42V 3A CC/CV Step-Down DC/DC Converter

General Description

HM4533A is a wide input voltage, high efficiency CC/CV step-down DC/DC converter that operates in either CV (Constant Output Voltage) mode or CC (Constant Output Current) mode. HM4533A provides up to 3A output current at 125kHz switching frequency.

HM4533A eliminates the expensive, high accuracy current sense resistor, making it ideal for battery charging applications and adaptors with accurate current limit. The HM4533A achieves higher efficiency than traditional constant current switching regulators by eliminating its associated power loss on the additional current sensing resistor. HM4533A provides OVP pin for output over voltage protection.

HM4533A integrates adaptive gate drive to achieve excellent EMI performance passing EN55022 Class B EMC standard without adding additional EMI components while maintaining high conversion efficiency. Protection features include cycle-by-cycle current limit, thermal shutdown, and frequency foldback at short circuit. HM4533A are available in a SOP8-EP package and require very few external devices for operation.

Applications

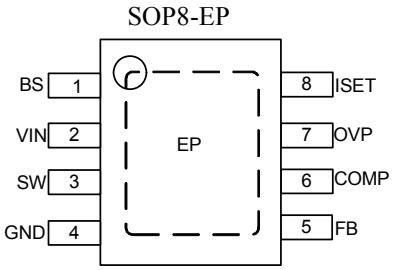
- Car Charger/ Adaptor
- Rechargeable Portable Devices
- General-Purpose CC/CV Supply

Features

- 42V Input Voltage Surge
- 36V Steady State Operation
- Up to 3A Output Current
- Output Voltage up to 12V
- 125kHz Switching Frequency
- Up to 91% Efficiency
- Stable with Low-ESR Ceramic Capacitors to Allow Low-Profile Designs
- Integrated Over Voltage Protection
- Excellent EMI Performance
- Constant Current Control Without Additional Current Sensing Resistor Improves Efficiency and Lowers Cost.
- Resistor Programmable Current Limit from 1.5A to 3.5A
- Up to 0.5V Excellent Cable Voltage Drop Compensation
- ±7.5% CC Accuracy
- 2% Feedback Voltage Accuracy
- Advanced Feature Set
  Integrated Soft Start
  Thermal Shutdown
  Cycle-by-Cycle Current Limit
- SOP8-EP Package

