USB Power-Distribution Switch with Fault Blanking

DESCRIPTION

The EUP3545/A is an incorporated 100mΩ P-channel MOSFET power-distribution switch for self-powered and bus-powered Universal Serial Bus (USB) applications.

When the output load exceeds the current-limit threshold or a short is present, the device limits the output current to safe level by switching into a constant-current limit mode with fold back, pulling the over-current ($\overline{OC}$) logic output low. When continuous heavy overloads or short-circuits increase the power dissipation in the switch, causing the junction temperature to rise, a thermal protection circuit shutdown the switch to prevent damage. Internal Under Voltage Lock-Out (UVLO) circuitry ensures that the switch remains off until valid input voltage is present.

$\overline{OC}$ is open-drain output which is asserted when over-current or over-temperature event occurs. A 8ms fault-blanking feature enables the circuit to ignore momentary faults, such as those caused when hot-swapping a capacitive load, preventing false alarms to the host system. The EUP3545/A eliminates any reversed current flow across the switch when it is powered off.

The EUP3545/A are available in SOT23-5, 8-pin MSOP and 8-pin MSOP(EP) packages, operates over the extended (-40°C to +85°C) temperature range.

FEATURES

- 100mΩ POWER MOSFET
- Operating Range : 2.7V to 5.5V
- Under Voltage Lockout
- 11μA Quiescent Current
- 1μA Shutdown Current
- Logic Level Enable Pin, Available with Active-Low or Active-High Version
- No Reverse Current when Power Off
- Fault Blanking Open-Drain Over-Current Flag Output ($\overline{OC}$)
- Output Shutdown Pull-low Resistor
- Available in SOT23-5,MSOP-8 and MSOP-8 (EP) Packages
- RoHS Compliant and 100% Lead(Pb)-Free Halogen-Free
- UL Listed-File No. E334299

APPLICATIONS

- USB Ports and Self-Powered Hubs
- USB Bus-Powered Hubs
- Hot Plug-In Power Supplies
- General Purpose High Side Switch Applications

Typical Application Circuit

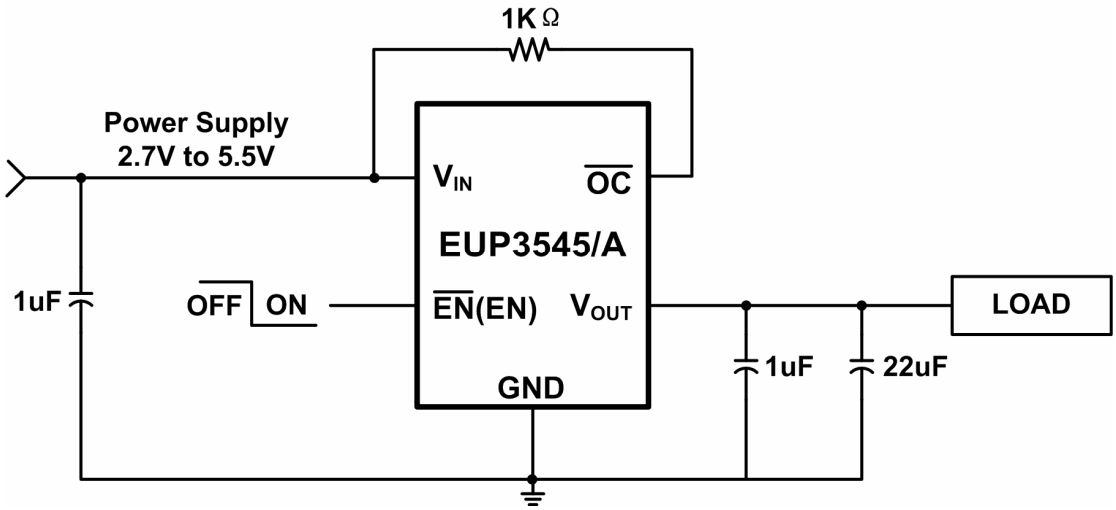
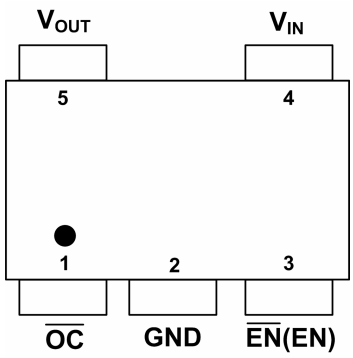
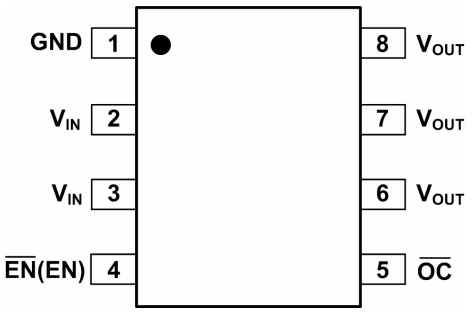
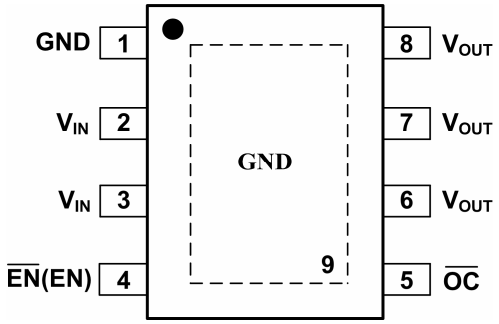


Figure 1.

Pin Configurations

Package Type	Pin Configurations	Package Type	Pin Configurations
SOT23-5	(Top View) 	MSOP-8	(Top View) 
MSOP-8 (EP)	(Top View) 		

Pin Description

NAME	SOT23-5	MSOP-8	MSOP-8 (EP)	DESCRIPTION
GND	2	1	1 9 (Exposed Pad)	**Ground**. The exposed pad must be soldered to a large PCB and connected to GND for maximum power dissipation.
V_{IN}	4	2,3	2,3	Power Input. Connect all V_{IN} inputs together and bypass with a 1uF or greater ceramic capacitor to GND. Load conditions might require additional bulk capacitance to prevent pulling V_{IN} down.
$\overline{EN}$(EN)	3	4	4	**Enable:** Logic level enable input. Make sure $\overline{EN}$(EN) pin never floating. $\overline{EN}$(EN): Logic low (high) turns on power switch.
$\overline{OC}$	1	5	5	Fault Indicator Output. Open-drain output asserts low when enters thermal shutdown, or a sustained (8ms typical) current-limit or short-circuit condition.
V_{OUT}	5	6,7,8	6,7,8	Power Output. Bypass V_{OUT} to GND with a 1uF ceramic capacitor. Load conditions might require additional bulk capacitance.

