1.5A SINGLE CHANNEL CURRENT-LIMITED POWER SWITCH WITH OUTPUT DISCHARGE

Description

The AP2181D and AP2191D 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 is 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 over-current reporting and does not require any external components.

All devices are available in SO-8, MSOP-8, MSOP-8EP, SOT25, and U-DFN2018-6 packages.

Features

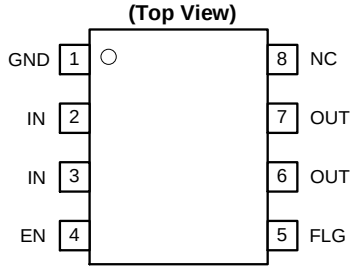
- Single USB Port Power Switches with Output Discharge
- Over-Current and Thermal Protection
- 2.1A Accurate Current Limiting
- Fast Transient Response
- Reverse Current Blocking
- 90mΩ On-Resistance
- Input Voltage Range: 2.7V to 5.5V
- 0.6ms Typical Rise Time
- Very Low Shutdown Current: 1µA (Max)
- Fault Report (FLG) with Blanking Time (7ms Typ)
- ESD Protection: 4kV HBM, 300V MM
- Active High (AP2191D) or Active Low (AP2181D) Enable
- Ambient Temperature Range -40°C to +85°C
- SOT25, SO-8, MSOP-8, MSOP-8EP (Exposed Pad), and U-DFN2018-6: Available in "Green" Molding Compound (No Br, Sb)
- **Lead-Free Finish; RoHS Compliant (Notes 1 & 2)**
- **Halogen and Antimony Free. "Green" Device (Note 3)**
- UL Recognized, File Number E322375
- IEC60950-1 CB Scheme Certified

Applications

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

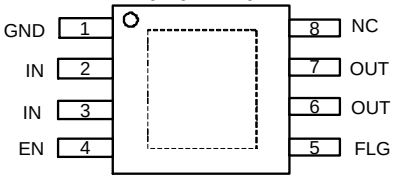
Pin Assignments

(Top View)



SO-8

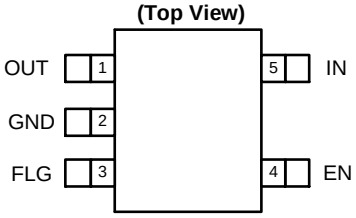
(Top View)



MSOP-8/MSOP-8EP

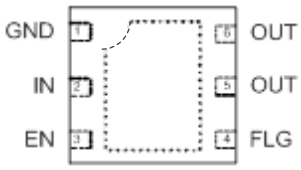
Note: Latter with Exposed Pad (Dotted Line)

(Top View)



SOT25

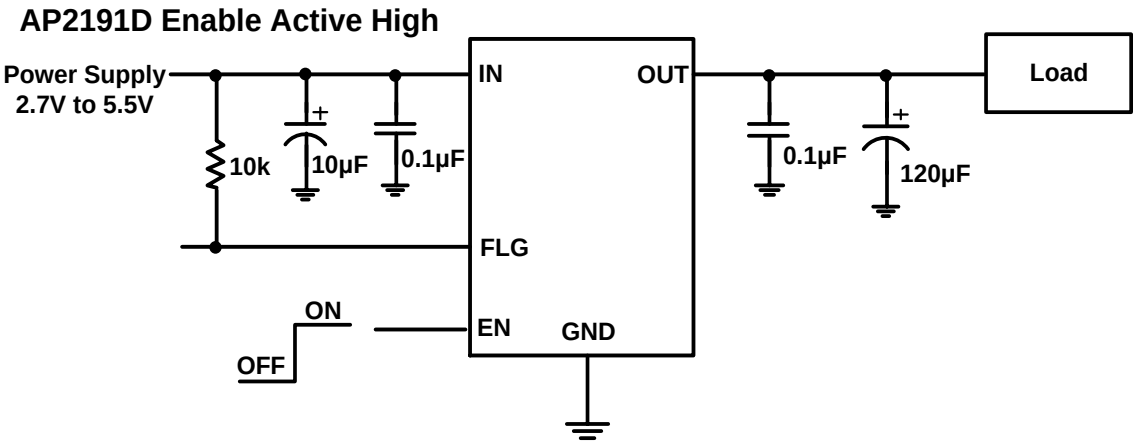
(Top View)



U-DFN2018-6

Notes:
1. EU Directive 2002/95/EC (RoHS), 2011/65/EU (RoHS 2) & 2015/863/EU (RoHS 3) compliant. All applicable RoHS exemptions applied.
2. See https://www.diodes.com/quality/lead-free/ 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



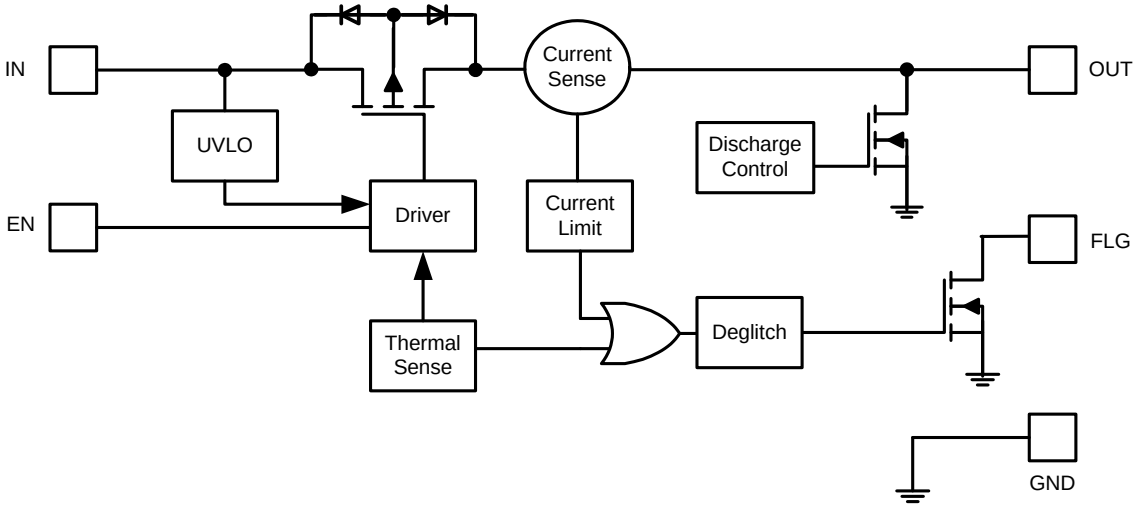
Available Options

Part Number	Channel	Enable Pin (EN)	Current Limit (Typical)	Recommended Maximum Continuous Load Current
AP2181D	1	Active Low	2.1A	1.5A
AP2191D	1	Active High	2.1A	1.5A

Pin Descriptions

Pin Name	Pin Number				Functions
	SO-8 MSOP-8	MSOP-8EP	SOT25	U-DFN2018-6	
GND	1	1	2	1	Ground
IN	2, 3	2, 3	5	2	Voltage input pin (all IN pins must be tied together externally)
EN	4	4	4	3	Enable input, active low (AP2181D) or active high (AP2191D)
FLG	5	5	3	4	Over-current and over-temperature fault report; open-drain flag is active low when triggered
OUT	6, 7	6, 7	1	5, 6	Voltage output pin (all OUT pins must be tied together externally)
NC	8	8	N/A	N/A	No internal connection; recommend tie to OUT pins
Exposed Tab	—	Exposed Tab	—	Exposed Tab	Exposed pad. It should be connected to GND and thermal mass for enhanced thermal impedance. It should not be used as electrical ground conduction path.

