13V, 10A全集成同步升压转换器

■ 特点

- 输入电压范围V_{IN}：2.7V-13V
- 输出电压范围V_{OUT}：4.5V-13V
- 内部固定峰值电流：10A
- 高转换效率：

  93% (V_{IN} = 7.4V, V_{OUT}=12V, I_{OUT} =3A)
  92% (V_{IN} = 3.6V, V_{OUT}=9V, I_{OUT} =1A)
- 脉频调制（PFM）方式
- 低关断功耗，关断电流1uA
- 内部固定开关频率
- 内部固定软启动
- 输出过压 (14V)、逐周期过流、热关断等保护
- SOP8-PP，无铅封装

■ 概述

HT7166是一款高功率、全集成升压转换器，集成16mΩ功率开关管和23mΩ同步整流管，为便携式系统提供高效的小尺寸解决方案。

HT7166具有2.7V至13V宽输入电压范围，可为采用单节或两节锂电池的应用提供支持。该器件具备10A开关电流能力，并且能够提供13V的输出电压。

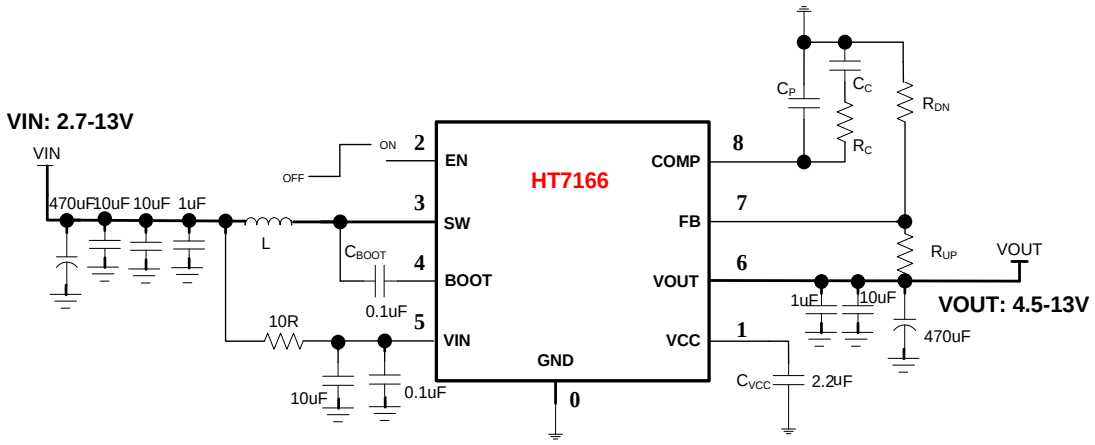
HT7166采用自适应恒定关断时间峰值电流控制拓扑结构来调节输出电压。在中等到重负载条件下，HT7166工作在PWM 模式。在轻负载条件下，该器件工作在一种可提高效率的PFM模式。

此外，该器件还提供有14V输出过压保护、逐周期过流保护和热关断保护。

■ 应用

- 无线音箱
- 便携式音箱
- 快充移动电源
- 电子烟
- USB TYPE-C 电源传输
- 拉杆音箱
- 平板电脑，笔记本电脑
- POS机终端

■ 典型应用图



13V,10A Fully-Integrated Synchronous Boost Converter

■ FEATURES

- Input voltage range V_{IN}: 2.7V to 13V
- Output voltage range V_{OUT}: 4.5V to 13V
- switch peak current limit: up to 10A
- High Efficiency
  93% (V_{IN} = 7.4V, V_{OUT}=12V, I_{OUT} =3A)
  92% (V_{IN} = 3.6V, V_{OUT}=9V, I_{OUT} =1A)
- PFM modulation mode at light load
- 1.0μA current consumption during shutdown
- Fix switching frequency
- FIX soft start time
- Output overvoltage protection (at 14V), cycle-by-cycle overcurrent protection, thermal shutdown protection
- Pb-free Packages,SOP8-PP

■ APPLICATIONS

- Wireless/ Speakers
- Portable Speakers
- Quick Charge Power Bank
- E-Cigarette
- Power Interface (USB Type-C, Thunderbolt)
- POS Terminal
- Tablet PC/Note Book

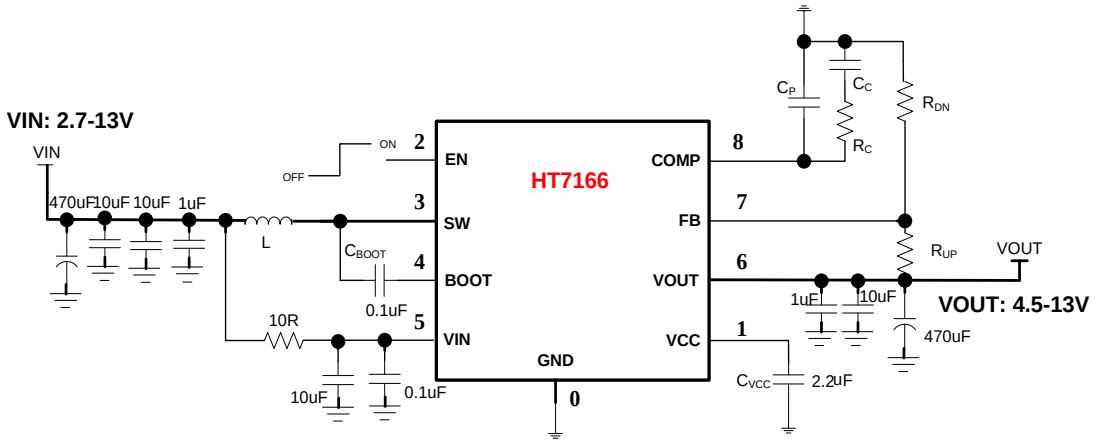
■ DESCRIPTION

The HT7166 is a high-power density, fully integrated synchronous boost converter with a 16mΩ power switch and a 23mΩ rectifier switch to provide a high efficiency and small size solution in portable systems. The HT7166 has wide input voltage range from 2.7 V to 13 V to support applications with single cell and two cell Lithium batteries. The device has 10A switch current capability and can provide an output voltage up to 13V.

