

4.0V~28V输入，3.5A同步降压变换器

4.0~28V Input, 3.5A, Synchronous Buck Converter

■ FEATURES

- 3.5A converter with 100mΩ and 60mΩ FETs
- Fast transient response with minimum external components
- Input voltage range: 4.0V~28V
- Output voltage range: 0.6 V~13V
- Pulse skip mode to keep high efficiency in light load
- 600kHz switching frequency
- Shutdown current: $\leq 1 \mu\text{A}$ (typical)
- Soft start and start delay with pre-biased output voltage
- Cycle-by-cycle over current limit
- Hiccup-mode over current protection
- Non-latching Undervoltage protection and Thermal Shutdown protection
- Enable pin
- Packages: Pb-free Packages, ESOP8
- 3.5A降压，内置100mΩ和60mΩ功率管
- 于快速瞬态响应，外部元器件少
- 输入电压范围：4.0V~28V
- 输出电压范围：0.6V~13V
- 脉冲跳跃模式使得轻载下高效率
- 600kHz开关频率
- 关断电流 $\leq 1\mu\text{A}$ (典型值)
- 软起动，输出预先有电压时有启动延迟
- 逐周期过流检测限制
- 打嗝模式过流关断
- 欠压保护、过热关断保护，不锁定可自动恢复
- 具有使能pin
- 无铅封装，ESOP8

■ APPLICATIONS

- 5V, 12V or 24V power rail applications
- TV
- Consumer electronics
- Industrial power supplies
- 5V, 12V或24V电源轨
- 嵌入式系统
- 消费电子
- 电视
- 机顶盒
- 工业电子

DESCRIPTION

The HT77231 is a 3.5A, step-down, buck converter with minimum external components and low shutdown current.

The device delivers a fast transient response with both low ESR (polymer) and ultra-low ESR (ceramic) output capacitors, and no external compensation is needed.

The device operates in Pulse Skip Mode when in light load with high efficiency.

The HT77231 is available in ESOP8 packages.

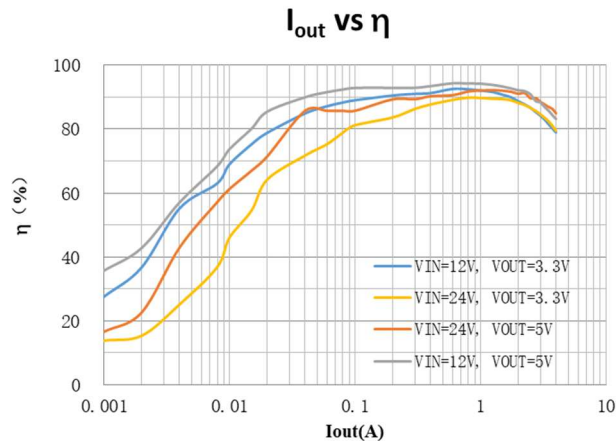
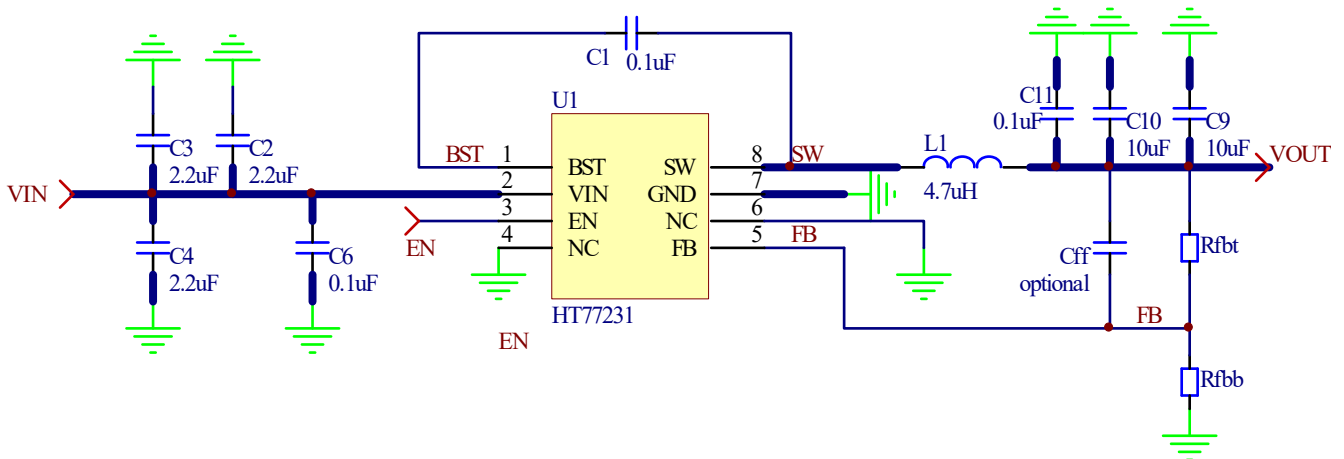
HT77231 是一款 3.5A 降压转换器，具有最少的外部元件和低关断电流。

