60mΩ Adjustable Current Limited Power Switches

General Description

The ET2016B are current limited P-channel MOSFET power switch designed for high-side load switching applications. This switch operates with inputs ranging from 2.5V to 5.5V, making it ideal for both 3.3V and 5V systems. An integrated current-limiting circuit protects the input supply against large currents which may cause the supply to fall out of regulation. The ET2016B is also protected from thermal overload which limits power dissipation and junction temperatures. It can be used to control loads that require from 0.275A to 2.7A. Current limit threshold is programmed with a resistor from SET to ground. The quiescent supply current in active mode is only 25μA. In shutdown mode, the supply current decreases to less than 1μA.

The ET2016B is available in Pb-free packages and is specified over the -40˚C to +85˚C ambient temperature range.

Features

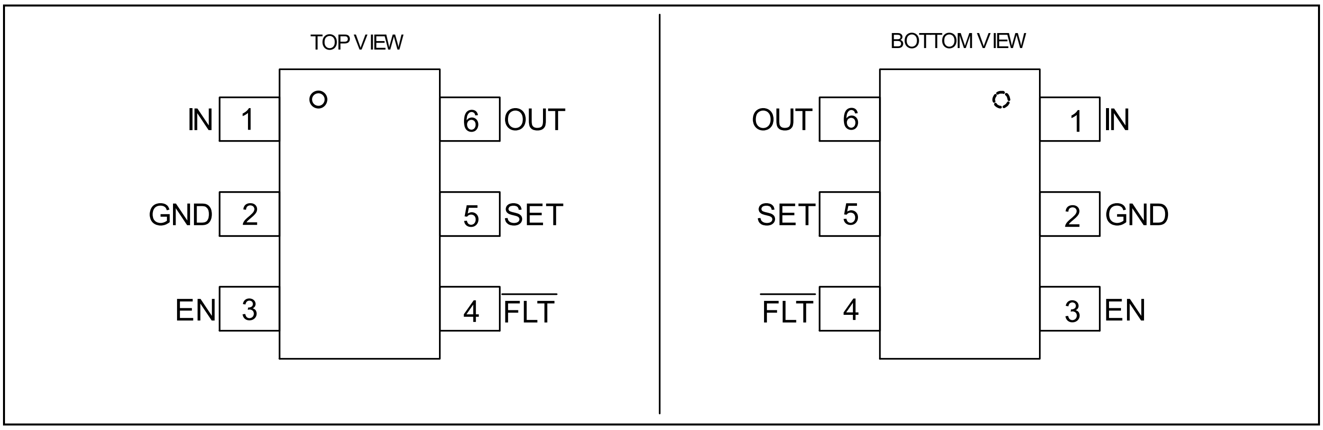
- Input Voltage Range from 2.5V to 5.5V
- Programmable Current Limit
- Reverse Current Blocking
- Short-Circuit Response is 2us Typical
- Very Low Quiescent Current is 25μA Typical
- 1μA Max Shutdown Supply Current
- Under-Voltage Lockout
- Thermal Shutdown
- 4kV ESD Rating
- Ambient Temperature Range: -40°C to +85°C
- Part No. and Package

Part No.	Package
ET2016B	SOT23-6

Applications

- Laptop/Desktop Computers and NetBooks
- LCD TVs and Monitors
- Portable Game Players
- Portable Media Players and MIDs
- USB Keyboards
- USB Hard Disk Drives
- USB Memory Drives
- USB Hubs

