1.5 A, Buck Converter IC

SI-8000JD Series

Data Sheet

Description

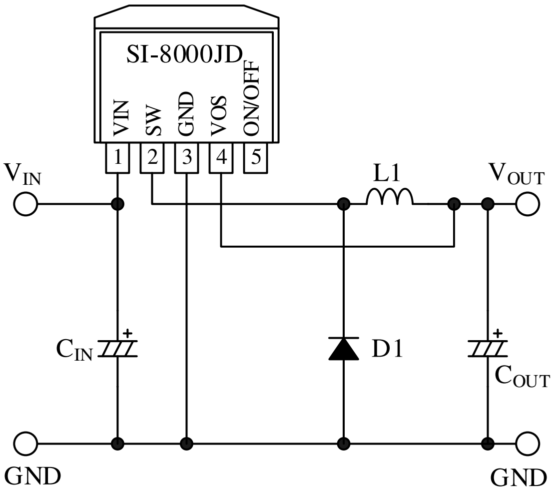
SI-8000JD series are buck converter ICs whose maximum output current is 1.5 A.

These products have various functions including the Output On/Off Function, the Overcurrent Protection and the Thermal Shutdown, and achieve a buck converter circuit with few external components.

Features

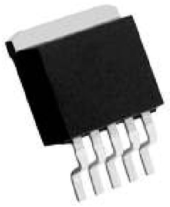
- High Efficiency 88%
  (SI-8120JD: V_{IN} = 24 V, I_{OUT} = 0.5 A)
- Few Components
- Downsized Choke Coil
  (Switching Frequency 125 kHz (typ.))
- Fixed Output Voltage
- On/Off Function
- Low Supply Current during Output Off
- Protection Functions
  Overcurrent Protections (OCP): Fold-back Type, Auto-restart
  Thermal Shutdown (TSD): Auto-restart

Typical Application



Package

TO263-5L



Not to scale

Selection Guide

Part Number	Output Voltage
SI-8033JD	3.3 V
SI-8050JD	5 V
SI-8090JD	9 V
SI-8120JD	12 V

Applications

For the systems requiring power supplies such as:

- Audio Visual Equipment
- Office Automation Equipment (e.g., Printer)
- Onboard power supply

Contents

1. Absolute Maximum Ratings

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 specifically noted, $T_A = 25$ °C.

Parameter	Symbol	Conditions	Rating	Unit	Remarks
Input Voltage	V_{IN}		43	V	
Allowable Power Dissipation	P_D(1)	(2)	3	W	
Junction Temperature	T_J		125	°C	
Storage Temperature	T_{STG}		−40 to 125	°C	

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(1) Limited by the thermal shutdown.

(2) Glass-epoxy board (40 mm × 40 mm), copper area 100%

2. Thermal Resistance Characteristics

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Thermal Resistance between Junction and Ambient	$\theta_{J\text{-}A}$	Mounted on the board.* See Figure 2-1.	—	—	33.3	°C/W
Thermal Resistance between Junction and Lead	$\theta_{J\text{-}L}$		—	—	3	°C/W

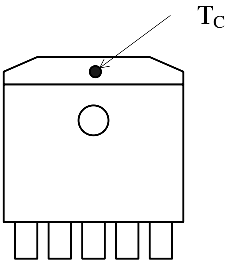

Figure 2-1. Case Temperature Measurement Point

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* Glass-epoxy board (40 mm × 40 mm), copper area 100%

3. Recommended Operating Conditions

Parameter	Symbol	Conditions	Min.	Max.	Unit	Remarks
Input Voltage	V_{IN}	I_{OUT} = 0 A to 1 A	5.3	40	V	SI-8033JD
		I_{OUT} = 0 A to 1.5 A	6.3	40	V	
		I_{OUT} = 0 A to 1 A	7	40	V	SI-8050JD
		I_{OUT} = 0 A to 1.5 A	8	40	V	
		I_{OUT} = 0 A to 1 A	11	40	V	SI-8090JD
		I_{OUT} = 0 A to 1.5 A	12	40	V	
		I_{OUT} = 0 A to 1 A	14	40	V	SI-8120JD
		I_{OUT} = 0 A to 1.5 A	15	40	V	
Output Current *	I_{OUT}	$V_{IN} \geq V_{OUT} + 3$ V	0	1.5	A	
Operating Junction Temperature	T_{JOP}		−30	125	°C	
Operating Ambient Temperature*	T_{OP}		−30	125	°C	

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* Must be used in the range of thermal derating (see Figure 13-25).

4. Electrical Characteristics

4.1. SI-8033JD

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

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

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Output Voltage	V_{OUT}	$V_{IN} = 15$ V, $I_{OUT} = 0.5$ A	3.234	3.30	3.366	V
Output Voltage Temperature Coefficient	$\Delta V_{OUT}/\Delta T$		—	±0.5	—	mV/°C
Efficiency*	H	$V_{IN} = 15$ V, $I_{OUT} = 0.5$ A	—	77	—	%
Operating Frequency	f_O	$V_{IN} = 15$ V, $I_{OUT} = 0.5$ A	—	125	—	kHz
Line Regulation	V_{LINE}	$V_{IN} = 8$ V to 30 V, $I_{OUT} = 0.5$ A	—	25	80	mV
Load Regulation	V_{LOAD}	$V_{IN} = 15$ V, $I_{OUT} = 0.2$ A to 0.8 A	—	10	30	mV
Overcurrent Protection Start Current	I_S	$V_{IN} = 15$ V	1.6	—	—	A
ON/OFF Pin Low Level Voltage	V_{ONOFF_L}		—	—	0.5	V
ON/OFF Pin Source Current at Low Level	I_{ONOFF_L}	$V_{ONOFF\_L} = 0$ V	—	—	100	µA
Quiescent Current 1	I_Q	$V_{IN} = 15$ V, $I_{OUT} = 0$ A	—	7	—	mA
Quiescent Current 2	$I_{Q(OFF)}$	$V_{IN} = 15$ V, $V_{ONOFF\_L} = 0.3$ A	—	—	200	µA

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* Efficiency is calculated by the following equation.

$$\eta(\%) = \frac{V_{OUT} \times I_{OUT}}{V_{IN} \times I_{IN}} \times 100$$

4.2. SI-8050JD

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

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

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Output Voltage	V_{OUT}	$V_{IN} = 20$ V, $I_{OUT} = 0.5$ A	4.9	5.0	5.1	V
Output Voltage Temperature Coefficient	$\Delta V_{OUT}/\Delta T$		—	±0.5	—	mV/°C
Efficiency *	η	$V_{IN} = 20$ V, $I_{OUT} = 0.5$ A	—	82	—	%
Operating Frequency	f_O	$V_{IN} = 20$ V, $I_{OUT} = 0.5$ A	—	125	—	kHz
Line Regulation	V_{LINE}	$V_{IN} = 10$ V to 30 V, $I_{OUT} = 0.5$ A	—	40	100	mV
Load Regulation	V_{LOAD}	$V_{IN} = 20$ V, $I_{OUT} = 0.2$ A to 0.8 A	—	10	40	mV
Overcurrent Protection Start Current	I_S	$V_{IN} = 20$ V	1.6	—	—	A
ON/OFF Pin Low Level Voltage	V_{ONOFF_L}		—	—	0.5	V
ON/OFF Pin Source Current at Low Level	I_{ONOFF_L}	$V_{ONOFF\_L} = 0$ V	—	—	100	µA
Quiescent Current 1	I_Q	$V_{IN} = 20$ V, $I_{OUT} = 0$ A	—	7	—	mA
Quiescent Current 2	$I_{Q(OFF)}$	$V_{IN} = 20$ V, $V_{ONOFF\_L} = 0.3$ A		—	200	µA

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* Efficiency is calculated by the following equation.

$$\eta(\%) = \frac{V_{OUT} \times I_{OUT}}{V_{IN} \times I_{IN}} \times 100$$

4.3. SI-8090JD

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

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

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Output Voltage	V_{OUT}	$V_{IN} = 21$ V, $I_{OUT} = 0.5$ A	8.82	9.00	9.18	V
Output Voltage Temperature Coefficient	$\Delta V_{OUT}/\Delta T$		—	±1.0	—	mV/°C
Efficiency *	η	$V_{IN} = 21$ V, $I_{OUT} = 0.5$ A	—	86	—	%
Operating Frequency	f_O	$V_{IN} = 21$ V, $I_{OUT} = 0.5$ A	—	125	—	kHz
Line Regulation	V_{LINE}	$V_{IN} = 15$ V to 30 V, $I_{OUT} = 0.5$ A	—	50	120	mV
Load Regulation	V_{LOAD}	$V_{IN} = 21$ V, $I_{OUT} = 0.2$ A to 0.8 A	—	10	40	mV
Overcurrent Protection Start Current	I_S	$V_{IN} = 21$ V	1.6	—	—	A
ON/OFF Pin Low Level Voltage	V_{ONOFF_L}		—	—	0.5	V
ON/OFF Pin Source Current at Low Level	I_{ONOFF_L}	$V_{ONOFF\_L} = 0$ V	—	—	100	µA
Quiescent Current 1	I_Q	$V_{IN} = 21$ V, $I_{OUT} = 0$ A	—	7	—	mA
Quiescent Current 2	$I_{Q(OFF)}$	$V_{IN} = 21$ V, $V_{ONOFF\_L} = 0.3$ A	—	—	200	µA

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* Efficiency is calculated by the following equation.