该器件具有快速瞬态响应的特点，输出电容器采用低 ESR（聚合物）或超低 ESR（陶瓷），无需外部补偿。

该器件在轻载时以脉冲跳跃模式工作，达到高效。

HT77231 采用ESOP8 封装。

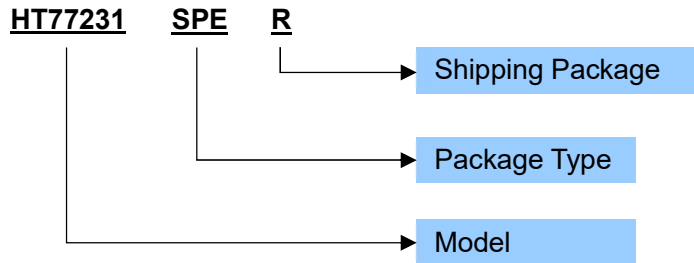
TYPICAL APPLICATION



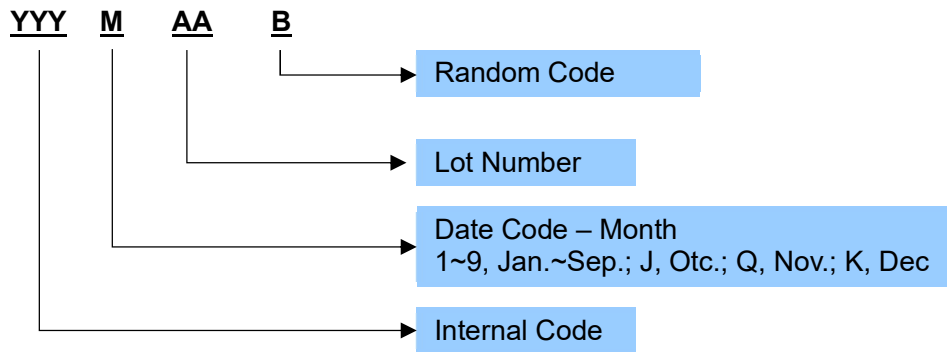
ORDERING INFORMATION

Part Number	Package Type	Marking	Operating Temperature Range	Shipping Package / MOQ
HT77231SPER	ESOP8 (SPE)	HT77231 YYYMAAB ¹	-40°C ~ 125°C	Tape and Reel / TBD

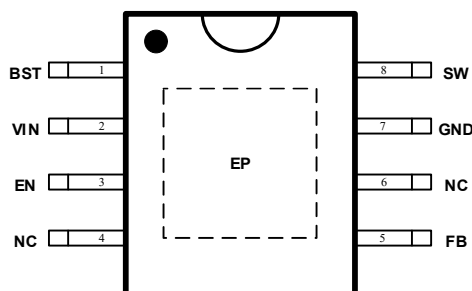
Part Number



Production Tracking Code



¹ YYYMAAB is production tracking code
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■ TERMINAL CONFIGURATION

Top View
■ TERMINAL FUNCTION

Terminal No.	Name	Description
1	BST	Bootstrap. Power supply for the high-side MOSFET driver. Connect a bypass capacitor between BST and SW. BST是内部高端MOSFET驱动器的正电源。在BST和SW之间连接一个旁路电容器。
2	VIN	Input supply. VIN supplies power to all of the internal control circuitries. A decoupling capacitor to ground must be placed close to VIN to minimize switching spikes. 输入电源。VIN为所有内部控制电路供电。接地滤波电容必须放置在VIN附近，以减少开关尖峰。
3	EN	Enable input, with internal pull-up current source. Pull EN below the specified threshold to shut down the device. Pull EN above the specified threshold to enable the device. Float to enable. 使能脚，内置上拉电流源。将EN拉到阈值以下以关闭。将EN拉至阈值以上启用。EN脚悬空启用使能。
4, 6	NC	No connection, connect to GND
5	FB	Feedback. Connect resistor divider to output voltage. 反馈。接分压电阻到输出电压。
7	GND	Ground. GND should be placed as close to the output capacitor as possible to avoid the high-current switch paths. 地。GND应尽可能靠近输出电容，以避免高电流开关路径。
8	SW	Switch node. 开关端口。
EP	-	Thermal pad, connect to GND for better thermal performance.