Functional Block Diagram



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

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 4)	-65 to +150	°C

Caution: Stresses greater than the 'Absolute Maximum Ratings' specified above, may cause permanent damage to the device. These are stress ratings only; functional operation of the device at these or any other conditions exceeding those indicated in this specification is not implied. Device reliability may be affected by exposure to absolute maximum rating conditions for extended periods of time.
Semiconductor devices are ESD sensitive and may be damaged by exposure to ESD events. Suitable ESD precautions should be taken when handling and transporting these devices.

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

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

Symbol	Parameter	Min	Max	Unit
V_{IN}	Input Voltage	2.7	5.5	V
I_{OUT}	Output Current	0	1.5	A
V_{IL}	EN Input Logic Low Voltage	0	0.8	V
V_{IH}	EN Input Logic High Voltage	2	V_{IN}	V
T_A	Operating Ambient Temperature	-40	+85	°C

Electrical Characteristics (@T_A = +25°C, V_{IN} = +5.0V, unless otherwise specified.)

Symbol	Parameter	Test Conditions			Min	Typ	Max	Unit
V_{UVLO}	Input UVLO	—			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	Enabled, I_{OUT} = 0			—	45	70	μA
I_{LEAK}	Input Leakage Current	Disabled, OUT grounded			—	0.1	1	μA
I_{REV}	Reverse Leakage Current	Disabled, V_{IN} = 0V, V_{OUT} = 5V, I_{REV} at V_{IN}			—	0.1	1	μA
$R_{DS(ON)}$	Switch On-Resistance	V_{IN} = 5V, I_{OUT} = 1.5A	T_A = +25°C	SOT25, MSOP-8, SO-8, MSOP-8-EP	—	95	115	mΩ
				U-DFN2018-6	—	90	110	
			-40°C ≤ T_A ≤ +85°C		—	—	140	
		V_{IN} = 3.3V, I_{OUT} = 1.5A	T_A = +25°C		—	120	140	
			-40°C ≤ T_A ≤ +85°C		—	—	170	
I_{SHORT}	Short-Circuit Current Limit	Enabled into short circuit, C_L=120μF			—	2.0	—	A
I_{LIMIT}	Over-Load Current Limit	V_{IN} = 5V, V_{OUT} = 4V, C_L = 120μF, -40°C ≤ T_A ≤ +85°C			1.6	2.1	2.6	A
I_{Trig}	Current Limiting Trigger Threshold	Output Current Slew Rate (<100A/s) , C_L = 120μF			—	2.6		A
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			—	0.05	—	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
t_{Blank}	FLG Blanking Time	C_{IN} = 10μF, C_L = 22F			4	7	15	ms
t_{DIS}	Discharge Time	C_L = 1μF, V_{IN} = 5V, disabled to V_{OUT} < 0.5V			—	0.6	—	ms
R_{DIS}	Discharge Resistance (Note 5)	V_{IN} = 5V, disabled, I_{OUT} = 1mA			—	100	—	Ω
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	SOT25 (Note 6)			—	170	—	°C/W
		SO-8 (Note 6)			—	127	—	
		MSOP-8 (Note 6)			—	118	—	
		MSOP-8-EP (Note 7)			—	67	—	
		U-DFN2018-6 (Note 7)			—	70	—	

Notes:
5. The discharge function is active when the device is disabled (when enable is de-asserted). The discharge function offers a resistive discharge path for the external storage capacitor.
6. Device mounted on FR-4 substrate PCB, 2oz copper, with minimum recommended pad layout.
7. 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

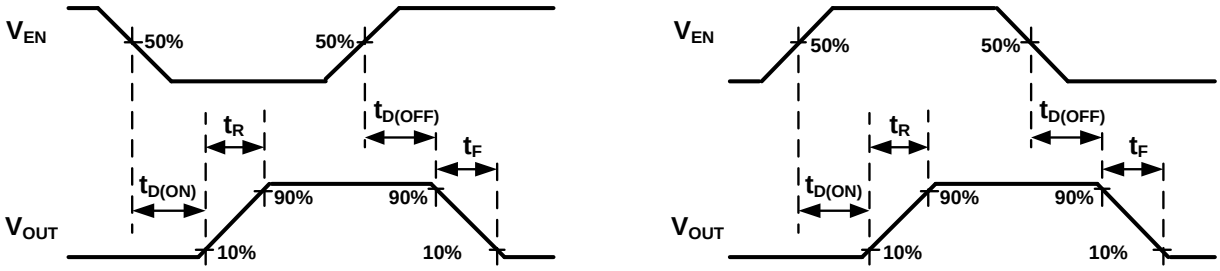
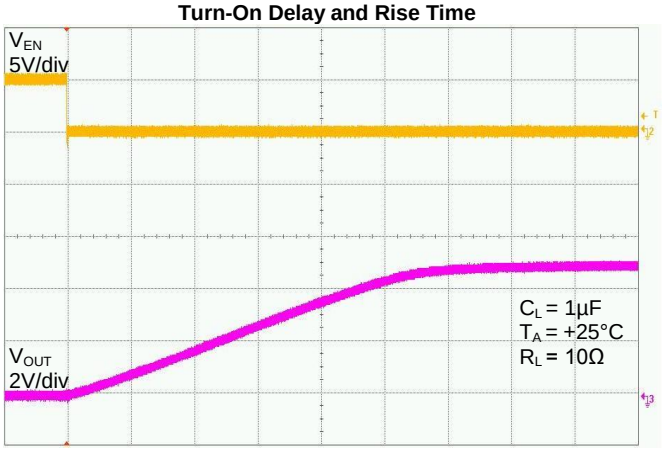


Figure 1. Voltage Waveforms: AP2181D (Left), AP2191D (Right)

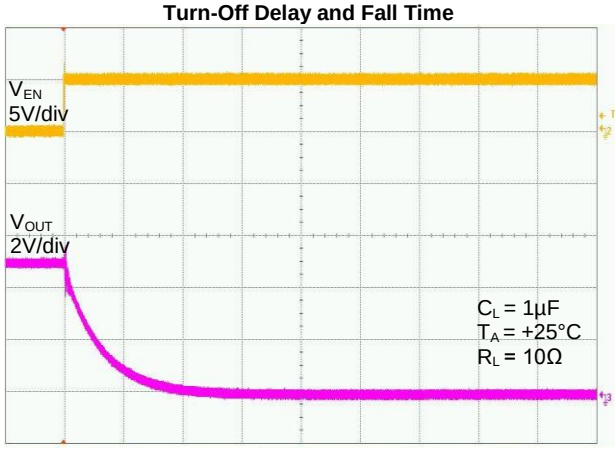
All Enable Plots are for AP2181D Active Low

