Application Note

Hyposaturation type Surface Molding Series Regulator IC

SI-3000KS series

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SANKEN ELECTRIC CO., LTD.

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1. General Information

The SI-3000KS 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.

It is a regulator which can use low ESR capacitors such as ceramic capacitors for the output capacitor at the voltage of 17V.

1-1 Features

- Output current 1A

  Output current is 1A at maximum with the outline of SOP8.
- 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.
- Built-in Overcurrent protection / Thermal shutdown

  The current limiting type overcurrent protection and Thermal shutdown circuits are built-in.

  (Automatic restoration type)

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

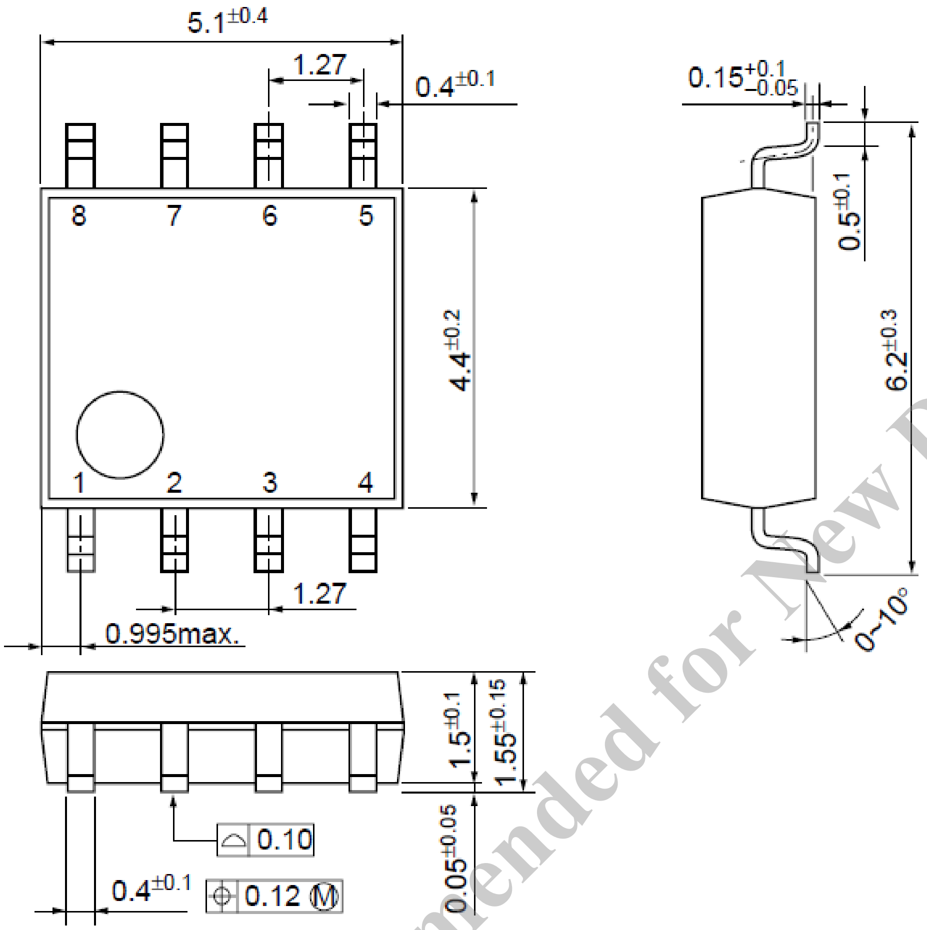
1-3 Type

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

2. Specification

Unit: mm

● 2-1 Package Information



Pin assignment

1. Vc
2. V_{IN}
3. Vo
4. Sense (ADJ for SI-3012KS)
5. GND
6. GND
7. GND
8. GND

Resin sealed type

Non-combustibility: UL standards 94V-0

Product mass: about 0.1 g

● 2-2 Ratings

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

Parameter	Symbol	Ratings	Unit
DC Input Voltage	V_{IN}*1	17	V
Output Control Terminal Voltage	V_C	V_{IN}	V
DC Output Current	I_O*1	1.0	A
Power Dissipation	P_D*1, *2	0.76	W
Junction Temperature	T_j	–40 to +125	°C
Storage Temperature	T_{stg}	–40 to +125	°C
Thermal Resistance (Junction to Ambient Air)	$\theta_{j\text{-}a}$	130	°C/W
Thermal resistance (Junction to Lead (pin 7))	$\theta_{j\text{-}L}$	22	°C/W

*1: 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 as shown hereinafter.

*2: When mounted on a glass epoxy board of 1600mm^2 (copper laminate are 2%).