SPECIFICATIONS¹
Absolute Maximum Ratings²

PARAMETER	Symbol	MIN	TYP	MAX	UNIT
VIN supply voltage	VIN	-0.3		32	V
BST voltage	BST	-0.3		37.5	V
BST voltage (10ns transient)	BST	-0.3		39.5	V
Voltage between BST and SW	BST to SW	-0.3		5.5	V
FB voltage	FB	-0.3		5.5	V
EN voltage	EN	-0.3		VIN+0.3	V
SW voltage	SW	-2		32	V
SW voltage (10ns transient)	SW	-3.5		35	V
Moisture Sensitivity Level (MSL)			MSL1		
Junction Temperature	TJ	-40		150	°C
Storage Temperature	TSTG	-55		150	°C
ESD, Human-body model (HBM)	HBM		±2000		V
ESD, Charged-device model (CDM)	CDM		±500		V

Recommended Operating Conditions

PARAMETER	Symbol	CONDITION	MIN	TYP	MAX	UNIT
VIN supply voltage	VIN		4.5		28	V
BST voltage	BST		-0.1		33	V
Voltage between BST and SW	BST to SW		-0.1		5	V
FB voltage	FB		-0.1		4.5	V
EN voltage	EN		-0.1		VIN	V
SW voltage	SW		-1.8		28	V
Junction Temperature	TJ		-40		125	°C

Electrical Characteristics

VIN = 24V, TA = +25°C, unless otherwise noted.

PARAMETER	Symbol	CONDITION	MIN	TYP	MAX	UNIT
VIN UVLO threshold	VUVLO	Rising		3.6		V
		Falling		3.3		V
VIN UVLO hysteresis	Vhys			0.3		V
Quiescent supply current	IQ	VEN = 24V, VFB = 1.0 V, no switching		260		uA
Shutdown supply current	ISD	VEN = 0V		0.75		µA
High-side switch on resistance	RDS(ON)_H	VBST - VSW = 5.5V		100		mΩ
Low-side switch on resistance	RDS(ON)_L			60		mΩ
Current limit (low-side switch)	ILIM			4.2		A
Zero cross current detection	IzC			0		A
EN up threshold	VENH			1.3		V
EN low threshold	VENL			1.17		V
EN threshold hysteresis	VENHY			130		mV
EN source current	IENSD	VEN < 0.7V		0.3		uA
	IENL	VEN = 1.3V - 50mV		1.2		uA
	IENH	VEN = 1.3V + 50mV		4		uA
Feedback voltage	VFBH			804		mV
FB input current	IFB	VFB = 0.8V	-100		100	nA
Minimum on time	tON_MIN			80		ns
Minimum off time	tOFF_MIN			200		ns

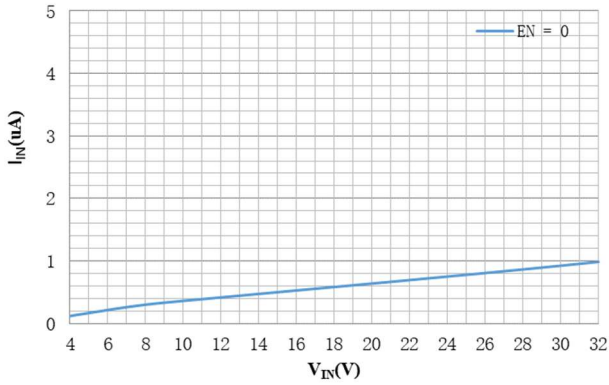
¹ Depending on parts and PCB layout, characteristics may be changed.

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.

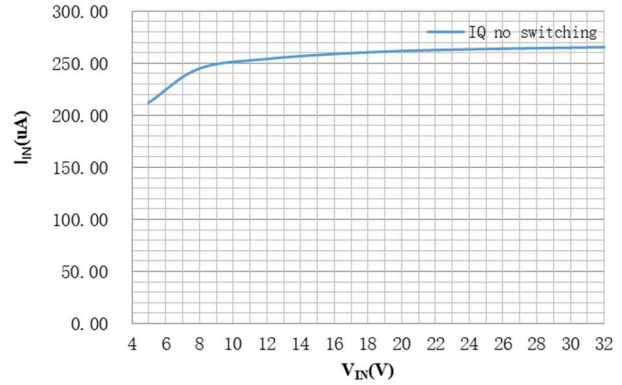
Soft-start time	t _{SS}		1.5	ms
Switching frequency	f _{sw}	V _{IN} = 12 V, V _{OUT} = 3.3 V, CCM mode	600	kHz
Output UVP falling threshold	V _{UVP}	Hiccup detect	65%	
UVP propagation delay	t _{PPD}		0.6	ms
Hiccup time before restart	t _{HCP_RE}		26	ms
Thermal shutdown		Trigger thermal shutdown	150	°C
		Hysteresis	25	°C

