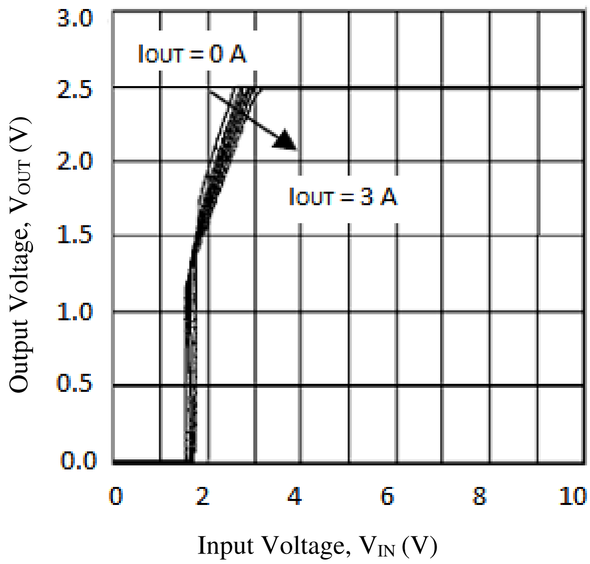

Figure 5-2. Output Rise Characteristics

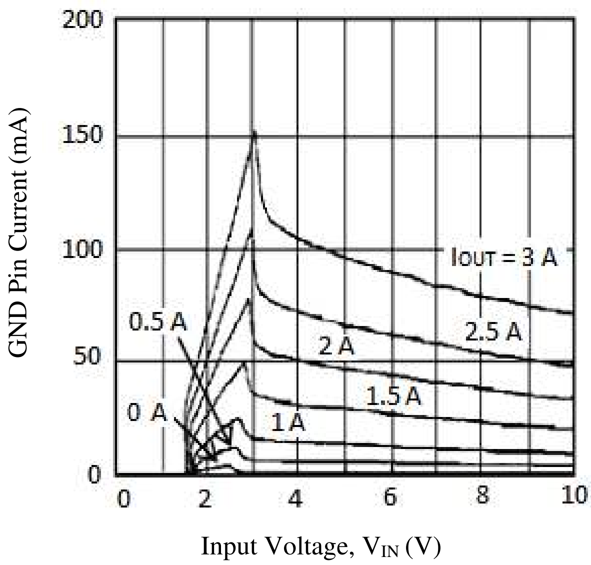

Figure 5-3. GND Pin Current

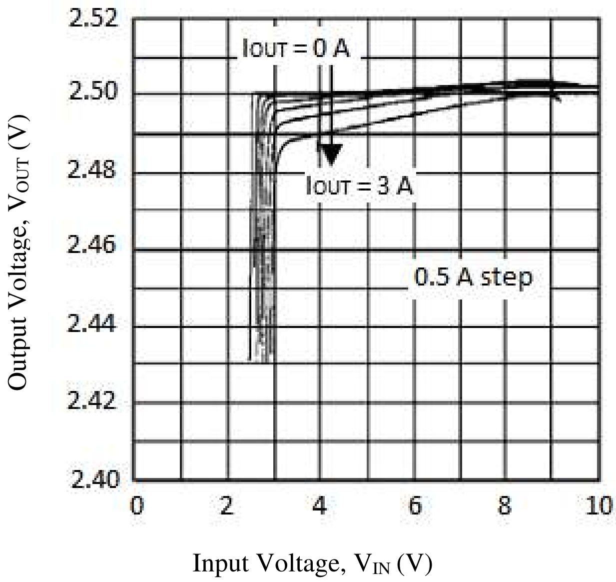

Figure 5-4. Line Regulation

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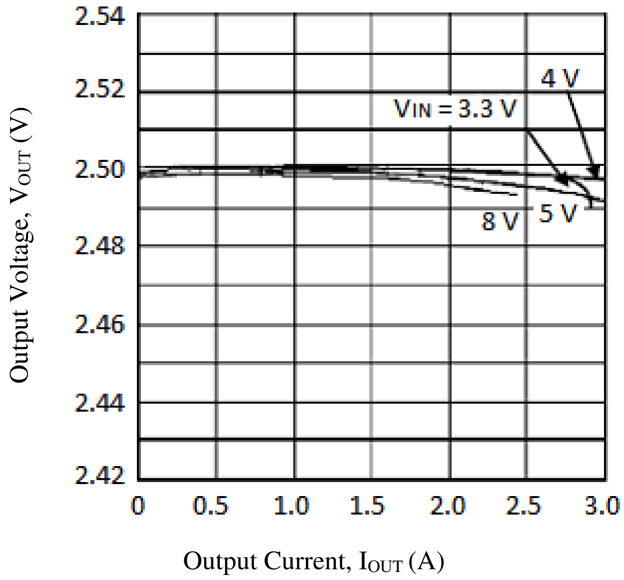