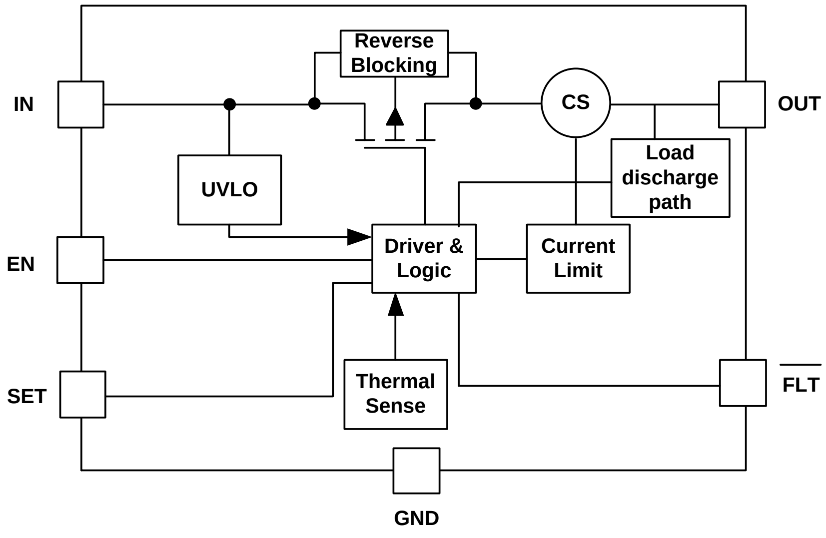
Pin Configuration



Pin Function

Pin No.	Pin Name	Pin Function
1	IN	Power supply input pin. Must be closely decoupled to GND pins with a 1μF or greater ceramic capacitor.
2	GND	Ground pin.
3	EN	Enable input pin.
4	$\overline{\text{FLT}}$	Over-current, reverse-voltage and over-temperature fault reporting signal output pin, active low with 6ms blanking time for over-current.
5	SET	Current limit programming pin.
6	OUT	Power output pin.

Block Diagram



Operation

ET2016B is an integrated power switch with a low $R_{DS(ON)}$ P-channel MOSFET, internal gate rive circuit,programmable current limiting. When the ET2016B turns on, it can deliver up to 2.5A continuous current to load. When the device is active, if there is no load, the device only consumes 25uA supply current, which makes the device suitable for battery powered applications.

Power Supply Considerations

A 0.01μF to 0.1μF ceramic bypass 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 0.01μF to 0.1μF ceramic capacitor improves the immunity of the device to short-circuit transients.

Power Dissipation and Junction Temperature

The low on-resistance on the P-channel MOSFET allows the small surface-mount packages to pass large currents. It is good design practice to check power dissipation and junction temperature for each application. Begin by determining the $R_{DS(ON)}$ of the P-channel MOSFET relative to the input voltage and operating temperature. Using the highest operating ambient temperature of interest and RDS(ON), the power dissipation per switch can be calculated by:

$$P_D = R_{DS(ON)} \times I_{OUT}{}^2 \qquad (1)$$

Finally, calculate the junction temperature:

$$T_J = P_D \times R_{\theta JA} + T_A \qquad (2)$$

Where:

T_A= Ambient temperature
$R_{\theta JA}$ = Thermal resistance
P_D = Total power dissipation

Compare the calculated junction temperature with the maximum junction temperature which is 125°C. If they are within degrees, either the maximum load current needs to be reduced or another package option will be required.

Over Current

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. ET2016B will limit the current until the overload condition is removed or the device begins to thermal cycle.

Three possible overload conditions can occur. In the first condition, the output has been shorted before the device is enabled or before VI(IN) has been applied. The ET2016B senses the short and immediately switches into a constant-current output.

In the second condition, a short or an overload occurs while the device is enabled. At the instant the overload occurs, high currents may flow for a short period of time before the current-limit circuit can react .

After the current-limit circuit reached the over-current trip threshold, the device switches into constant-current mode.

In the third condition, the load has been gradually increased beyond the recommended operating current.

The current is permitted to rise until the current-limit threshold is reached or until the thermal limit of the device is exceeded. The ET2016B is capable of delivering current up to the current-limit threshold without damaging the device. Once the threshold has been reached, the device switches into its constant-current mode.

