Application Note

Surface Molding Series Regulator IC

SI-3000KD Series

1st Edition January 2010

SANKEN ELECTRIC CO., LTD.

――― Contents ―――

1. General Information

The SI-3000KD is a series regulator IC using a hyposaturation type PNP bipolar transistor in the power section and it can be used with the low difference of input/output voltages. It is provided with an ON/OFF terminal which operates in Active High mode and the current consumption of circuits at OFF time is zero. Two product groups are available. One is a product group which can use a ceramic capacitor for the output capacitor at the voltage of 17V (SI-3012KD, SI-3033KD) and another is a group which can use an electrolytic capacitor for the output capacitor at the high voltage (35V) (SI-3010KD, SI-3050KD).

● 1-1 Features

- Output current 1A

  Output current is 1A at maximum with the outline of TO263-5.
- Hyposaturation (V_{dif} = 0.6Vmax / Io = 1A)

  It can be designed with low difference of input/output voltages.
- ON/OFF function

  The ON/OFF terminal which can be directly controlled by TTL logic signals is provided.
- Low current consumption

  Current consumption of circuits at OFF time is zero.

  Dark currents at no load are 350µA at maximum (SI-3012KD, SI-3033KD)

  and 600µA at maximum (SI-3010KD, SI-3050KD).
- High ripple attenuation ratio

  75dB (SI-3050KD): F = 100 - 120kHz)
- Built-in overcurrent protection

  The automatic restoration type overcurrent protection circuit is built in.

  SI-3012KD, SI-3033KD: Current limiting type overcurrent protection

  SI-3010KD, SI-3050KD: Fold back type overcurrent protection
- Built-in overheat protection

  Automatic restoration type overheat protection circuit is built in.

● 1-2 Application

For on-board local power supplies, power supplies for OA equipment, stabilization of secondary output voltage of regulator and power supply for communication equipment

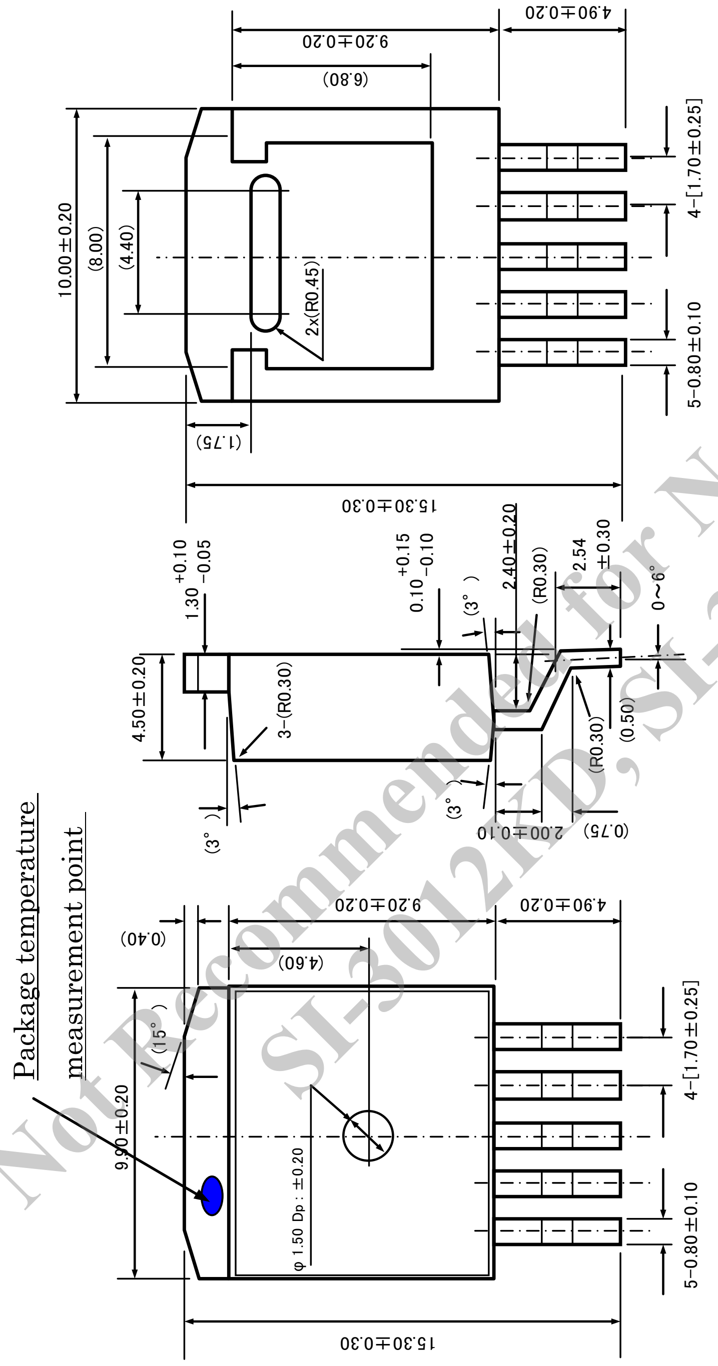
● 1-3 Type

- Type: Semiconductor integrated circuits (monolithic IC)
- Structure: Resin molding type (transfer molding)

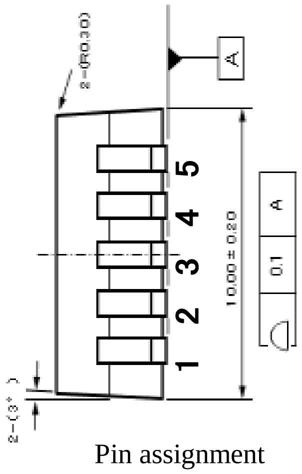
2. Specification

Unit: mm

● 2-1 Package Information



Note
1) Dimensions do not include molding burr.
2) Figures in parentheses ( ) are shown only for reference.
3) Figures in parentheses [ ] are dimensions after lead forming.
4) Backside bumps: 0.8 mm at maximum
5) Unit: mm



Products Weight：Approx.1.48g

The stem part has same potential as No. 3 pin (GND).

Pin assignment
1. Vc (on/off)
2. VIN
3. GND
4. Vout
5. ADJ

● 2-2 Ratings

2-2-1 Absolute Maximum Ratings Ta=25°C

Parameter	Symbol	Ratings		Unit
		SI-3012KD/3033KD	SI-3010KD/3050KD	
DC Input Voltage	V_{IN}	17	35*1	V
DC Output Current	Io	1.0		A
Power Dissipation	P_D*2	3		W
Junction Temperature	T_j	–30 to +125		°C
Storage Temperature	T_{stg}	–30 to +125		°C
Thermal Resistance (Junction to Ambient Air)	$\theta_{j\text{-}a}$	33.3		°C/W
Thermal Resistance (Junction to Case)	$\theta_{j\text{-}c}$	3		°C/W

*1: A built-in input-overvoltage-protection circuit shuts down the output voltage at the Input Overvoltage Shutdown Voltage of the electrical characteristics.

*2: When mounted on glass-epoxy board of 1600mm$_2$ (copper laminate area 100%).