Package

SOP8-EP



Typical Application Circuit

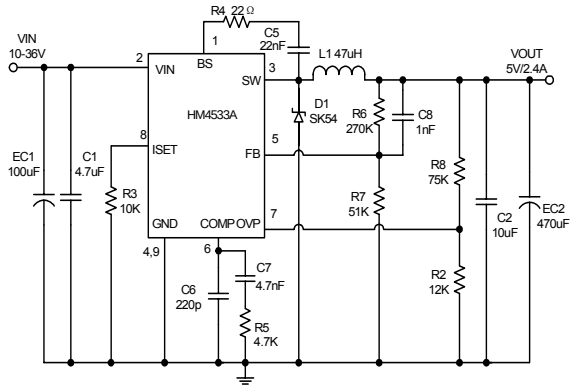


Figure 1. Typical Application Circuit with HM4533A

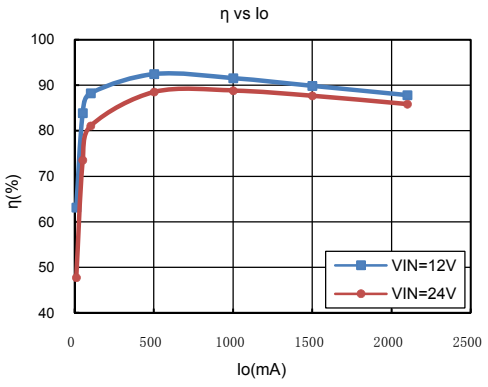


Figure 2. Typical Efficiency Curve

Ordering Information

Order codes	Mark	Package
HM4533A	HM4533A YYWW	SOP8-EP

1.YYWW=date code

Pin Description

Pin No.	Pin Name	Pin Function
1	BS	High Side Bias Pin. This provides power to the internal high-side MOSFET gate driver. Connect a 22nF capacitor from BS pin to SW pin.
2	VIN	Power Supply Input. Bypass this pin with a minimum 10μF ceramic capacitor to GND, placed as close to the IC as possible.
3	SW	Power Switching Output to External Inductor.
4	GND	Ground. Connect this pin to a large PCB copper area for best heat dissipation. Return FB, COMP, and ISET to this GND, and connect this GND to power GND at a single point for best noise immunity.
5	FB	Feedback Input. The voltage at this pin is regulated to 0.808V. Connect to the resistor divider between output and GND to set the output voltage.
6	COMP	Error Amplifier Output. This pin is used to compensate the converter.
7	OVP	OVP input. If the voltage at this pin exceeds 0.8V, the IC shuts down high-side switch.
8	ISET	Output Current Setting Pin. Connect a resistor from ISET to GND to program the output current.
9	Exposed Pad	Heat Dissipation Pad. Connect this exposed pad to large ground copper area with copper and vias.

Functional Block Diagram

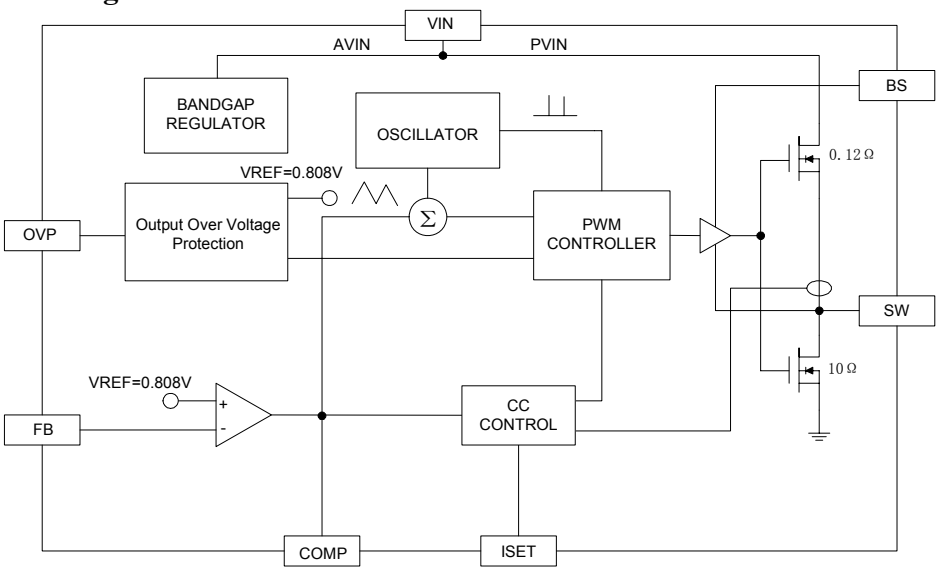


Figure 3 Functional Block Diagram

Absolute Maximum Ratings (Note 1)

Input Supply Voltage..... -0.3V ~ 42V
SW Voltage..... -1V ~ V_{IN} + 1V
Boost Voltage..... V_{SW} - 0.3V ~ V_{SW} + 7V
All Other Pins Voltage..... -0.3V ~ 6V
Junction to Ambient Thermal Resistance...46°C/W

Operating Junction Temperature.....-40~160°C
Storage Temperature.....-55°C ~ 150°C
Operating Temperature.....-40°C ~ 85°C
Lead Temperature (Soldering 10 sec.) .....300℃

Note 1: Stresses exceed those ratings may damage the device.

Electrical Characteristics (V_{IN} = 20V, T_A = +25℃, unless otherwise noted.)

