1A DUAL CHANNEL CURRENT-LIMITED POWER SWITCH

Description

The AP2166 and AP2176 are integrated high-side power switches optimized for Universal Serial Bus (USB) and other hot-swap applications. The family of devices complies with USB 2.0 and available with both polarities of Enable input. They offer current and thermal limiting 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 overcurrent reporting and does not require any external components.

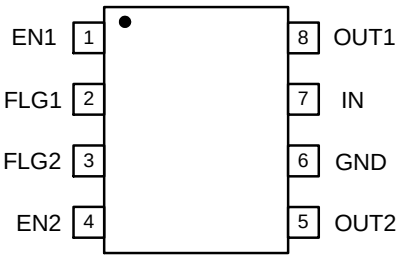
All devices are available in SO-8 and MSOP-8EP packages.

Features

- Dual USB port power switches
- Overcurrent and thermal protection
- 1.5A accurate current limiting
- Reverse Current Blocking
- 90mΩ on-resistance
- Input voltage range: 2.7V - 5.5V
- 0.6ms typical rise time
- Very low shutdown current: 1µA (max)
- Fault report (FLG) with blanking time (7ms typ)
- ESD protection: 6KV HBM, 300V MM
- Active low (AP2166) or active high (AP2176) enable
- Ambient temperature range -40°C to +85°C
- SO-8 and MSOP-8EP (Exposed Pad): Available in "Green" Molding Compound (No Br, Sb)
- UL Recognized, File Number E322375
- IEC60950-1 CB Scheme Certified
- **Totally Lead-Free & Fully RoHS Compliant (Notes 1 & 2)**
- **Halogen and Antimony Free. "Green" Device (Note 3)**

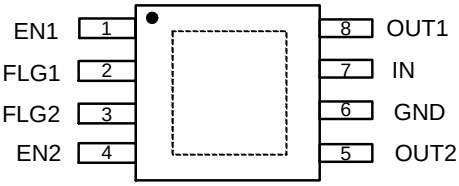
Pin Assignments

(Top View)



SO-8

(Top View)



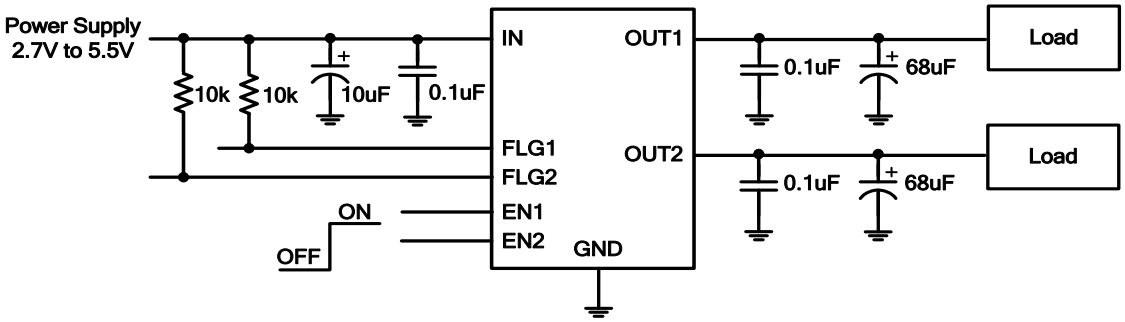
MSOP-8EP

Applications

- Consumer Electronics – LCD TVs & Monitors, Game Machines
- Communications – Set-Top-Boxes, GPS, Smartphones
- Computing – Laptops, Desktops, Servers, Printers, Docking Stations, HUBs

Notes:
1. No purposely added lead. Fully EU Directive 2002/95/EC (RoHS) & 2011/65/EU (RoHS 2) compliant.
2. See http://www.diodes.com/quality/lead_free.html for more information about Diodes Incorporated's definitions of Halogen- and Antimony-free, "Green" and Lead-free.
3. Halogen- and Antimony-free "Green" products are defined as those which contain <900ppm bromine, <900ppm chlorine (<1500ppm total Br + Cl) and <1000ppm antimony compounds.

Typical Applications Circuit



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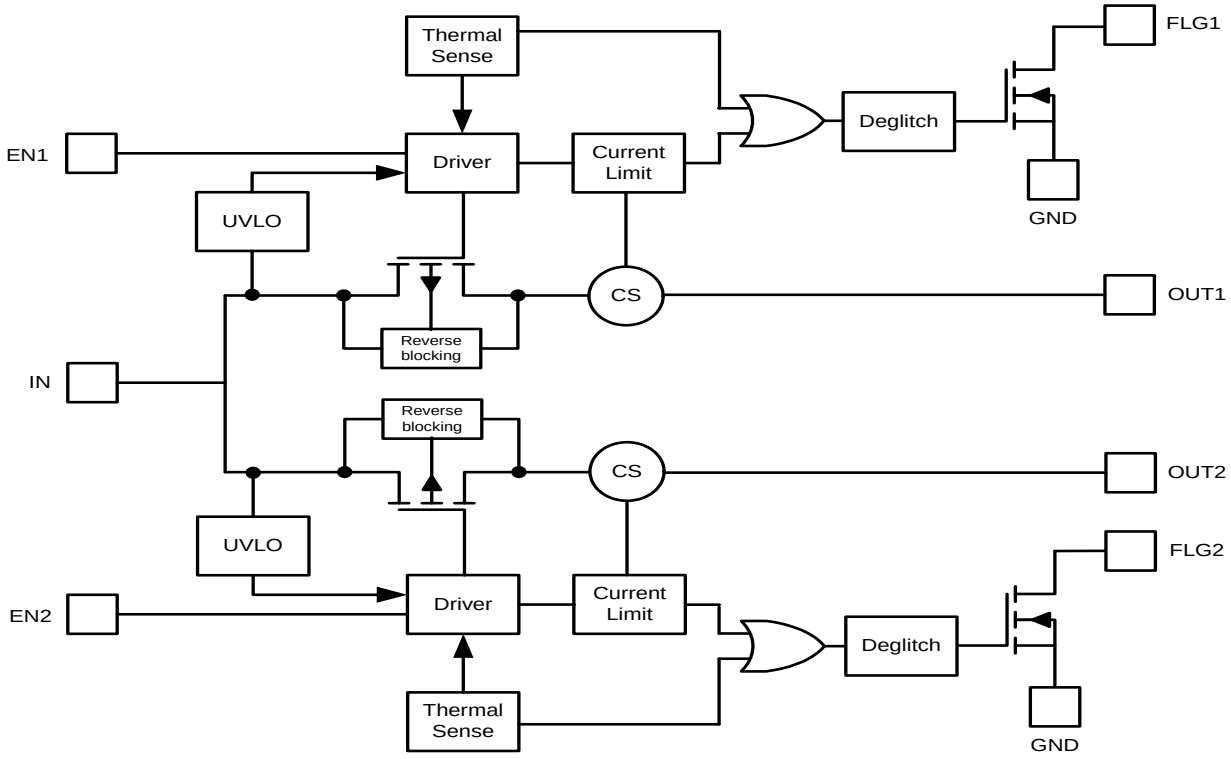
Available Options

Part Number	Channel	Enable Pin (EN)	Current Limit (typ)	Recommended Maximum Continuous Load Current
AP2166	2	Active Low	1.5A	1.0A
AP2176	2	Active High	1.5A	1.0A

Pin Descriptions

Pin Name	Pin Number		Function
	SO-8	MSOP-8EP	
EN1	1	1	Switch 1 enable input, active low (AP2166) or active high (AP2176)
FLG1	2	2	Switch 1 over-current and over-temperature fault report, open-drain
FLG2	3	3	Switch 2 over-current and over-temperature fault report, open-drain
EN2	4	4	Switch 2 enable input, active low (AP2166) or active high (AP2176)
OUT2	5	5	Switch 2 voltage output pin
GND	6	6	Ground
IN	7	7	Voltage input pin
OUT1	8	8	Switch 1 voltage output pin
Exposed Pad	—	Exposed Pad	Exposed Pad: It should be connected externally to GND and thermal mass for enhanced thermal impedance. It should not be used as electrical ground conduction path.

