

5.5 A, Buck Converter IC SI-8008HD

Description

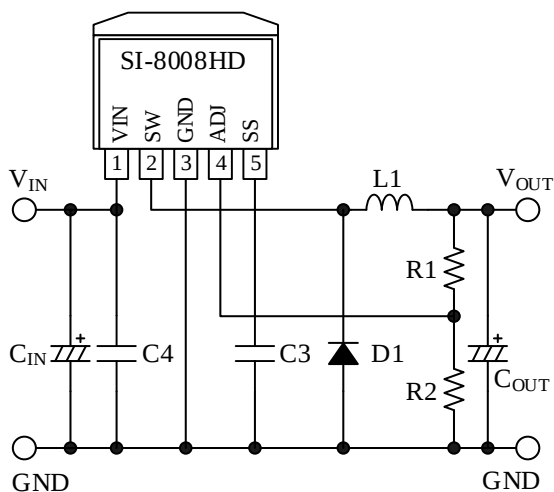
SI-8008HD is a buck converter IC whose maximum output current is 5.5 A. Output voltage is adjusted by external resistors.

The IC has various functions including the Soft Start Function, the Output On/Off Function, the Overcurrent Protection and the Thermal Shutdown, and achieves a buck converter circuit with few external components.

Features

- High Efficiency 83% ($V_{IN} = 15\text{ V}$, $I_{OUT} = 3\text{ A}$)
- Few Components
- Downsized Choke Coil
(Switching Frequency 150 kHz (typ.))
- Soft Start Function
- On/Off Function
- Low Supply Current during Output Off
- Protection Functions
 - Overcurrent Protections (OCP): Drooping Type, Auto-restart
 - Thermal Shutdown (TSD): Auto-restart

Typical Application



Package

TO263-5L



Not to scale

Specifications

- Input Voltage: $V_{OUT} + 3\text{ V}$ to 40 V
- Output Voltage: 0.8 V to 24 V
- Output Current: 0 to 5.5 A
- Reference Voltage: 0.8 V
- Efficiency: 83% (typ.)
($V_{IN} = 15\text{ V}$, $I_{OUT} = 3\text{ A}$, $V_{OUT} = 5\text{ V}$)

Applications

For the systems requiring power supplies such as:

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

Contents

Description	1
Contents	2
1. Absolute Maximum Ratings	3
2. Thermal Resistance Characteristics	3
3. Recommended Operating Conditions	4
4. Electrical Characteristics	4
5. Block Diagram	5
6. Pin Configuration Definitions	5
7. Typical Application	6
8. Physical Dimensions	7
8.1. Land Pattern Example	7
9. Marking Diagram	8
10. Operational Description	9
10.1. PWM Output Voltage Control	9
10.2. Input/output Current and Inductor Current	9
10.3. Output Voltage Setting	10
10.4. Overcurrent Protection Function (OCP)	10
10.5. Thermal Shutdown (TSD)	10
10.6. Soft Start Function	10
10.7. Output On/Off Function	11
11. Design Notes	12
11.1. Selecting External Components	12
11.1.1. Inductor, L1	12
11.1.2. Input Capacitor, C _{IN}	12
11.1.3. Output Capacitor, C _{OUT}	13
11.1.4. Freewheeling Diode, D1	14
11.1.5. Spike Noise Reduction	14
11.1.6. Reverse Biasing Protection	15
11.2. PCB Layout	15
11.2.1. High Current Line	15
11.2.2. Input/ Output Capacitor	15
11.2.3. ADJ Pin	15
11.3. Operational Waveforms Confirmation	15
11.4. Thermal Design	17
12. Pattern Layout Example	18
13. Typical Characteristics	19
Important Notes	21

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, $T_A = 25\text{ }^{\circ}\text{C}$.

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		150	$^{\circ}\text{C}$	⁽³⁾
Storage Temperature	T_{STG}		-40 to 150	$^{\circ}\text{C}$	

⁽¹⁾ Limited by the thermal shutdown.

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

⁽³⁾ When the junction temperature increases to 130 $^{\circ}\text{C}$ or more, the thermal shutdown is activated.

2. Thermal Resistance Characteristics

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

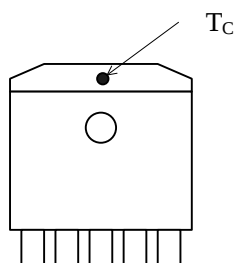


Figure 2-1. Case Temperature Measurement Point

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

3. Recommended Operating Conditions

Parameter	Symbol	Conditions	Min.	Max.	Unit
Input Voltage ⁽¹⁾	V _{IN}		V _{OUT} + 3 V	40	V
Output Voltage	V _{OUT}		0.8	24	V
Output Current	I _{OUT}	V _{IN} ≥ V _{OUT} + 3 V	0	5.5	A
Operating Junction Temperature	T _{JOP}		−30	100	°C
Operating Ambient Temperature ⁽²⁾	T _{OP}		−30	85	°C

⁽¹⁾ The minimum input voltage is either 4.5 V or V_{OUT} + 3 V, whichever is higher.

⁽²⁾ Must be used in the range of thermal derating (see Figure 13-6).

4. Electrical Characteristics

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 (−).

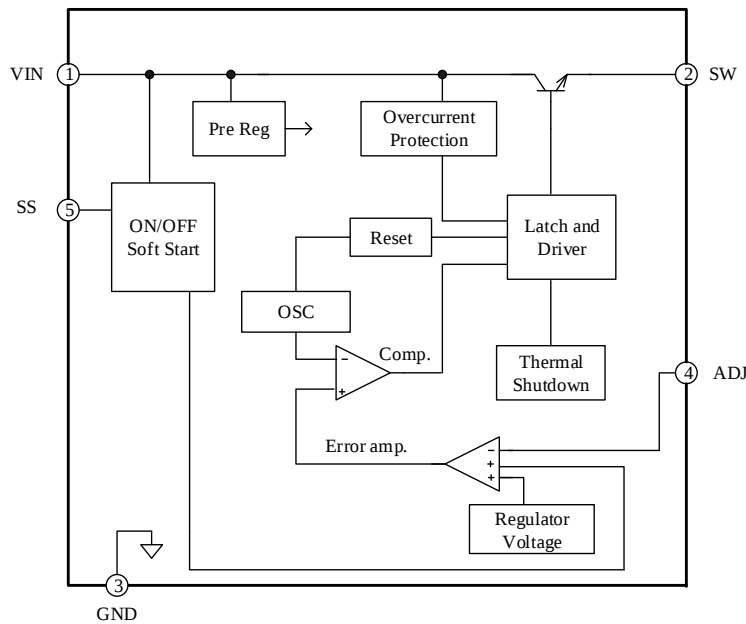
Unless otherwise specified, T_A = 25 °C, V_{IN} = 15 V, V_{OUT} = 5 V, R₁ = 4.2 kΩ, and R₂ = 0.8 kΩ.

