High Efficiency 40V,3.5A, 250KHz, Sensorless CC/CV Synchronous Step-Down Converter

GENERAL DESCRIPTION

The HM1686 is a high frequency synchronous active CC/CV step-down switching regulator with integrated internal high-side and low-side high voltage power MOSFET. It offers a very compact solution to achieve a 3.5A-max continuous output current over a wide input supply range. It operate in either CV (Constant Output Voltage)Mode or CC (Constant Output Current)Mode. provides 3.5A-max output with current mode control for fast loop response. The wide 4V to 40V input range accommodates a variety of step-down applications, including those in automotive input environment. Less than 1μA shut-down current allows using in battery-powered applications.

It provides low-ripple power, high efficiency, excellent transient characteristics. An over current protection and short circuit functions are built outside that it can set by a resistance. The Low ESR output capacitor can be used.

High power conversion efficiency over a wide load range is achieved by scaling down the switching frequency at light load condition to reduce the switching and gate driving losses.

FEATURES

- Wide 4V to 40V Operating Input Range
- 80mohm Internal Power MOSFET
- 250K Fix Switching Frequency
- Low Quiescent Current 1.1mA
- Low Shut down Current <1uA
- Adjustable Output Voltage from 0.8V to 36V
- Ceramic Capacitor Stable
- Internal Soft-Start、Comp circuit
- External current limit setting
- Built in adjustable line-compensation
- Up to 95% Efficiency
- Under Voltage Lockout, Over Current, Short Current, and Thermal Protection
- Operating Temperature: -40°C to +85°C
- Available in SOP8-PP Package
- RoHS Compliant and 100% Lead(Pb)-Free

Applications

- Car Charger
- Portable Charger Device

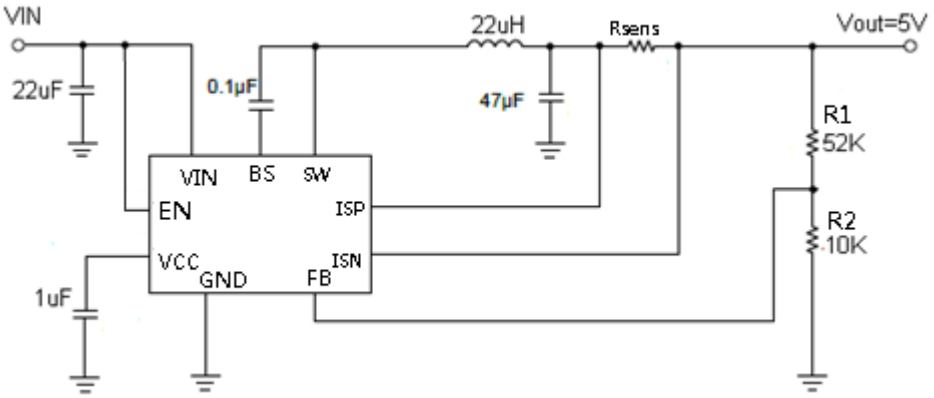


Figure 1. Typical Application Circuit

ORDERING INFORMATION

PART NUMBER	TEMP RANGE	SWICHING FREQUENCY	OUTPUT VOLTAGE (V)	OUTPUT CURRENT (A)	PACKAGE	PINS
HM1686	-40°C to 85°C	250K FIX	Adjustable	3.5	SOP8-PP	8

