

## Description

The AP2401 and AP2411 are single channel current-limited integrated high-side power switches optimized for Universal Serial Bus (USB) and other hot-swap applications. The family of devices complies with USB standards and is available with both polarities of Enable input.

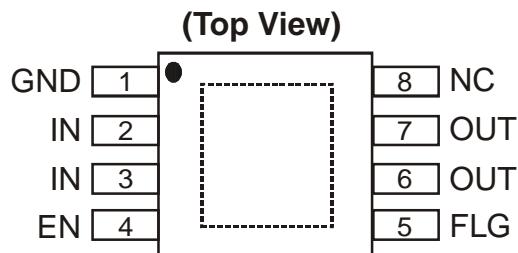
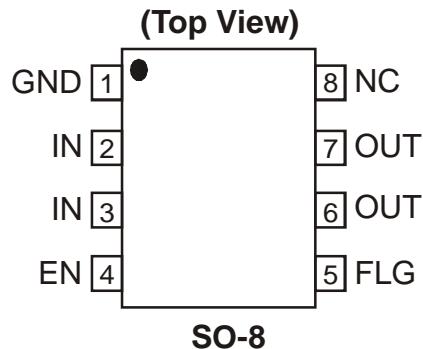
The devices have fast short-circuit response time for improved overall system robustness, and have integrated output discharge function to ensure completely controlled discharging of the output voltage capacitor. They provide a complete protection solution for applications subject to heavy capacitive loads and the prospect of short circuit, and offer reverse current blocking, over-current, over-temperature and short-circuit protection, as well as controlled rise time and under-voltage lockout functionality. A 7ms deglitch capability on the open-drain Flag output prevents false over-current reporting and does not require any external components. AP2401 and AP2411 will be latched off after 7ms deglitch.

All devices are available in SO-8, MSOP-8, MSOP-8EP and U-DFN3030-8 packages.

## Features

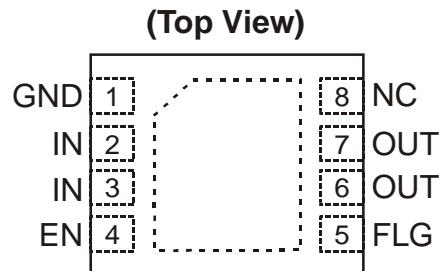
- Single channel current-limited power switch
- Output discharge function
- Output current latch-off when OCP triggered
- Fast short-circuit response time: 2µs
- 2.5A accurate current limiting
- Reverse current blocking
- 70mΩ on-resistance
- Input voltage range: 2.7V – 5.5V
- Built-in soft-start with 0.6ms typical rise time
- Over-current and thermal protection
- Fault report (FLG) with blanking time (7ms typ)
- ESD protection: 4KV HBM, 300V MM
- Active low (AP2401) or active high (AP2411) enable
- Ambient temperature range: -40°C to 85°C
- SO-8, MSOP-8, MSOP-8EP and U-DFN3030-8:  
Available in "Green" Molding Compound (No Br, Sb)
- Lead Free Finish / RoHS Compliant (Note 1)
- UL Recognized, File Number E322375
- IEC60950-1 CB Scheme Certified

## Pin Assignments



### MSOP-8/MSOP-8EP

Note: Latter with exposed pad  
(dotted line)



### U-DFN3030-8

## Applications

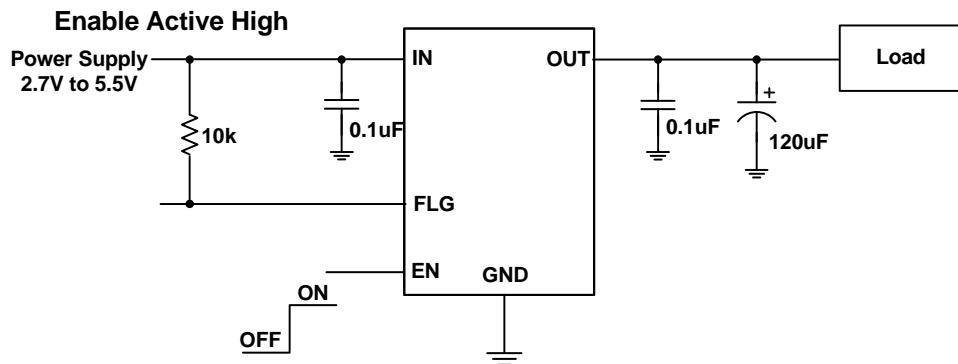
- LCD TVs & Monitors
- Set-Top-Boxes, Residential Gateways
- Laptops, Desktops, Servers, e-Readers
- Printers, Docking Stations, HUBs

Note: 1. EU Directive 2002/95/EC (RoHS). All applicable RoHS Exemptions Applied. See EU Directive 2002/95/EC Annex Notes.

---

**Typical Application Circuit**


---


**Available Options**

Part Number	Channel	Enable pin (EN)	Recommended maximum continuous load current (A)	Typical current limit (A)	Package
AP2401	1	Active Low	2.0A	2.5A	SO-8 MSOP-8 MSOP-8EP U-DFN3030-8
AP2411	1	Active High			

---

**Pin Descriptions**

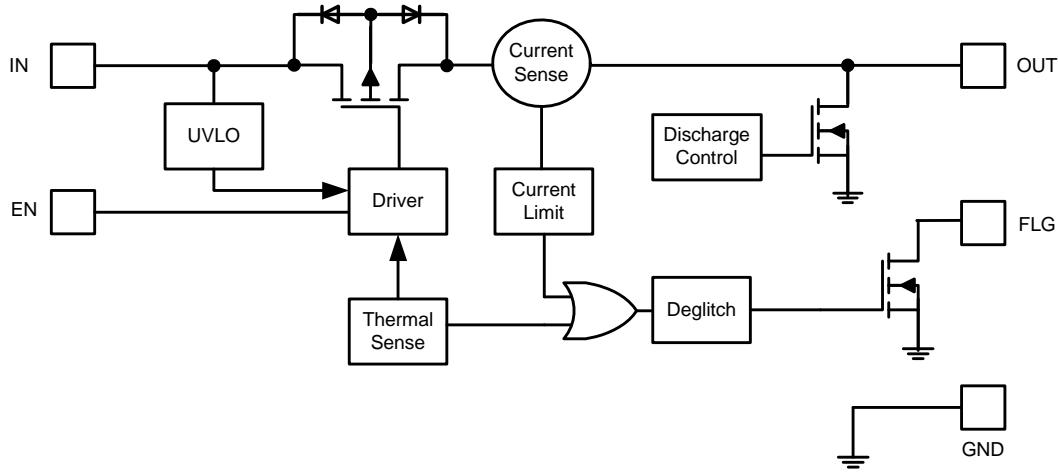

---

Pin Name	Pin Number	Descriptions
GND	1	Ground
IN	2, 3	Voltage input pin; connect a 0.1µF or larger ceramic capacitor from IN to GND as close as possible. (all IN pins must be tied together externally)
EN	4	Enable input, active low (AP2401) or active high (AP2411)
FLG	5	Over-temperature and over-current fault reporting with 7ms deglitch; active low open-drain output. FLG is disabled for 7ms after turn-on.
OUT	6, 7	Voltage output pin (all OUT pins must be tied together externally)
NC	8	No internal connection; recommend tie to OUT pins
Exposed Pad	-	Internally connected to GND; recommend connecting to the GND externally for improved power dissipation