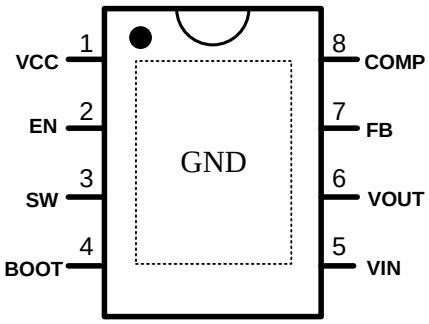
The HT7166 uses adaptive constant off-time peak current control topology to regulate the output voltage. In moderate to heavy load condition, it works in the PWM mode. In light load condition, the device works in the PFM mode to improve the efficiency. The switching frequency in the PWM mode is fixed.

The HT7166 also implements a fix soft-start function and a fixed switching peak current limit function. In addition, the device provides 14V output overvoltage protection, cycle-by-cycle overcurrent protection, and thermal shutdown protection

■ TYPICAL APPLICATION



■ TERMINAL CONFIGURATION



Top View

■ TERMINAL FUNCTION

Terminal No.	NAME	I/O[*1]	Description
1	VCC	O	Output of the internal regulator. A ceramic capacitor of 2.2uF is required between this pin and ground.
2	EN	I	Enable logic input. Logic high level enables the device. Logic low level disables the device and turns it into shutdown mode.
3	SW	PWR	The switching node pin of the converter.
4	BOOT	O	Power supply for high-side MOSTFET gate driver. A ceramic capacitor of 0.1μF must be connected between this pin and the SW pin.
5	VIN	I	IC power supply input.
6	VOUT	PWR	Boost converter output.
7	FB	I	Voltage feedback.
8	COMP	O	Output of the internal error amplifier, the loop compensation network should be connected between this pin and the GND pin.
0	GND	PWR	Power ground of the IC.

[1] I: input O: output PWR: power

■ ORDERING INFORMATION

Part Number	Package Type	Marking	Operating Temperature Range	Shipping Package / MOQ
HT7166SPET	SOP8-PP	HT7166	-40℃～85℃	Tube/100PCS

■ ELECTRICAL CHARACTERISTIC

● Absolute Maximum Ratings[*2]

PARAMETER		Symbol	MIN	MAX	UNIT
Voltage range	BOOT	/	-0.3	SW+7	V
	SW, V_{OUT}, V_{IN}		-0.3	14.2	
	EN, VCC, COMP		-0.3	7	
	FB		-0.3	3.6	
Operating temperature range		T_A	-40	85	℃
Operating junction temperature range		T_J	-40	150	℃
Storage temperature range		T_{STG}	-50	150	℃

● Recommended Operating Conditions

PARAMETER	Symbol	CONDITION	MIN	TYP	MAX	UNIT
Input power voltage range	V_{IN}		2.7		13.2	V
IC power supply voltage range	V_{IN}		2.7		13.2	V
Output voltage range	V_{OUT}		4.5		13.8	V
Inductance, effective value	L		0.47	2.2	10	μH
Input capacitance, effective value	C_I		10			μF
Output capacitance, effective value	C_O		6.8	47	1000	μF
Operating temperature	T_a		-40	25	85	℃
Operating junction temperature	T_J		-40		125	℃

[2] Stresses beyond those listed under absolute maximum ratings may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under recommended operating conditions is not implied. Exposure to absolute–maximum–rated conditions for extended periods may affect device reliability.

Electrical Characteristics[3]

Condition: Ta = 25ºC, V_{IN} = 2.7V-13.2V, V_{OUT}=4.5-13.2V, unless otherwise specified.

Power Supply

PARAMETER	Symbol	CONDITION	MIN	TYP	MAX	UNIT
Input power voltage range	V_{IN}		2.7		13.2	V
IC power supply voltage range	V_{IN}		2.7		13.2	V
Under-voltage lockout (UVLO) threshold	V_{IN_UVLO}	VIN rising			2.7	V
		VIN falling			2.5	V
VIN UVLO hysteresis	V_{IN_HYS}			200		mV
VCC UVLO threshold	V_{CC_UVLO}			2.1		V
Operating quiescent current from V_{IN}	I_Q	IC enabled, no load, V_{FB} = 1.3V, V_{OUT} = 12V		1		uA
Operating quiescent current from V_{OUT}				120		
Shutdown current into V_{IN}	I_{SD}	IC disabled, no load, no feedback resistor divider		1		uA
VCC regulation	V_{CC}	V_{IN} = 3.6V, V_{OUT} = 12V, light load		5.6		V
		V_{IN} = 3.6V, V_{OUT} = 12V, I_{LOAD} = 0.5A		5.2		V

EN and Mode Input

PARAMETER	Symbol	CONDITION	MIN	TYP	MAX	UNIT
EN high threshold voltage	V_{ENH}		1.5			V
EN low threshold voltage	V_{ENL}				0.4	V
EN internal pull-down resistance	R_{EN}			800		kΩ
MODE high threshold voltage	V_{MODEH}		4			V
MODE low threshold voltage	V_{MODEL}				1.5	V
MODE internal pull-up resistance	R_{MODE}			800		kΩ

OUTPUT

PARAMETER	Symbol	CONDITION	MIN	TYP	MAX	UNIT
Output voltage range	V_{OUT}	Freq = 500 kHz	4.5		13.2	V
Output overvoltage protection	V_{OVP}			14.2		V
Reference voltage at the FB pin	V_{REF}		1.186	1.204	1.222	V
Soft-start charging current	I_{SS}			5		uA