Parameter	Conditions	Min	Typ	Max	unit
Input Voltage		10		36	V
Input Voltage Surge				42	V
VIN UVLO Turn-On Voltage	Input Voltage Rising		6.7		V
VIN UVLO Hysteresis	Input Voltage Falling		0.1		V
Standby Supply Current	V_{FB} = 1V		2.5		mA
Feedback Voltage		792	808	824	mV
Internal Soft-Start Time			3		ms
Error Amplifier Transconductance	V_{FB} = V_{COMP} = 0.8V, ΔI_{COMP} = ± 10μA		500		μA/V
Error Amplifier DC Gain			4000		V/V
Switching Frequency	V_{FB} = 0.808V		125		kHz
Foldback Switching Frequency	V_{FB} = 0V		50		kHz
Maximum Duty Cycle			98		%
Minimum On-Time			200		ns
COMP to Current Limit Transconductance	V_{COMP} = 1.2V		4		A/V
Secondary Cycle-by-Cycle Current Limit	Vout=3.5V		4.5		A
Slope Compensation	Duty = D_{MAX}		1.2		A
ISET Voltage			1		V
ISET to IOUT DC Room Temp Current Gain	I_{OUT} / I_{SET}, R_{ISET} = 11.5kΩ		27500		A/A
CC Controller DC Accuracy	R_{ISET} = 22kΩ, V_{IN}=14V, V_{OUT} = 3.5V Open-Loop DC Test		1250		mA
OVP pin Voltage	OVP Pin Rising		0.8		V
OVP pin Voltage	OVP Pin Voltage Falling		0.57		V
High-Side Switch ON-Resistance			0.12		Ω
SW Off Leakage Current	V_{IN} = V_{SW} = 0V		1	10	μA
Thermal Shutdown Temperature	Temperature Rising		160		°C
Thermal Shutdown Temperature Hysteresis	Temperature Falling		40		°C

Functional Description

CV/CC Loop Regulation

As seen in Functional Block Diagram, the HM4533A is a peak current mode pulse width modulation (PWM) converter with CC and CV control. The converter operates as follows:

A switching cycle starts when the rising edge of the Oscillator clock output causes the High-Side Power Switch to turn on and the Low-Side Power Switch to turn off. With the SW side of the inductor now connected to VIN, the inductor current ramps up to store energy in the magnetic field. The inductor current level is measured by the Current Sense Amplifier and added to the Oscillator ramp signal. If the resulting summation is higher than the COMP voltage, the output of the PWM Comparator goes high. When this happens or when Oscillator clock output goes low, the High-Side Power Switch turns off.

At this point, the SW side of the inductor swings to a diode voltage below ground, causing the inductor current to decrease and magnetic energy to be transferred to output. This state continues until the cycle starts again. The High-Side Power Switch is driven by logic using BS as the positive rail. This pin is charged to V_{SW} + 5V when the Low-Side Power Switch turns on. The COMP voltage is the integration of the error between FB input and the internal 0.808V reference. If FB is lower than the reference voltage, COMP tends to go higher to increase current to the output. Output current will increase until it reaches the CC limit set by the ISET resistor. At this point, the device will transition from regulating output voltage to regulating output current, and the output voltage will drop with increasing load.

The Oscillator normally switches at 125kHz. However, if FB voltage is less than 0.3V, then the switching frequency decreases to 50kHz.

Over Voltage Protection

The HM4533A has an OVP pin. If the voltage at this pin exceeds 0.8V, the IC shuts down high side switch.

Thermal Shutdown

The HM4533A disables switching when its junction temperature exceeds 160°C and resumes when the temperature has dropped by 40°C.

APPLICATIONS INFORMATION

Output Voltage Setting

Figure 4:
Output Voltage Setting

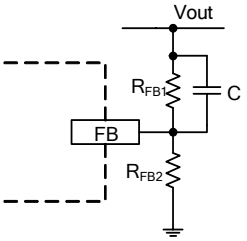


Figure 4 shows the connections for setting the output voltage. Select the proper ratio of the two feedback resistors R_{FB1} and R_{FB2} based on the output voltage. Adding a capacitor in parallel with R_{FB1} helps the system stability. Typically, use R_{FB2} ≈10kΩ and determine R_{FB1} from the following equation:

$$R_{FB1} = R_{FB2}\left(\frac{V_{OUT}}{0.808V} - 1\right)$$

CC Current Setting

HM4533A constant current value is set by a resistor connected between the ISET pin and GND. The CC output current is approximating linearly proportional to the current flowing out of the ISET pin. The voltage at ISET is roughly 1V and the current gain from ISET to output is roughly 27500 (27.5mA/1μA). To determine the proper resistor for a desired current, please refer to Figure 5 below.