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Reference Voltage	V _{ADJ}	I _{OUT} = 1 A	0.784	0.800	0.816	V
Reference Voltage Temperature Coefficient	ΔV _{ADJ} /ΔT	I _{OUT} = 1 A, T _C = 0 °C to 100 °C	—	±0.1	—	mV/°C
Efficiency*	η	I _{OUT} = 3 A	—	83	—	%
Operating Frequency	f _O	I _{OUT} = 3 A	—	150	—	kHz
Line Regulation	V _{LINE}	V _{IN} = 10 V to 30 V, I _{OUT} = 3 A	—	60	80	mV
Load Regulation	V _{LOAD}	I _{OUT} = 0.2 V to 5.5 A	—	20	50	mV
Overcurrent Protection Start Current	I _S		5.6	6.5	7.5	A
SS Pin Low Level Voltage	V _{SSL}		—	—	0.5	V
SS Pin Source Current at Low Level	I _{SSL}	V _{SSL} = 0 V	—	10	30	μA
Quiescent Current 1	I _Q	I _{OUT} = 0 A	—	6	—	mA
Quiescent Current 2	I _{Q(OFF)}	V _{SS} = 0 V	—	200	400	μA

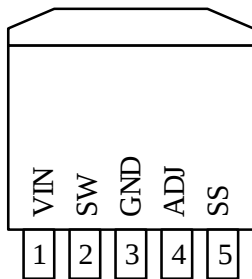
* Efficiency is calculated by the following equation.

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

5. Block Diagram



6. Pin Configuration Definitions



Pin Number	Pin Name	Description
1	VIN	Input pin
2	SW	Output pin
3	GND	Ground
4	ADJ	Output voltage setting
5	SS	Soft start period adjustment capacitor connection, on/off signal input

7. Typical Application

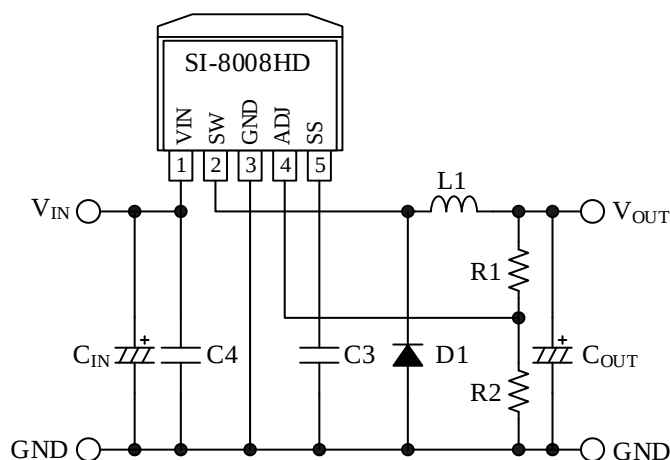


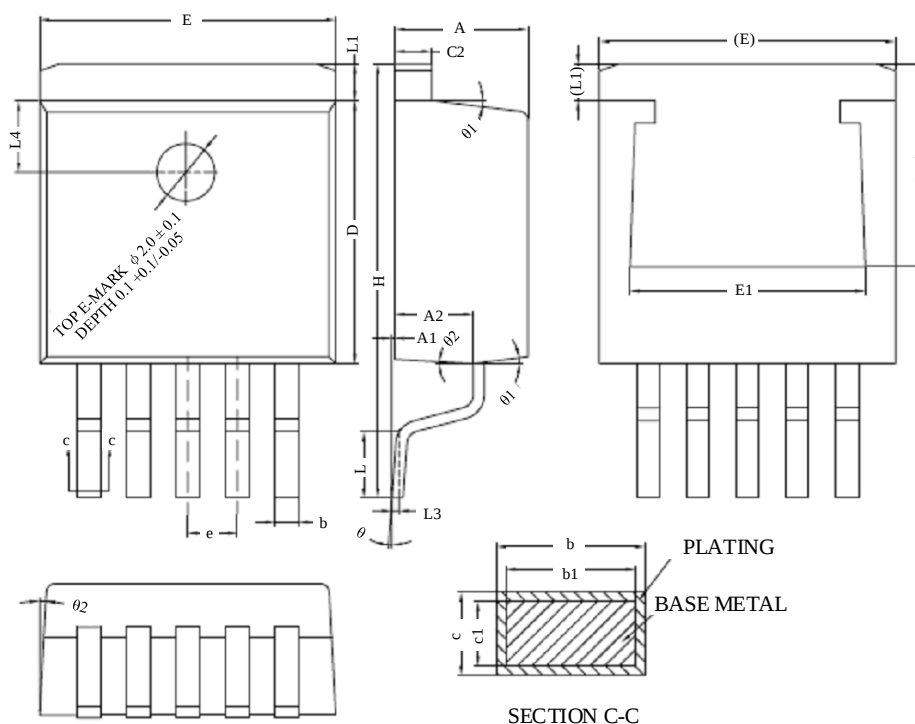
Figure 7-1. Typical Application

Table 7-1. Reference Value of External Components

Symbol	Part Type	Reference Value	Remarks
C_{IN}	Electrolytic capacitor	1000 μ F	See Section 11.1.2.
C_{OUT}	Electrolytic capacitor	1500 μ F	See Section 11.1.3.
C3	Ceramic capacitor	0.1 μ F	Soft start period adjustment capacitor. See Section 10.6.
C4	Ceramic capacitor	4.7 μ F	VIN pin noise filter capacitor. For stable operation, C4 is connected to the IC with a minimum length of traces.
R1	Resistor	—	Adjust resistance according to the output voltage. See Section 10.3.
R2	Resistor	—	
D1	Schottky diode	60 V, 6 A	See Section 11.1.4.
L1	Choke coil	100 μ H	See Section 11.1.1.