ERROR AMPLIFIER

PARAMETER	Symbol	CONDITION	MIN	TYP	MAX	UNIT
COMP pin sink current	I_{SINK}	V_{FB} = V_{REF} +200 mV, V_{COMP} = 1.5 V		20		uA
COMP pin source current	I_{SOURCE}	V_{FB} = V_{REF} –200 mV, V_{COMP} = 1.5 V		20		uA
High clamp voltage at the COMP pin	V_{CC_LPH}	V_{FB} = 1 V		2.3		V
Low clamp voltage at the COMP pin	V_{CC_LPL}	V_{FB} = 1.5 V		1.4		V
Error amplifier transconductance	G_{EA}	V_{COMP} = 1.5 V		190		uA/V

[3] Depending on parts and pattern layout, characteristics may be changed

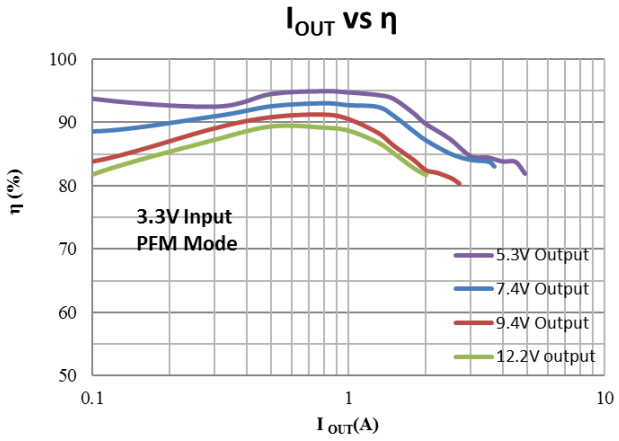
PARAMETER	Symbol	CONDITION	MIN	TYP	MAX	UNIT
POWER SWITCH						
MOSFET on-resistance	$R_{DS(on)}$	High-side MOSFET		23		mΩ
		Low-side MOSFET		16		mΩ
CURRENT LIMIT						
Peak switch current limit	I_{LIM}			10.6		A
SWITCHING FREQUENCY						
Switching frequency	f_{SW}	V_{IN} = 5V, V_{OUT} = 12V		660		kHz
Minimum on-time	t_{ON_min}	V_{IN} = 3.6V, V_{OUT} = 12V		190		ns
THERMAL SHUTDOWN						
Thermal shutdown threshold	T_{SD}			150		℃
Thermal shutdown hysteresis	T_{SD_HYS}			20		℃

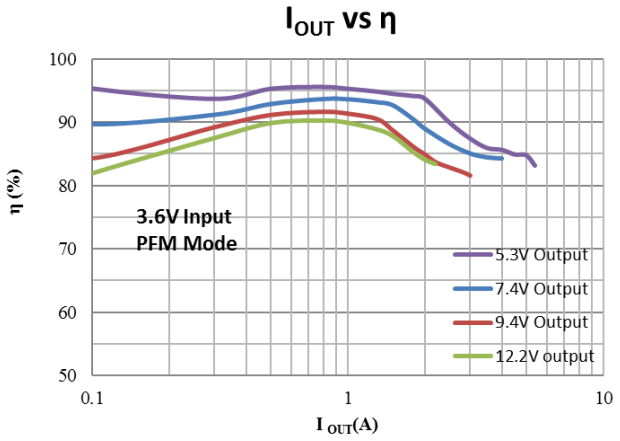
- **Voltage Setting Reference for HT7166**

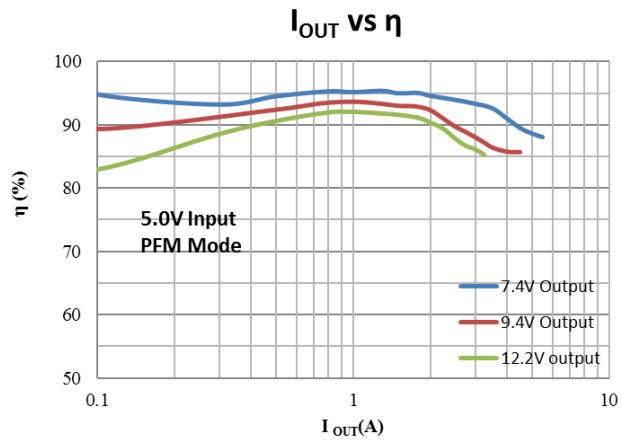
Input Power	Referred Max Input Current (RMS Value)	Input Voltage	Output Voltage	Referred Max Output Current (RMS Value)	Output Power	Efficiency	Pull-up resistor from FB	Pull-down resistor from FB
P_{PIN} (W)	I_{PIN}(A)	V_{IN}(V)	V_{OUT}(V)	I_{OUT}(A)	P_{OUT} (W)	η(%)	R_{UP}(Ω)	R_{DN}(Ω)
30.0	8.4	3.6	7.3	3.5	25.7	85.5%	510k	100k
31.8	8.8	3.6	9.3	2.8	26.1	82.2%	510k	75k
32.1	8.9	3.6	12.2	2.2	26.8	83.4%	510k	56k
44.5	8.9	5.0	7.3	5.5	39.2	88.0%	510k	100k
43.5	8.7	5.0	9.3	4.0	37.3	85.8%	510k	75k
46.2	9.2	5.0	12.2	3.2	39.4	85.2%	510k	56k
67.2	9.1	7.4	9.3	6.5	60.5	90.1%	510k	75k
68.5	9.3	7.4	12.2	5.0	60.8	88.8%	510k	56k