$$\eta(\%) = \frac{V_{OUT} \times I_{OUT}}{V_{IN} \times I_{IN}} \times 100$$

4.4. SI-8120JD

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

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

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Output Voltage	V_{OUT}	$V_{IN} = 24$ V, $I_{OUT} = 0.5$ A	11.76	12.00	12.24	V
Output Voltage Temperature Coefficient	$\Delta V_{OUT}/\Delta T$		—	±1.0	—	mV/°C
Efficiency [*]	η	$V_{IN} = 24$ V, $I_{OUT} = 0.5$ A	—	88	—	%
Operating Frequency	f_O	$V_{IN} = 24$ V, $I_{OUT} = 0.5$ A	—	125	—	kHz
Line Regulation	V_{LINE}	$V_{IN} = 18$ V to 30 V, $I_{OUT} = 0.5$ A	—	60	130	mV
Load Regulation	V_{LOAD}	$V_{IN} = 24$ V, $I_{OUT} = 0.2$ A to 0.8 A	—	10	40	mV
Overcurrent Protection Start Current	I_S	$V_{IN} = 24$ V	1.6	—	—	A
ON/OFF Pin Low Level Voltage	V_{ONOFF_L}		—	—	0.5	V
ON/OFF Pin Source Current at Low Level	I_{ONOFF_L}	$V_{ONOFF\_L} = 0$ V	—	—	100	µA
Quiescent Current 1	I_Q	$V_{IN} = 24$ V, $I_{OUT} = 0$ A	—	7	—	mA
Quiescent Current 2	$I_{Q(OFF)}$	$V_{IN} = 24$ V, $V_{ONOFF\_L} = 0.3$ A	—	—	200	µA

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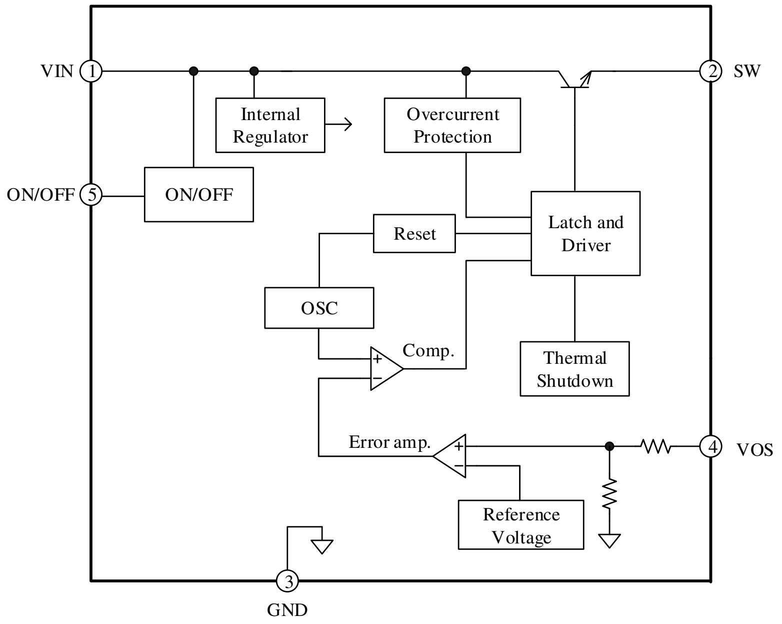
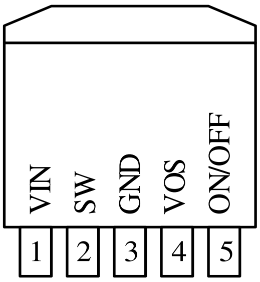
[*] Efficiency is calculated by the following equation.

$$\eta(\%) = \frac{V_{OUT} \times I_{OUT}}{V_{IN} \times I_{IN}} \times 100$$

5. Block Diagram



6. Pin Configuration Definitions



Pin Number	Pin Name	Description
1	VIN	Input pin
2	SW	Output pin
3	GND	Ground
4	VOS	Feedback Pin
5	ON/OFF	On/off signal input, open if on/off function is not used.

7. Typical Application

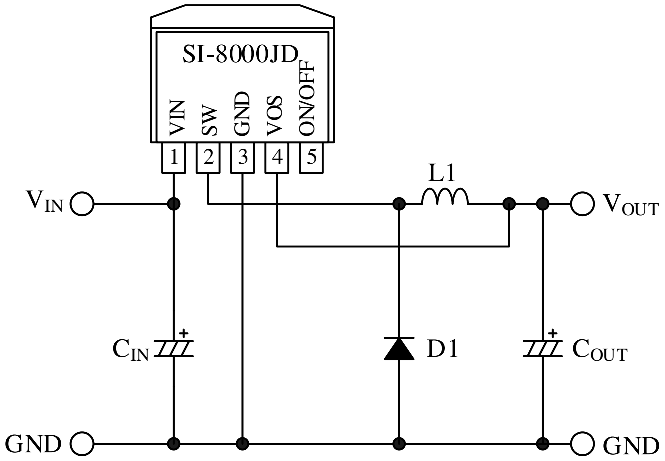


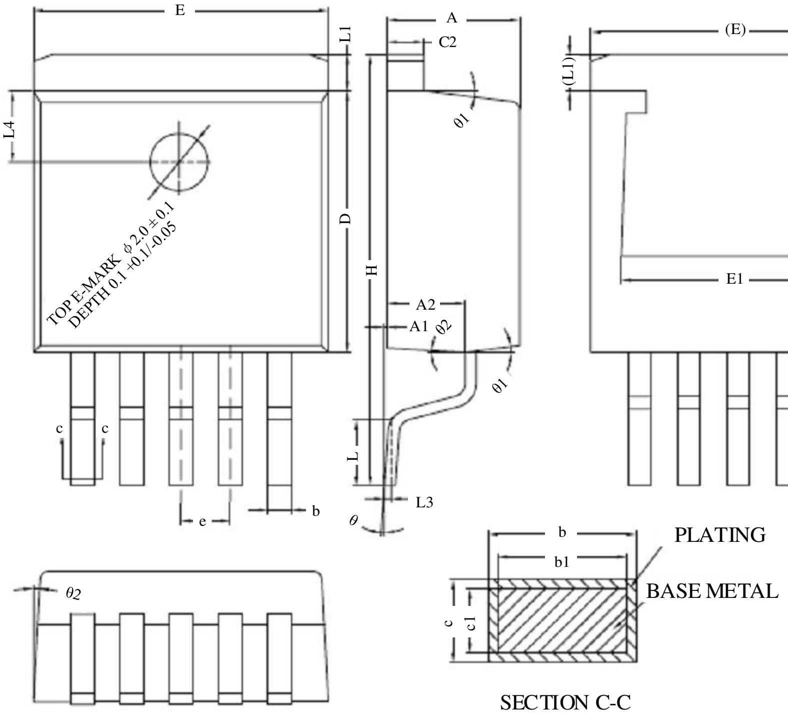
Figure 7-1. Typical Application

Table 7-1. Reference Value of External Components

Symbol	Part Type	Reference Value	Remarks
C_{IN}	Electrolytic capacitor	50 V/220 µF	See Section 11.1.2.
C_{OUT}	Electrolytic capacitor	50 V/470 µF	See Section 11.1.3.
D1	Schottky diode	60 V, 2 A	See Section 11.1.4.
L1	Choke coil	100 µH	See Section 11.1.1.

8. Physical Dimensions

- **TO263-5L**

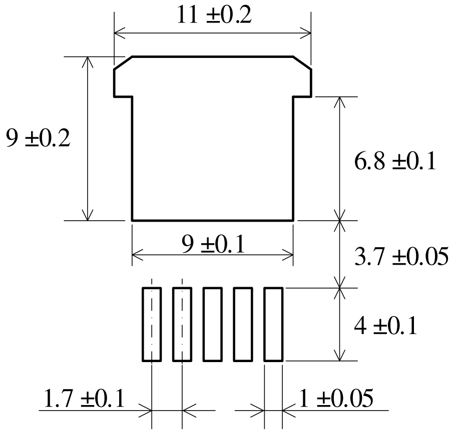


Symbol	Min.	Nom.	Max.
A	4.40	4.57	4.70
A1	0	0.10	0.25
A2	2.59	2.69	2.79
b	0.77	—	0.90
b1	0.76	0.81	0.86
c	0.34	—	0.47
c1	0.33	0.38	0.43
C2	1.22	—	1.32
D	9.05	9.15	9.25
D1	6.86	—	7.50
E	10.06	10.16	10.26
E1	7.50	—	8.30
e		1.70 BSC	
H	14.70	15.10	15.50
L	2.00	2.30	2.60
L1	1.17	1.27	1.40
L3	0.25 BSC		
L4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

NOTES:

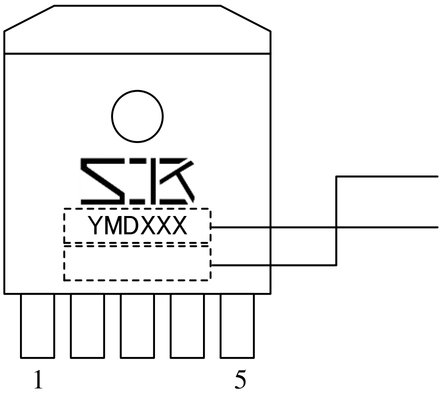
- Dimensions in millimeters
- Bare lead frame: Pb-free (RoHS compliant)
- Dimensions do not include mold burrs.

8.1. Land Pattern Example



Dimensions in millimeters

9. Marking Diagram



Specific Device Code (See Table 9-1)

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 9-1. Specific Device Code

Specific Device Code	Part Number
8033JD	SI-8033JD
8050JD	SI-8050JD
8090JD	SI-8090JD
8120JD	SI-8120JD

10. Operational Description

All the characteristic values given in this section are typical values, unless they are specified as minimum or maximum.

10.1. PWM Output Voltage Control

The SI-8000JD series control the output voltage by the PWM method and have a built-in PWM comparator, oscillator, error amplifier, reference voltage, output transistor drive circuit, etc. The PWM comparator outputs the switching transistor control signal as a square wave by comparing the triangular wave output (≈125 kHz) from the oscillator with the error amplifier output. The PWM comparator controls the switching transistor to turn on during the period when the error amplifier output exceeds the oscillator output. When the output voltage rises, the output of the error amplifier decreases because the error amplifier is an inverting type. When the error amplifier output decreases, the period below the oscillator triangle wave level decreases. Thus, the turn-on period of the switching transistor is shortened. In this way, the output voltage is regulated by changing the turn-on time of the switching transistor with the switching frequency fixed. The higher the V_{IN}, the shorter the turn-on period of the switching transistor. The square wave output of the switching transistor is smoothed by an LC low-pass filter consisting of an inductor and a capacitor. As a result, a regulated DC voltage is supplied to the load.