8. Physical Dimensions

• TO263-5L

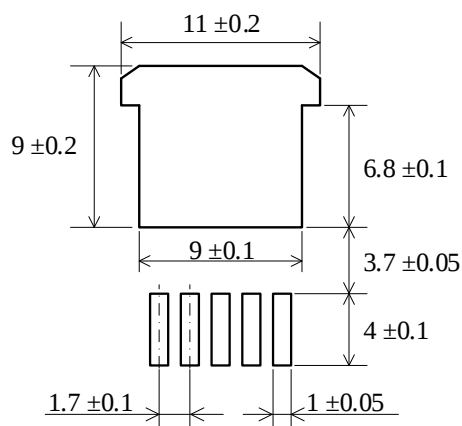


Symbol	Min.	Nom.	Max.
A	4.40	4.57	4.70
A1	0	0.10	0.25
A2	2.59	2.69	2.79
b	0.77	—	0.90
b1	0.76	0.81	0.86
c	0.34	—	0.47
c1	0.33	0.38	0.43
C2	1.22	—	1.32
D	9.05	9.15	9.25
D1	6.86	—	7.50
E	10.06	10.16	10.26
E1	7.50	—	8.30
e		1.70 BSC	
H	14.70	15.10	15.50
L	2.00	2.30	2.60
L1	1.17	1.27	1.40
L3	0.25 BSC		
L4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

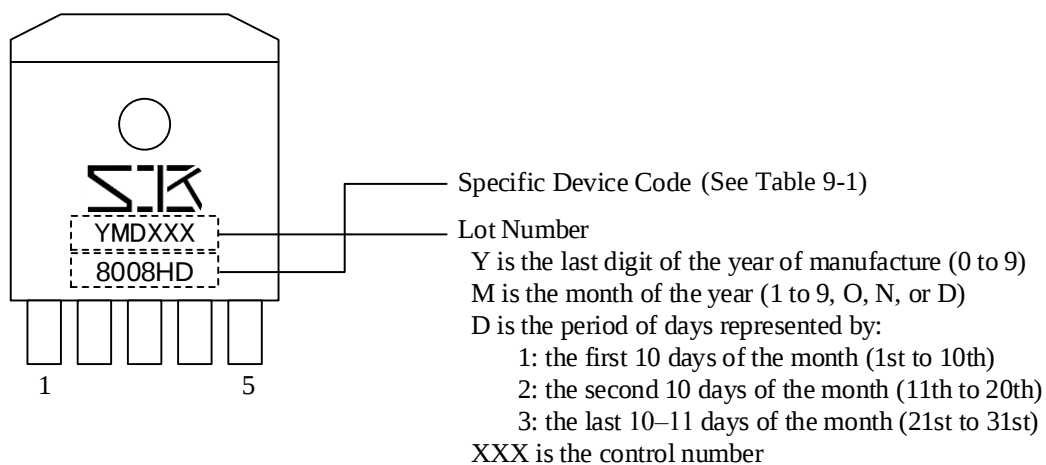


Table 9-1. Specific Device Code

Specific Device Code	Part Number
8008HD	SI-8008HD

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-8008HD controls the output voltage by the PWM method and has 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 (≈ 150 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.

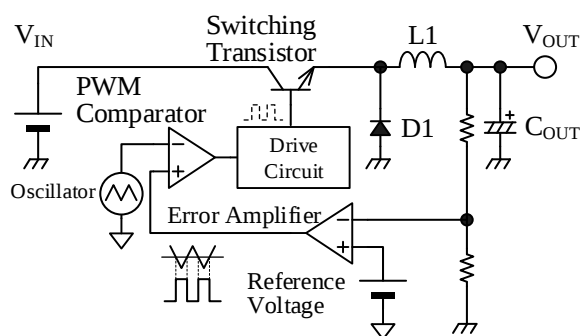


Figure 10-1. Basic Structure of Switching Regulator with PWM Control

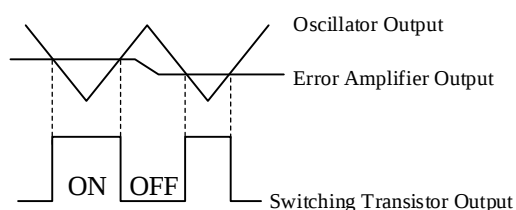


Figure 10-2. PWM Comparator Operation Diagram

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.

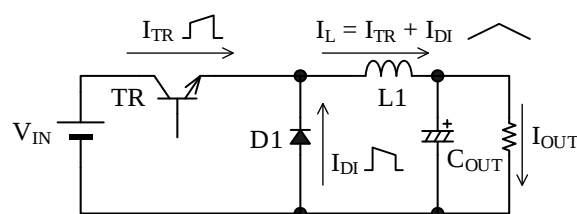


Figure 10-3. Schematic Diagram of Circuit Current

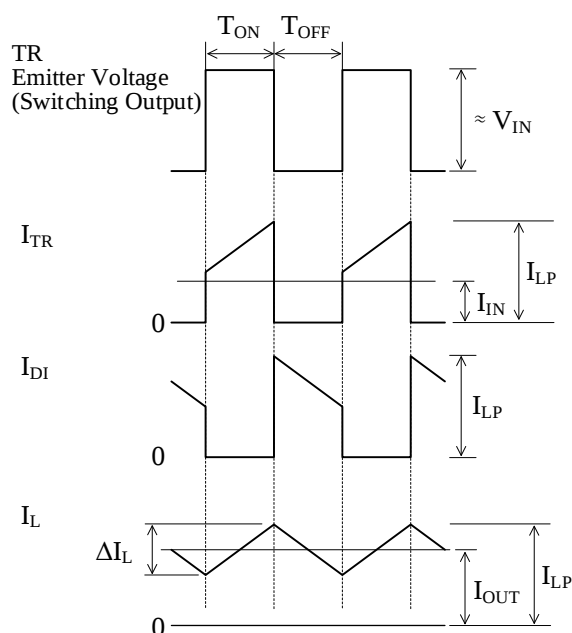


Figure 10-4. Waveforms of Current through Each Element

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. Output Voltage Setting

Output voltage is adjusted by external resistors, R1 and R2 (see Figure 7-1). The ADJ pin is for feedback signal input to control 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 1 mA. The setting reference voltage, V_{ADJ} , is 0.800 V. R2 is calculated by Equation (1).

$$R2 = \frac{V_{ADJ}}{I_{ADJ}} = \frac{0.8 \text{ (V)}}{1 \text{ (mA)}} = 0.8 \text{ (k}\Omega\text{)} \quad (1)$$

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

$$V_{OUT} = \frac{R1 + R2}{R2} \times V_{ADJ} \quad (2)$$

Thus, R1 is calculated by Equation (3).

$$R1 = \frac{R2 \times (V_{OUT} - V_{ADJ})}{V_{ADJ}} \\ = \frac{0.8 \text{ k}\Omega \times (V_{OUT} - 0.8 \text{ V})}{0.8 \text{ V}} \quad (3)$$

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 0.8 V, add R2 for stable operation. Set the output duty cycle to $\geq 8\%$.