PIN CONFIGURATION

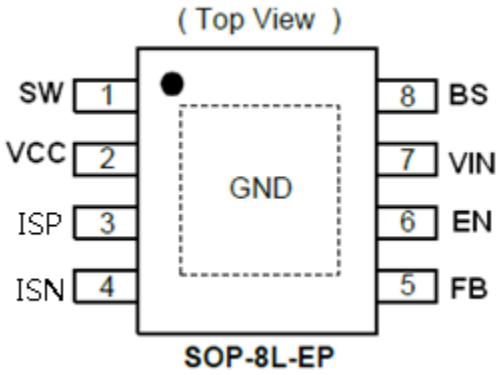


Figure 2. PIN Configuration

PIN DESCRIPTION

PIN #	NAME	FUNCTION
1	SW	Switch Node.
2	VCC	Controller inside power logic Power Supply，inside LDO output pin，need one 1uF MLCC close to VCC pin and GND
3	ISP	Current Sense input positive pole
4	ISN	Current Sense input negative pole
5	FB	Feedback. This is the input to the error amplifier. An external resistive divider connected between the output and GND is compared to the internal +0.8V reference to set the regulation voltage.
6	EN	Enable Input. Pulling this pin below the specified threshold shuts the chip down. Pulling it up above the specified threshold enables the chip. You can connect 100K resistor or 0ohm up to Vin. Don't let EN pin float.
7	VIN	Input Supply. This supplies power to all the internal control circuitry, both BS regulators and the high-side switch. A decoupling capacitor to ground must be placed close to this pin to minimize switching spikes.
8	BST	Bootstrap. This is the positive power supply for the internal floating high-side MOSFET driver. Connect a bypass capacitor between this pin and SW pin as close as possible.
9	EPAD/GND	Ground. It should be connected as close as possible to the output capacitor avoiding the high current switch paths. Connect exposed pad to GND plane for optimal thermal performance.

ABSOLUTE MAXIMUM RATINGS

(Note: Do not exceed these limits to prevent damage to the device. Exposure to absolute maximum rating conditions for long periods may affect device reliability.)

PARAMETER	VALUE	UNIT
VIN、EN	-0.3V to +46V	V
FB, VCC,ISP,ISN	-0.3V to 6V	V
SW Voltage	-0.3V to VIN+0.3V	V
BST to SW	-0.3V to +5V	V
Operating Ambient Temperature	-40 to 85	℃
Maximum Junction Temperature	125	℃
Storage Temperature	-55 to 150	℃
Lead Temperature (Soldering, 10 sec)	300	℃

ELECTRICAL CHARACTERISTICS

V_{IN} = 12V, T_A= 25°C,EN connect VIN(100K Resistor) unless otherwise specified

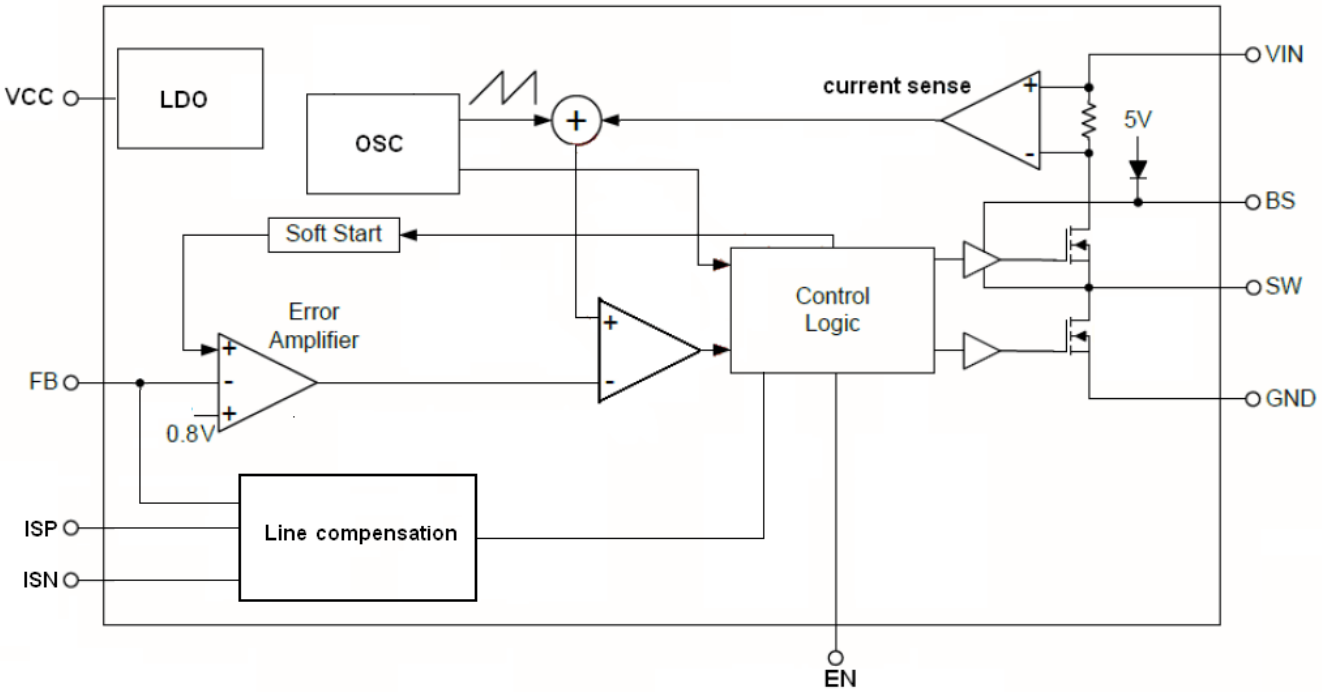
Specifications over temperature are guaranteed by design and characterization.