Ordering Information

Order Number	Package Type	Marking	ENABLE	Current Limit	Continuous Load Current	Operating Temperature Range
EUP3545VIR1	SOT23-5	90 xxxx	Logic Low	2A	0.7A	-40 °C to +85°C
EUP3545MIR1	MSOP-8	xxxxx P3545	Logic Low	2A	1.5A	-40 °C to +85°C
EUP3545AVIR1	SOT23-5	xxxxx Am00	Logic High	1.5A	0.7A	-40 °C to +85°C
EUP3545APIR1	MSOP-8 (EP)	xxxxx 3545A	Logic High	1.5A	1.0A	-40 °C to +85°C
EUP3545A-25PIR1	MSOP-8 (EP)	xxxxx 3545A 1B	Logic High	2.5A	2.0A	-40 °C to +85°C

EUP3545/A-□□ □ □ □ □

Lead Free Code
1: Lead Free, Halogen Free 0: Lead

Packing
R: Tape & Reel

Operating temperature range
I: Industry Standard

Package Type
V: SOT23
M: MSOP
P : MSOP-8 (EP)

Current Limit Rating
25: 2.5A

Block Diagram

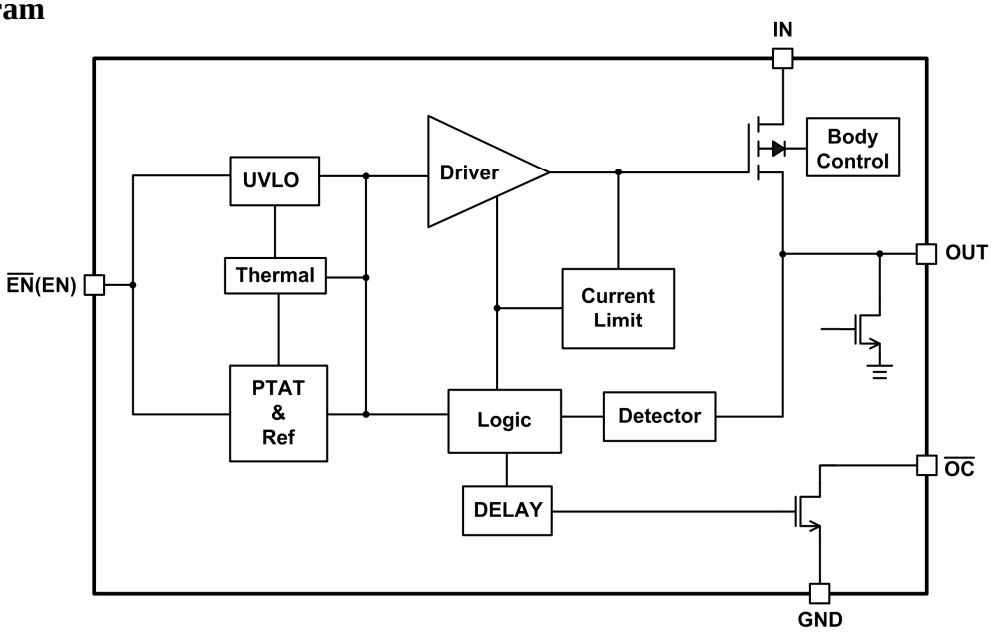


Figure 2.

Absolute Maximum Ratings (1)

- Supply Voltage (V_{IN}) ---------- 6V
- Output Voltages (V_{OUT}) ---------- 6V
- Output Current (I_{OUT}) ---------- Internally Limited
- Enable Input ($V_{\overline{EN}}$) ---------- -0.3V to 6V
- Storage Temperature (T_S) ---------- -65°C to 150°C
- Reflow Temperature (soldering,10sec) ---------- 260°C
- Thermal Resistance θ_{JA} (SOT23-5) ---------- 220°C /W
- Thermal Resistance θ_{JA} (MSOP-8) ---------- 102°C /W
- Thermal Resistance θ_{JA} (MSOP-8_EP) ---------- 70°C /W
- ESD protection ---------- 4kV

Recommend Operating Conditions (2)

- Supply Voltage (V_{IN}) ---------- 2.7V to 5.5V
- Operating Temperature (T_A) ---------- -40°C to +85°C

Note (1): Stress beyond those listed under "Absolute Maximum Ratings" may damage the device.
Note (2): The device is not guaranteed to function outside the recommended operating conditions.

Electrical Characteristics

Unless otherwise specified, V_{IN}=5V, C_{IN}=C_L=1µF, T_A=+25°C.

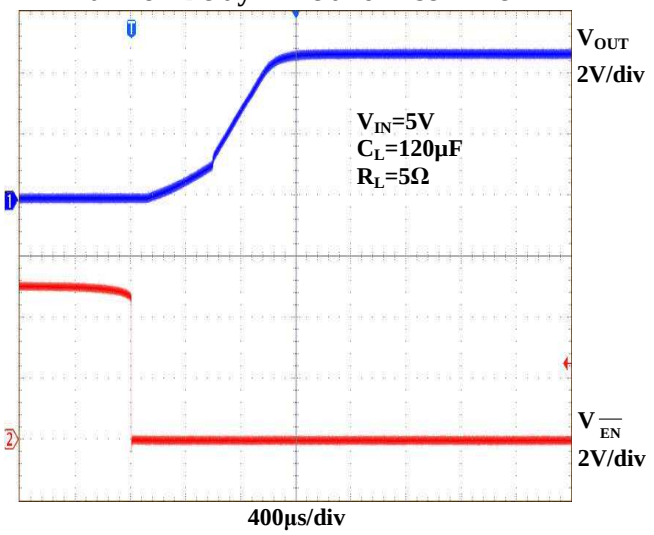
Symbol	Parameter	Conditions		EUP3545/A			Units
				Min.	Typ.	Max.	
V_{IN}	Operating Voltage			2.7		5.5	V
R_{ON}	Output MOS $R_{DS(ON)}$	IC Enable, I_{OUT}=1A			100	150	mΩ
I_Q	Supply Current	IC Enable			11	15	µA
T_{RISE}	Output Turn-on Rising Time				350		us
I_{LIMIT}	Current Limit Threshold	V_{OUT}=4V	EUP3545	1.6	2	2.5	A
			EUP3545A	1.1	1.5	1.9	
			EUP3545A-25	2.1	2.5	2.9	
I_{SHORT}	Short-Circuit Current	V_{OUT}=0V	EUP3545		1.25		A
			EUP3545A		0.8		
			EUP3545A-25		1.5		
V_{IL}	Low-Level Input Voltage	(Note 3)				0.8	V
V_{IH}	High-Level Input Voltage	(Note 3)		2			V
I_{SHDN}	Shutdown Supply Current	IC Disable			0.4	1	µA
R_{SHDN}	Shutdown Pull Low Resistance				55		Ω
I_{LEAK}	Output Leakage Current	IC Disable, V_{OUT}=0V			0	1	µA
V_{UVLO}	V_{IN} Under Voltage Lockout			1.9	2.1	2.3	V
$V_{UVLO-Hys}$	V_{IN} Under Voltage Hysteresis				200		mV
$T_{\overline{OC}}$	$\overline{OC}$ Deglitch			6	8	12	ms
$V_{\overline{OC}}$	$\overline{OC}$ Output Low Voltage	$I_{\overline{OC}}$ = 5mA				0.2	V
$I_{\overline{OC}}$	$\overline{OC}$ Off-State Current	$V_{\overline{OC}}$ = 5V				1	µA
	Thermal Limit				135		°C
	Thermal Limit Hysteresis				20		°C