10.4. Overcurrent Protection Function (OCP)

The IC has the drooping 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, the switching frequency is decreased to about 30 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.

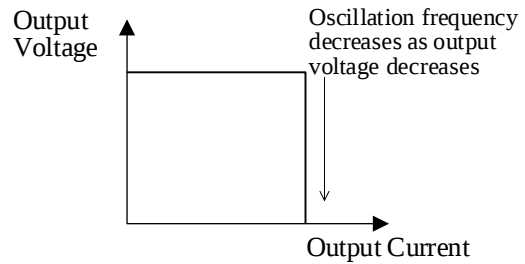


Figure 10-5. Overcurrent Protection Characteristics

10.5. 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.

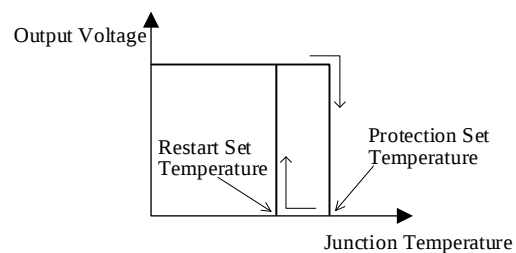


Figure 10-6. Thermal Shutdown Characteristics

10.6. Soft Start Function

When a capacitor, C3, is connected to the SS pin, soft start is activated at input voltage turned-on. The soft start time, t_{SS} , until V_{OUT} rises is determined by the capacitance of C3. t_{SS} is calculated by the Equation (4).

$$t_{SS} = \frac{C3 \times 2.3 \text{ V}}{I_{SSL}} \quad (4)$$

Where:

I_{SSL} is SS pin source current at low

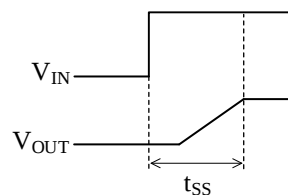


Figure 10-7. Soft Start Waveform

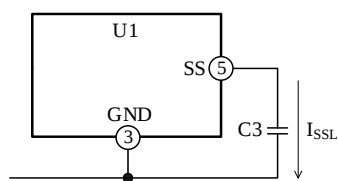


Figure 10-8. Soft Start Function

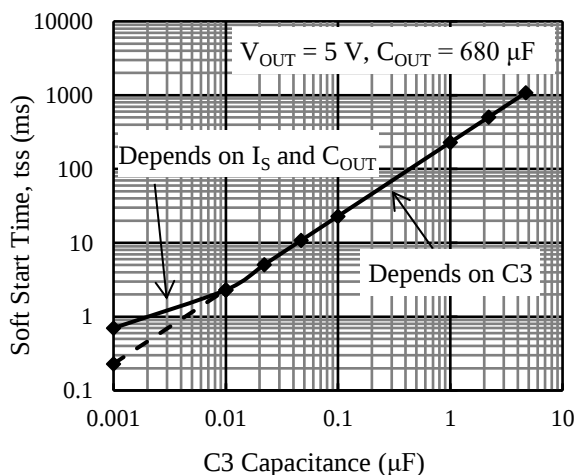
The voltage cannot be externally applied because the SS pin is pulled up (3.7 V (typ.)) to the internal power supply. Leave the SS pin open if the soft start function is not used.

Increasing the capacitance of C3 increases the discharging time at input voltage off. A capacitor of $\leq 10 \mu\text{F}$ should be used. When the input voltage drops, the charge of C3 is discharged from the VIN pin.

Figure 10-9 shows the relationship between the capacitance of C3 and t_{ss} . When the SS pin is open or the capacitance of C3 is extremely small, the soft start time is the time to charge C_{OUT} with the overcurrent protection start current, I_S (see Figure 10-9). The soft start time (at no load) is calculated by the Equation (5)

$$t_{ss} = \frac{C_{OUT} \times V_{OUT}}{I_S} \quad (5)$$

With a load, subtract the load current value from the I_S value.

Figure 10-9. C3 Capacitance vs. t_{ss}

10.7. Output On/Off Function

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

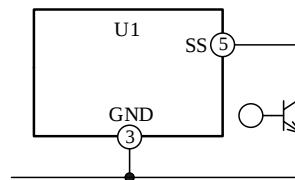


Figure 10-10. On/Off Function

The soft start function can be used in combination with on/off function by connecting a transistor and a capacitor as shown in Figure 10-11. 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.

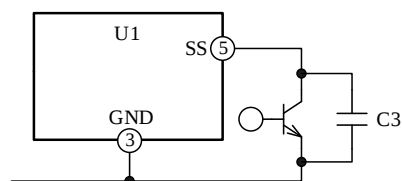


Figure 10-11. Soft Start Function, On/Off Function

The voltage cannot be externally applied because the SS pin is pulled up (3.7 V (typ.)) to the internal power supply. Leave the SS 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.

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

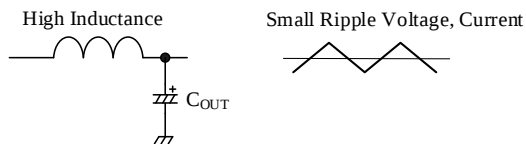


Figure 11-1. Ripple Voltage and Current (High Inductance)

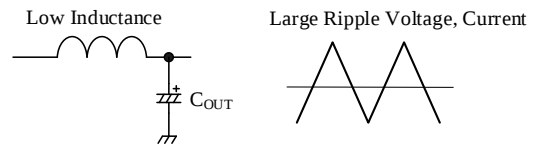


Figure 11-2. Ripple Voltage and Current (Low Inductance)

Inductance is calculated by the Equation, (1)(6).

$$L = \frac{(V_{IN} - V_{OUT}) \times V_{OUT}}{\Delta I_L \times V_{IN} \times f} \quad (6)$$

In the Equation, (6), 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 (5.5 A): 0.1 times the output current
- When the output current in your application is approximately 3 A or less: 0.3 to 0.4 times the output current

For example, when $V_{IN} = 25$ V, $V_{OUT} = 5$ V, $\Delta I_L = 0.5$ A, and $f = 150$ kHz, L is calculated as follows:

$$L = \frac{(25 - 5) \times 5}{0.5 \times 25 \times 150 \times 10^3} \approx 53.3 \mu\text{H}$$