Figure 5:
Curve for Programming Output CC Current

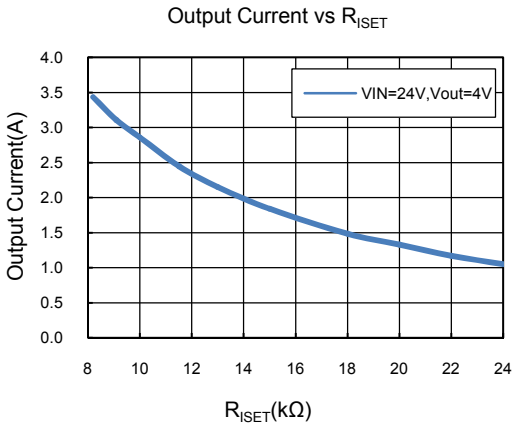
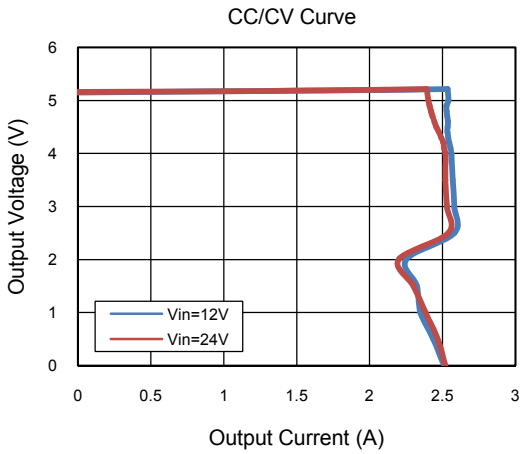


Figure 6:
CC/CV Curve（R3=11.5k, R8=52.3k, R2=10k）



Inductor Selection

The inductor maintains a continuous current to the output load. This inductor current has a ripple that is dependent on the inductance value:
Higher inductance reduces the peak-to-peak ripple current. The trade off for high inductance value is the increase in inductor core size and series resistance, and the reduction in current handling capability. In general, select an inductance value L based on ripple current requirement:

$$L = \frac{V_{OUT} \times (V_{IN} - V_{OUT})}{V_{IN} f_{SW} I_{LOADMAX} K_{RIPPLE}}$$

where VIN is the input voltage, VOUT is the output voltage, f_{SW} is the switching frequency, $I_{LOADMAX}$ is the maximum load current, and K_{RIPPLE} is the ripple factor. Typically, choose K_{RIPPLE} = 30% to correspond to the peak-to-peak ripple current being 30% of the maximum load current.
With a selected inductor value the peak-to-peak inductor current is estimated as:

$$I_{LPK-PK} = \frac{V_{OUT} \times (V_{IN} - V_{OUT})}{L \times V_{IN} \times f_{SW}}$$

The peak inductor current is estimated as:

$$I_{LPK} = I_{LOADMAX} + \frac{1}{2} I_{LPK-PK}$$

The selected inductor should not saturate at I_{LPK}. The maximum output current is calculated as:

$$I_{OUTMAX} = I_{LIM} - \frac{1}{2} I_{LPK-PK}$$

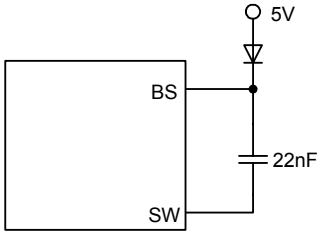
L_{LIM} is the internal current limit, which is typically 4.5A, as shown in Electrical Characteristics Table.

External High Voltage Bias Diode

It is recommended that an external High Voltage Bias diode be added when the system has a 5V fixed input or the power supply generates a 5V output. This helps improve the efficiency of the regulator. The High Voltage Bias diode can be a low cost one such as IN4148 or BAT54.

Figure 7:

External High Voltage Bias Diode



This diode is also recommended for high duty cycle operation and high output voltage applications.

Input Capacitor

The input capacitor needs to be carefully selected to maintain sufficiently low ripple at the supply input of the converter. A low ESR capacitor is highly recommended. Since large current flows in and out of this capacitor during switching, its ESR also affects efficiency.
The input capacitance needs to be higher than 10µF. The best choice is the ceramic type, however, low ESR tantalum or electrolytic types may also be used provided that the RMS ripple current rating is higher than 50% of the output current. The input capacitor should be placed close to the IN and GND pins of the IC, with the shortest traces possible. In the case of tantalum or electrolytic types, they can be further away if a small parallel 10µF ceramic capacitor is placed right next to the IC.