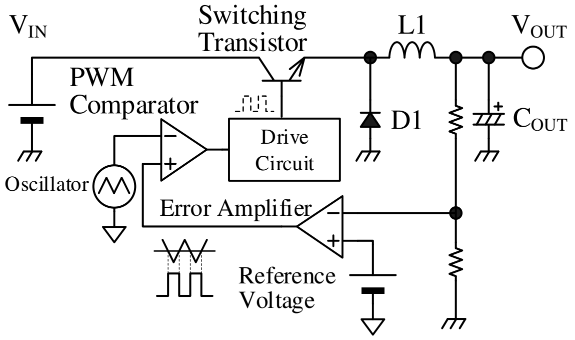


Figure 10-1. Basic Structure of Switching Regulator with PWM Control

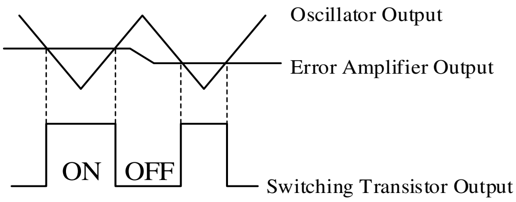


Figure 10-2. PWM Comparator Operation Diagram

10.2. Input/output Current and Inductor Current

The square wave output generated by the switching transistor built in the IC is smoothed by the LC filter composed of the inductor and the output capacitor, and converted to the DC output voltage. The operation of the LC filter significantly affects the stable operation of the switching regulator. Figure 10-3 shows the schematic diagram of the current flowing through the circuit, and Figure 10-4 shows the waveforms of the current flowing through each element.

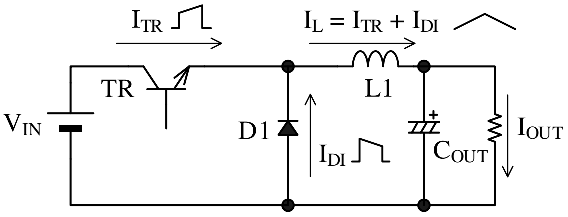


Figure 10-3. Schematic Diagram of Circuit Current

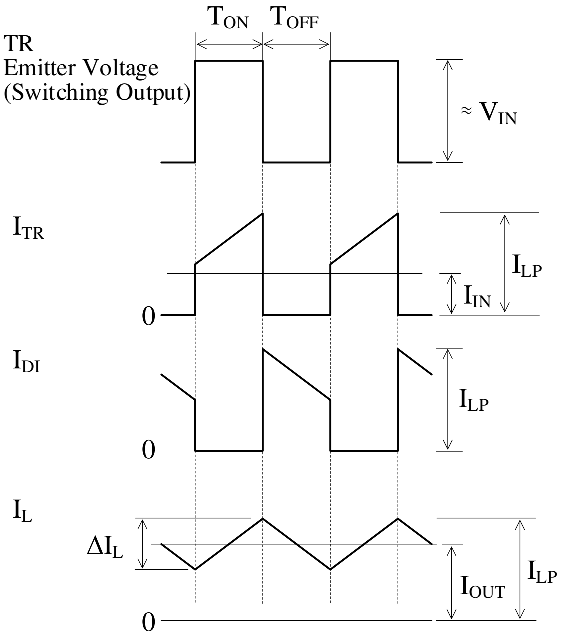


Figure 10-4. Waveforms of Current through Each Element

As shown in Figure 10-3, the current, I_L, flowing through the inductor has a triangular waveform. This triangular waveform is composed of two types of current components, I_{TR} and I_{DI}. The current, I_{TR}, is the current supplied from the input side through the transistor at transistor turn-on, and the average value is the input current, I_{IN}. The current, I_{DI}, is the current that the energy stored in the inductor is commutated through the freewheeling diode at transistor turn-off.

The inductor current, I_L, is the sum of I_{TR} and I_{DI}. Moreover, the average I_L is the DC output current, I_{OUT}, because the triangular wave component on which I_L is superimposed is smoothed by the capacitor, C_{OUT}.

10.3. Overcurrent Protection Function (OCP)

The IC has the fold-back type overcurrent protection (OCP) circuit. The overcurrent protection circuit detects the peak current of the switching transistor. When the peak current exceeds the set value, the current is limited by forcibly shortening the on-time of the transistor and reducing the output voltage. When the output voltage decreases further to 50% of the rated value, the switching frequency is decreased to about 40 kHz. As a result, the current increase at the low output voltage is suppressed. When the overcurrent state is released, the output voltage restarts automatically.

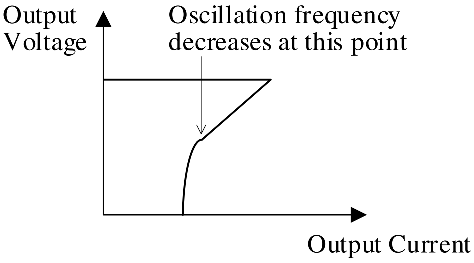


Figure 10-5. Overcurrent Protection Characteristics

10.4. Thermal Shutdown (TSD)

The thermal shutdown (TSD) circuit of the IC detects the junction temperature of the IC. When the junction temperature exceeds the set value, the TSD turns off the output by stopping the output transistor. When the junction temperature drops for about 15 °C from the thermal shutdown set value, the TSD automatically restarts the normal operation.

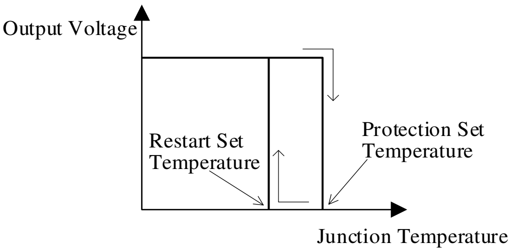


Figure 10-6. Thermal Shutdown Characteristics

10.5. Output On/Off Function

Output can be turned on/off using the ON/OFF pin. To use on/off function, connect a transistor as shown in Figure 10-7. When the ON/OFF pin voltage decreases to be V_{ONOFF_L} or lower, the output is stopped.

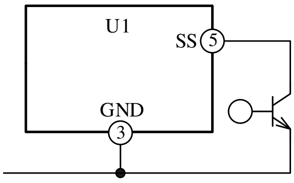


Figure 10-7. On/Off Function

By connecting C3 as shown in Figure 10-8, the rising delay time is set by using the on/off function. In this case, the discharge current of C3 flows through the transistor for on/off function. Therefore, protection such as current limiting is required when the capacitance of C3 is large.

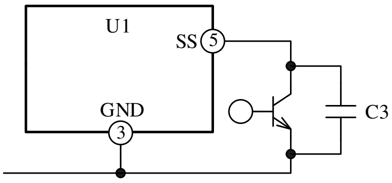


Figure 10-8. Rising Delay Time Setting

The voltage cannot be externally applied because the ON/OFF pin is pulled up to the internal power supply. Leave the ON/OFF pin open if the soft start function is not used.

11. Design Notes

11.1. Selecting External Components

11.1.1. Inductor, L1

The inductor, L, supplies the current to the load side at switching transistor turn-off. For the regulator stable operation, it is required to avoid saturating the inductor and excessive self-heating. The following are the key considerations and the guidelines for selecting an inductor.

a) An inductor should be for switching regulator
Do not use an inductor for noise filter because it has a large loss.

b) Rated current
The inductor rated current must be larger than the maximum load current according to your application. When the load current exceeds the rated current of the inductor, the inductance decreases significantly, resulting in saturation. Note that in this state, the high frequency impedance decreases and an excessive current flows.

c) Low noise
In the open magnetic circuit core such as drum type, the peripheral circuit may be significantly affected by noise because the magnetic flux passes outside the coil. It is recommended to use a closed magnetic circuit core coil such as a toroidal type, EI type, or EE type.

d) Inductance value should be appropriate
The larger the inductance of the choke coil, the larger the external size of the coil. On the other hand, the ripple current flowing through the coil decreases and the output ripple voltage also decreases (see Figure 11-1).
The smaller the inductance, the larger the peak current that flows through the switching transistor or diode. Thus, the loss increases and the ripple voltage also increases (see Figure 11-2).

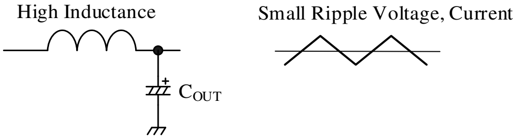


Figure 11-1. Ripple Voltage and Current (High Inductance)

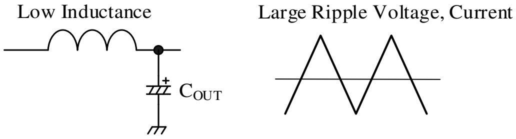


Figure 11-2. Ripple Voltage and Current (Low Inductance)

Inductance is calculated by the Equation (1).

$$L = \frac{(V_{IN} - V_{OUT}) \times V_{OUT}}{\Delta IL \times V_{IN} \times f} \tag{1}$$

In the Equation, (1), ΔI_L shows the ripple current value of the choke coil, and the reference value is set as follows:

- When the output current in your application is close to the maximum rating (1.5 A): 0.2 to 0.3 times the output current
- When the output current in your application is approximately 0.5 A or less: 0.5 to 0.6 times the output current

For example, when V_{IN} = 25 V, V_{OUT} = 5 V, ΔI_L = 0.3 A, and f = 125 kHz, L is calculated as follows:

$$L = \frac{(25 - 5) \times 5}{0.3 \times 25 \times 125 \times 10^3} \fallingdotseq 106\ \mu H$$

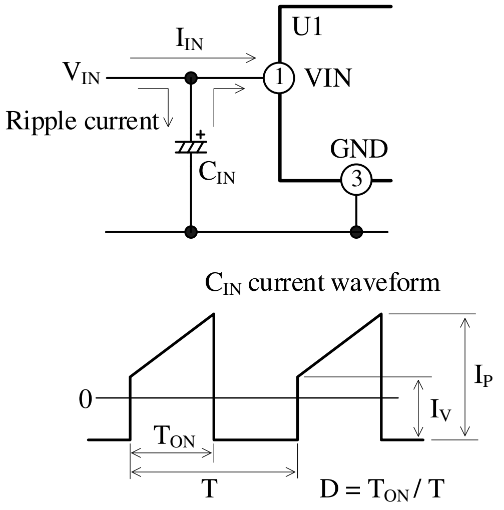
Thus, the inductor of about 100 µH should be selected.