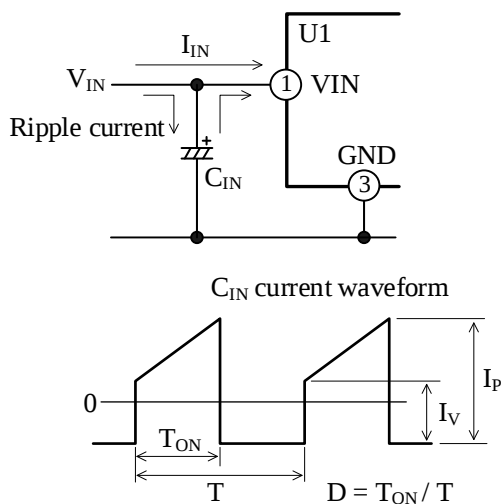
Thus, the inductor of about 54 μH should be selected.

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} .

- Within the rated voltage
- 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 (7).

$$I_{RMS} \approx 1.2 \times \frac{V_{OUT}}{V_{IN}} \times I_{OUT} \quad (7)$$

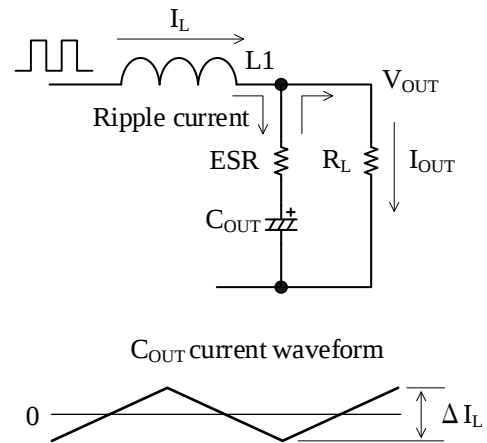
For example, when $I_{OUT} = 3$ A, $V_{IN} = 20$ V, and $V_{OUT} = 5$ V, I_{RMS} is calculated as follows:

$$I_{RMS} \approx 1.2 \times \frac{5}{20} \times 3 = 0.9 \text{ A}$$

Thus, select a capacitor that has an allowable ripple current of > 0.9 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 (8).

$$I_{RMS} = \frac{\Delta I_L}{2\sqrt{3}} \quad (8)$$

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

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

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 (9) and (10). ESR changes with temperature. Note that the ESR decreases at high temperatures.

$$V_{RIP} \approx \frac{(V_{IN} - V_{OUT}) \times V_{OUT}}{L1 \times V_{IN} \times f} \times ESR \quad (9)$$

$$V_{RIP} \approx \Delta I_L \times ESR \quad (10)$$

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.

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

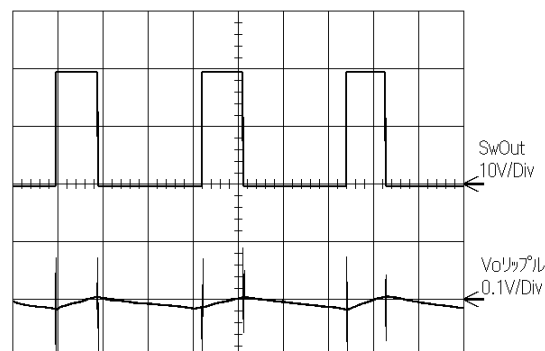


Figure 11-6. Without Noise Reduction Circuit

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 barrier 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.

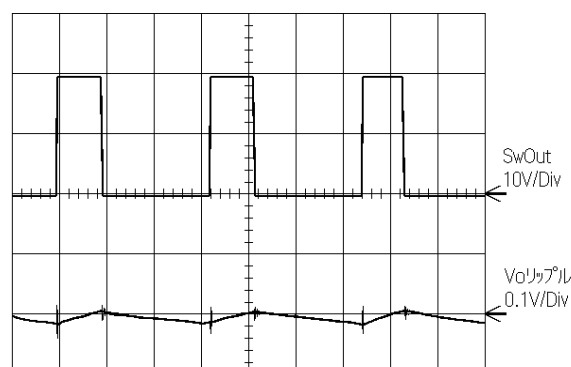


Figure 11-7. With Noise Reduction Circuit

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.

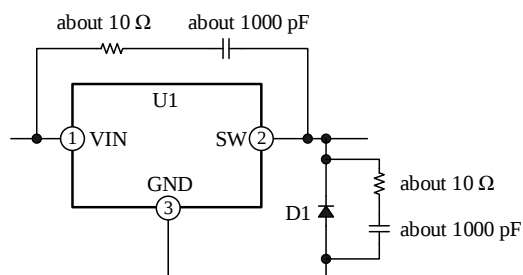


Figure 11-5. Spike Noise Reduction

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.

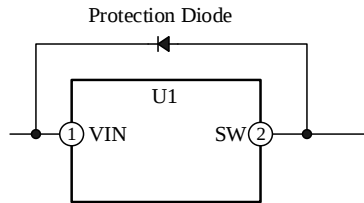


Figure 11-8. Addition of Reverse Bias Protection Diode

11.2. PCB Layout

11.2.1. High Current Line

Traces where the switching current flows (bold line in Figure 11-9) should be as wide and short as possible.

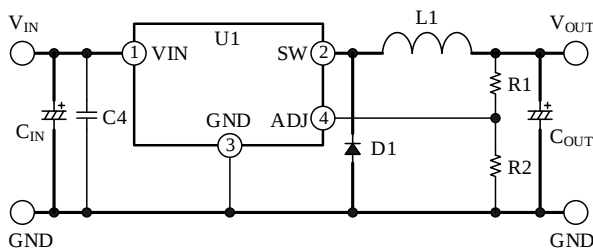


Figure 11-9. High Current Line

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.

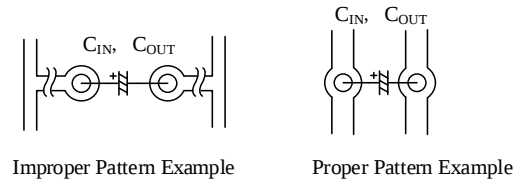


Figure 11-10. Pattern Example

11.2.3. ADJ Pin

Traces from ADJ pin to R2 should be as short as possible. The traces of ADJ pin, R1, and R2 should not run in parallel with the freewheeling diode trace. Switching noise may interfere with the ADJ pin and cause abnormal oscillation.

