3.0 ~ 26V, 0.7 ~ 5A, Current Limit Power Switch with Output Over-Voltage Clamp and Reverse Block

General Description

The ET20176 is a current limit N-Channel MOSFET power switch. It is designed to protect circuitry on the output from transients on the input. It also protects the input from undesired shorts and transients coming from the output.

The current limit magnitude is controlled by an external resistor from ILIMIT to GND. It is fixed 2.5A when ILIMIT is floating. Programmable soft-start time controls the slew rate of the output voltage during the start-up time. It can be controlled by the DV/DT pin setting and MODE pin setting. The output voltage is limited by the OVP function. The clamping voltage can be set by the MODE connection.

The ET20176 offer a GATE drive signal connected to an external N-Channel MOSFET gate to block current flowing from the output to the input when the IC is disable, power off or thermal shutdown.

Features

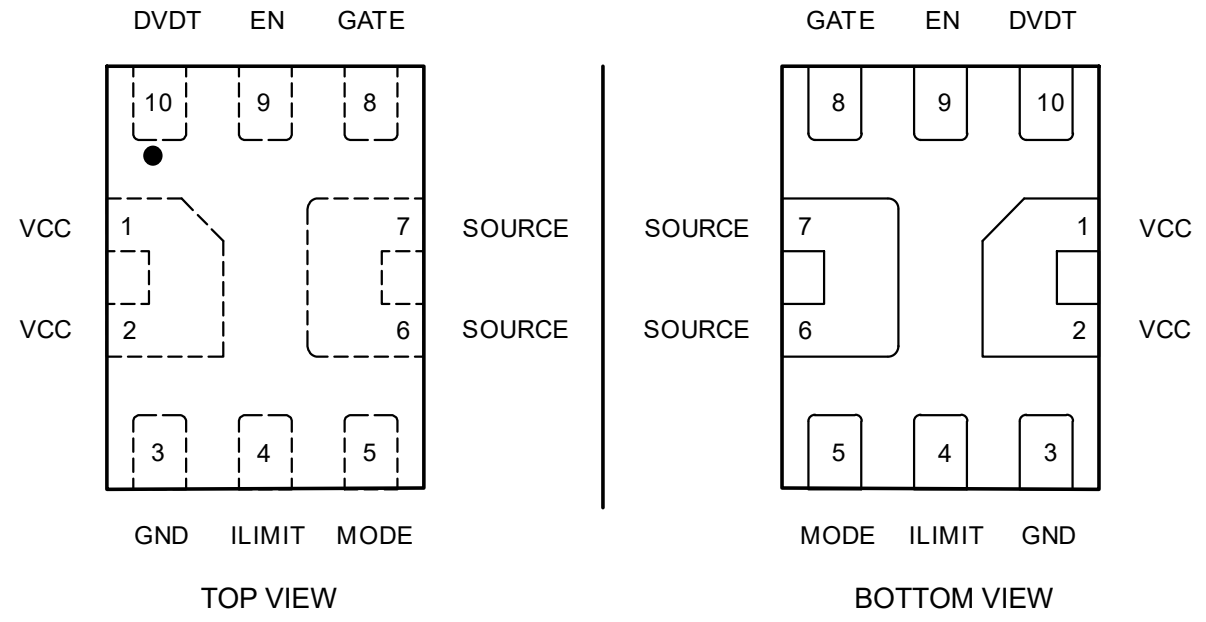
- V_{IN} Operating Range: 3.0V to 26V
- Programmable Current Limit and Soft-Start Time
- Selectable Over-Voltage Clamping Voltage
- Fast Output Over-Voltage Protection(OVP) Response
- Short-Circuit Protection
- Typical R_{ON}: 30mΩ From Input to Output Power Path
- Very Low Quiescent Current: 100μA (Typ)
- Reverse-Blocking MOSFET Driver
- Over-Current Protection (With Lock up Mode)
- Internal Thermal Shutdown Protection
- ESD Protected: ±2KV Pass (Human Body Model,JESD22-A114,All pins)
- Package Information

Part No.	Package	MSL
ET20176	QFN10 (1.5mm × 2.0mm)	Level 1

Application

- SSD Hard Disk
- PC Cards
- Wireless Modem Data Cards
- USB Power Distribution/USB Protection
- USB 3.1 Power Delivery
- Server PC

