



XTP8221D

18V 2A, Sync Step-Down Converter

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4.5V-18V 2A, Sync Step-Down Converter

General Description

The XTP8221D high efficiency synchronous buck converter operates over a wide input voltage range of 4.5V to 18V, and can deliver an output current up to 2A. It integrates a top MOSFET and a bottom MOSFET with very low $R_{DS(ON)}$ to minimize conduction loss. The high pseudo-constant switching frequency enables using small external inductor and capacitor values.

The device uses constant on-time and ripple-based control strategy to achieve fast transient response for applications with high step-down ratios. It also provides cycle-by-cycle current limit protection, output under voltage protection and over temperature protection.

The XTP8221D is available in a 6-pin SOT23-6 package, which provides a compact solution with minimal external components.

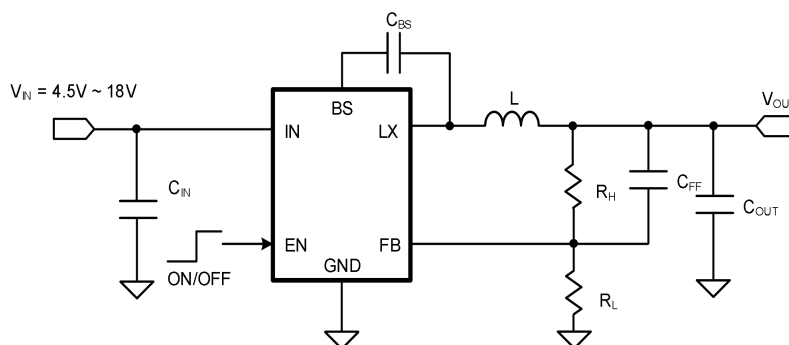
Application

- Set-Top Box
- Portable TV
- DSL Modem
- LCD TV
- IP Camera
- Other electronic equipment products

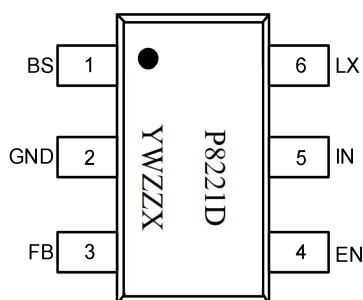
Features

- Wide Input Voltage Range: 4.5V ~ 18V
- Up to 2A Output Current
- Low $R_{DS(ON)}$: 156m Ω Top, 126m Ω Bottom
- $\pm 1.5\%$ 0.6V Reference
- Pulse-Frequency Modulation (PFM) Mode Operation
- Internal Soft-Start Limits the Inrush Current
- Support Smooth Startup with Pre-Biased Output
- 500kHz Switching Frequency
- Constant On-time and Ripple-Based Control to Achieve Fast Transient Responses
- Cycle-by-Cycle Valley and Peak Current Limit Protection
- Hic-Cup Mode Output Under Voltage Protection
- Auto-Recovery Mode Over Temperature Protection
- Input Under Voltage Lockout (UVLO)
- Available in SOT23-6 package

Typical Application Circuit



Function Order Information



XTP8221D SOT23-6

Pin Description

Pin No	Pin Name	Pin Description
1	BS	Bootstrap pin. Supply top MOSFET gate driver. Connect a 0.1μF ceramic capacitor between the BS and the LX pin.
2	GND	Ground pin.
3	FB	Output feedback pin. Connect this pin to the center point of the output resistor divider as shown in Figure 1. $V_{OUT} = 0.6 \times (1 + R_H/R_L)$.
4	EN	Enable pin. Pull this pin higher than EN rising threshold to turn on the device and pull this pin lower than EN falling threshold to turn off the device. Do not leave this pin floating.
5	IN	Input pin. Decouple this pin from the GND pin with at least a 10μF ceramic capacitor.
6	LX	Inductor pin. Connect this pin to the switching node of inductor.

Order Information

Part No	Package	Top Marking	Tape & Reel
XTP8221DS3CT	SOT23-6	P8221D YWZZX	3000/Reel

MARKING INFORMATION

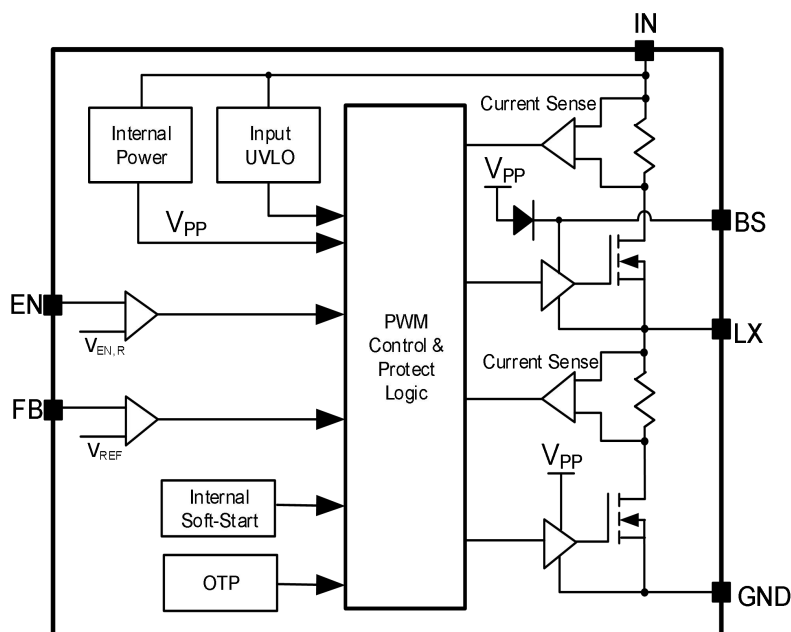
NOTE:

P8221D: Device Code

YW: Date Code

ZZX: Inside Code

Function Block Diagram



Absolute Maximum Ratings

Parameter (Note 1)	Min	Max	Unit
IN	-0.3	19	V
EN, LX	-0.3	IN + 0.3	
LX, 10ns duration	-5	IN + 3	
BS-LX, FB	-0.3	4	
Junction Temperature, Operating	-40	150	°C
Lead Temperature (Soldering, 10s)		260	
Storage Temperature	-65	150	

Notes1:Exceeding these ratings may damage the device.