TYPICAL OPERATING CHARACTERISTICS

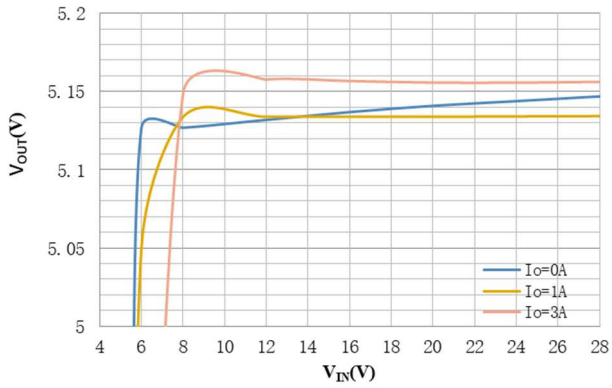
V_{IN} vs I_{IN}



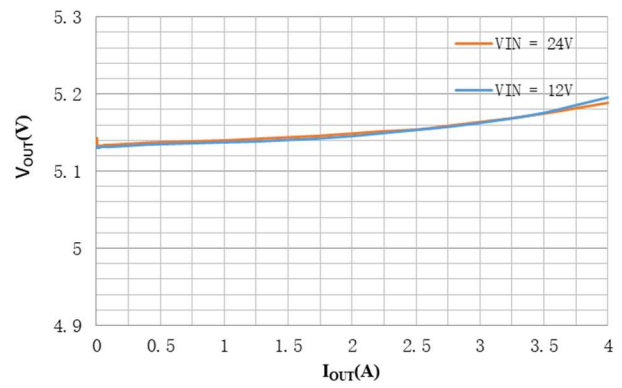
V_{IN} vs I_{IN}



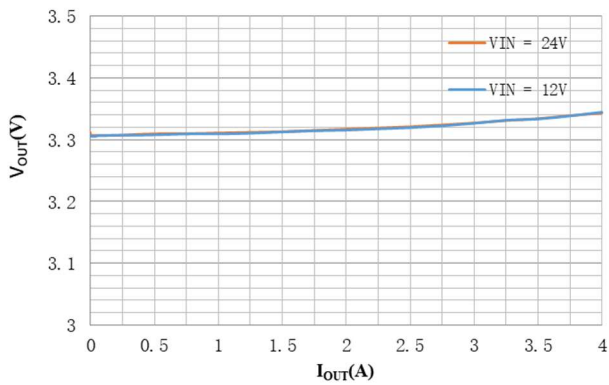
V_{IN} vs V_{OUT}



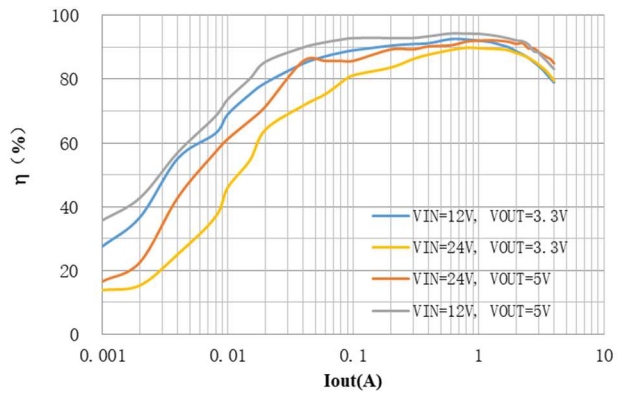
I_{OUT} vs V_{OUT}



I_{OUT} vs V_{OUT}



I_{out} vs η



APPLICATION INFORMATION

1 Description

The HT77231 is a 3.5A, step-down, buck converter with minimum external components and low shutdown current.

The device employs an adaptive on-time PWM controller with internal compensation to realize pseudo-fixed frequency and minimum external components requirement.

The device delivers a fast transient response with both low ESR (polymer) and ultra-low ESR (ceramic) output capacitors, and no external compensation is needed.

The device operates in Pulse Skip Mode when in light load with high efficiency.

The HT77231 is available in ESOP8 packages.