Turn-On Delay and Rise Time



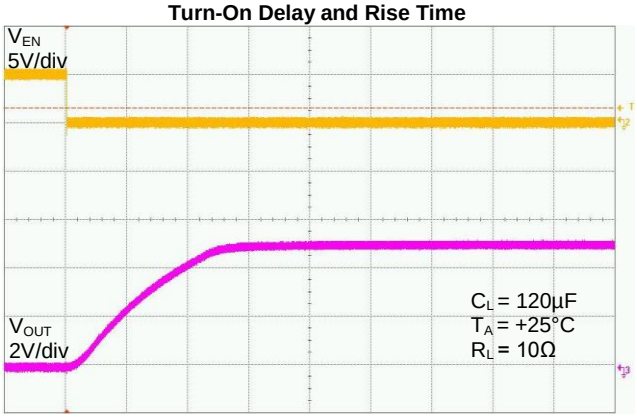
100µs/div

Turn-Off Delay and Fall Time



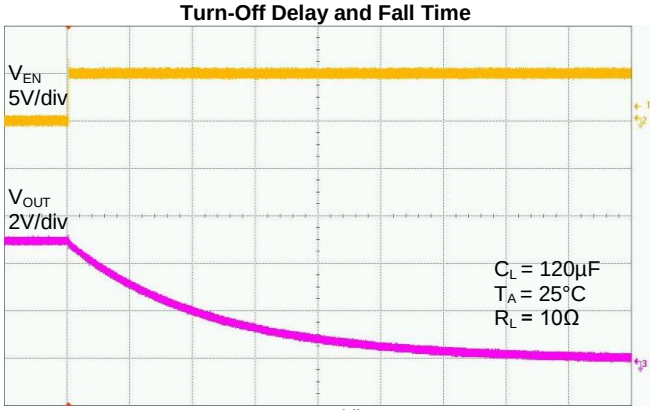
100µs/div

Turn-On Delay and Rise Time



500µs/div

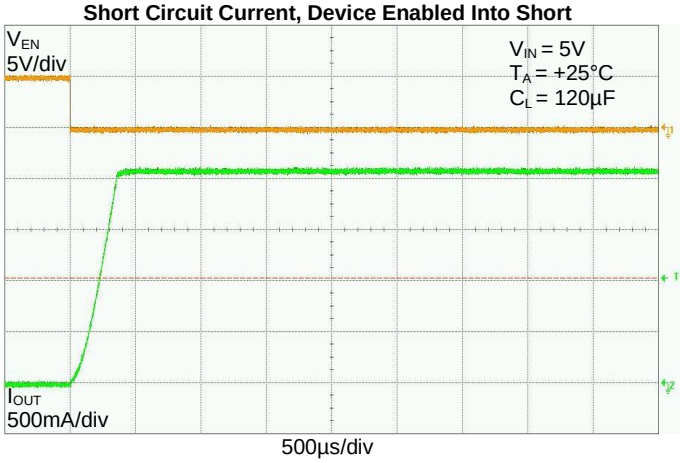
Turn-Off Delay and Fall Time



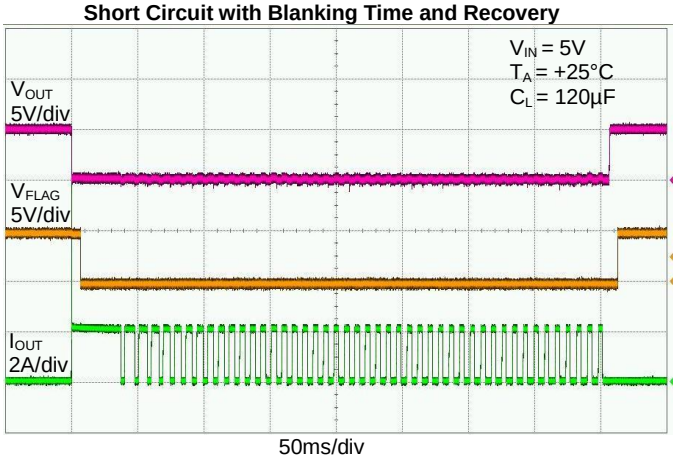
500µs/div

Typical Performance Characteristics (Cont.)

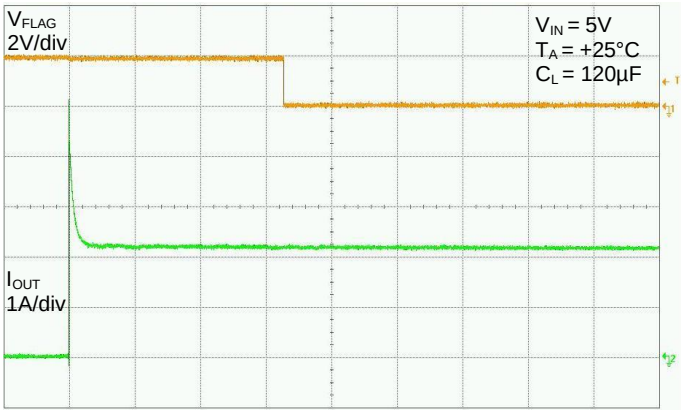
Short Circuit Current, Device Enabled Into Short



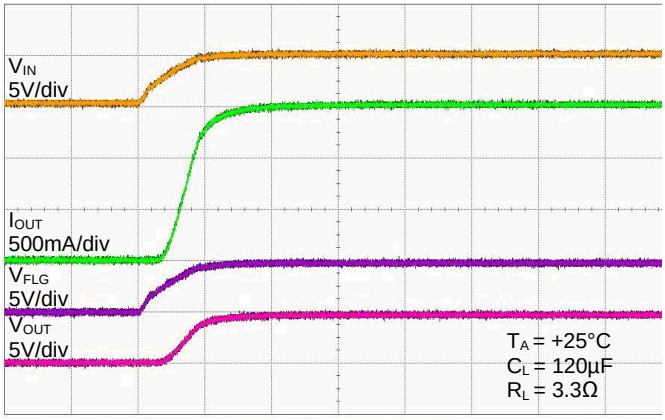
Short Circuit with Blanking Time and Recovery