Functional Block Diagram



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Absolute Maximum Ratings (@T_A = +25°C, unless otherwise specified.)

Symbol	Parameter	Rating	Unit
ESD HBM	Human Body Model ESD Protection	6	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
$T_{J(MAX)}$	Maximum Junction Temperature	+150	°C
T_{ST}	Storage Temperature Range (Note 4)	-65 to +150	°C

Note: 4. UL Recognized Rating from -30°C to +70°C (Diodes qualified T_{ST} from -65°C to +150°C).

Recommended Operating Conditions (@T_A = +25°C, unless otherwise specified.)

Symbol	Parameter	Min	Max	Units
V_{IN}	Input Voltage	2.7	5.5	V
I_{OUT}	Output Current	0	1.0	A
V_{IL}	Low-Level Input Voltage on EN or $\overline{EN}$	0	0.8	V
V_{IH}	High-Level Input Voltage on EN or $\overline{EN}$	2	V_{IN}	V
T_A	Operating Ambient Temperature	-40	+85	°C

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Electrical Characteristics (@T_A = +25°C, C_{IN} = 10µF, V_{IN} = +5V, unless otherwise specified.)

Symbol	Parameter	Test Conditions		Min	Typ	Max	Unit
V_{UVLO}	Input UVLO	R_{LOAD} = 1kΩ		1.6	1.9	2.5	V
I_{SHDN}	Input Shutdown Current	Disabled, I_{OUT} = 0		-	0.5	1	µA
I_Q	Input Quiescent Current, Dual	Enabled, I_{OUT} = 0		-	95	140	µA
I_{LEAK}	Input Leakage Current	Disabled, OUT grounded		-	-	1	µA
I_{REV}	Reverse Leakage Current	Disabled, V_{IN} = 0V, V_{OUT} = 5V, I_{REV} at V_{IN}		-	1	-	µA
$R_{DS(ON)}$	Switch On-Resistance	V_{IN} = 5V, I_{OUT} = 1A, -40°C ≤ T_A ≤ +85°C	MSOP-8EP	-	90	135	mΩ
			SO-8	-	100	135	mΩ
		V_{IN} = 3.3V, I_{OUT} = 1A, -40°C ≤ T_A ≤ +85°C		-	120	160	mΩ
I_{SHORT}	Short-Circuit Current Limit	Enabled into short circuit, C_L = 68µF		-	1.5	-	A
I_{LIMIT}	Overload Current Limit	V_{IN} = 5V, V_{OUT} = 4.8V, C_L = 120µF, -40°C ≤ T_A ≤ +85°C		1.1	1.5	1.9	A
I_{Trig}	Current Limiting Trigger Threshold	V_{IN} = V_{EN}, Output Current Slew rate (<100A/WS), C_L = 68µF		-	2.0	-	A
T_{SHORT}	Short-Circuit Response Time	V_{OUT} = 0V to I_{OUT} = I_{LIMIT} (short applied to output), C_L = 68µF		-	20	-	µs
V_{IL}	EN Input Logic Low Voltage	V_{IN} = 2.7V to 5.5V		-	-	0.8	V
V_{IH}	EN Input Logic High Voltage	V_{IN} = 2.7V to 5.5V		2	-	-	V
I_{SINK}	EN Input Leakage	V_{EN} = 5V		-	-	1	µA
$T_{D(ON)}$	Output Turn-on Delay Time	C_L=1µF, R_{LOAD} = 10Ω		-	0.05	-	ms
T_R	Output Turn-on Rise Time	C_L=1µF, R_{LOAD} = 10Ω		-	0.6	1.5	ms
$T_{D(OFF)}$	Output Turn-off Delay Time	C_L=1µF, R_{LOAD} = 10Ω		-	0.01	-	ms
T_F	Output Turn-off Fall Time	C_L=1µF, R_{LOAD} = 10Ω		-	0.05	0.1	ms
R_{FLG}	FLG Output FET on-Resistance	I_{FLG} =10mA		-	20	40	Ω
I_{FOH}	Error Flag Iff Current	V_{FLG} = 5V		-	0.01	1	µA
T_{Blank}	FLG Blanking Time	C_L = 68µF		4	7	15	ms
T_{SHDN}	Thermal Shutdown Threshold	Enabled, R_{LOAD} = 1kΩ		-	+140	-	°C
T_{HYS}	Thermal Shutdown Hysteresis	-		-	+25	-	°C
θ_{JA}	Thermal Resistance Junction-to-Ambient	SO-8 (Note 5)		-	110	-	°C/W
		MSOP-8EP (Note 6)		-	60	-	°C/W

Notes: 5. Test condition for SO-8: Device mounted on FR-4 2-layer board, 2oz. copper, with minimum recommended pad layout.
6. Test condition for MSOP-8EP: Device mounted on FR-4 2-layer board, 2oz. copper, with minimum recommended pad on top layer and 3 vias to bottom layer ground plane.

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Typical Performance Characteristics

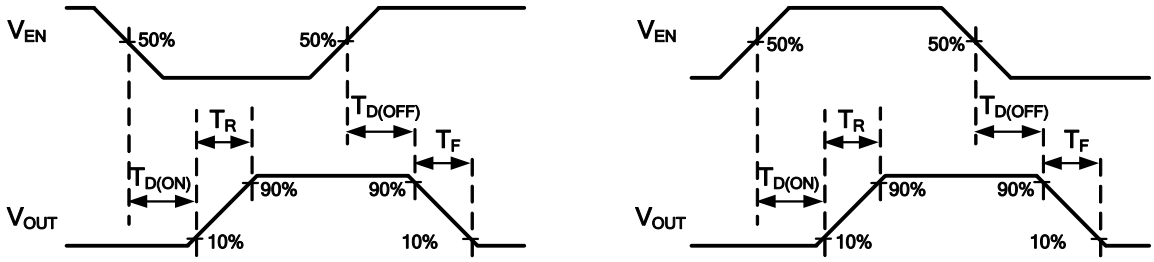
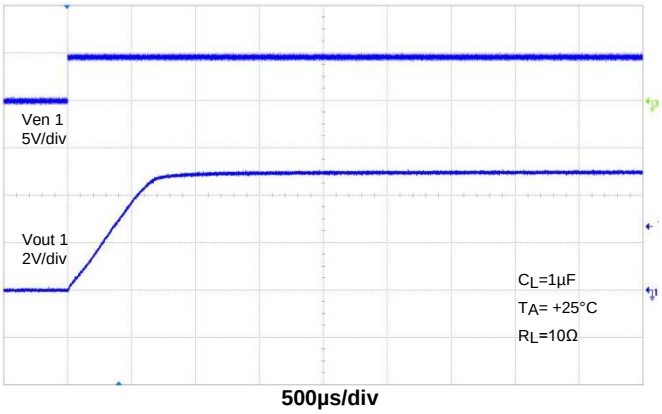
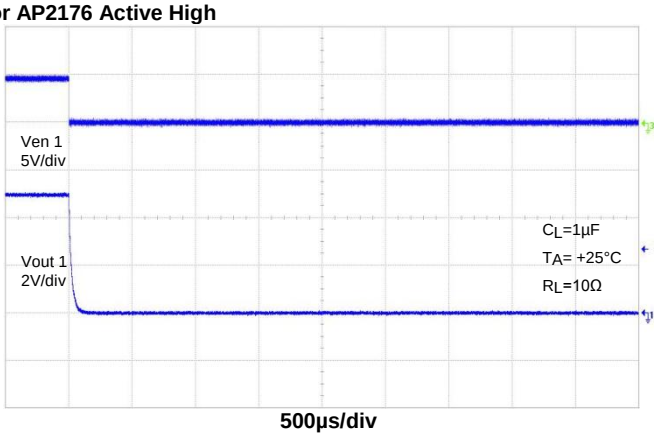