11.1.2. Input Capacitor, C_{IN}

The input capacitor, C_{IN}, operates as a bypass capacitor for the input circuit. C_{IN} compensates for the voltage drop in the input side by supplying a steep current at switching to the regulator. Therefore, C_{IN} should be placed as close as possible to the IC. When the smoothing capacitor of AC rectifier circuit is in the input circuit, the smoothing capacitor can also be used as the input capacitor.

The following are the key considerations and the guidelines for selecting C_{IN}.

a) Within the rated voltage
b) Within the allowable ripple current



As the load current increases, the ripple current of the input capacitor increases.

Figure 11-3. C_{IN} Current Flow

Exceeding the rated voltage or the allowable ripple current or using without considering the derating may cause abnormal oscillation of the switching regulator as well as shorten the life of the capacitor. Therefore, select C_{IN} with sufficient margin for the rated voltage and allowable ripple current. The ripple effective current, I_{RMS}, flowing through the input capacitor is calculated by Equation (2).

$$I_{RMS} \approx 1.2 \times \frac{V_{OUT}}{V_{IN}} \times I_{OUT} \qquad (2)$$

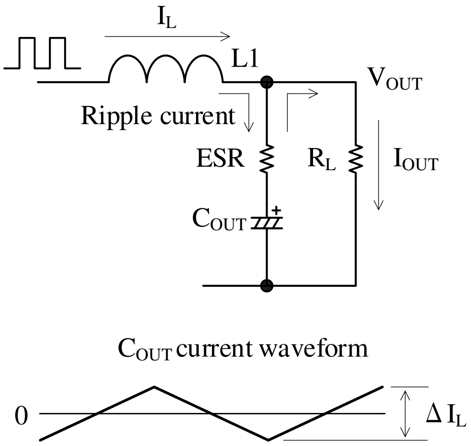
For example, when I_{OUT} = 1.5 A, V_{IN} = 20 V, and V_{OUT} = 5 V, I_{RMS} is calculated as follows:

$$I_{RMS} \approx 1.2 \times \frac{5}{20} \times 1.5 = 0.45\ \mathrm{A}$$

Thus, select a capacitor that has an allowable ripple current of > 0.45 A.

11.1.3. Output Capacitor, C_{OUT}

The output capacitor, C_{OUT}, operates as an LC low-pass filter along with the inductor, L1, and operates as a smoothing capacitor for switching output. The output capacitor is charged and discharged with a current equal to the ripple current of the choke coil, ΔI_L. Therefore, as in the input capacitor, C_{IN}, C_{OUT} is selected with sufficient margin and equivalent series resistance (ESR) for the rated voltage and allowable ripple current. The following are the key considerations and the guidelines for selecting C_{OUT}.



The ripple current of the output capacitor is equal to the ripple current of the choke coil and does not change even if the load current increases or decreases.

Figure 11-4. C_{OUT} Current Flow

- Allowable ripple current
  The ripple effective current of the output capacitor is calculated by Equation (3).

$$I_{RMS} = \frac{\Delta I_L}{2\sqrt{3}} \qquad (3)$$

For example, when ΔI_L is 0.5 A, I_{RMS} is calculated as follows:

$$I_{RMS} = \frac{0.5}{2\sqrt{3}} \approx 0.14\ \mathrm{A}$$

Thus, select a capacitor that has an allowable ripple current of > 0.14 A.

- Equivalent series resistance (ESR)

Select an appropriate value for ESR for stable operation. If the ESR is too large, the output ripple voltage increases, and abnormal oscillation may be caused. On the other hand, if the ESR is too small, the phase margin becomes insufficient. The output ripple voltage is determined by the product of the inductor ripple current, ΔI_L (= C_{OUT} charge/discharge current) and ESR. For stable operation, the output ripple voltage should be 0.5% to 2% of the output voltage. The output ripple voltage is calculated using equations (4) and (5). ESR changes with temperature. Note that the ESR decreases at high temperatures.

$$V_{RIP} \approx \frac{(V_{IN} - V_{OUT}) \times V_{OUT}}{L1 \times V_{IN} \times f} \times ESR \qquad (4)$$

$$V_{RIP} \approx \Delta I_L \times ESR \qquad (5)$$

If the ESR is too small (about 10 mΩ to 30 mΩ or less), the phase delay becomes large and abnormal oscillation may occur. Do not use tantalum capacitors and monolithic ceramic capacitors alone for C_{OUT} as they have low ESR. When used at low temperature (0 °C or less), connecting a tantalum capacitor or a laminated ceramic capacitor in parallel with the electrolytic capacitor is effective in reducing the output ripple voltage. In order to further reduce the output ripple voltage, it is effective to add an LC filter to configure a pi filter (see Figure 11-5). When an LC filter is added, connect the point A to the VOS pin so that point A in Figure 11-5 is the output voltage detection point. If point A is not set as the output voltage detection point, abnormal oscillation may occur.

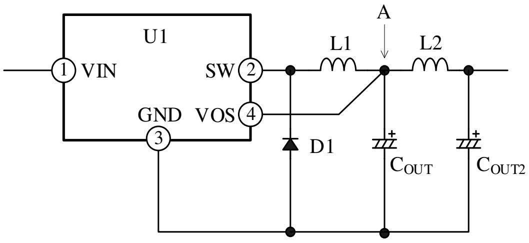


Figure 11-5. Pi Filter
(L2: 20 µH, C_{OUT2}: 200 µF)

The output capacitor should be placed as close as possible to the IC.

11.1.4. Freewheeling Diode, D1

The freewheel diode is used to release the energy stored in the inductor at switching off. Be sure to use a Schottky diode for the freewheeling diode. If a diode with a long recovery time and a large forward voltage, such as a general-purpose rectifier diode, is used, a reverse voltage is applied to the IC, which may damage the IC.

The voltage output from the SW pin is close to the input voltage. Therefore, use a freewheeling diode whose reverse breakdown voltage is higher than the input voltage. Do not add ferrite beads to the freewheeling diode.

11.1.5. Spike Noise Reduction

To reduce spike noise, add a noise reduction circuit between the input and output of the IC and both ends of the freewheeling diode, D1. Note that the efficiency is decreased.

When measuring spike noise with an oscilloscope, connect the probe to the root of the output capacitor with the shortest probe lead wire. If the probe ground lead wire is long, the spike noises may be measured abnormally large because the lead wire acts as an antenna.

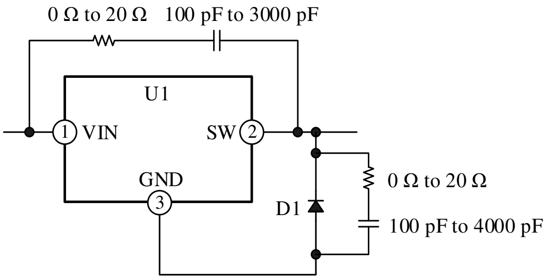


Figure 11-6. Spike Noise Reduction

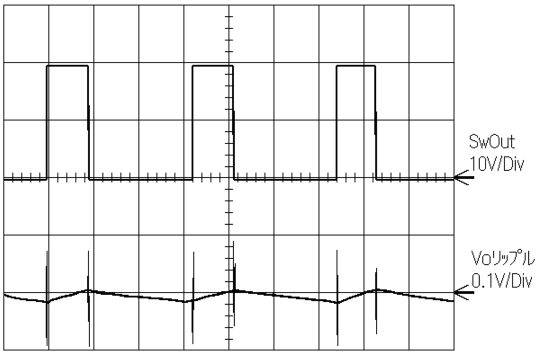


Figure 11-7. Without Noise Reduction Circuit

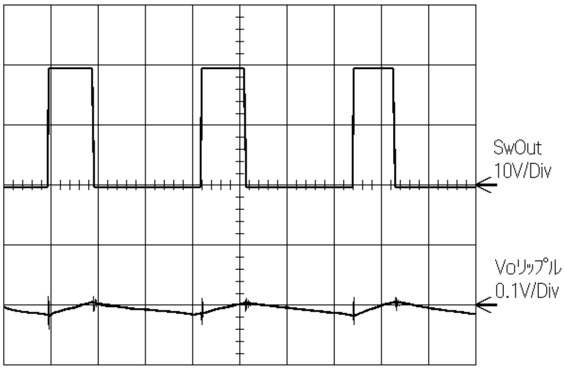


Figure 11-8. With Noise Reduction Circuit

11.1.6. Reverse Biasing Protection

For the applications where the output pin voltage is higher than the input pin voltage (e.g., battery charger), add a diode for reverse bias protection between the input and output.

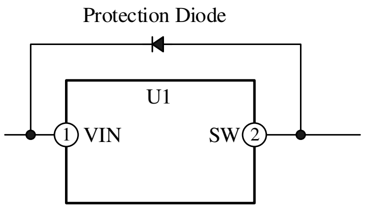


Figure 11-9. Addition of Reverse Bias Protection Diode

11.2. PCB Layout

11.2.1. High Current Line

Traces where the switching current flows (bold line in Figure 11-10) should be as wide and short as possible.