Thermal Information

Parameter	Typ	Unit
θ_{JA} Junction-to-Ambient Thermal Resistance	55	°C/W
θ_{JC} Junction-to-Case Thermal Resistance	6.5	
P_D Power Dissipation $T_A = 25^\circ\text{C}$	1000	mW

Recommended Operating Conditions

Parameter	Min	Max	Unit
Input Voltage	4.5	18	V
Output Voltage	0.6	9.0	
Continuous Output Current		2	A
Ambient Temperature	-40	85	°C
Junction Temperature	-40	125	

Electrical Characteristics

All typical values are at $V_{IN} = 12\text{V}$, $V_{OUT} = 3.3\text{V}$, $L = 4.7\mu\text{H}$, $C_{OUT} = 10\mu\text{F}$, $T_J = 25^\circ\text{C}$, $I_{OUT} = 1\text{A}$.

Parameter		Symbol	Test Conditions	Min	Typ	Max	Unit
Input	Voltage Range	V_{IN}		4.5		18	V
	UVLO Rising Threshold	$V_{IN,UVLO}$	V_{IN} rising			4.45	
	UVLO Hysteresis	$V_{IN,HYS}$			0.3		
	Quiescent Current	I_Q	$I_{OUT} = 0\text{A}$		200	280	μA
	Shutdown Current	I_{SHDN}	$V_{EN} = 0\text{V}$		5	10	
Output	Voltage Range	V_{SET}		0.6		9.0	V
	FB Reference Voltage	V_{REF}		0.591	0.6	0.609	
	FB Input Current	I_{FB}	$V_{FB} = 1\text{V}$	-50		50	nA
	Turn On Delay Time	$t_{ON,DLY}$	From EN high to LX starts switching		180		μs
	Soft-Start Time	t_{SS}	V_{OUT} from 0% to 100% V_{SET}	0.5	1	1.6	ms
	UVP Threshold	V_{UVP}			33		% V_{REF}
	UVP Delay Time	$t_{UVP,DLY}$			100		μs
	UVP Hiccup On-Time	$t_{HICCUP,ON}$			1.5		ms
	UVP Hiccup Off-Time	$t_{HICCUP,OFF}$			4.5		
Enable (EN)	Rising Threshold	$V_{EN,R}$		1.08	1.2	1.32	V
	Falling Threshold	$V_{EN,F}$		0.9	1.0	1.1	
	Input Current	I_{EN}	$V_{EN} = 3.3\text{V}$		0		μA

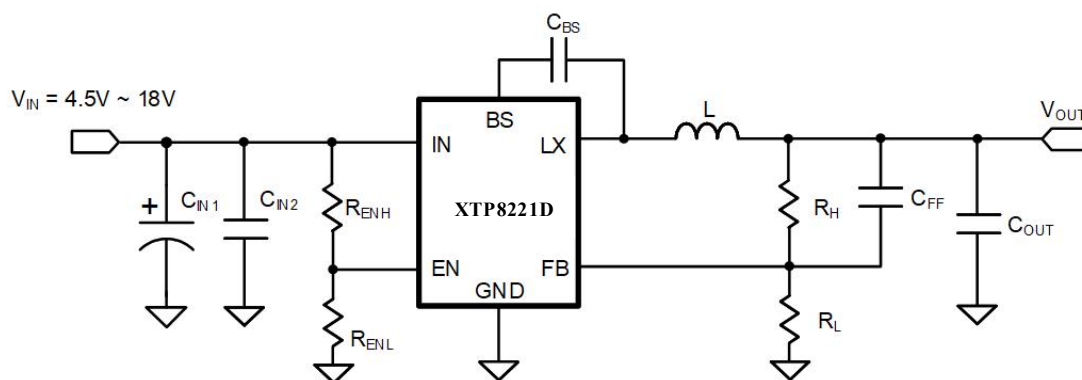
Parameter		Symbol	Test Conditions	Min	Typ	Max	Unit
MOSFET	Top MOSFET R _{DS(ON)}	R _{DS(ON),TOP}			156		mΩ
	Bottom MOSFET R _{DS(ON)}	R _{DS(ON),BOT}			126		
	Top MOSFET Current Limit Threshold	I _{LMT,TOP}		3			A
	Bottom MOSFET Current Limit Threshold	I _{LMT,BOT}		2	2.8	3.7	
Frequency	Switching Frequency	f _{SW}	I _{OUT} = 1A, CCM,	350	500	650	kHz
	Minimum On-Time	t _{ON,MIN}			50		ns
	Minimum Off-Time	t _{OFF,MIN}			100		
OTP	Temperature	T _{OTP}			150		°C
	Temperature Hysteresis	T _{HYS}			15		

Remarks:

The minimum and maximum parameter ranges in the specification are guaranteed by testing, and the typical values are guaranteed by design, testing or statistical analysis.