---

**Functional Block Diagram**


---




---

**Absolute Maximum Ratings**


---

Symbol	Parameter	Ratings	Unit
ESD HBM	Human Body Model ESD Protection	4	KV
ESD MM	Machine Model ESD Protection	300	V
$V_{IN}$	Input Voltage	6.5	V
$V_{OUT}$	Output Voltage	$V_{IN} + 0.3$	V
$V_{EN}, V_{FLG}$	Enable Voltage	6.5	V
$I_{load}$	Maximum Continuous Load Current	Internal Limited	A
$T_{Jmax}$	Maximum Junction Temperature	150	°C
$T_{ST}$	Storage Temperature Range (Note 2)	-65 to 150	°C

Note: 2. UL Recognized Rating from -30°C to 70°C (Diodes qualified  $T_{ST}$  from -65°C to 150°C)

---

**Recommended Operating Conditions**


---

Symbol	Parameter	Min	Max	Unit
$V_{IN}$	Input voltage	2.7	5.5	V
$I_{OUT}$	Output Current	0	2.0	A
$T_A$	Operating Ambient Temperature	-40	85	°C

**Electrical Characteristics (T<sub>A</sub> = 25°C, V<sub>IN</sub> = +5.0V, C<sub>IN</sub> = 0.1µF, C<sub>L</sub> = 1µF, unless otherwise specified)**

Symbol	Parameter	Test Conditions (Note 3)	Min	Typ.	Max	Unit	
V <sub>UVLO</sub>	Input UVLO	V <sub>IN</sub> rising	1.6	2.0	2.4	V	
ΔV <sub>UVLO</sub>	Input UVLO Hysteresis	V <sub>IN</sub> decreasing		50		mV	
I <sub>SHDN</sub>	Input Shutdown Current	Disabled, OUT = open		0.1	1	µA	
I <sub>Q</sub>	Input Quiescent Current	Enabled, OUT = open		60	100	µA	
I <sub>LEAK</sub>	Input Leakage Current	Disabled, OUT grounded		0.1	1	µA	
I <sub>REV</sub>	Reverse Leakage Current	Disabled, V <sub>IN</sub> = 0V, V <sub>OUT</sub> = 5V, I <sub>REV</sub> at V <sub>IN</sub>		0.01	1	µA	
R <sub>DS(ON)</sub>	Switch on-resistance	V <sub>IN</sub> = 5V, I <sub>OUT</sub> = 2.0A	T <sub>A</sub> = 25°C	70	84	mΩ	
			-40°C ≤ T <sub>A</sub> ≤ 85°C		105		
		V <sub>IN</sub> = 3.3V, I <sub>OUT</sub> = 2.0A	T <sub>A</sub> = 25°C	90	108		
			-40°C ≤ T <sub>A</sub> ≤ 85°C		135		
I <sub>LIMIT</sub>	Over-Load Current Limit (Note 3)	V <sub>IN</sub> = 5V, V <sub>OUT</sub> = 4.5V	-40°C ≤ T <sub>A</sub> ≤ 85°C	2.0	2.5	2.85	A
I <sub>Trig</sub>	Current limiting trigger threshold	Output Current Slew rate (<100A/s)		2.5			A
I <sub>SHORT</sub>	Short-Circuit Current Limit	Enabled into short circuit		2.1	2.75	3.3	A
T <sub>SHORT</sub>	Short-circuit Response Time	V <sub>OUT</sub> = 0V to I <sub>OUT</sub> = I <sub>LIMIT</sub> (OUT shorted to ground)		2			µs
V <sub>IL</sub>	EN Input Logic Low Voltage	V <sub>IN</sub> = 2.7V to 5.5V			0.8	V	
V <sub>IH</sub>	EN Input Logic High Voltage	V <sub>IN</sub> = 2.7V to 5.5V	2			V	
I <sub>LEAK-EN</sub>	EN Input leakage	V <sub>IN</sub> = 5V, V <sub>EN</sub> = 0V and 5.5V		0.01	1	µA	
I <sub>LEAK-O</sub>	Output leakage current	Disabled, V <sub>OUT</sub> = 0V		0.5	1	µA	
T <sub>D(ON)</sub>	Output turn-on delay time	C <sub>L</sub> = 1µF, R <sub>load</sub> = 5Ω		0.1			ms
T <sub>R</sub>	Output turn-on rise time	C <sub>L</sub> = 1µF, R <sub>load</sub> = 5Ω		0.6	1.5		ms
T <sub>D(OFF)</sub>	Output turn-off delay time	C <sub>L</sub> = 1µF, R <sub>load</sub> = 5Ω		0.1			ms
T <sub>F</sub>	Output turn-off fall time	C <sub>L</sub> = 1µF, R <sub>load</sub> = 5Ω		0.05	0.1		ms
R <sub>FLG</sub>	FLG output FET on-resistance	I <sub>FLG</sub> = 10mA		20	40		Ω
I <sub>FOH</sub>	FLG Off Current	V <sub>FLG</sub> = 5V		0.01	1		µA
T <sub>Blank</sub>	FLG blanking and latch off time	Assertion or deassertion due to overcurrent and over-temperature condition	4	7	15		ms
T <sub>DIS</sub>	Discharge time	C <sub>L</sub> = 1µF, V <sub>IN</sub> = 5V, disabled to V <sub>OUT</sub> < 0.5V		0.6			ms
R <sub>DIS</sub>	Discharge resistance (Note 4)	V <sub>IN</sub> = 5V, disabled, I <sub>OUT</sub> = 1mA		100			Ω
T <sub>SHDN</sub>	Thermal Shutdown Threshold	Enabled		140			°C
T <sub>HYS</sub>	Thermal Shutdown Hysteresis			20			°C
θ <sub>JA</sub>	Thermal Resistance Junction-to-Ambient	SO-8 (Note 5)		96			°C/W
		MSOP-8 (Note 5)		130			°C/W
		MSOP-8EP (Note 6)		92			°C/W
		U-DFN3030-8 (Note 6)		84			°C/W

Notes:

- Pulse-testing techniques maintain junction temperature close to ambient temperature; thermal effects must be taken into account separately.
- The discharge function is active when the device is disabled (when enable is de-asserted or during power-up power-down when V<sub>IN</sub> < V<sub>UVLO</sub>). The discharge function offers a resistive discharge path for the external storage capacitor for limited time.
- Device mounted on 2" x 2" FR-4 substrate PCB, 2oz copper, with minimum recommended pad layout.
- Device mounted on 2" x 2" FR-4 substrate PCB, 2oz copper, with minimum recommended pad on top layer and thermal vias to bottom layer ground plane.