Figure 5-5. Load Regulation

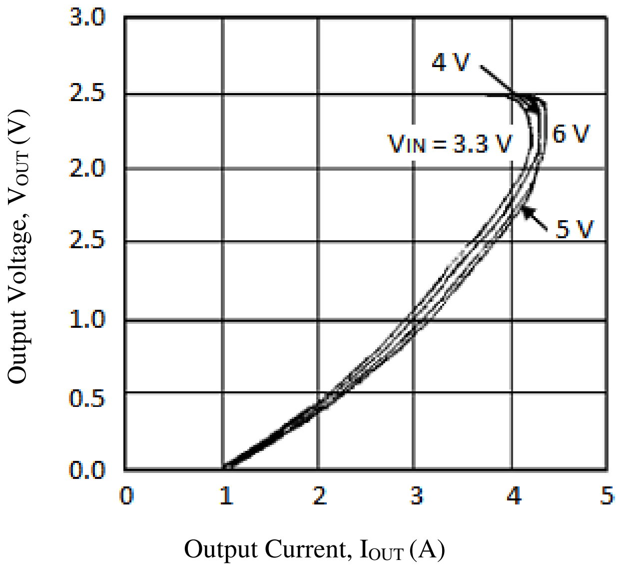

Figure 5-6. Overcurrent Protection Characteristics

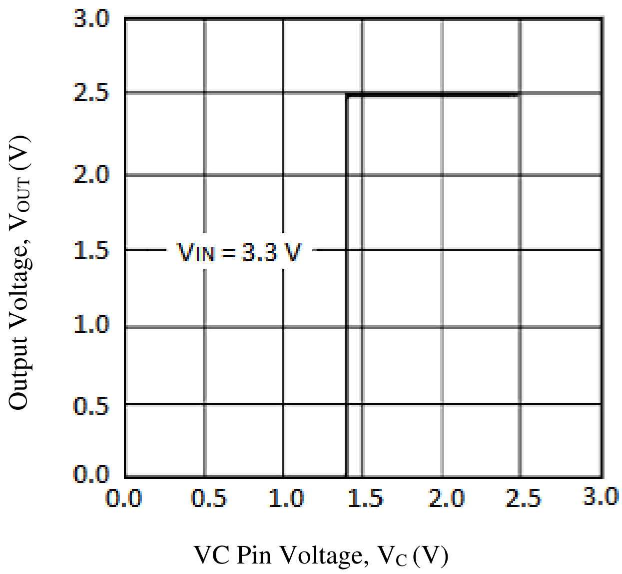

Figure 5-7. $V_{OUT} - V_C$

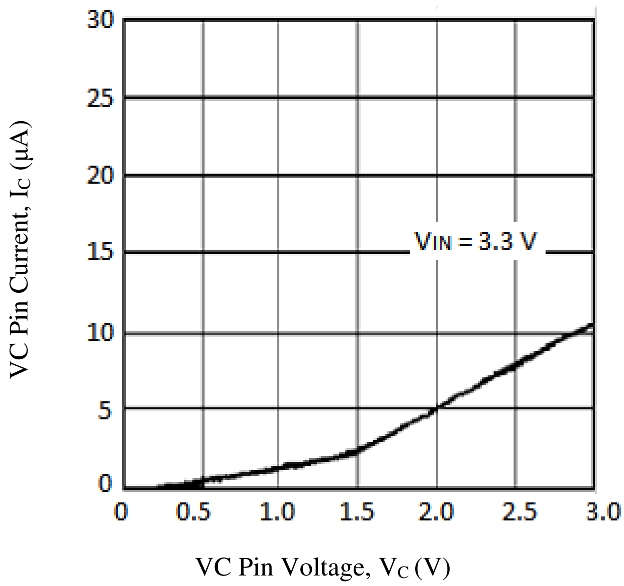

Figure 5-8. $I_C - V_C$

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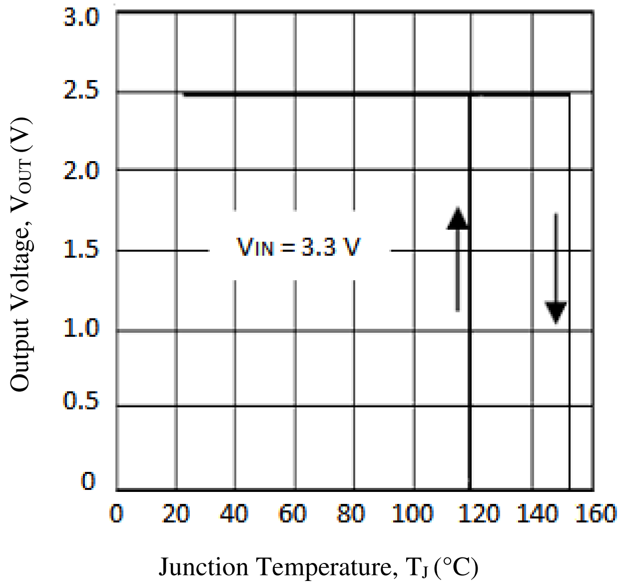

