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Lead-free Green

AP22913

SINGLE SLEW RATE CONTROLLED LOAD SWITCH

NEW PRODUCT

Description

The AP22913 slew rate controlled load switch is a single P-channel MOSFET power switch designed for high-side load-switching applications. The MOSFET has a typical $R_{DS(ON)}$ of 54mΩ at 5V (X1-WLB0909-4) and a typical $R_{DS(ON)}$ of 84mΩ at 5V (SOT26), allowing increased load current handling capacity with a low forward voltage drop. The turn-on slew rate of the device is controlled internally. V_{IN} and V_{OUT} are isolated during OFF state with TRCB (True Reverse Current Blocking) feature.

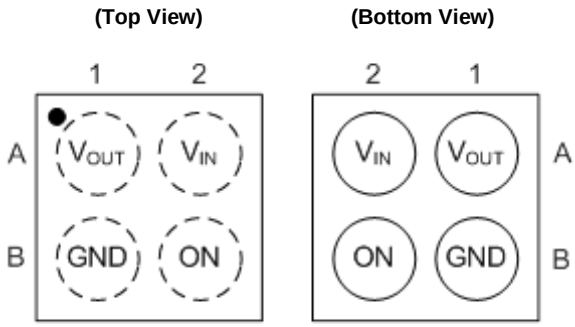
The AP22913 load switch is designed to operate from 1.4V to 5.5V, making it ideal for 1.8V, 2.5V, 3.3V and 5V systems. The typical quiescent supply current is only 1µA.

The AP22913 is available in the wafer level chip scale 4-pin, X1-WLB0909-4 0.5mm pitch and standard SOT26 packages.

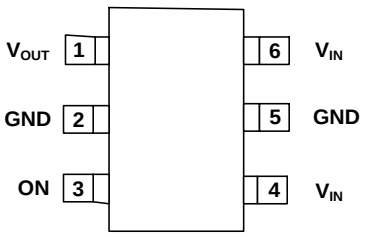
Features

- Wide Input Voltage Range: 1.4V to 5.5V
- Low On-Resistance (X1-WLB0909-4):
  - 92mΩ Typical @1.5V
  - 76mΩ Typical @1.8V
  - 56mΩ Typical @3.3V
  - 54mΩ Typical @5.0V
- Low On-Resistance (SOT26):
  - 122mΩ Typical @1.5V
  - 106mΩ Typical @1.8V
  - 86mΩ Typical @3.3V
  - 84mΩ Typical @5.0V
- High DC Current Capability up to 2A
- Truly Reverse Current Block (TRCB)
- Discharging Resistor on V_{OUT} When Disabled
- Ultra Low Quiescent Current 1µA
- Active-High Control Pin
  - Minimum 1.1V V_{IH} of ON
- ESD Protection:
  - Human Body Model: 2kV
  - Charged Device Model: 1kV
- Package:
  - X1-WLB0909-4 with Backside Laminate
  - 0.9mm x 0.9mm, 0.5mm Ball Pitch
  - Standard Green SOT26
- **Totally Lead-Free & Fully RoHS Compliant (Notes 1 & 2)**
- **Halogen and Antimony Free. "Green" Device (Notes 3)**

Pin Assignments



X1-WLB0909-4



SOT26

Applications

- Mobile Device and Smart Phones
- Portable Media Devices
- Wearable Devices
- Advanced Notebook, UMPC and MID
- Portable Medical Devices
- GPS and Navigation Equipment

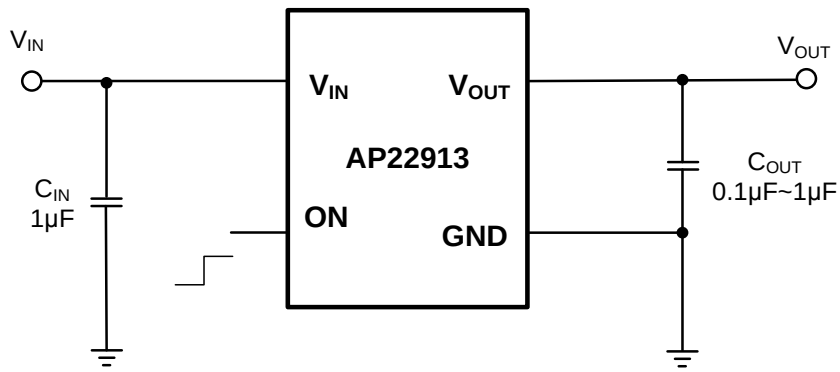
Notes:
1. No purposely added lead. Fully EU Directive 2002/95/EC (RoHS), 2011/65/EU (RoHS 2) & 2015/863/EU (RoHS 3) compliant.
2. See https://www.diodes.com/quality/lead-free/ for more information about Diodes Incorporated's definitions of Halogen- and Antimony-free, "Green" and Lead-free.
3. Halogen- and Antimony-free "Green" products are defined as those which contain <900ppm bromine, <900ppm chlorine (<1500ppm total Br + Cl) and <1000ppm antimony compounds.

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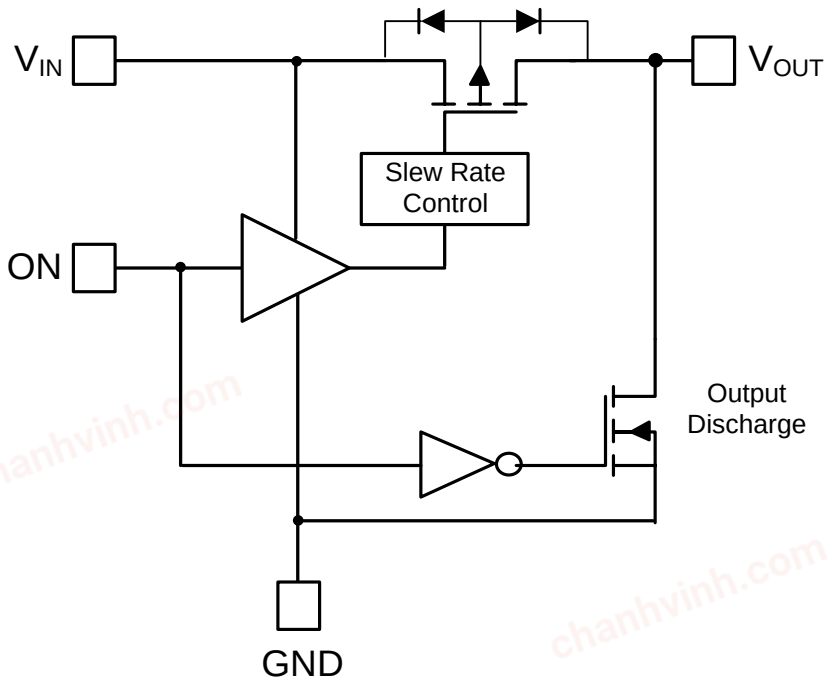
Typical Applications Circuit



Pin Descriptions

Pin Name	Pin Number		Function
	SOT26	X1-WLB0909-4	
V_{OUT}	1	A1	Voltage output pin. This is the pin to the P-channel MOSFET drain connection. Bypass to ground through a 0.1µF or 1µF capacitor.
V_{IN}	4, 6	A2	Voltage input pin. This is the pin to the P-channel MOSFET source. Bypass to ground through a 1µF capacitor.
GND	2, 5	B1	Ground
ON	3	B2	Enable input, active high

Functional Block Diagram



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

Symbol	Parameter	Ratings		Unit
ESD HBM	Human Body Model ESD Protection	6		kV
ESD CDM	Charged Device Model ESD Protection	2		kV
V_{IN}	Input Voltage	-0.3 to 6		V
V_{OUT}	Output Voltage	-0.3 to 6		V
V_{ON}	ON Voltage	-0.3 to 6		V
I_{LOAD}	Maximum Continuous Load Current	2		A
I_{LOAD}	Maximum Pulse Load Current, Pulse <300µs, 2% Duty Cycle	2.5		A
T_J	Maximum Junction Temperature	+125		°C
T_{ST}	Storage Temperature Range	-65 to +150		°C
P_D	Power Dissipation	X1-WLB0909-4	930	mW
		SOT26	760	mW
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient (Note 4)	X1-WLB0909-4	136	°C/W
		SOT26	165	°C/W
$R_{\theta JC}$	Thermal Resistance, Junction to Case (Note 5)	X1-WLB0909-4	31	°C/W
		SOT26	30	°C/W

Notes: 4. The JEDEC high-K (2s2p) board used to derive this data was a 3 inch x 3 inch, multilayer board with 1oz internal power and ground planes with 2oz copper traces on top and bottom of the board.
5. Thermal resistance from junction to case.