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Recommend Input Voltage Range	*V_{IN}		4.0		40	V
UVLO Threshold	V_{UVLO}	$V_{HYSTERESIS}$ =200mV	3.2	3.6	4.0	V
Operating Supply Current	I_{SUPPLY}	I_{Load} =0 Switching		1	1.5	mA
Shutdown Supply Current		V_{EN} =0V			1.5	μA
Regulated Feedback Voltage	V_{FB}	4.5V < VIN < 40V	0.784	0.8	0.816	V
		-40°C < T_a <85°C	0.770		0.830	
Upper Switch On Resistance	*R_{up}	VBST – VSW = 5V		90		mΩ
Lower Switch On Resistance	*R_{lw}			80		mΩ
Soft-Start Time	*Tss	0V < V_{FB} < 0.8V		1		ms
Current Limit				4.5		A
UVLO Threshold	V_{UVLO}	$V_{HYSTERESIS}$ =200mV	3.2	3.6	4.0	V
Inside LDO output	VCC	VIN>6V I_{load}=0A	4	4.5	5	V
Enable Threshold			0.4	1	1.5	V

Enable Leakage Current			-0.1		0.1	μA
Minimum On Time	*			100		ns
Minimum Off Time	*			50		ns
Thermal Shutdown	*	Hysteresis = 20°C		150		˚C

Note:*---The parameter is guaranteed by design.

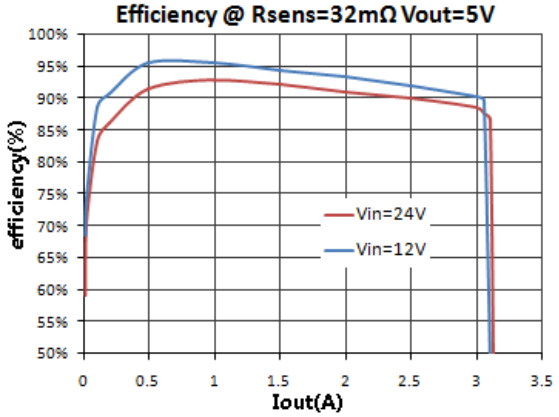
FUNCTIONAL BLOCK DIAGRAM



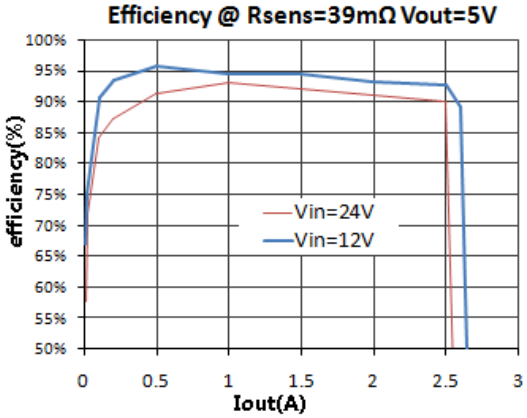
TYPICAL PERFORMANCE CHARACTERISTICS

(VIN = 12V, VOUT =5V, Cin = 22μF, Cout = 47μF, L1 = 22μH F=250KHz and TA = +25°C, unless otherwise noted.)