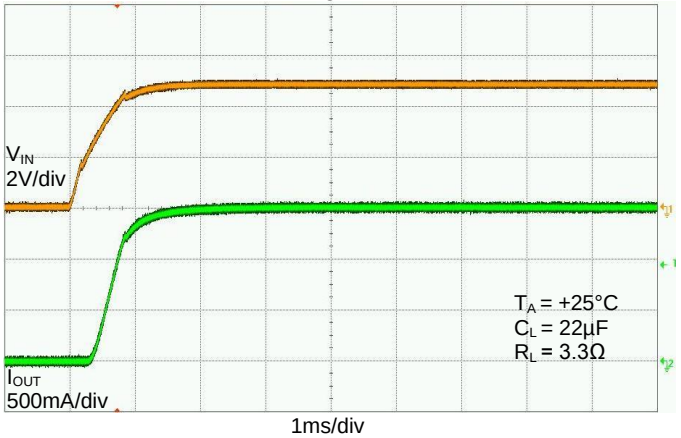
0.6Ω Load Connected to Enabled Device



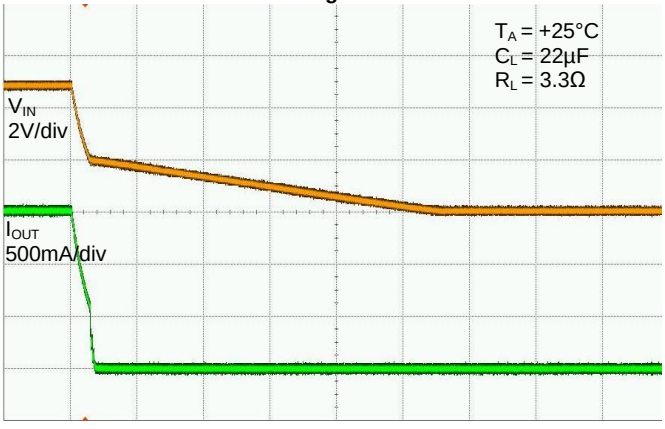
Power On with Full Load



UVLO Increasing With Full Load

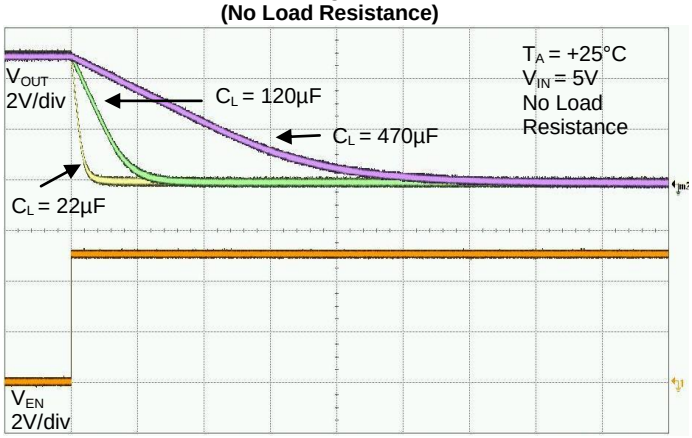


UVLO Decreasing With Full Load

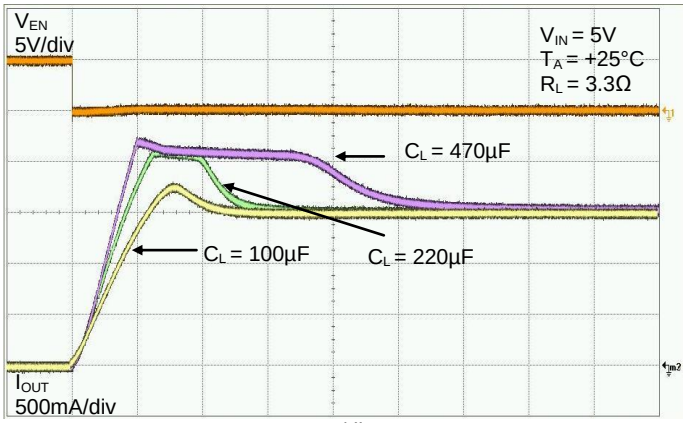


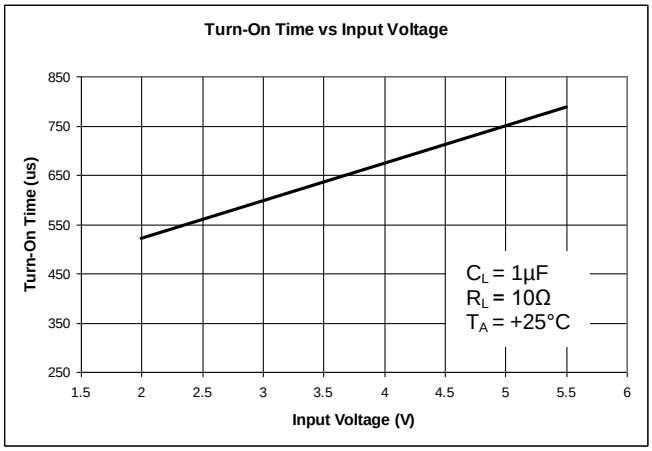
Typical Performance Characteristics (Cont.)

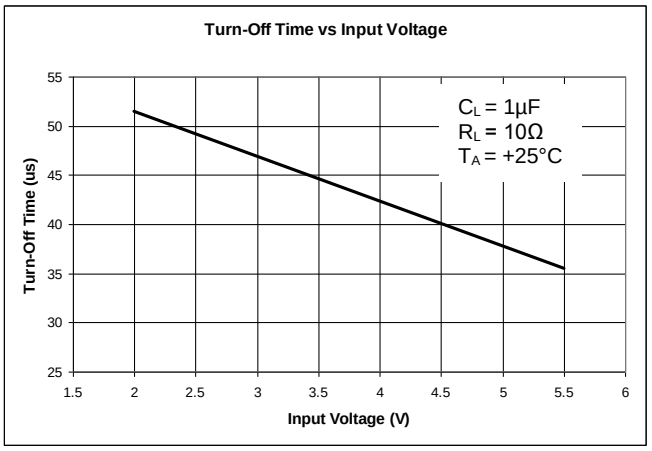
Discharge Time (No Load Resistance)