Application Circuits

Typical application circuits



BOM List for XTP8221D ($V_{OUT} = 3.3V$)

Reference Designator	Description	Reference Designator	Description
C_{IN1}	47 μ F/50V Electrolytic Capacitor	L	4.7 μ H/inductor, 3.8A
C_{IN2}	10 μ F/25V/X5R	R_H	100k Ω , 1%
C_{OUT}	10 μ F/16V/X5R	R_L	22.1k Ω , 1%
C_{BS}	0.1 μ F/50V/X5R	R_{ENH}	10k Ω , 1%
C_{FF}	47pF/50V/C0G	R_{ENL}	1M Ω , 1%

Recommend Component Values for XTP8221D

VOUT(V)	RH(kΩ)	RL(kΩ)	CFF(pF)	L/Part Number	COUT
1.2	100	100	10	3.3μH	22μF/16V/X5R
1.8	100	49.9	10	3.3μH	10μF/16V/X5R
3.3	100	22.1	47	4.7μH	10μF/16V/X5R
5	100	13.7	47	6.8μH	10μF/16V/X5R

Functional Description

General Description

The XTP8221D efficiency synchronous buck converter operates over a wide input voltage range of 4.5V to 18V, and can deliver an output current up to 2A. It integrates a top MOSFET and a bottom MOSFET with very low $R_{DS(ON)}$ to minimize conduction loss. The high pseudo-constant switching frequency allows small external inductor and capacitor values.

The device also provides cycle-by-cycle current limit protection output under voltage protection and over temperature protection.

Constant On-Time and Ripple-Based Control Strategy

The XTP8221D uses instant PWM architecture to achieve fast transient response for applications with high step-down ratios, and high efficiency at light loads. It uses a constant on-time and ripple-based control strategy in which a virtual replica of the inductor current signal is synthesized internally and combined with the feedback voltage. When the sum voltage is lower than the reference voltage, the bottom MOSFET turns off and the top MOSFET turns on for a fixed period of time (Constant t_{ON}). t_{ON} is internally calculated according to the input voltage, output voltage, and desired switching frequency (f_{SW}):

$$t_{ON} = \frac{V_{OUT}/V_{IN}}{f_{SW}}$$

The top MOSFET turns off after a period of t_{ON} .

Minimum and Maximum Duty Cycle

In the COT architecture, there is no limitation for operating the part at low duty cycle, since in this case, when the on-time is close to the minimum on-time, the switching frequency is reduced as needed to always ensure a proper operation.

The device can support a maximum duty cycle of up to 75% across the entire operating temperature range of -40°C ~ 125°C.

PFM Light Load Operation

XTP8221D use pulse-frequency modulation (PFM) operation mode under light load condition for high efficiency. Under light load conditions, typically when the load satisfies the following equation:

$$I_{OUT_CTL} = \frac{\Delta I_L}{2} = \frac{V_{OUT} \times (1 - D)}{2 \times f_{SW} \times L}$$

the current through the bottom MOSFET will ramp to near zero before the next t_{ON} time. When this occurs, the bottom MOSFET turns off, preventing recirculation current that can seriously reduce efficiency under these light load conditions. As

load current is further reduced, the combined feedback and ramp signals remain much higher than the reference voltage, the instant-PWM control loop will not trigger another t_{ON} until needed, and the apparent operating switching frequency will correspondingly drop, improving efficiency. Continuous conduction mode (CCM) resumes smoothly as soon as the load current increases sufficiently for the inductor current to remain above zero at the time of the next t_{ON} cycle. The buck converter enters CCM once the load current exceeds the threshold shown in. Above the threshold, the switching frequency stays fairly constant over the output current range.

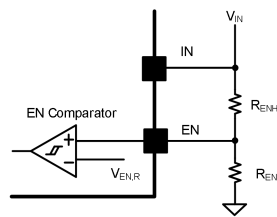
While in PFM mode, the output of the device doesn't require over voltage protection because the device stops switching as soon as the voltage at the FB node increases above V_{REF} , preventing the output voltage from increasing further.

Input Under Voltage Lockout (UVLO)

To prevent operation before the internal circuitry is ready and to ensure that the top and bottom MOSFETs can be properly driven, the device incorporates an input under voltage lockout protection. The device remains in a low current state and all LX node switching actions are inhibited until V_{IN} exceeds its rising threshold. At that time, if EN is enabled, the device will startup. If V_{IN} falls below $V_{IN,UVLO}$ less than the input UVLO hysteresis, the LX node switching actions will again be suppressed.

Precise EN Threshold

The EN pin uses precise rising and falling thresholds to provide programmable ON/OFF control. The device will be turned on when the EN pin voltage exceeds the rising threshold. The device will be turned off while the EN pin voltage falls below the falling threshold. Increasing the input UVLO threshold is possible using an external resistor divider as shown below:



EN Control

It is not recommended to connect EN pin to the V_{IN} or another voltage source directly. A resistor with a value between $1k\Omega$ and $1M\Omega$ is recommended if the EN pin is pulled high.

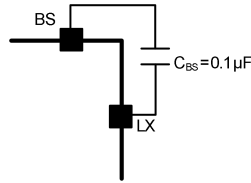
Soft-Start and Startup with Pre-Biased Output

The device incorporates an internal soft-start circuit to ramp the output to the desired voltage whenever the device is enabled. For XTP8221D, the soft-start circuit clamps the output at a low voltage internally and then allows the output to rise to the desired voltage over approximately 1ms, which avoids high current flow and transients during startup.

The device supports startup with pre-biased output. If the output is pre-biased to a certain voltage before startup, the buck converter disables the switching of both the top MOSFET and the bottom MOSFET until the internal soft-start voltage V_{SS} exceeds the sensed output voltage at the FB node. The first pulse on-time is internally calculated based the input voltage and pre-biased output voltage.

External Bootstrap Capacitor

The external bootstrap capacitor provides the gate driver voltage for the N-channel top MOSFET. A 0.1μF low ESR ceramic capacitor connected between the BS pin and the LX pin is recommended.