2-2-2 Recommended Conditions

Parameter	Symbol	Ratings			Unit
		*2 SI-3012KS *1	*2 SI-3025KS *1	*2 SI-3033KS *1	
Input Voltage	V_{IN}	2.4 - 6.0	- 6	- 6	V
Output Current	Io	0 - 1.0			A
Operational Ambient Temperature	Top	-30 - 85			°C
Junction Temperature in Operation	Tj	-20 - 100			°C

*1: Because of the relation of $P_D = (V_{IN} - Vo) \times Io$, 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 Ta = 25°C

Parameter	Symbol	Ratings									Unit
		SI-3012KS (variable type)			SI-3025KS			SI-3033KS			
		min.	typ.	max.	min.	typ.	max.	min.	typ.	max.	
Input Voltage	V_{IN}	2.4			*1			*1			V
Output Voltage (Reference voltage V_{ADJ} for SI-3012KS)	V_O (V_{ADJ})	1.24	1.28	1.32	2.45	2.50	2.55	3.234	3.300	3.366	V
	Conditions	V_{IN}=3.3V, I_O=10mA			V_{IN}=3.3V, I_O=10mA			V_{IN}=5V, I_O=10mA			
Dropout Voltage	V_{DIF}			0.3			0.4			0.4	V
	Conditions	I_O=0.5A (V_O=2.5V)			I_O=0.5A			I_O=0.5A			
				0.6			0.6			0.6	
	Conditions	I_O=1A (V_O=2.5V)			I_O=1A			I_O=1A			
Line Regulation	ΔV_{OLINE}			10			10			15	mV
	Conditions	V_{IN}=3.3 to 8V, I_O=10mA (V_O=2.5V)			V_{IN}=3.3 to 8V, I_O=10mA			V_{IN}=5 to 10V, I_O=10mA			
Load Regulation	ΔV_{OLOAD}			40			40			50	mV
	Conditions	V_{IN}=3.3V, I_O=0 to 1A (V_O=2.5V)			V_{IN}=3.3V, I_O=0 to 1A			V_{IN}=5V, I_O=0 to 1A			
Quiescent Circuit Current	I_q			350			350			350	μA
	Conditions	V_{IN}=3.3V, I_O=0A, V_C=2V, R_2=24kΩ			V_{IN}=3.3V, I_O=0A, V_C=2V			V_{IN}=5V, I_O=0A, V_C=2V			
Circuit Current at Output OFF	I_q (OFF)			1			1			1	μA
	Conditions	V_{IN}=3.3V, V_C=0V			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			±0.3		mV/°C
	Conditions	T_j=0 to 100°C (V_O=2.5V)			T_j=0 to 100°C			T_j=0 to 100°C			
Ripple Rejection	R_{REJ}		55			55			55		dB
	Conditions	V_{IN}=3.3V, f=100 to 120Hz (V_O=2.5V)			V_{IN}=3.3V, f=100 to 120Hz			V_{IN}=5V, f=100 to 120Hz			
Overcurrent Protection Starting Current*2	I_{S1}	1.2			1.2			1.2			A
	Conditions	V_{IN}=3.3V (V_O=2.5V)			V_{IN}=3.3V			V_{IN}=5V			
V_C Terminal: Control Voltage (Output ON)*3	$V_{C, IH}$	2.0			2.0			2.0			V
V_C Terminal: Control Voltage (Output OFF)	$V_{C, IL}$			0.8			0.8			0.8	V
V_C Terminal: Control Current (Output ON)	$I_{C, IH}$			40			40			40	μA
	Conditions	V_C=2V									
V_C Terminal: Control Current (Output OFF)	$I_{C, IL}$	−5	0		−5	0		−5	0		μA
	Conditions	V_C=0V									

*1: Refer to the Dropout Voltage parameter.

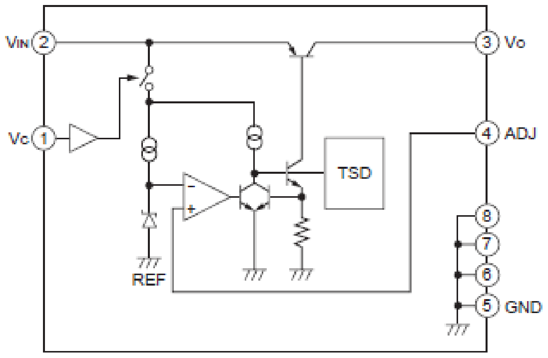
*2: The Is1 is specified at the 5% drop point of output voltage Vo on the condition that VIN = Vo +1V, and Io = 10mA.