## Typical Performance Characteristics

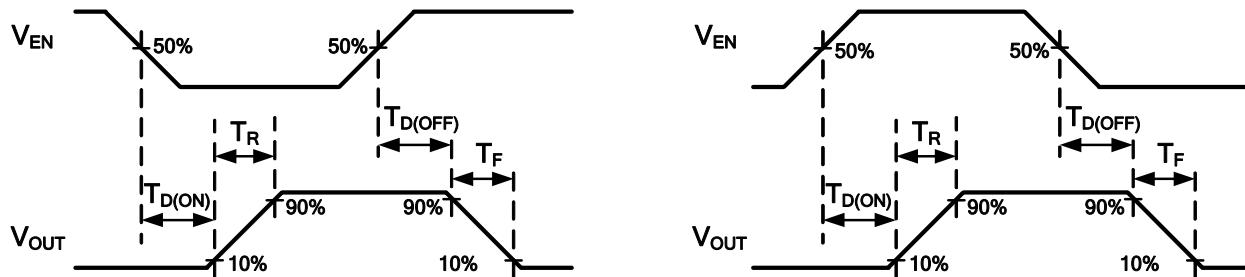
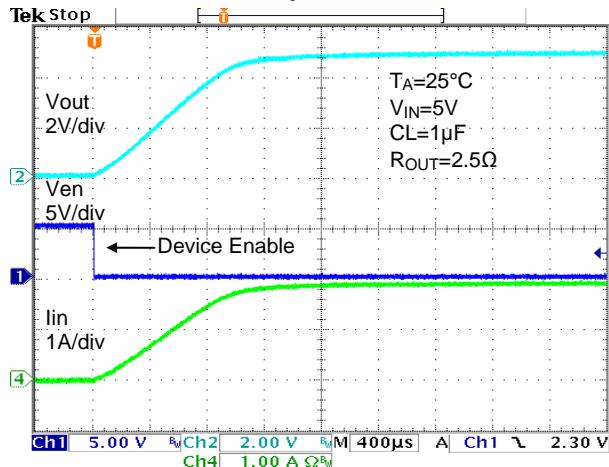


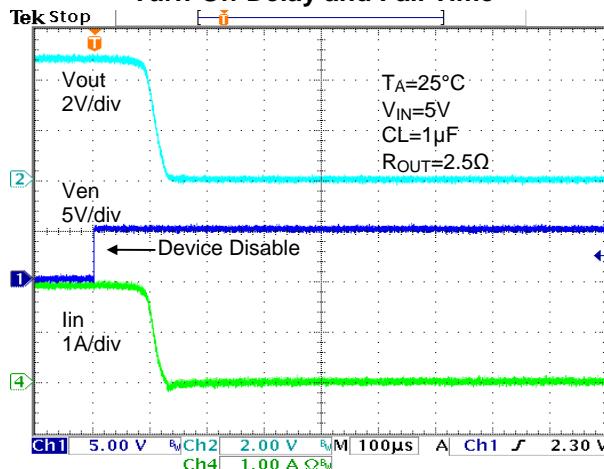
Figure 1. Voltage Waveforms: AP2401 (left), AP2411 (right)