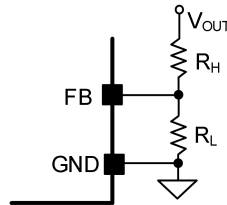


Bootstrap Capacitor Connection

Feedback Resistor Divider R_H and R_L

Choose R_H and R_L to program the proper output voltage. A value between 1kΩ and 1MΩ is recommended for both resistors to minimize power consumption under light loads. As an example, if V_{OUT} = 3.3V and R_H selected value is 100kΩ, R_L can be calculated as follows:

$$R_L = \frac{0.6}{V_{OUT} - 0.6V} \times R_H$$



Feedback Resistor Divider

With a calculated value of 22.2kΩ for R_L, a standard 1% resistor is selected.

Output Inductor L

Consider the following when choosing this inductor:

- 1) Choose the inductance to provide a ripple current that is approximately 40% of the maximum output current. The recommended inductance is calculated as:

$$L = \frac{V_{OUT}(1 - V_{OUT} / V_{IN, MAX})}{f_{sw} \times I_{OUT, MAX} \times 0.4}$$

where f_{sw} is the switching frequency and I_{OUT, MAX} is the maximum load current.

The device has high tolerance for ripple current amplitude variation. As a result, the final choice of inductance can vary slightly from the calculated value with no significant performance impact.

- 2) For buck converter using FCCM light load operation mode, make sure the inductance value is high enough to avoid reverse current limit threshold is been triggered just under steady state if the load current is zero.

- 3) The inductor's saturation current rating must be greater than the peak inductor current under full load:

$$I_{SAT,MIN} > I_{OUT,MAX} + \frac{V_{OUT}(1 - V_{OUT}/V_{IN,MAX})}{2 \times f_{SW} \times L}$$

- 4) The DCR of the inductor and the core loss at the switching frequency must be low enough to achieve the desired efficiency requirement. Use an inductor with DCR less than 50mΩ to achieve good overall efficiency.

Fault Protection Modes

Cycle-by-Cycle Current Limit Protection

If the top MOSFET current exceeds the top current limit threshold, it will turn off and the bottom MOSFET will turn on. If the bottom MOSFET current exceeds the bottom current limit threshold, it will stay on until the current decreases below its current limit threshold. As a result, both inductor peak and valley currents are limited.

Output Under Voltage Protection (UVP)

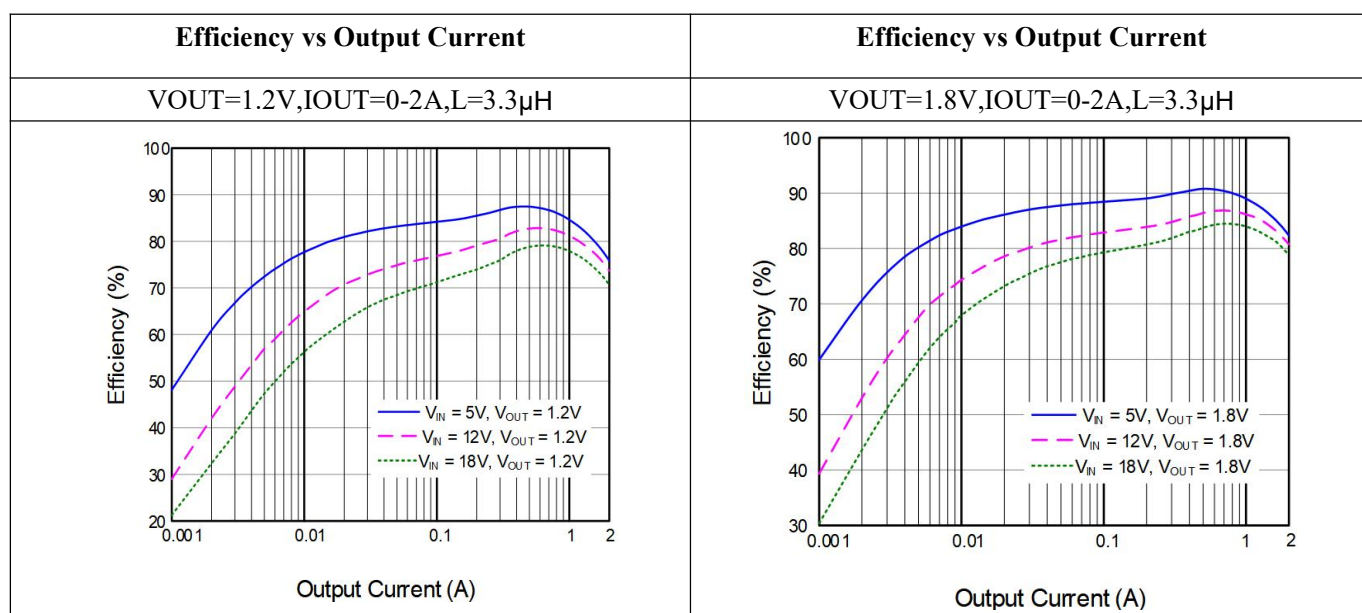
With output current increasing, as soon as the bottom MOSFET current exceeds its current limit threshold, the top MOSFET will not be allowed to turn on any more. If the load current continues to increase, the output voltage will drop. When the output voltage falls below 33% of the regulated level, the output under voltage protection will be activated and the device will operate in hiccup mode. For XTP8221D, the hiccup on-time is 1.5ms, and the hiccup off-time is 4.5ms.