2-2-2 Recommended Conditions

Parameter	Symbol	Ratings				Unit
		SI-3012KD	SI-3033KD	SI-3010KD	SI-3050KD	
Input Voltage	V_{IN}	2.4 - 6.0 *1	*2 - 6 *1	2.4 - 27 *1	*2 - 27 *1	V
Output Current	Io	0 - 1.0 *1				A
Operational Ambient Temperature	Top	-30 - 85				°C
Junction Temperature in Operation	Tj	-20 - 100				°C

*1: Because of the relation of Pd = (V_{IN} - Vo) × Io, Vin (max.) and Io (max.) may be restricted subject to conditions of use. For each value, refer to the data of copper foil area - permissible loss for calculation.

*2: It should be Vo + input/output voltage difference.

2-2-3 Electrical Characteristics (SI-3012KD, SI-3033KD)   Ta=25°C

Parameter		Symbol	Ratings						Unit
			SI-3012KD (Variable type)			SI-3033KD			
			min.	typ.	max.	min.	typ.	max.	
Input Voltage		V_{IN}	2.4*3		*4	*3		*4	V
Output Voltage (Reference Voltage for SI-3012KD)		V_O (V_{ADJ})	1.24	1.28	1.32	3.234	3.300	3.366	V
		Conditions	V_{IN}=3.3V, I_O=10mA			V_{IN}=5V, I_O=10mA			
Line Regulation		ΔV_{OLINE}			15			15	mV
		Conditions	V_{IN}=3.3 to 8V, I_O=10mA (V_O=2.5V)			V_{IN}=5 to 10V, I_O=10mA			
Load Regulation		ΔV_{OLOAD}			40			50	mV
		Conditions	V_{IN}=3.3V, I_O=0 to 1A (V_O=2.5V)			V_{IN}=5V, I_O=0 to 1A			
Dropout Voltage		V_{DIF}			0.4			0.4	V
		Conditions	I_O=0.5A (V_O=2.5V)			I_O=0.5A			
					0.6			0.6	
		Conditions	I_O=1A (V_O=2.5V)			I_O=1A			
Quiescent Circuit Current		I_q			350			350	μA
		Conditions	V_{IN}=3.3V, I_O=0A, V_C=2V, R2=2.4kΩ			V_{IN}=5V, I_O=0A, V_C=2V			
Circuit Current at Output OFF		I_q (OFF)			1			1	μA
		Conditions	V_{IN}=3.3V, V_C=0V			V_{IN}=5V, V_C=0V			
Temperature Coefficient of Output Voltage		$\Delta V_O/\Delta T_a$		±0.3			±0.3		mV/°C
		Conditions	T_j=0 to 100°C (V_O=2.5V)			T_j=0 to 100°C			
Ripple Rejection		R_{REJ}		55			55		dB
		Conditions	V_{IN}=3.3V, f=100 to 120Hz, I_O=0.1A (V_O=2.5V)			V_{IN}=5V, f=100 to 120Hz, I_O=0.1A			
Overcurrent Protection Starting Current*1		I_{S1}	1.1			1.1			A
		Conditions	V_{IN}=3.3V			V_{IN}=5V			
Vc Terminal	Control Voltage (Output ON)*2	$V_{C, IH}$	2			2			V
	Control Voltage (Output OFF)	$V_{C, IL}$			0.8			0.8	
	Control Current (Output ON)	$I_{C, IH}$			40			40	μA
		Conditions	V_C=2V			V_C=2V			
	Control Current (Output OFF)	$I_{C, IL}$	−5	0		−5	0		μA
		Conditions	V_C=0V			V_C=0V			

*1: Is1 is specified at the 5% drop point of output voltage Vo under the condition of Output Voltage parameter.

*2: Output is OFF when the output control terminal (Vc terminal) is open. Each input level is equivalent to LS-TTL level. Therefore, the device can be driven directly by LS-TTLs.

*3: Refer to the Dropout Voltage parameter.

*4: V_{IN} (max) and Io (max) are restricted by the relation $P_D = (V_{IN} – Vo) \times Io$. Please calculate these values referring to the Copper laminate area vs. Power dissipation data.

2-2-4 Electrical Characteristics (SI-3010KD, SI-3050KD) Ta=25°C

Parameter		Symbol	Ratings						Unit
			SI-3010KD (Variable type)			SI-3050KD			
			min.	typ.	max.	min.	typ.	max.	
Input Voltage		V_{IN}	2.4*1		27*5	*1		15*5	V
Output Voltage (Reference Voltage V_{ADJ} for SI-3010KD)		V_O (V_{ADJ})	0.98	1.00	1.02	4.90	5.00	5.10	V
		Conditions	V_{IN}=7V, I_O=10mA			V_{IN}=7V, I_O=10mA			
Line Regulation		ΔV_{OLINE}			30			30	mV
		Conditions	V_{IN}=6 to 11V, I_O=10mA (V_O=5V)			V_{IN}=6 to 11V, I_O=10mA			
Load Regulation		ΔV_{OLOAD}			75			75	mV
		Conditions	V_{IN}=7V, I_O=0 to 1A (V_O=5V)			V_{IN}=7V, I_O=0 to 1A			
Dropout Voltage		V_{DIF}			0.3			0.3	V
		Conditions	I_O=0.5A (V_O=5V)			I_O=0.5A			
					0.6			0.6	
		Conditions	I_O=1A (V_O=5V)			I_O=1A			
Quiescent Circuit Current		I_q			600			600	μA
		Conditions	V_{IN}=7V, I_O=0A, V_C=2V R2=10kΩ			V_{IN}=7V, I_O=0A, V_C=2V			
Circuit Current at Output OFF		I_q (OFF)			1			1	μA
		Conditions	V_{IN}=7V, V_C=0V			V_{IN}=7V, V_C=0V			
Temperature Coefficient of Output Voltage		$\Delta V_O/\Delta T_a$		±0.5			±0.5		mV/°C
		Conditions	T_j=0 to 100°C (V_O=5V)			T_j=0 to 100°C			
Ripple Rejection		R_{REJ}		75			75		dB
		Conditions	V_{IN}=7V, f=100 to 120Hz, I_O=0.1A (V_O=5V)			V_{IN}=7V, f=100 to 120Hz, I_O=0.1A			
Overcurrent Protection Starting Current*2 *4		I_{S1}	1.1			1.1			A
		Conditions	V_{IN}=7V			V_{IN}=7V			
Vc Terminal	Control Voltage (Output ON)*3	$V_{C, IH}$	2.0			2.0			V
	Control Voltage (Output OFF)*3	$V_{C, IL}$			0.8			0.8	
	Control Current (Output ON)	$I_{C, IH}$			40			40	μA
		Conditions	V_C=2V			V_C=2V			
	Control Current (Output OFF)	$I_{C, IL}$	−5	0		−5	0		μA
		Conditions	V_C=0V			V_C=0V			
Input Overvoltage Shutdown Voltage		V_{OVP}	33			26			V
		Conditions	I_O=10mA			I_O=10mA			

*1: Refer to the Dropout Voltage parameter.

*2: Is1 is specified at the 5% drop point of output voltage Vo under the condition of Output Voltage parameter.

*3: Output is OFF when the output control terminal (Vc terminal) is open. Each input level is equivalent to LS-TTL level. Therefore, the device can be driven directly by LS-TTLs.