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 11-11 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.

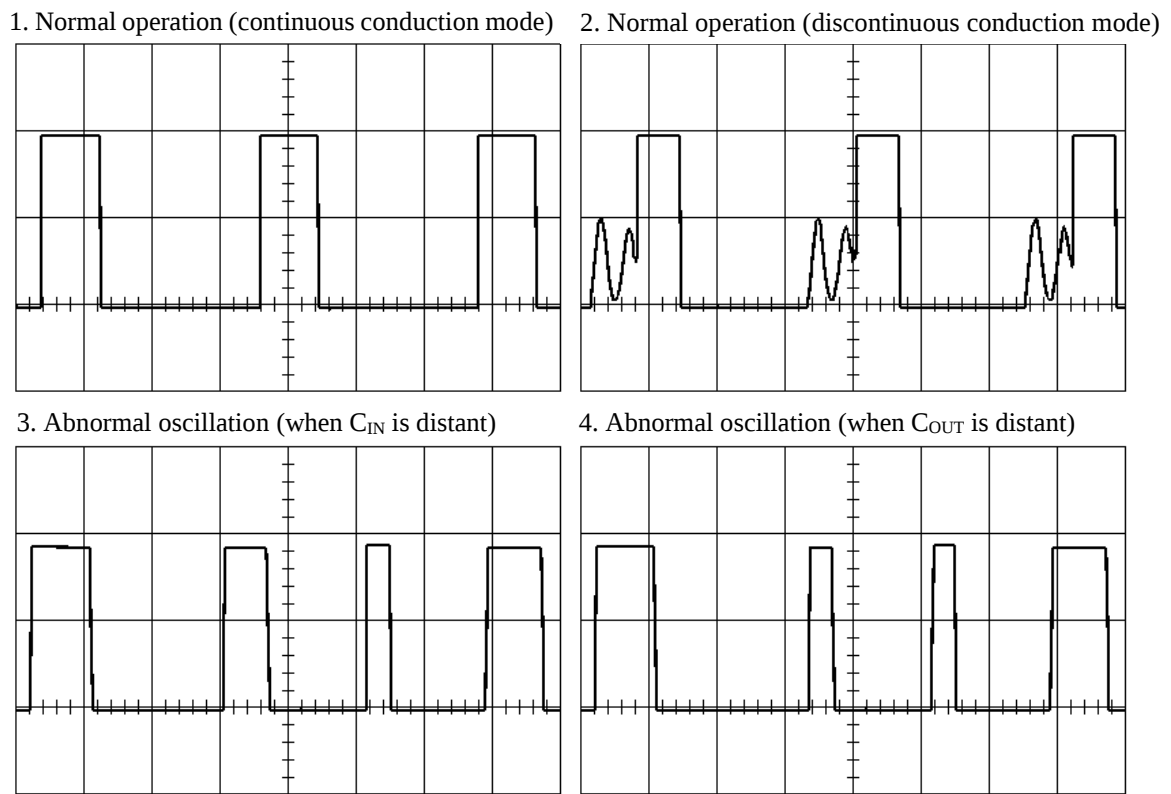


Figure 11-11. Waveform Examples

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 13-6 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 (11).

$$P_D = V_O \times I_O \left(\frac{100}{\eta} - 1 \right) - V_F \times I_O \left(1 - \frac{V_O}{V_{IN}} \right) \quad (11)$$

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)

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 13-6.

For reference, Figure 11-12 shows the relationship between the copper area and thermal resistance of a single-sided copper foil board, FR-4.

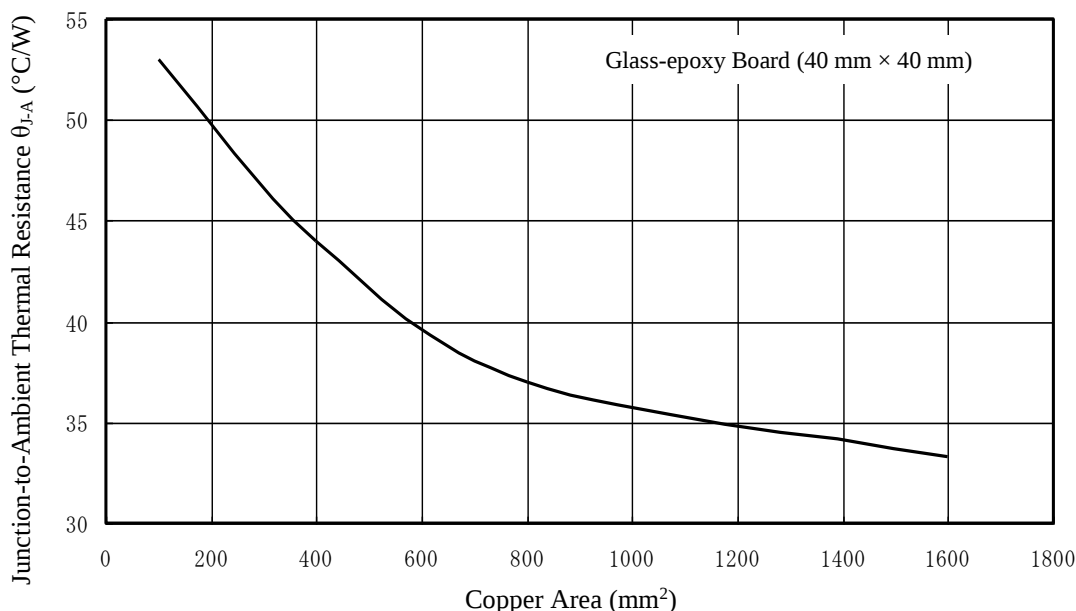


Figure 11-12. Thermal Resistance - Copper Area Reference Characteristics (Single-sided Copper Foil Board, FR-4)*

* 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.

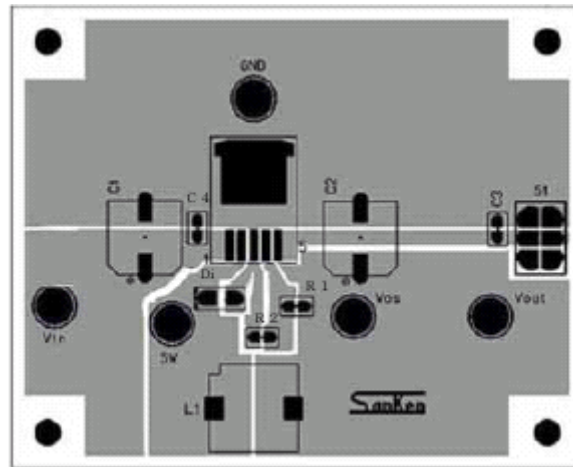


Figure 12-1. Pattern Layout Example

13. Typical Characteristics

Unless specifically noted, $T_A = 25\text{ }^{\circ}\text{C}$, $V_{OUT} = 5\text{ V}$, $R_1 = 4.2\text{ k}\Omega$, and $R_2 = 0.8\text{ k}\Omega$.