Figure 1 Voltage Waveforms: AP2166 (left), AP2176 (right)

All Enable Plots are for AP2176 Active High



500µs/div
Channel 1 Turn-On Delay and Rise Time



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Channel 1 Turn-Off Delay and Fall Time

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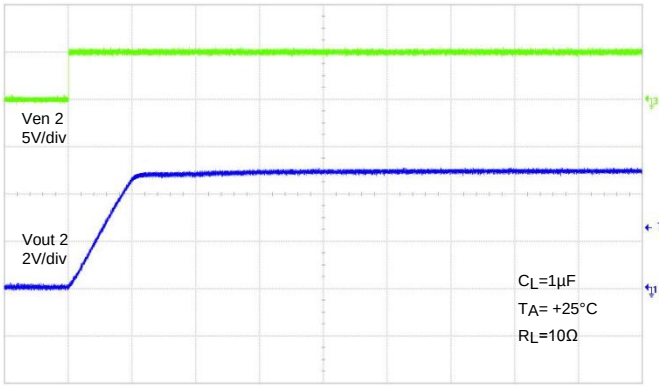
Typical Performance Characteristics (continued)



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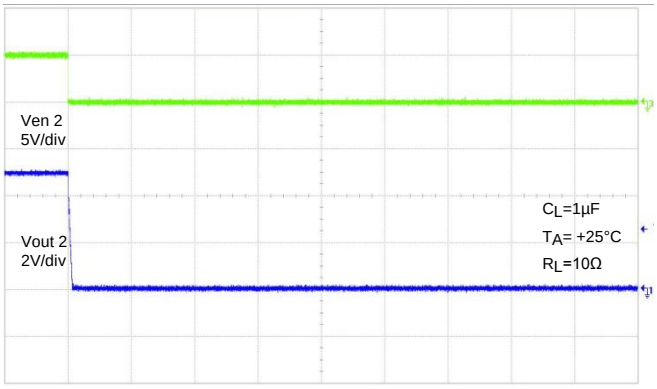
Channel 2 Turn-On Delay and Rise Time



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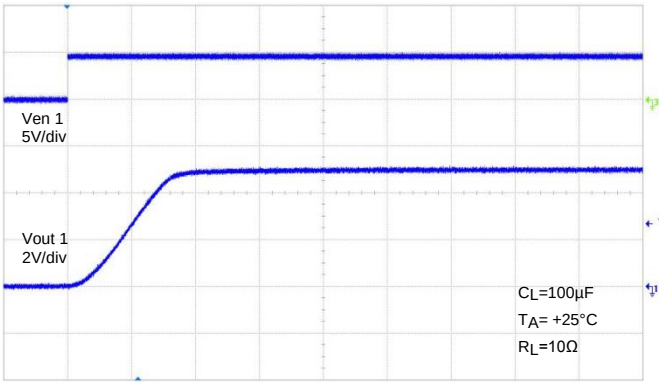
Channel 2 Turn-Off Delay and Fall Time



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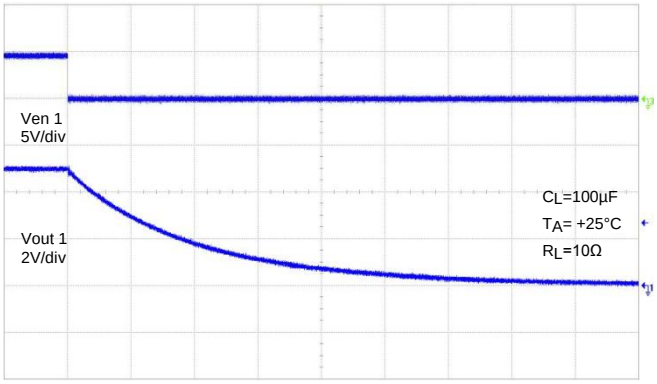
Channel 1 Turn-On Delay and Rise Time



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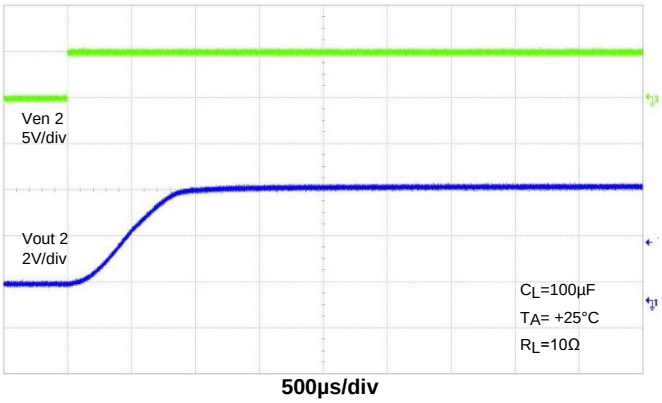
Channel 1 Turn-Off Delay and Fall Time



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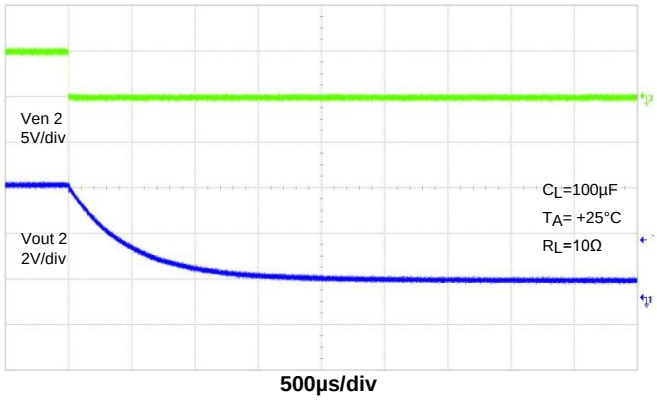
Channel 2 Turn-On Delay and Rise Time



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Channel 2 Turn-Off Delay and Fall Time

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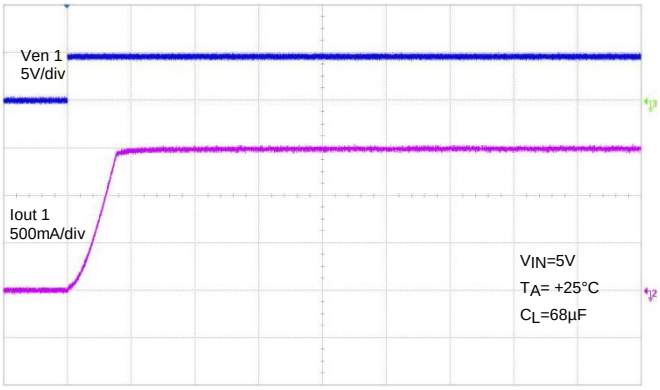
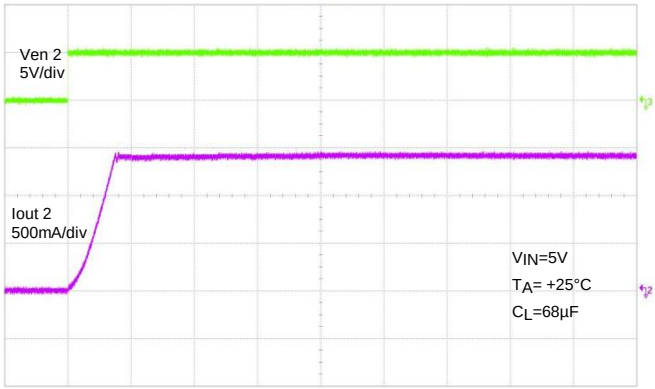
Typical Performance Characteristics (cont.)