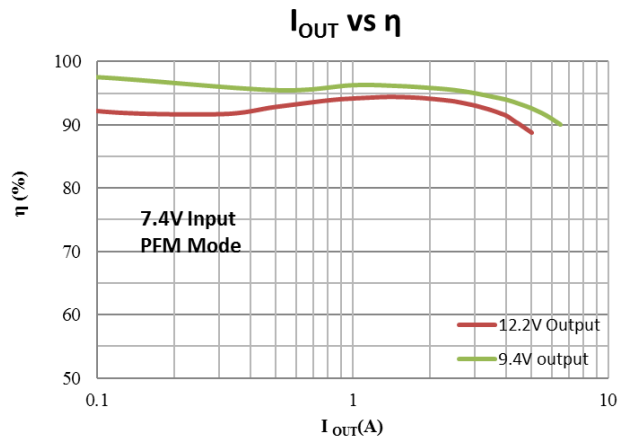
■ TYPICAL OPERATING CHARACTERISTICS

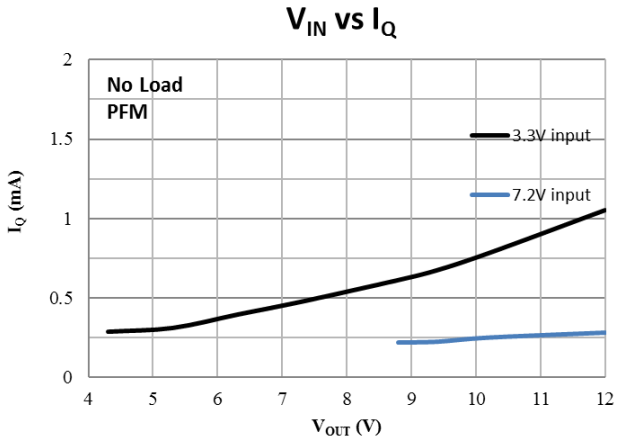
Condition: L = 2.2uH, Output Capacitor = 1uF//10uF//10uF//220uF, otherwise specified.





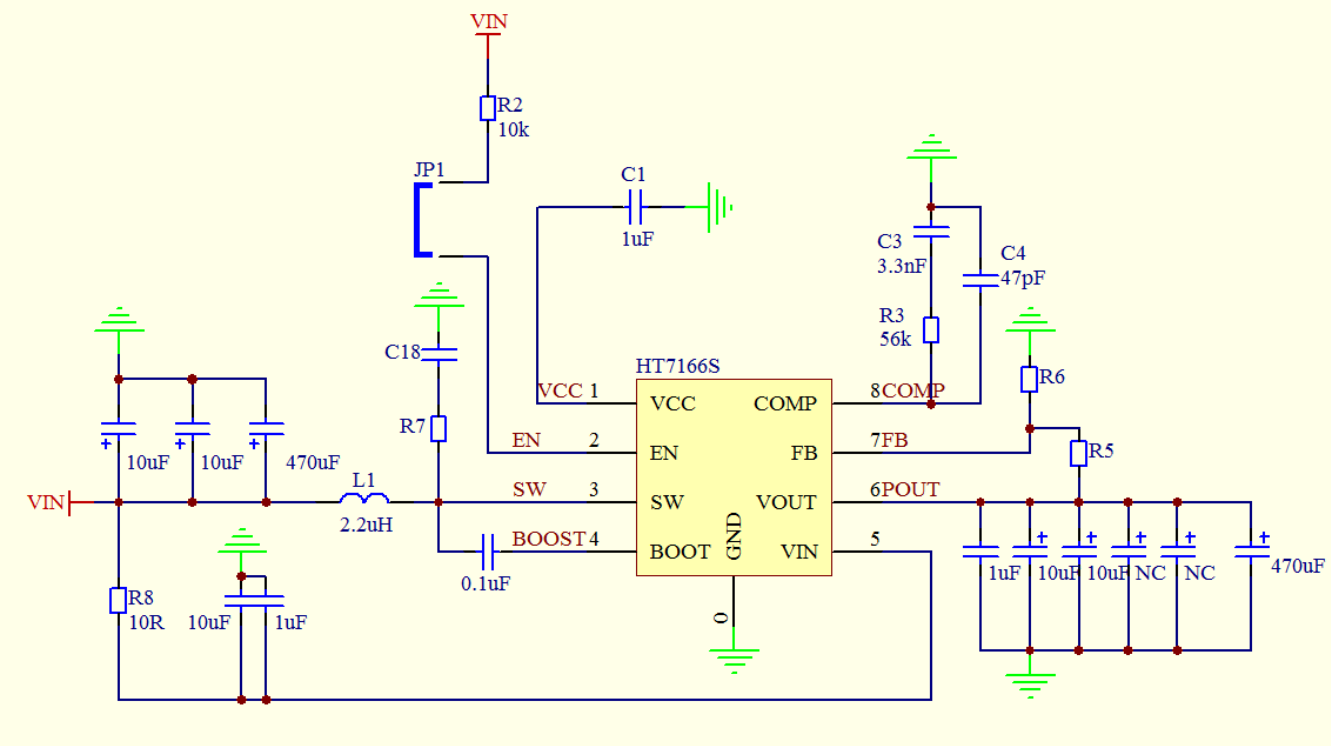






■ APPLICATION INFORMATION

1. Typical Application



2. Feature Description

2.1. Functional Modes

Operation

The synchronous boost converter HT7166 operates at a quasi-constant frequency pulse width modulation (PWM) in moderate to heavy load condition. Based on the V_{IN} to V_{OUT} ratio, a circuit predicts the required off-time of the switching cycle. At the beginning of each switching cycle, the low-side N-MOSFET switch is turned on, and the inductor current ramps up to a peak current that is determined by the output of the internal error amplifier. After the peak current is reached, the current comparator trips, and it turns off the low-side N-MOSFET switch and the inductor current goes through the body diode of the high-side N-MOSFET in a dead-time duration. After the dead-time duration, the high-side N-MOSFET switch is turned on. Because the output voltage is higher than the input voltage, the inductor current decreases. The high-side switch is not turned off until the fixed off-time is reached. After a short dead-time duration, the low-side switch turns on again and the switching cycle is repeated.

In light load condition, the HT7166 implements PFM mode.