Caution: Stresses greater than the 'Absolute Maximum Ratings' specified above, can 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 can be affected by exposure to absolute maximum rating conditions for extended periods of time.

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

Symbol	Parameter		Min	Max	Unit
V_{IN}	Input Voltage		1.4	5.5	V
V_{ON}	ON Voltage Range		0	5.5	V
V_{OUT}	Output Voltage		1.4	5.5	V
I_{OUT}	Output Current		0	2.0	A
V_{IH}	ON High-Level Input Voltage		1.1	5.5	V
V_{IL}	ON Low-Level Input Voltage	V_{IN} = 3.6V to 5.5V	0	0.6	V
		V_{IN} = 1.4V to 3.6V	0	0.4	V
T_A	Operating Ambient Temperature		-40	+85	°C

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NEW PRODUCT

Electrical Characteristics

(T_A = -40°C to +85°C, V_{IN} = 1.4 to 5.5V, V_{ON} = V_{IN} (Enabled), V_{ON} = 0V (Disabled), C_{IN} = 1µF, C_{OUT} = 0.1µF, unless otherwise specified.) (Note 6)

Symbol	Parameters	Test Conditions		Min	Typ	Max	Unit
I_Q	Input Quiescent Current	I_{OUT} = 0mA, V_{ON} = Enabled	V_{IN} = 5.25V	—	1.4	7	µA
			V_{IN} = 4.2V	—	1	5	
			V_{IN} = 3.6V	—	0.7	5	
			V_{IN} = 2.5V	—	0.5	3.5	
			V_{IN} = 1.5V	—	0.3	3.5	
I_{SHDN}	Input Shutdown Current	R_L = 1MΩ, V_{ON} = Disabled	V_{IN} = 5.25V	—	0.1	1	µA
			V_{IN} = 4.2V	—	0.1	1	
			V_{IN} = 3.6V	—	0.1	1	
			V_{IN} = 2.5V	—	0.1	1	
			V_{IN} = 1.5V	—	0.1	1	
I_{IN_LEAK}	Input Leakage Current	V_{OUT} = 0V, V_{ON} = Disabled	V_{IN} = 5.25V	—	0.1	2	µA
			V_{IN} = 4.2V	—	0.1	2	
			V_{IN} = 3.6V	—	0.1	2	
			V_{IN} = 2.5V	—	0.1	2	
			V_{IN} = 1.5V	—	0.1	2	
$R_{DS(ON)}$	Switch On-Resistance, I_{OUT} = -200mA at X1-WLB0909-4 Package	V_{IN} = 5.0V	+25°C	—	54	70	mΩ
			Full	—	—	95	
		V_{IN} = 4.2V	+25°C	—	55	70	
			Full	—	—	95	
		V_{IN} = 3.3V	+25°C	—	56	80	
			Full	—	—	95	
		V_{IN} = 2.5V	+25°C	—	60	85	
			Full	—	—	115	
		V_{IN} = 1.8V	+25°C	—	76	100	
			Full	—	—	130	
		V_{IN} = 1.5V	+25°C	—	92	120	
			Full	—	—	150	
	Switch On-Resistance, I_{OUT} = -200mA at SOT26 Package	V_{IN} = 5.0V	+25°C	—	84	100	mΩ
			Full	—	—	125	
		V_{IN} = 4.2V	+25°C	—	85	100	
			Full	—	—	125	
		V_{IN} = 3.3V	+25°C	—	86	100	
			Full	—	—	125	
		V_{IN} = 2.5V	+25°C	—	90	115	
			Full	—	—	145	
		V_{IN} = 1.8V	+25°C	—	106	130	
			Full	—	—	160	
		V_{IN} = 1.5V	+25°C	—	122	150	
			Full	—	—	180	
R_{DIS}	Discharge FET On-Resistance	V_{IN} = 3.3V, V_{ON} = 0V, I_{OUT} = 30mA, T_A = +25°C		—	150	200	Ω
UVLO	Under-Voltage Lockout	V_{IN} increasing		—	—	1.2	V
		V_{IN} decreasing		0.5	—	—	
V_{T_RCB}	TRCB Trigger Point	V_{OUT} - V_{IN}		—	44	—	mV
V_{R_RCB}	TRCB Release Point	V_{IN} - V_{OUT}		—	0	—	mV
t_{T_RCB}	TRCB Response Time	V_{IN} = 5V, V_{ON} = V_{IN}		—	10	—	µs
I_{RCB}	TRCB Reverse Leakage Current (Current from V_{IN})	V_{OUT} - V_{IN} > V_{T_RCB}, V_{ON} = Enabled		—	0.3	—	µA
		V_{IN} = 0V, V_{OUT} = 5.5V, V_{ON} = Disabled					
I_{ON}	ON Input Leakage	V_{ON} = 0V, 5.25V or V_{ON} = V_{IN}		—	—	1	µA

Note: 6. Specifications are over -40°C to +85°C and are guaranteed by characterization and design.

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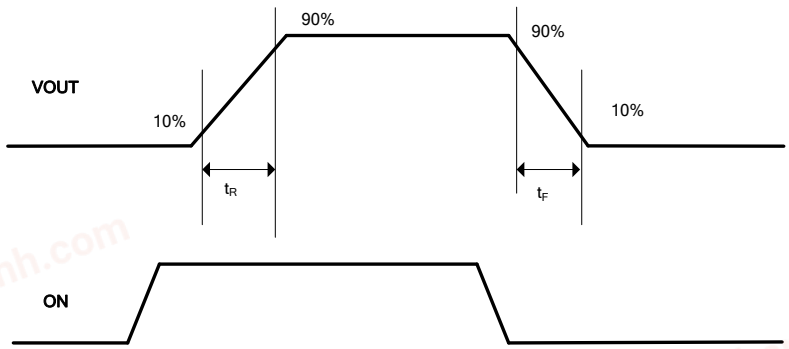
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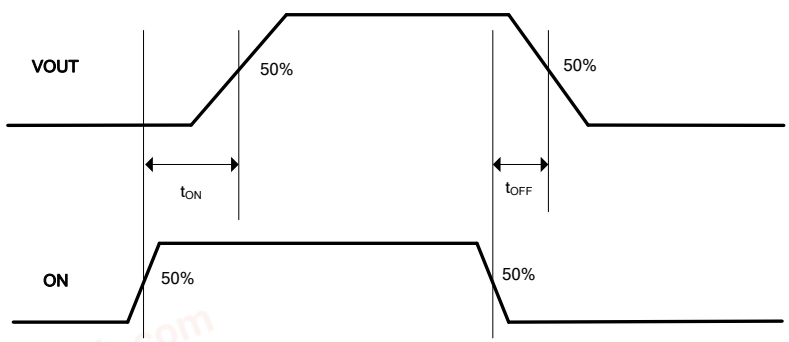
Timing Characteristics (Note 7)