All Enable Plots are for Enable Active Low

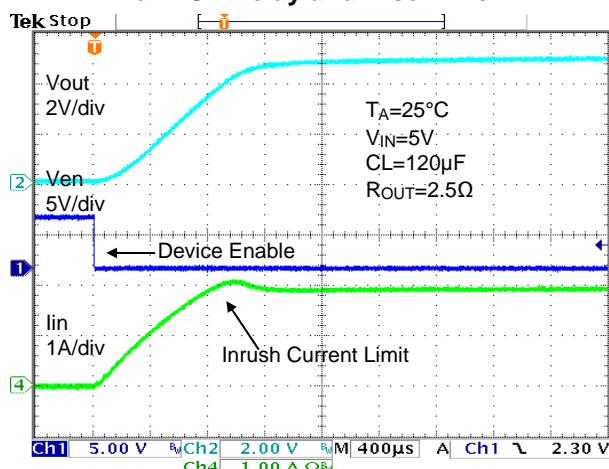
### Turn-On Delay and Rise Time



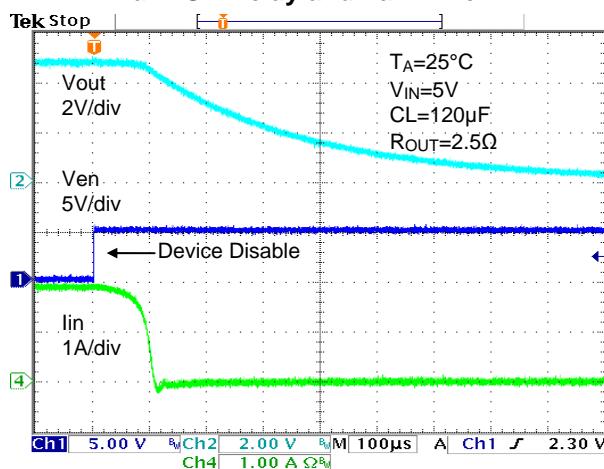
### Turn-Off Delay and Fall Time



### Turn-On Delay and Rise Time

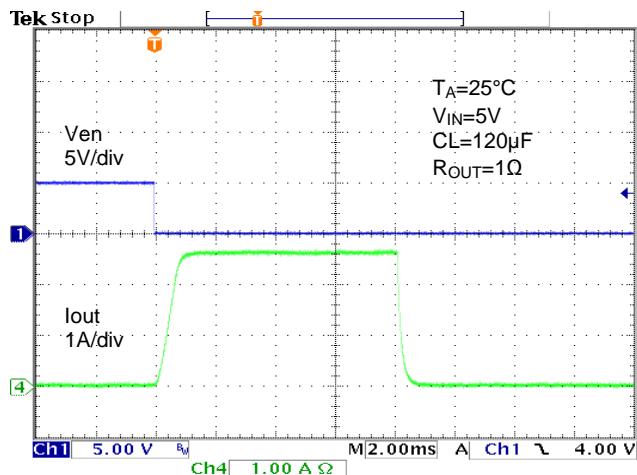


### Turn-Off Delay and Fall Time

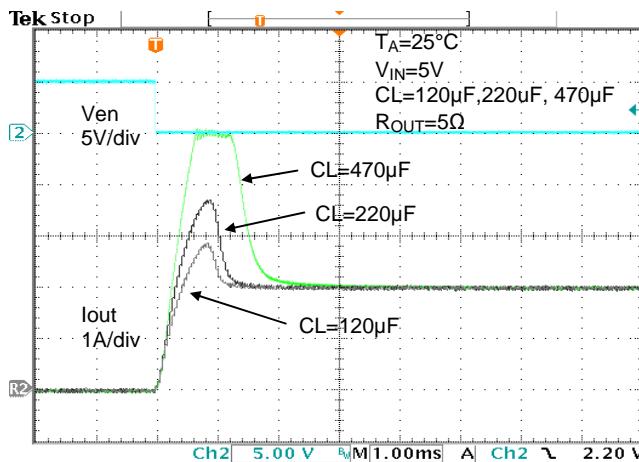


**Typical Performance Characteristics (cont.)**

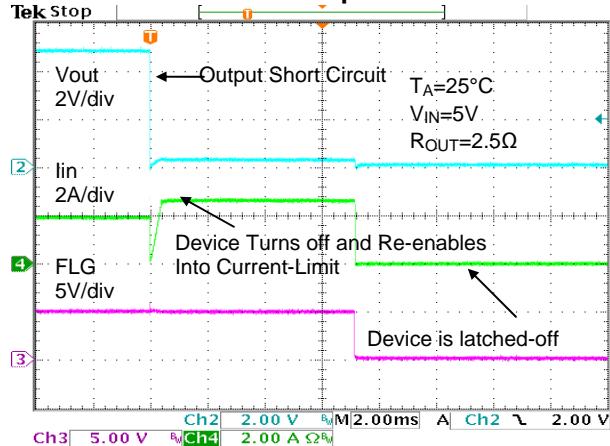
**Device Enabled Into Short-Circuit**



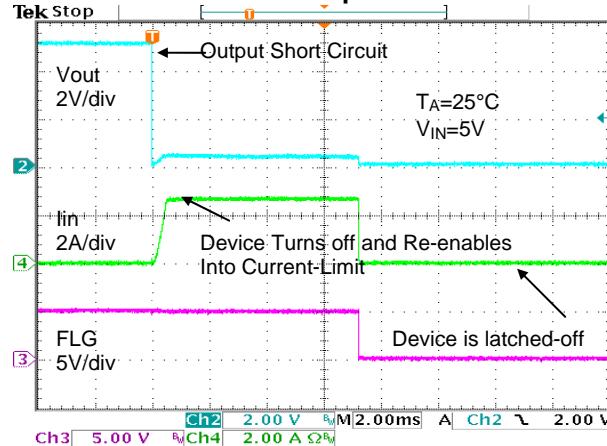
**Inrush Current**



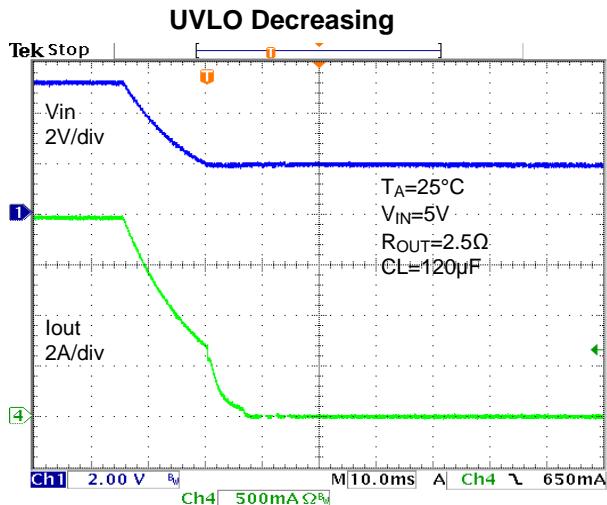
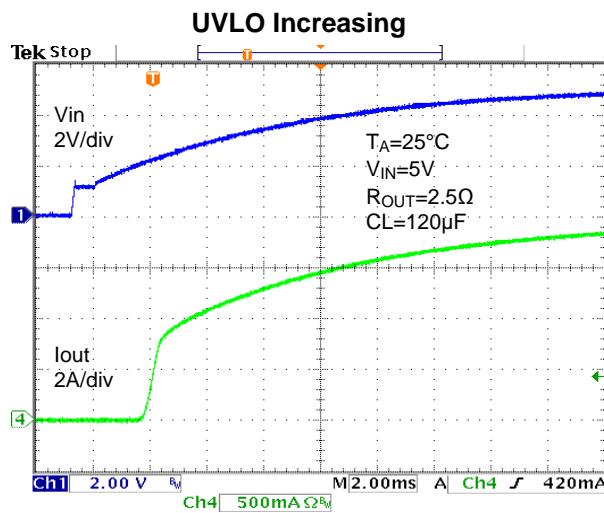
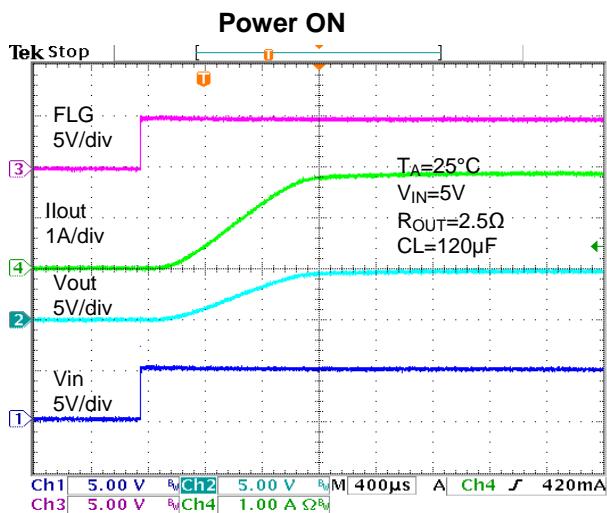
**Full-Load to Short-Circuit  
Transient Response**



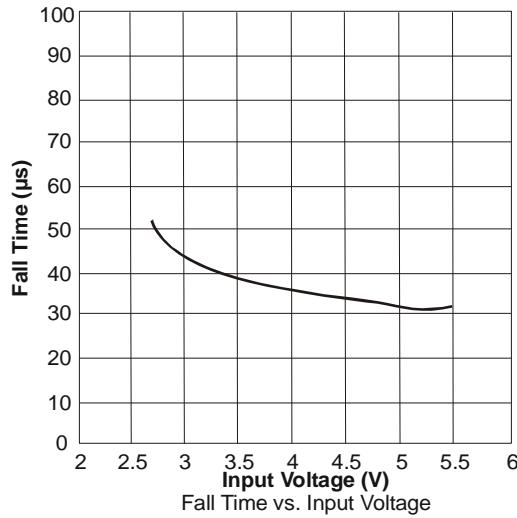
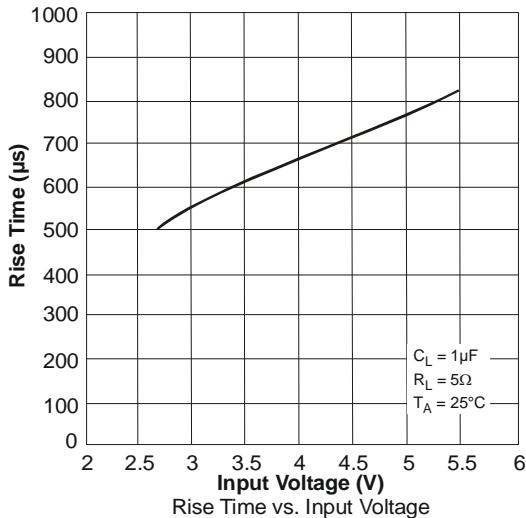
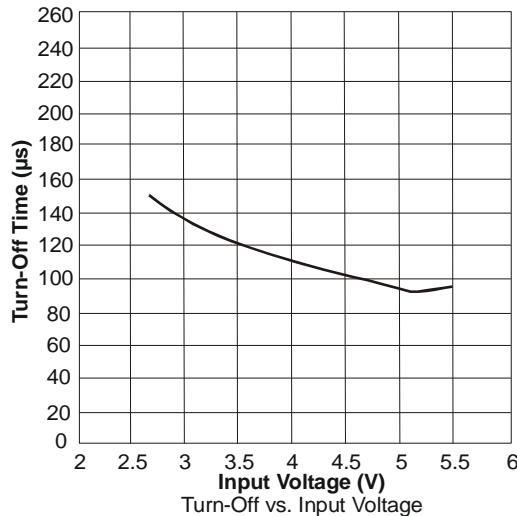
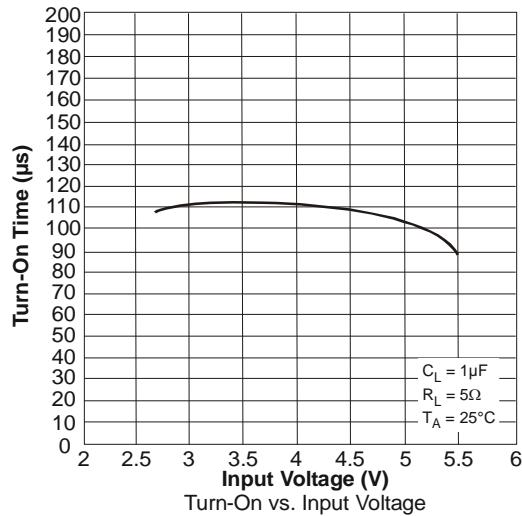
**No-Load to Short-Circuit  
Transient Response**