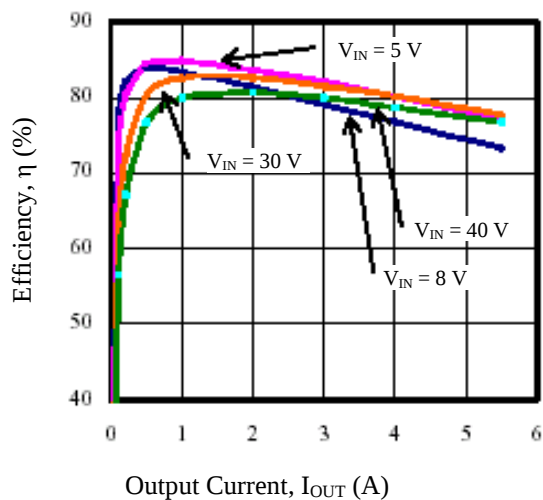


Figure 13-1. Efficiency

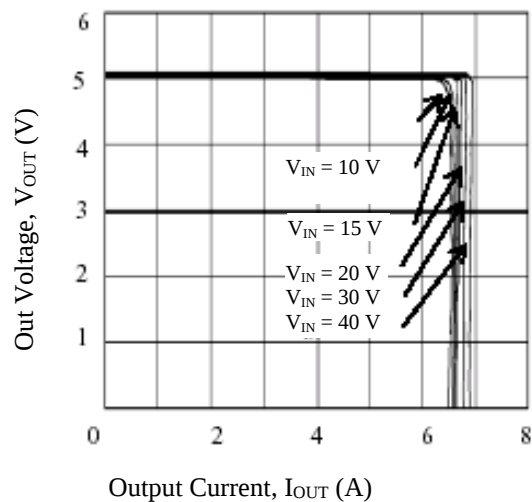


Figure 13-2. Overcurrent Protection Characteristics

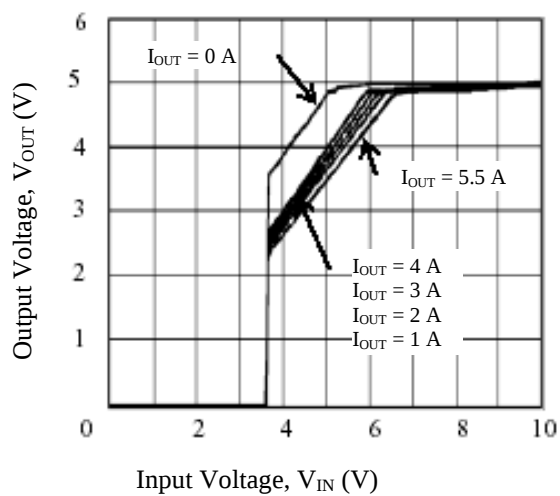


Figure 13-3. Rising Characteristics

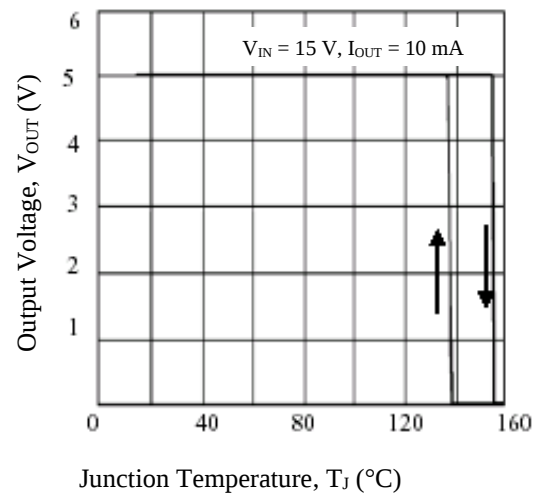


Figure 13-4. Thermal Shutdown Characteristics

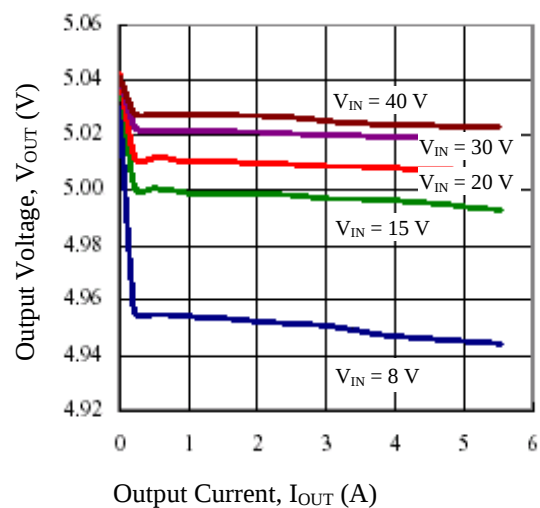


Figure 13-5. Load Regulation

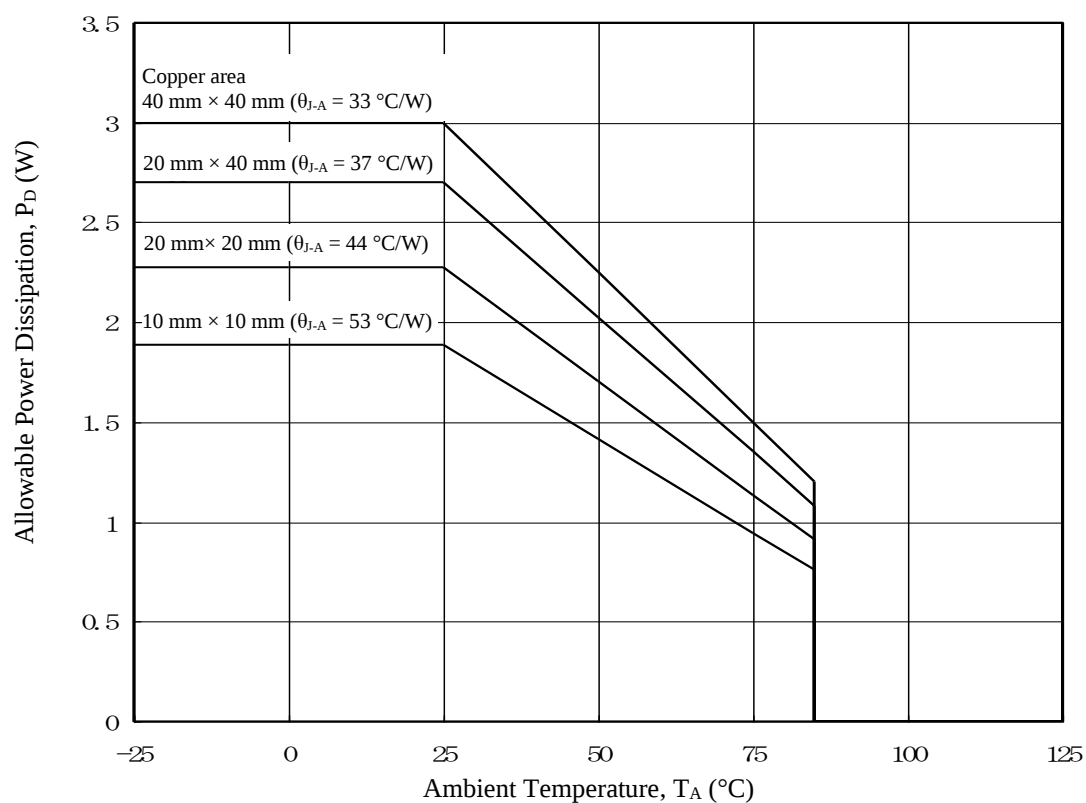


Figure 13-6. Thermal Derating

Important Notes

- All data, illustrations, graphs, tables and any other information included in this document (the “Information”) as to Sanken’s products listed herein (the “Sanken Products”) are current as of the date this document is issued. The Information is subject to any change without notice due to improvement of the Sanken Products, etc. Please make sure to confirm with a Sanken sales representative that the contents set forth in this document reflect the latest revisions before use.
- The Sanken Products are intended for use as components of general purpose electronic equipment or apparatus (such as home appliances, office equipment, telecommunication equipment, measuring equipment, etc.). Prior to use of the Sanken Products, please put your signature, or affix your name and seal, on the specification documents of the Sanken Products and return them to Sanken. When considering use of the Sanken Products for any applications that require higher reliability (such as transportation equipment and its control systems, traffic signal control systems or equipment, disaster/crime alarm systems, various safety devices, etc.), you must contact a Sanken sales representative to discuss the suitability of such use and put your signature, or affix your name and seal, on the specification documents of the Sanken Products and return them to Sanken, prior to the use of the Sanken Products. The Sanken Products are not intended for use in any applications that require extremely high reliability such as: aerospace equipment; nuclear power control systems; and medical equipment or systems, whose failure or malfunction may result in death or serious injury to people, i.e., medical devices in Class III or a higher class as defined by relevant laws of Japan (collectively, the “Specific Applications”). Sanken assumes no liability or responsibility whatsoever for any and all damages and losses that may be suffered by you, users or any third party, resulting from the use of the Sanken Products in the Specific Applications or in manner not in compliance with the instructions set forth herein.
- In the event of using the Sanken Products by either (i) combining other products or materials or both therewith or (ii) physically, chemically or otherwise processing or treating or both the same, you must duly consider all possible risks that may result from all such uses in advance and proceed therewith at your own responsibility.
- Although Sanken is making efforts to enhance the quality and reliability of its products, it is impossible to completely avoid the occurrence of any failure or defect or both in semiconductor products at a certain rate. You must take, at your own responsibility, preventative measures including using a sufficient safety design and confirming safety of any equipment or systems in/for which the Sanken Products are used, upon due consideration of a failure occurrence rate and derating, etc., in order not to cause any human injury or death, fire accident or social harm which may result from any failure or malfunction of the Sanken Products. Please refer to the relevant specification documents and Sanken’s official website in relation to derating.