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Symbol	Parameters	Test Conditions	Min	Typ	Max	Unit
t_{ON}	Output Turn-On Time	V_{IN} = 5V, R_L = 10Ω, C_{OUT} = 0.1μF	—	720	—	μs
t_{OFF}	Output Turn-Off Time		—	5	—	μs
t_R	Output Rise Time		—	660	—	μs
t_F	Output Fall Time		—	2.5	—	μs
t_{ON}	Output Turn-On Time	V_{IN} = 3.3V, R_L = 10Ω, C_{OUT} = 0.1μF	—	1050	—	μs
t_{OFF}	Output Turn-Off Time		—	6.5	—	μs
t_R	Output Rise Time		—	770	—	μs
t_F	Output Fall Time		—	3.0	—	μs
t_{ON}	Output Turn-On Time	V_{IN} = 1.5V, R_L = 10Ω, C_{OUT} = 0.1μF	—	2300	—	μs
t_{OFF}	Output Turn-Off Time		—	18	—	μs
t_R	Output Rise Time		—	1400	—	μs
t_F	Output Fall Time		—	5.0	—	μs



Output Rise (t_R) and Fall (t_F) Time



Output Turn On (t_{ON}) and Turn Off (t_{OFF}) Time

Note: 7. Rise and fall time of the control signal are less than 100ns.

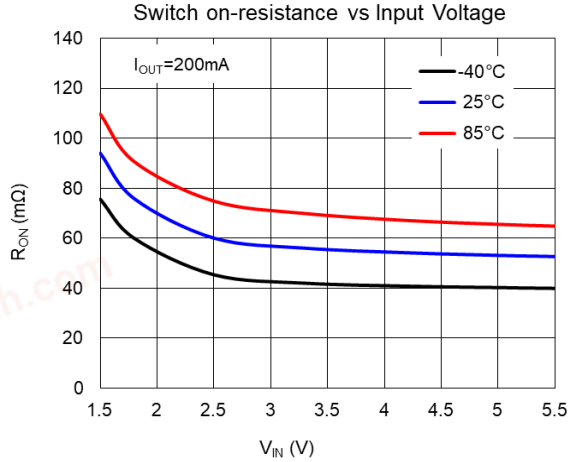
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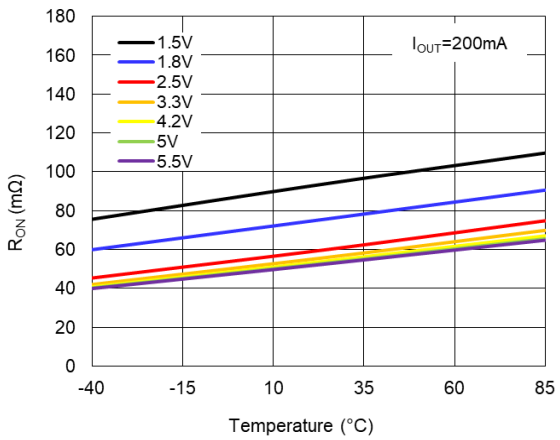
NEW PRODUCT

Typical Performance Characteristics (C_{IN} = 1μF, C_{OUT} = 0.1μF, unless otherwise specified.)

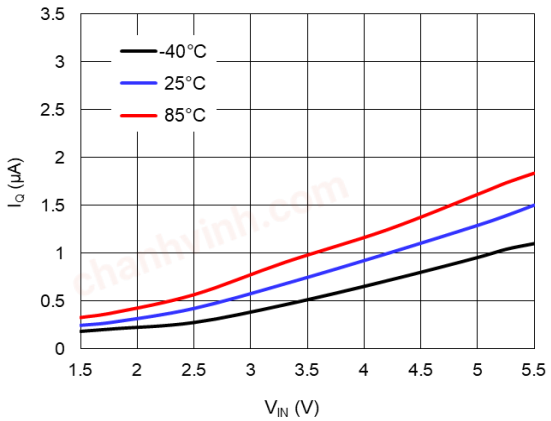
Switch on-resistance vs Input Voltage



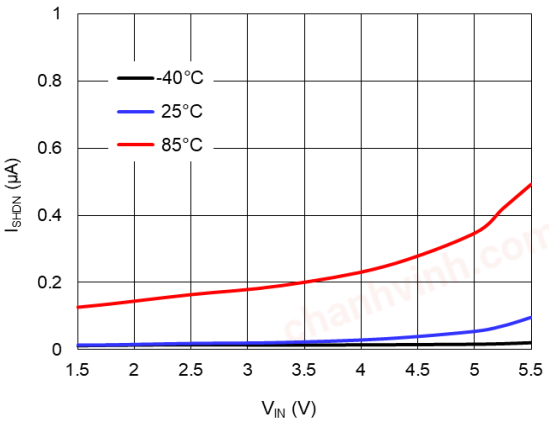
Switch on-resistance vs Temperature



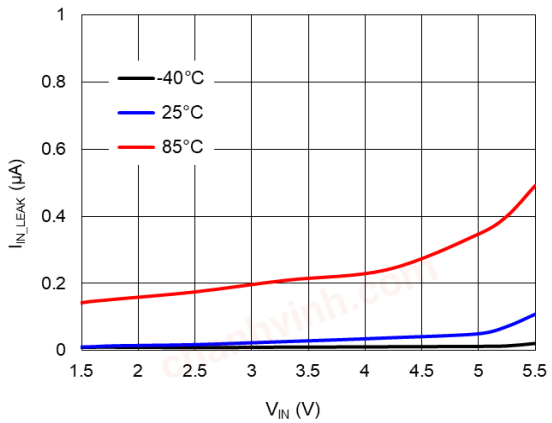
Input Quiescent Current vs Input Voltage



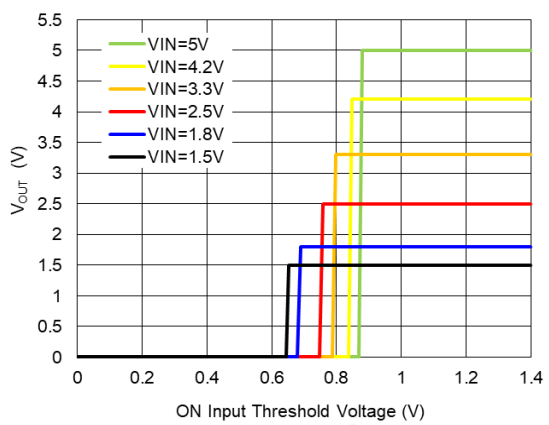
Input Shutdown Current vs Input Voltage



Input Leakage Current vs Input Voltage



ON Input Threshold Voltage (High Active)



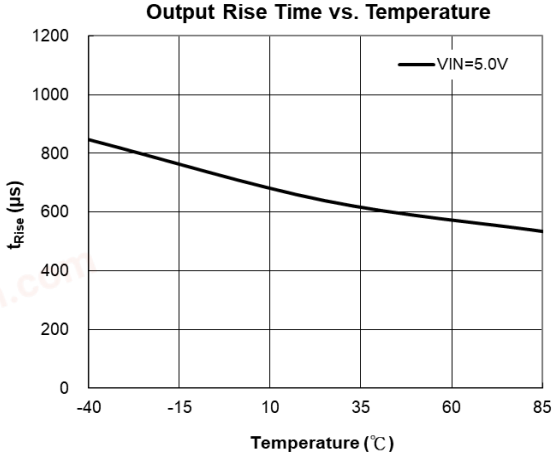
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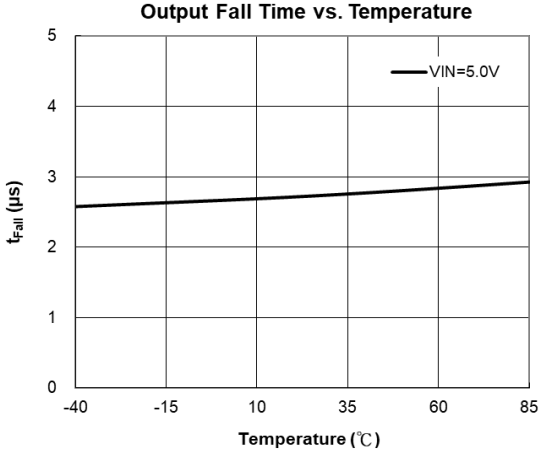
NEW PRODUCT

Typical Performance Characteristics (continued) (C_{IN} = 1μF, C_{OUT} = 0.1μF, R_L = 10Ω, unless otherwise specified.)