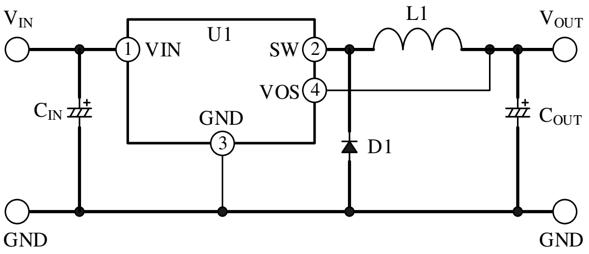
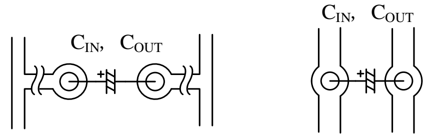


Figure 11-10. High Current Line

11.2.2. Input/ Output Capacitor

The input capacitor, C_{IN}, and the output capacitor, C_{OUT}, must be placed as close as possible to the IC. When C_{IN} and C_{OUT} are far from the IC, it may cause poor regulation or abnormal oscillation due to increased switching ripple.

When a smoothing capacitor for the AC rectifier circuit is in the input side, the smoothing capacitor can also be used as the input capacitor. When the input smoothing capacitor and the IC are distant, connect an input capacitor separated from the smoothing capacitor. Since the large current is charged and discharged to the input/output capacitor at high speed, the lead wire should be as short as possible. The pattern of the capacitor should also be the shortest.



Improper Pattern Example Proper Pattern Example

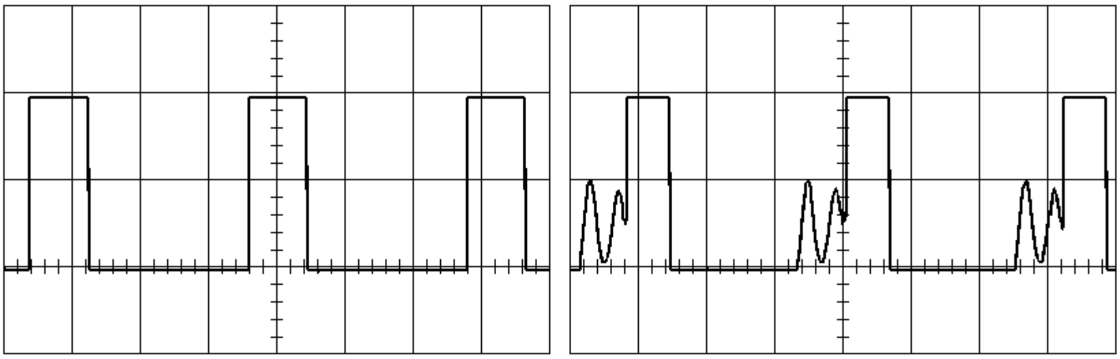
Figure 11-11. Pattern Example

11.3. Operational Waveforms Confirmation

Whether the switching operation is normal can be confirmed by the waveform between the SW and GND pins of the IC. Figure 11-12 shows examples of waveforms in normal operation and abnormal oscillation.

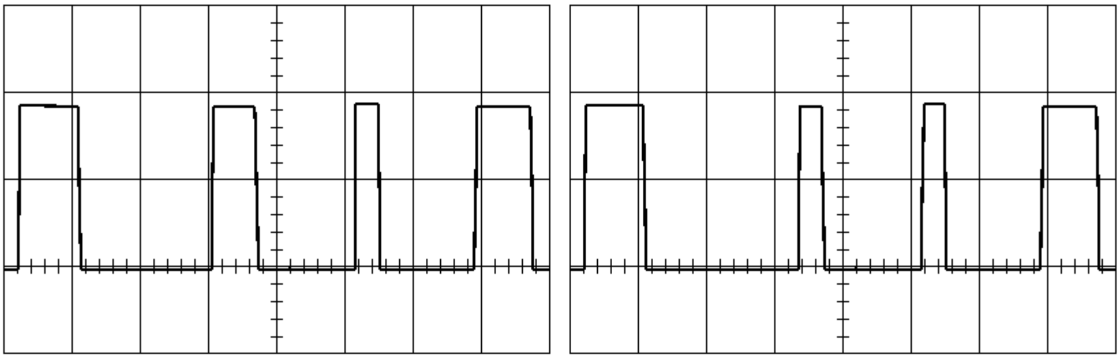
When the load current is large, the IC operates in continuous conduction mode. In continuous conduction mode, the period when the current through inductor becomes zero does not occur. The switching waveform has the shape of a normal square wave (waveform 1).

When the load current is small, the IC operates in discontinuous conduction mode. In discontinuous conduction mode, the period when the current through inductor becomes zero occurs. The damped oscillation occurs in the switching waveform, which is normal operation (waveform 2).
If the IC and C_{IN}, C_{OUT} are distant from each other, abnormal on/off time of switching is disturbed, and abnormal oscillation occurs as shown in waveform 3 and waveform 4.



1. Normal operation (continuous conduction mode)

2. Normal operation (discontinuous conduction mode)



3. Abnormal oscillation (when C_{IN} is distant)

4. Abnormal oscillation (when C_{OUT} is distant)

Figure 11-12. Waveform Examples

11.4. 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.

Figure 13-25 shows the thermal 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) $P_{D(MAX)}$ is calculated by changing the input/output conditions and checking the power dissipation, P_D. P_D is calculated by Equation (6).

$$P_D = V_O \times I_O \left(\frac{100}{\eta} - 1 \right) - V_F \times I_O \left(1 - \frac{V_O}{V_{IN}} \right) \qquad (6)$$

Where:

V_{OUT} is the output voltage

V_{IN} is the input voltage

I_{OUT} is the output current

η is the efficiency (%) (calculated by Figure 13-1 and Figure 13-7)

V_F is D1 forward voltage

(3) Determine the copper area by confirming the intersection of ambient temperature and power dissipation by the thermal derating characteristics shown in Figure 13-25.

For reference, Figure 11-13 shows the relationship between the copper area and thermal resistance of a single-sided copper foil board, FR-4.

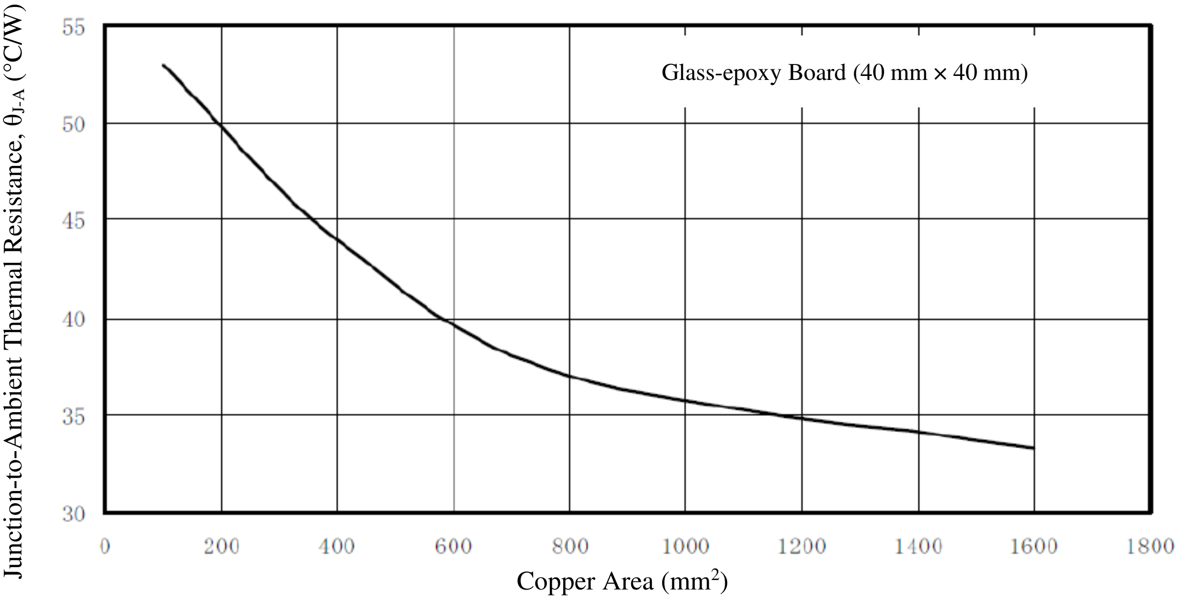


Figure 11-13. Thermal Resistance - Copper Area Reference Characteristics (Single-sided Copper Foil Board, FR-4)*

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* Limited by the condition of the input voltage and output current because the power dissipation of the IC package is 3 W.

12. Pattern Layout Example

Connect the ground traces to the GND pin at a single point. Place control components near the IC with a minimal length of PCB traces.

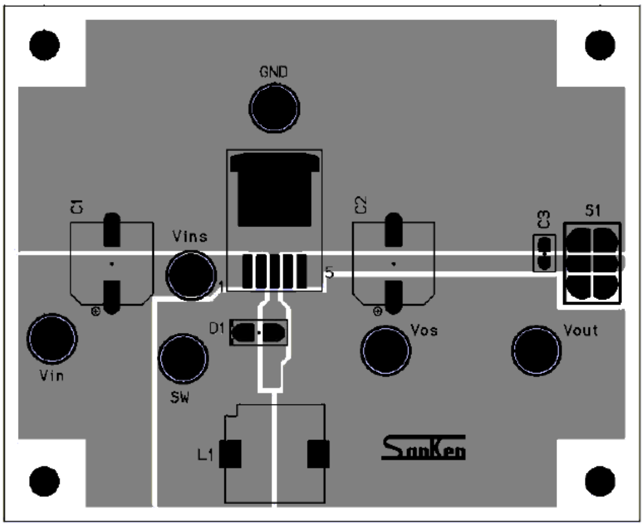


Figure 12-1. Pattern Layout Example

13. Typical Characteristics

13.1. SI-8033JD

Unless specifically noted, $T_A = 25$ °C.