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

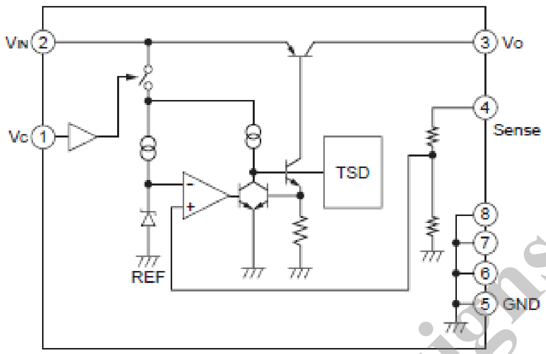
● 2-3 Circuit Diagram

2-3-1 Block Diagram

(SI-3012KS)

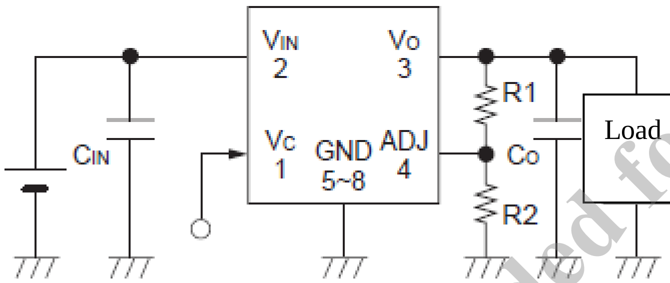


(SI-3025KS, SI-3033KS)



2-3-2 Typical Connection Diagram

(SI-3012KS)



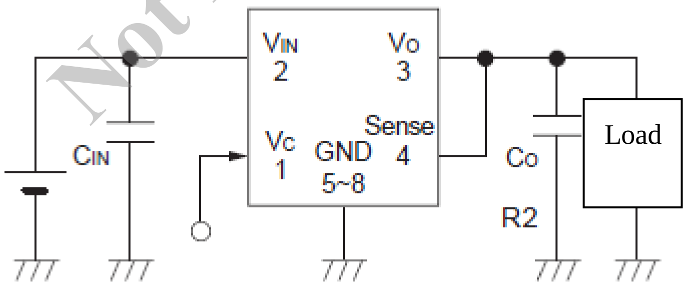
R1, R2: resistors for setting output voltages

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

R2: 24kΩ is recommended.

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

(SI-3025KS, SI-3033KS)



Low ESR capacitors such as ceramic capacitors are used for the output capacitor to compose a circuit in SI-3000KS. In the case that electrolytic capacitors are used, they may oscillate because of increase of ESR. Therefore the use of electrolytic capacitors is not recommendable.

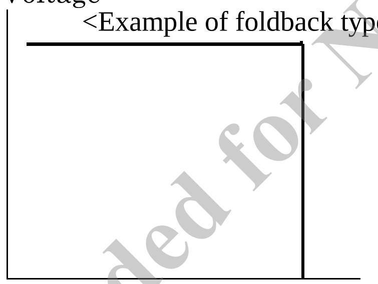
3. Operational Description

● 3-1 Voltage Control

In the SI-3000KS 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

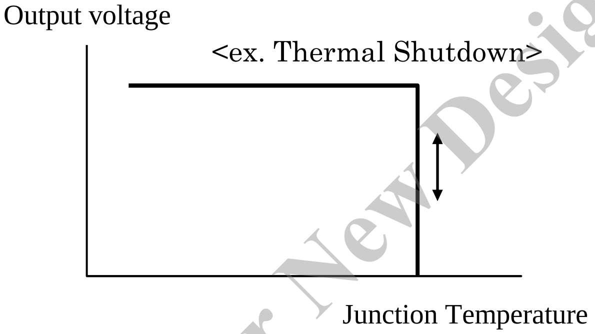
The current limiting type overcurrent protection function is provided in the SI-3012KD and the SI-3033KD. In the case of the series regulator, as the output voltage drops subject to the overcurrent protection, the difference of input/output voltages increases to cause significant heating. Special care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



<Example of foldback type overcurrent protection characteristic>

● 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.

- SI-3012KS, SI-3025KS, SI3033KS 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).