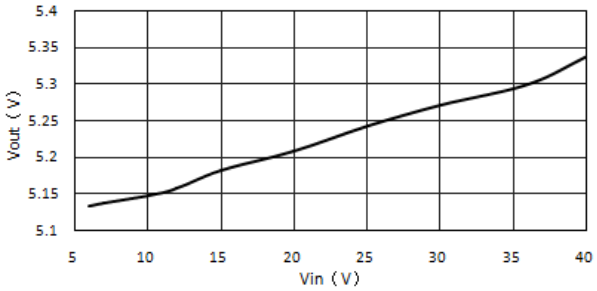
Efficiency @ Rsens=32mΩ Vout=5V



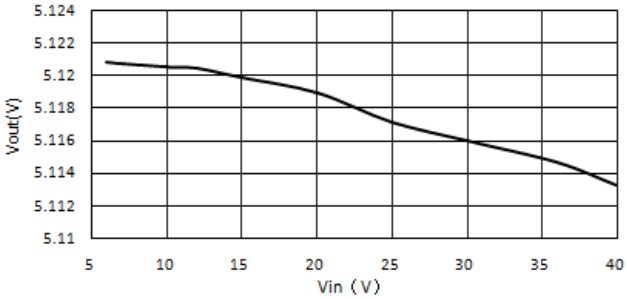
Efficiency @ Rsens=39mΩ Vout=5V



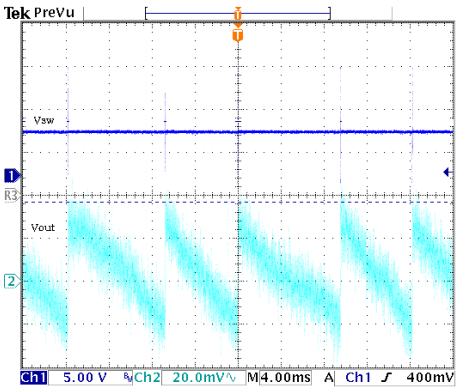
Line Regulation Iout=0A



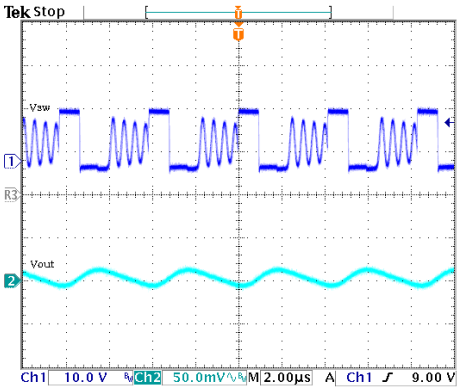
Line Reglation Iout=1A



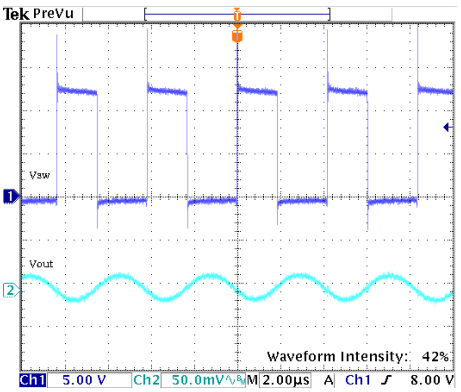
Steady State(Io=0A)



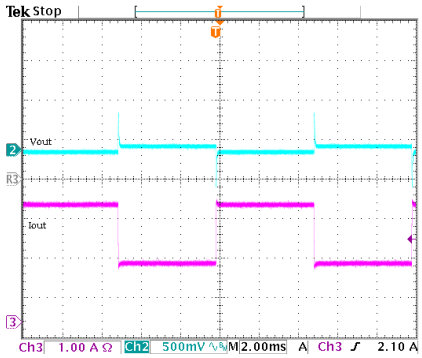
Steady State(Io=0.1A)