Pin Configuration

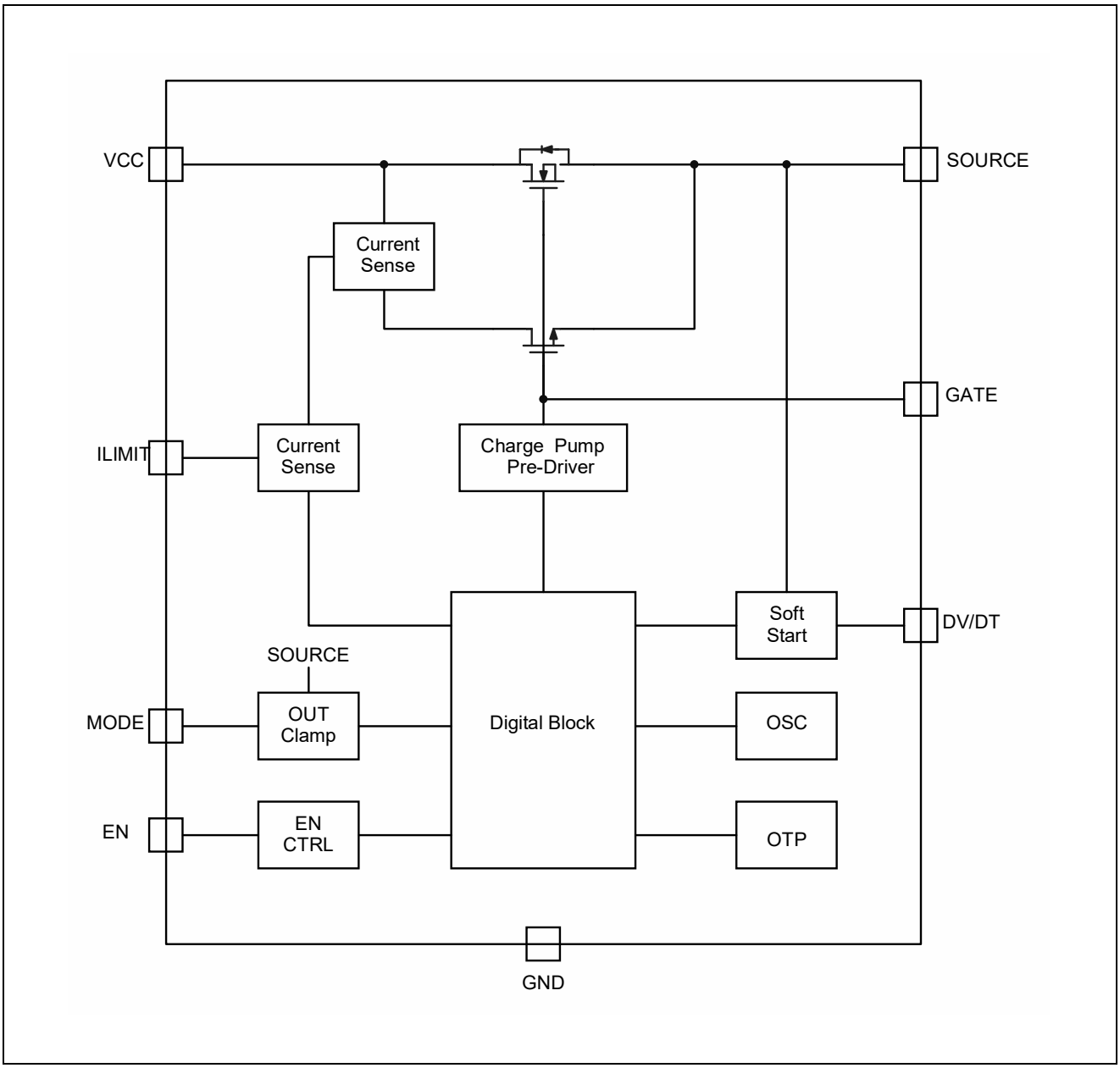


QFN10 (ET20176)

Pin Function

Pin	Name	Description
1,2	VCC	Power supply input. Must be closely decoupled to GND pins with a 1uF or greater ceramic capacitor. Connect VCC using a wide PCB trace.
3	GND	Ground pin.
4	ILIMIT	Current limit programming pin. Program the current limit by connecting a resistor to GND. Floating ILIMIT pin to achieve a 2.5A fixed current limit.
5	MODE	Output over-voltage protection clamp voltage select pin. Connecting a resistor to GND to sets the OVP threshold voltage. Three digital inputs are provided for MODE as VCC/GND/Floating.
6,7	SOURCE	Source of internal power n-channel MOSFET and the output terminal.
8	GATE	Gate pin for external reverse-current block MOSFET.
9	EN	Enable pin. Force EN high to enable the IC. Floating or pull to GND to disable the IC. Full EN up to VCC through a 300kΩ resistor for quick start-up mode.
10	DV/DT	Soft start programming pin. Connect a capacity from DV/DT to GND to set the DV/DT slew rate.

Block Diagram



Operation

ET20176 is an an integrated power switch with a low R_{DS_ON} N-Channel MOSFET, programmable current limiting and OVP clamp voltage.When the ET20176 turns on, it can deliver up to 5A continuous current to load. When the device is active, the device only consumes 90uA supply current if no load.

Power Supply Considerations

A 10μF MLCC capacitor between IN and GND, close to the device, is recommended. Placing a high-value electrolytic capacitor on the output pin(s) is recommended when the output load is heavy. This precaution reduces power-supply transients that may cause ringing on the input and minimize the input voltage droops. Additionally, bypassing the output with a 10μF MLCC capacitor improves the immunity of the device to short-circuit transients.

Current Limit(ILIMIT)

A sense FET is employed to check for over current conditions. When an over current condition is detected, the device maintains a constant output current and reduces the output voltage accordingly. ET20176 will limit the current until the overload condition is removed or the device begins to thermal cycle.

The current limit can be programmed by an external resistor. It can be approximated with equation below.

$$I_{LIMIT} = \frac{0.55}{R_{LIMIT}} \times 3870$$

If the current limit condition lasts longer than 2ms, the ET20176 will be shutdown and restart when re-enable or re-power-on.

The ET20176 allows ILIMIT to be floated during operation. The internal fixed current limit threshold is set at 2.5A. The current limit response time is about 40us(1).

When short ILIMIT to GND, the normal current limit function is disabled, but the secondary current limit still works. The secondary current limit is set at 8A. When the OCP is triggered, the power MOSFET will be shutdown immediately.

Short-Circuit Protection(SCP)

The secondary current limit is set at 8A. If the load current reaches 8A rapidly due to a short-circuit event, a fast turn-off circuit activates to turn off the MOSFET. The total short-circuit response time is about 3us(1). After switched off, the MOSFET restarts. If the short still exists, the ET20176 regulates the MOSFET to hold the current at threshold level. If it lasts for 2ms, the MOSFET will be turned off again and restart when re-enable or re-power-on.

To prevent safe operating area(SOA) damage during a high input voltage short-circuit protection(SCP) condition, the IC current limit folds back when the power MOSFET VDS voltage is above the typical 11V and the junction temperature is over 100°C.

OVP Clamp Voltage

The OVP clamp voltage can be programmed by MODE pin. Three digital inputs are provided for MODE. Drive MODE to VCC to set the OVP clamp voltage at 15.2V. Drive MODE to GND to set it at 5.75V. Float MODE pin for no clamp function. Also clamp voltage can be set by connecting a resistor from MODE to GND.

Soft Start

The soft start time can be set by an external capacity connecting from DV/DT to GND. Different clamp MODE have different soft start time. The soft start time can be calculated with Equation:

$$t_{ss}(ms) = \frac{V_{IN}(V)}{dV/dt(V/ms)}$$

The dV/dt slew rate is determined by external DVDT capacitor and voltage clamp mode.