HT77231 是一款 3.5A 降压转换器，具有最少的外部元件和低关断电流。

HT77231 采用带内部补偿的自适应导通时间 PWM 控制，可实现伪固定频率和最小外部组件要求。

该器件具有快速瞬态响应的特点，输出电容器采用低 ESR（聚合物）或超低 ESR（陶瓷），无需外部补偿。

该器件在轻载时以脉冲跳跃模式工作，达到高效。

HT77231 采用 ESOP8 封装。

2 Functional Block Diagram

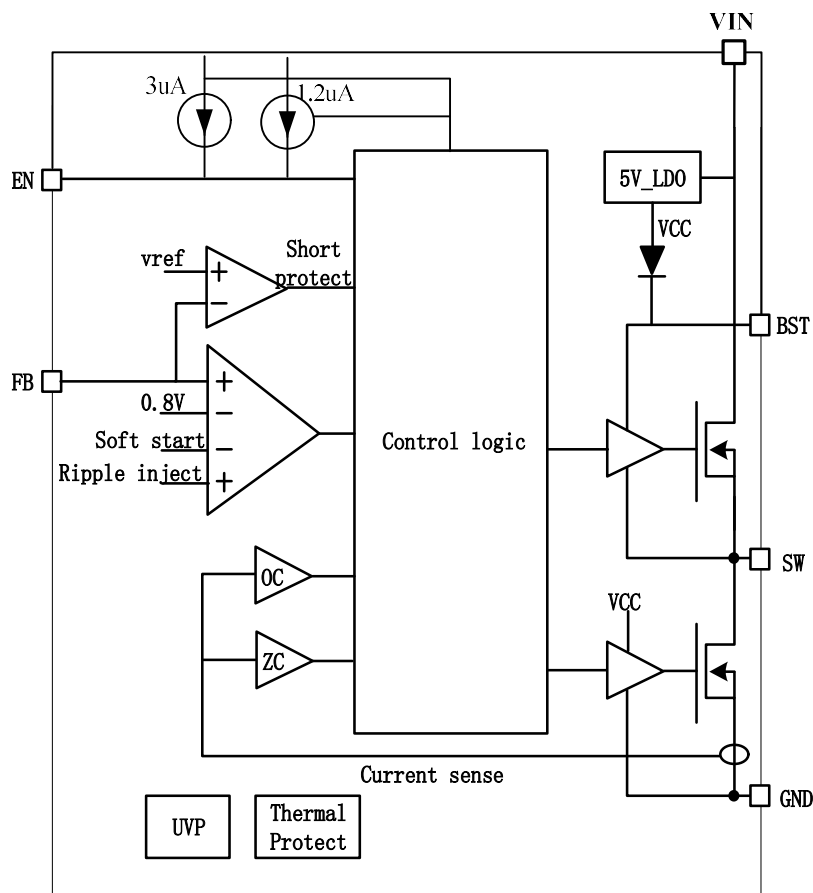


Figure 1 Block Diagram

3 Enable (EN) Control

The HT77231 has a dedicated enable control pin (EN) with positive logic. Its falling threshold is 1.17V, and its rising threshold is 1.3V.

When EN is below the threshold, the device is in shutdown mode where the switching regulator turns off. EN can be float to enable, as it integrates internal pull-up current source.

4 Soft Start and Start Delay with Pre-biased Output Voltage

The HT77231 employs an internal 1.5ms soft start to ramp up the FB voltage from 0V to 0.804V linearly once EN pulled high.

If the output voltage is prebiased when EN is pulled high, the device start switching and ramping up only after internal reference voltage is larger than V_{FB} .

5 Under-Voltage Lockout (UVLO)

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

6 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, the entire chip shuts down. When the temperature is lower than its lower threshold, the chip is enabled again.

7 Continuous Conduction Mode and Pulse Skip Mode

Once the load current is higher than half of peak-to-peak inductor current, the frequency is pseudo fixed, the output voltage ripple is pretty low, and a maximum larger than 3.5A output current can be delivered.

The inductor current is reduced when the output current is decreased. Once the ripple of inductor current touches zero level, the low side switch is turned off. As the load current further decreases, the device works in a discontinuous conduction mode. The on-time is kept almost the same as in the continuous conduction mode, so that it takes longer time to discharge the output capacitor with smaller load current to the level of the reference voltage. This makes the switching frequency lower, proportional to the load current, and keeps the light load efficiency high. As the load current continues to decrease, the switching frequency also decreases. The on-time starts to decrease once the switching frequency is lower than 250 kHz. The on-time can be about 22% reduced at most for extremely light load condition. This function is employed to achieve smaller ripple at extremely light load condition.