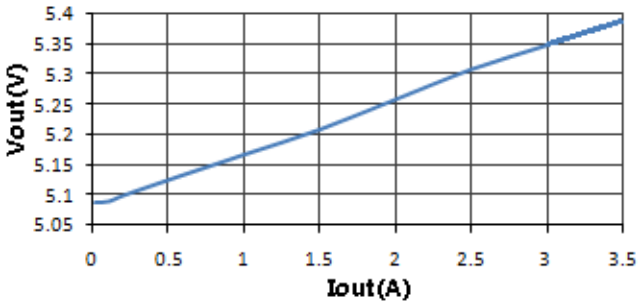
Steady State(Io=3A)



Load Transient(1.5A->3A)



Line Compensation(R1=53K)



FUNCTIONAL DESCRIPTION

NORMAL OPERATION

The HM1686 is a high frequency synchronous step-down switching regulator with integrated internal high-side and low-side high voltage power MOSFET. It offers a very compact solution to achieve a 3A continuous output current with excellent load and line regulation over a wide input supply range.

PWM CONTROL MODE

At moderate to high output current, the HM1686 operates in a fixed frequency, peak current control mode to regulate the output voltage. A PWM cycle is initiated by the internal clock. The power MOSFET is turned on and remains on until its current reaches the value set by the COMP voltage. When the power switch is off, it remains off for at least 100ns before the next cycle starts.

INTERNAL REGULATOR

The 4.5V internal regulator power most of the internal circuitries. This regulator takes the VIN input and operates in the full VIN range: When VIN exceeds 5V, the output of the regulator is in full regulation; when VIN falls below 5.0V, the output of the regulator decreases following the VIN. A 1uF decoupling ceramic capacitor is needed at the pin.

ENABLE CONTROL

The HM1686 has a dedicated enable control pin (EN). If EN voltage >1.5V the chip can be enabled and disabled by EN voltage<0.4V, 0.4V~1.5V voltage add to EN pin, the chip status is uncertain.
EN pin is high voltage pin, you can connect with Vin directly. Also, you can connect 100K resistor with Vin.

UNDER-VOLTAGE LOCKOUT (UVLO)

Under-voltage lockout (UVLO) is implemented to protect the chip from operating at insufficient supply voltage. The UVLO rising threshold is about 3.6V while its falling threshold is a consistent 3.3V.

INTERNAL SOFT-START

The soft-start is implemented to prevent the converter output voltage from overshooting during startup. When the chip starts, the internal circuitry generates a soft-start voltage (SS) ramping up from 0V to 3.6V. When it is lower than the internal reference (REF), SS overrides REF so the error amplifier uses SS as the reference. When SS is higher than REF, REF regains control.

OVER-CURRENT PROTECTION

The HM1686 has cycle-by-cycle over current limit when the inductor current peak value exceeds the set current limit threshold.

SHORT CIRCUIT PROTECTION

When the output is shorted to the ground, the switching frequency is folded back and the current limit is reduced to lower the short circuit current. When the voltage of FB is lower than 0.12V, the current limit is reduced to 2A. When FB is higher than 0.12V, the frequency and current limit return to normal values.

STARTUP AND SHUTDOWN

If both VIN and EN are higher than their appropriate thresholds, the chip starts. The reference block starts first, generating stable reference voltage and currents, and then the internal regulator is enabled. The regulator provides stable supply for the remaining circuitries.

THERMAL SHUTDOWN

Thermal shutdown is implemented to prevent the chip from operating at exceedingly high temperatures. When the silicon die temperature is higher than its upper threshold, it shuts down the whole chip. When the temperature is lower than its lower threshold, the chip is enabled again.

APPLICATION INFORMATION

INDUCTOR SELECTION

Table 1 lists a number of suitable inductors from various manufacturers. The choice of which style inductor to use mainly depends on the price vs. size requirements and any EMI requirement.