Reverse-Blocking MOSFET Driver

The ET20176 has a GATE pin to provide an external N-channel MOSFET gate drive signal for reverse-current blocking (RCB). Three events can pull down the GATE voltage: VIN below the under-voltage lockout (UVLO), the enable (EN) voltage below the low level threshold, or thermal shutdown. If any of these conditions occur, GATE sinks the current from the gate of the external MOSFET to initiate a fast turn-off.

For 3.3V low input voltage application, it is recommended to choose a small threshold voltage(VGS<1.6V) reverse-blocking MOSFET to reduce the voltage drop.

A 100pF capacitor is required on GATE if it is not connected to external MOSFET.

Thermal Protection - Lock-Out

Thermal protection prevents damage to the IC when heavy-overload or short-circuit faults are present for extended periods of time. The ET20176 implements a thermal sensing to monitor the operating junction temperature of the power MOSFET. In an over-current or short-circuit condition, the junction temperature rises due to excessive power dissipation.

Once the die temperature rises to approximately 155°C due to over-current conditions, the internal thermal sense circuitry turns the power switch off, thus preventing the power switch from damage. The chip will restart when re-enable or re-power-on.

Note1： Test condition is as V_{IN}=5V, I_{LIM}=2.5A, T_A=25°C, C_{OUT}=0uF. Current Limit Response Time is the time difference between I_{OUT} first exceeding ILIM and falling back to I_{LIM}. and falling back to I_{LIM}. Short-circuit Response Time is the time difference between I_{OUT} exceeding 8A and falling back to 0A.

Absolute Maximum Ratings

Symbol	Parameters		Min	Max	Unit
V_{CC},V_{SOURCE}	VCC,SOURCE to GND		-0.3	29	V
V_{MODE}	MODE to GND		-0.3	29	V
V_{GATE}	GATE to GND		-0.3	V_{SOURCE}+5.5	V
V_{ILIMIT} ,V_{EN} ,V_{DVDT}	ILIMIT, EN, DV/DT to GND		-0.3	7	V
P_D	Power Dissipation at T_A= +85°C (1)(3)			1.05	W
T_J	Junction Temperature		-40	+150	°C
T_{STG}	Storage Junction Temperature		-65	+150	°C
T_{SOLD}	Soldering Temperature (reflow)			+260	°C
V_{ESD}	Electrostatic Discharge Capability	Human Body Mode, ESDA/JEDEC JS-001-2017	-2	+2	KV
		Charged Device Mode, ESDA/JEDEC JS-002-2018	-1.5	+1.5	KV

Thermal Resistance

Package	PCB Version	θ_{JA}	θ_{JC}	Unit
QFN10 (1.5mm×2.0mm)	ETPB4433 (2)	89	26	°C/W
	ETPB3624 (3)	75	18	°C/W
	ETPB4433 (4)	63	15	°C/W

Notes:

1. The maximum allowable Power Dissipation is recording to maximum allowable Junction Temperature. $P_{D(MAX)}$ @T_A=($T_{J(MAX)}$-T_A)/ θ_{JA}.

2. Measured on ETPB4433, 1-layer PCB, 1oz Cu, 60mm×42mm.

3. Measured on ETPB4433, 2-layer PCB, 1oz Cu, 60mm×42mm.

4. Measured on ETPB4433, 2-layer PCB, 2oz Cu, 60mm×42mm.

Recommended Operating Conditions

Symbol	Parameter	Min	Max	Unit
V_{IN}	DC Input Voltage	3.0	26	V
I_{OUT}	DC Output Current Limit	0.7	5.0	A
T_A	Operating Temperature Range	-40	+85	°C

Electrical Characteristics

Unless otherwise noted, V_{CC}=5V, R_{LIMIT}=NS, C_{OUT}=10uF, T_A=-40°C+85°C, typical value is tested at T_A=25°C.

Symbol	Parameters	Conditions	Min	Typ	Max	Unit
Basic Operation						
V_{IN}	Input Voltage		3.0		26	V
I_Q	V_{IN} Quiescent Current	EN = High MODE = VCC/GND/float		60	100	μA
		EN = High MODE series resistor to GND		100	150	uA
I_S	V_{IN} Shutdown Current	EN = GND		5	15	uA
Power MOSFET						
R_{ON}	On-Resistance of Switch IN-OUT	I_{OUT}=1A		30	60	mΩ
t_{DELAY}	Turn-on Delay Time	DV/DT float, MODE float		500		us
I_{OFF}	Off-state Leakage Current	V_{CC} = 12V, V_{EN} = GND		0.1	1	uA
V_{UVLO_R}	Under Voltage Lockout Threshold	V_{IN} Rising	2.6	2.8	3.0	V
$V_{UNLOHYS}$	UVLO Hysteresis			200		mV
V_{CLAMP}	Output Clamping Voltage (1)	V_{MODE} = GND	5.5	5.75	6	V
		V_{MODE} = VCC	14.2	15.2	16.2	
		R_{MODE} = 76.8kΩ	3.60	3.84	4.08	V
		R_{MODE} = 115kΩ	5.35	5.75	6.15	V
		R_{MODE} = 324kΩ	14.9	16.2	17.5	V
		R_{MODE} = 422kΩ	19.3	21.1	22.9	V
DV/DT						
DV/DT	DV/DT Slew Rate	DV/DT float, V_{MODE} = GND	0.4	0.8	1.2	V/ms
		DV/DT float, V_{MODE} = VCC	1.3	2	2.7	V/ms
		DV/DT float, MODE float	2.8	3.8	4.8	V/ms
$I_{DV/DT}$	DV/DT Current (2)	$V_{DV/DT}$ = 0.5V		6.5		uA
Current Limit						
I_{LIMIT_NO}	Current Limit at Normal Operation (3)	ILIMIT float, V_{CC}=5V	2.3	2.5	2.7	A
		R_{LIMIT} = 604Ω, V_{CC}=5V	3.3	3.5	3.7	A
		R_{LIMIT} = 3kΩ, V_{CC}=5V	0.6	0.75	0.9	A
Enable (EN)						
V_{EN_RISING}	EN rising Threshold		1.86	2	2.16	V
V_{EN_HYS}	EN Hysteresis			350		mV
R_{EN}	EN Pull-down Resistor		1.4	2.2	3.0	MΩ

Electrical Characteristics(Continued)

Unless otherwise noted, V_{CC}=5V, R_{LIMIT}=NS, C_{OUT}=10uF, T_A=-40°C+85°C, typical value is tested at T_A=25°C.