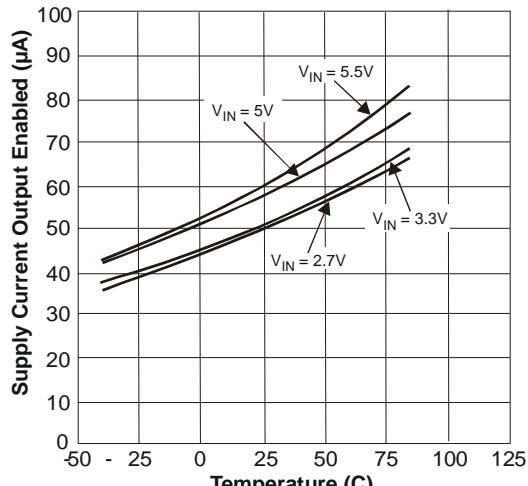
**Typical Performance Characteristics (cont.)**



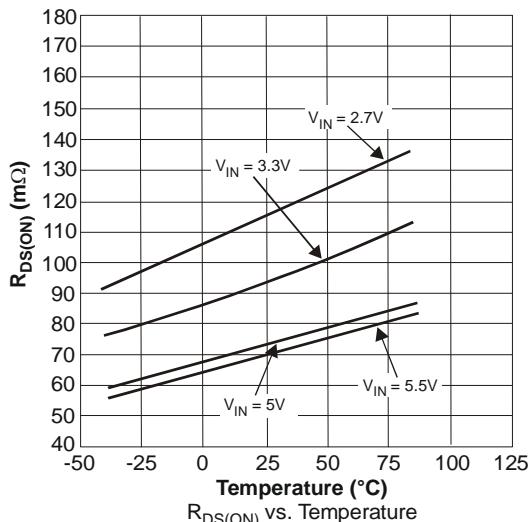
**Typical Performance Characteristics (cont.)**



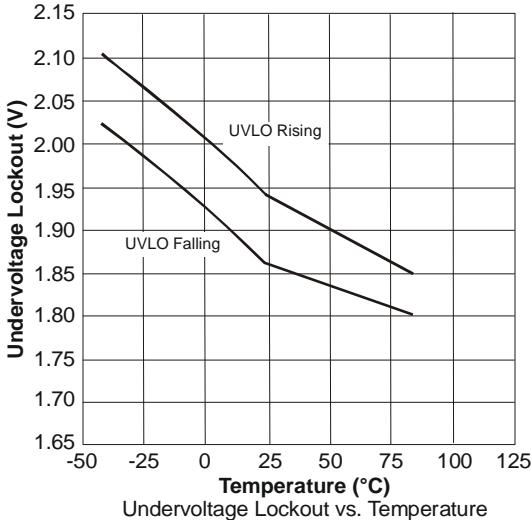
**Typical Performance Characteristics (cont.)**



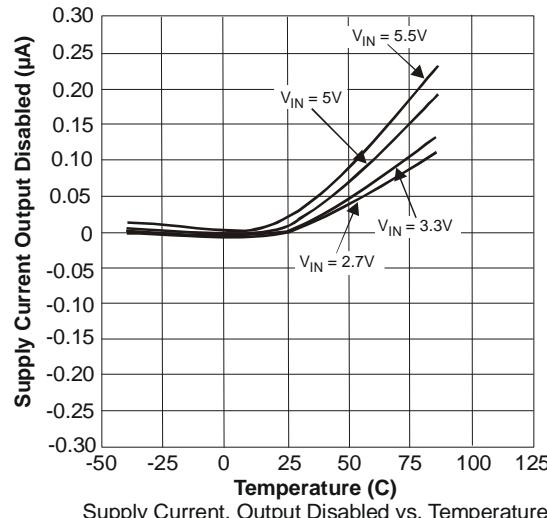
Supply Current, Output Enabled vs. Temperature



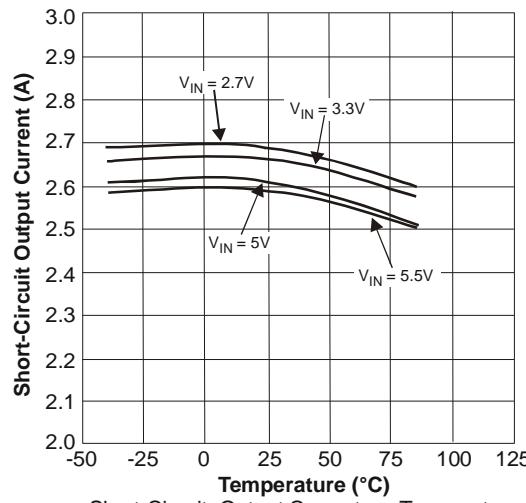
R<sub>DS(ON)</sub> vs. Temperature



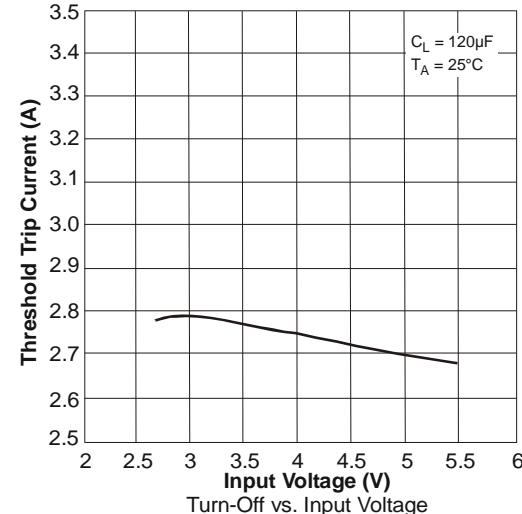
Undervoltage Lockout vs. Temperature



Supply Current, Output Disabled vs. Temperature



Short-Circuit, Output Current vs. Temperature



Turn-Off vs. Input Voltage

### Application Notes

#### Power Supply Considerations

A  $0.1\mu\text{F}$  to  $2.2\mu\text{F}$  X7R or X5R ceramic bypass capacitor placed between IN and GND, close to the device, is recommended. When an external power supply is used, or an additional ferrite bead is added to the input, high inrush current may cause voltage spikes higher than the device maximum input rating during short circuit condition. In this case a  $2.2\mu\text{F}$  or bigger capacitor is recommended. Placing a high-value electrolytic capacitor on the input and output pin(s) is recommended when the output load is heavy. This precaution reduces power-supply transients that may cause ringing on the input. Additionally, bypassing the output with a  $0.1\mu\text{F}$  to  $1.0\mu\text{F}$  ceramic capacitor improves the immunity of the device to short circuit transients.

#### Over-current and Short Circuit Protection

An internal sensing FET is employed to check for over-current conditions. Unlike current-sense resistors, sense FETs do not increase the series resistance of the current path. When an overcurrent condition is detected, the devices will limit the current until the overload condition is removed or the internal deglitch time (7-ms typical) is reached and the device is turned off. The device will remain latched off even overload condition is removed until power is cycled or the device enable is toggled.

Three possible overload conditions can occur. In the first condition, the output has been shorted to GND before the device is enabled or before VIN has been applied. The AP2401/AP2411 senses the short circuit and immediately clamps output current to a certain safe level namely  $I_{LIMIT}$ , and turns off after deglitch time(7-ms typical).