Note (3): For the EUP3545, OFF is $\overline{EN} \geq 2V$ and ON is $\overline{EN} \leq 0.8V$. For the EUP3545A, OFF is $EN \leq 0.8V$ and ON is $EN \geq 2V$.

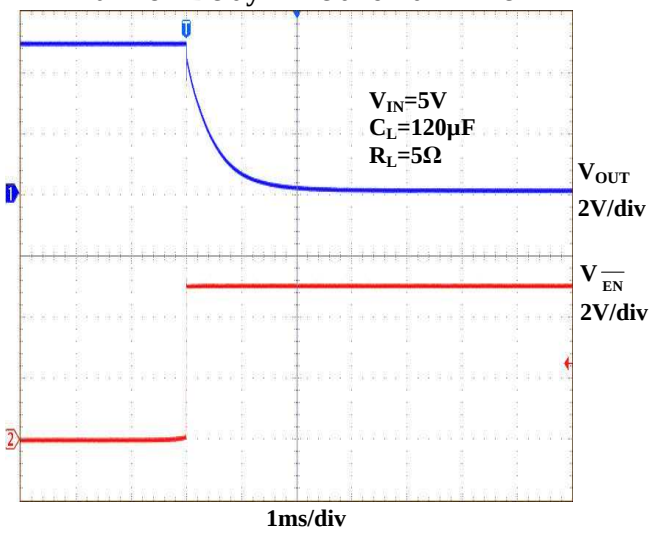
Typical Operating Characteristics

(V_{IN}=5V, C_{IN}=1μF, C_{OUT}=1μF, $V_{\overline{EN}}$ =0V, T_A=+25°C, unless otherwise noted.)

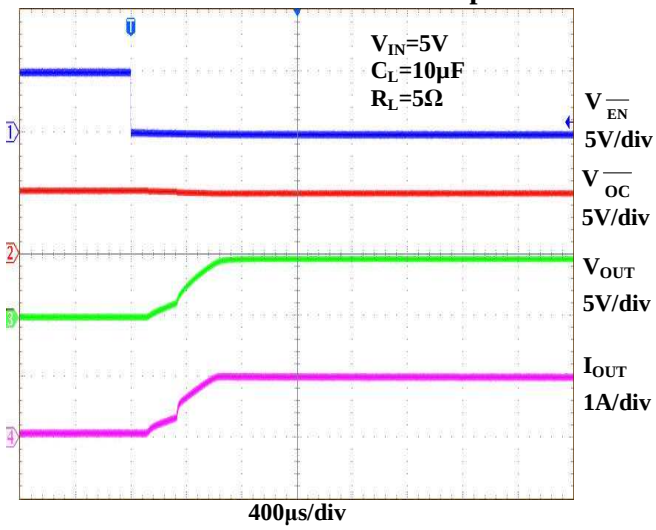
Turn on Delay Time and Rise Time



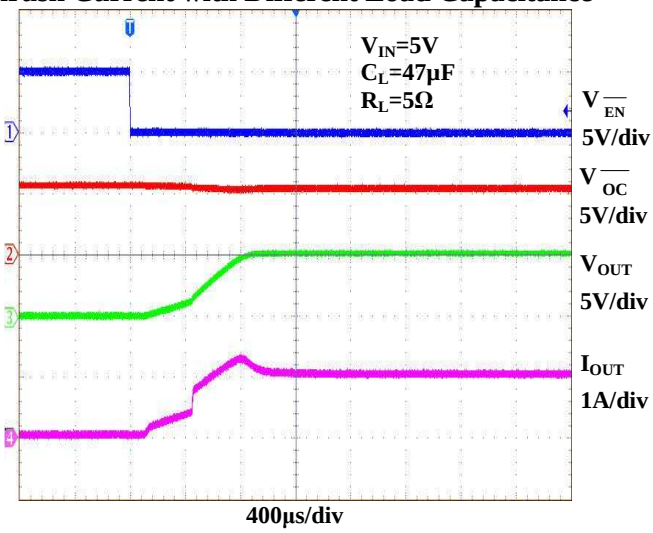
Turn off Delay Time and Fall Time



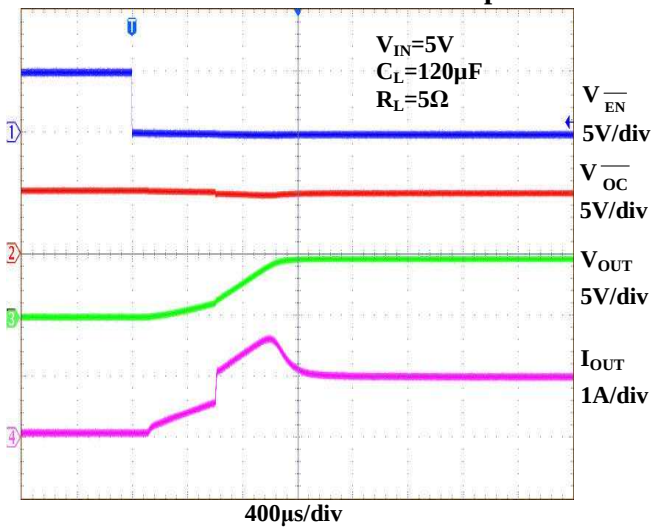
Inrush Current with Different Load Capacitance