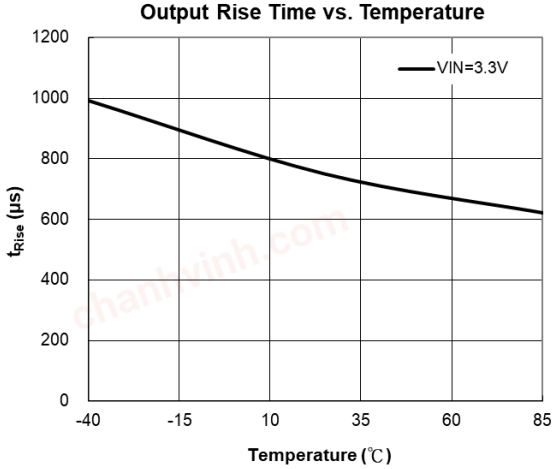
Output Rise Time vs. Temperature



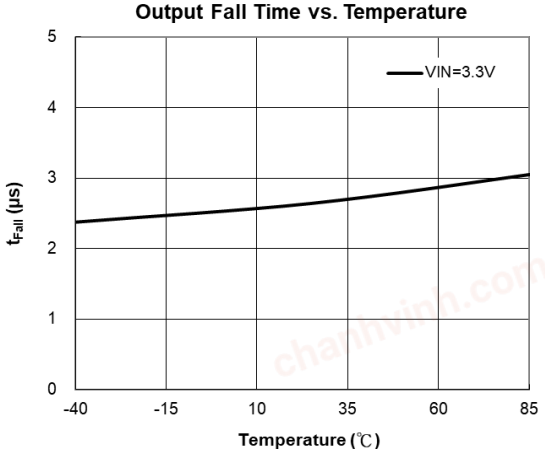
Output Fall Time vs. Temperature



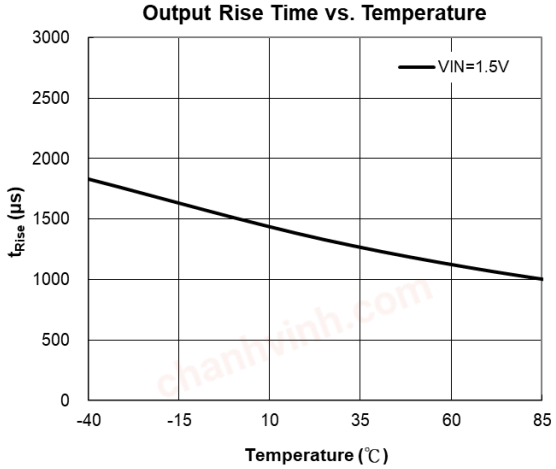
Output Rise Time vs. Temperature



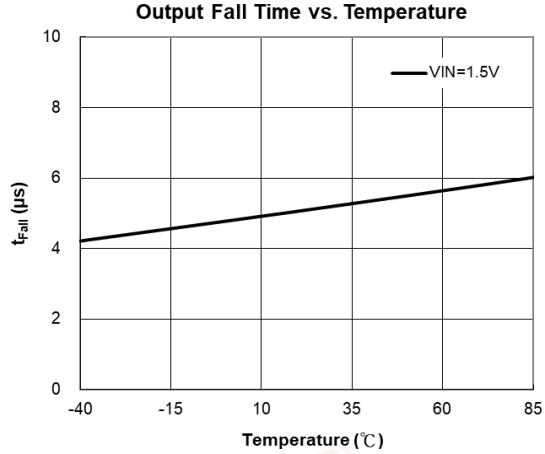
Output Fall Time vs. Temperature



Output Rise Time vs. Temperature



Output Fall Time vs. Temperature



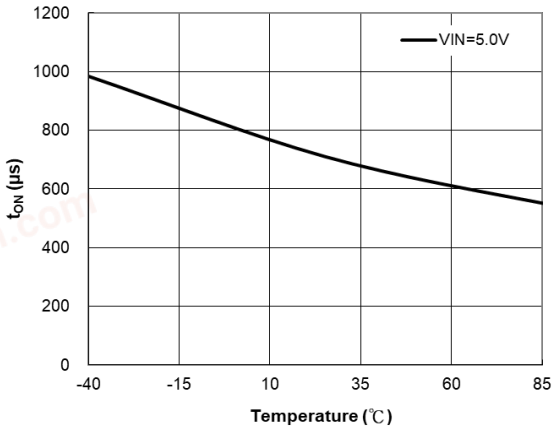
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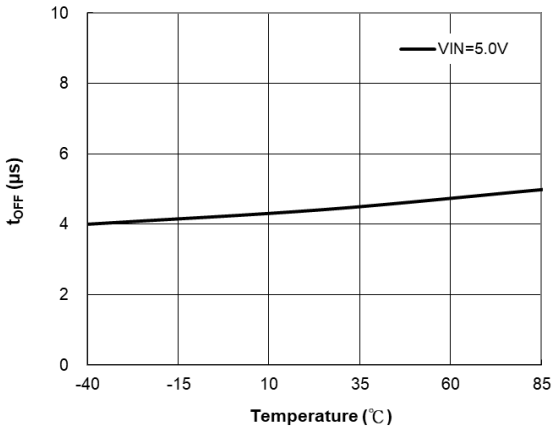
NEW PRODUCT

Typical Performance Characteristics (continued) (C_{IN} = 1μF, C_{OUT} = 0.1μF, R_L = 10Ω, unless otherwise specified.)