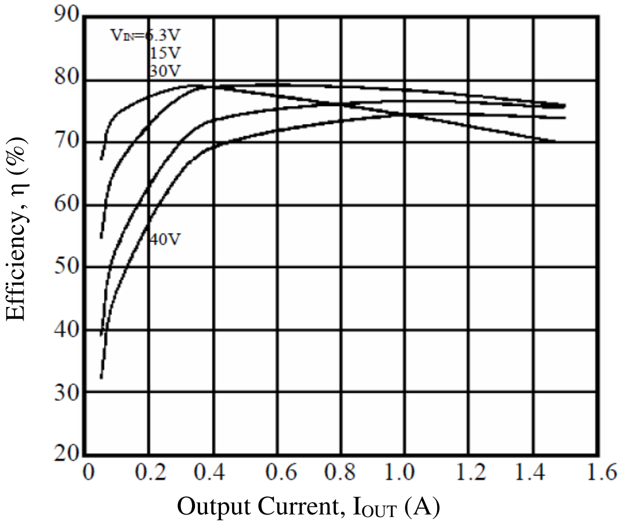


Figure 13-1. Efficiency

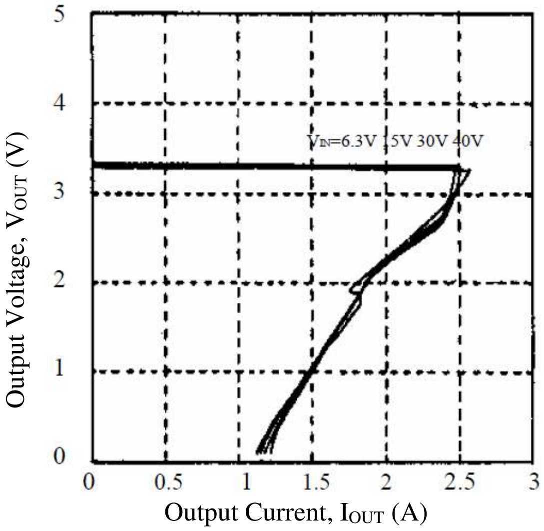


Figure 13-2. Overcurrent Protection Characteristics

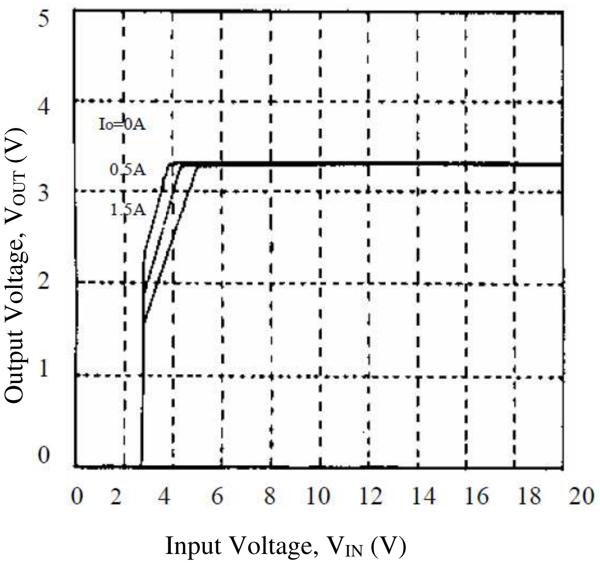


Figure 13-3. Rising Characteristics

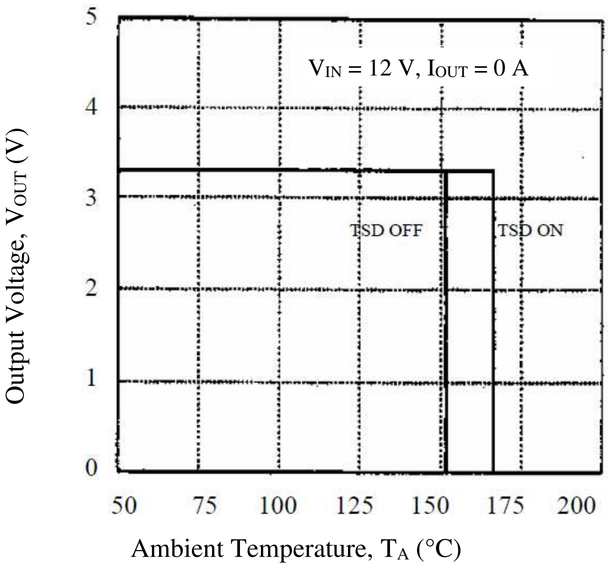


Figure 13-4. Thermal Shutdown Characteristics

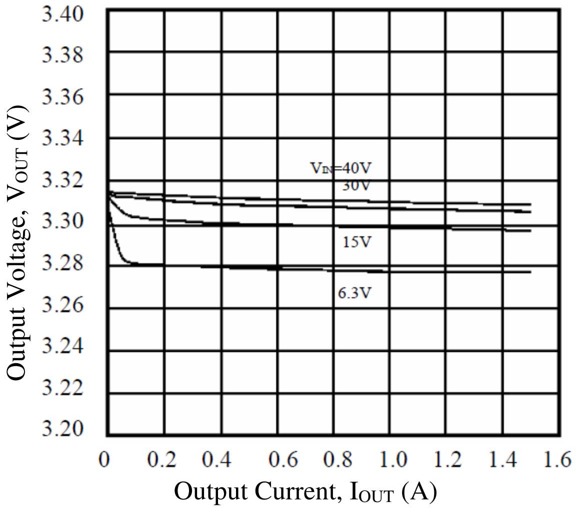


Figure 13-5. Load Regulation

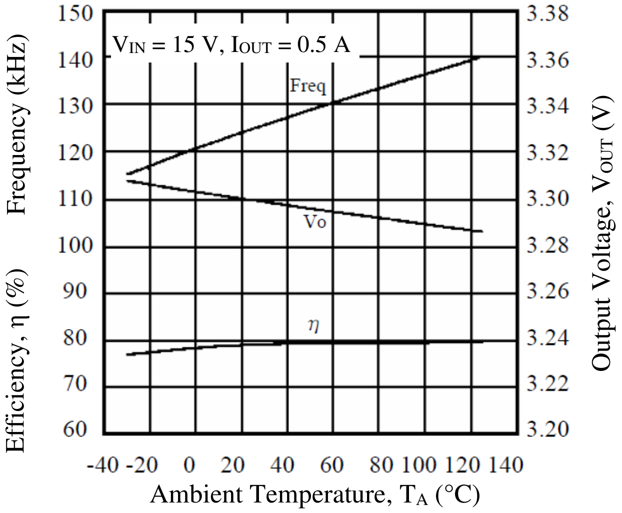


Figure 13-6. Temperature Characteristic

13.2. SI-8050JD

Unless specifically noted, T_A = 25 °C.