Part Number	Inductance (uH)	Max DCR (mΩ)	Current Rating (A)	Dimensions LxWxH(mm3)
TDK				
CLF10060NIT-220M	22	43	3.6	10x10x6
CLF12577NIT-220M	22	27	5.8	12.8x12.5x7
Wurth Electronics				
744771122	22	31	3.37	12x12x6
7443551221	22	24.7	6	13.2x12.8x6.2

Table 1. Recommend Surface Mount Inductors

Notes：Please select inductor according to Iout. The IL need to be 1.5~2*Iout. For getting higher efficiency, need to use low DRC inductors.

INPUT CAPACITOR SELECTION

The input current to the step-down converter is discontinuous, therefore a capacitor is required to supply the AC current to the step-down converter while maintaining the DC input voltage. Use low ESR capacitors for the best performance. Ceramic capacitors are preferred, but tantalum or low-ESR electrolytic capacitors may also suffice.

When using electrolytic or tantalum capacitors, a small, high quality ceramic capacitor, i.e. 0.1μF, should be placed as close to the IC as possible. When using ceramic capacitors, make sure that they have enough capacitance to provide sufficient charge to prevent excessive voltage ripple at input.

OUTPUT CAPACITOR SELECTION

The output capacitor (C2) is required to maintain the DC output voltage. Ceramic, tantalum, or low ESR electrolytic capacitors are recommended. Low ESR capacitors are preferred to keep the output voltage ripple low. TDK's MLCC or GUOGUANG electronics' PA CAP is recommended.

The characteristics of the output capacitor also affect the stability of the regulation system.

OUTPUT CURRENT LIMIT SETTING

the output current limit--Ilimit is set by outside resistance (Rsen), when the isp-isn voltage larger than 100mv, the current limit is happened that driver can be turned off. the current limit set according to the following equation:

$$I_{limit}=100mV/Rsen$$

For Example, Rsens=40mohm,Ilimit=2.5A; Rsen=30mohm,Ilimit=3.3A;

ADJUSTABLE LINE-COMPENSATION SETTING

The resistors Rsen and R1 are used for compensate line change and keep output voltage accuracy. the Line compensation set according to the following equation:

$$\delta Vout = 5 * 10^{-5} * Iout * R1 * Rsen$$

For Example, When R1=52.5K,Rsen=50mohm, If Iout=0A,Vout=5V, then Iout=1A, Vout=5.132V;

Iout=1.5A Vout=5.197V, and so on.

OUTPUT VOLTAGE PROGRAMMING

In the adjustable version, the output voltage is set by a resistive divider according to the following equation:

$$R_1 = R_2 \times \left(\frac{V_{OUT}}{0.8} - 1 \right)$$

Typically choose R2=10K and determine R1 from the following equation:(Please ensure R2<20K)

For Example, R1=52.5K R2=10K to set Vout=5V

LAYOUT SUGGESTION

PCB layout is very important to achieve stable operation. It is highly recommended to duplicate EVB layout for optimum performance.

If change is necessary, please follow these guidelines and take Figure 5 for reference.

1) Keep the path of switching current short and minimize the loop area formed by Input cap, high-side MOSFET and low-side MOSFET.

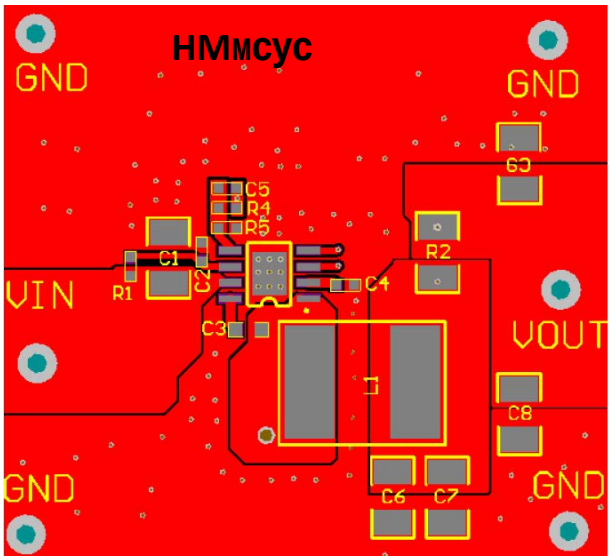
2) Bypass ceramic capacitors are suggested to be put close to the VIN Pin/VCC Pin & GND mass Metal.