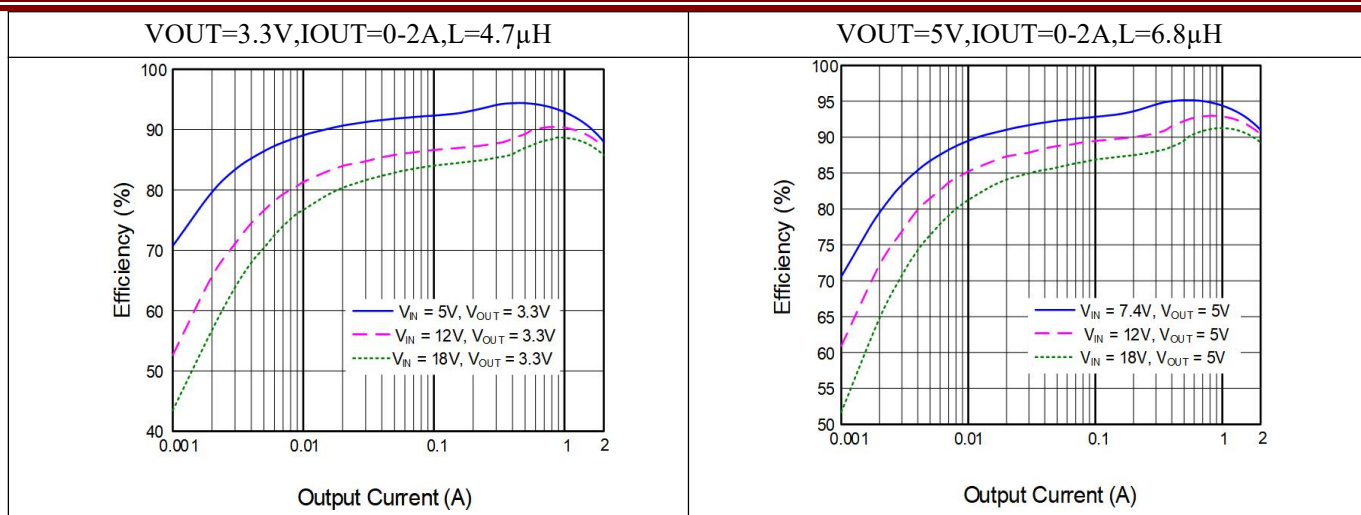
Over Temperature Protection (OTP)

The device includes over temperature protection (OTP) circuitry to prevent overheating due to excessive power dissipation. This will shut down the device when the junction temperature exceeds 150°C. When the junction temperature is reduced by approximately 15°C, the device will resume normal operation after a complete soft-start cycle. For continuous operation, provide adequate thermal dissipation so that the junction temperature does not exceed the OTP threshold.

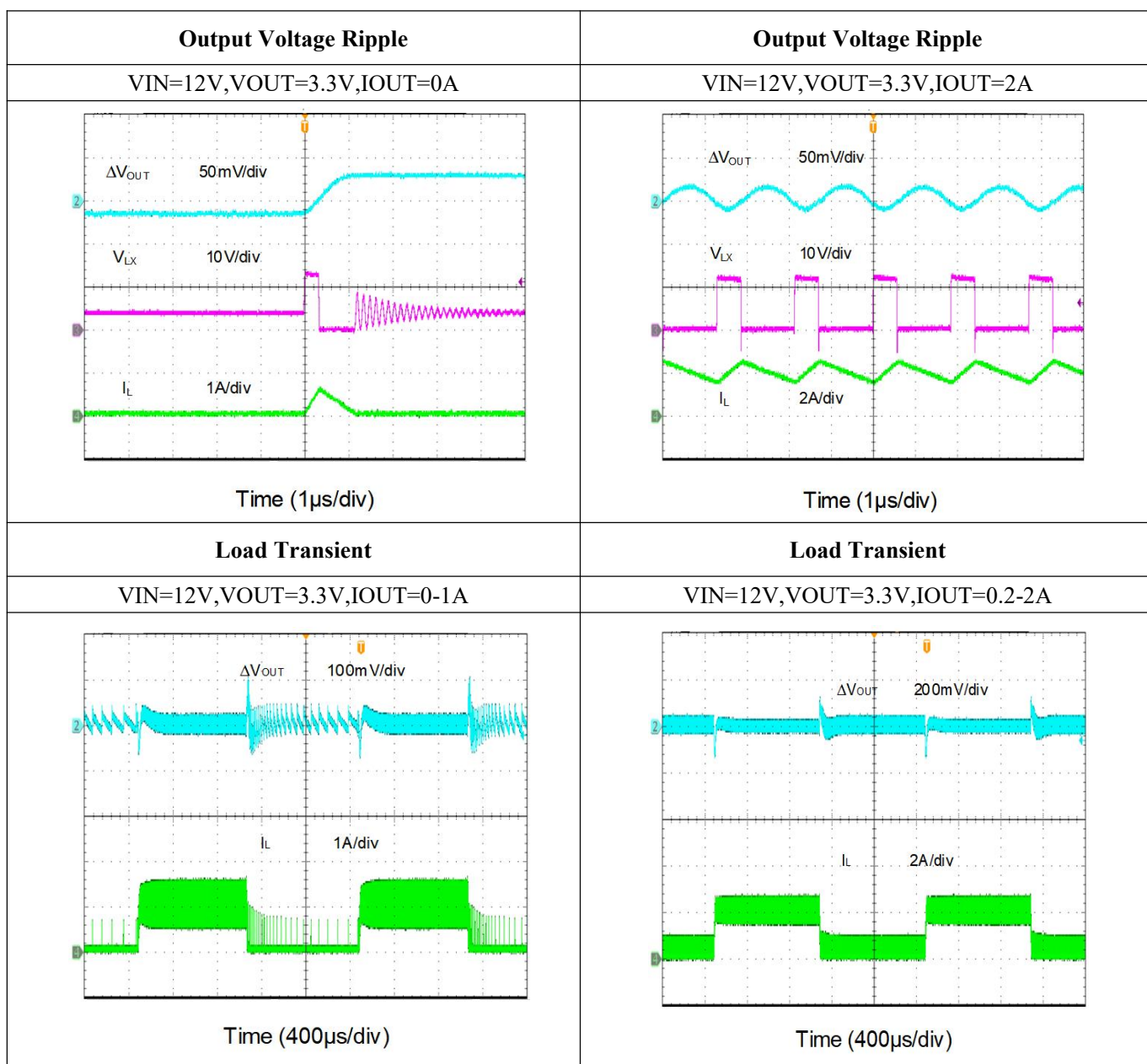
Typical Performance Characteristics

(T_A = 25°C, V_{IN} = 12V, V_{OUT} = 3.3V, L = 4.7μH, C_{OUT} = 10μF, unless otherwise noted)