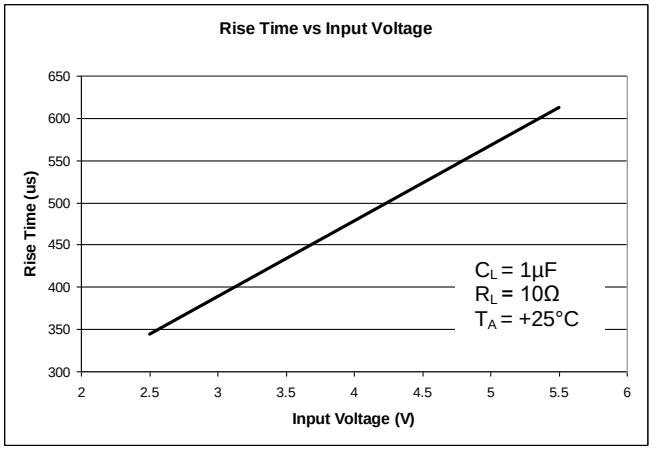


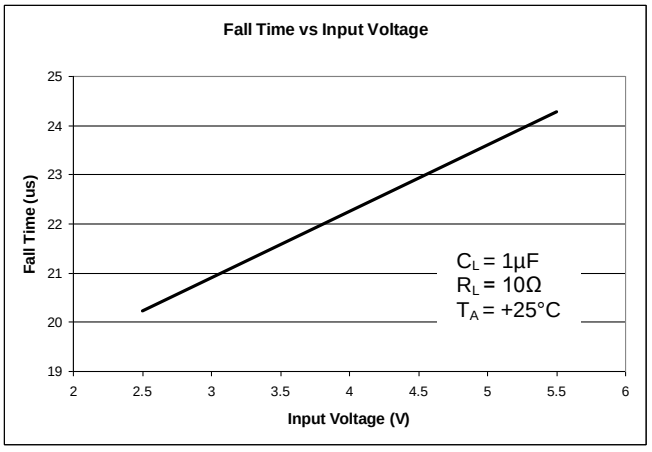
Inrush Current



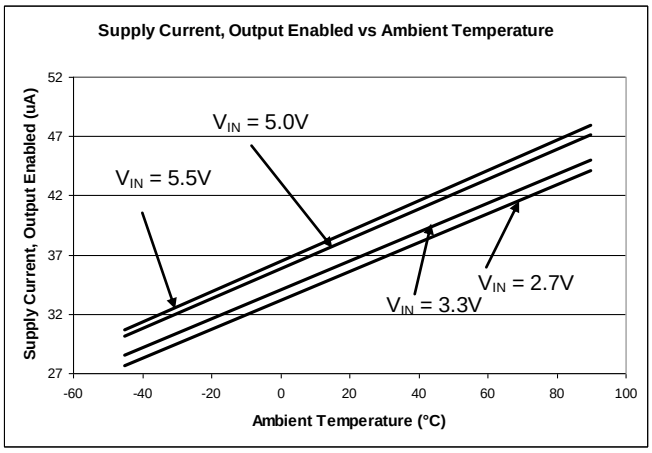


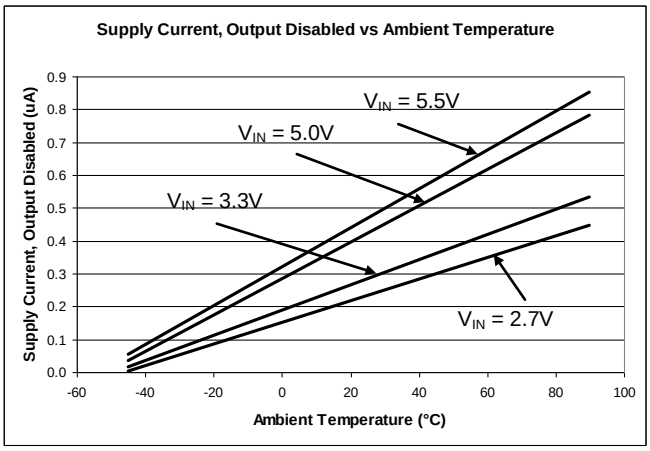


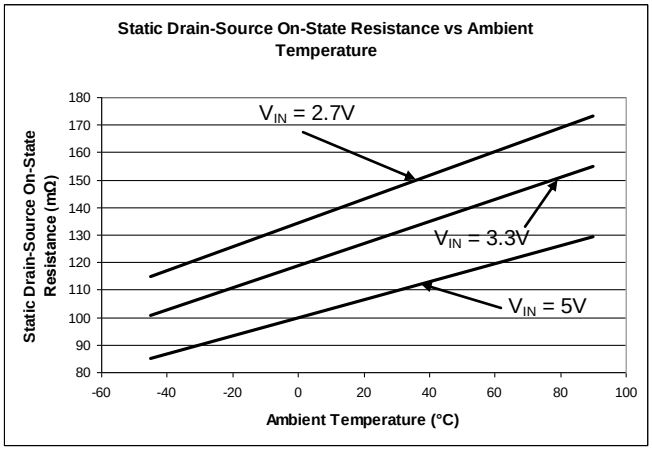


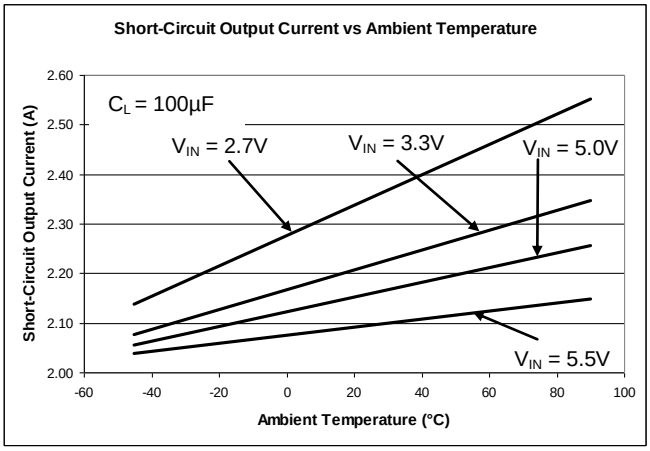


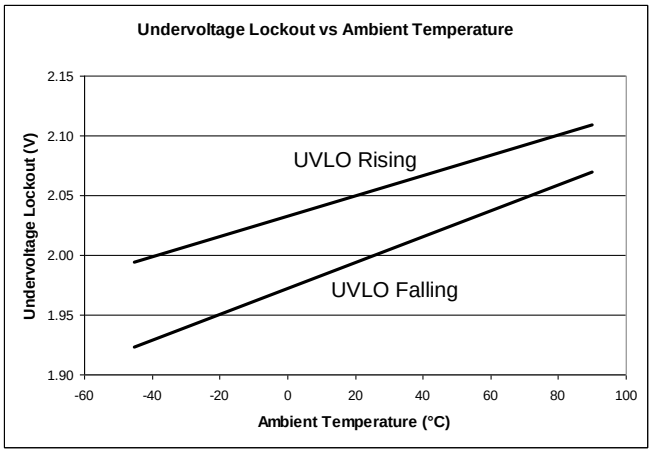
Typical Performance Characteristics (Cont.)

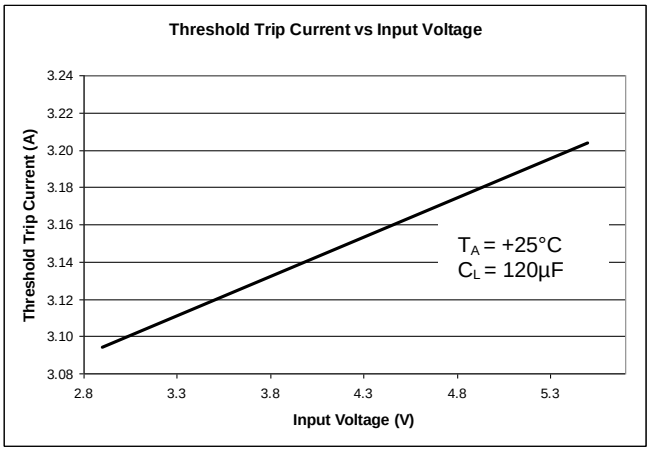












Application Note

The AP2181D and AP2191D are integrated high-side power switches optimized for Universal Serial Bus (USB) that require protection functions. The power switches are equipped with a driver that controls the gate voltage and incorporates slew-rate limitation. This, along with the various protection features and special functions, make these power switches ideal for hot-swap or hot-plug applications.

Protection Features:

Under-Voltage Lockout (UVLO)

Under-voltage lockout function (UVLO) guarantees that the internal power switch is initially off during start-up. The UVLO functions only when the switch is enabled. Even if the switch is enabled, the switch is not turned ON until the power supply has reached at least 1.9V. Whenever the input voltage falls below approximately 1.9V, the power switch is 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.

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 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.

The different overload conditions and the corresponding response of the AP2181D/AP2191D are outlined below:

S. NO	Conditions	Explanation	Behavior of the AP2181D/AP2191D
1	Short circuit condition at start-up	Output is shorted before input voltage is applied or before the part is enabled.	The IC senses the short circuit and immediately clamps output current to a certain safe level namely $I_{LIMIT.}$
2	Short-circuit or over current condition	Short-circuit or overload condition that occurs when the part 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}.
3	Gradual increase from nominal operating current to I_{LIMIT}	Load increases gradually until the current-limit threshold.(I_{TRIG})	The current rises until I_{TRIG} or thermal limit. 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 an extremely low temperature (< -20°C), a minimum 120µF 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 a 10% variation of capacitance change when operated at extremely low temperatures. Our recommended aluminum electrolytic capacitor type is Panasonic FC series.