500µs/div
Channel 1 Short Circuit Current,
Device Enabled Into Short



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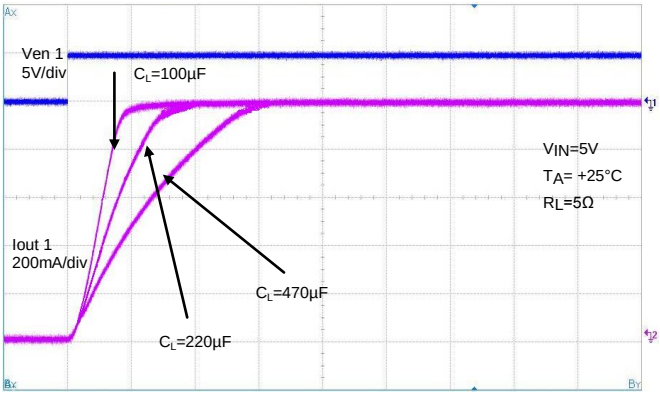
Channel 2 Short Circuit Current,
Device Enabled Into Short



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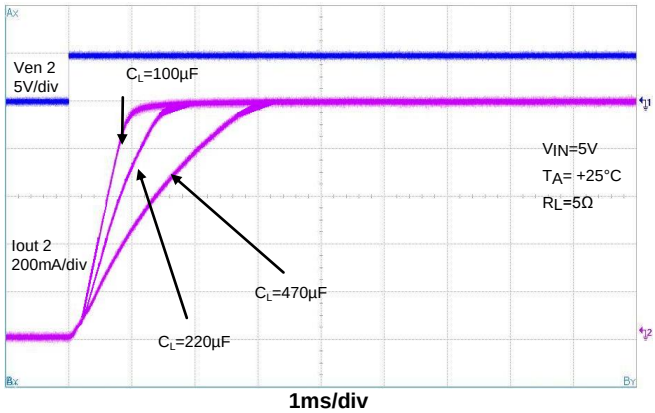
Channel 1 Inrush Current



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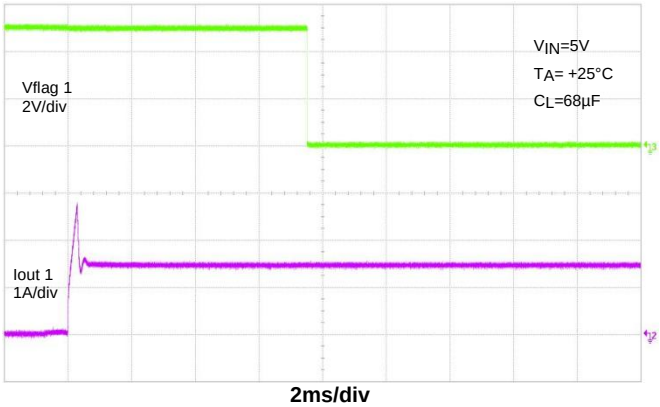
Channel 2 Inrush Current



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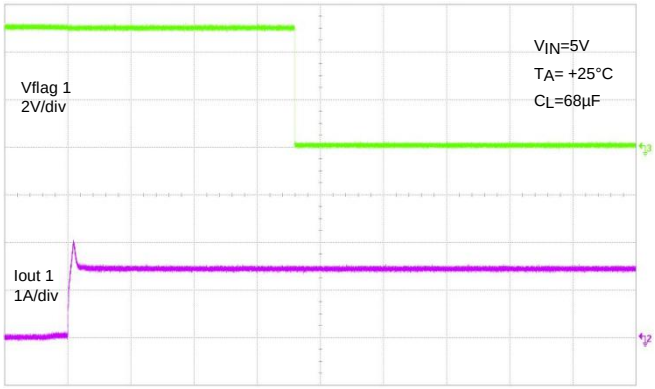
Channel 1
1Ω Load Connected to Enabled Device



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Channel 1
2Ω Load Connected to Enabled Device

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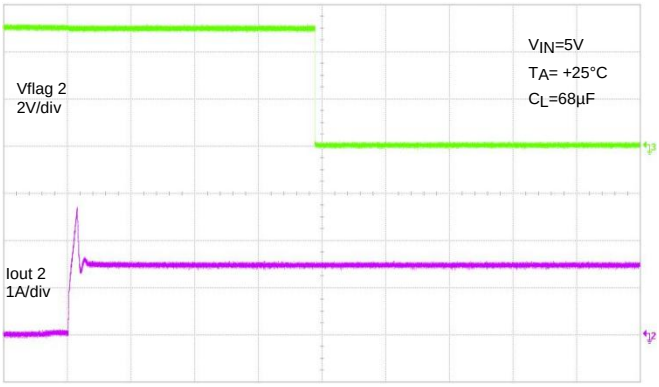
Typical Performance Characteristics (cont.)



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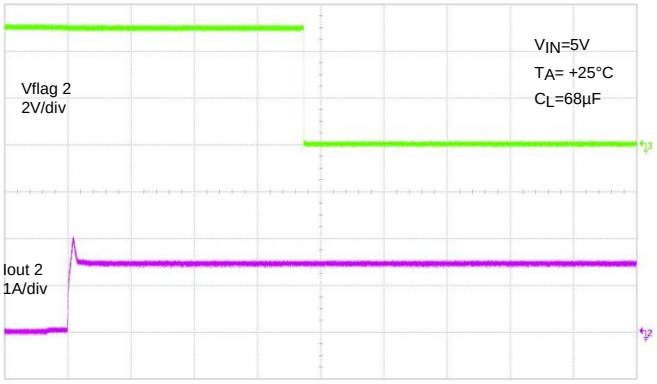

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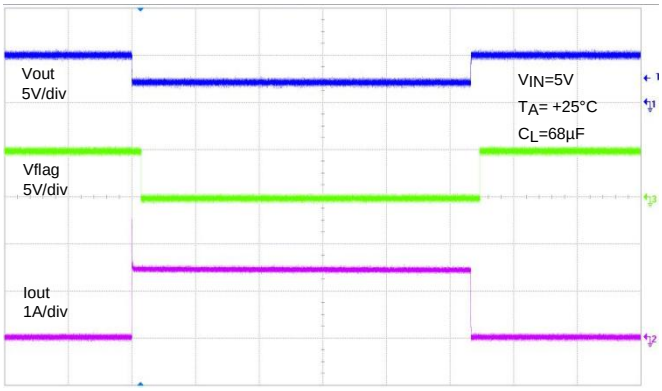
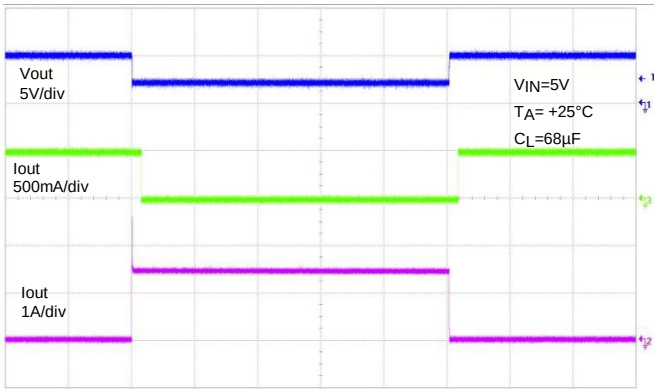
2Ω Load Connected to Enabled Device