Symbol	Parameters	Conditions	Min	Typ	Max	Unit
GATE						
I_{G_SOURCE}	GATE Maximum Source Current	I_{OUT} = 1A	7	12		uA
I_{G_SINK}	GATE Maximum Sink Current	V_{CC} = V_{SOURCE} = 5.5V, V_{GATE} = 10.5V		3		mA
Output Discharge						
R_{DIS}	Discharge Resistor		580	980	1300	Ω
Output Discharge						
T_{SD}	Thermal Shutdown			155		°C
T_{SD_HYS}	Thermal-shutdown Hysteresis			30		°C

Notes：

1. The OVP clamp threshold can be set by connecting a resistor from MODE to GND as below.

$$V_{CLAMP} = 0.05 \times R_{MODE} \ (k\Omega)$$

2. For cases with an external DV/DT capacitor, the slew rate of V_{SOURCE} can be calculated with equation:

$$dv/dt(V/ms) = \frac{6.5\mu. \times K1}{C_{DV/DT}(nF)}$$

K1 factor is as below.

MODE Connection	K1
GND	5.75
VCC	15.2
FLOAT	27
R_{MODE}	$\frac{V_{CLAMP}}{6.8\mu \times R_{MODE}}$

3. The current limit can be approximated with Equation below.

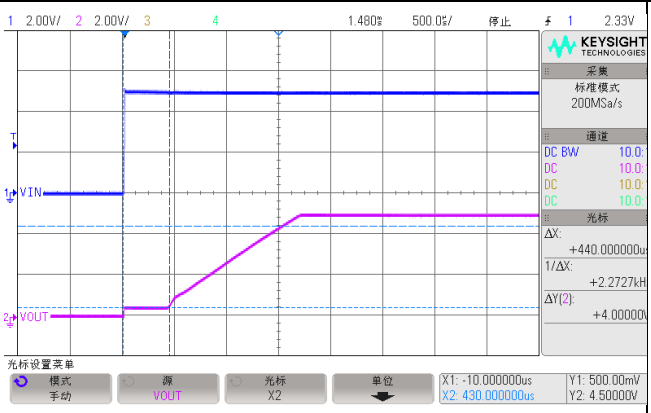
$$I_{LIMIT} = \frac{0.55}{R_{LIMIT}} \times 3870$$

Typical Performance Characteristics

Unless otherwise noted, V_{CC}=5V, V_{EN}=5V, R_{LIMIT}=604Ω, C_{OUT}=10uF, MODE floating, DVDT floating, T_A=25°C.

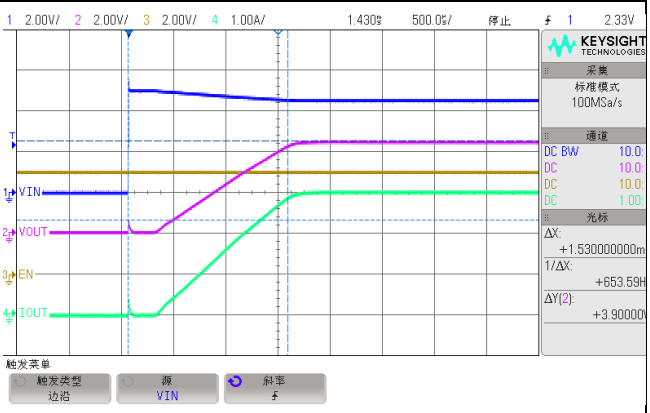
Start-up Test

Start-up through Input voltage(I_{OUT}=0A)



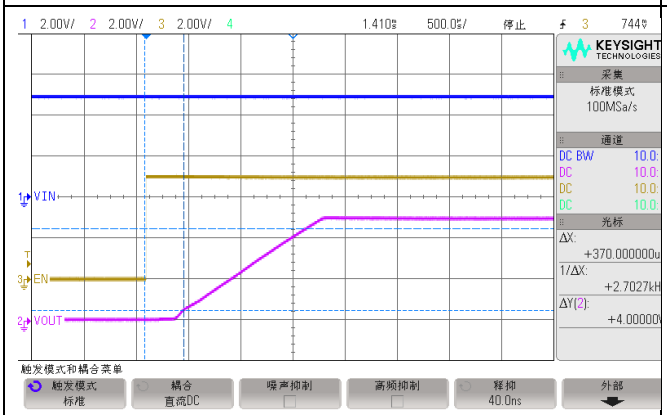
500us/div

Start-up through Input voltage(I_{OUT}=3A)



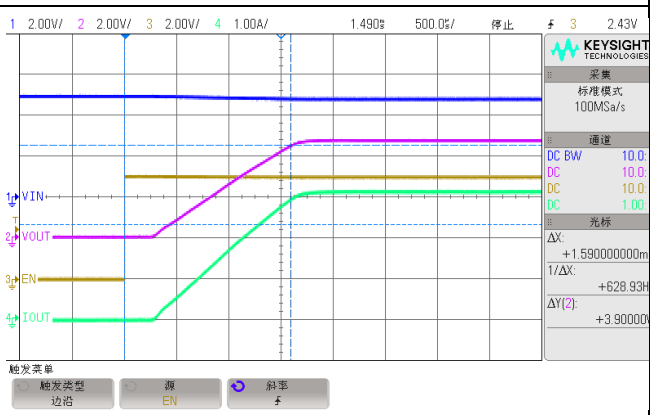
500us/div

Start-up through EN(I_{OUT}=0A)



500us/div

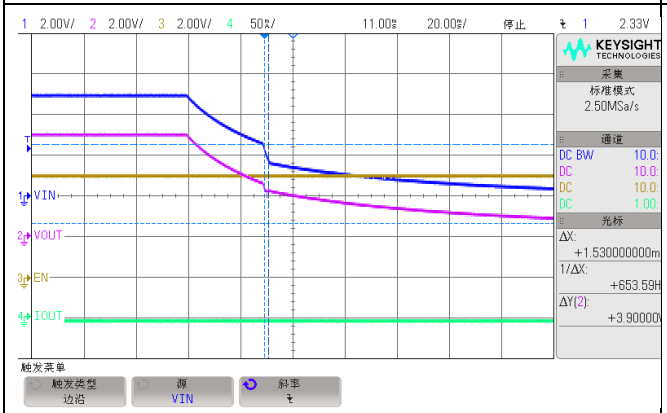
Start-up through EN(I_{OUT}=3A)