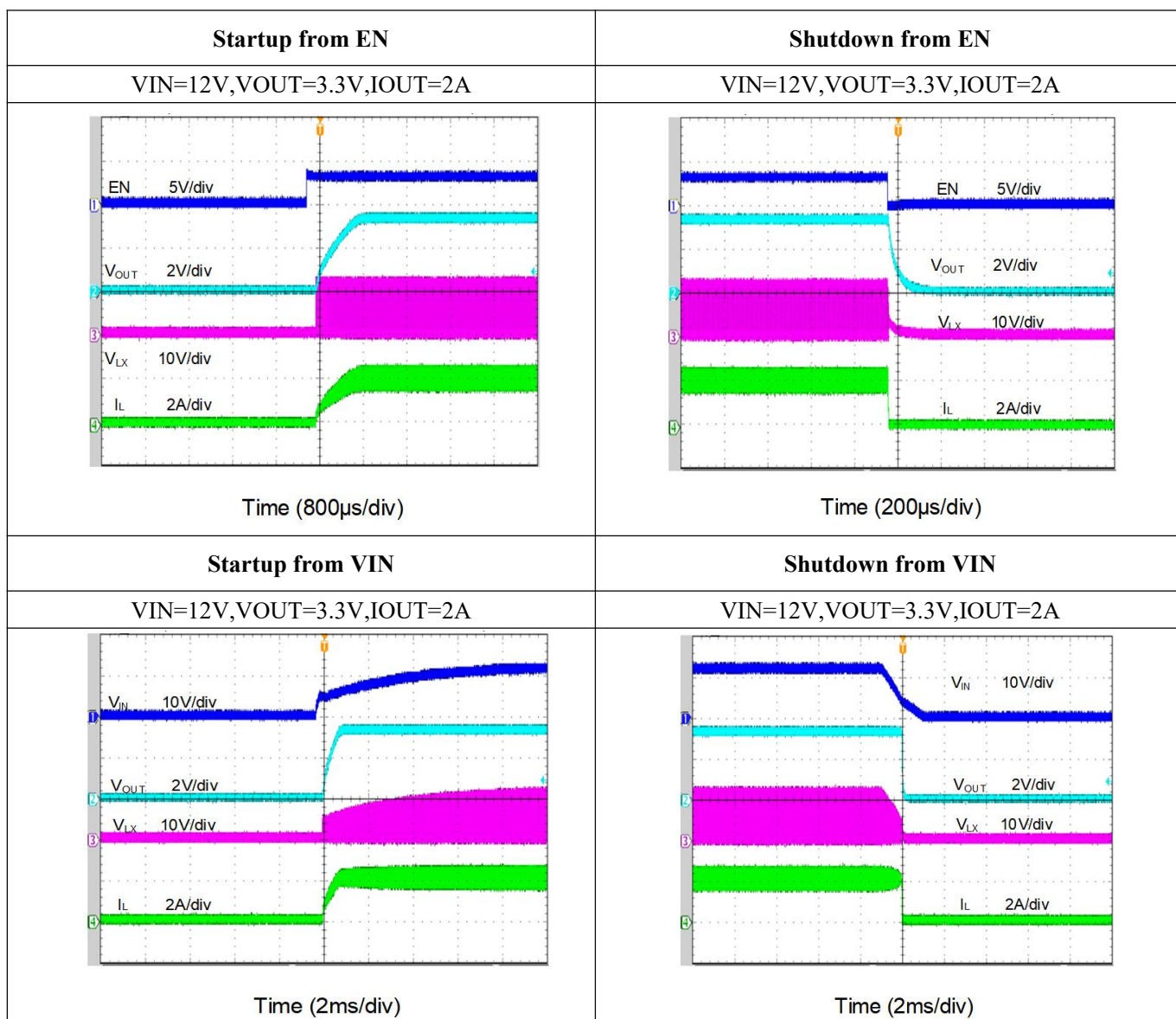




Output Voltage Ripple



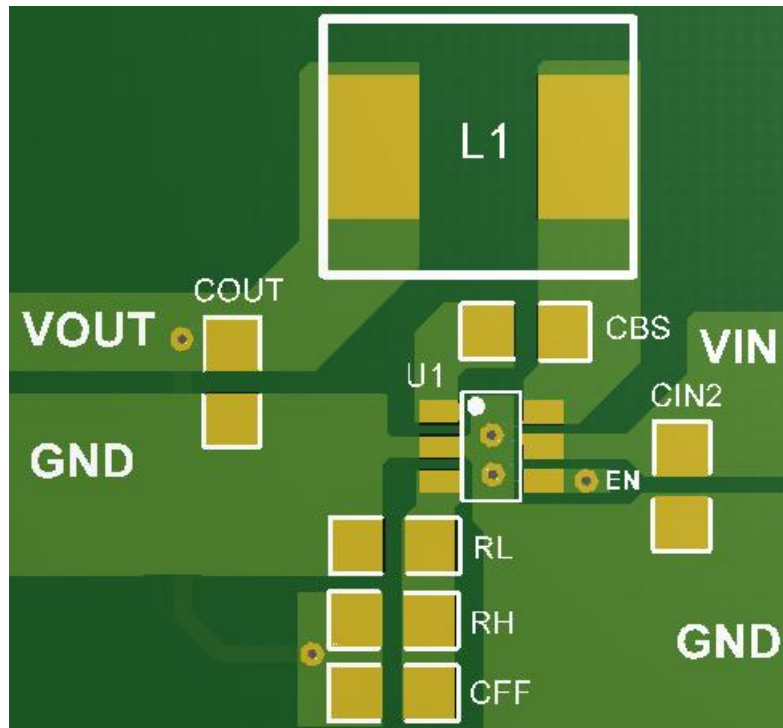
Power On/Off Waveforms



PCB Layout Guidelines

The reasonable layout of the switching power supply is crucial to the stable operation of the switching power supply. For high-frequency switching converters, poor layout design can lead to poor line or load regulation and stability problems. For best results, refer to the image below and follow the guidelines below.