In the second condition, an output short or an overload occurs while the device is enabled. At the instance the overload occurs, higher current may flow for a very short period of time before the current limit function can react. After the current limit function has tripped (reached the over-current trip threshold), the device switches into current limiting mode and the current is clamped at  $I_{LIMIT}$  current for deglitch time period (7-ms typical), and then turned off.

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 ( $I_{TRIG}$ ) is reached or until the thermal limit of the device is exceeded. The AP2401/AP2411 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 current limiting

mode and output current is clamped at  $I_{LIMIT}$  for deglitch time period (7-ms typical), and then turned off.

#### FLG Response

When an over-current or over-temperature shutdown condition is encountered, the FLG open-drain output goes active low after a nominal 7-ms deglitch timeout.

When that happens, the FLG will remain low and the switch will be latched off until the fault condition is removed. Connecting a heavy capacitive load to the output of the device can cause a momentary over-current condition, which does not trigger the FLG due to the 7-ms deglitch timeout. The AP2401/AP2411 is designed to eliminate false over-current reporting without the need of external components to remove unwanted pulses.

#### Power Dissipation and Junction Temperature

The low on-resistance of the internal MOSFET allows the small surface-mount packages to pass large current. Using the maximum operating ambient temperature (TA) and  $R_{DS(ON)}$ , the power dissipation can be calculated by:

$$P_D = R_{DS(ON)} \times I^2$$

Finally, calculate the junction temperature:

$$T_J = P_D \times R_{\theta JA} + T_A$$

Where:

$T_A$  = Ambient temperature $^{\circ}\text{C}$

$R_{\theta JA}$  = Thermal resistance

$P_D$  = Total power dissipation

#### Thermal Protection

Thermal protection prevents the IC from damage when heavy-overload or short-circuit faults are present for extended periods of time. The AP2401/AP2411 implements a thermal sensing to monitor the operating junction temperature of the power distribution switch. Once the die temperature rises to approximately  $140^{\circ}\text{C}$  due to excessive power dissipation in an over-current condition, 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 allowing the device to cool down approximately  $25^{\circ}\text{C}$  before the switch turns back on. The switch continues to cycle in this manner until the load fault or input power is removed. The FLG open-drain output is asserted when an over-temperature shutdown occurs with 7-ms deglitch.



## AP2401/AP2411

## 2.0A SINGLE CHANNEL CURRENT-LIMITED POWER SWITCH WITH LATCH-OFF

---

## Application Notes

## Thermal Protection (cont.)

When the FLG is asserted, the switch will be latched off until the temperature drops to 20°C below the thermal shutdown threshold and the power or EN pin is cycled.

## Under-Voltage Lockout (UVLO)

Under-voltage lockout function (UVLO) keeps the internal power switch from being turned on until the power supply has reached at least 2V, even if the switch is enabled. Whenever the input voltage falls below approximately 2V, the power switch is quickly turned off. This facilitates the

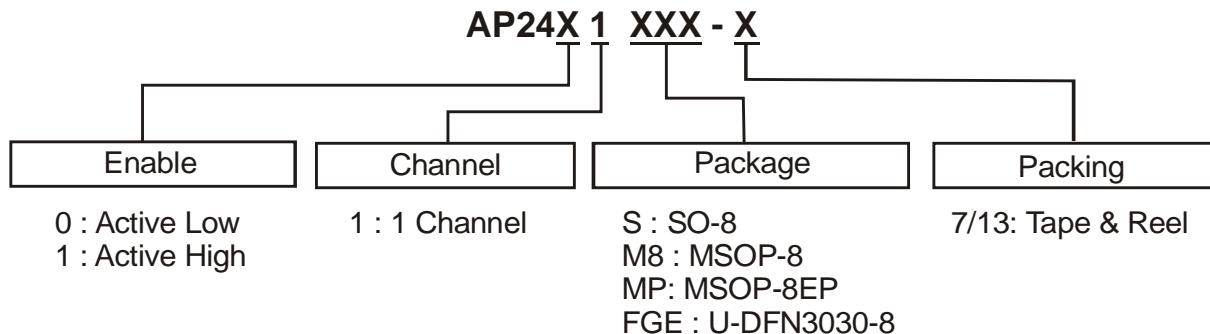
design of hot-insertion systems where it is not possible to turn off the power switch before input power is removed.

## Discharge Function

The discharge function of the device is active when enable is disabled or de-asserted. The discharge function with the N-MOS power switch implementation is activated and offers a resistive discharge path for the external storage capacitor. This is designed for discharging any residue of the output voltage when either no external output resistance or load resistance is present at the output.

---

## Ordering Information

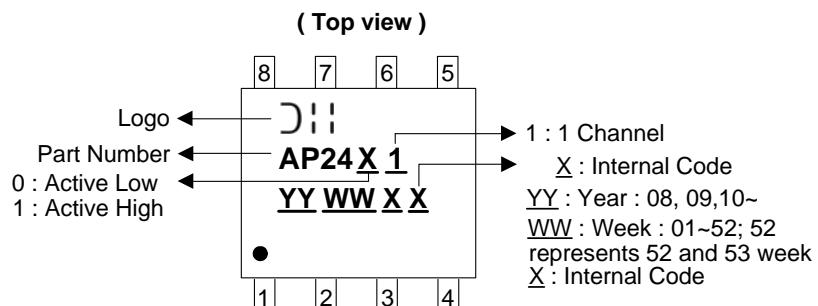


Device	Package Code	Packaging (Note 7)	7"/13" Tape and Reel	
			Quantity	Part Number Suffix
AP24X1S-13	S	SO-8	2500/Tape & Reel	-13
AP24X1M8-13	M8	MSOP-8	2500/Tape & Reel	-13
AP24X1MP-13	MP	MSOP-8EP	2500/Tape & Reel	-13
AP24X1FGE-7	FGE	U-DFN3030-8	3000/Tape & Reel	-7

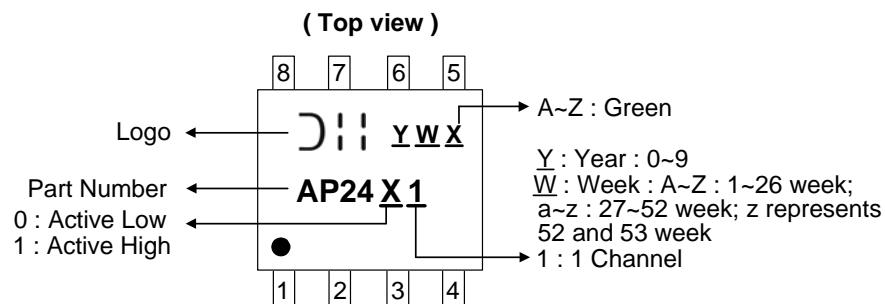
Note: 7. Pad layout as shown on Diodes Inc. suggested pad layout document AP02001, which can be found on our website at <http://www.diodes.com/datasheets/ap02001.pdf>.