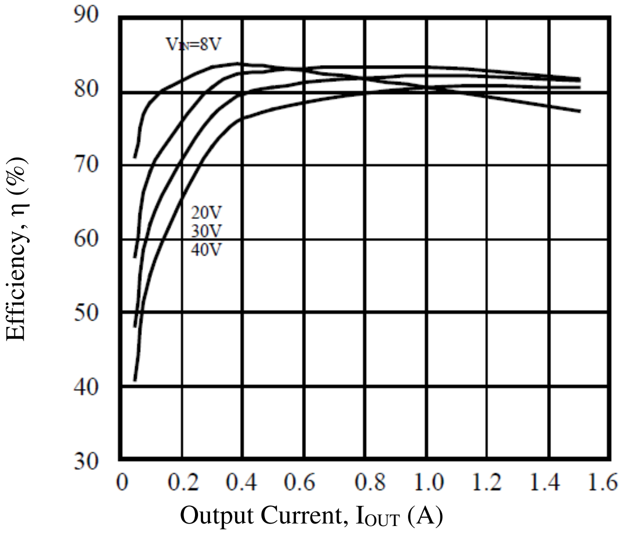


Figure 13-7. Efficiency

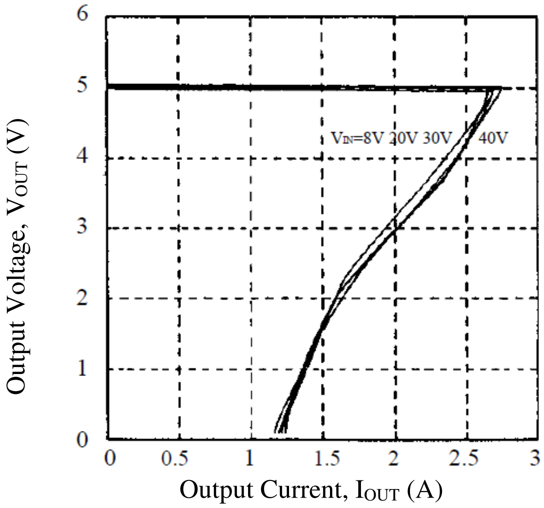


Figure 13-8. Overcurrent Protection Characteristics

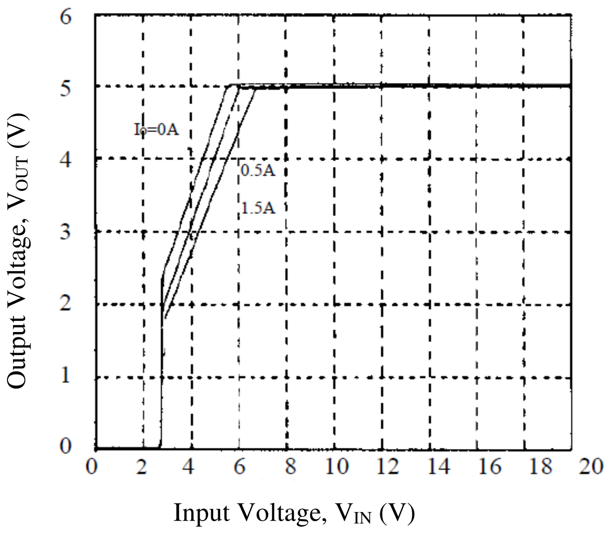


Figure 13-9. Rising Characteristics

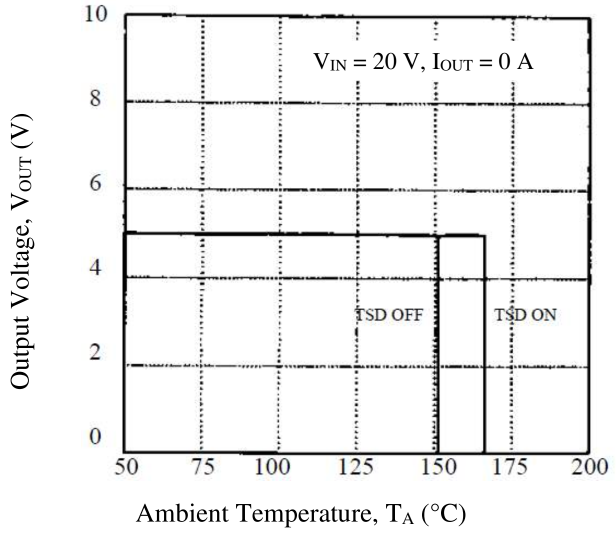


Figure 13-10. Thermal Shutdown Characteristics

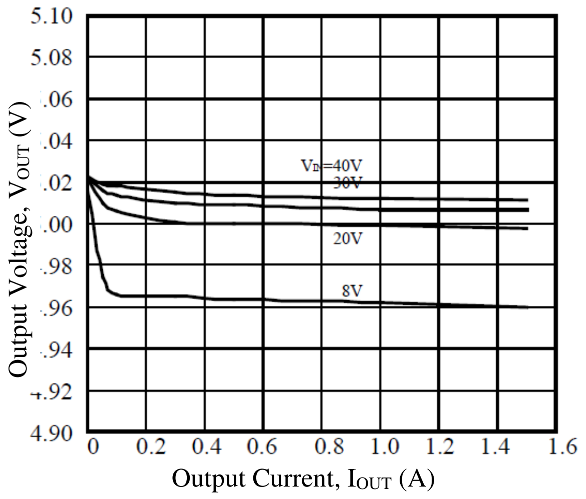


Figure 13-11. Load Regulation

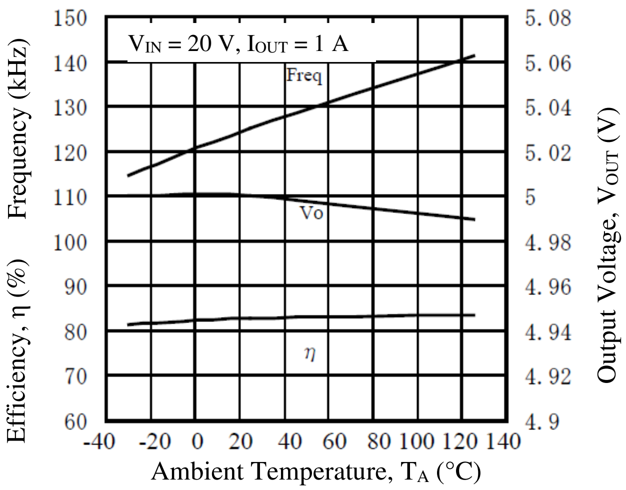


Figure 13-12. Temperature Characteristic

13.3. SI-8090JD

Unless specifically noted, T_A = 25 °C.

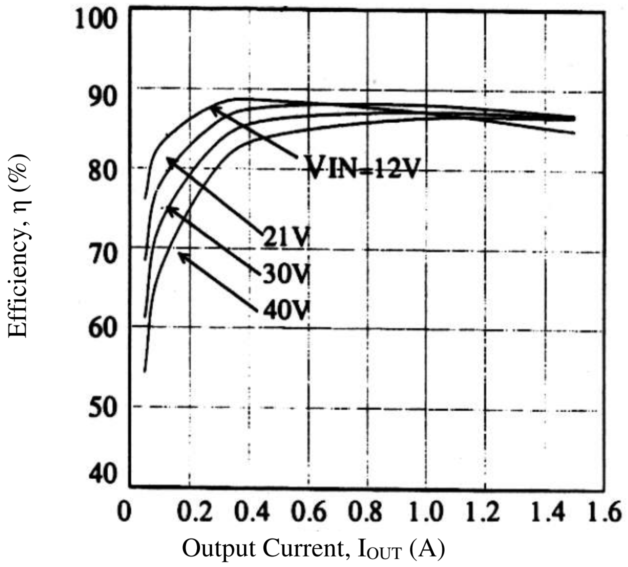


Figure 13-13. Efficiency

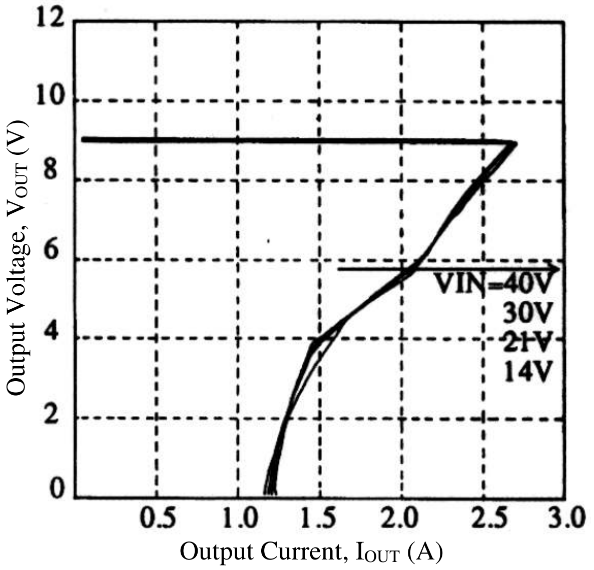


Figure 13-14. Overcurrent Protection Characteristics

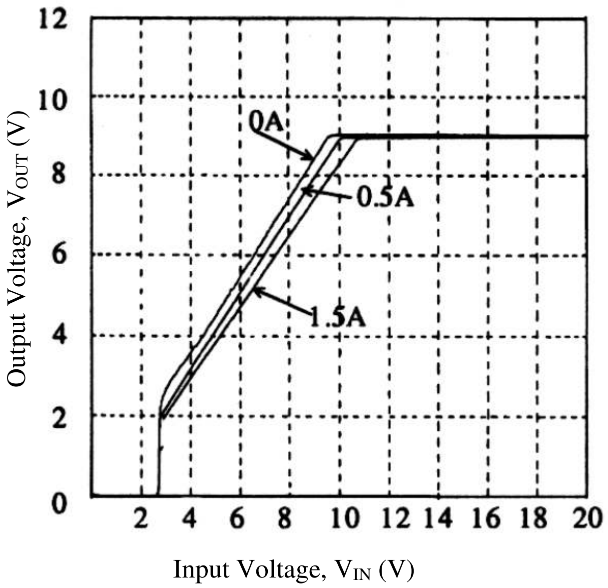


Figure 13-15. Rising Characteristics

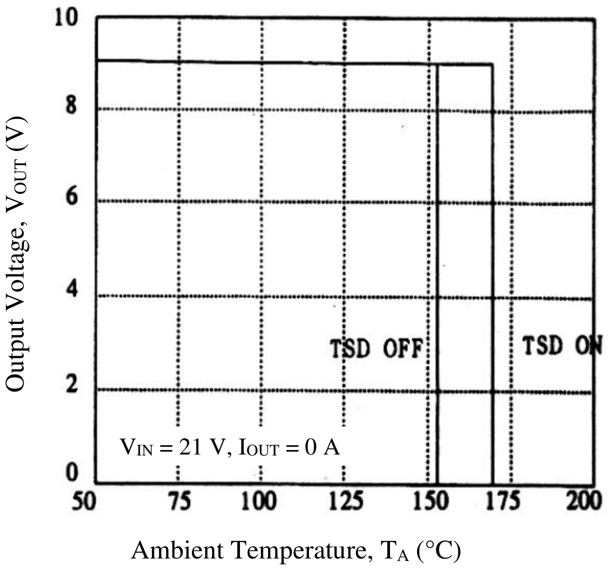


Figure 13-16. Thermal Shutdown Characteristics

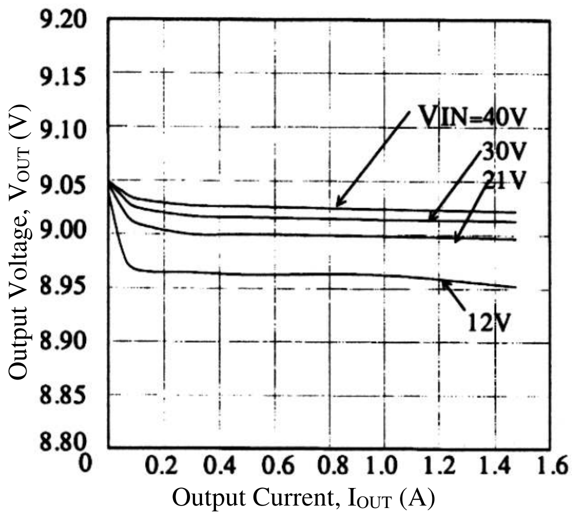


Figure 13-17. Load Regulation

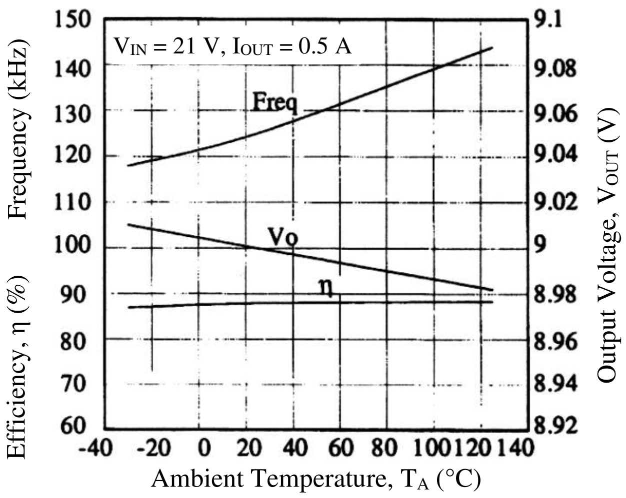
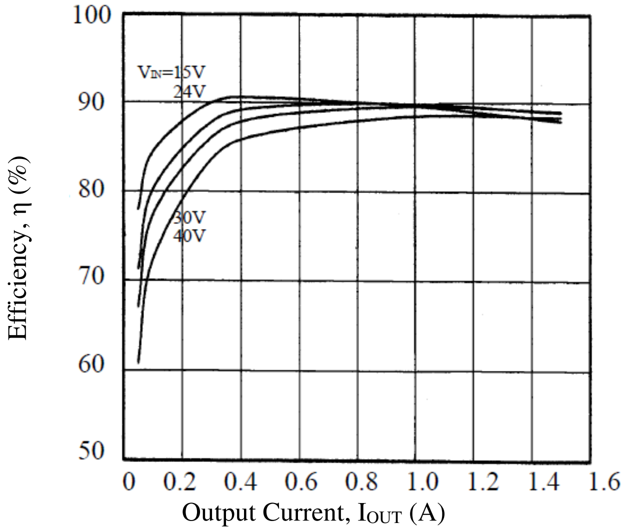


Figure 13-18. Temperature Characteristic

13.4. SI-8120JD

Unless specifically noted, T_A = 25 °C.