The transition point to the light load operation current I_{OUT_LL} can be calculated as follows.

$$I_{OUT_LL} = \frac{1}{2 \times L \times f_{sw}} \times \frac{(V_{IN} - V_{OUT}) \times V_{OUT}}{V_{IN}} \quad (1)$$

HT77231 的 EN 脚高电平有效，控制芯片使能。其下降阈值为 1.17V，上升阈值为 1.3V。当 EN 低于 1.17V，器件进入关断模式。EN 脚悬空使能芯片，因 HT77231 的 EN 脚内置上拉电流源。

HT77231 采用内部 1.5ms 软启动，一旦 EN 拉高，FB 电压就会线性上升至 0.804V。

如果 EN 被拉高时输出有预偏置电压，器件仅在内部基准电压大于 V_{FB} 后开始工作。

欠压锁定 (UVLO) 功能可避免芯片工作在电源电压不足的条件。UVLO 上升阈值约为 3.6V，下降阈值为 3.3V。

过热关断保护是为了防止芯片在极高的温度下工作。当芯片温度高于其上限阈值时，整个芯片关闭。当温度低于其下限阈值时，芯片再次启用。

当负载电流高于峰峰值电感电流的一半，频率固定，输出电压纹波低，最大输出电流可达 3.5A 以上。

当输出电流减小时，电感电流减小。一旦电感电流纹波触及零电平，低边开关管关闭。随着负载电流的进一步减小，器件以不连续导通模式工作。导通时间与连续导通模式相同，因此将负载电流较小的输出电容放电至基准电压水平需要更长的时间。这使得开关频率更低，与负载电流成正比，并保持高的轻载效率。随着负载电流的不断减小，开关频率也会降低。一旦开关频率低于 250 kHz，导通时间就会开始下降。对于极轻负载条件，导通时间最多可减少约 22%。此功能用于在极轻负载条件下实现较小的纹波。

轻负载工作电流 I_{OUT_LL} 的过渡点可以计算如下。

8 Over Current and Short Protection

The device is protected from over current by cycle-by-cycle current limit on the valley of the inductor current. The low side power MOSFET current is accurately sensed via a current sense MOSFET. When the LS MOSFET turns on and the inductor current ramps down, the LS MOSFET will not turn off until the inductor current ramps below I_{LIM} . And after a dead time, the high side MOSFET turns on.

Once the V_{FB} drops below threshold (typ. 0.38V) after a delay time (typ. 2.5ms), hiccup-mode over current protection is activated and the regulator is shutdown for a restart time (typ. 26ms). After the restart time, the device will try to restart. If the over current condition still exist, the operation will repeat until the over current condition is removed.

9 Setting the Output Voltage

The output voltage (V_{OUT}) is set by a resistor divider (R_{FBT} and R_{FBB}). The resistors can be determined with following Equation.

Where V_{FB} is 0.804V, typically.

$$V_{OUT} = V_{FB} \times \left(1 + \frac{R_{FBT}}{R_{FBB}}\right) \quad (2)$$

10 Selecting the Inductor and Output Capacitor

Use the inductor and output capacitor as following.

推荐电感和输出电容如下表。

OUTPUT VOLTAGE (V)	R_{FBT} (k Ω)	R_{FBB} (k Ω)	Cff	L (uH)			C _{OUT} (uF)
				MIN	TYP	MAX	
1.8	33	26.1	NC	1.5	2.2	4.7	20~68
2.5	31.6	15	NC	2.2	2.2	4.7	20~68
3.3	62	20	NC	3.3	4.7	4.7	20~68
5	24.9	4.7	NC	3.3	4.7	4.7	20~68
12	140	10	22pF	6.8	10	15	68~100

The inductor peak-to-peak ripple current I_{L_PP} , peak current I_{L_PK} and RMS current I_{L_RMS} are calculated as following. The inductor saturation current rating must be greater than the I_{L_PK} and the RMS or heating current rating must be greater than I_{L_RMS} .

电感峰峰值电流 I_{L_PP} 、峰值电流 I_{L_PK} 和 RMS 电流 I_{L_RMS} 计算如下。电感额定饱和电流必须大于 I_{L_PK} ，RMS 或热电流额定值必须大于 I_{L_RMS} 。

$$I_{LPP} = \frac{V_{OUT}}{V_{INMAX}} \times \frac{V_{INMAX} - V_{OUT}}{L \times f_{SW}} \quad (3)$$

$$I_{LPK} = I_{OUT} + \frac{I_{LPP}}{2} \quad (4)$$

$$I_{LRMS} = \sqrt{I_{OUT}^2 + \frac{1}{12} \times I_{LPP}^2} \quad (5)$$

The output capacitor should be used with ceramic or other low ESR capacitors. The required RMS current rating for the output capacitor is as follow.