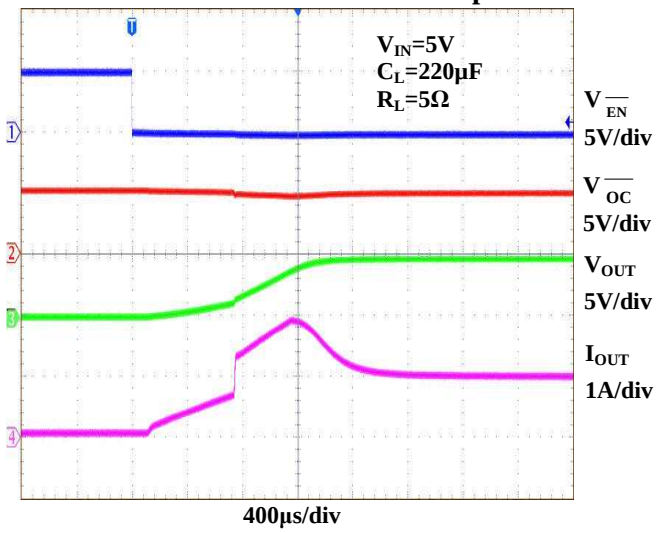
Inrush Current with Different Load Capacitance



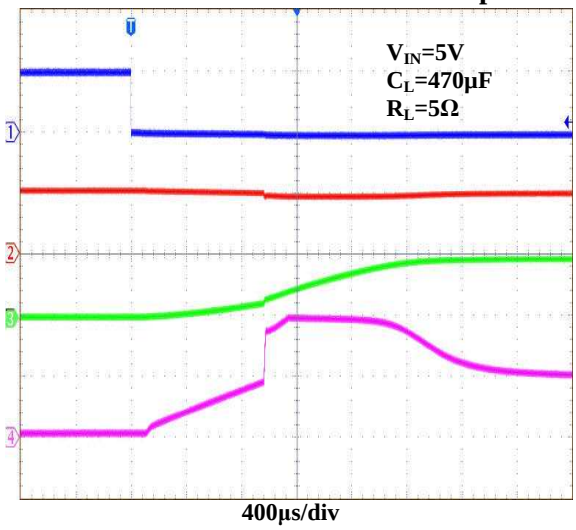
Inrush Current with Different Load Capacitance



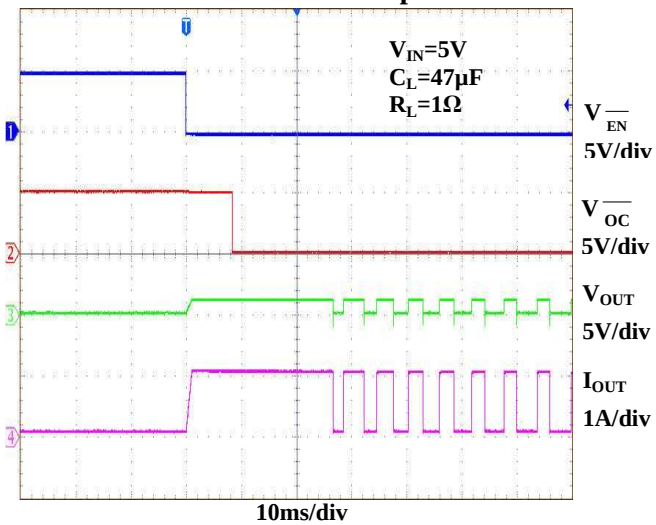
Inrush Current with Different Load Capacitance



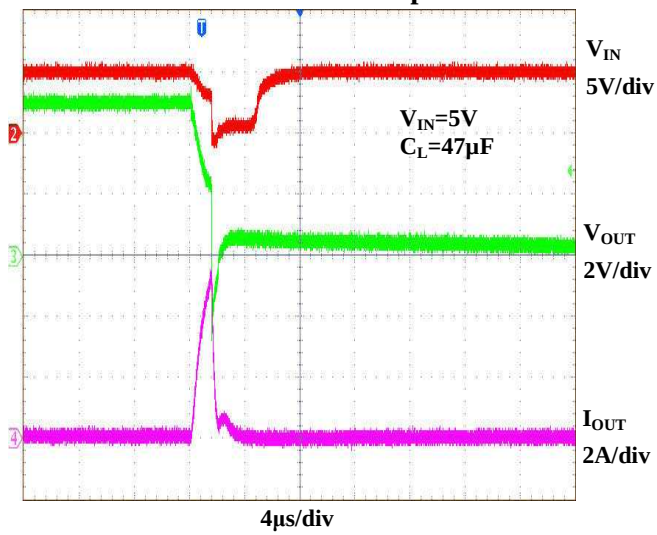
Inrush Current with Different Load Capacitance