*4: SI-3010KE, SI-3050KD, cannot be used in the following applications because the built-in foldback-type overcurrent protection may cause errors during start-up stage.

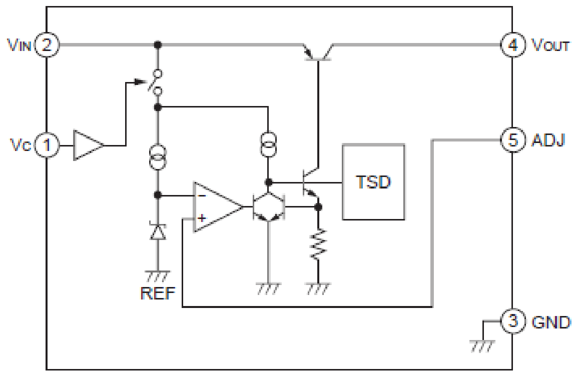
(1) Constant current load (2) Positive and negative power supply (3) Series-connected power supply (4) Vo adjustment by raising ground voltage

*5: V_{IN} (max) and Io (max) are restricted by the relation $P_D = (V_{IN} - Vo) \times Io$. Please calculate these values referring to the Copper laminate area vs. Power dissipation data.

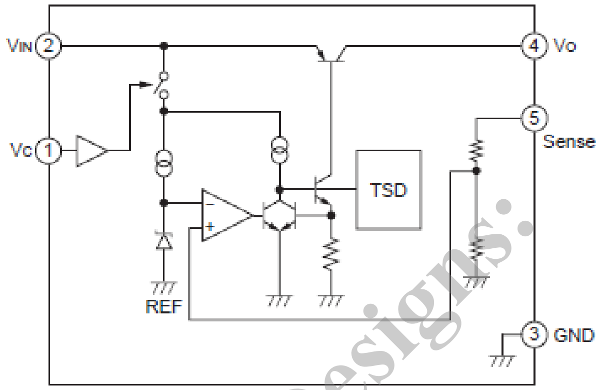
● 2-3 Circuit Diagram

2-3-1 Circuit block diagrams

(SI-3010KD, SI-3012KD)

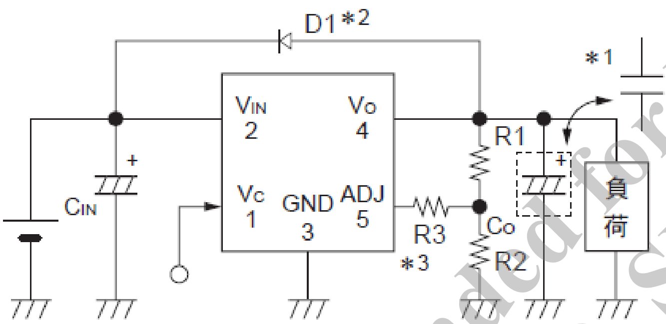


(SI-3033KD, SI-3050KD)

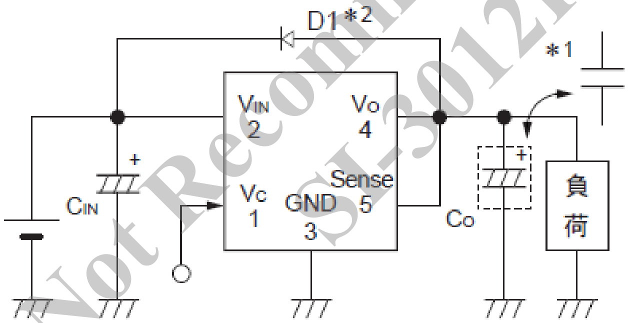


2-3-2 Typical Connection Diagram

(SI-3010KD, SI-3012KD)



(SI-3033KD, SI-3050KD)



*1　SI-3012KD/SI-3033KD

Low ESR capacitors such as ceramic capacitors are used for the output capacitor to compose a circuit. In the case that the electrolytic capacitor is used, it may oscillate at low temperature.

SI-3010KD/SI-3050KD

In the case that capacitors having extremely low ESR such as ceramic capacitors are used for output capacitors, they may oscillate.

*2: D1: Reverse biased protection diodes

In the case of reverse bias between input and output, this diode will be required. (Recommended diodes: SJPL-H2 made by Sanken) Vo ≦3.3V is not required.

R1, R2: resistors for setting output voltages

Output voltages can be set by connecting R1 and R2 as shown in the above figure.

R2: 10kΩ is recommended (24kΩ for SI-3012KD).

$$R1 = \frac{(Vo - V_{ADJ})}{(V_{ADJ} / R2)}$$

*3: In the case that Vo ≦ 1.5V is set for the SI-3010KD, R3 should be inserted.

10 kΩ is recommended for R3.

R3 is not required for the SI-3012KD regardless of set voltages.

3. Operational Description

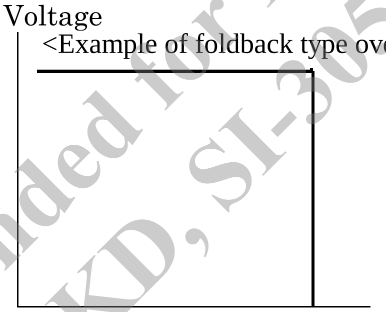
● 3-1 Voltage Control

In the SI-3000KD series, the driving circuit is controlled by comparing the reference voltage with the ADJ terminal voltage (voltage divided by Vo detection resistor in fixed output products) to stabilize the output voltage by varying the voltage between the emitter and collector of a main PNP power transistor. The product of voltage between emitter and collector and the output current at this moment is consumed as heat.

● 3-2 Overcurrent Protection

3-2-1 Overcurrent Protection Characterization (SI-3012KD, SI-3033KD)

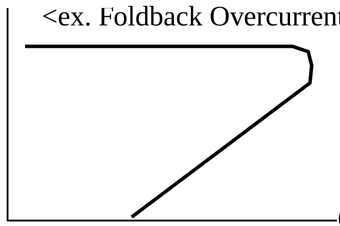
The current limiting type overcurrent protection function is provided in the SI-3012KD and the SI-3033KD. In the case of the series regulator, as the output voltage drops subject to the overcurrent protection, the difference of input/output voltages increases to cause significant heating. Special care should be taken for the current limiting type overcurrent protection, since large current flows continuously.



3-2-2 Overcurrent Protection Characterization (SI-3010KD, SI-3050KD)

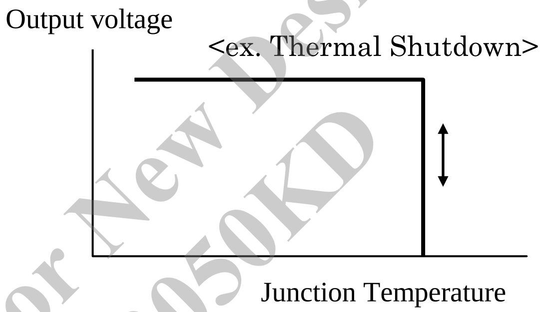
The foldback type overcurrent protection function is provided in the SI-3010KD and the SI-3050KD.
After operation of the overcurrent protection function, if the load resistance decreases and the output voltage drops, the output current of products is squeezed to reduce the increase of loss. However, in the case of the foldback type overcurrent protection function, since current limiting is also made at start-up, the function may not be used for the following applications, as it may cause a start-up error.