输出电容应使用陶瓷电容或其他低 ESR 电容。输出电容要求的额定 RMS 电流如下。

$$I_{C_{RMS}} = \frac{(V_{IN_{MAX}} - V_{OUT}) \times V_{OUT}}{\sqrt{12} \times F_{SW} \times V_{IN_{MAX}} \times L} \quad (6)$$

11 Bootstrap Capacitor Selection

A 0.1uF ceramic capacitor with 10V or higher voltage rating should be connected between BST and SW.

在 BST 和 SW 之间接一个 0.1uF 陶瓷电容器，额定电压 10V 或更高。

12 Input Capacitor (C_{IN})

An input decoupling capacitor (0.1uF) and a bulk capacitor (Over 10uF) is needed. The voltage rating should be higher than the maximum input voltage.

输入端推荐一个滤波电容 (0.1uF) 和一个储能电容 (超过 10uF)。额定电压应高于最大输入电压。

13 PCB Layout Guidelines

Efficient PCB layout is critical for stable operation. For best results, refer to following figure and follow the guidelines below.

有效的 PCB 布局对于稳定运行至关重要。要获得最佳结果，请参考下图并遵循以下指南。

- (1) Place the input capacitor and output capacitor as close to the device as possible.
- (2) Keep the power traces very short and fairly wide, especially for the SW node.

(1) 将输入电容、输出电容尽可能靠近芯片。

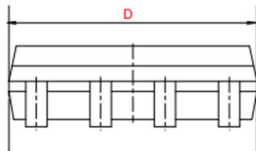
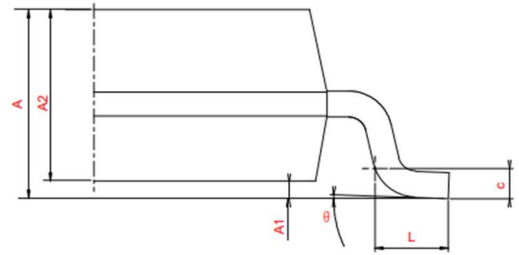
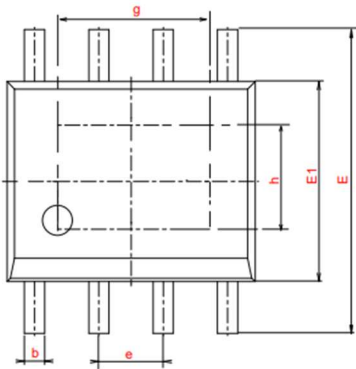
(2) 保持电源轨迹非常短且相当宽，特别是对于 SW 节点。

This can help greatly reduce voltage spikes on the SW node and lower the EMI noise level.

这有助于大大降低 SW 节点上的电压尖峰，并降低 EMI 噪声水平。

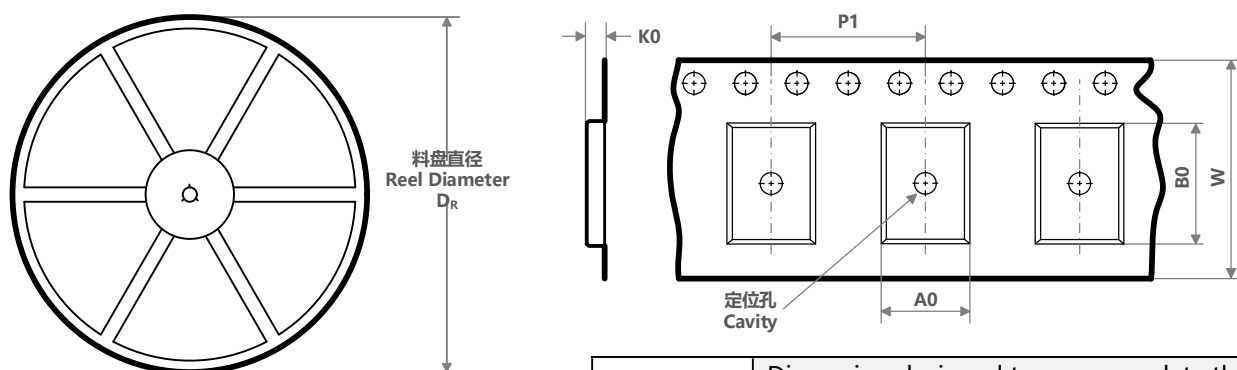
- (3) Run the feedback trace as far from the inductor and noisy power traces (like the SW node) as possible.