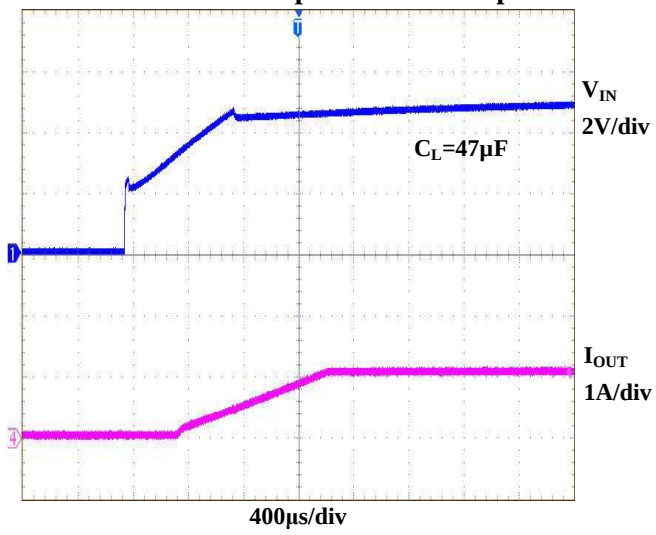
Thermal Shutdown Response



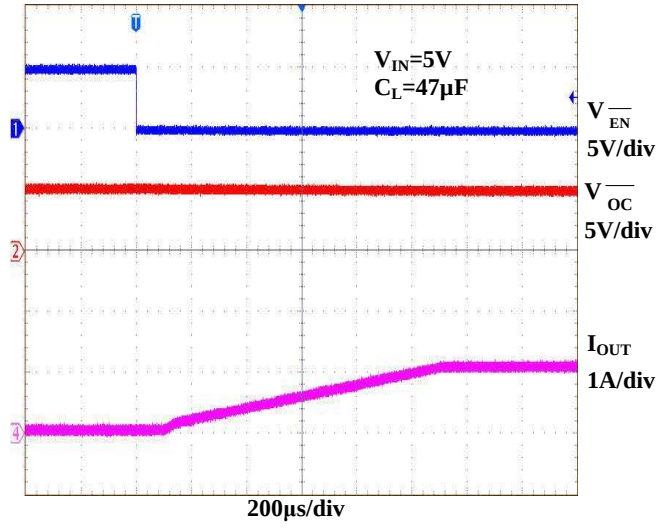
Inrush Short Circuit Response



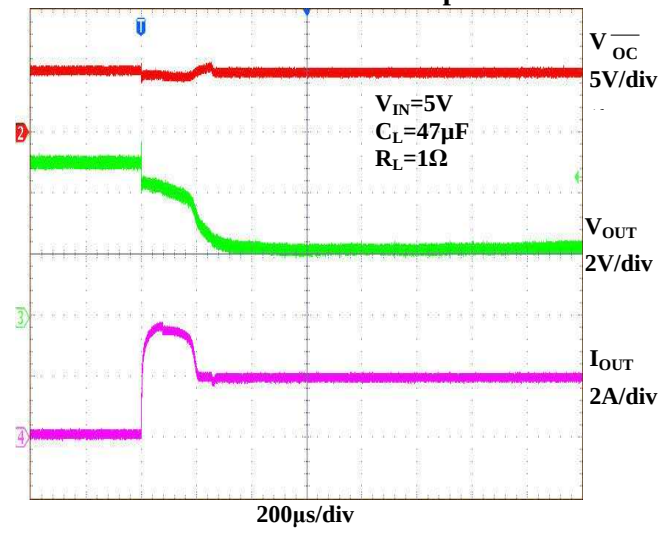
Short Circuit Response at Start Up



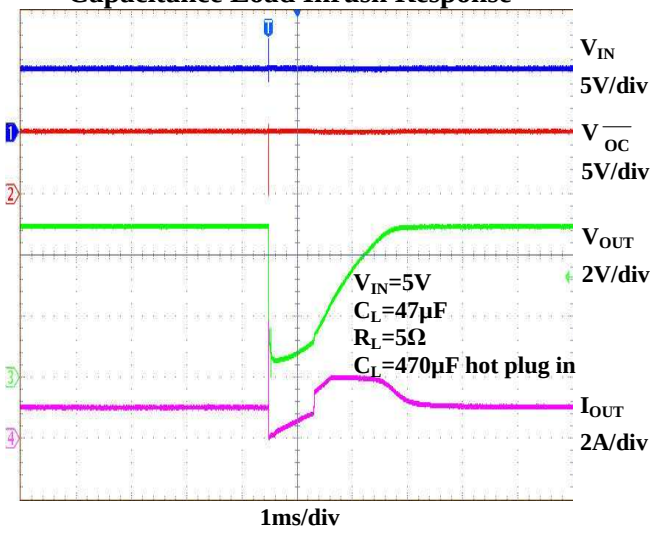
Short Circuit Current, Device Enable into Short