- No anti-radioactive ray design has been adopted for the Sanken Products.
- The circuit constant, operation examples, circuit examples, pattern layout examples, design examples, recommended examples, all information and evaluation results based thereon, etc., described in this document are presented for the sole purpose of reference of use of the Sanken Products.
- Sanken assumes no responsibility whatsoever for any and all damages and losses that may be suffered by you, users or any third party, or any possible infringement of any and all property rights including intellectual property rights and any other rights of you, users or any third party, resulting from the Information.
- No information in this document can be transcribed or copied or both without Sanken’s prior written consent.
- Regarding the Information, no license, express, implied or otherwise, is granted hereby under any intellectual property rights and any other rights of Sanken.
- Unless otherwise agreed in writing between Sanken and you, Sanken makes no warranty of any kind, whether express or implied, including, without limitation, any warranty (i) as to the quality or performance of the Sanken Products (such as implied warranty of merchantability, and implied warranty of fitness for a particular purpose or special environment), (ii) that any Sanken Product is delivered free of claims of third parties by way of infringement or the like, (iii) that may arise from course of performance, course of dealing or usage of trade, and (iv) as to the Information (including its accuracy, usefulness, and reliability).
- In the event of using the Sanken Products, you must use the same after carefully examining all applicable environmental laws and regulations that regulate the inclusion or use or both of any particular controlled substances, including, but not limited to, the EU RoHS Directive, so as to be in strict compliance with such applicable laws and regulations.
- You must not use the Sanken Products or the Information for the purpose of any military applications or use, including but not limited to the development of weapons of mass destruction. In the event of exporting the Sanken Products or the Information, or providing them for non-residents, you must comply with all applicable export control laws and regulations in each country including the U.S. Export Administration Regulations (EAR) and the Foreign Exchange and Foreign Trade Act of Japan, and follow the procedures required by such applicable laws and regulations.
- Sanken assumes no responsibility for any troubles, which may occur during the transportation of the Sanken Products including the falling thereof, out of Sanken’s distribution network.
- Although Sanken has prepared this document with its due care to pursue the accuracy thereof, Sanken does not warrant that it is error free and Sanken assumes no liability whatsoever for any and all damages and losses which may be suffered by you resulting from any possible errors or omissions in connection with the Information.
- Please refer to our official website in relation to general instructions and directions for using the Sanken Products, and refer to the relevant specification documents in relation to particular precautions when using the Sanken Products.
- All rights and title in and to any specific trademark or tradename belong to Sanken and such original right holder(s).

DSGN-CEZ-16003