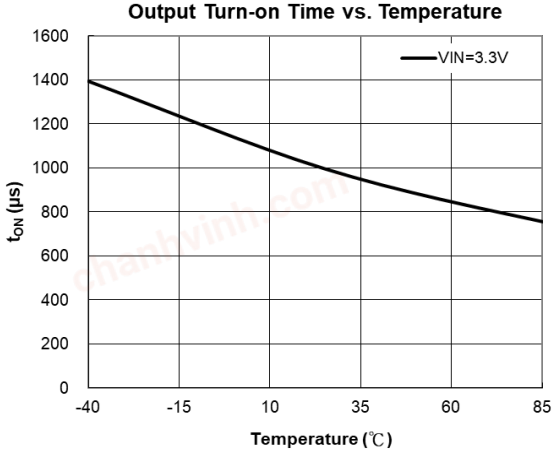
Output Turn-on Time vs. Temperature



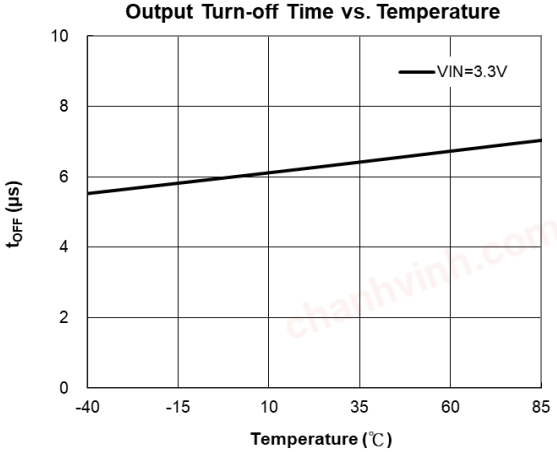
Output Turn-off Time vs. Temperature



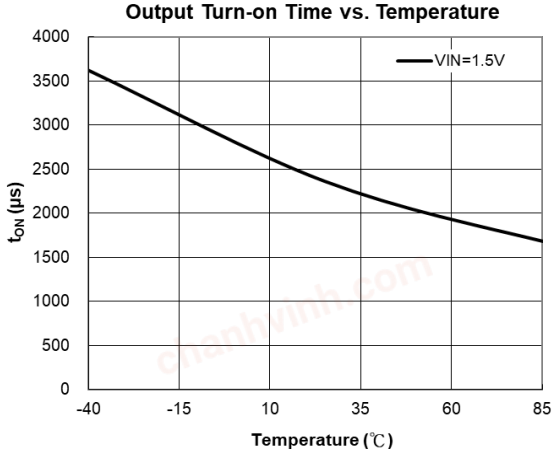
Output Turn-on Time vs. Temperature



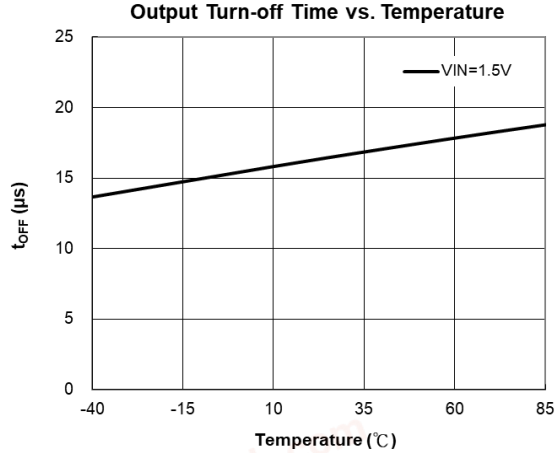
Output Turn-off Time vs. Temperature



Output Turn-on Time vs. Temperature



Output Turn-off Time vs. Temperature



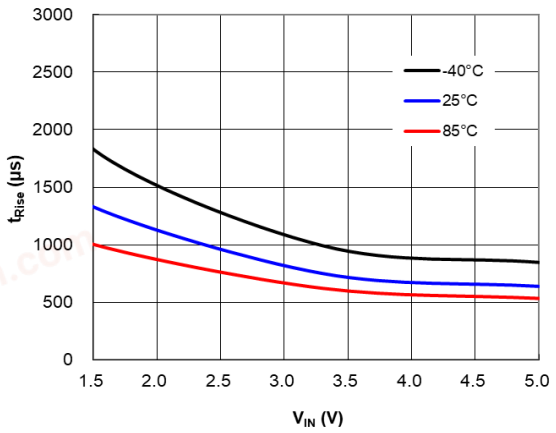
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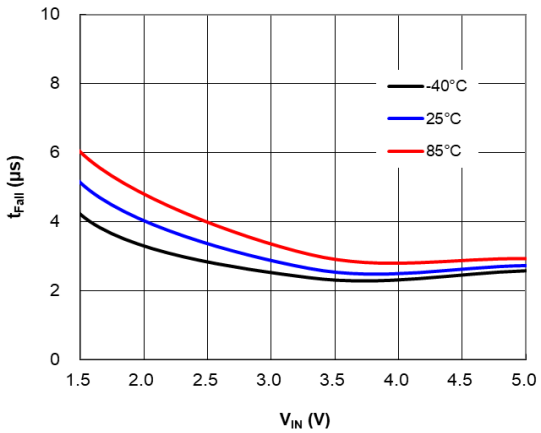
NEW PRODUCT

Typical Performance Characteristics (continued) (C_{IN} = 1µF, C_{OUT} = 0.1µF, R_L = 10Ω, unless otherwise specified.)

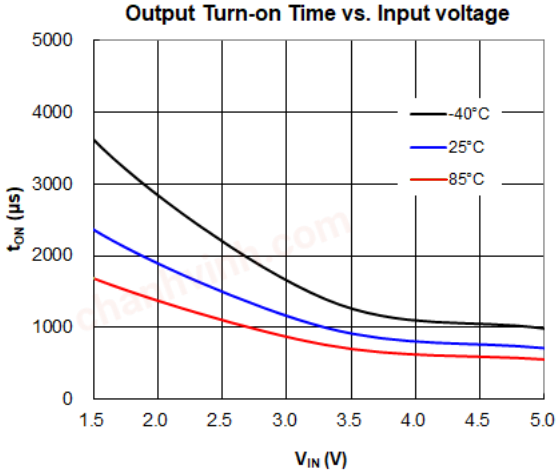
Output Rise Time vs. Input voltage



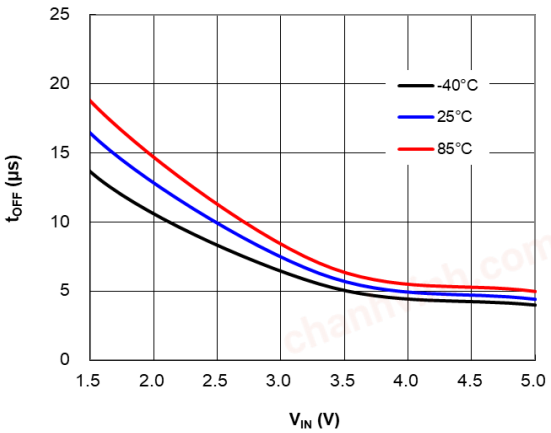
Output Fall Time vs. Input voltage



Output Turn-on Time vs. Input voltage



Output Turn-off Time vs. Input voltage



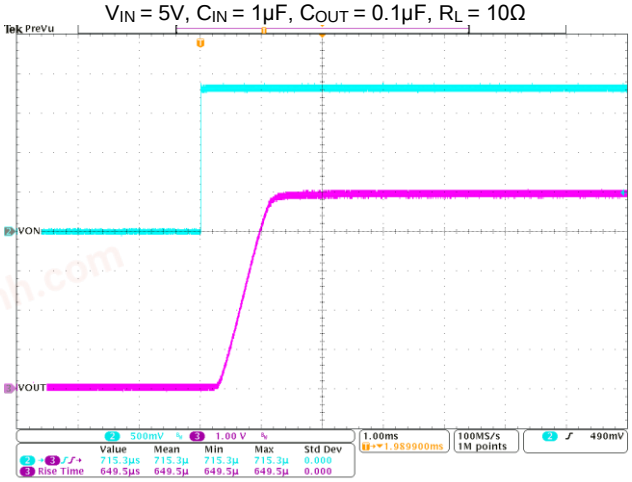
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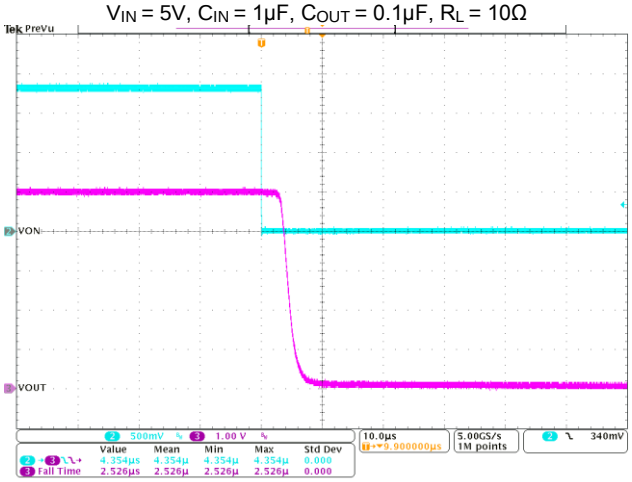
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Typical Performance Characteristics (continued) (T_A = +25°C, V_{ON} = 1.8V, unless otherwise specified.)