Figure 5-9. Thermal Shutdown Characteristics

6. Derating Curve

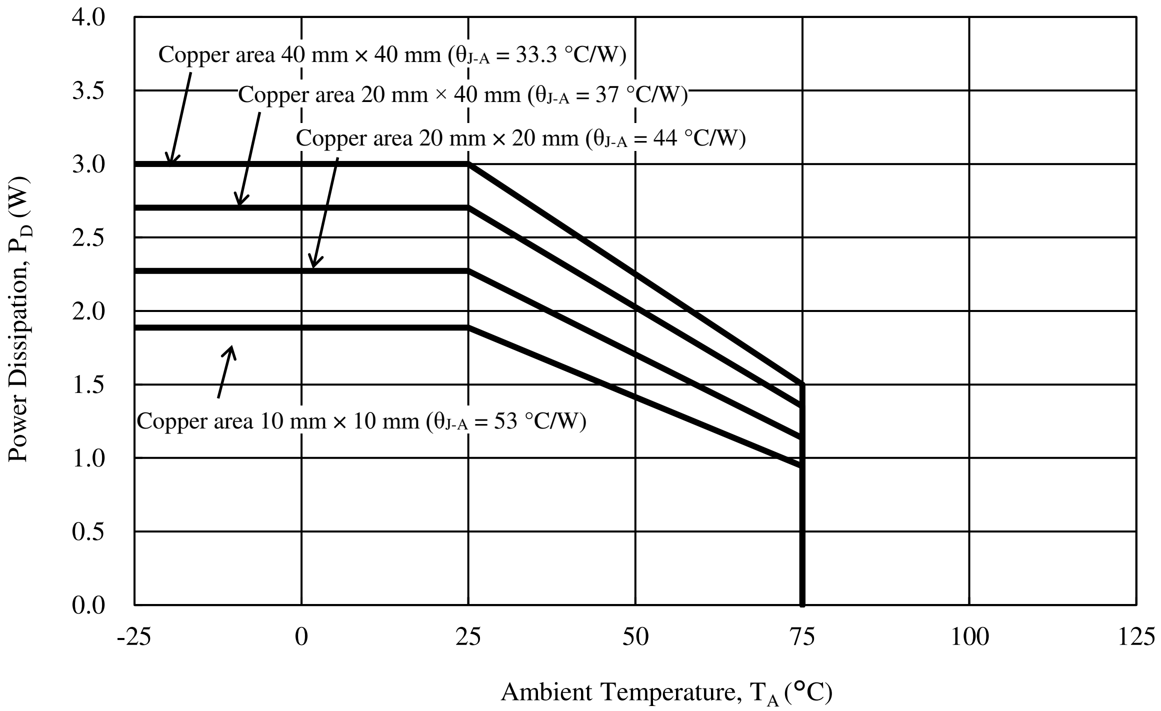

Figure 6-1. Power Dissipation, P_D vs. Ambient Temperature, T_A

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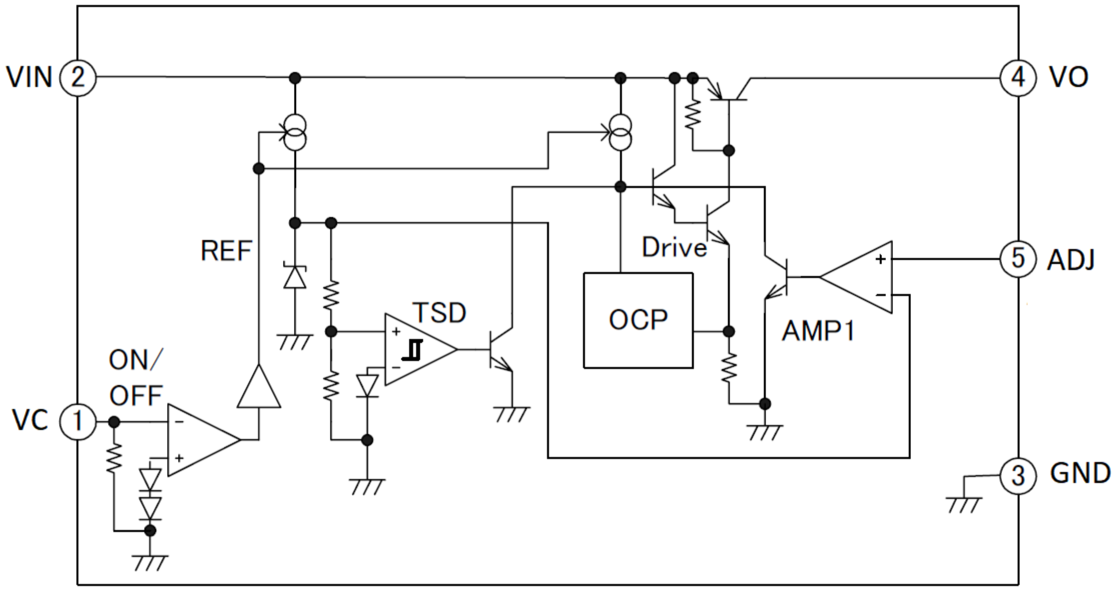
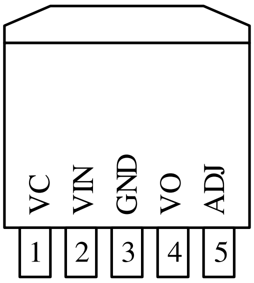
7. Block Diagram



8. Pin Configuration Definitions



Pin Number	Pin Name	Function
1	VC	On/off signal input
2	VIN	Voltage input
3	GND	Ground
4	VO	Voltage output
5	ADJ	Output voltage setting resistor connection
(Back Side)	—	Heatsink (A heatsink is internally connected to the GND pin. In order to improve heat dissipation, be sure to solder the heatsink of the IC to copper trace on PCB. The copper area should be as wide as possible.)