PFM Mode

The HT7166 improves the efficiency at light load with the PFM mode. When the converter operates in light load condition, the output of the internal error amplifier decreases to make the inductor peak current down, delivering less power to the load. When the output current further reduces, the current through the inductor will decrease to zero during the off-time. Once the current through the high side N-MOSFET is zero, the high-side MOSFET is turned off until the beginning of the next switching cycle. When the output of the error amplifier continuously goes down and reaches a threshold with respect to the peak current of ILIM / 12, the output of the error amplifier is clamped at this value and does not decrease any more. If the load current is smaller than what the HT7166 delivers, the output voltage increases above the nominal setting output voltage. The HT7166 extends its off time of the switching period to deliver less energy to the output and regulate the output voltage to 0.7% higher than the nominal setting voltage. With the PFM operation mode, the HT7166 keeps the efficiency above 80% even when the load current decreases to 1 mA. In addition,

the output voltage ripple is much smaller at light load due to low peak current.

2.2. Enable and Startup (EN)

The HT7166 has an fix soft start function to prevent high inrush current during start-up. The soft start time is normally 4ms.

When the EN pin is pulled into logic low (below 0.4V), the HT7166 goes into the shutdown mode and stops switching. Only when EN pin is pulled into logic high (above 1.5V), the HT7166 works.

2.3. Switching Frequency

This device features a fix switching frequency. The switching frequency is determined by Vin and Vout. The switching frequency is usually 600kHz.

2.4. Peak Current Limit (ILIM)

To avoid an accidental large peak current, an internal cycle-by-cycle current limit is adopted. The low-side switch is turned off immediately as soon as the switch current touches the limit. The peak switch current limit is usually 10A peak.

2.5. Output Voltage Setting (FB pin)

The output voltage is set by an external resistor divider (R_{UP}, R_{DN} in the Typical Application Circuit). To get the output voltage V_{OUT}, the Value of R_{UP} and R_{DN} can be calculated as:

$$V_{OUT} = V_{REF} \times (1 + \frac{R_{UP}}{R_{DN}})$$

Where V_{REF} = 1.204V.

Some typical output voltages can be set as the following parameters.

V_{OUT}(V)	R_{UP}(Ω)	R_{DN}(Ω)
5.3	510k	150k
7.4	510k	100k
9.4	510k	75k
12.2	510k	56k

2.6. Inductor Selection (SW pin)

Because the selection of the inductor affects the power supply's steady state operation, transient behavior, loop stability, and boost converter efficiency, the inductor is the most important component in switching power regulator design. Three most important specifications to the performance of the inductor are the inductor value, DC resistance, and saturation current.

To be simplified, the inductor value can be set as 2.2uH which can be used in most cases.

The rated current, especially the saturation current should be larger than the peak current during the whole operation. The peak current can be calculated as follows.

$$I_{Lpeak} = I_{DC} + \frac{I_{PP}}{2}$$

$$I_{DC} = \frac{V_{OUT} \times I_{OUT}}{V_{IN} \times \eta}$$

$$I_{PP} = \frac{1}{L \times (\frac{1}{V_{OUT} - V_{IN}} + \frac{1}{V_{IN}}) \times f_{SW}}$$

Boost converter efficiency is affected significantly by the inductor's DC resistance (DCR), equivalent series resistance (ESR) at the switching frequency, and the core loss. An inductor with lower DCR and ESR would

increase the efficiency significantly.

The inductor should be placed as close as possible to the SW pin. For a lower EMI radiation, connecting a resistor and a capacitor in series to the ground would be helpful. 1ohm resistor and 10nF capacitor would be recommended in most cases.

2.7. Input Capacitor Selection (V_{IN}, VCC pin)

For good input voltage filtering and small voltage ripple (less than 100mV is required), we recommend low-ESR capacitors of 1uF//10uF//10uF//470uF ("//" represents paralleled) be placed as close as possible to the inductor.

The V_{IN} pin is the power supply for the HT7166, a 1uF paralleled with 10uF ceramic capacitor should be placed as close as possible to the V_{IN} pin. Notice that the maximum voltage of V_{IN} should be lower than 13V. A resistor of 100R is recommended between input power supply and V_{IN} pin so that the power supply of HT7166 would be more stable. An extensive power supply such as the logic power supply connecting to V_{IN} would be another choice.

The VCC pin is the output of internal LDO. A ceramic capacitor of 2.2uF is required at the VCC pin to get a stable operation of LDO.

2.8. Output Capacitor Selection (V_{OUT} pin)

To be simplified, we recommend low-ESR capacitors of 1uF//10uF//10uF//470uF ("//" represents paralleled) be placed as close as possible to VOUT pin for small output voltage ripple.

Capacitors can lose most of their capacitance at rated voltage. Therefore, leave margin on the voltage rating to ensure adequate effective capacitance.

In detail, for the require output voltage ripple, use the following equations to calculate the minimum required effective capacitance C_{OUT}

$$V_{ripple\_dis} = \frac{(V_{OUT} - V_{IN_{MIN}}) \times I_{OUT}}{V_{OUT} \times f_{SW} \times C_{OUT}}$$

$$V_{ripple\_ESR} = I_{Lpeak} \times R_{C\_ESR}$$

Where

- V_{ripple_dis} is output voltage ripple caused by charging and discharging of the output capacitor.
- V_{ripple_ESR} is output voltage ripple caused by ESR of the output capacitor.
- V_{IN_MIN} is the minimum input voltage of boost converter..
- V_{OUT} is the output voltage..
- I_{OUT} is the output current.
- I_{Lpeak} is the peak current of the inductor.
- f_{SW} is the converter switching frequency.
- R_{C_ESR} is the ESR of the output capacitors.

2.9. Loop Stability (COMP pin)

The HT7166 requires external compensation, which allows the loop response to be optimized for each application. The COMP pin is the output of the internal error amplifier. An external compensation network comprised of resister R_C, ceramic capacitors C_C and C_P is connected to the COMP pin.

To be simplified, R_C is 56kΩ, C_C is 3.3nF, and C_P can be floating. But notice that this setting can only be adopted in most cases. In detail, the compensation network parameters can be calculated as follows.