Output Capacitor

The output capacitor also needs to have low ESR to keep low output voltage ripple. The output ripple voltage is:

$$V_{RIPPLE} = I_{OUTMAX} K_{RIPPLE} R_{ESR} + \frac{V_{IN}}{28 \times f_{SW}^{2} LC_{OUT}}$$

Where I_{OUTMAX} is the maximum output current, K_{RIPPLE} is the ripple factor, R_{ESR} is the ESR of the output capacitor, f_{SW} is the switching frequency, L is the inductor value, and COUT is the output capacitance. In the case of ceramic output capacitors, R_{ESR} is very small and does not contribute to the ripple. Therefore, a lower capacitance value can be used for ceramic type. In the case of tantalum or electrolytic capacitors, the ripple is dominated by RESR multiplied by the ripple current. In that case, the output capacitor is chosen to have sufficiently low ESR.
For ceramic output capacitor, typically choose a capacitance of about 22µF. For tantalum or electrolytic capacitors, choose a capacitor with less than 50mΩ ESR.

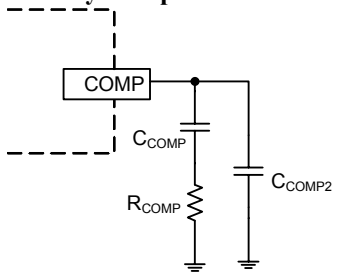
Rectifier Diode

Use a Schottky diode as the rectifier to conduct current when the High-Side Power Switch is off. The Schottky diode must have current rating higher than the maximum output current and a reverse voltage rating higher than the

maximum input voltage.

STABILITY COMPENSATION

Figure 8:
Stability Compensation



C_{COMP2} is needed only for high ESR output capacitor
The feedback loop of the IC is stabilized by the components at the COMP pin, as shown in Figure 8. The DC loop gain of the system is determined by the following equation:

$$A_{VDC} = \frac{0.808V}{I_{OUT}} A_{VEA} G_{COMP}$$

The dominant pole P1 is due to C_{COMP}:

$$f_{P1} = \frac{G_{EA}}{2\pi A_{VEA} C_{COMP}}$$

The second pole P2 is the output pole:

$$f_{P2} = \frac{I_{OUT}}{2\pi V_{OUT} C_{OUT}}$$

The first zero Z1 is due to R_{COMP} and C_{COMP}:

$$f_{Z1} = \frac{1}{2\pi R_{COMP} C_{COMP}}$$

And finally, the third pole is due to R_{COMP} and C_{COMP2} (if C_{COMP2} is used):

$$f_{P3} = \frac{1}{2\pi R_{COMP} C_{COMP2}}$$

The following steps should be used to compensate the IC:
STEP 1. Set the cross over frequency at 1/10 of the switching frequency via R_{COMP}:

$$R_{COMP} = \frac{2\pi V_{OUT} C_{OUT} f_{SW}}{10 G_{EA} G_{COMP} \times 0.808V}$$

$$= 5.12 \times 10^7 V_{OUT} C_{OUT} \quad (\Omega)$$

STEP 2. Set the zero f_{Z1} at 1/4 of the cross over frequency. If R_{COMP} is less than 15kΩ, the equation for C_{COMP} is:

$$C_{COMP} = \frac{2.83 \times 10^5}{R_{COMP}} \quad (F)$$

If R_{COMP} is limited to 15kΩ, then the actual cross over frequency is 6.58 / ($V_{OUT}C_{OUT}$). Therefore:

$$C_{COMP} = 6.45 \times 10^{-6} V_{OUT} C_{OUT} \quad (F)$$

STEP 3. If the output capacitor's ESR is high enough to cause a zero at lower than 4 times the cross over frequency, an additional compensation capacitor C_{COMP2} is required. The condition for using C_{COMP2} is:

$$R_{ESRCOUT} \geq \left(Min \frac{1.77 \times 10^{-6}}{C_{OUT}}, 0.006 \times V_{OUT} \right) (\Omega)$$

And the proper value for C_{COMP2} is:

$$C_{COMP2} = \frac{C_{OUT} R_{ESRCOUT}}{R_{COMP}}$$

Though C_{COMP2} is unnecessary when the output capacitor has sufficiently low ESR, a small value C_{COMP2} such as 100pF may improve stability against PCB layout parasitic effects.
Table 1 shows some calculated results based on the compensation method above.