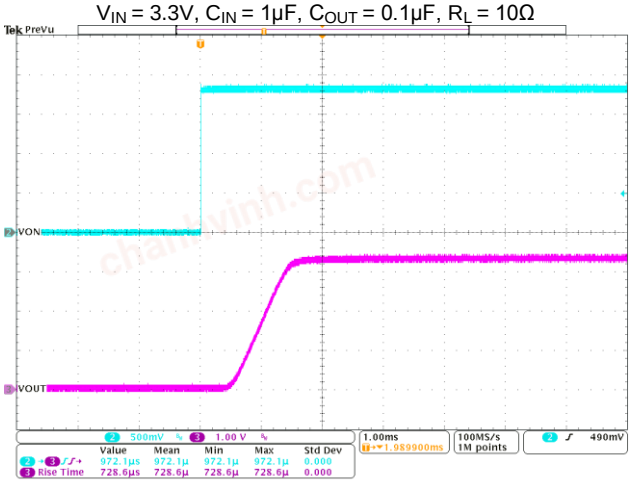
Output Turn On Response
V_{IN} = 5V, C_{IN} = 1µF, C_{OUT} = 0.1µF, R_L = 10Ω



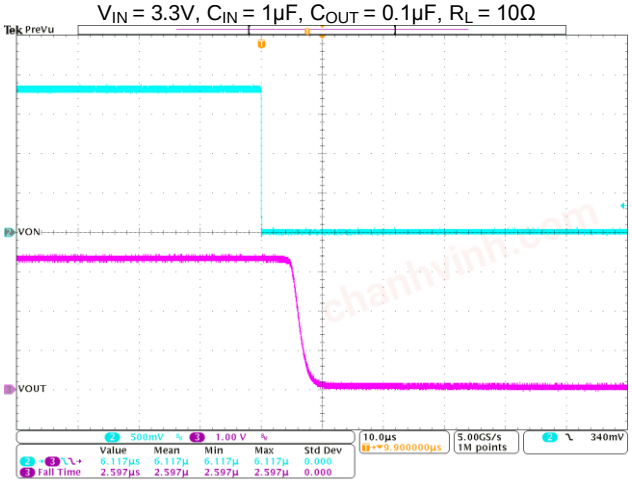
Output Turn Off Response
V_{IN} = 5V, C_{IN} = 1µF, C_{OUT} = 0.1µF, R_L = 10Ω



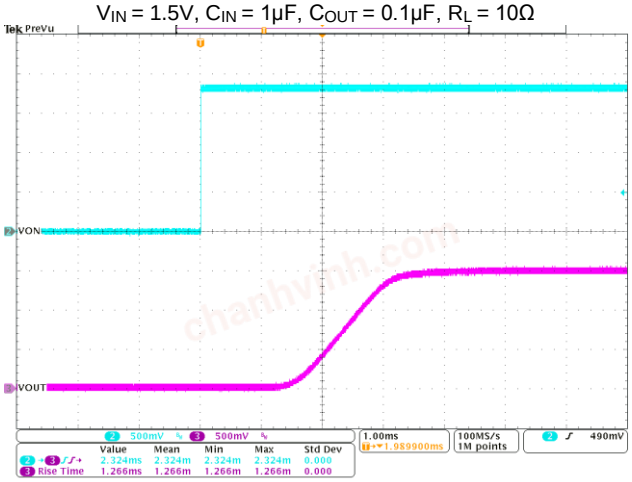
Output Turn On Response
V_{IN} = 3.3V, C_{IN} = 1µF, C_{OUT} = 0.1µF, R_L = 10Ω



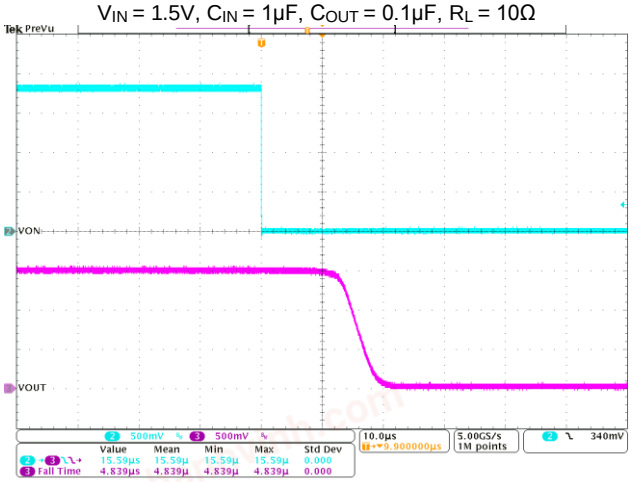
Output Turn Off Response
V_{IN} = 3.3V, C_{IN} = 1µF, C_{OUT} = 0.1µF, R_L = 10Ω



Output Turn On Response
V_{IN} = 1.5V, C_{IN} = 1µF, C_{OUT} = 0.1µF, R_L = 10Ω



Output Turn Off Response
V_{IN} = 1.5V, C_{IN} = 1µF, C_{OUT} = 0.1µF, R_L = 10Ω



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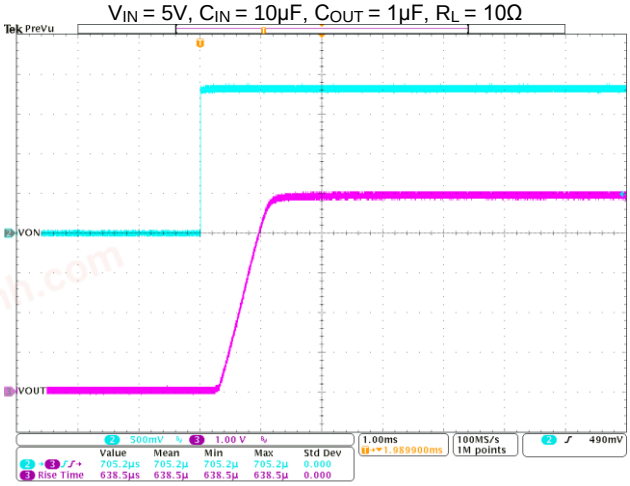
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Typical Performance Characteristics (continued) (T_A = +25°C, V_{ON} = 1.8V, unless otherwise specified.)