## Marking Information

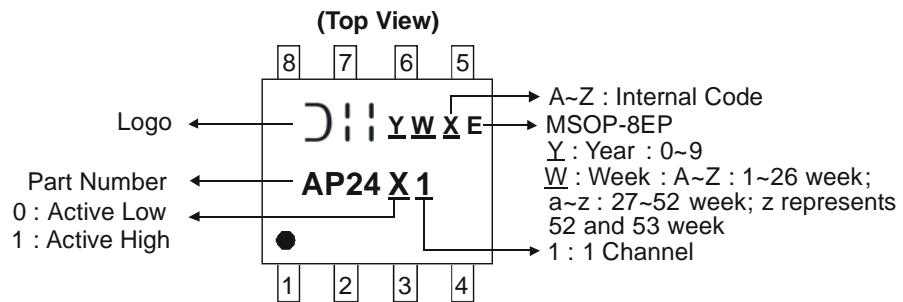
### (1) SO-8



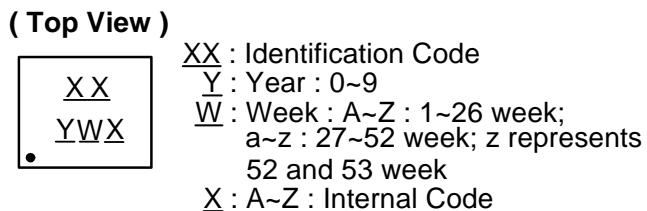
### (2) MSOP-8



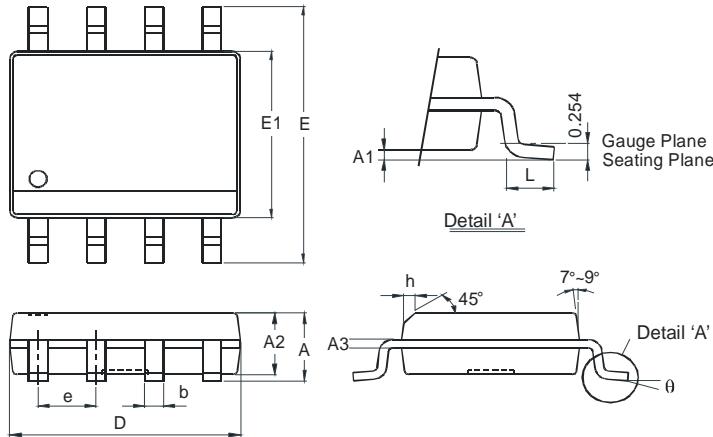
### (3) MSOP-8EP



### (4) U-DFN3030-8

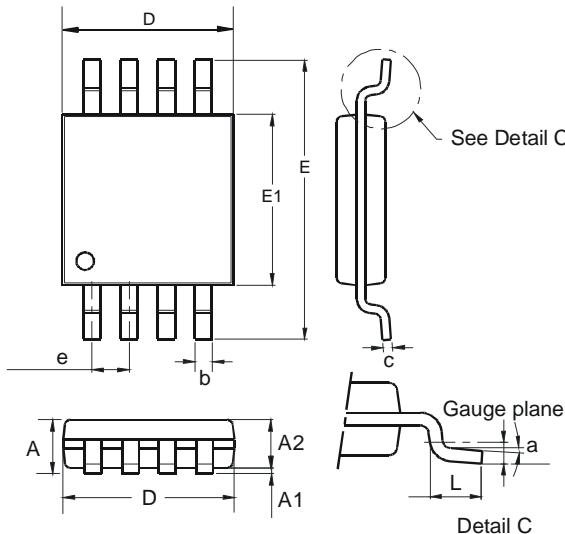


Part Number	Package	Identification Code
AP2401FGE-7	U-DFN3030-8	BD
AP2411FGE-7	U-DFN3030-8	BF

**Package Outline Dimensions (All Dimensions in mm)**
**1. Package type: SO-8**


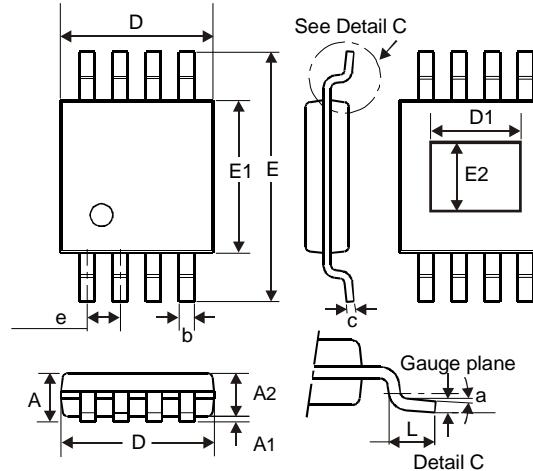
SO-8		
Dim	Min	Max
<b>A</b>	-	1.75
<b>A1</b>	0.10	0.20
<b>A2</b>	1.30	1.50
<b>A3</b>	0.15	0.25
<b>b</b>	0.3	0.5
<b>D</b>	4.85	4.95
<b>E</b>	5.90	6.10
<b>E1</b>	3.85	3.95
<b>e</b>	1.27 Typ	
<b>h</b>	-	0.35
<b>L</b>	0.62	0.82
<b>θ</b>	0°	8°

All Dimensions in mm

**2. Package type: MSOP-8**


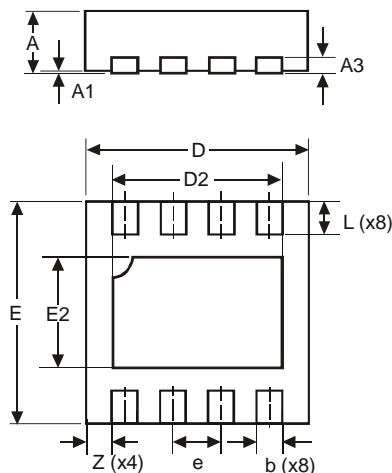
MSOP-8				
Dim	Min	Max	Typ	
<b>a</b>	0°	6°	4°	
<b>A</b>	—	1.10	—	
<b>A1</b>	0.05	0.15	0.10	
<b>A2</b>	0.75	0.95	0.86	
<b>b</b>	0.22	0.38	0.30	
<b>c</b>	0.08	0.23	0.15	
<b>D</b>	2.90	3.05	3.00	
<b>e</b>	—	—	0.65	
<b>E</b>	4.80	5.00	4.90	
<b>E1</b>	2.90	3.00	3.10	
<b>L</b>	0.40	0.80	0.60	

All Dimensions in mm

**Package Outline Dimensions (cont.) (All Dimensions in mm)**
**3. Package type: MSOP-8EP**


MSOP-8EP			
Dim	Min	Typ	Max
<b>A</b>	-	1.10	-
<b>A1</b>	0.05	0.15	0.10
<b>A2</b>	0.75	0.95	0.86
<b>b</b>	0.22	0.38	0.30
<b>c</b>	0.08	0.23	0.15
<b>D</b>	2.90	3.10	3.00
<b>D1</b>	1.65	-	1.95
<b>E</b>	4.70	5.10	4.90
<b>E1</b>	2.90	3.00	3.10
<b>E2</b>	1.35	-	1.65
<b>e</b>	-	-	0.65
<b>L</b>	0.40	0.80	0.60
<b>a</b>	0	8°	4°