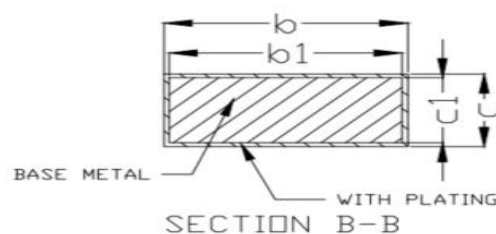
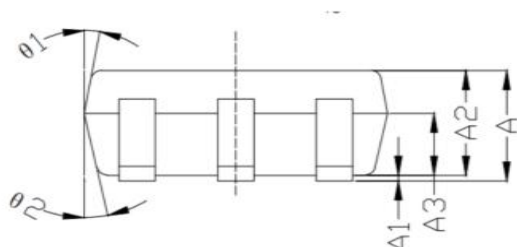
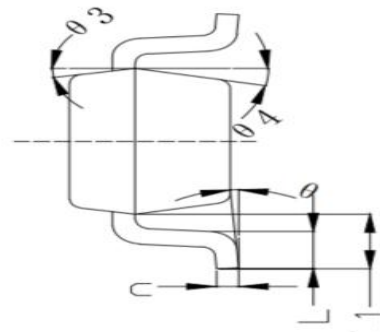
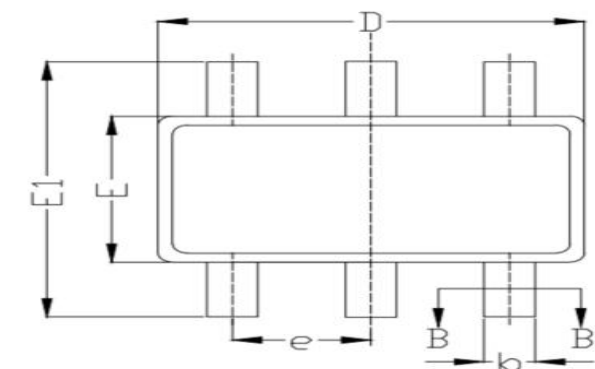
1. Place input capacitor as close as possible to VIN and GND.
2. Place feedback resistors close to the FB pin.
3. Keep switching nodes (SW, BST) away from the feedback network.
4. Add thermal vias on exposed copper to improve heat dissipation.