(1) Constant current loads
(2) Plus/minus power supply
(3) DC power supply
(4) Output voltage adjustment by grounding-up



● 3-3 Thermal Shutdown

This IC is provided with the overheat protection circuit which detects the semiconductor junction temperature of the IC to limit the driving current, when the junction temperature exceeds the set value (around 150°C). Since the minimum operating temperature of the overheat protection circuit is 130°C, the thermal design of Tj<125°C is required. Since the overheat protection has no hysteresis, as soon as the overload state is released and Tj falls below the set temperature, the normal operation is automatically restored. When the overheat protection function is operated in the overload state, the output voltage falls, but at the same time the output current is decreased and in the consequence, overheat protection operation and automatic restoration are repeated in a short interval, resulting eventually in the waveforms of output voltage oscillation.



*Note for thermal shutdown characteristic

This circuit protects the IC against overheat resulting from the instantaneous short circuit, but it should be noted that this function does not assure the operation including reliability in the state that overheat continues due to long time short circuit.

4. Cautions

● 4-1 External Components

4-1-1 Input Capacitor C_{IN}

The input capacitor is required to eliminate noise and stabilize the operation and values of 0.47μF - 22μF are recommended. Any of ceramic capacitors or electrolytic ones may be used for the input capacitor.

4-1-2 Output Capacitor Co

In the output capacitor Co, larger capacitance than the recommended value is required for phase compensation. Equivalent series resistance values (ESR) of capacitors are limited, and depending on products, therefore the type of recommended capacitors is limited.

- Recommended values of SI-3010KD and SI-3050KD: 2Ω > ESR > 0.2Ω

It is recommended to use electrolytic capacitors. When capacitors with extremely high ESR such as ceramic capacitors, functional polymer capacitors etc., are used, phase margin is decreased, possibly causing the oscillation of output voltage.

- SI-3012KD，SI-3033KD　Recommendation: ESR < 0.2Ω

It is recommended to use ceramic capacitors or functional polymer capacitors. If electrolytic capacitors having large ESR are used, the phase margin is decreased to cause the possible oscillation of output voltage. Even if oscillation does not occur at low temperature, ESR is increased to cause oscillation. Therefore the use of electrolytic capacitors is not recommendable.

4-1-3 Reverse bias protection diode D1

In the case of falling-down of the input voltage, it is recommended to insert a protection diode D1 against the reverse bias between input and output. However, in the case of setting the Vout < 3.3V or lower, D1 is not required including the case of reverse bias. In order to select a suitable D1, it should be taken into consideration that the diode has adequate forward current withstand voltage against the instantaneous discharge of energy stored in Cout.

The permissible value of the forward current per unit time of diode is specified in I_{FSM} (A) and in the case of our diode, it is specified at 50Hz half wave (10ms), but it should be noted that different companies may specify different times. The selection of diode should be made by converting the specified time into the actual discharging time so as to meet the required I_{FSM} (A).
The discharging time of Co is normally shorter than 1ms, but it is recommended to do the conversion with 1ms in consideration of margin.

For conversion into I_{FSM}, calculation should be made by using the equations (1) and (2).

$$\left(\frac{I_{FSM}}{\sqrt{2}}\right)^2 * t1 = X \qquad \text{--- (1)}$$

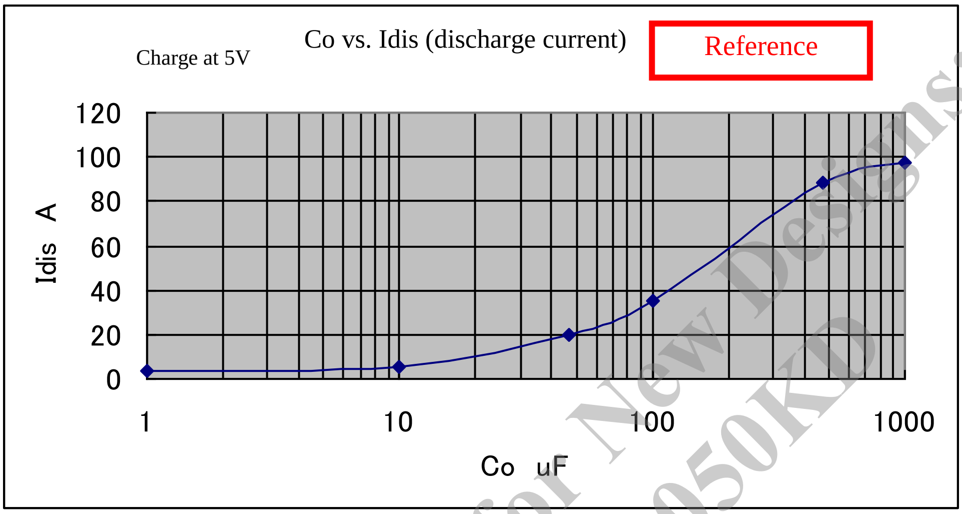
As for I_{FSM}, please refer to the catalog of each company.

t1 = specified time in catalog of each company

$$\text{Converted IFSM} = \sqrt{\frac{2 * X}{t2}} \qquad \text{--- (2)}$$

t2: converted time (discharging time of Co)

<Graph 1>



On the assumption of Cout = 470µF, I_{FSM} of around 90A or more (in 1ms time period) is required and according to our specifications of Di, I_{FSM} is specified for 10ms, therefore the Di of 30A has the tolerated dose of 94.8A (in 1ms) to prove that it is usable.

● 4-2 Pattern Design Notes

4-2-1 Input / Output Capacitor

The input capacitor C1 and the output capacitor C2 should be connected to the IC as close as possible. If the rectifying capacitor for AC rectifier circuit is on the input side, it can be used as an input capacitor. However, if it is no close to the IC, the input capacitor should be connected in addition to the rectifying capacitor.

4-2-2 ADJ Terminal (Output Voltage Set-up for SI-3010KD, SI-3102KD)

The ADJ terminal is a feedback detection terminal for controlling the output voltage.

The output voltage set-up is achieved by connecting R1 and R2.

SI-3010KD: it should be set in a manner that I_{ADJ} is around 100µA.

SI-3012KD: it should be set in a manner that I_{ADJ} is around 50µA.

R1, R2 and output voltage can be obtained by the following equations:

$I_{ADJ}=V_{ADJ}/R2$

(*V_{ADJ} = 1.0V ± 2% (SI-3010KD), R2 = 10kΩ recommended
*V_{ADJ} = 1.28V ± 3% (SI-3012KD), R2 = 24kΩ recommended)

$R1 = (Vo-V_{ADJ}) / I_{ADJ}$ $R2 = V_{ADJ} / I_{ADJ}$

$Vout = R1 \times (V_{ADJ} / R2) + V_{ADJ}$

5. Applications

● 5-1 Output ON/OFF Control

The ON/OFF control of output can be made by directly applying voltage to No. 1 Vc terminal. When the Vc terminal is open, the operation is in OFF.

The Vc terminal is in OFF below 0.8V and in ON at above 2V.