500us/div

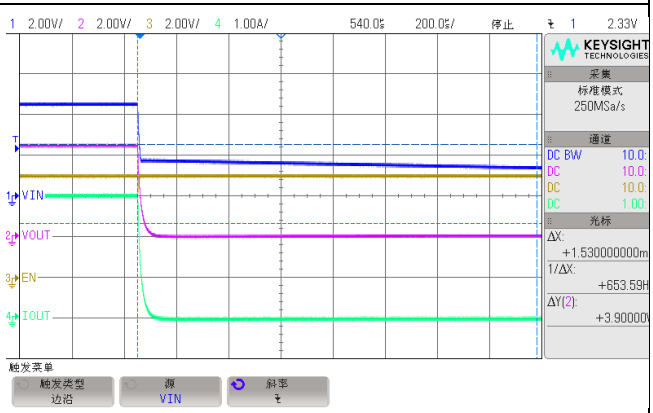
Shut-down Test

Shut-down through input voltage(I_{OUT}=0A)

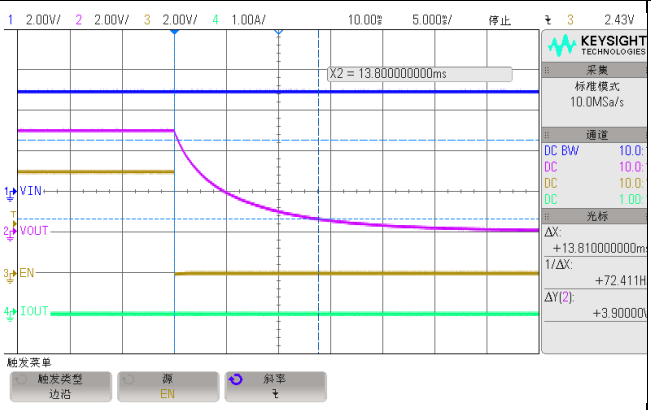
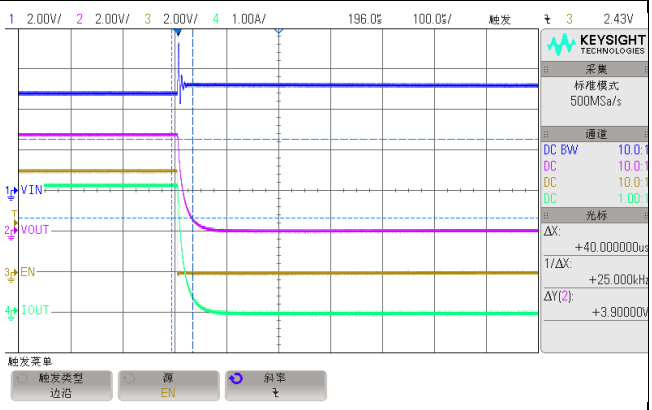


20ms/div

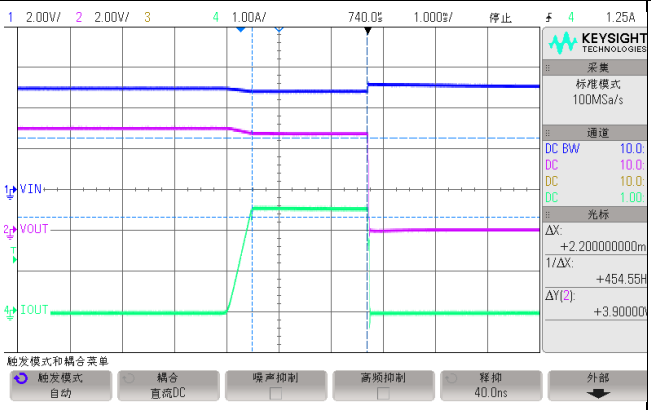
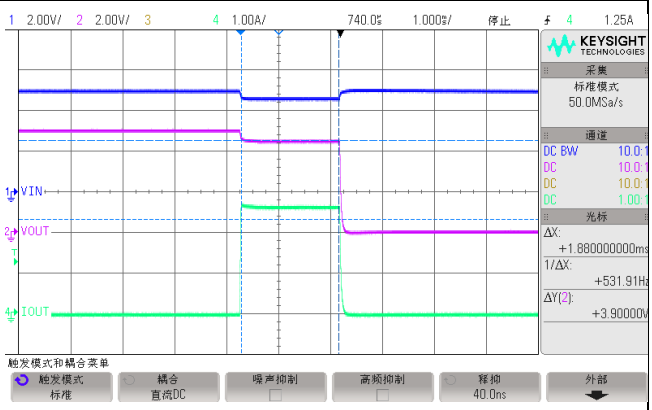
Shut-down through input voltage(I_{OUT}=3A)



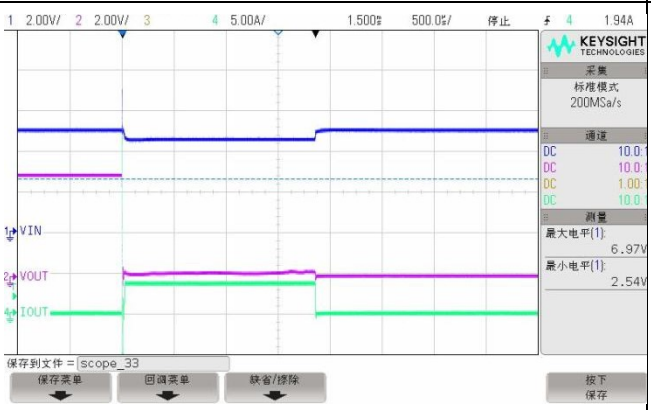
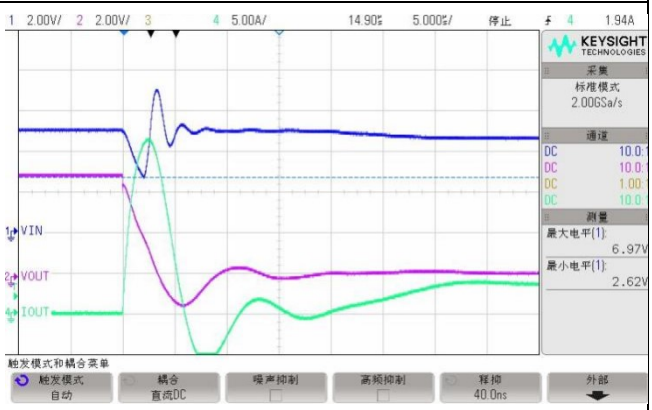
200us/div