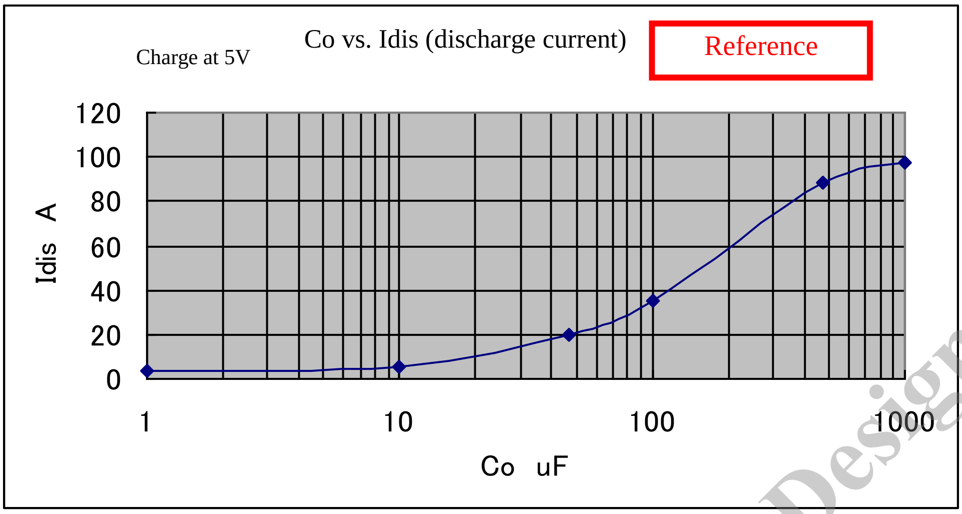
$$\left(\frac{I_{FSM}}{\sqrt{2}}\right)^2 * t1 = X \qquad \text{--- (1)}$$

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

t1 = specified time in catalog of each company

Converted IFSM $= \sqrt{\dfrac{2 * X}{t2}}$ --- (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-3012KS)

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-3012KS: 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:

IADJ=VADJ/R2 (*V_{ADJ} = 1.28V ± 3% (SI-3012KS, R2 = 24kΩ recommended)

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

Vout = R1× (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. The inner frame stage on which the monolithic IC is mounted is directly connected to the GND terminal (5 – 8 pins). Therefore, the heat dissipation effect is increased by enlarging the copper foil area connected to the GND terminal. As shown in Fig. 1, it is recommended to design in a manner that the insulation film is opened only in the solder pattern of Nos. 5, 6, 7 and 8 pins connected to the GND pattern widely arranged.

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.

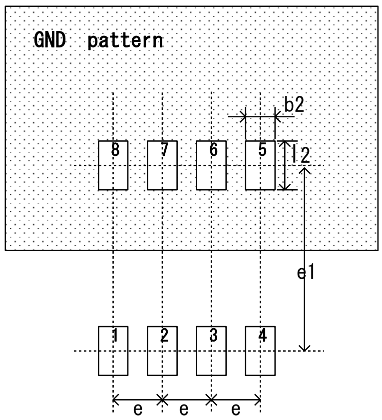


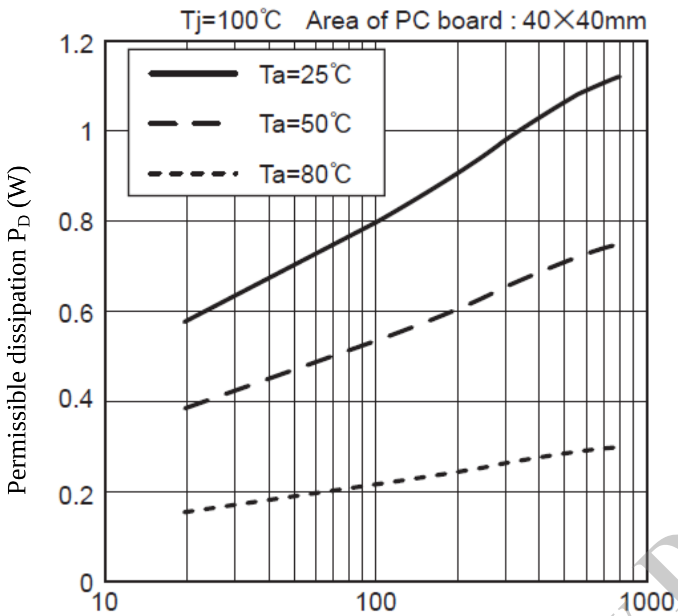
図 1

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 graph of copper foil area vs. permissible dissipation below shown.