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9. Typical Application

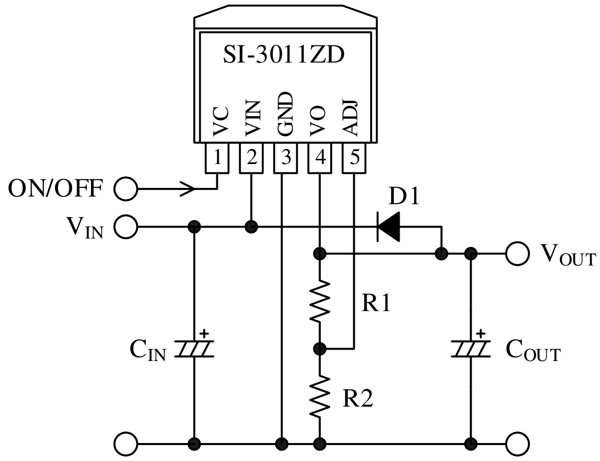

Figure 9-1. Typical Application (V_{OUT} > 1.8 V)

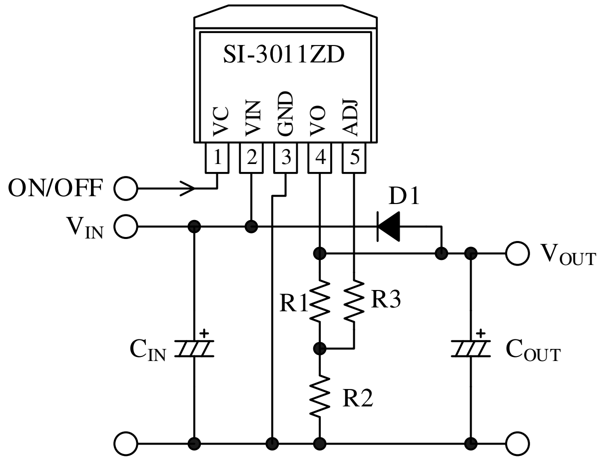

Figure 9-2. Typical Application ($V_{OUT} \leq 1.8$ V)

Table 9-1 Reference Value of External Components (V_{IN} = 6 V, V_{OUT} = 5 V)

Symbol	Part Type	Reference Value	Remarks
C_{IN}	Electrolytic capacitor/ ceramic capacitor	10 µF	C_{IN} is required when the input line contains inductance, or the wiring is long. C_{IN} should be connected as close as possible to the VIN and GND pins with short traces.
C_{OUT}	Electrolytic capacitor	≥ 47 µF	Ceramic capacitors cannot be used.
R1	Resistor	35.4 kΩ	Adjust resistance according to the output voltage. See Section 12.2.
R2	Resistor	10 kΩ	See Section 12.2.
R3	Resistor	10 kΩ	Add R3 when $V_{OUT} \leq 1.8$ V.
D1	Diode	See Section 13.2.	Add D1 when V_{OUT} > 3.3 V. Select a diode that has sufficient Surge Forward Current tolerance against the discharge current of C_{OUT}.

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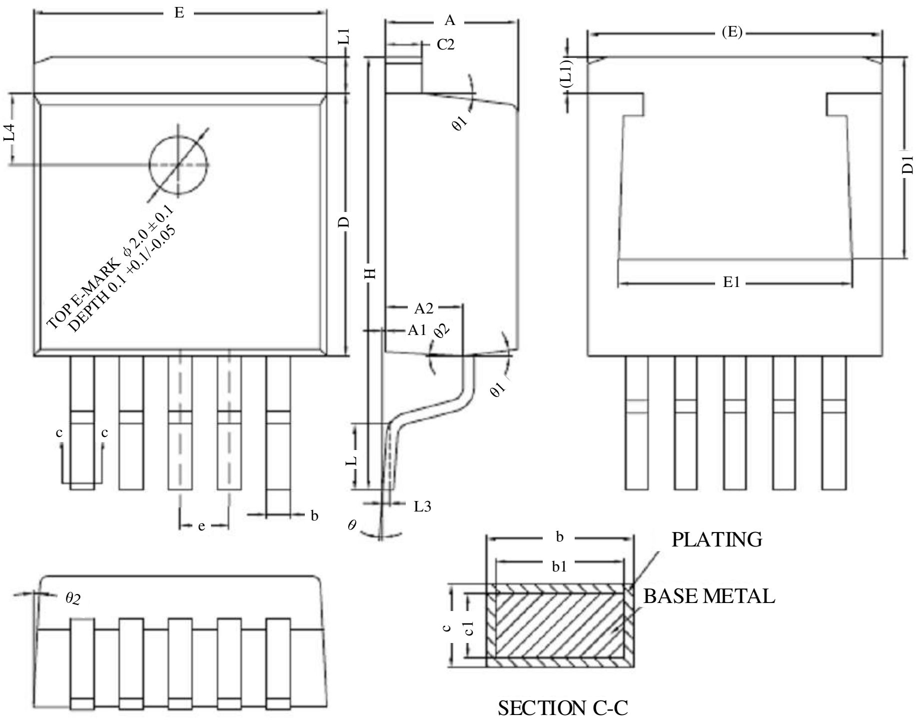
10. Physical Dimensions