FLT Output

The FAULT Flag ($\overline{\text{FLT}}$) is provided to alert the system if a ET2016B load is not receiving sufficient voltage to operate properly. If current limiting circuit is active for more than approximately 6ms, the FAULT Flag is pulled to ground through an approximately 100Ω resistor. The filtering of voltage or current transients of less than 6ms prevents capacitive loads connected to the ET2016B output from activating the FAULT Flag when they are initially attached. However, if the device is entering over-temperature conditions, the $\overline{\text{FLT}}$ will be pulled low without delay or deglitch. Pull-up resistance of 1kΩ to 100kΩ on FLT pin is recommended. Since $\overline{\text{FLT}}$ is an open drain terminal, it may be pulled up to any unrelated voltage less than the maximum operating voltage of 5.5V, allowing for level shifting between circuits.

Thermal Protection

Thermal protection prevents damage to the IC when heavy-overload or short-circuit faults are present for extended periods of time. The ET2016B implements a thermal sensing to monitor the operating junction temperature of the power distribution switch. 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. Hysteresis is built into the thermal sense circuit, and after the device has cooled approximately 25°C, the switch turns back on. The switch continues to cycle in this manner until the load fault or input power is removed.

Absolute Maximum Ratings

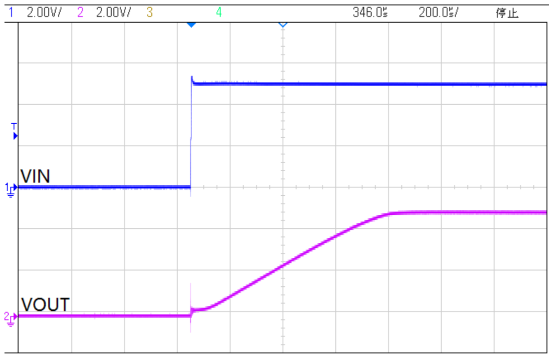
Parameter	Rating	Unit
IN, EN , $\overline{\text{FLT}}$ Voltage	-0.3 to 6.0	V
OUT Voltage	-0.3 to V_{IN} + 0.3	V
OUT Current	Adjustable Limited	A
Power Dissipation	300	mW
Package Thermal Resistance (θ_{JA})	250	°C/W
Operating Junction Temperature	-40 to 150	°C
Storage Temperature	-65 to 150	°C
Lead Temperature (Soldering, 10 sec)	300	°C

Electrical Characteristics

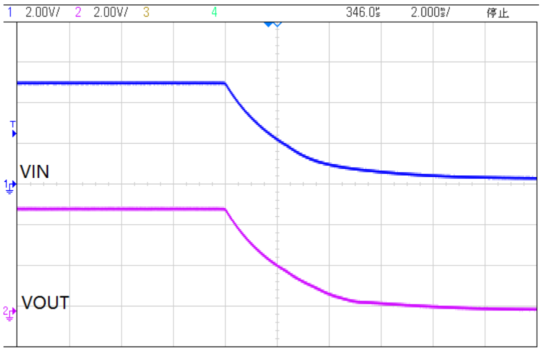
(V_{IN} = +5.0V, V_{EN}=0V or V_{EN}=V_{IN} ,T_A = -40℃ to 85℃, typical values at T_A=25℃, unless otherwise stated)

Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit
V_{IN}	Input Voltage Range		2.5		5.5	V
V_{UVLO}	Input UVLO		1.4	1.8	2.4	V
V_{UVLO_HYS}	UVLO Hysteresis			0.25		V
I_{SHDN}	Input Shutdown Quiescent Current	Disabled, OUT floating or shorted to ground		0.1	1	uA
I_Q	Input Quiescent Current /Channel	Enabled, I_{OUT}= 0		25	60	uA
$R_{DS(ON)}$	Switch On-resistance	V_{IN}=5V, I_{OUT}=0.6A		60	120	mΩ
I_{LMT}	Current Limit	V_{IN}=5V ,R_{SET}=55K, T_A=25˚C	1.00	1.10	1.20	A
I_{LMT_MIN}				0.275		A
V_{IL}	EN Input Logic Low Voltage				0.8	V
V_{IH}	EN Input Logic High Voltage		2			V
I_{SINK}	EN Input Leakage	V_{EN} = 5V		0.01	1	uA
T_{ON}	Output Turn-on Delay Time	V_{IN} =5V, C_L=1uF, R_{LOAD}=100Ω	0.2	0.6	1	ms
T_R	Output Turn-on Rise Time	V_{IN} =5V, C_L=1uF, R_{LOAD}=100Ω	0.2	0.5	0.8	ms
T_{OFF}	Output Turn-off Delay Time	V_{IN} =5V, C_L=1uF, R_{LOAD}=100Ω	0.1	0.3	0.5	ms
T_F	Output Turn-off Fall Time	V_{IN} =5V, C_L=1uF, R_{LOAD}=100Ω	50	120	200	us
T_{FLT_BLANK}	FLT Blanking Time		2	6	15	ms
V_{FLT_Lo}	FLT Logic Low Voltage	$I_{FLT(SINK)}$ =1mA			0.2	V
I_{FLT}	FLT Leakage Current	V_{FLT} = 5V, Enabled, No Fault Conditions		0.1	1	uA
R_{DIS}	Output Discharge FET Rdson	Disabled, V_{IN} = 5V, V_{OUT}=5V	200	400	800	Ω
I_{REV}	Reverse Leakage Current	V_{OUT} = 5V , V_{IN} =0V measure I_{VOUT}	0.1	1	3	uA
T_{SHDN}	Thermal Shutdown Threshold	V_{IN} = 5V	140	155	165	°C
T_{HYS}	Thermal Shutdown Hysteresis	V_{IN} = 5V		25		°C