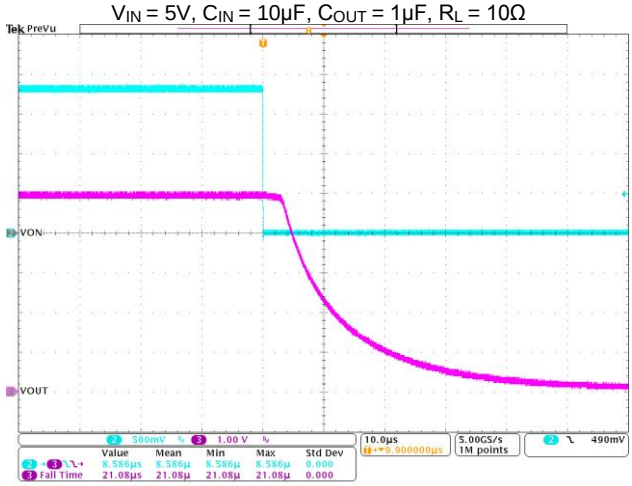
Output Turn On Response

V_{IN} = 5V, C_{IN} = 10µF, C_{OUT} = 1µF, R_L = 10Ω



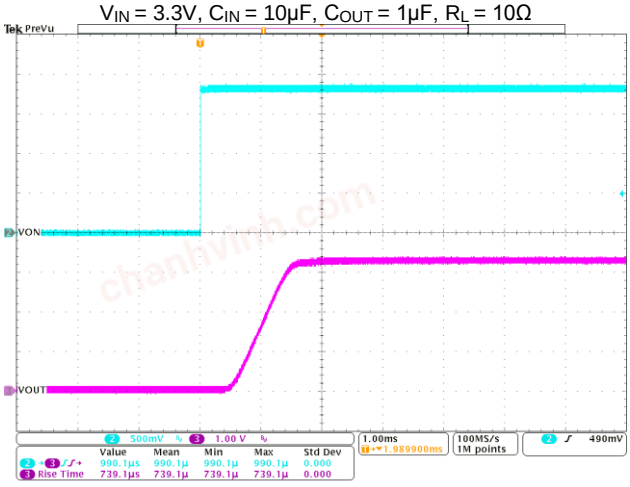
Output Turn Off Response

V_{IN} = 5V, C_{IN} = 10µF, C_{OUT} = 1µF, R_L = 10Ω



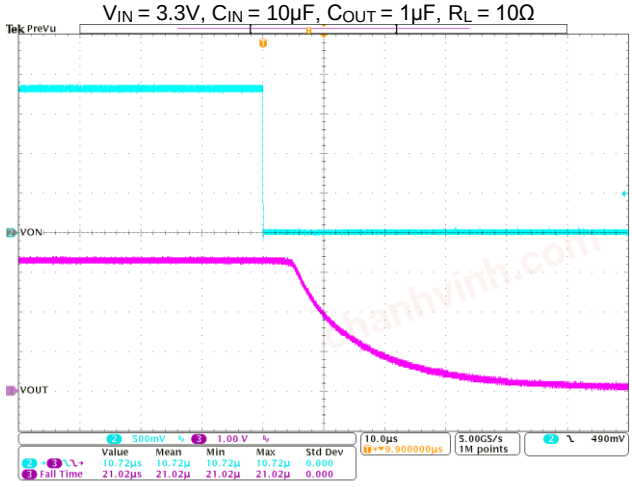
Output Turn On Response

V_{IN} = 3.3V, C_{IN} = 10µF, C_{OUT} = 1µF, R_L = 10Ω



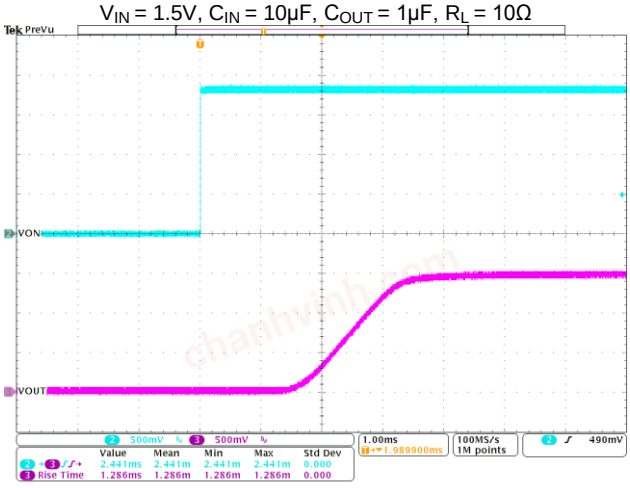
Output Turn Off Response

V_{IN} = 3.3V, C_{IN} = 10µF, C_{OUT} = 1µF, R_L = 10Ω



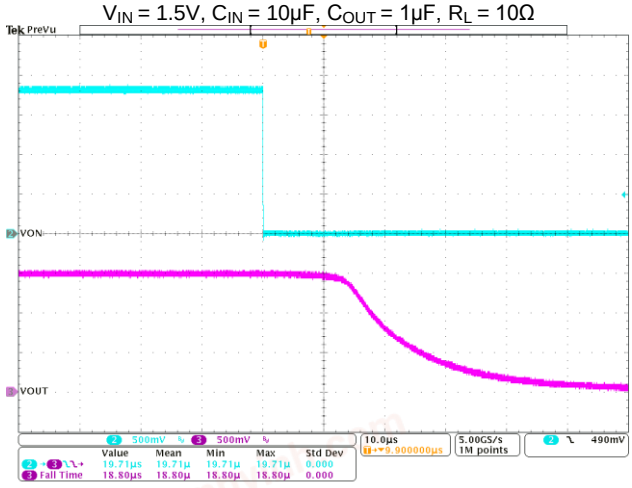
Output Turn On Response

V_{IN} = 1.5V, C_{IN} = 10µF, C_{OUT} = 1µF, R_L = 10Ω



Output Turn Off Response

V_{IN} = 1.5V, C_{IN} = 10µF, C_{OUT} = 1µF, R_L = 10Ω



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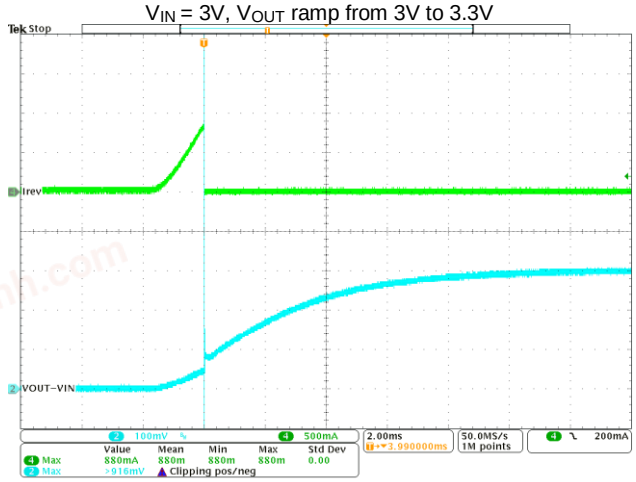
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Typical Performance Characteristics (continued) (T_A = +25°C, C_{IN} = 1µF, C_{OUT} = 0.1µF, unless otherwise specified.)

True Reverse Current Blocking

V_{IN} = 3V, V_{OUT} ramp from 3V to 3.3V



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Application Information

Input Capacitor

A 1μF capacitor is recommended to connect between V_{IN} and GND pins to decouple input power supply glitch and noise. The input capacitor has no specific type or ESR (Equivalent Series Resistance) requirement. However, for higher current application, ceramic capacitors are recommended due to their capability to withstand input current surges from low impedance sources, such as batteries in portable applications. This input capacitor must be located as close as possible to the device to assure input stability and less noise. For PCB layout, a wide copper trace is required for both V_{IN} and GND.

Output Capacitor

The 0.1μF to 1μF capacitor is recommended to connect between V_{OUT} and GND pins to stabilize and accommodate load transient condition. The output capacitor has no specific type or ESR requirement. The amount of the capacitance may be increased without limit. For PCB layout, the output capacitor must be placed as close as possible to V_{OUT} and GND pins, and keep the traces as short as possible.

Enable/Shutdown Operation

The AP22913 is turned on by setting the ON pin high, and is turned off by pulling it low. To ensure proper operation, the signal source used to drive the ON pin must be able to swing above and below the specified turn-on/off voltage thresholds listed in the *Electrical Characteristics* section under V_{IL} and V_{IH}.

True Reverse Current Blocking

An internal reverse voltage comparator disables the power-switch when the output voltage (V_{OUT}) is driven higher than the input voltage (V_{IN}), by V_{T_RCB} , to quickly (10μs typ) stop the flow of current towards the input side of the switch.

Reverse current protection is always active, even when the power switch is disabled. Additionally, under-voltage lockout (UVLO) protection turns the switch off if the input voltage is too low.

Discharge Operation

The AP22913 offers discharge option that helps to discharge the output charge when disabled.