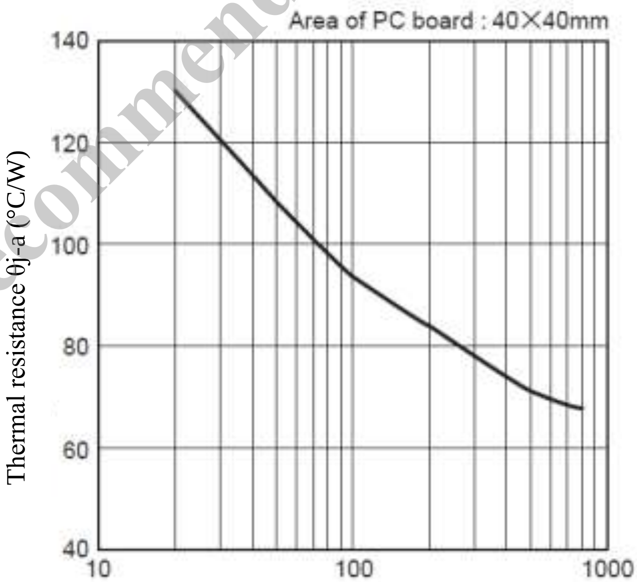
Copper foil area vs. Permissible dissipation



Copper foil area (mm^2)
(GND terminal)

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

Copper foil area vs. thermal resistance θj-a



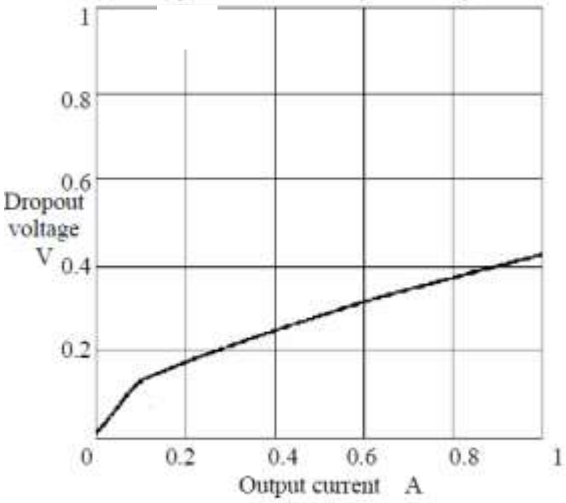
Copper foil area (mm^2)
(GND terminal)