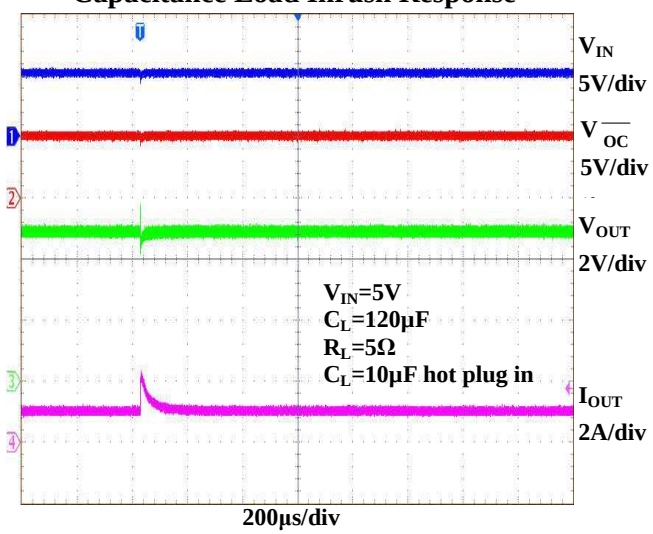
Resistance Load Inrush Response



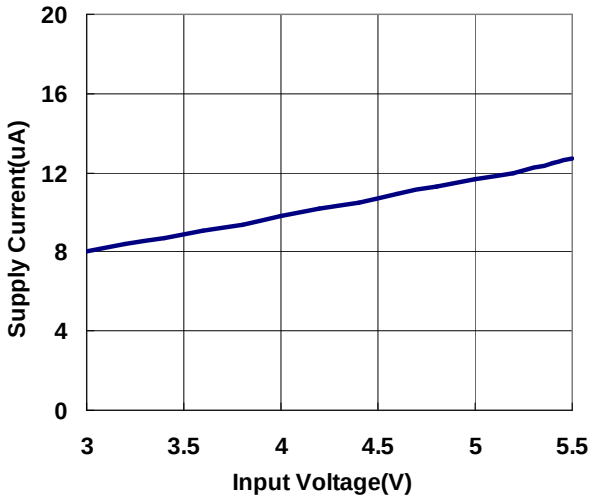
Capacitance Load Inrush Response



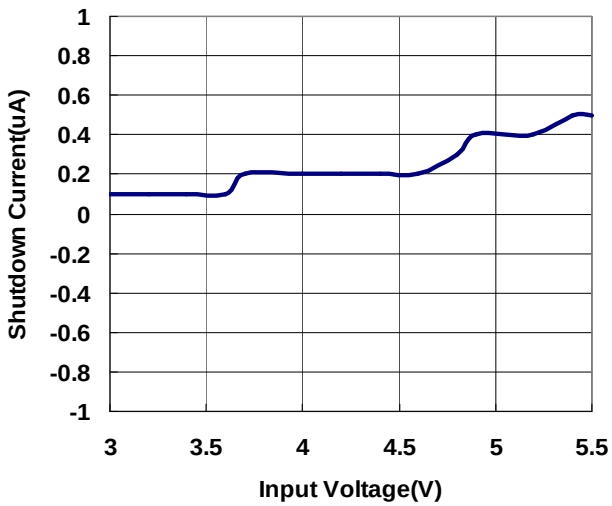
Capacitance Load Inrush Response



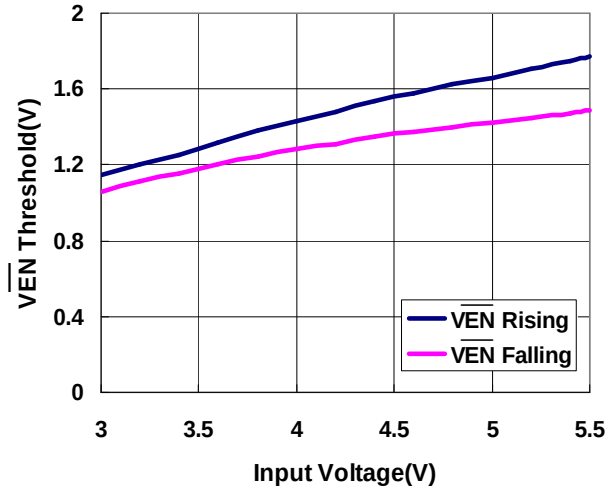
Supply Current vs. Input Voltage



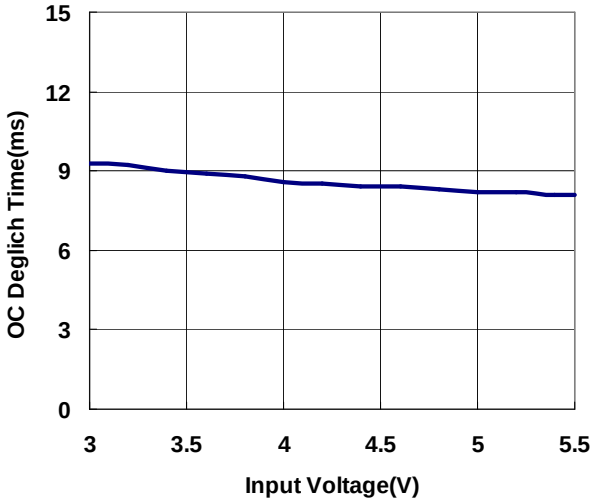
Shutdown Current vs. Input Voltage



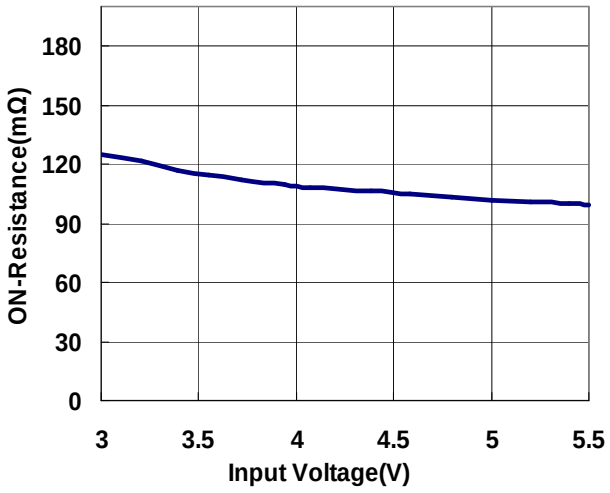
$V_{\overline{EN}}$ Threshold vs. Input Voltage



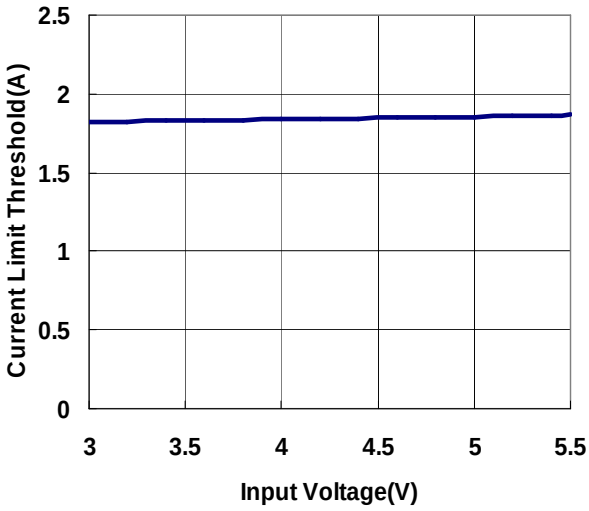
$\overline{OC}$ Deglitch Time vs. Input Voltage



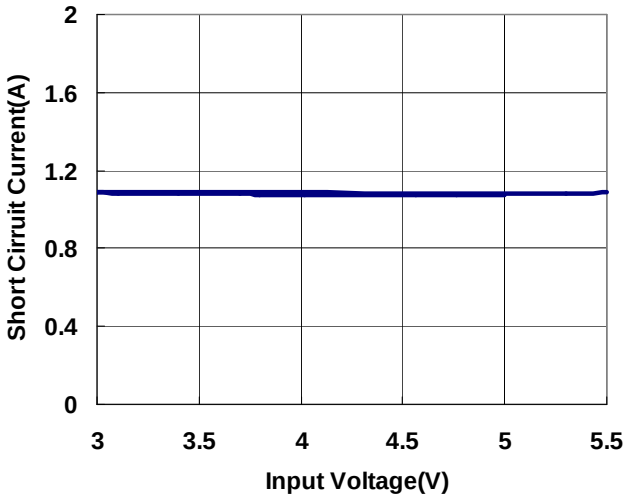
ON-Resistance vs. Input Voltage



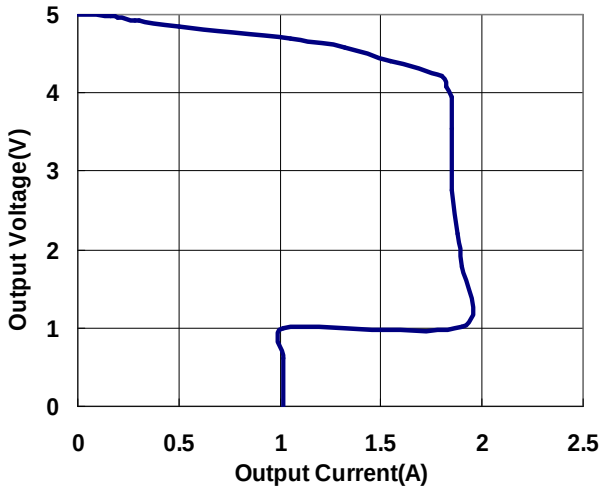
Current Limit Threshold vs. Input Voltage



Short Circuit Current vs. Input Voltage



Output Current vs. Output Voltage



Functional Description

Input and Output

V_{IN} (input) is the power supply connection to the logic circuitry and the source of the power MOSFET. V_{OUT} (output) is the drain of the power MOSFET. In a typical application, current flows through the switch from V_{IN} to V_{OUT} toward the load. All V_{OUT} pins must connect together to the load.