● 5-2 Thermal Design

Calculation of heat dissipation

Heat generation of the surface mounting IC is generally dependent on size, material and copper foil area of the mounted printed circuit board. Full attention should be paid to heat dissipation and adequate margin be taken into consideration at thermal design. In order to enhance the heat dissipation effect, it is recommended to enlarge the copper foil area connected to the stem part on the back side of the product.

The copper foil area of the printed circuit board significantly affects the heat dissipation effect.

As the junction temperature Tj (MAX) is a product-specific value, it must be observed strictly. For this purpose, heat sink design (thermal resistance of board) which is appropriate for Pd (MAX) and Ta MAX is required. This is graphically shown in the heat derating curve for easy understanding. The heat dissipation design is done in the following procedure.

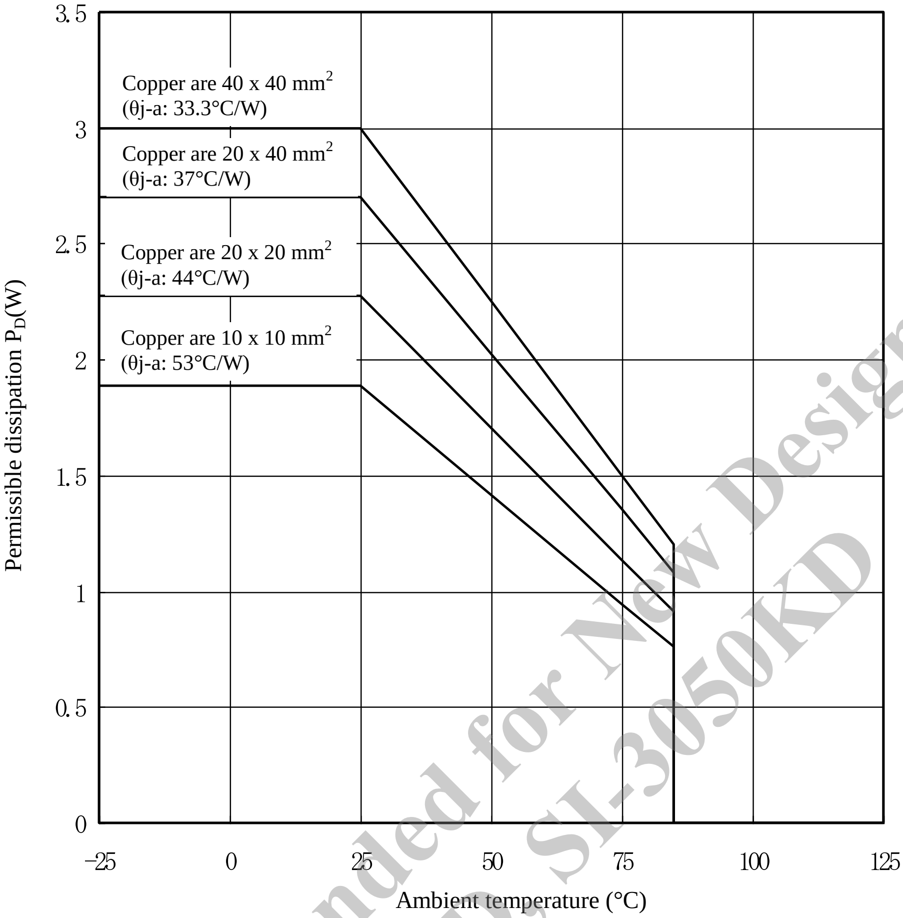
1) The highest ambient temperature in the set Ta MAX is obtained.

2) The maximum loss PdMAX which varies the input/output conditions is obtained.

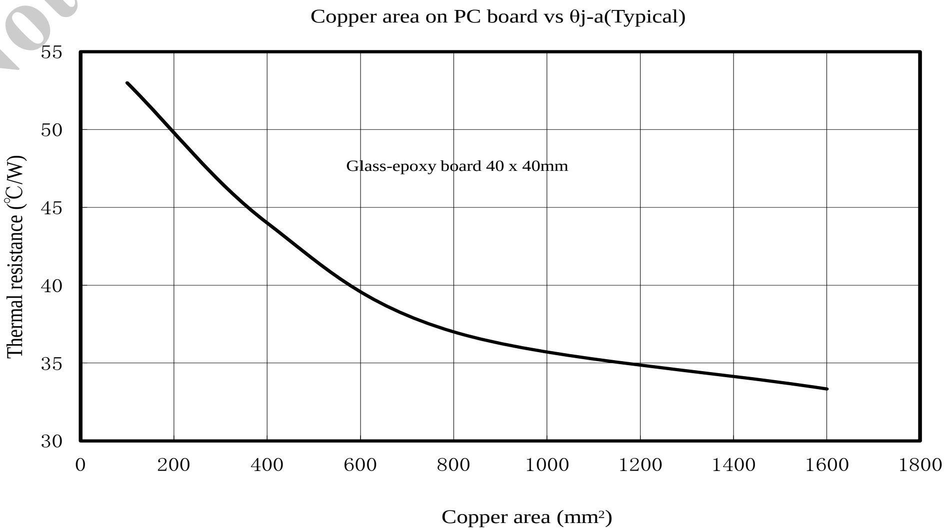
$$Pd = (V_{IN} - Vout) \times Iout$$

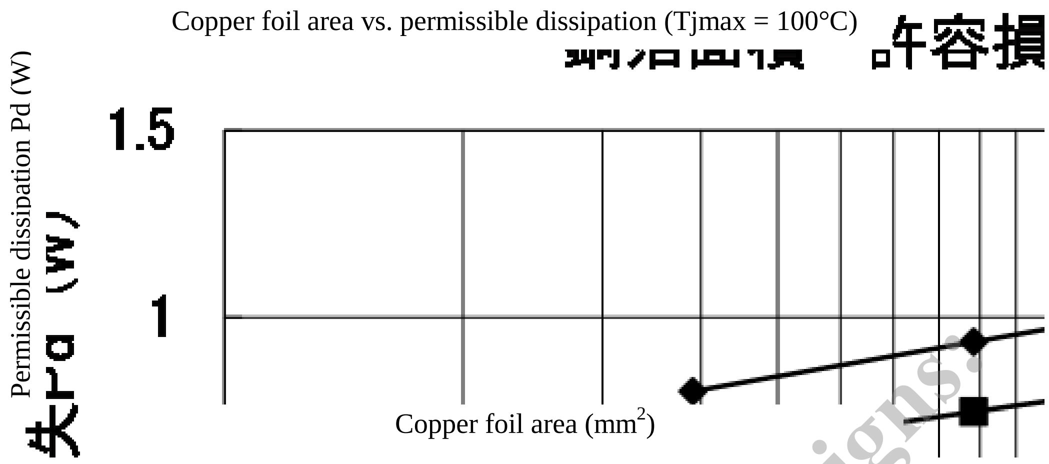
3) The area of copper foil is determined from the intersection point in the heat derating curve below shown.

- SI – 3000KD derating curve



For reference information, the graph of copper foil area vs. thermal resistance between junction temperature and ambient temperature θj-a and the graph of copper foil area vs. permissible dissipation that both are in the single side copper foil board FR - 4 are shown below.