6. Typical Characteristics

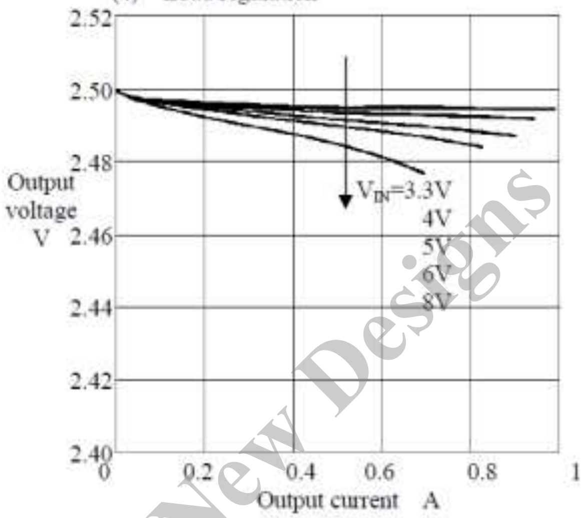
- SI-3012KS

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

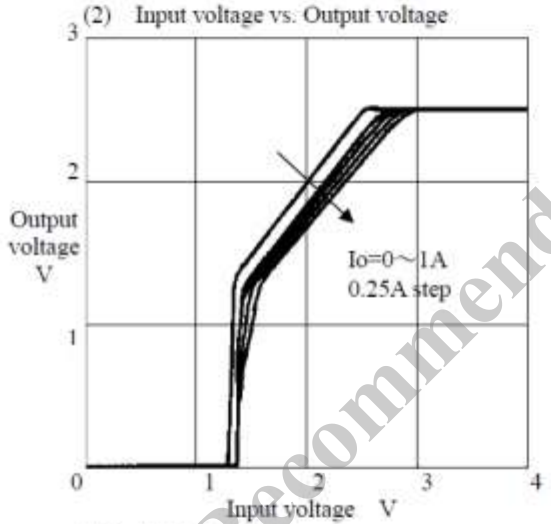
(1) Output current vs. Dropout voltage



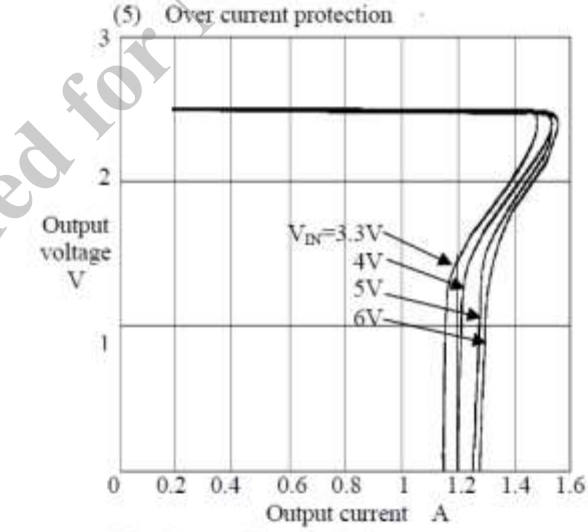
(4) Load regulation



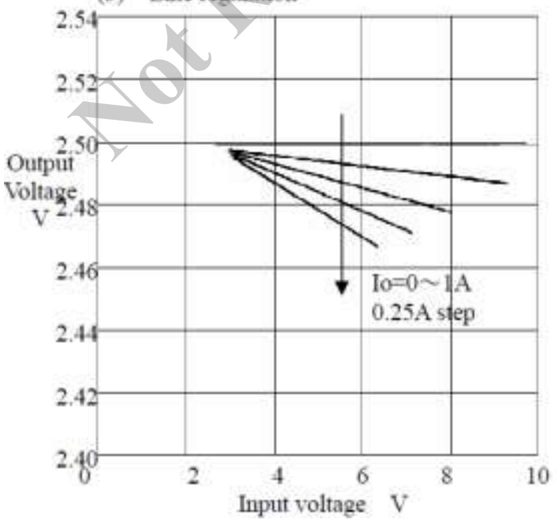