Current Limiting

With the present of a sense FET, over-current conditions can be detected without increasing the series resistance of the current path. Under over-current condition, the device maintains a constant output current and reduces the output voltage accordingly. Complete shutdown occurs only if the fault is present long enough to activate thermal limiting. There are several possible over-current conditions can occur.

- The output has been shorted before the device is enabled or before V_{IN} has been applied, the EUP3545/A senses the short immediately switches into a constant-current limit mode.
- 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 has tripped (reached the over-current trip threshold), the device switches into constant current mode.
- 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 EUP3545/A 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.

The current limit value refer to typical operating characteristics.

Thermal Shutdown

Thermal shutdown protects EUP3545/A from excessive power dissipation. If the die temperature exceeds 135°C, the MOSFETS switch is shut off. 20°C of hystersis prevents the switch from turning on until the die temperature drops to 115°C. Thermal shutdown circuit functions only when the switch is enabled.

Under-Voltage Lockout

Whenever the input voltage falls below approximately 2.1V, the power switch is quickly turned off. This facilitates the design of hot-insertion systems where it is not possible to turn off the power switch before input power is removed. The UVLO also keeps the switch from being turned on until the power supply has reached at least 2.3V, even if the switch is enabled.

$\overline{OC}$ Function

The $\overline{OC}$ open-drain output is asserted (active low) when an over current condition is encountered after a 8ms fault-blanking timeout (to eliminate false over-current reporting). This feature allows the device to handle USB loads that might not be fully compliant with USB specifications. The EUP3545/A successfully powers USB loads with additional bypass capacitance and/or large startup currents while protecting the upstream power source. No fault is reported if the switch brings up the load within the 8ms blanking period.

Application Information

Input Power Supply and Capacitance

Connect all V_{IN} inputs together externally. V_{IN} powers the internal control circuitry. A 1µF bypass capacitor from V_{IN} to GND, located near the EUP3545/A, is strongly recommended to control supply transients. When driving inductive loads or operating from inductive sources, which may occur when the EUP3545/A is powered by long leads or PC traces, larger input bypass capacitance is required to prevent voltage spikes from exceeding the EUP3545/A's absolute maximum ratings (V_{INMAX} = 6V) during short-circuit events.

Output Capacitor

Bypass V_{OUT} to GND with a 1uF ceramic capacitor for local decoupling. 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 reduces output voltage transients under dynamic load conditions. Using output capacitors greater than 470uF might assert $\overline{OC}$ if the current limit cannot charge the output capacitor within the 8ms fault-blanking period.

$\overline{EN}$ or EN, the Enable Logic Input

$\overline{EN}$ must be driven logic low or logic high for a clearly defined input. Floating the input may cause unpredictable operation. $\overline{EN}$ should not be allowed to go negative with respect to GND.

Driving Inductive Loads

A wide variety of devices (mice, keyboards, cameras, and printers) typically connect to the USB port with cables, which might add an inductive component to the load. This inductance causes the output voltage at the USB port to oscillate during a load step. The EUP3545/A drives inductive loads, but avoid exceeding the device's absolute maximum ratings. Usually, the load inductance is relatively small, and the EUP3545/A's input includes a substantial bulk capacitance from an upstream regulator as well as local bypass capacitors, limiting overshoot.

Layout and Thermal Dissipation

Keep all traces as short as possible to reduce the effect of undesirable parasitic inductance and optimize the switch response time to output short circuit conditions. Place input and output capacitors no more than 5mm from device leads. Connect V_{IN} and V_{OUT} to the power bus with short traces. Wide power bus planes at V_{IN} and V_{OUT} provide superior heat dissipation as well.

An active switch dissipates little power with minimal change in package temperature. Calculate the power dissipation for this condition as follows:

$$P = I_{OUT}^2 \times R_{(DS)ON}$$

At the normal operating current (I_{OUT} = 1A) and the maximum on resistance of the switch (150mΩ), the power dissipation is:

$$P = (1A)^2 \times 0.15\Omega = 150mW$$

The worst-case power dissipation occurs when the output current is just below the current limit threshold (2.5A max) with a low output voltage 1V, for example. For a 5V input, the power dissipated is the voltage drop across the switch multiplied by the current limit:

$$P = I_{LIM} \times (V_{IN} - V_{OUT}) = 2.5A \times (5V - 1V) = 10W$$

In this case, the EUP3545/A die temperature exceeds the 135°C thermal shutdown threshold, and the switch output shuts down until the junction temperature cools by 20°C. The duty cycle and period are strong functions of the ambient temperature and the PC board layout (see the Thermal Shutdown section). If the output current exceeds the current limit threshold, the EUP3545/A asserts a fault state after 8ms.

Test Circuit

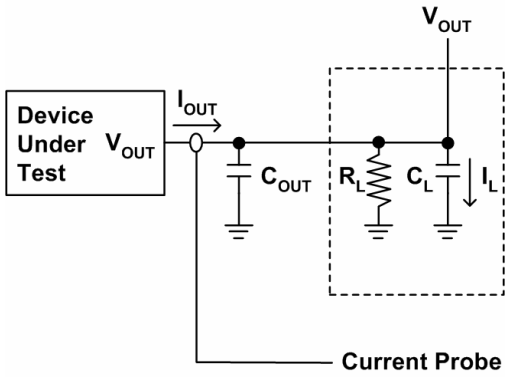


Figure 3.