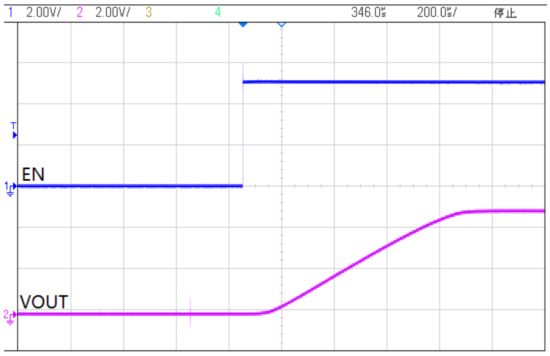
Typical Performance Characteristics



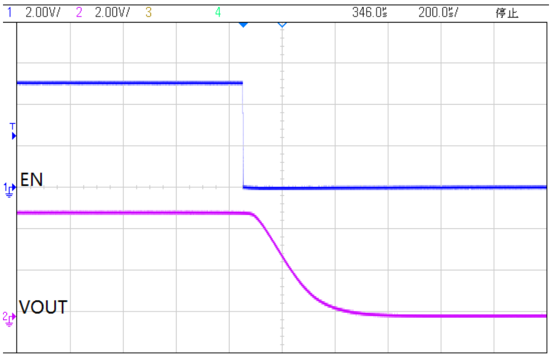
UVLO at Rising



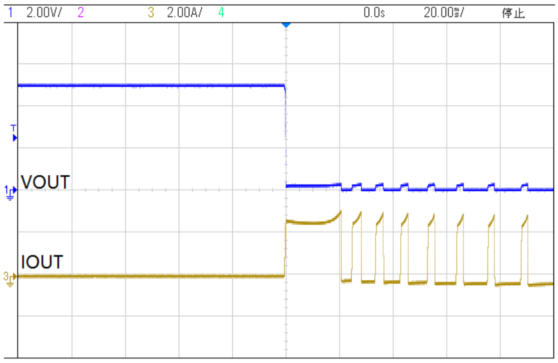
UVLO at Falling



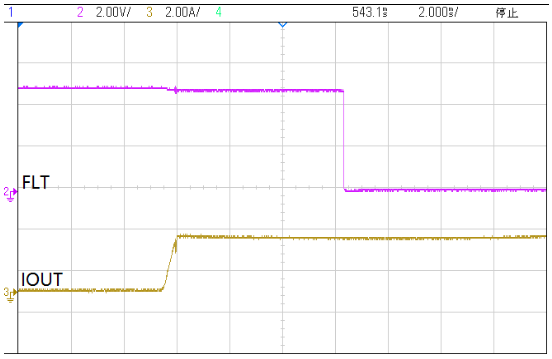
Turn on delay



Turn off delay



Short circuit response and Themal shut down



Over load response VS FLT

Current Limiting Setting

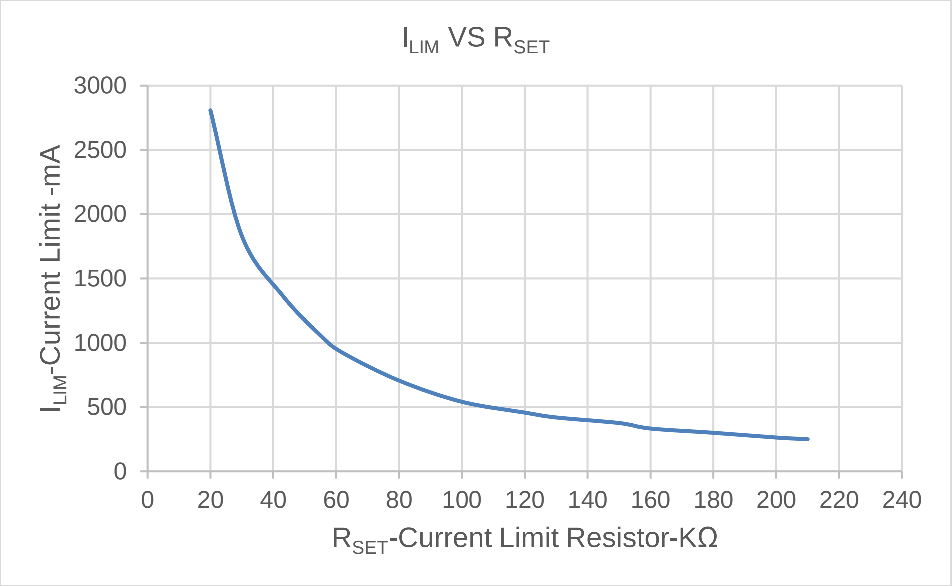
Current limit is programmable to protect the power source from over current and short circuit conditions. Connect a resistor RSET from SET pin to GND to program the current limit:

$$I_{LIM\_min}(mA) = \frac{66027}{R_{LIMIT}{}^{1.046}(k\,\Omega)}$$

$$I_{LIM\_nom}(mA) = \frac{72998}{R_{LIMIT}{}^{1.045}(k\,\Omega)}$$

$$I_{LIM\_max}(mA) = \frac{79882}{R_{LIMIT}{}^{1.044}(k\,\Omega)}$$

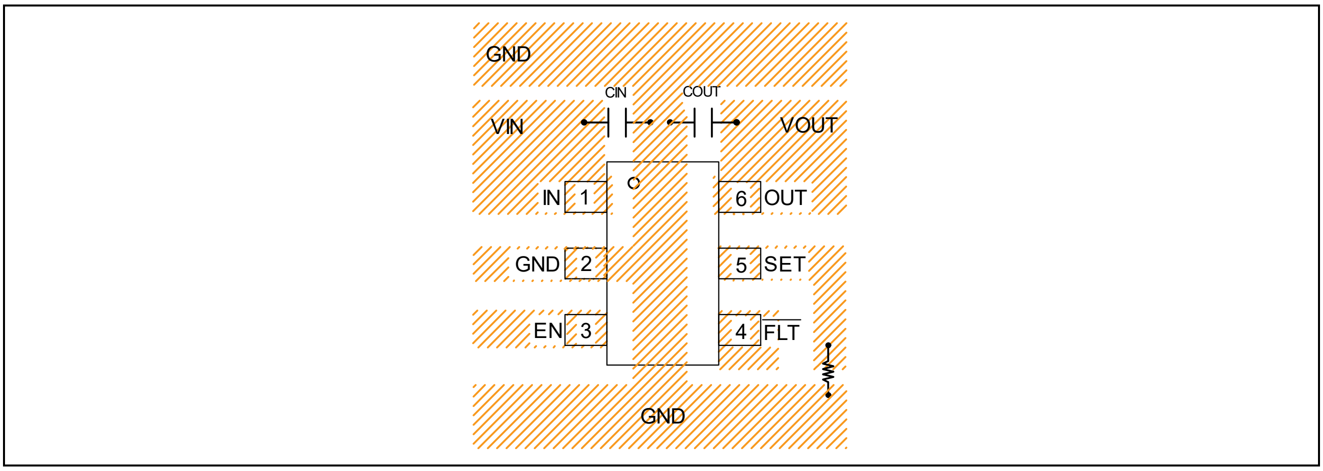
The minimum current limit is 0.275A. Current limit beyond 2.7A is not recommended.



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.

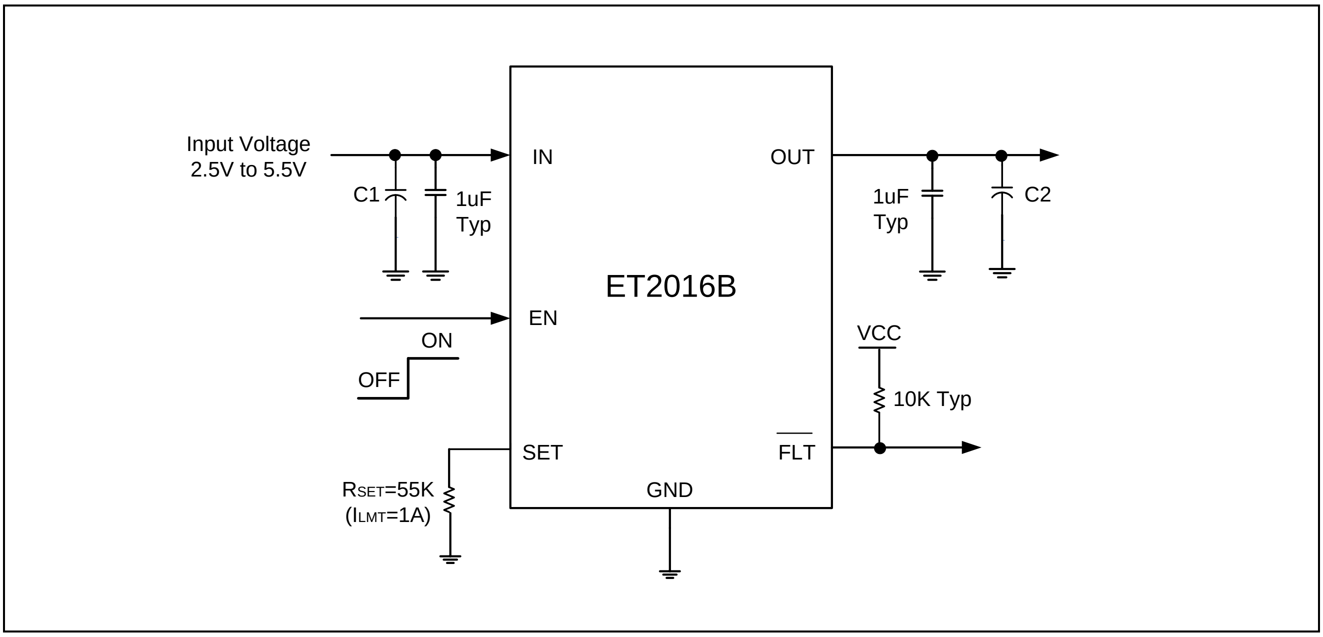
1) Keep the path of current short and minimize the loop area formed by Input and output capacitor.
2) Output capacitor and IC must be on the same side. The distance of out pin and output capacitor <3mm is recommended.