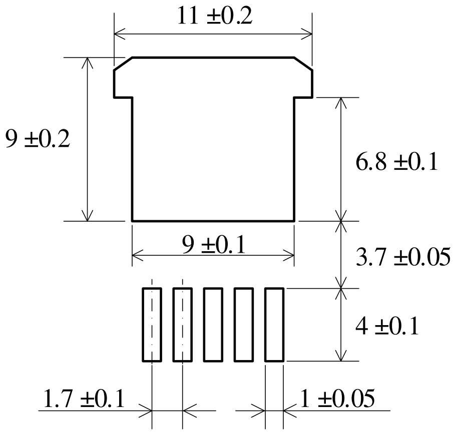
- **TO263-5L**



Symbol	Min.	Nom.	Max.
A	4.40	4.57	4.70
A1	0	0.10	0.25
A2	2.59	2.69	2.79
b	0.77	—	0.90
b1	0.76	0.81	0.86
c	0.34	—	0.47
c1	0.33	0.38	0.43
C2	1.22	—	1.32
D	9.05	9.15	9.25
D1	6.86	—	7.50
E	10.06	10.16	10.26
E1	7.50	—	8.30
e		1.70 BSC	
H	14.70	15.10	15.50
L	2.00	2.30	2.60
L1	1.17	1.27	1.40
L3		0.25 BSC	
L4		2.00 REF	
θ	0°	—	8°
θ1	5°	7°	9°
θ2	1°	3°	5°

NOTES:
- Dimensions in millimeters
- Bare lead frame: Pb-free (RoHS compliant)
- Dimensions do not include mold burrs.

10.1. Land Pattern Example



Dimensions in millimeters.

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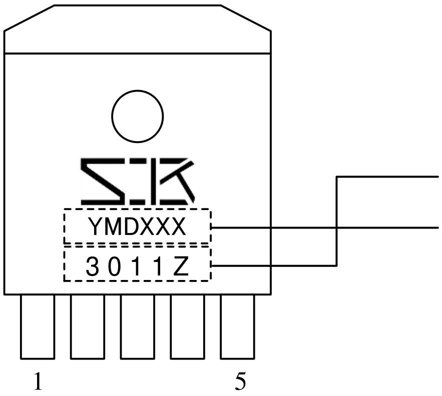
11. Marking Diagram



Specific Device Code (See Table 11-1.)

Lot Number:

Y is the last digit of the year of manufacture (0 to 9)

M is the month of the year (1 to 9, O, N, or D)

D is the period of days represented by:

1: the first 10 days of the month (1st to 10th)

2: the second 10 days of the month (11th to 20th)

3: the last 10–11 days of the month (21st to 31st)

XXX is the control number

Table 11-1 Specific Device Code

Specific Device Code	Part Number
3011Z	SI-3011ZD

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12. Operational Description

All the characteristic values given in this section are typical values, unless they are specified as minimum or maximum. See Figure 9-1 and Figure 9-2 for symbols used in the description.

12.1. Constant Voltage Control

The IC consists of some circuit such as a reference voltage, an error amplifier, and a PNP transistor.

To regulate the output voltage, the emitter-to-collector voltage of the PNP transistor is linear controlled so that the ADJ pin voltage becomes equal to the reference voltage by the internal error amplifier.

The thermal design must be taken into account, because the product of the emitter-collector voltage (Dropout Voltage) and the output current result in the loss of the IC.