(1) Set the cross over frequency, f_c

The first step is to set the loop crossover frequency, f_C. The higher crossover frequency, the faster the loop

response is. It is generally accepted that the loop gain cross over no higher than the lower of either 1/10 of the switching frequency, f_{SW}, or 1/5 of the RHPZ frequency, f_{RHPZ}. It's proper to use a fixed parameter of 10kHz for f_C.

$$f_{RHPZ} = \frac{R_O \times (1-D)^2}{2\pi \times L}$$

(2) Set the compensation resistor, R_C.

$$R_C = \frac{2\pi \times V_{OUT} \times R_{sense} \times f_C \times C_O}{(1-D) \times V_{REF} \times G_{EA}}$$

(3) Set the compensation zero capacitor, C_C

$$C_C = \frac{R_O \times C_O}{2 \times R_C}$$

(4) Set the compensation pole capacitor, C_P

$$C_P = \frac{R_{ESR} \times C_O}{R_C}$$

If the C_P is less than 10pF, it can be left open.

- R_O is the output load resistance.
- D is the switching duty cycle. 1 - D = V_{IN} / V_{OUT}
- R_{sense} is the equivalent internal current sense resistor, which is 0.084 Ω.
- C_O is output capacitor.
- V_{REF} is the reference voltage at the FB pin, which is 1.204V.
- G_{EA} is the amplifier's transconductance, which is 190uA/V.
- R_{ESR} is the equivalent series resistance of the output capacitor.

2.10. Selecting the Bootstrap Capacitor (BOOT pin)

The bootstrap capacitor (C_{BST}) between the BOOT and SW pin supplies the gate current to charge the high-side FET device gate during each cycle's turn-on and supplies charge for the bootstrap capacitor. The recommended value of the bootstrap capacitor is 0.1μF to 1μF. C_{BST} should be a good quality, low ESR, ceramic capacitor located at the pins of the device to minimize potentially damaging voltage transients caused by trace inductance. A value of 0.1μF can be used in most cases.

2.11. Protection Function

Under-voltage Lockout (UVLO)

The UVLO circuit prevents the device from malfunctioning at low input voltage and the battery from excessive discharge. The HT7166 has both V_{IN} UVLO function and VCC UVLO function. It disables the device from switching when the falling voltage at the V_{IN} pin trips the UVLO threshold V_{IN_UVLO}, which is typically 2.4V. The device starts operating when the rising voltage at the VIN pin is 200mV above the V_{IN_UVLO}. It also disables the device when the falling voltage at the VCC pin trips the UVLO threshold V_{CC_UVLO}, which is typically 2.1V.

Over-voltage Protection

If the output voltage at the VOUT pin is detected above 14.2 V (typical value), the HT7166 stops switching immediately until the voltage at the VOUT pin drops the hysteresis value lower than the output overvoltage protection threshold. This function prevents overvoltage on the output and secures the circuits connected to the output from excessive overvoltage.

Thermal Shutdown

A thermal shutdown is implemented to prevent damages due to excessive heat and power dissipation. Typically, the thermal shutdown happens at a junction temperature of 150°C. When the thermal shutdown is triggered, the device stops switching until the junction temperature falls below typically 130°C, then the device starts switching again.

3. Application Notes

3.1. Radiated EMI Reduction

(1) Minimize High di/dt Path Loop Area

EMI Starts off from high di/dt loops. The high di/dt critical path locates as the red circle showed in the following figure. The output capacitor should be placed as close to the VOUT pin as possible resulting in minimum area of the high di/dt loop.

(2) PCB Trace and Ground Plane

High trace inductance leads to poor radiation EMI. The inductance of a PCB trance is a function of its length and width. So, increase the trace width and decrease the trace length will significantly decrease the radiation EMI.

Meanwhile, good designed ground planes will help decrease the radiation EMI too:

- Placing a solid ground plane with minimum distance to the critical trace;
- Wider and bigger ground plane result in smaller signal trace inductance;
- Thinner insulation thickness between the ground plane and the signal traces also results in smaller inductance;

(3) RC Snubber

Adding an RC snubber across the SW pin and the power ground can help reduce the radiation EMI levels. The RC snubber should be placed as close as possible to the switching node and the power ground.

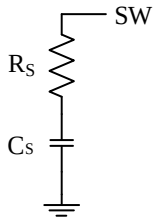


Figure 1 Placement of RC Snubber

The aim of the snubber resistor RS is to add sufficient damping to the parasitic resonant circuit. The value of R_S depends on the desired damping factor and the parasitic inductor I_P and parasitic capacitor C_P of the circuit:

$$R_S = \frac{1}{\xi} \times \sqrt{\frac{L_P}{C_P}}$$

Where ξ is the damping factor, normally can range from 0.5 to 1.

The value of L_P and C_P can be measured by:

- Measure the original ringing frequency f_{RING};
- Add some small capacitance from switch node to ground. Keep increasing capacitance until the ringing frequency is 50% of the original ringing frequency f_{RING}, and the capacitance is C_S, $C_P = 1/(3C_S)$;
- $L_P = \frac{1}{C_P \times (2\pi \times f_{RING})^2}$

To be simplified, a resistor of 1ohm (R_S) and a capacitor of 2.2nF (C_S) can be used. However, notice that larger C_S results in higher power loss.

(4) Radiation from Cables

A longer input or output cables result in poor radiation EMI. So, make the length of input cable and output cable very close to the real application.

(5) Ferrite Bead

Ferrite Bead is used in series with the power line. Before using a ferrite bead, you need to consider about

the specifications of the bead as follows:

- The frequency characteristics

Make sure that the resistive impedance of the bead is much higher than the reactive impedance in the noise frequency range.

- The rated current

Make sure that the rated current of the bead should be at least 30% higher than the expected maximum current.

- The DC resistance

The DC resistance of the ferrite bead should be as low as possible.