20ms/div
Channel 1
Short Circuit with Blanking Time and Recovery



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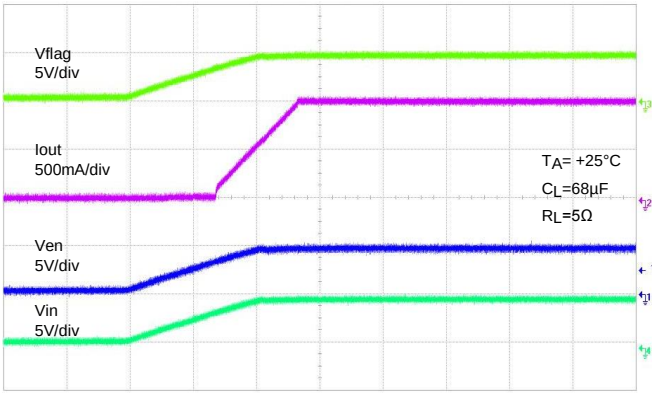
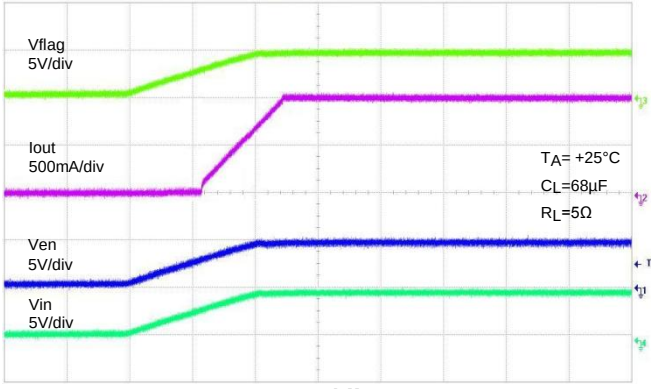
Short Circuit with Blanking Time and Recovery



1ms/div
Channel 1 Power On



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Channel 2 Power On

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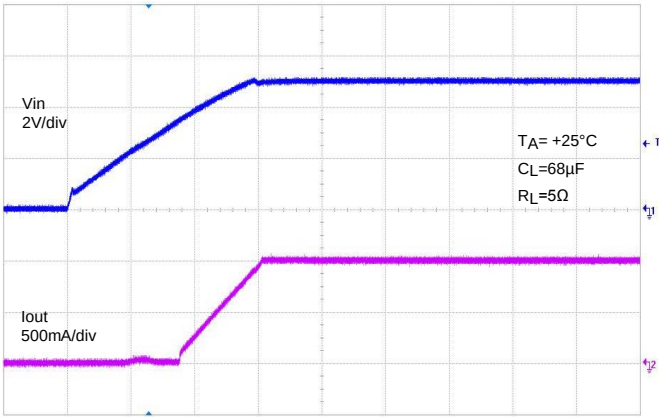
Typical Performance Characteristics (cont.)



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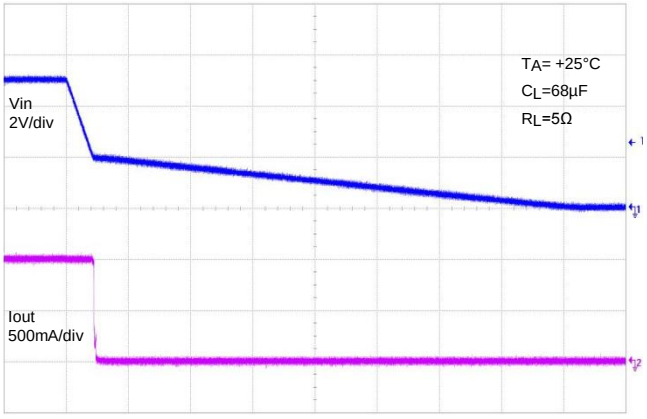
Channel 1 UVLO Increasing



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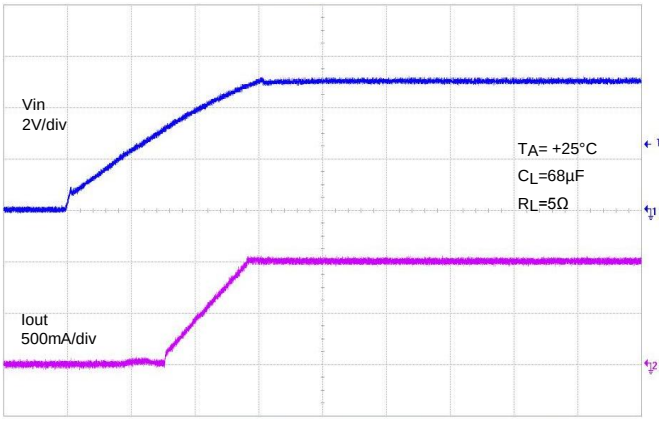
Channel 1 UVLO Decreasing



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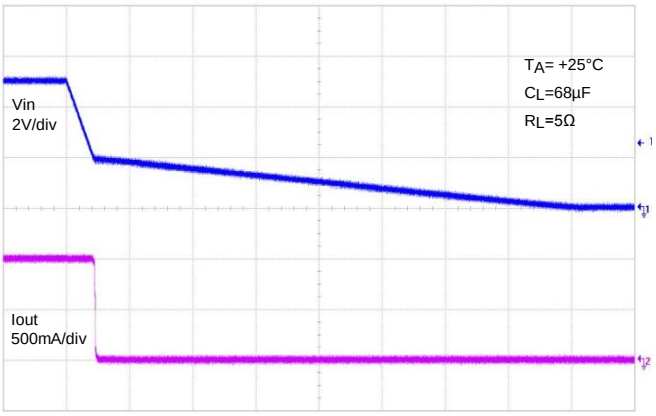
Channel 2 UVLO Increasing



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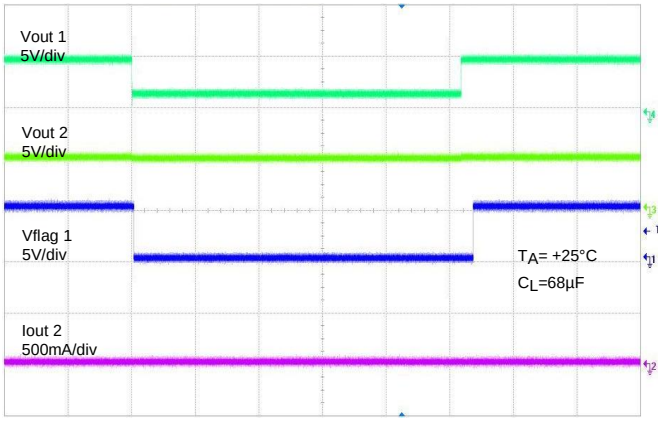
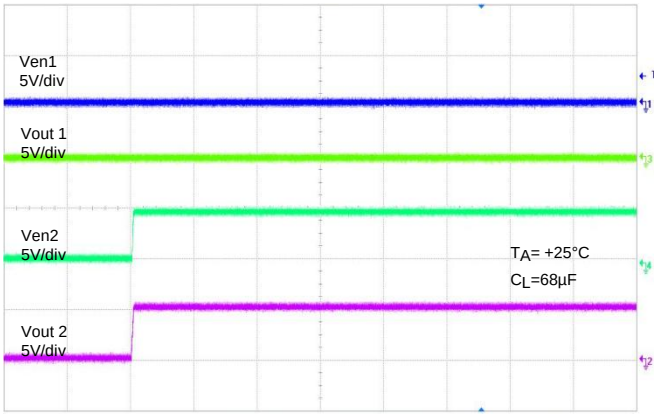