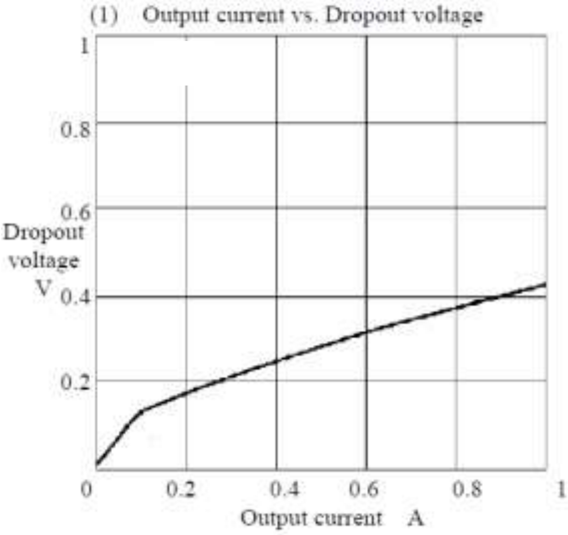


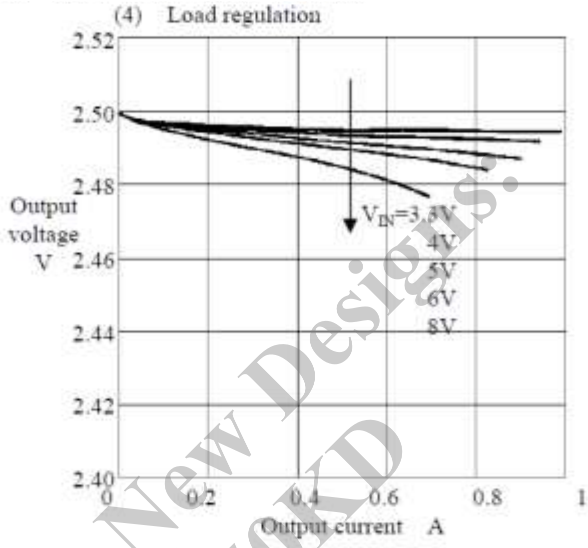

Copper foil area vs. permissible dissipation (Tjmax = 100°C)
Permissible dissipation Pd (W)
1.5
1
Copper foil area (mm2)

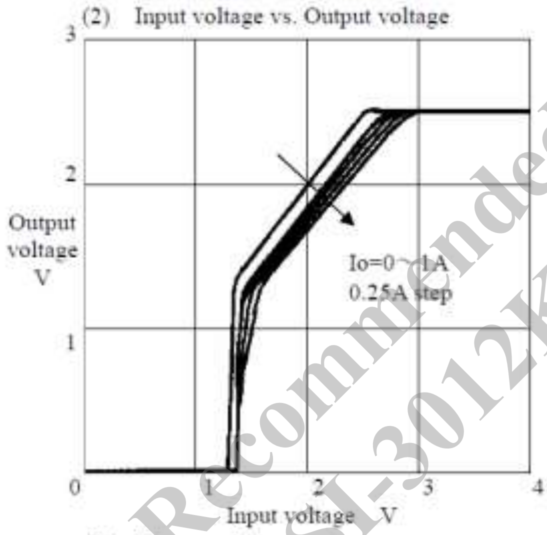
6. Typical Characteristics

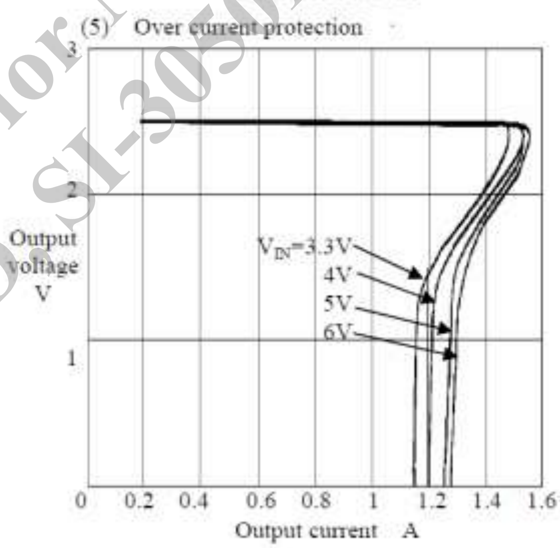
- SI-3012KD

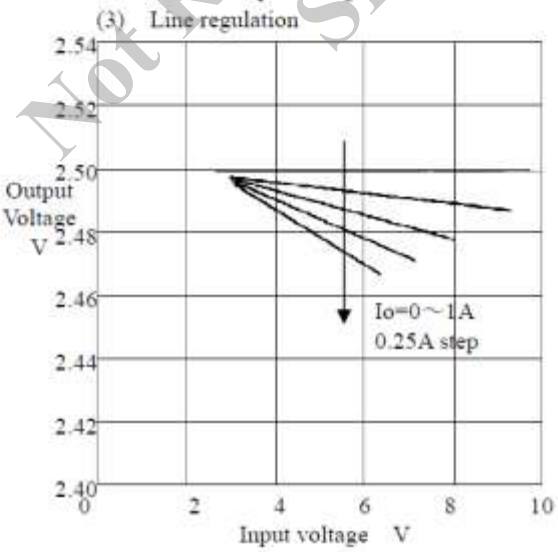
(Ta = 25°C) *Set Vout = 2.5V (R2 = 24kΩ)