Shut-down through EN(I_{OUT}=0A)	Shut-down through EN(I_{OUT}=3A)
	
5ms/div	100us/div

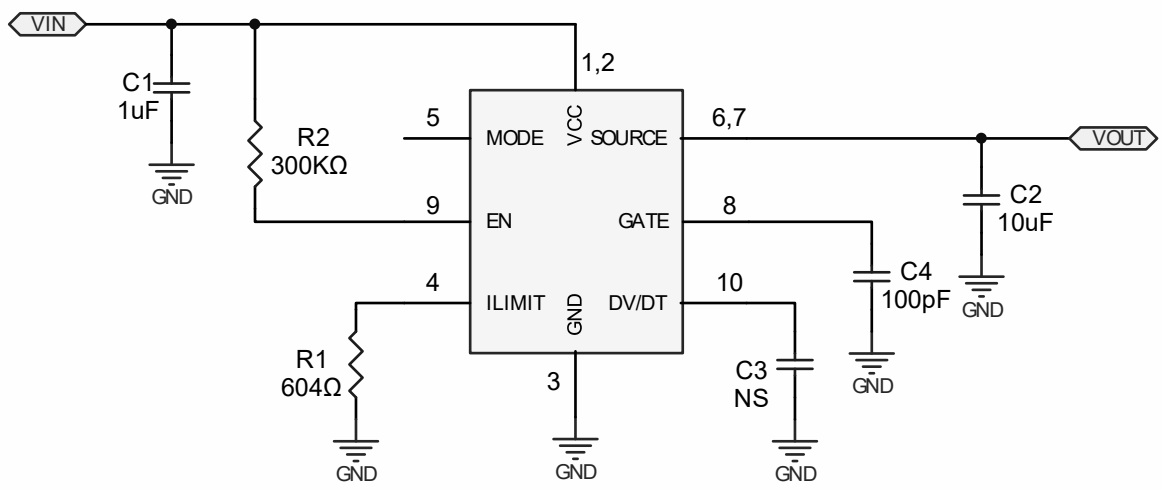
Current Limit Test

Current Limit(Electronic Load)	Current Limit(Resistor Load)
	