100ms/div
Channel 1 Enabled and Shorted with Channel 2 Disabled



50ms/div
Channel 1 Disabled and Channel 2 Enabled

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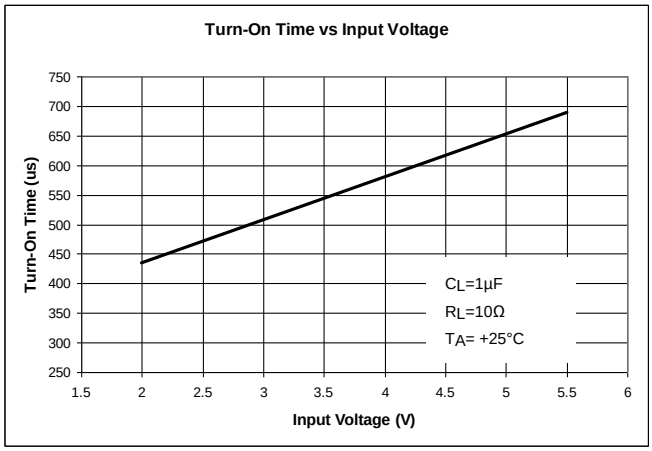
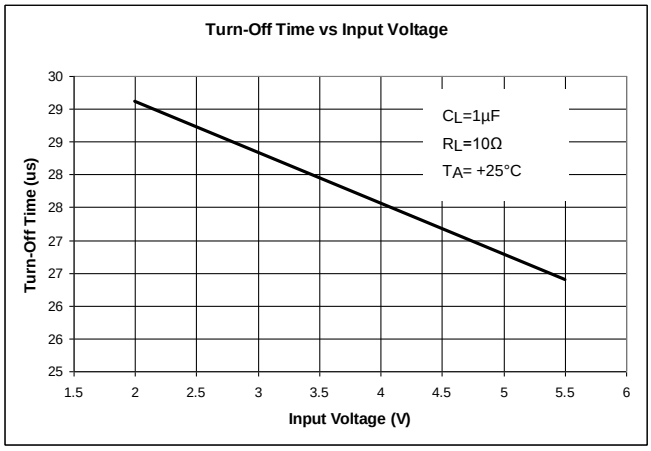
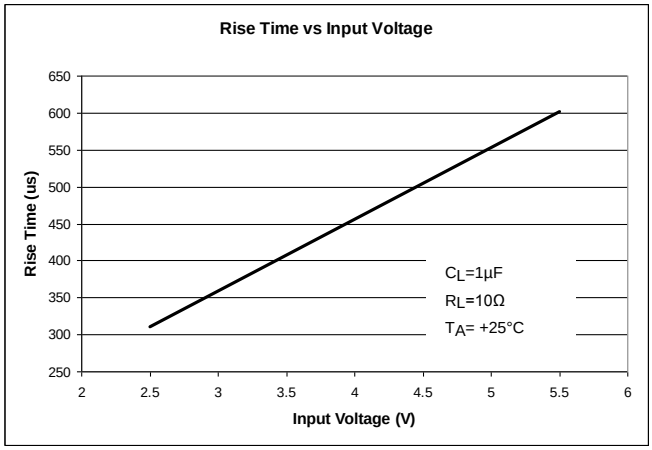
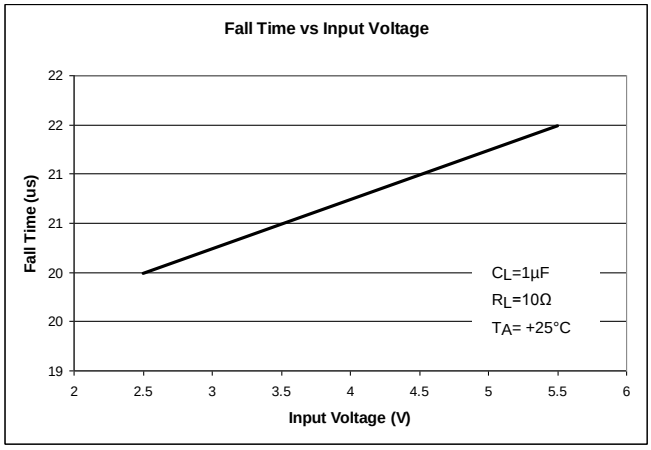
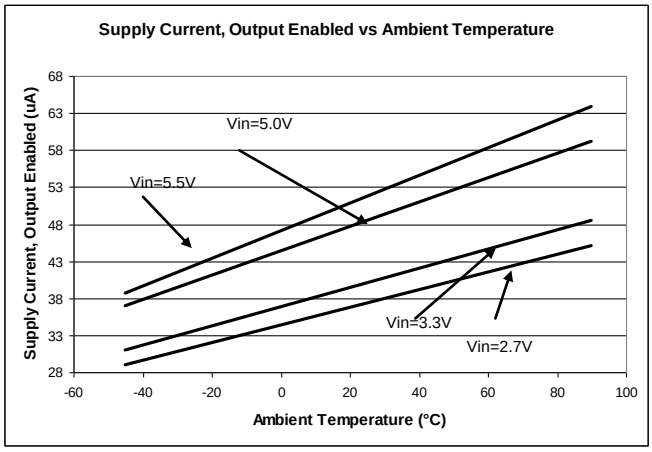
Typical Performance Characteristics (cont.)