Sample of PCB Layout

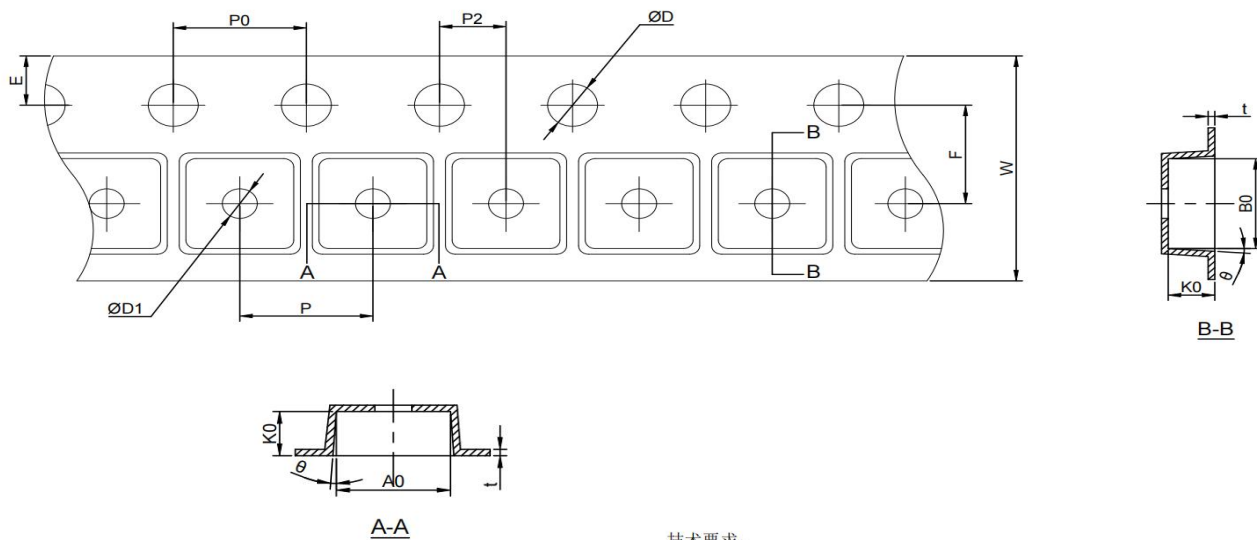
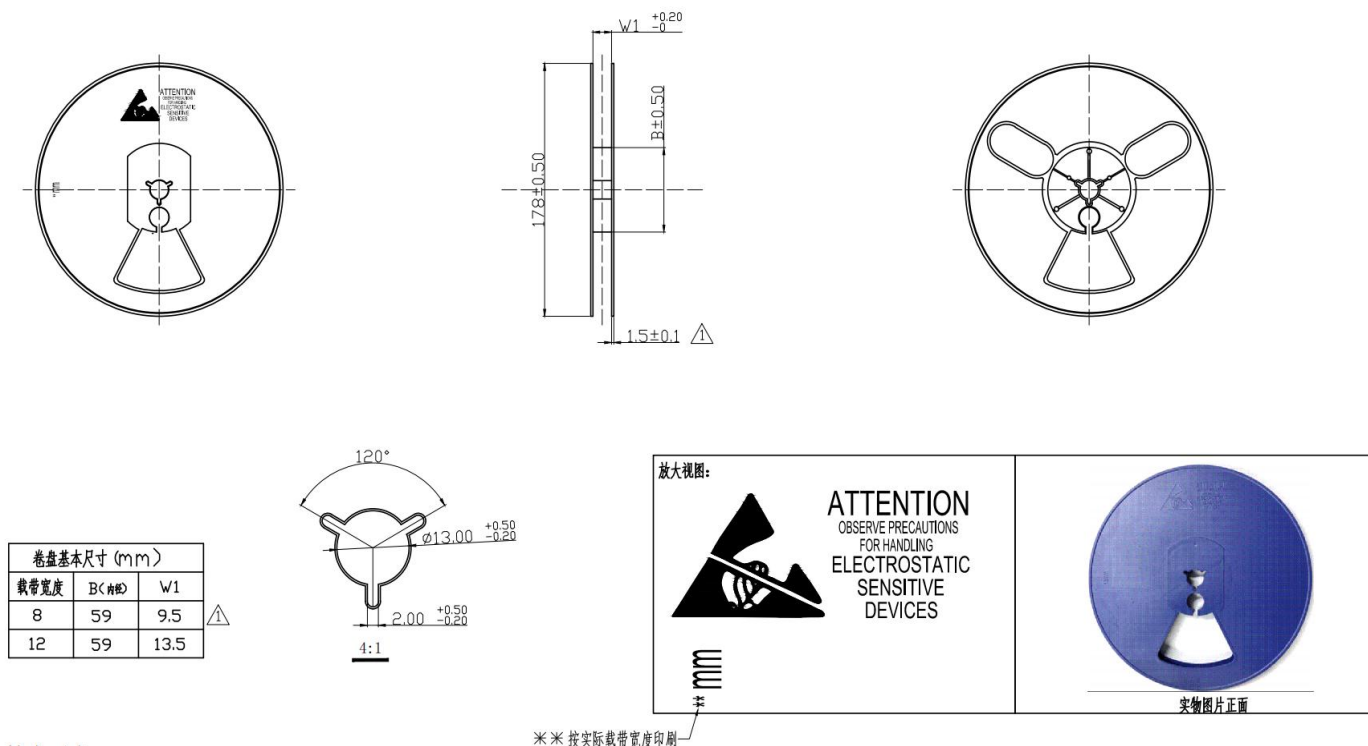
Package Information (unit:mm)

SOT23-6



SYMBOL	MILLIMETER		
	MIN	NOM	MAX
A	--	--	1.25
A1	0.03	0.06	0.10
A2	1.00	1.10	1.20
A3	0.60	0.65	0.70
b	0.33	--	0.41
b1	0.32	0.35	0.38
c	0.15	--	0.17
c1	0.14	0.15	0.16
D	2.82	2.92	3.02
E	1.50	1.60	1.70
E1	2.60	2.80	3.00
e	0.95 BSC		
L	0.30	0.40	0.50
L1	0.60 REF		
θ	0°	--	6°
θ_1	8°	--	12°
θ_2	12°	--	14°
θ_3	8°	--	12°
θ_4	12°	--	14°

Tape and Reel Information:



外观尺寸

外观	尺寸 (MM)
E	1.75 ± 0.10
F	3.50 ± 0.05
P2	2.00 ± 0.05
D	1.50 ± 0.10
D1	1.05 ± 0.05
P0	4.00 ± 0.10
10P0	40.0 ± 0.20

变动尺寸

外观	尺寸 (MM)
w	8.00 ± 0.10
P	4.00 ± 0.10
A0	3.24 ± 0.10
B0	3.20 ± 0.10
K0	1.40 ± 0.10
t	0.20 ± 0.02
θ	$3^\circ \sim 5^\circ \text{ TYP}$

技术要求:

- 外观质量: 无毛刺、划痕、缺料、烧焦与气孔; 封合位置不得有杂质; 颜色均匀一致;
- 颜色: 黑色;
- 表面粗糙度 $Ra < 0.8 \mu m$;
- 表面电阻: $10^5 \sim 10^{10} \Omega/\square$;
- 摩擦起电电压: $< 100V$;
- 测量方法: 沿口袋中心线剖开, 从口袋内部底面上方 $0.3mm$ 处测量 $A0$ 与 $B0$ 值, $K0$ 是从口袋内部底面到载带顶部表面测量的尺寸, 其余尺寸采用投影仪直接测量;
- 任意 10 个传输孔间距的累计误差为 $\pm 0.20mm$;
- 载带沿长度方向的侧弯 $\leq 1mm/250mm$;
- 未注明 $R: < 0.30mm$, 未标注公差为 $\pm 0.10mm$;
- 配套热封性盖带: 透明防静电, 宽度尺寸为 $5.7 \pm 0.05mm$, 厚度为 $0.055 \pm 0.005mm$ 。

REVISION HISTORY

Number	Description
Rev 1.0	XTP8221D datasheet release
Rev 1.1	Tape and Reel Information