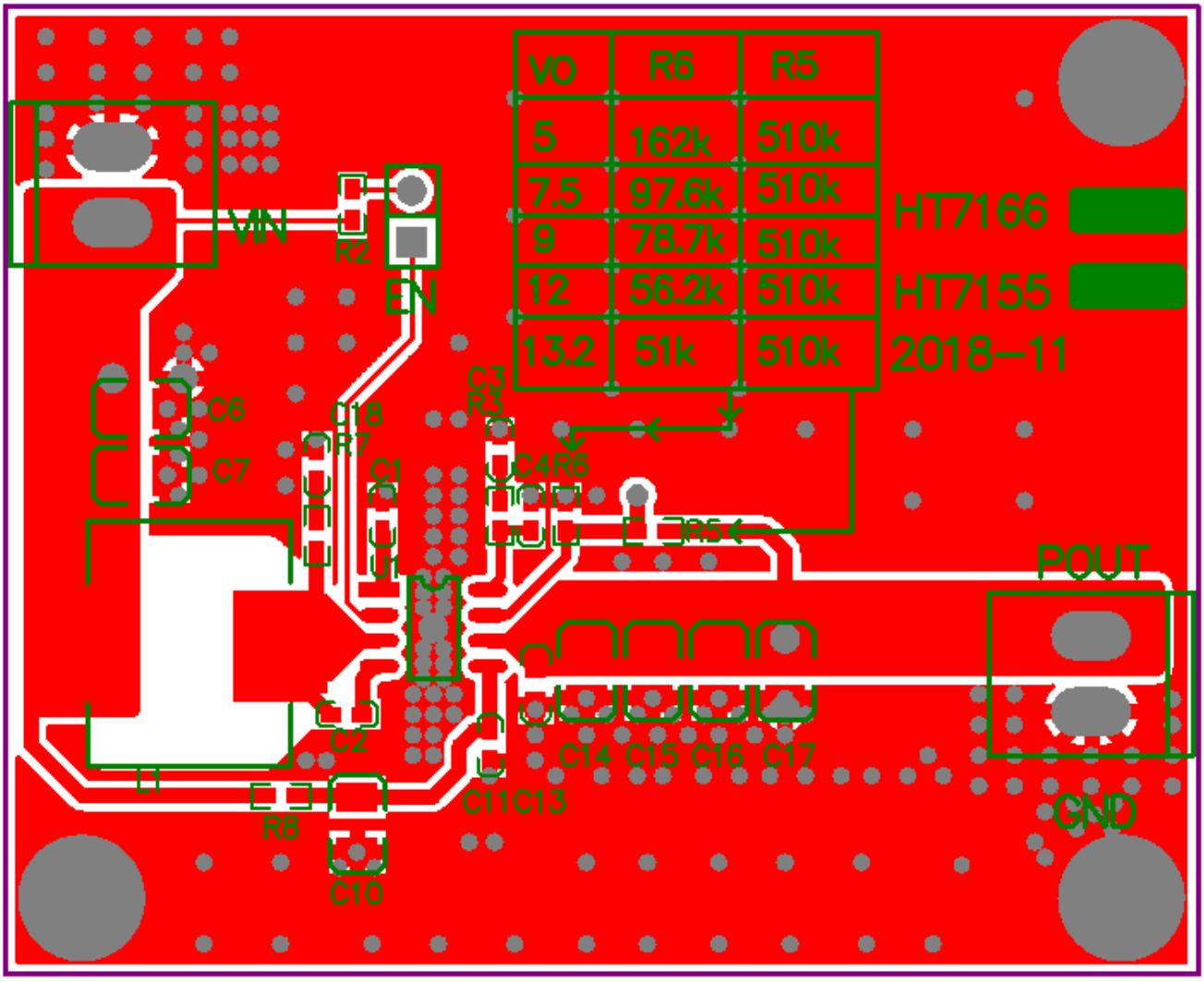
3.2. Layout Guidelines

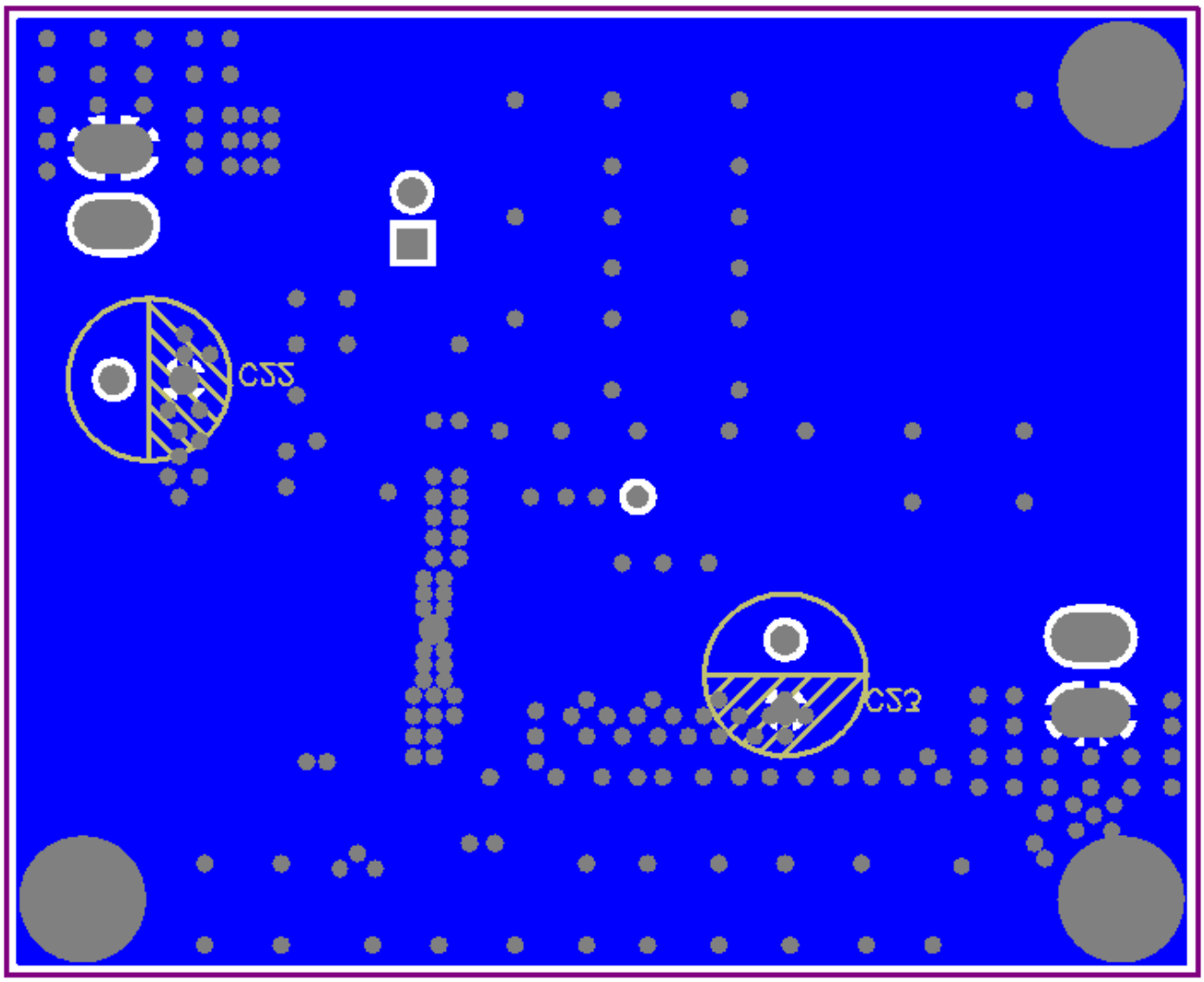
As for all switching power supplies, especially those running at high switching frequency and high currents, layout is an important design step. If layout is not carefully done, the regulator could suffer from instability and noise problems. To maximize efficiency, switch rise and fall times are very fast. To prevent radiation of high frequency noise (for example, EMI), proper layout of the high-frequency switching path is essential. Minimize the length and area of all traces connected to the SW pin, and always use a ground plane under the switching regulator to minimize interplane coupling.