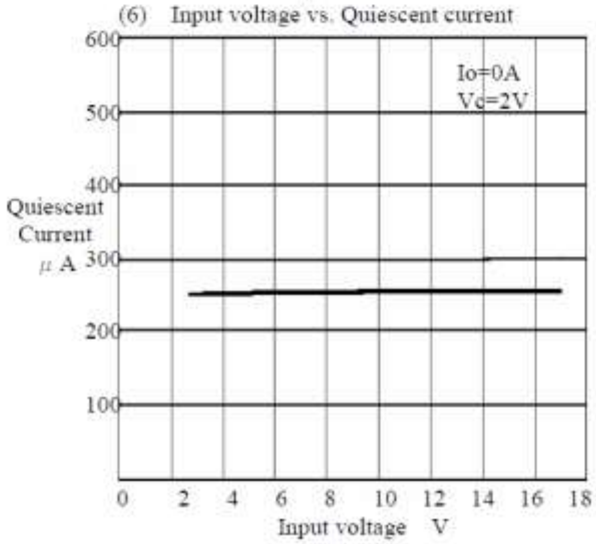




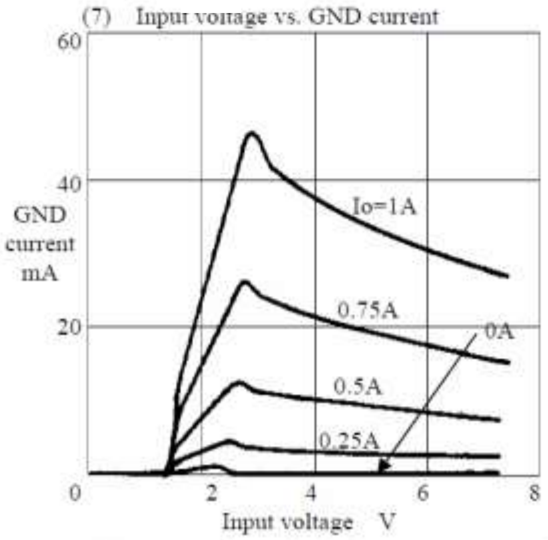


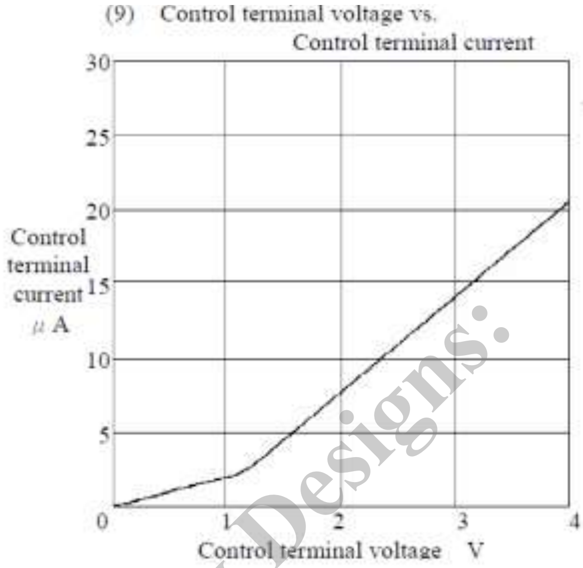


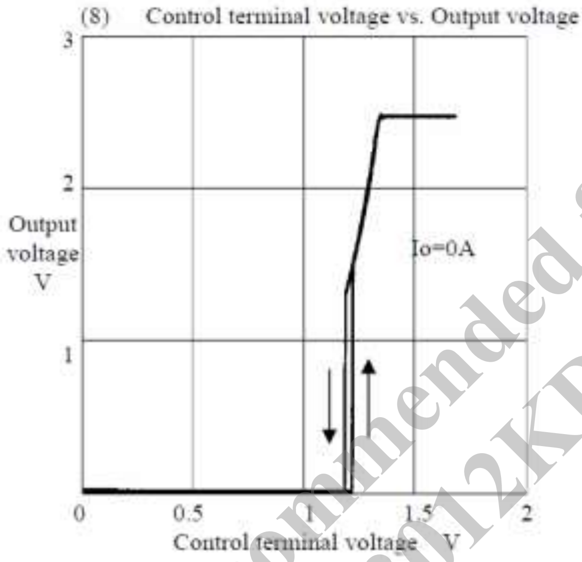




(Ta = 25°C)


(7) Input voltage vs. GND current
GND current mA
Input voltage V
Io=1A
0.75A
0.5A
0.25A
0A
60
40
20
0
2
4
6
8

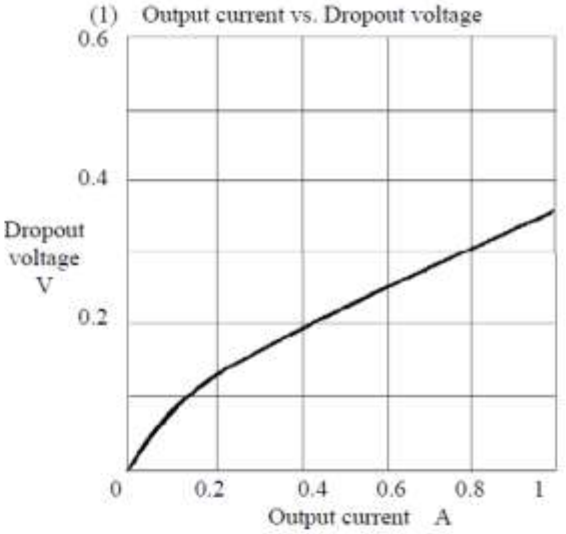

(9) Control terminal voltage vs. Control terminal current
Control terminal current μA
Control terminal voltage V
30
25
20
15
10
5
0
1
2
3
4


(8) Control terminal voltage vs. Output voltage
Output voltage V
Control terminal voltage V
Io=0A
3
2
1
0
0.5
1
1.5
2

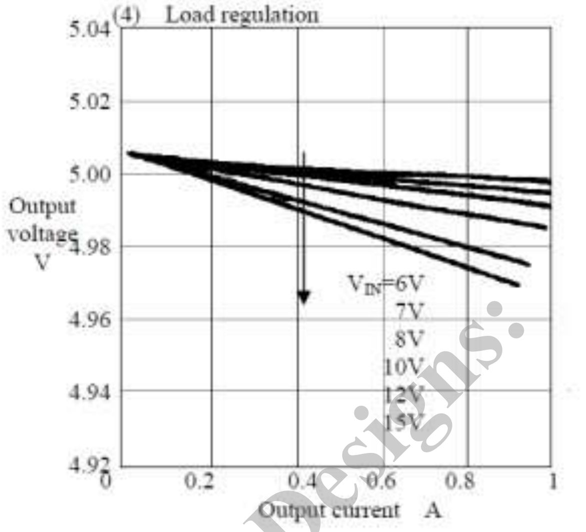
- SI-3010KD

(Ta = 25°C) *Set Vout = 5V (R2 = 10kΩ)