Table 1:
Typical Compensation for Different Output Voltages and Output Capacitors

V_{out}	C_{out}	R_{COMP}	C_{COMP}	C_{COMP2}①
2.5V	47uF Ceramic CAP	5.6KΩ	2.2nF	None
3.3V	47uF Ceramic CAP	6.2KΩ	2.2nF	None
5.0V	47uF Ceramic CAP	12KΩ	2.2nF	None
2.5V	220uF/10V/30mΩ	20KΩ	2.2nF	47pF
3.3V	220uF/10V/30mΩ	20KΩ	2.2nF	47pF
5.0V	220uF/10V/30mΩ	20KΩ	2.2nF	47pF

C_{COMP2} is needed for high ESR output capacitor.
$C_{COMP2} \leq 47pF$ is recommended.

CC Loop Stability

The constant-current control loop is internally compensated over the 1500mA-3000mA output range. No additional external compensation is required to stabilize the CC current.

Output Cable Resistance Compensation

To compensate for resistive voltage drop across the charger's output cable, the HM4533A integrates a simple, user-programmable cable voltage drop compensation using the impedance at the FB pin. Use the curve in Figure 9 to choose the proper feedback resistance values for cable compensation. R_{FB1} is the high side resistor of voltage divider.
In the case of high R_{FB1} used, the frequency compensation needs to be adjusted correspondingly. As show in Figure 10, adding a capacitor in paralleled with R_{FB1} or increasing the compensation capacitance at COMP pin helps the system stability.

Figure 9:
Cable Compensation at Various Resistor Divider Values

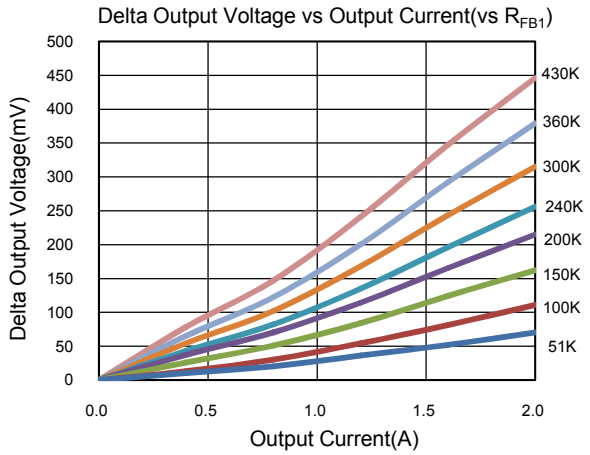
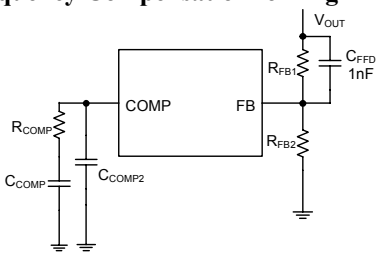


Figure 10:
Frequency Compensation for High RFB1

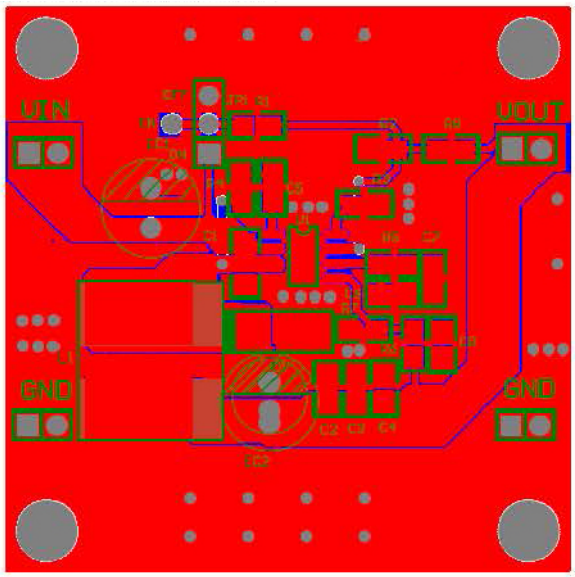


PC Board Layout Guidance

Figure11 showed the example of components placement and PCB layout. When laying out the printed circuit board, the following checklist should be used to ensure proper operation of the IC.