Timing Diagrams

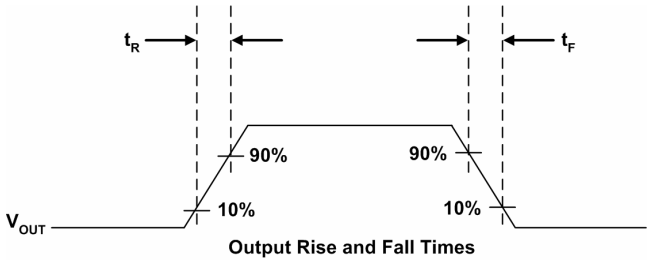
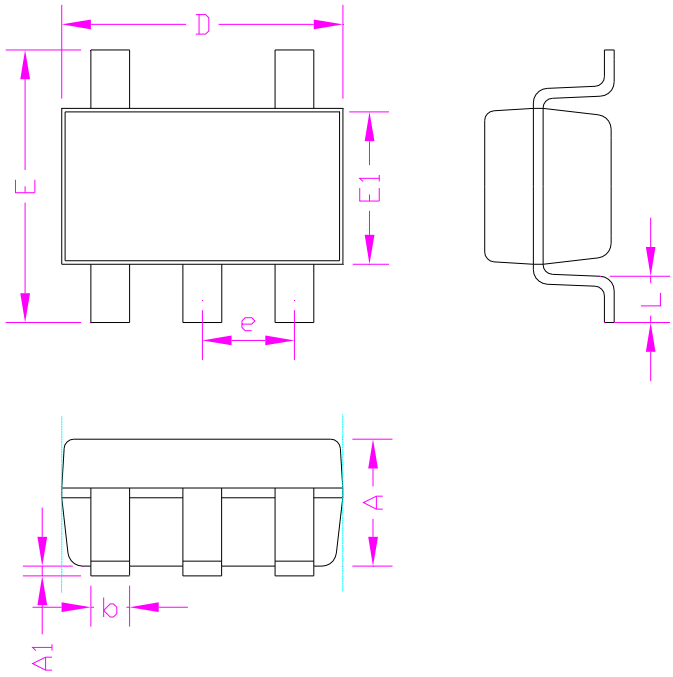


Figure 4.

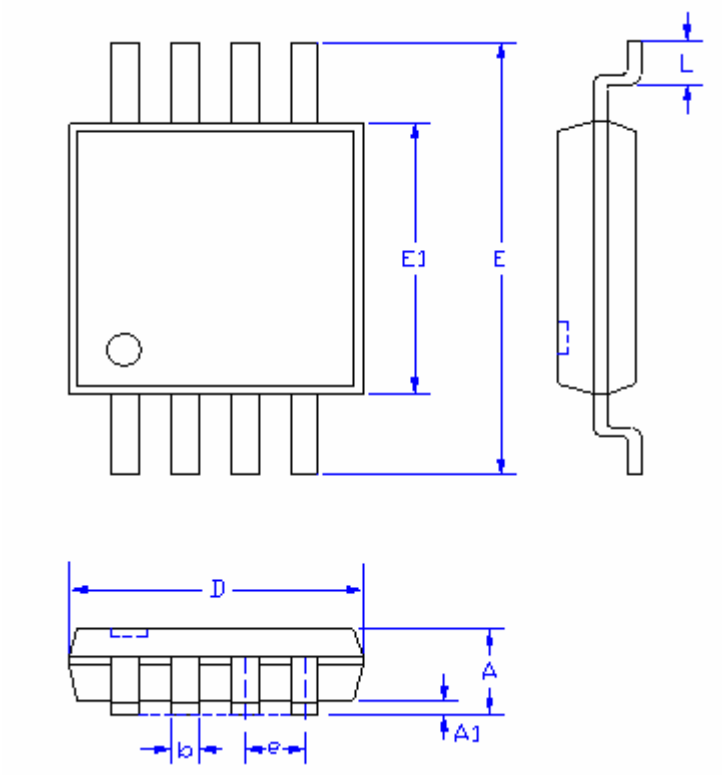
Packaging Information

SOT23-5



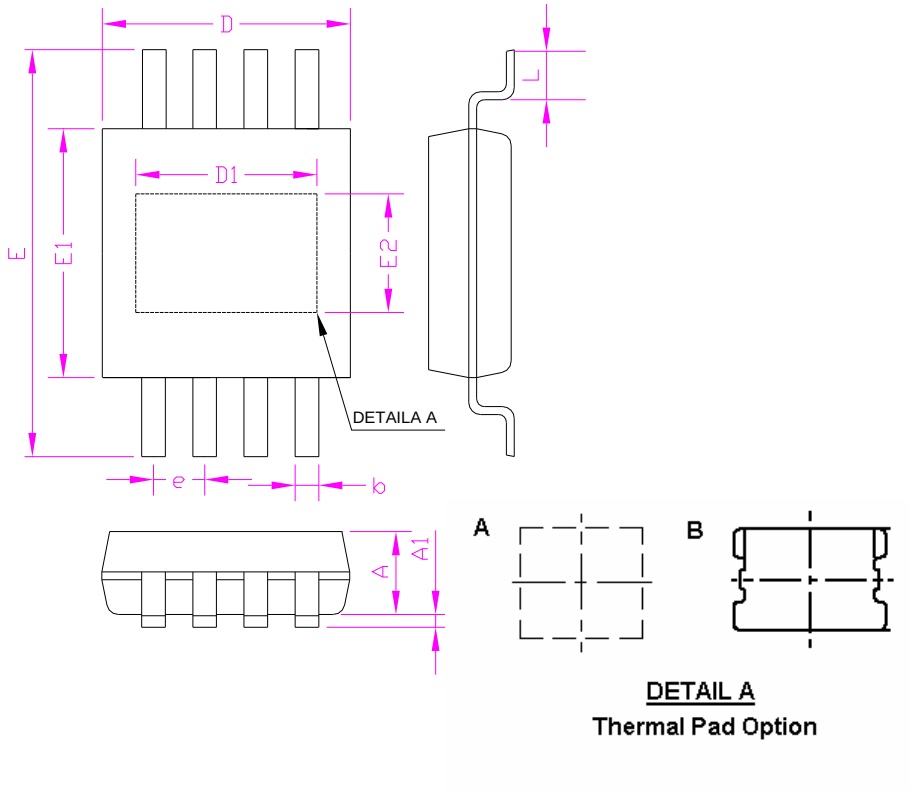
SYMBOLS	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A	-	1.30	-	0.052
A1	0.00	0.15	0.000	0.006
D	2.90		0.114	
E1	1.60		0.063	
E	2.60	3.00	0.102	0.118
L	0.30	0.60	0.012	0.024
b	0.30	0.50	0.012	0.020
e	0.95		0.037	

MSOP-8



SYMBOLS	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A	-	1.10	-	0.043
A1	0.00	0.15	0.000	0.006
D	3.00		0.118	
E1	3.00		0.118	
E	4.70	5.10	0.185	0.201
L	0.40	0.80	0.016	0.031
b	0.22	0.38	0.008	0.015
e	0.65		0.026	

MSOP-8 (EP)



SYMBOLS	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A	-	1.10	-	0.043
A1	0.00	0.15	0.000	0.006
D	3.00		0.118	
E	4.70	5.10	0.185	0.201
E1	3.00		0.118	
D1	1.28	2.30	0.050	0.091
E2	1.21	1.72	0.048	0.068
L	0.40	0.80	0.016	0.031
b	0.22	0.38	0.008	0.015
e	0.65		0.026	