Power Dissipation

The maximum IC junction temperature should be restricted to +125°C under normal operating conditions. The device power dissipation and proper sizing of the thermal plane are critical to avoid thermal shutdown and ensure reliable operation. Power dissipation of the device depends on input voltage and load conditions and can be calculated by:

$$P_D = I_{OUT}^2 x R_{DSON} \qquad \textbf{(1)}$$

However, the maximum power dissipation that can be handled by the device depends on the maximum junction to ambient thermal resistance, maximum ambient temperature, and maximum device junction temperature, which can be approximated by the equation below:

$$P_{D(MAX)} = \frac{(125°C - T_A)}{\theta_{JA}} \qquad \textbf{(2)}$$

Layout Guildline

Good PCB layout is important for improving the thermal performance of the device. All trace lengths should be kept as short as possible. The input (V_{IN}) and output (V_{OUT}) PCB traces should be as wide as possible to reduce stray impedance.

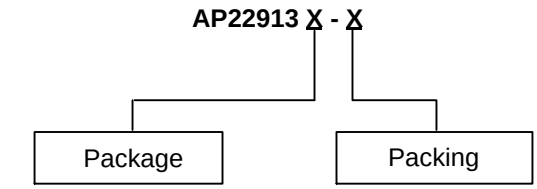
Use a ground plane to enhance the power dissipation capability of the device if applicable. Place input and output capacitors close to the device to minimize the effects of parasitic inductance.

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Ordering Information

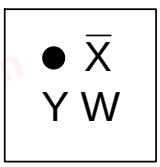


Part Number	Package Code	Packaging	7" Tape and Reel	
			Quantity	Part Number Suffix
AP22913CN4-7	CN4	X1-WLB0909-4	3,000/Tape & Reel	-7
AP22913W6-7	W6	SOT26	3,000/Tape & Reel	-7

Marking Information

(1) X1-WLB0909-4

(Top View)

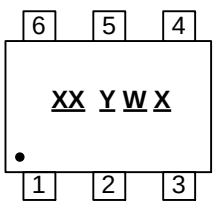


X̄ : Identification Code
Y : Year : 0~9
W : Week : A~Z : 1~26 week;
a~z : 27~52 week; z represents
52 and 53 week

Part Number	Package	Identification Code
AP22913CN4-7	X1-WLB0909-4	C̄

(2) SOT26

(Top View)



XX : Identification Code
Y : Year 0~9
W : Week : A~Z : 1~26 week;
a~z : 27~52 week; z represents
52 and 53 week
X : Internal Code

Part Number	Package	Identification Code
AP22913W6-7	SOT26	N9

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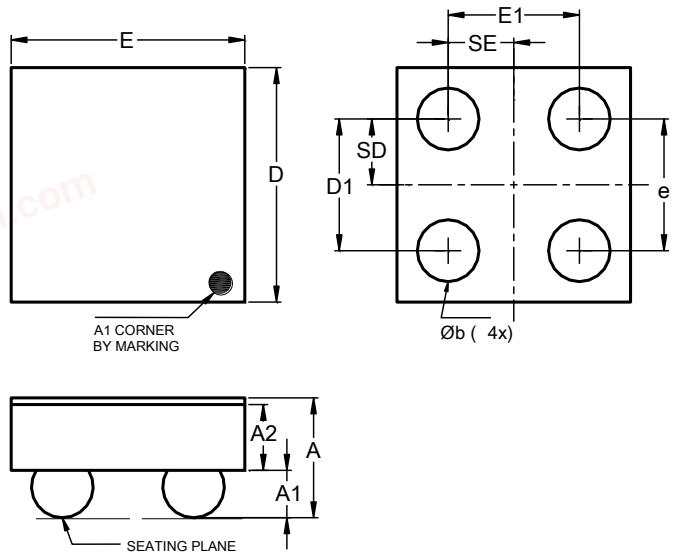
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Package Outline Dimensions

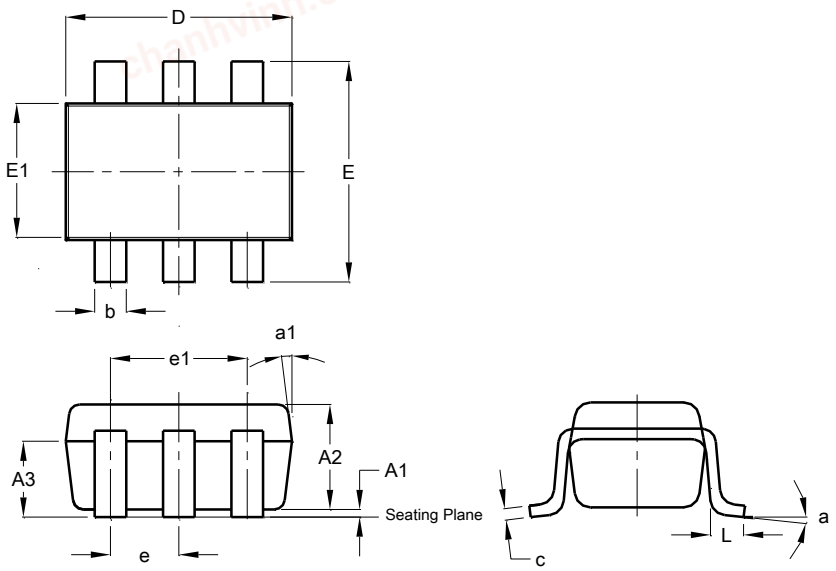
Please see http://www.diodes.com/package-outlines.html for the latest version.

(1) Package Type: X1-WLB0909-4



X1-WLB0909-4			
Dim	**Min**	**Max**	**Typ**
A	0.410	0.500	0.455
A1	0.160	0.200	0.180
A2	0.225	0.275	0.250
b	0.215	0.255	0.235
D	0.875	0.905	0.890
D1	0.450	0.550	0.500
E	0.875	0.905	0.890
E1	0.450	0.550	0.500
e	0.500 BSC		
SD	0.250 BSC		
SE	0.250 BSC		
All Dimensions in mm			

(2) Package Type: SOT26



SOT26			
Dim	**Min**	**Max**	**Typ**
A1	0.013	0.10	0.05
A2	1.00	1.30	1.10
A3	0.70	0.80	0.75
b	0.35	0.50	0.38
c	0.10	0.20	0.15
D	2.90	3.10	3.00
e	-	-	0.95
e1	-	-	1.90
E	2.70	3.00	2.80
E1	1.50	1.70	1.60
L	0.35	0.55	0.40
a	-	-	8°
a1	-	-	7°
All Dimensions in mm			

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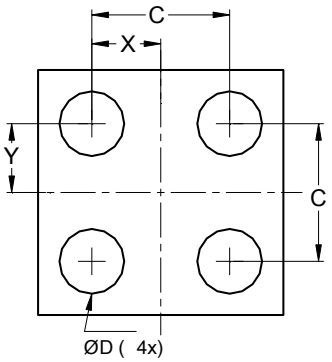
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Suggested Pad Layout

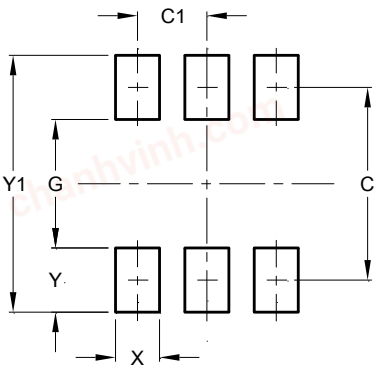
Please see http://www.diodes.com/package-outlines.html for the latest version.

(1) Package Type: X1-WLB0909-4



Dimensions	Value (in mm)
C	0.500
D	0.235
X	0.250
Y	0.250

(2) Package Type: SOT26



Dimensions	Value (in mm)
C	2.40
C1	0.95
G	1.60
X	0.55
Y	0.80
Y1	3.20

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