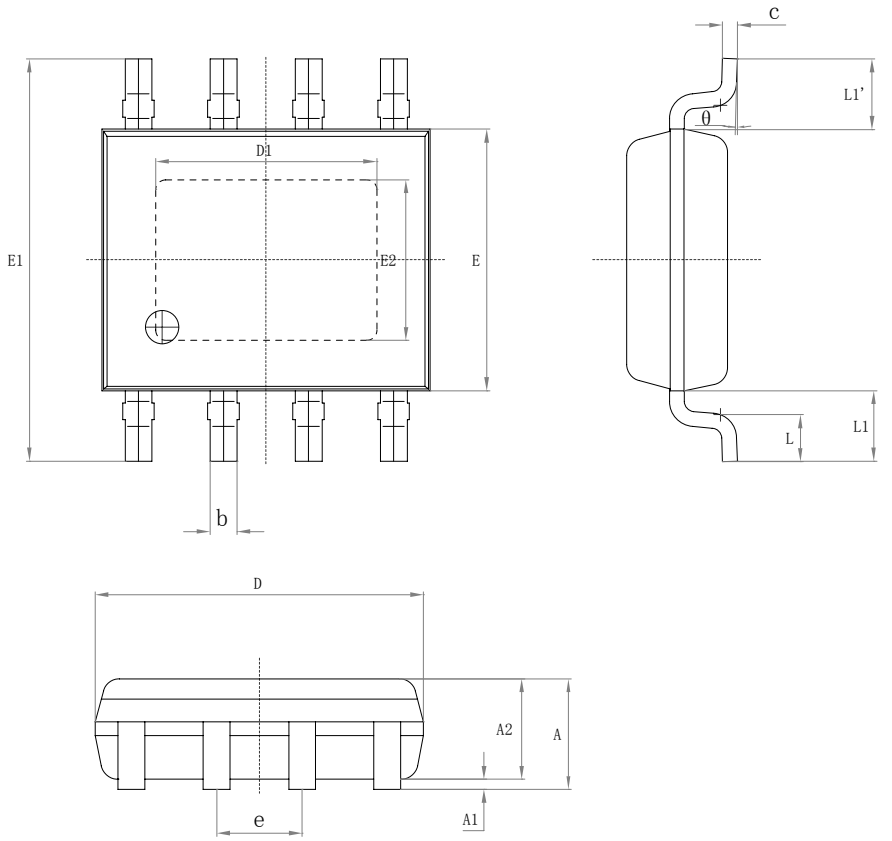
1) Arrange the power components to reduce the AC loop size， consisting of input ceramic capacitor C1, VIN pin, SW pin and the schottky diode D1.
2) Place input decoupling ceramic capacitor C1 as close to VIN pin as possible. C1 is connected power GND with vias or short and wide path.
3) Return FB, COMP and ISET to signal GND pin, and connect the signal GND to power GND at a single point for best noise immunity. Connect exposed pad to power ground copper area with copper and vias.
4) Use copper plane for power GND for best heat dissipation and noise immunity.
5) Place feedback resistor close to FB pin.
6) Use short trace connecting BS-C5-SW loop.

Figure 11:
Example of PCB Layout



Package Information

SOP8-EP



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	1.400	1.700	0.055	0.067
A1	0.050	0.150	0.002	0.006
A2	1.350	1.550	0.053	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.007	0.010
D	4.700	5.100	0.185	0.200
D1	3.202	3.402	0.126	0.134
E	3.800	4.000	0.150	0.157
E1	5.800	6.200	0.228	0.244
E2	2.313	2.513	0.091	0.099
e	1.270(BSC)		0.050(BSC)	
L	0.400	1.270	0.016	0.050
L1	1.04REF		0.041REF	
L1-L1'	----	0.12	----	0.005
θ	0°	8°	0°	8°