The input capacitor needs to be close to inductor L, the V_{IN} pin and GND pin in order to reduce the input supply ripple. The output capacitor needs to be close to V_{OUT} pin and GND pin in order to reduce the output supply ripple.

The layout should also be done with well consideration of the thermal as this is a high-power density device. A thermal pad that improves the thermal capabilities of the package should be soldered to the large ground plate, using thermal vias underneath the thermal pad.

3.3. Layout Examples

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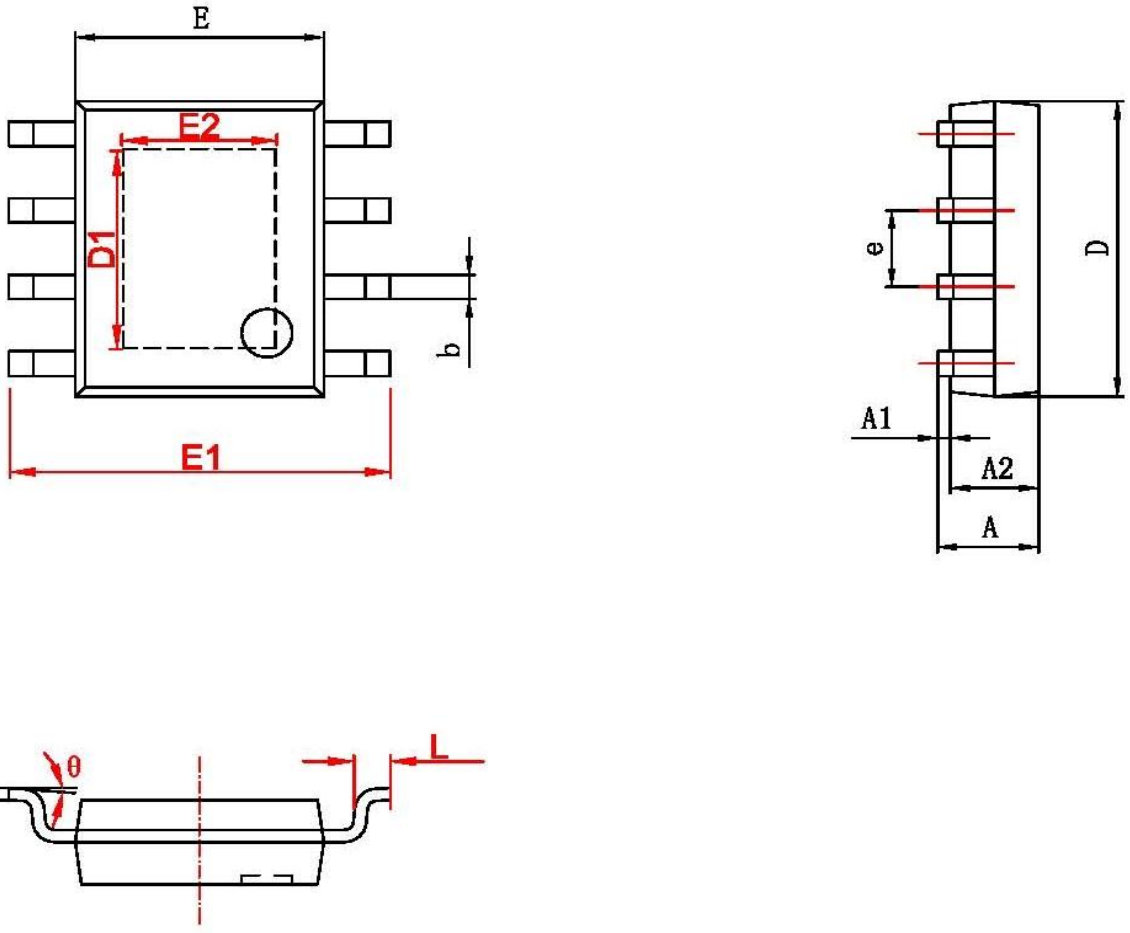
■ PACKAGE OUTLINE

SOP8-PP(EXP PAD) PACKAGE OUTLINE DIMENSIONS



字符	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	1.350	1.750	0.053	0.069
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
θ	0°	8°	0°	8°