1ms/div	1ms/div

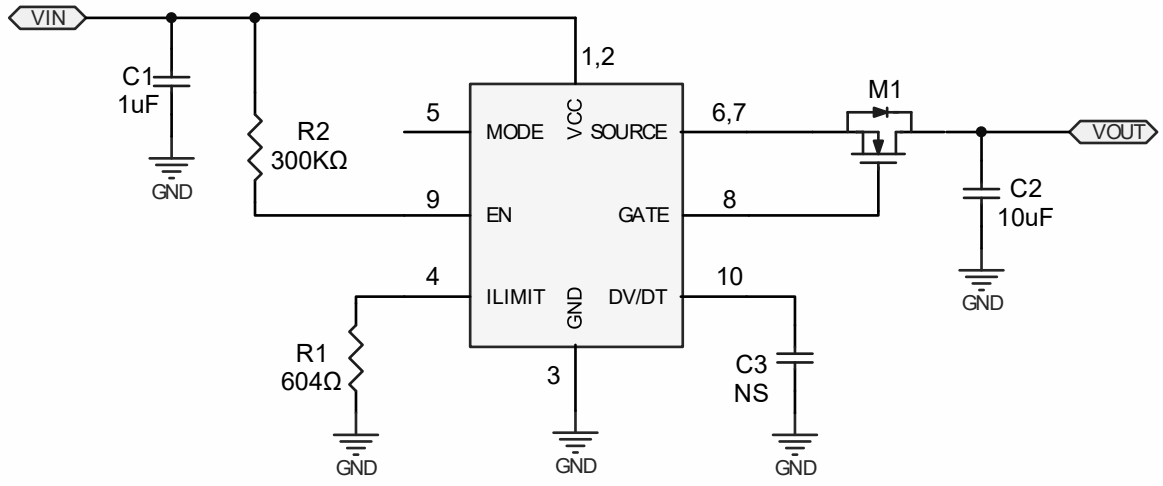
Short Circuit Test

Short Circuit during Normal Operation	Short Circuit during Normal Operation
	
500us/div	5us/div

Application Circuits



Typical Application Circuit without RCB Mosfet

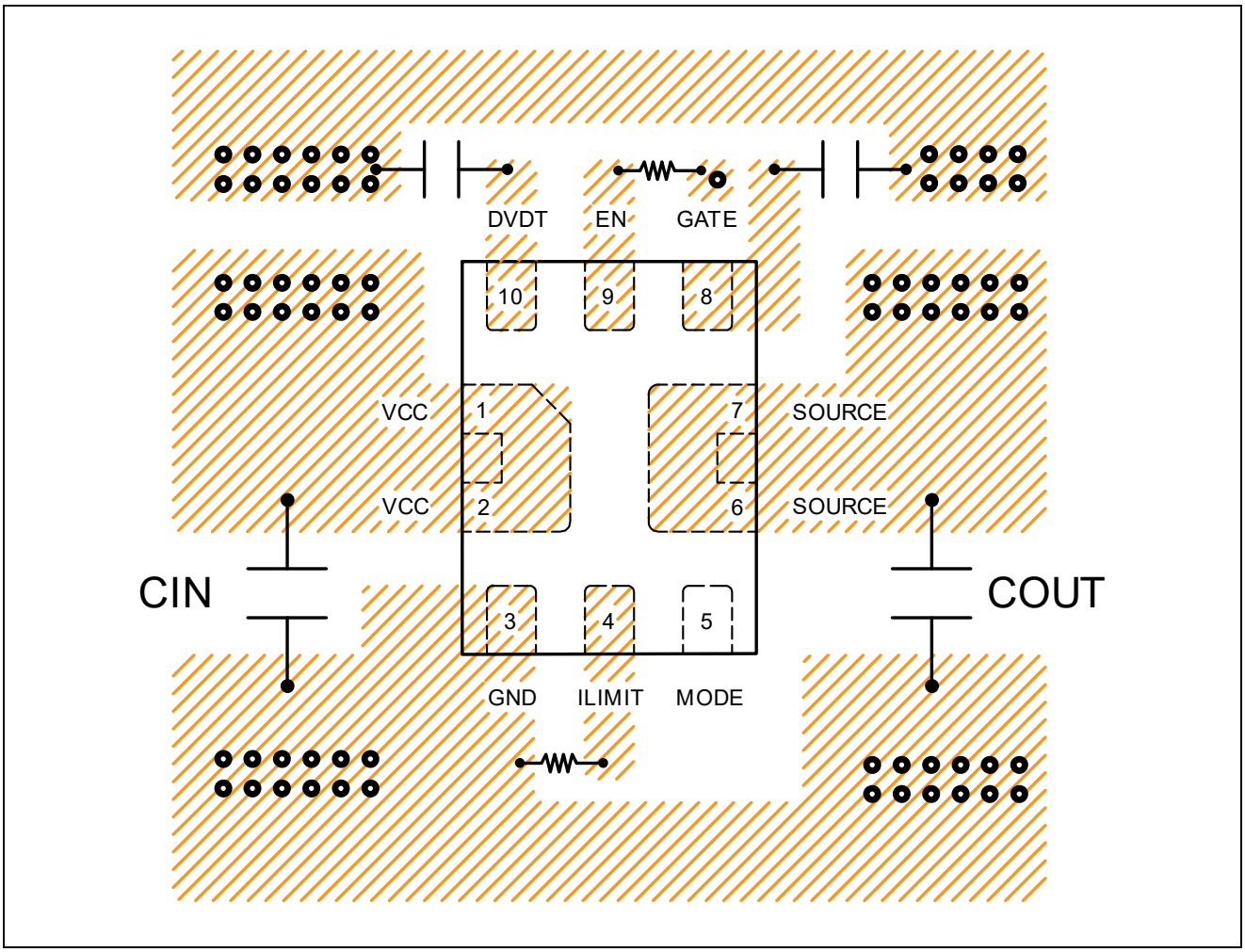


Typical Application Circuit with RCB Mosfet

*：This electric circuit only supplies for reference.

PCB Layout Guide

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 for reference.



1) Keep the path of current short and minimize the loop area formed by Input and output capacitor.

2) Output capacitor and IC must be on the same side. The distance of outpin and output capacitor <3mm is recommended.

3) Bypass ceramic capacitors are suggested to be put close to the VIN Pin.

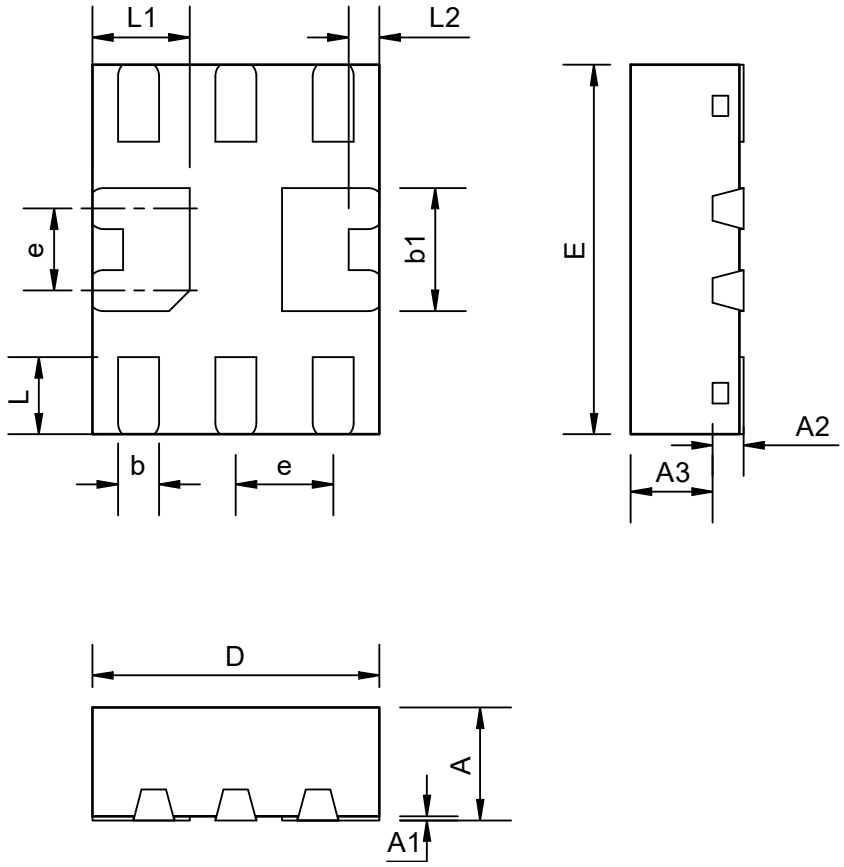
4) Connect IN, OUT, and especially GND respectively to a large copper area to cool the chip to improve thermal performance and long-term reliability.

5) Place a current-limit resistor close to ILIMIT.

6) Place the DV/DT capacitor close to DV/DT.