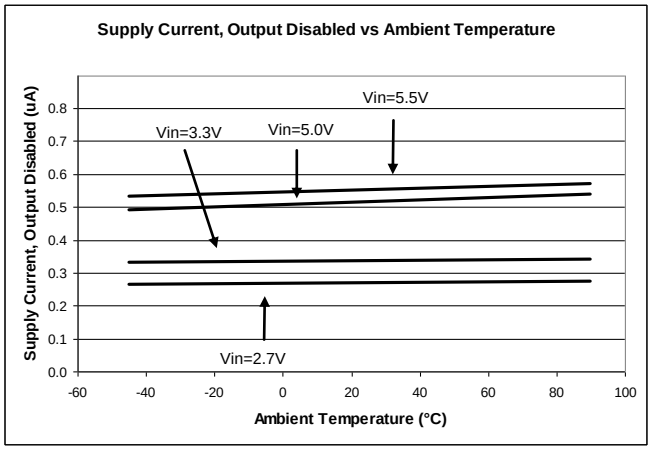












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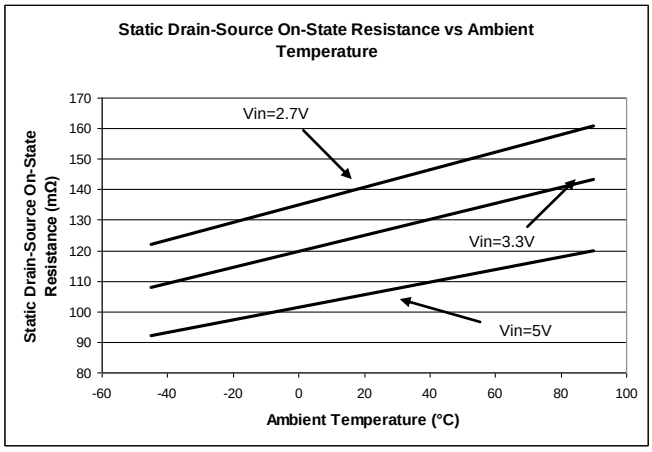
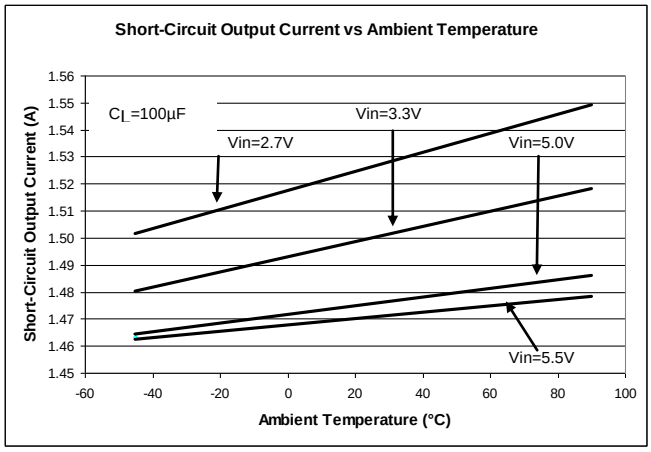
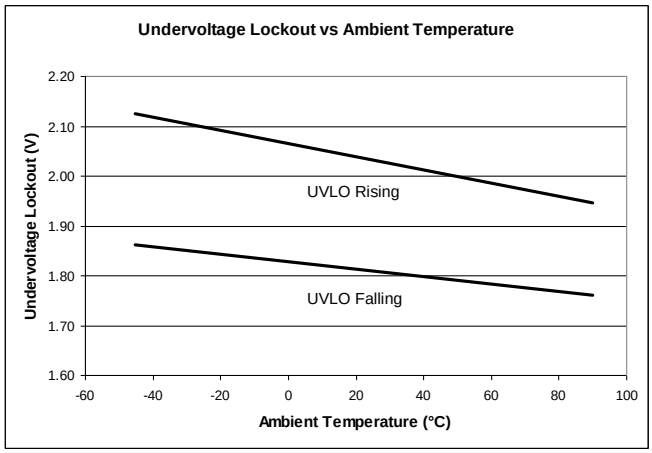
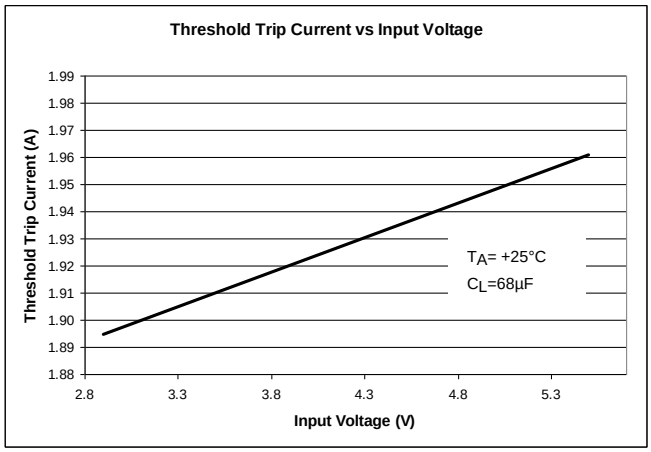
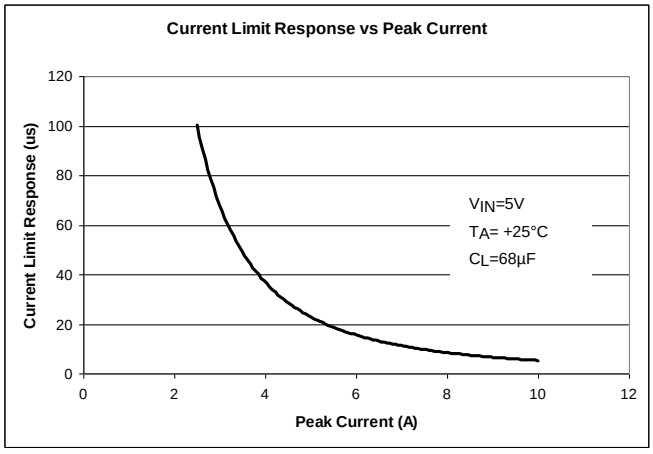
Typical Performance Characteristics (cont.)











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Application Information

Power Supply Considerations

A 0.01-µF to 0.1-µF X7R or X5R ceramic bypass capacitor between IN and GND, close to the device, is recommended. Placing a high-value electrolytic capacitor on the input (10-µF minimum) 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 0.01-µF to 0.1-µF ceramic capacitor improves the immunity of the device to short-circuit transients.

Overcurrent 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 device maintains a constant output current and reduces the output voltage accordingly. Complete shutdown occurs only if the fault stays long enough to activate thermal limiting.

Three possible overload conditions can occur. In the first condition, the output has been shorted to GND before the device is enabled or before V_{IN} has been applied. The AP2166/AP2176 senses the short circuit and immediately clamps output current to a certain safe level namely I_{LIMIT}.

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 overcurrent trip threshold), the device switches into current limiting mode and the current is clamped at I_{LIMIT}.

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 AP2166/AP2176 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 is set at I_{LIMIT}.

Note that when the output has been shorted to GND at extremely low temperature (< -30°C), a minimum 120-µF electrolytic capacitor on the output pin is recommended. A correct capacitor type with capacitor voltage rating and temperature characteristics must be properly chosen so that capacitance value does not drop too low at the extremely low temperature operation. A recommended capacitor should have temperature characteristics of less than 10% variation of capacitance change when operated at extremely low temp. Our recommended aluminum electrolytic capacitor type is Panasonic FC series.

FLG Response

When an overcurrent or over-temperature shutdown condition is encountered, the FLG open-drain output goes active low after a nominal 7-ms deglitch timeout. The FLG output remains low until both overcurrent and over-temperature conditions are removed. Connecting a heavy capacitive load to the output of the device can cause a momentary overcurrent condition, which does not trigger the FLG due to the 7-ms deglitch timeout. The AP2166/AP2176 is designed to eliminate false overcurrent 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 (T_A) 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 °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 AP2166/AP2176 implements a thermal sensing to monitor the operating junction temperature of the power distribution switch. Once the die temperature rises to approximately +140°C due to excessive power dissipation in an overcurrent or short-circuit 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°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 or overcurrent occurs with 7-ms deglitch.

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Application Information (continued)

Undervoltage Lockout (UVLO)

Undervoltage lockout function (UVLO) keeps the internal power switch from being turned on until the power supply has reached at least 1.9V, even if the switch is enabled. Whenever the input voltage falls below approximately 1.9V, 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.

Host/Self-Powered HUBs

Hosts and self-powered hubs (SPH) have a local power supply that powers the embedded functions and the downstream ports (see Figure 2). This power supply must provide from 5.25V to 4.75V to the board side of the downstream connection under both full-load and no-load conditions. Hosts and SPHs are required to have current-limit protection and must report overcurrent conditions to the USB controller. Typical SPHs are desktop PCs, monitors, printers, and stand-alone hubs.

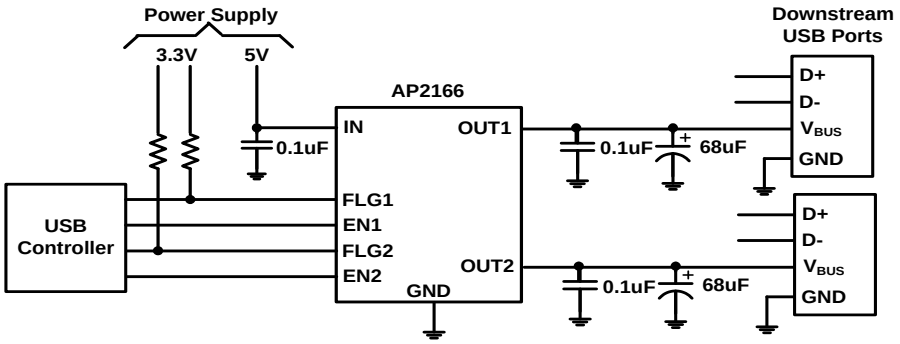

Figure 2 Typical Two-Port USB Host/ Self-Powered Hub

Generic Hot-Plug Applications

In many applications it may be necessary to remove modules or PC boards while the main unit is still operating. These are considered hot-plug applications. Such implementations require the control of current surges seen by the main power supply and the card being inserted. The most effective way to control these surges is to limit and slowly ramp the current and voltage being applied to the card, similar to the way in which a power supply normally turns on. Due to the controlled rise times and fall times of the AP2166/AP2176, these devices can be used to provide a softer start-up to devices being hot-plugged into a powered system. The UVLO feature of the AP2166/AP2176 also ensures that the switch is off after the card has been removed, and that the switch is off during the next insertion.