12.2. Output Voltage Setting

Output voltage is adjusted by external resistors, R1 and R2 (see Figure 9-1 and Figure 9-2). The ADJ pin is for feedback signal input to set the output voltage. Do not apply any voltage other than this feedback signal to the ADJ pin.

The feedback current flowing through R1 and R2 is set to about 100 µA. The reference voltage of the ADJ pin, V_{REF}, is 1.10 V. R2 is calculated by Equation (1).

$$R2 = \frac{V_{REF}}{100\ (\mu A)} = \frac{1.10\ (V)}{100\ (\mu A)} = 11\ (k\Omega) \tag{1}$$

Output voltage, V_{OUT}, is calculated by Equation (2).

$$V_{OUT} = \frac{R1 + R2}{R2} \times V_{REF} \tag{2}$$

Thus, R1 is calculated by using Equation (3).

$$R1 = \frac{R2 \times (V_{OUT} - V_{REF})}{V_{REF}}$$

$$= \frac{10\ k\Omega \times (V_{OUT} - 1.10\ V)}{1.10\ V} \tag{3}$$

If the calculation result does not match the value defined by the E series, adjustment resistors should be added in series or parallel to R1.

When setting the output voltage to ≤ 1.8 V, add R3 as shown in Figure 9-2. R3 is about 10 kΩ.

12.3. Overcurrent Protection Function (OCP)

The IC has Overcurrent Protection (OCP) with the fold-back characteristic that the output current at the short circuit load (V_{OUT} = 0 V) is smaller than that at OCP activation (see Figure 5-6). In the short circuit load, the loss ($V_{IN} \times I_O$) of a fold-back system is less than the loss of the constant current or fold-forward system.

When the voltage across the output capacitor is 0 V at IC startup, the IC gradually increases the output voltage while limiting the output current with OCP.

12.4. Thermal Shutdown (TSD)

The IC has the Thermal Shutdown (TSD) with hysteresis. When the junction temperature of the IC increases to 130 °C or more, TSD is activated, and turns off the internal PNP transistor to shutdown the load current.

The temperature hysteresis of TSD is about 30 °C. When the junction temperature decreases to about 100 °C after the load current shutdown, the IC restarts the constant voltage control.

The TSD protects the IC against the heat generation when the loss of the IC increases due to the instantaneous short-circuit of the load. This does not guarantee the operation including the reliability in the short-circuit state for long period or the state where the heat generation continues.

12.5. Output On/Off Function

The output is turned on/off by the input signal to the VC pin. When the VC pin voltage, V_C, is 2 V or more, the output is supplied. When V_C is 0.8 V or less, the output is turned off. When the VC pin is open, the output is turned off.

Since the VC pin input is equivalent to the low power Schottky TTL circuit (LS-TTL), the VC pin can be driven directly by LS-TTL.

Note that the voltage applied to the VC pin should not exceed the maximum rating of 6 V.

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13. Design Notes

13.1. Considerations in Circuit Configuration

The overcurrent protection of the IC has the fold-back characteristic. To avoid startup failure, do not use the circuit configurations as follows:

- Constant current circuit is connected to the IC.
- CV/CC circuit is connected to the IC.
- Load 2 is stacked on Load 1 (see in Figure 13-1).
- The output voltage setting resistor is connected between the GND pin and Ground (see Figure 13-2).

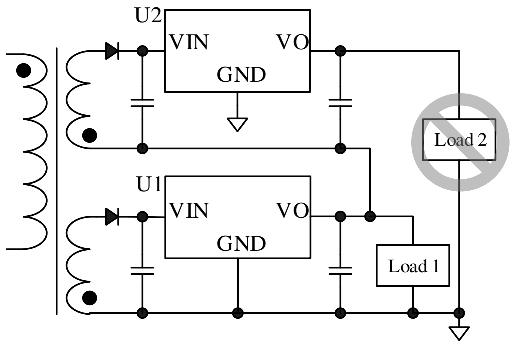

Figure 13-1 Stacked on Loads
(Do not connect Load 2.)