Thermal Protection

Thermal protection prevents the IC from damage when the die temperature exceeds safe margins. This mainly occurs when heavy-overload or short-circuit faults are present for extended periods of time. The AP2181D/AP2191D implements thermal sensing to monitor the operating junction temperature of the power distribution switch. Once the die temperature rises to approximately +140°C, the Thermal protection feature gets activated as follows: The internal thermal sense circuitry turns the power switch off and the FLG output is asserted thus preventing the power switch from damage. Hysteresis in the thermal sense circuit allows the device to cool down to approximately +25°C before the output is turned back on. The built-in thermal hysteresis feature avoids undesirable oscillations of the thermal protection circuit. The switch continues to cycle in this manner until the load fault is removed, resulting in a pulsed output. The FLG open-drain output is asserted when an over-current occurs with 7ms deglitch.

Reverse Current Protection

In a normal MOSFET switch, current can flow in reverse direction (from the output side to the input side) when the output side voltage is higher than the input side, even when the switch is turned off. A reverse-current blocking feature is implemented in the AP21x1 series to prevent such back currents. This circuit is activated by the difference between the output voltage and the input voltage. When the switch is disabled, this feature blocks reverse current flow from the output back to the input.

Application Note (Cont.)

Special Functions:

Discharge Function

When enable is de-asserted, the discharge function is active. The output capacitor is discharged through an internal NMOS that has a discharge resistance of 100Ω. Hence, the output voltage drops down to zero. The time taken for discharge is dependent on the RC time constant of the resistance and the output capacitor.

FLG Response

The FLG open-drain output goes active low for any of the two conditions: Over-Current or Over-Temperature. The time from when a fault condition is encountered to when the FLG output goes low is 7ms (TYP). The FLG output remains low until both over-current and over-temperature conditions are 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 7ms deglitch timeout. This 7ms timeout is also applicable for Over-current recovery and Thermal recovery. The AP2181D/AP2191D is designed to eliminate erroneous Over-current reporting without the need for external components, such as an RC delay network.

Power Supply Considerations

A 0.01μF to 0.1μF X7R or X5R ceramic bypass capacitor between IN and GND, close to the device, is recommended. This limits the input voltage drop during line transients. Placing a high-value electrolytic capacitor on the input (10μF minimum) and output pin(s) is recommended when the output load is heavy. This precaution also reduces power-supply transients that may cause ringing on the input. Additionally, bypassing the output with a 0.01μF to 0.1μF ceramic capacitor improves the immunity of the device to short-circuit transients. This capacitor also prevents output from going negative during turn-off due to inductive parasitics.

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:

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

The junction temperature can be calculated by:

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

Where:
T_A= Ambient Temperature °C
$R_{\theta JA}$ = Thermal Resistance
P_D = Total Power Dissipation

Generic Hot-Plug Applications

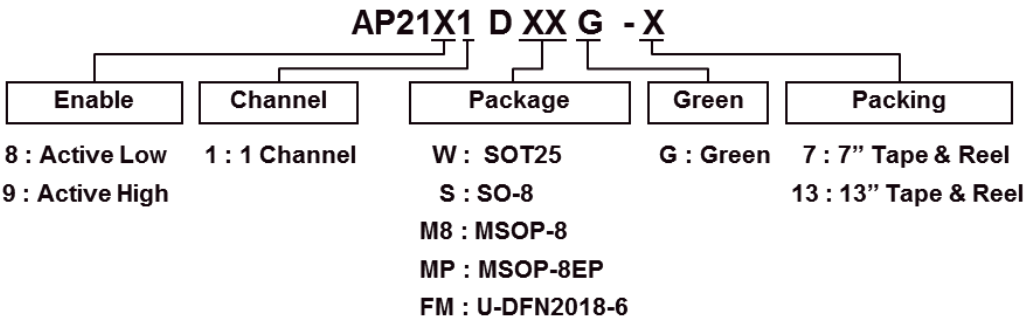
In many applications it may be necessary to remove modules or PC boards while the main unit is still operating. These are considered hot-plug applications. Such implementations require the control of current surges as seen by the main power supply and the card being inserted. The most effective way to control these surges is to limit and slowly ramp up 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 and fall time of the AP2181D/AP2191D, 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 AP2181D/AP2191D 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 AP2181D/AP2191D 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 the system surge current and provides a hot-plugging mechanism for any device.

Dual-Purpose Port Applications

AP2181D/AP2191D is not recommended for use in dual-purpose port applications in which a single port is used for data communication between the host and peripheral devices while simultaneously maintaining a charge to the battery of the peripheral device. An example of such a non-recommended application is a shared HDMI/MHL (Mobile High-definition Link) port that allows streaming video between an HDTV or set-top box and a smartphone or tablet while maintaining a charge to the smartphone or tablet battery. Since the AP2181D/AP2191D includes an embedded discharge feature that discharges the output load of the device when the device is disabled, the batteries of the connected peripheral device will be subject to continual discharge whenever the AP2181D/AP2191D is disabled. In addition, if the output of the AP2181D/AP2191D is subjected to a constant voltage that would be present during a dual-purpose port application such as MHL, an overstress condition to the device's discharge MOS transistor may result.

Ordering Information

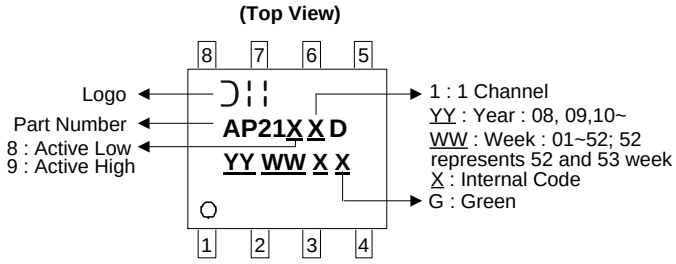


Part Number	Package (Note 9)	Package Code	7"/13" Tape and Reel Quantity	Status (Note 8)
AP2181DWG-7	SOT25	S	3000	In Production
AP2181DSG-13	SO-8	SN	2500	In Production
AP2181DMPG-13	MSOP-8EP	MP	2500	In Production
AP2181DFMG-7	U-DFN2018-6	FM	3000	In Production
AP2191DWG-7	SOT25	S	3000	In Production
AP2191DSG-13	SO-8	SN	2500	In Production
AP2191DM8G-13	MSOP-8	M8	2500	In Production
AP2191DMPG-13	MSOP-8EP	MP	2500	In Production
AP2191DFMG-7	U-DFN2018-6	FM	3000	In Production

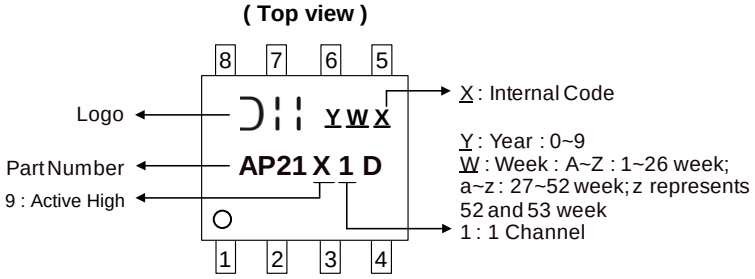
Notes: 8. AP2181DM8G-13 is End of Life (EOL) and recommended alternative is AP2181DMPG-13 or AP2191DM8G-13.
9. For packaging details, go to our website at: https://www.diodes.com/design/support/packaging/diodes-packaging/.