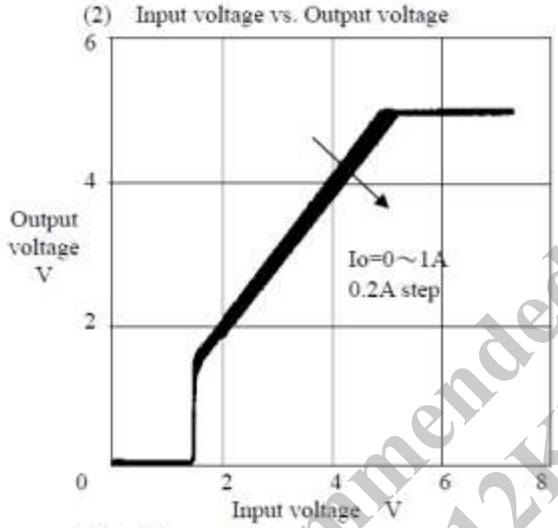
(1) Output current vs. Dropout voltage



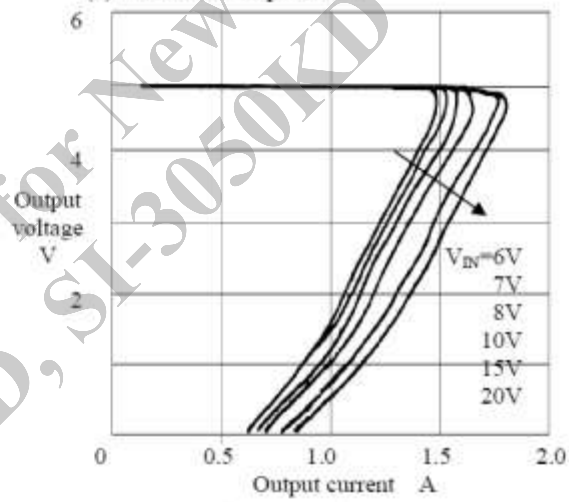
(4) Load regulation



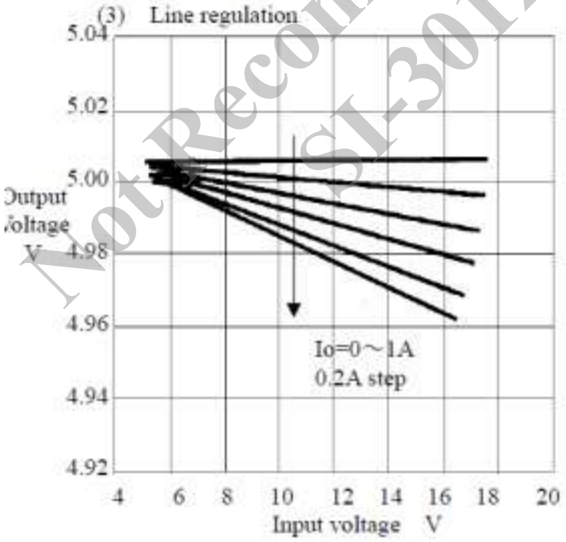
(2) Input voltage vs. Output voltage



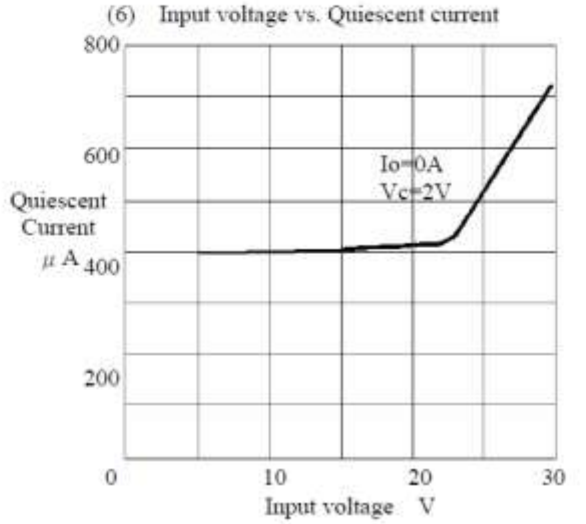
(5) Over current protection



(3) Line regulation

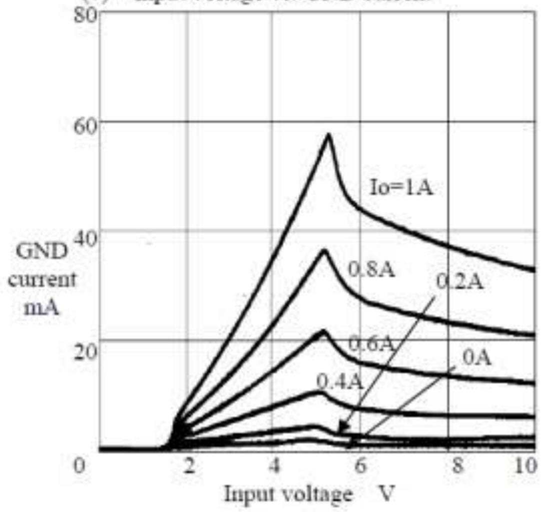


(6) Input voltage vs. Quiescent current

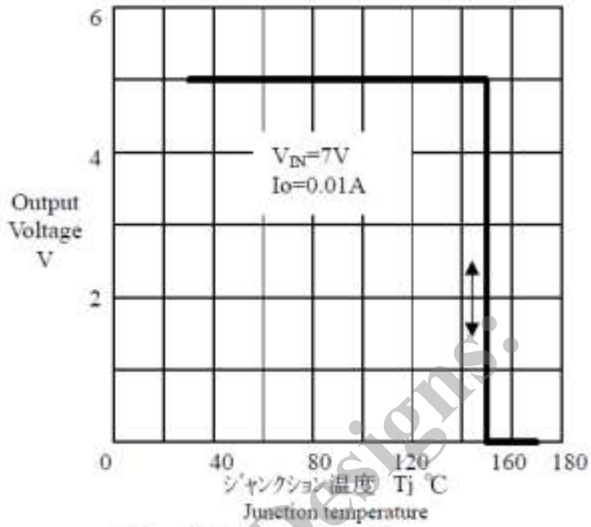


(Ta = 25°C) *Set Vout = 5V (R2 = 10kΩ)

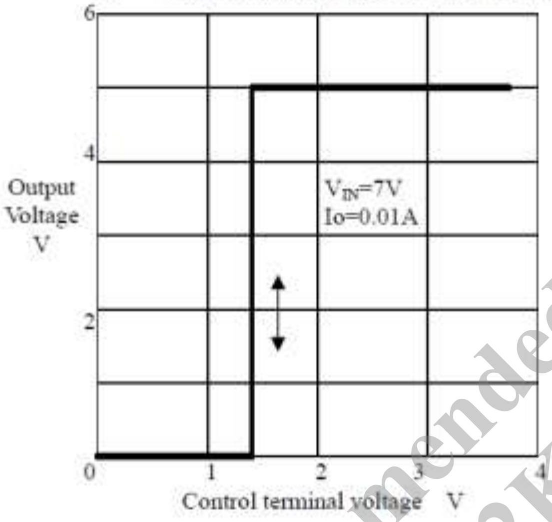
(7) Input voltage vs. GND current



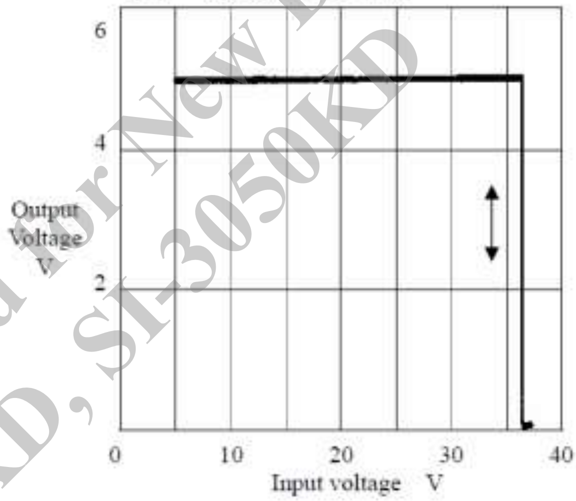
(10) Thermal protection



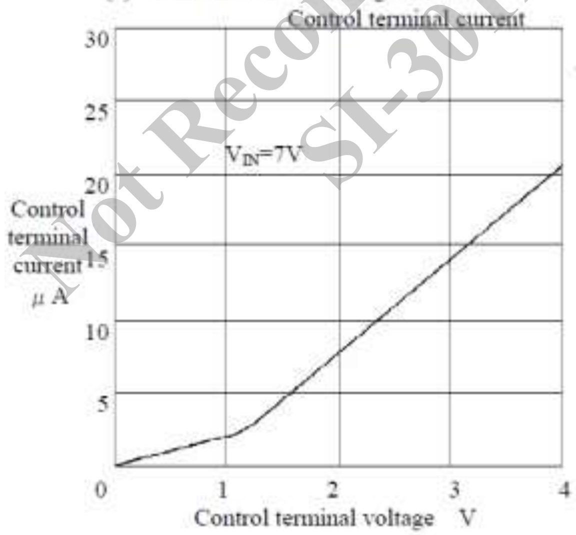
(8) Control terminal voltage vs. Output voltage



(11) Over Voltage protection



(9) Control terminal voltage vs. Control terminal current



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