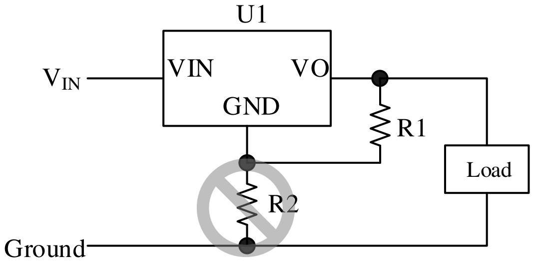

Figure 13-2 Output Voltage Setting
(Do not connect R2.)

13.2. External Components

- **Input Capacitor, C_{IN}**

The capacitor, C_{IN}, connected to the VIN pin is a bypass capacitor for suppressing noise and stabilizing voltage. Use electrolytic or ceramic capacitor for C_{IN}. The capacitance is about 0.47 µF to 22 µF.

- **Output Capacitor**

The output capacitor, C_{OUT}, is connected to the VO pin. C_{OUT} is a capacitor for phase compensation and is an electrolytic capacitor of ≥ 47 µF. Select an electrolytic capacitor with a series equivalent resistance (ESR) in the range of 0.2 Ω to 2 Ω.

If a low ESR type capacitor such as a ceramic capacitor is used for the output capacitor, the output voltage may oscillate.

- **Protection Diode for Reverse Biasing**

If the output voltage is 3.3 V or higher, connect the diode, D1, for reverse bias protection. The IC is protected when a reverse bias is applied between input and output such as when the input voltage is turned off. D1 is not required if the output voltage is less than 3.3 V.

13.3. PCB Pattern Layout

- **Input/ output Capacitor, C_{IN}, C_{OUT}**

Place C_{IN} and C_{OUT} as close as possible to the IC with a minimum length of traces to the VIN and VO pins.

- **Output Voltage Setting Resistor, R1, R2**

R1 and R2 should be placed as close as possible to the IC. R2 should be connected to the ADJ and GND pins with a minimum length of traces.

- **Ground**

Ground traces should be as wide and short as possible so that EMI levels can be reduced.

13.4. Thermal Design

Generally, the heat dissipation of an IC depends on the size and material of the board and the copper area. To improve the thermal performance, the copper area of the part where the backside of the IC is soldered should be as large as possible.

Figure13-3 shows the derating of the IC. When using the IC, ensure a sufficient margin.

Follow the procedure below to design heat dissipation.

(1) Measure the maximum ambient temperature, $T_{A(MAX)}$ of the IC.
(2) Change the input/output conditions and check the power dissipation, P_D. Calculate the maximum

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power dissipation, $P_{D(MAX)}$ with the Equation (4).

$$P_D = (V_{IN} - V_{OUT}) \times I_{OUT} \quad (4)$$

(3) Determine the copper area by confirming the intersection of ambient temperature and power dissipation by the thermal derating characteristics shown in Figure13-3.

For reference, Figure13-3 shows the relationship between the copper area and thermal resistance of a single-sided copper foil board, FR-4.

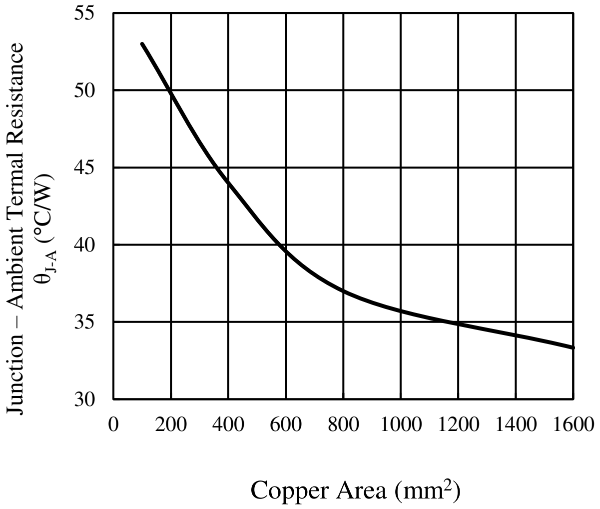

Figure13-3 Thermal Resistance – Copper Area Reference Characteristics (Single-sided Copper Foil Board, FR-4)

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