Package Dimension

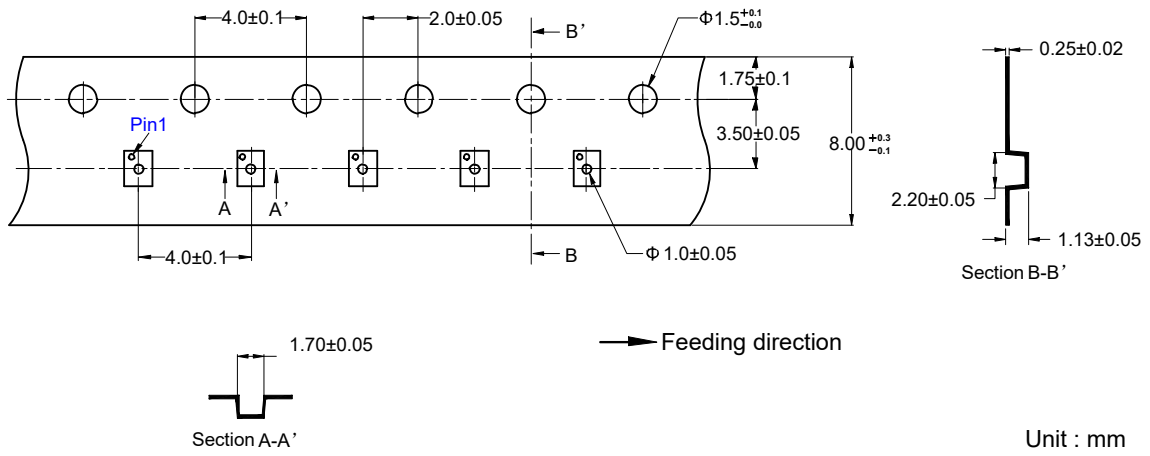
QFN10



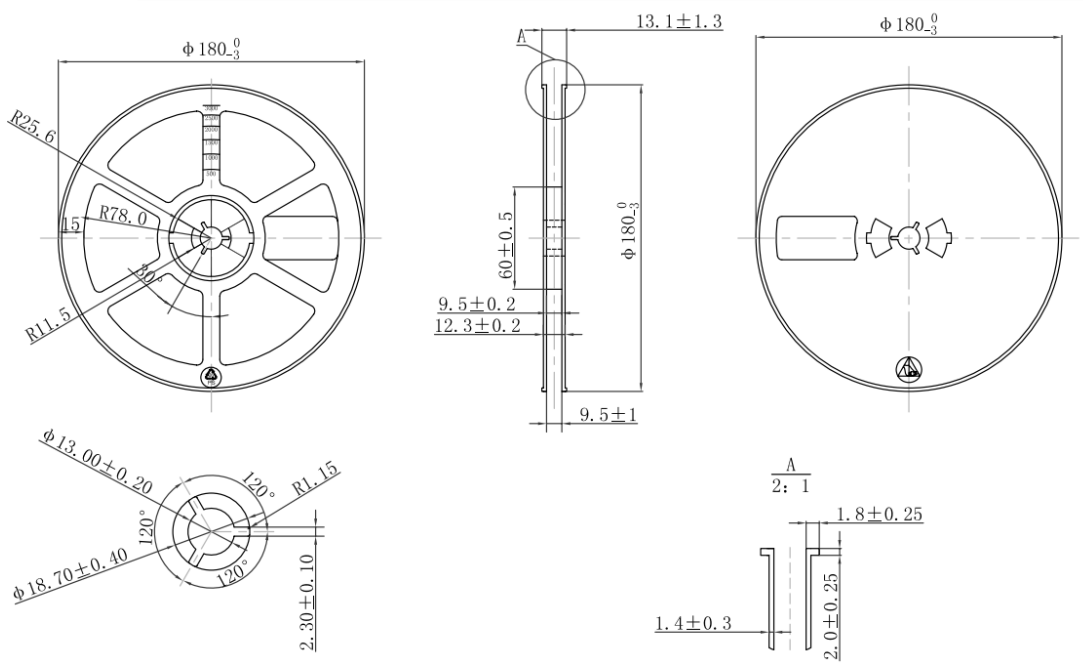
COMMON DIMENSIONS
(UNITS OF MEASURE=MILLIMETER)

SYMBOL	MIN	NOM	MAX
A	0.80	0.85	0.90
A1	0.00	0.02	0.05
A2		0.203REF	
A3	0.60	0.65	0.70
b	0.20	0.25	0.30
b1	0.70	0.75	0.80
D	1.45	1.50	1.55
E	1.95	2.00	2.05
e		0.50BSC	
L	0.30	0.35	0.40
L1	0.50	0.55	0.60
L2	0.15	0.20	0.25

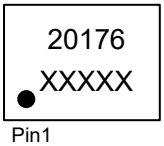
Tape Information



Reel Information



Marking



20176 - Part Number

XXXXX - Tracking Number

Revision History and Checking Table

Version	Date	Revision Item	Modifier	Function & Spec Checking	Package & Tape Checking
1.0	2020-11-19	Initial Version	Yangz	Yangz	Zhujl
1.1	2021-1-26	Modify Thermal Shutdown T_{SD} and Thermal-shutdown Hysteresis T_{SD_HYS}	Yangz	Yangz	Zhujl
1.2	2021-4-30	Modify Current Limit function description, delete current limit hiccup mode.	Yangz	Yangz	Zhujl
1.3	2021-5-28	Add tape,reel information	Yangz	Yangz	Zhujl
1.4	2021-8-9	1. Modify VIN Quiescent Current. 2. Modify VIN Shutdown Current. 3. Modify clamping voltage within $R_{MODE.}$ 4. Modify GATE maximum sink current. 5. Modify VCLAMP calculate equation within RMODE. 6. Add dv/dt calculate equation within DVDT capacitor mode. 7. Add ESD Test Spec. 8. Add full-temperature Electrical Characteristics Limit. 9. Add SCP description. 10. Modify Thermal Shutdown description. 11. Add Typical Performance Characteristics	Yangz	Yangz	Zhujl
1.5	2021-9-5	1. Modify PD and Add θ_{JA} in Absolute Maximum Ratings. 2. Modify total short-circuit response time from 1us to 5us. 3. Add Current Limit Response time.Modify short-circuit response time from 1us to 3us. Add test condition note. 4. Modify Over-Current Protection Mode in Features.	Yangz	Yangz	Zhujl
1.6	2021-11-16	Add recommended land pattern	Yangz	Yangz	Zhujl
1.7	2022-1-5	Add thermal resistance.	Yangz	Yangz	Zhujl
1.8	2023-5-18	Update Typeset	Wuhs	Yangz	Zhujl
1.9	2023-12-6	Add Marking	Shibo	Yangz	Liujy