Marking Information

(1) SO-8



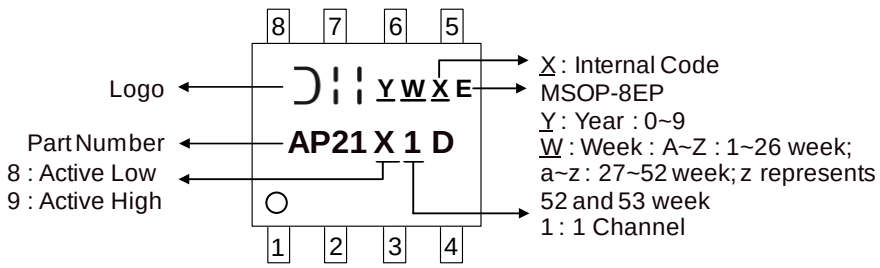
(2) MSOP-8



Marking Information (Cont.)

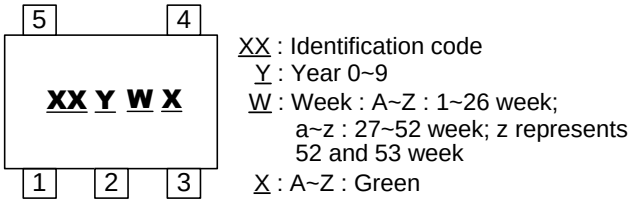
(3) MSOP-8EP

(Top view)



(4) SOT25

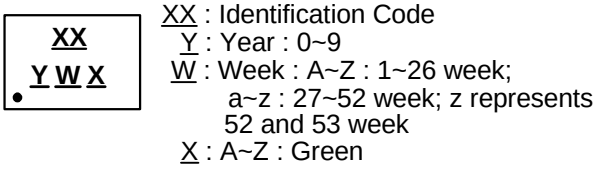
(Top View)



Device	Package Type	Identification Code
AP2181DW	SOT25	JE
AP2191DW	SOT25	JF

(5) U-DFN2018-6

(Top View)

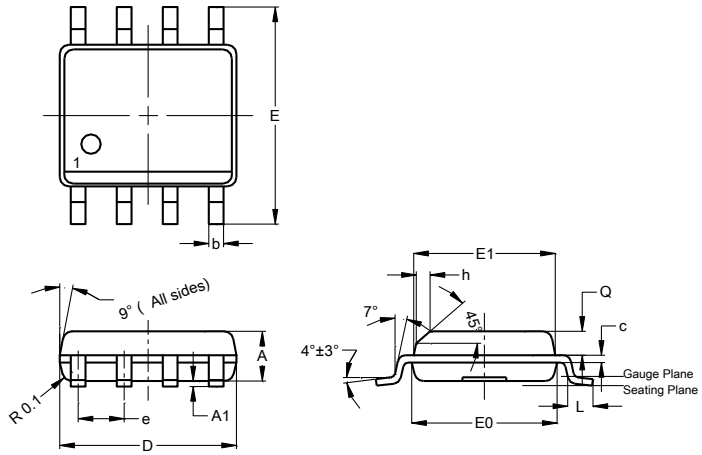


Device	Package Type	Identification Code
AP2181DFM	U-DFN2018-6	JE
AP2191DFM	U-DFN2018-6	JF

Package Outline Dimensions

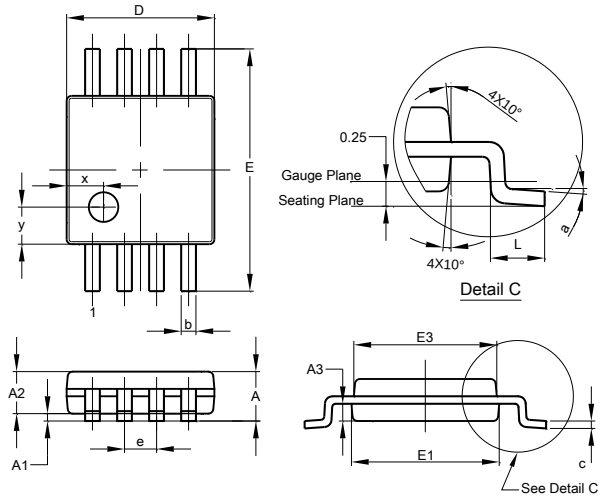
Please see http://www.diodes.com/package-outlines.html for the latest version.

(1) SO-8



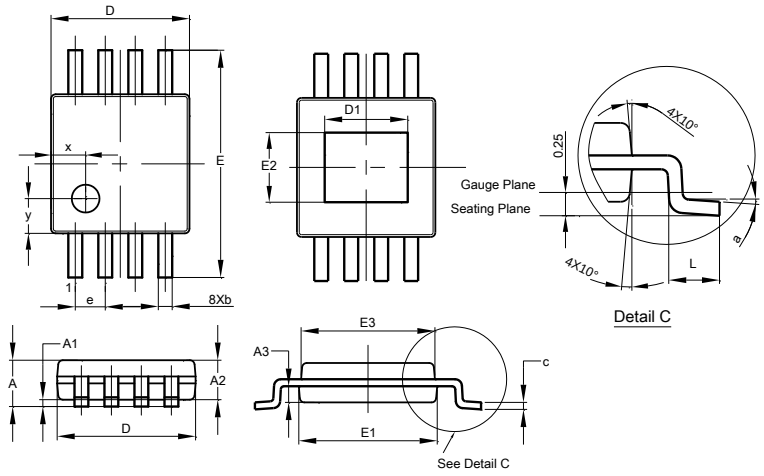
SO-8			
Dim	Min	Max	Typ
A	1.40	1.50	1.45
A1	0.10	0.20	0.15
b	0.30	0.50	0.40
c	0.15	0.25	0.20
D	4.85	4.95	4.90
E	5.90	6.10	6.00
E1	3.80	3.90	3.85
E0	3.85	3.95	3.90
e	--	--	1.27
h	-	--	0.35
L	0.62	0.82	0.72
Q	0.60	0.70	0.65
All Dimensions in mm			

(2) MSOP-8



MSOP-8			
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
E	4.70	5.10	4.90
E1	2.90	3.10	3.00
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			

(3) MSOP-8EP

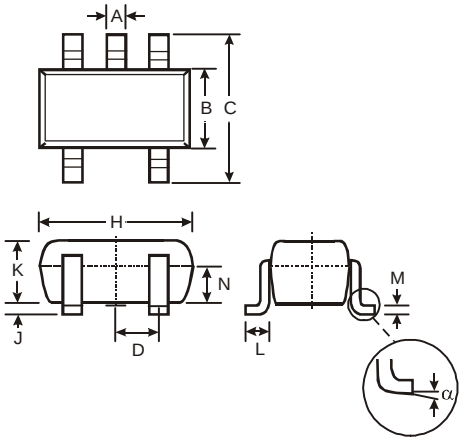


MSOP-8EP			
Dim	Min	Max	Typ
A	-	1.10	-
A1	0.05	0.15	0.10
A2	0.75	0.95	0.86
A3	0.29	0.49	0.39
b	0.22	0.38	0.30
c	0.08	0.23	0.15
D	2.90	3.10	3.00
D1	1.60	2.00	1.80
E	4.70	5.10	4.90
E1	2.90	3.10	3.00
E2	1.30	1.70	1.50
E3	2.85	3.05	2.95
e	-	-	0.65
L	0.40	0.80	0.60
a	0°	8°	4°
x	-	-	0.750
y	-	-	0.750
All Dimensions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

Package Outline Dimensions (Cont.)