By placing the AP2166/AP2176 between the V_{CC} input and the rest of the circuitry, the input power reaches these devices first after insertion. The typical rise time of the switch is approximately 1ms, providing a slow voltage ramp at the output of the device. This implementation controls system surge current and provides a hot-plugging mechanism for any device.

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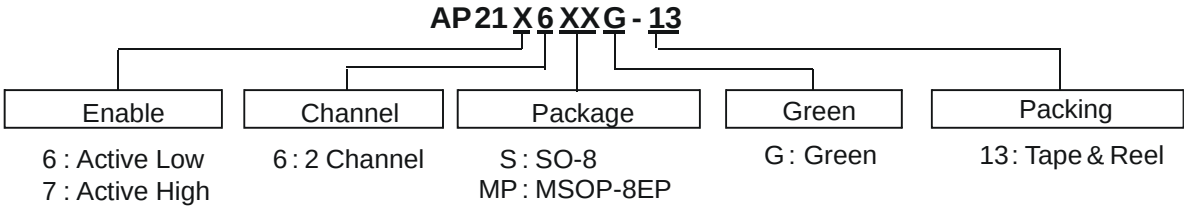
Ordering Information

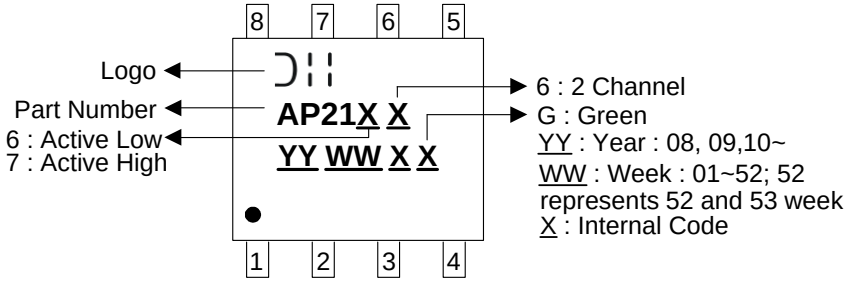


Part Number	Package Code	Packaging	13" Tape and Reel	
			Quantity	Part Number Suffix
AP21X6SG-13	S	SO-8	2,500/Tape & Reel	-13
AP21X6MPG-13	MP	MSOP-8EP	2,500/Tape & Reel	-13

Marking Information

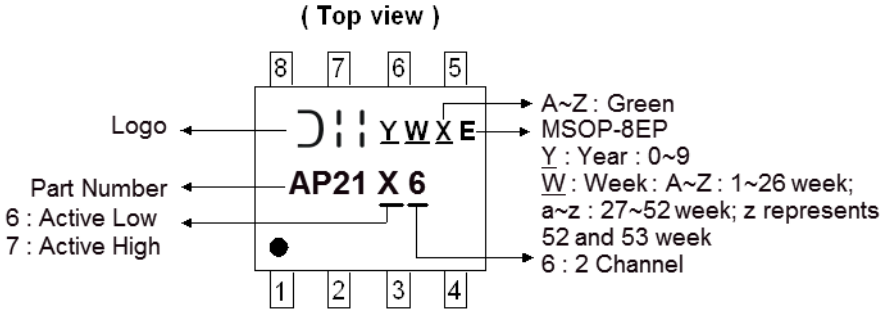
(1) SO-8

(Top view)



(2) MSOP-8EP

(Top view)



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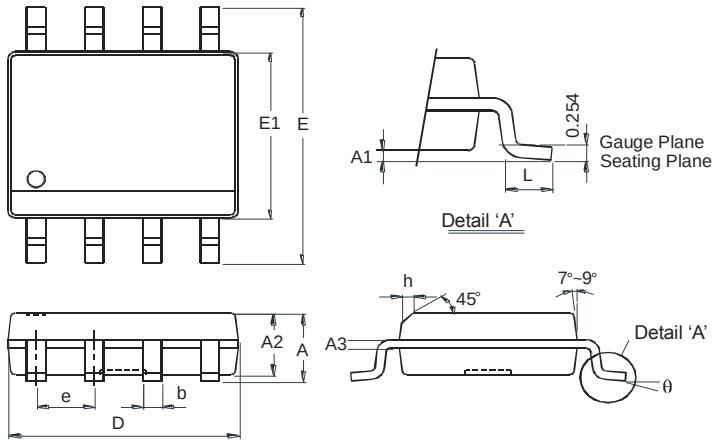
Package Outline Dimensions (All dimensions in mm.)

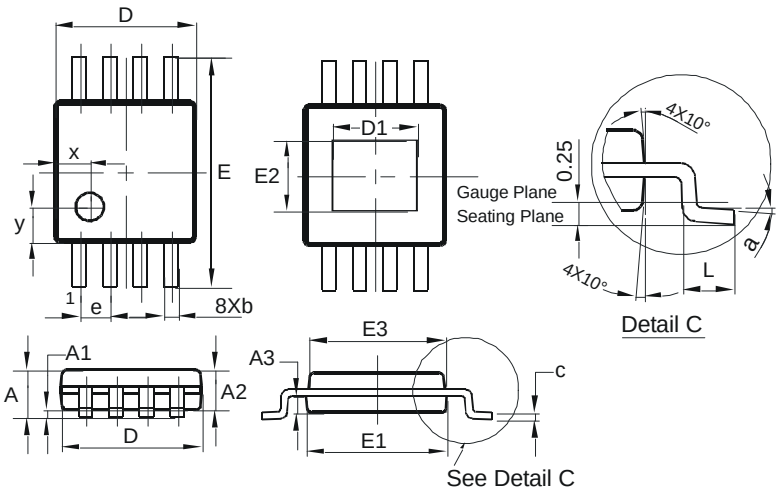
Please see http://www.diodes.com/package-outlines.html for the latest version.

(1) Package type: SO-8



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

(2) Package type: MSOP-8EP



MSOP-8EP			
Dim	**Min**	**Max**	**Typ**
A	-	1.10	-
A1	0.05	0.15	0.10
A2	0.75	0.95	0.86
A3	0.29	0.49	0.39
b	0.22	0.38	0.30
c	0.08	0.23	0.15
D	2.90	3.10	3.00
D1	1.60	2.00	1.80
E	4.70	5.10	4.90
E1	2.90	3.10	3.00
E2	1.30	1.70	1.50
E3	2.85	3.05	2.95
e	-	-	0.65
L	0.40	0.80	0.60
a	0°	8°	4°
x	-	-	0.750
y	-	-	0.750
All Dimensions in mm			

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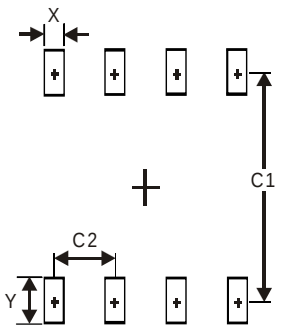
Suggested Pad Layout

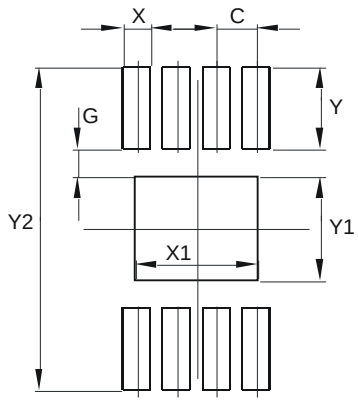
Please see http://www.diodes.com/package-outlines.html for the latest version.

(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-8EP



Dimensions	Value (in mm)
C	0.650
G	0.450
X	0.450
X1	2.000
Y	1.350
Y1	1.700
Y2	5.300

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