(2) Input voltage vs. Output voltage



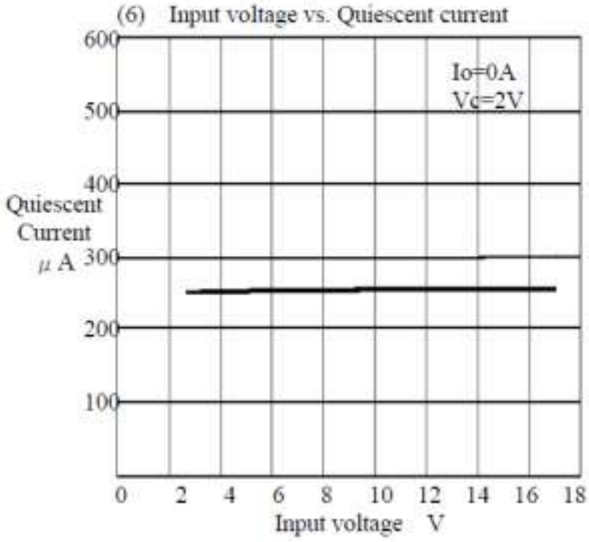
(5) Over current protection



(3) Line regulation

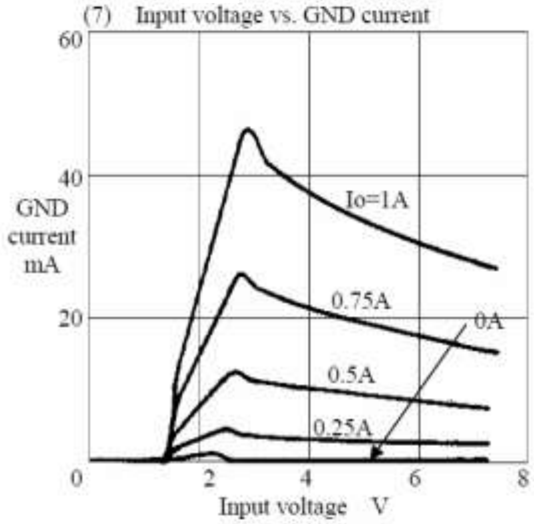


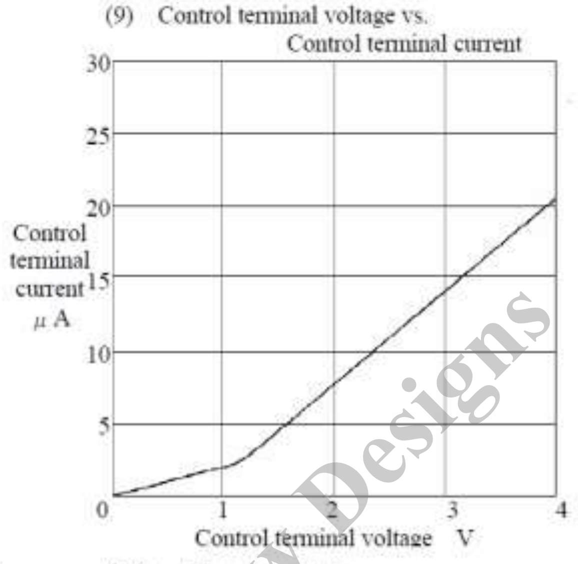
(6) Input voltage vs. Quiescent current

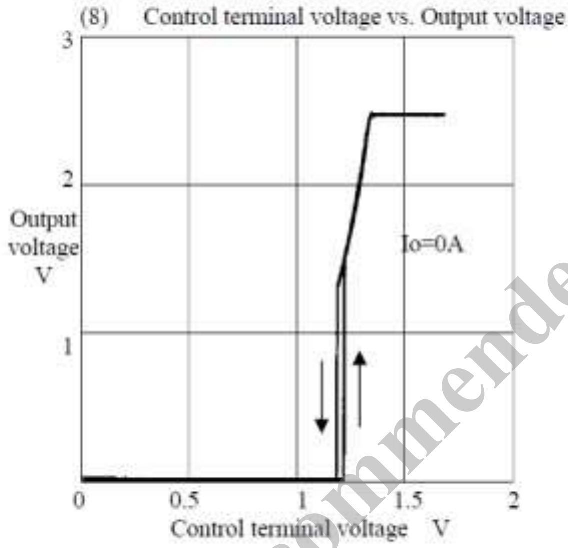


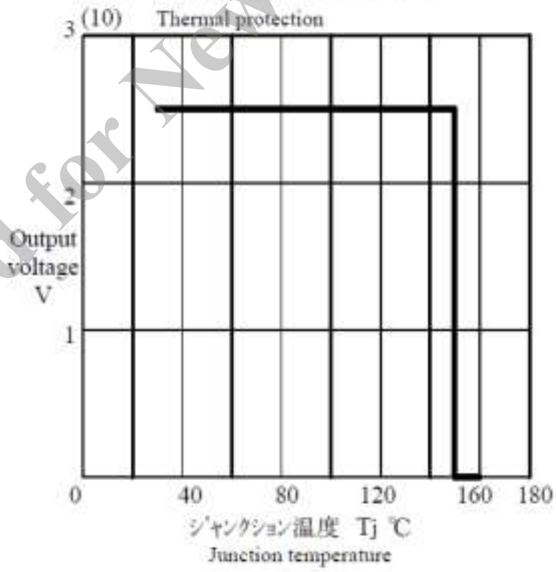
- SI-3012KS