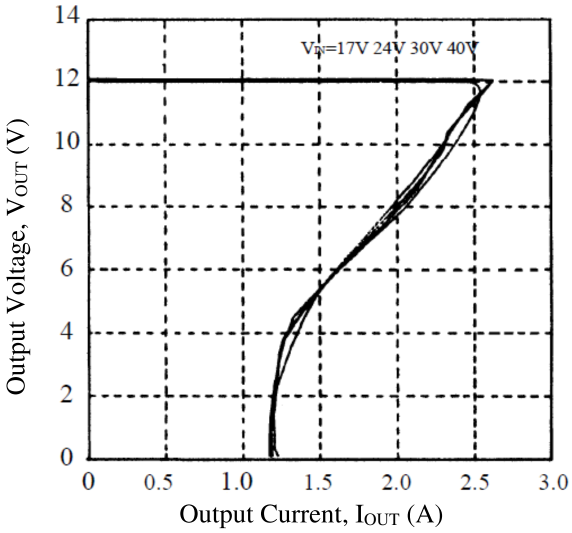


Figure 13-19. Efficiency

Figure 13-20. Overcurrent Protection Characteristics

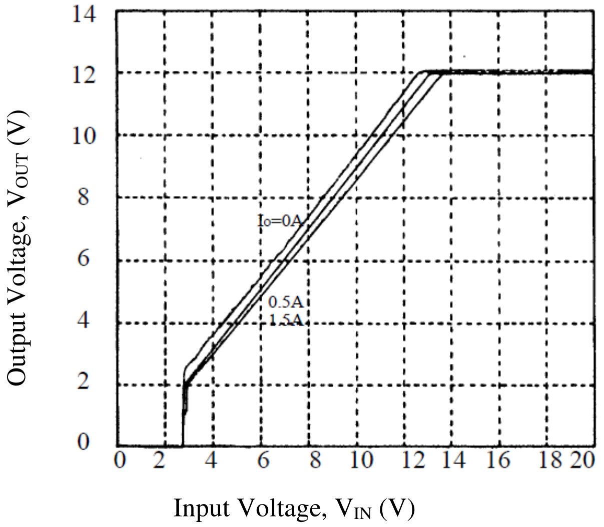


Figure 13-21. Rising Characteristics

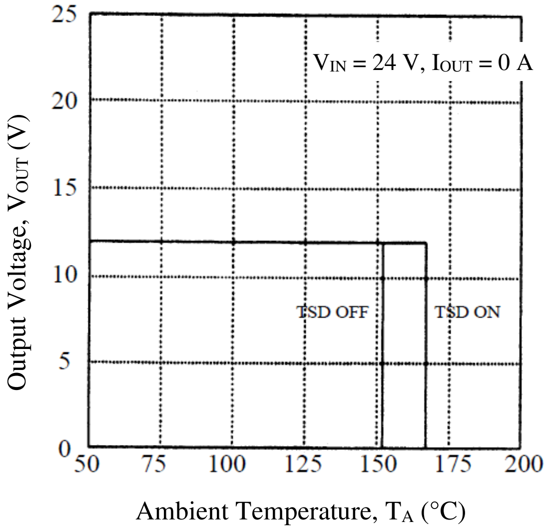


Figure 13-22. Thermal Shutdown Characteristics

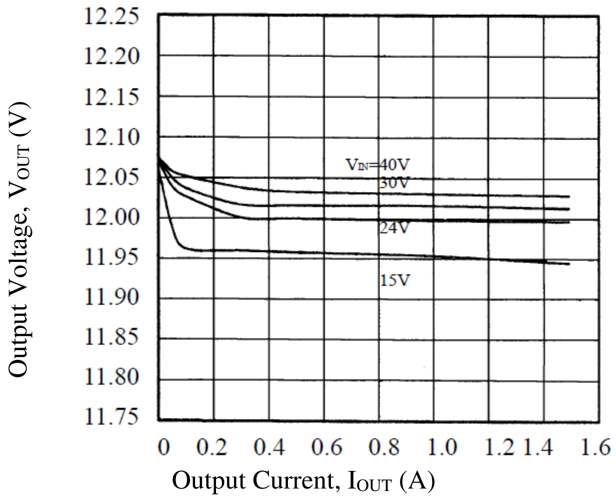


Figure 13-23. Load Regulation

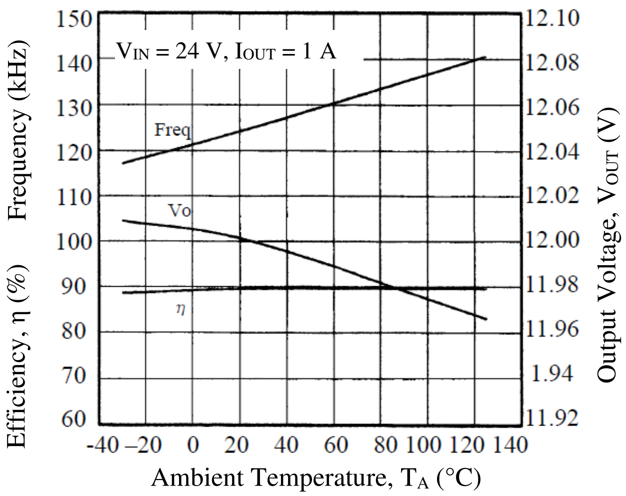


Figure 13-24. Temperature Characteristic

13.6. Thermal Derating Curve

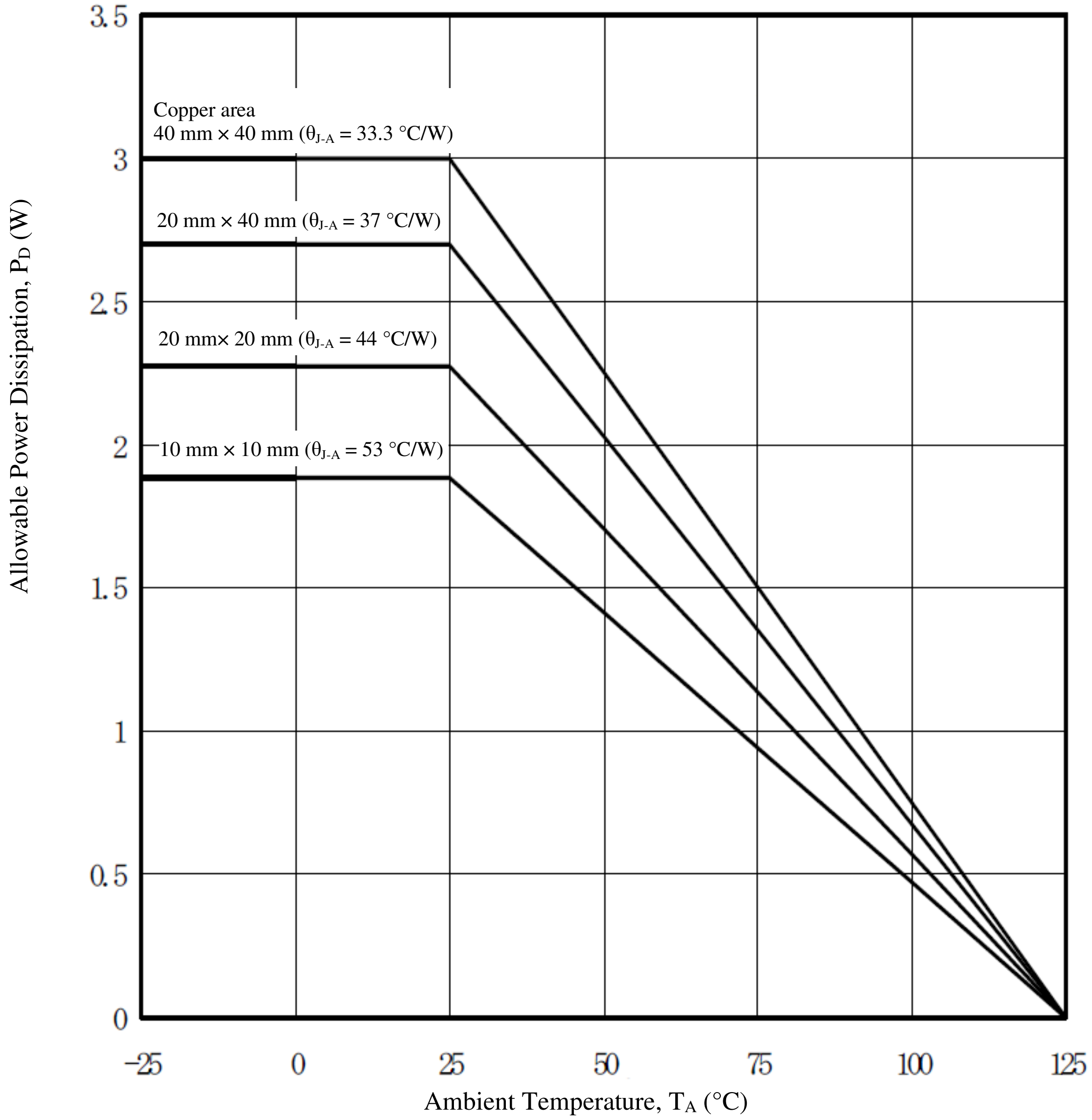


Figure 13-25. Thermal Derating

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