(3) FB 走线尽可能远离电感和功率走线 (如 SW 节点)。

PACKAGE OUTLINE
ESOP8


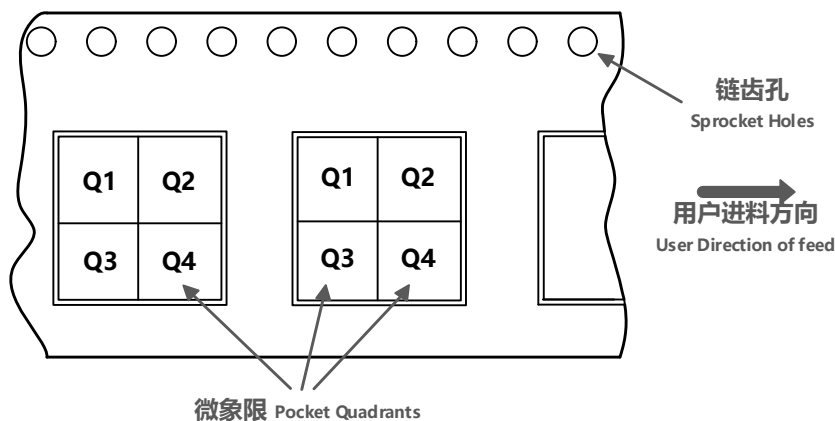
名称	尺寸	
	Min	Max
A	1.45	1.75
A1	0.05	0.15
A2	1.35	1.55
b	0.3	0.5
c	0.22	0.28
D	4.7	5.1
E	5.8	6.2
E1	3.85	4.05
L	0.4	1.27
θ	0°	8°
e	1.270 (BSC)	
h	2.4	
g	3.3	

TAPE AND REEL INFORMATION

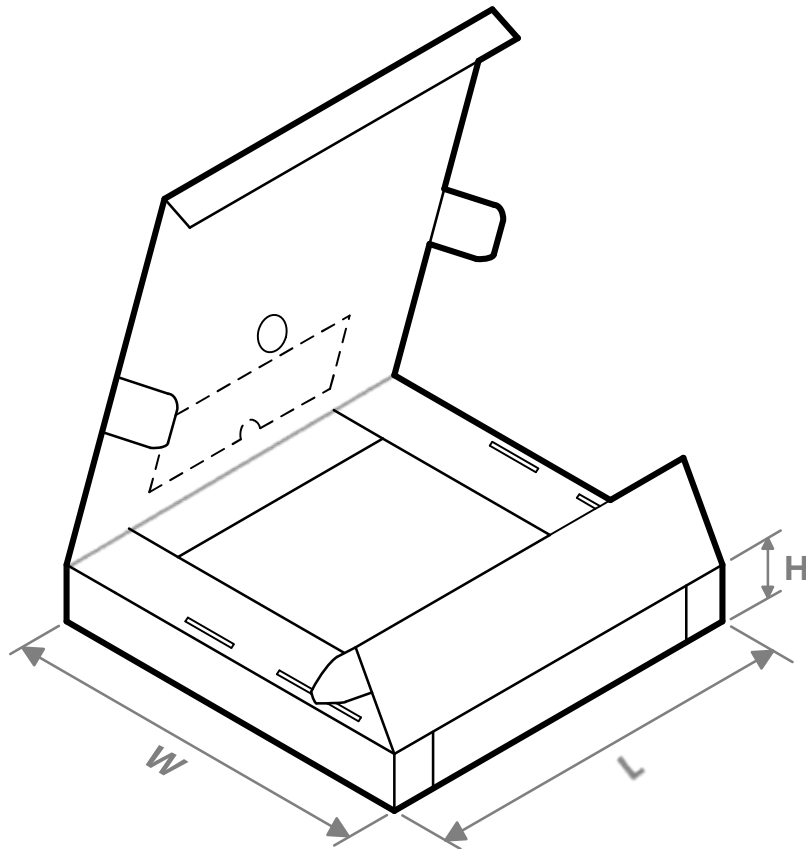


A0	Dimension designed to accommodate the component width; 料槽宽度
B0	Dimension designed to accommodate the component length; 料槽长度
K0	Dimension designed to accommodate the component thickness; 料槽厚度
W	Overall width of the carrier tape; 载带整体宽度
P1	Pitch between successive cavity centers; 相邻槽中心间距

编带 PIN1 方位象限分配
Quadrant Assignments for Pin1 Orientation in Tape



器件料号 Part No.	封装类型 Package Type	封装标识 Package Code	引脚数 Pins	SPQ	料盘直径 DR(mm)	料盘宽度 W1(mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 象限 Quadrant
HT77231SPER	ESOP	SPE	8	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD

TAPE AND REEL BOX INFORMATION


器件料号 Part No.	封装类型 Package Type	封装标识 Package Code	引脚数 Pins	SPQ	长度 Length (mm)	宽度 Width (mm)	高度 Height (mm)
HT77231SPER	ESOP	SPE	8	TBD	TBD	TBD	TBD

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