3) Ensure all feedback connections are short and direct. Place the feedback resistors as close to the chip as possible.

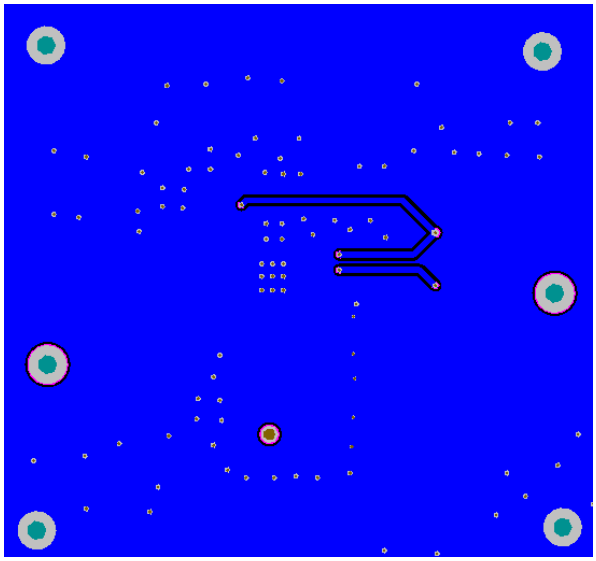
4) Route SW away from sensitive analog areas such as FB、 ISN & ISP sense circuit.

5) Connect a bypass capacitor between BST pin and SW pin as close as possible

5) Connect IN, SW, and especially GND respectively to a large copper area to cool the chip to improve thermal performance and long-term reliability.



TOP LAYER

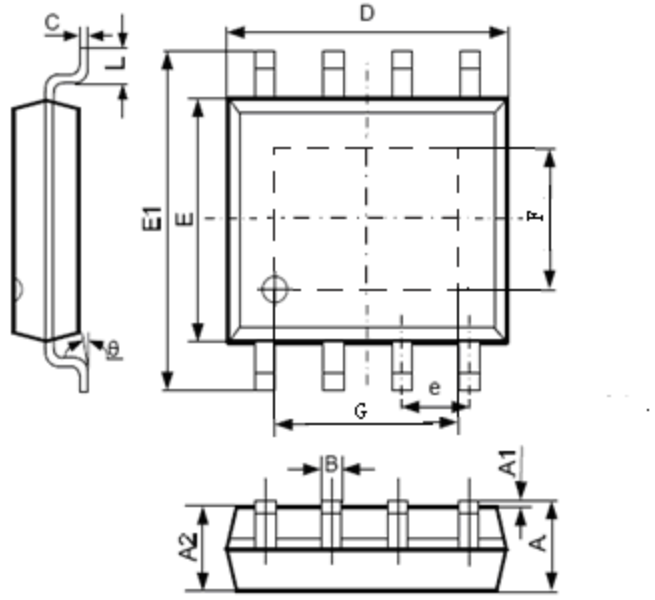


BOTTOM LAYER

Figure5: HM1686 Layout Guide

PACKAGE OUTLINE

SOP8-EPAD PACKAGE OUTLINE AND DIMENSIONS



SYMBOL	Dimension in Millimeters		Dimension in Inches	
	MIN	MAX	MIN	MAX
A	1.35	1.75	0.053	0.069
A1	0.100	0.250	0.004	0.010
A2	1.350	1.550	0.053	0.061
B	0.330	0.510	0.013	0.020
C	0.190	0.250	0.007	0.010
D	4.700	5.100	0.185	0.201
E	3.800	4.000	0.150	0.157
E1	5.800	6.300	0.228	0.248
e	1.27 TYP		0.050 TYP	
L	0.400	1.270	0.016	0.050
θ	0^o	8^o	0^o	8^o
F	2.26	2.56	0.089	0.101
G	3.15	3.45	0.124	0.136

In order to increase the driver current capability of HM1686 and improve the temperature of package, Please ensure Epad and enough ground PCB to release energy.