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



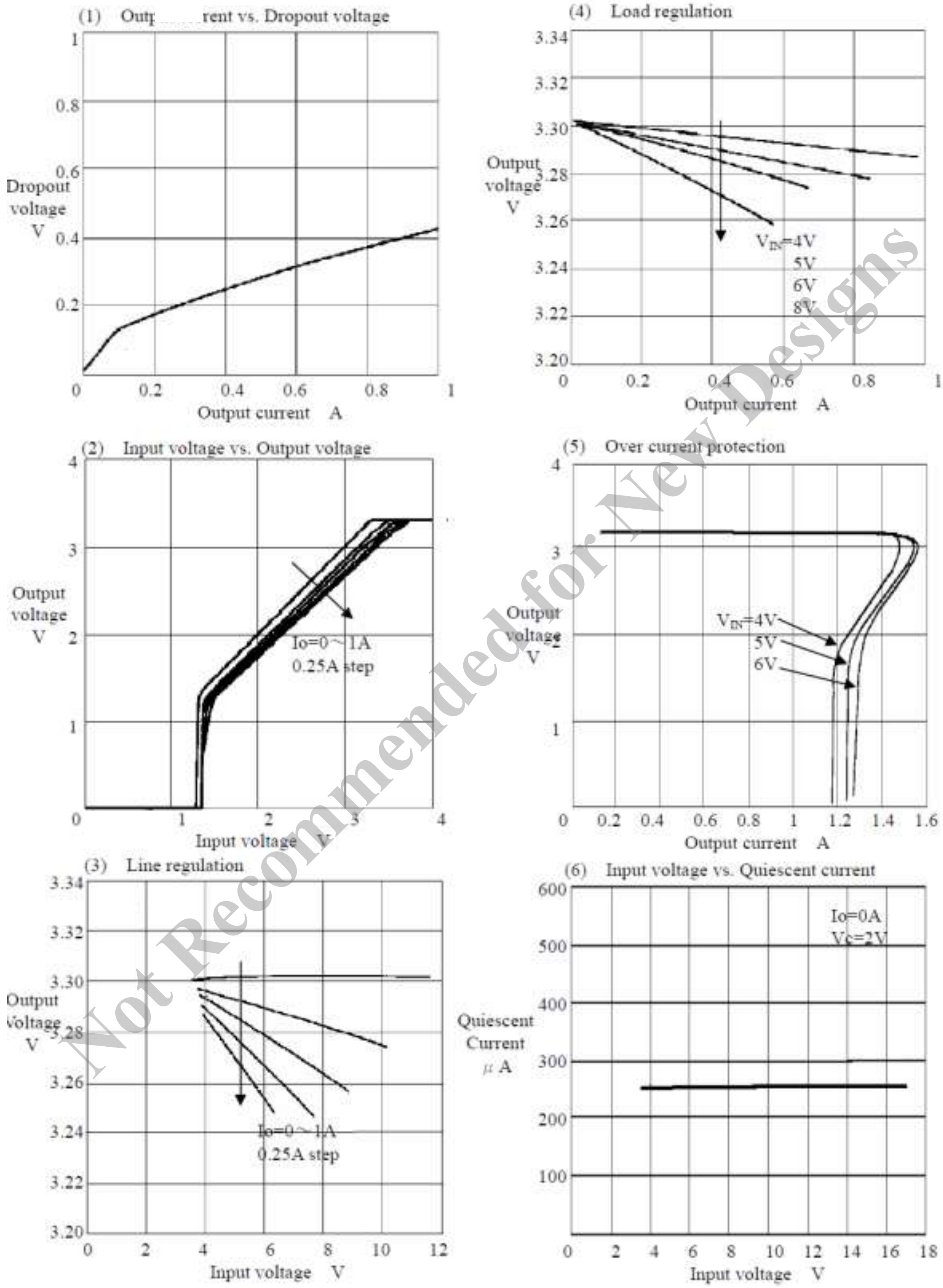






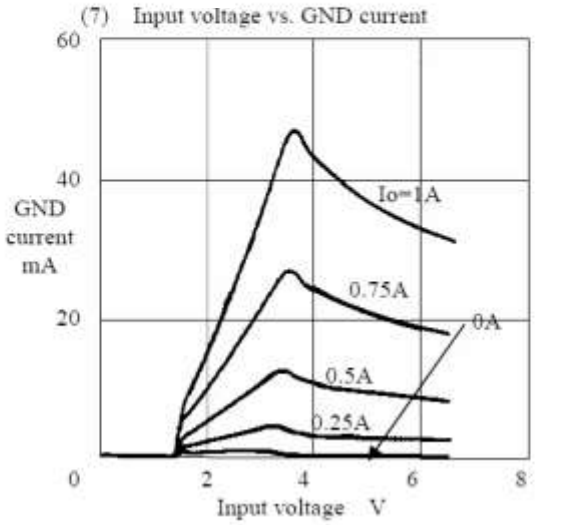
- SI-3033KS

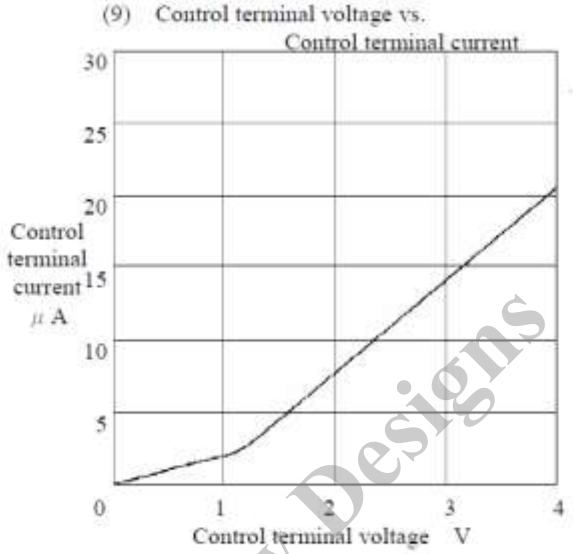
(Ta = 25°C)

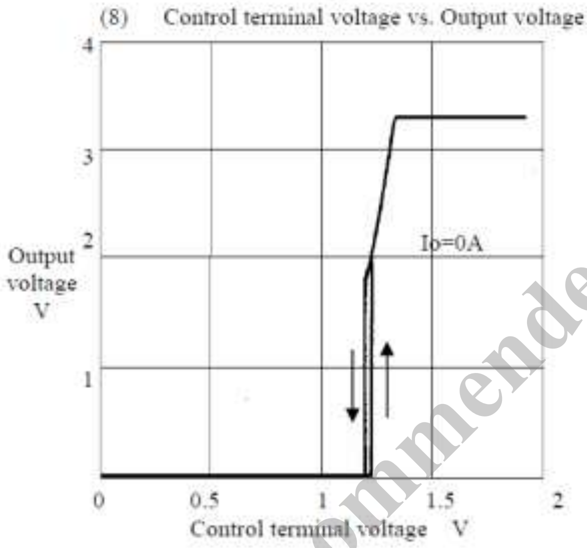


- SI-3033KS

(Ta = 25°C)







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