All Dimensions in mm

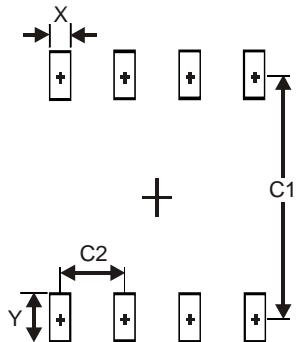
**4. Package type: U-DFN3030-8**


U-DFN3030-8 Type E			
Dim	Min	Max	Typ
<b>A</b>	0.57	0.63	0.60
<b>A1</b>	0	0.05	0.02
<b>A3</b>	—	—	0.15
<b>b</b>	0.20	0.30	0.25
<b>D</b>	2.95	3.05	3.00
<b>D2</b>	2.15	2.35	2.25
<b>E</b>	2.95	3.05	3.00
<b>e</b>	—	—	0.65
<b>E2</b>	1.40	1.60	1.50
<b>L</b>	0.30	0.60	0.45
<b>Z</b>	—	—	0.40

All Dimensions in mm

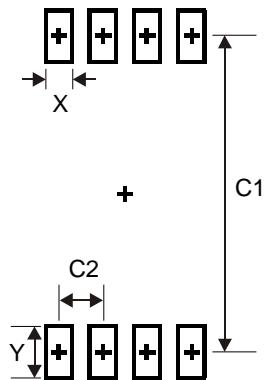
## Suggested Pad Layout

### 1. Package type: SO-8



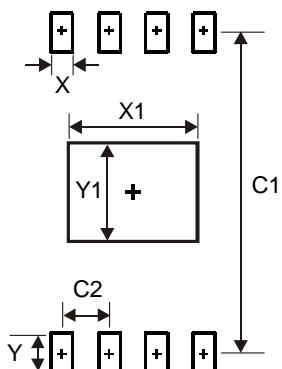
Dimensions	Value (in mm)
X	0.60
Y	1.55
C1	5.4
C2	1.27

### 2. Package type: MSOP-8



Dimensions	Value (in mm)
X	0.45
Y	1.4
C1	4.4
C2	0.65

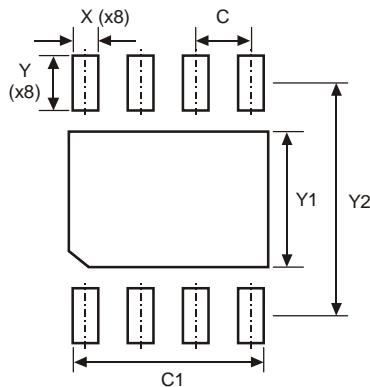
### 3. Package type: MSOP-8EP



Dimensions	Value (in mm)
C1	4.2
C2	0.65
X	0.32
X1	1.95
Y	0.8
Y1	1.65

**Suggested Pad Layout (cont.)**

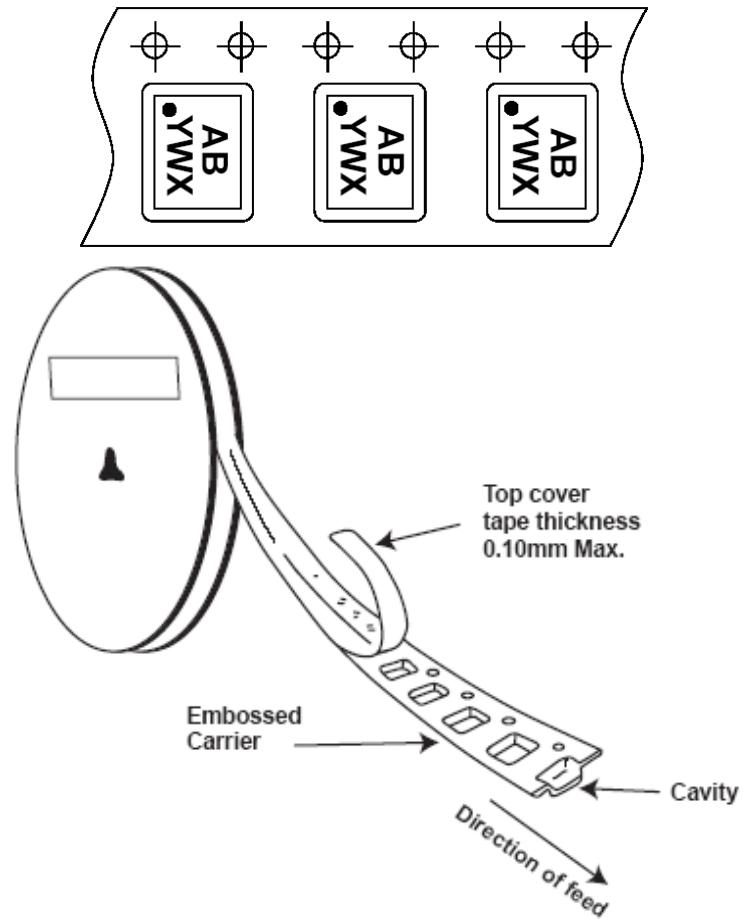
**4. Package type: U-DFN3030-8**



Dimensions	Value (in mm)
C	0.65
C1	2.35
X	0.30
Y	0.65
Y1	1.60
Y2	2.75

**Taping Orientation (Note 8)**

**For DFN3030-8**



Note: 8. The taping orientation of the other package type can be found on our website at <http://www.diodes.com/datasheets/ap02007.pdf>



# AP2401/AP2411

## 2.0A SINGLE CHANNEL CURRENT-LIMITED POWER SWITCH WITH LATCH-OFF

### IMPORTANT NOTICE

DIODES INCORPORATED MAKES NO WARRANTY OF ANY KIND, EXPRESS OR IMPLIED, WITH REGARDS TO THIS DOCUMENT, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE (AND THEIR EQUIVALENTS UNDER THE LAWS OF ANY JURISDICTION).

Diodes Incorporated and its subsidiaries reserve the right to make modifications, enhancements, improvements, corrections or other changes without further notice to this document and any product described herein. Diodes Incorporated does not assume any liability arising out of the application or use of this document or any product described herein; neither does Diodes Incorporated convey any license under its patent or trademark rights, nor the rights of others. Any Customer or user of this document or products described herein in such applications shall assume all risks of such use and will agree to hold Diodes Incorporated and all the companies whose products are represented on Diodes Incorporated website, harmless against all damages.

Diodes Incorporated does not warrant or accept any liability whatsoever in respect of any products purchased through unauthorized sales channel.

Should Customers purchase or use Diodes Incorporated products for any unintended or unauthorized application, Customers shall indemnify and hold Diodes Incorporated and its representatives harmless against all claims, damages, expenses, and attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized application.

Products described herein may be covered by one or more United States, international or foreign patents pending. Product names and markings noted herein may also be covered by one or more United States, international or foreign trademarks.

### LIFE SUPPORT

Diodes Incorporated products are specifically not authorized for use as critical components in life support devices or systems without the express written approval of the Chief Executive Officer of Diodes Incorporated. As used herein:

A. Life support devices or systems are devices or systems which:

1. are intended to implant into the body, or
2. support or sustain life and whose failure to perform when properly used in accordance with instructions for use provided in the labeling can be reasonably expected to result in significant injury to the user.

B. A critical component is any component in a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or to affect its safety or effectiveness.

Customers represent that they have all necessary expertise in the safety and regulatory ramifications of their life support devices or systems, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of Diodes Incorporated products in such safety-critical, life support devices or systems, notwithstanding any devices- or systems-related information or support that may be provided by Diodes Incorporated. Further, Customers must fully indemnify Diodes Incorporated and its representatives against any damages arising out of the use of Diodes Incorporated products in such safety-critical, life support devices or systems.

Copyright © 2011, Diodes Incorporated

[www.diodes.com](http://www.diodes.com)