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

Application Circuits

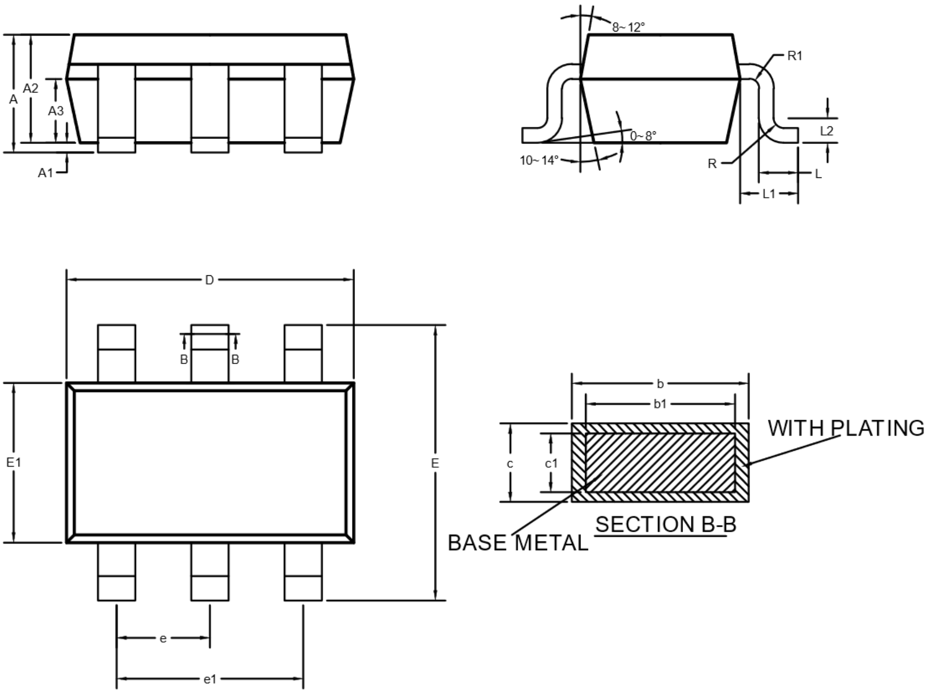


Note:

Tantalum or Aluminum Electrolytic capacitors (C1 and C2) may be required for USB applications.

Package Dimension

SOT23-6



Dimensions Table (Units:mm)

Symbol	Min	Typ	Max
A	—	—	1.250
A1	0	—	0.150
A2	0.750	—	1.200
A3	0.350	0.650	0.700
b	0.360	—	0.460
b1	0.350	0.380	0.430
c	0.130	—	0.200
c1	0.120	0.150	0.160
D	2.820	2.926	3.026
E	2.600	2.800	3.000
E1	1.500	1.626	1.726
e	0.900	0.950	1.000
e1	1.800	1.900	2.000
L	0.300	0.400	0.500
L1	0.590 REF		
L2	0.250 BSC		
R	0.050	—	0.200
R1	0.050	—	0.200

Revision History and Checking Table

Version	Date	Revision Item	Modifier	Function & Spec Checking	Package & Tape Checking
0.0	2022-10-12	Preliminary version	Wu Hesong	Liu Yi Guo	Liujy
1.0	2023-03-29	Update Typeset	Zou Chaomin	Wu Hesong	Liujy
1.1	2023-04-23	Update Application Circuits	Zou Chaomin	Shi Bo	Shi Bo
1.2	2023-11-16	Update Current Limit	Zou Chaomin	Shi Bo	Shi Bo
1.3	2023-11-16	Update Calculation formula	Zou Chaomin	Shi Bo	Shi Bo
1.4	2025-09-25	Update Calculation formula	Wuhs	Shi Bo	Shi Bo