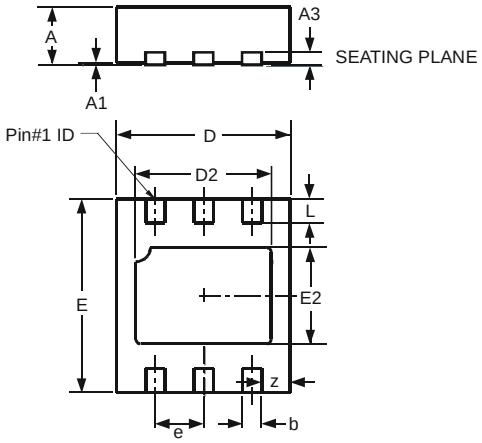
Please see http://www.diodes.com/package-outlines.html for the latest version.

(4) SOT25



SOT25			
Dim	**Min**	**Max**	**Typ**
A	0.35	0.50	0.38
B	1.50	1.70	1.60
C	2.70	3.00	2.80
D	-	-	0.95
H	2.90	3.10	3.00
J	0.013	0.10	0.05
K	1.00	1.30	1.10
L	0.35	0.55	0.40
M	0.10	0.20	0.15
N	0.70	0.80	0.75
α	0°	8°	-
All Dimensions in mm			

(5) U-DFN2018-6

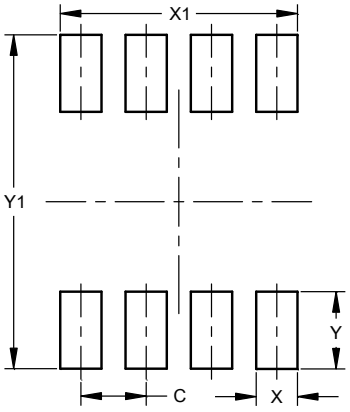


U-DFN2018-6			
Dim	**Min**	**Max**	**Typ**
A	0.545	0.605	0.575
A1	0	0.05	0.02
A3	-	-	0.13
b	0.15	0.25	0.20
D	1.750	1.875	1.80
D2	1.30	1.50	1.40
e	-	-	0.50
E	1.95	2.075	2.00
E2	0.90	1.10	1.00
L	0.20	0.30	0.25
z	-	-	0.30
All Dimensions in mm			

Suggested Pad Layout

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

(1) SO-8

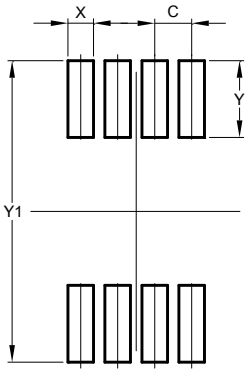


Dimensions	Value (in mm)
C	1.27
X	0.802
X1	4.612
Y	1.505
Y1	6.50

Suggested Pad Layout (Cont.)

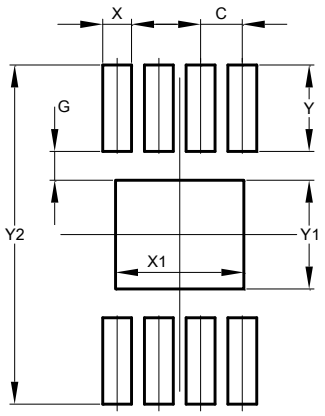
Please see http://www.diodes.com/package-outlines.html for the latest version.

(2) MSOP-8



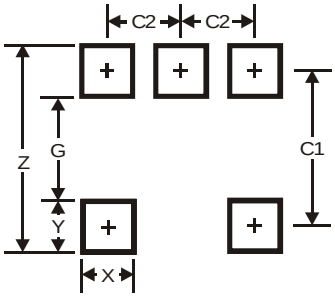
Dimensions	Value (in mm)
C	0.650
X	0.450
Y	1.350
Y1	5.300

(3) MSOP-8-EP



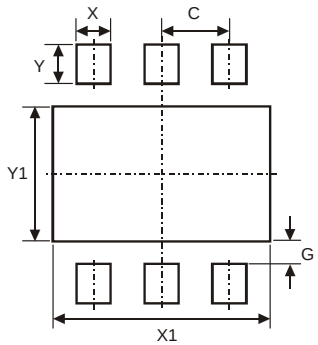
Dimensions	Value (in mm)
C	0.650
G	0.450
X	0.450
X1	2.000
Y	1.350
Y1	1.700
Y2	5.300

(4) SOT25



Dimensions	Value
Z	3.20
G	1.60
X	0.55
Y	0.80
C1	2.40
C2	0.95

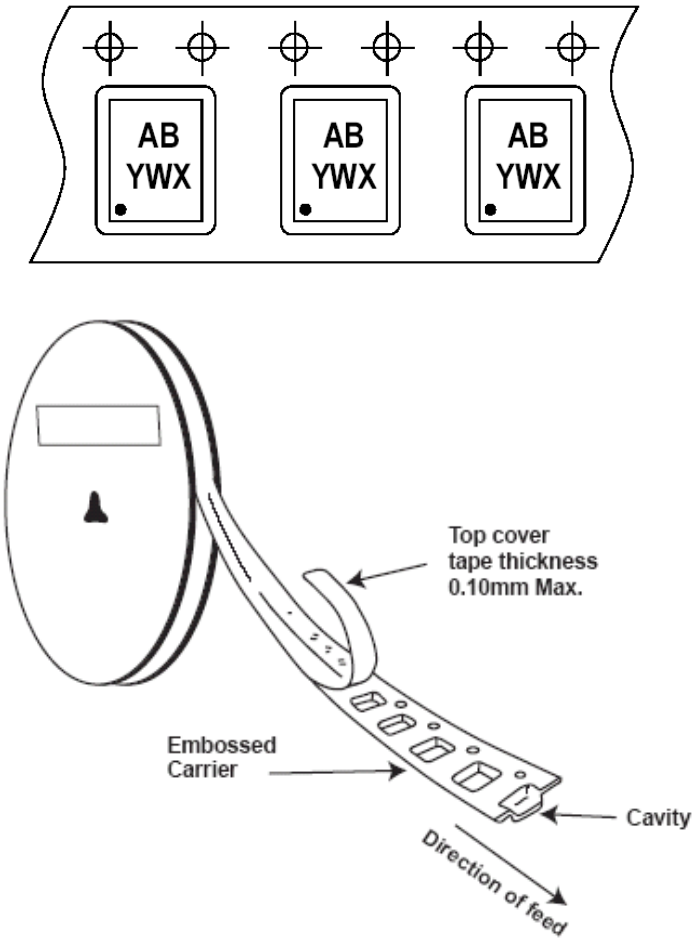
(5) U-DFN2018-6



Dimensions	Value (in mm)
C	0.50
G	0.20
X	0.25
X1	1.60
Y	0.35
Y1	1.20

Taping Orientation (Note 10)

For U-DFN2018-6



Note: 10. The taping orientation of the other package type can be found on our website at http://www.diodes.com/datasheets/ap02007.pdf.