AP22970

4 V/4 A, 4.7 mΩ RON SWITCH WITH ACTIVE OUTPUT DISCHARGE

Description

The AP22970 is a single-channel load switch with controlled turn-on and active output discharge path in an ultra-compact size.

The AP22970 contains an N-channel MOSFET that can operate over an input voltage range of 0.65V to 3.6V and switch currents up to 4A. An integrated charge pump biases the NMOS switch to achieve a minimum switch ON resistance (R_{ON}). The switch is controlled by an on-and-off input (ON), which is capable of interfacing directly with low-voltage control signals.

The AP22970 includes thermal shutdown when the junction temperature is above the threshold, turning the switch off. The switch turns on again when the junction temperature stabilizes to a safe range.

The AP22970 has a 150Ω on-chip resistor for quick discharge of the output when the switch is disabled to avoid any unknown states caused by a floating supply to the downstream load.

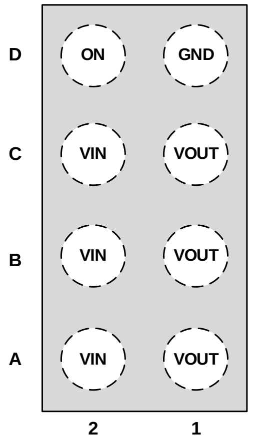
The AP22970 is available in the ultra-small X1-WLB1909-8 package.

Applications

- Laptops, tablet PCs
- Smartphones
- Telecom
- Storage

Pin Assignments

(Top View)



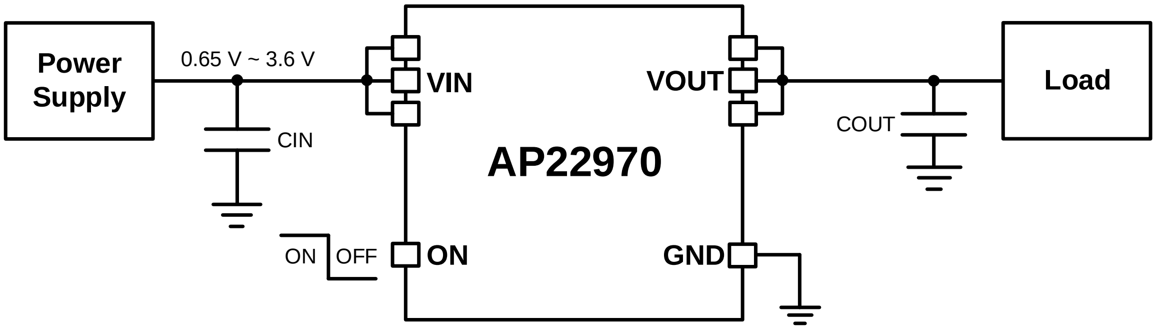
X1-WLB1909-8

Features

- Integrated Single-Channel Load Switch
- 0.65V to 3.6V Input Voltage Range
- Ultra-Low R_{ON}
  - Typ. 4.7mΩ at V_{IN} = 1.8V
  - Typ. 5.1mΩ at V_{IN} = 1.05V
  - Typ. 6.4mΩ at V_{IN} = 0.65V
- 4A Maximum Continuous Current
- Low Quiescent Current of typ. 30µA at V_{IN} > 1.2V
- Low Shutdown Current of typ. 1µA at V_{IN} > 1.8V
- Controlled Slew Rate to Reduce Inrush Current
  - Turn-ON time (tON) = 1,530µs at V_{IN} = 3.6V
  - Turn-ON time (tON) = 815µs at V_{IN} = 0.65V
- Quick Output Discharge of 150Ω (QOD)
- Low-Voltage Logic Enable of 0.71V for V_{IH}
- Active HIGH operation
- Thermal Shutdown (TSD)
- ESD Protection: 2kV of HBM and 1kV of CDM
- Smaller Form-Factor Package: X1-WLB1909-8
- **Totally Lead-Free & Fully RoHS Compliant (Notes 1&2)**
- **Halogen and Antimony Free. "Green" Device (Note 3)**
- **For automotive applications requiring specific change control (i.e. parts qualified to AEC-Q100/101/104/200, PPAP capable, and manufactured in IATF 16949 certified facilities), please contact us or your local Diodes representative.**
  https://www.diodes.com/quality/product-definitions/

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.

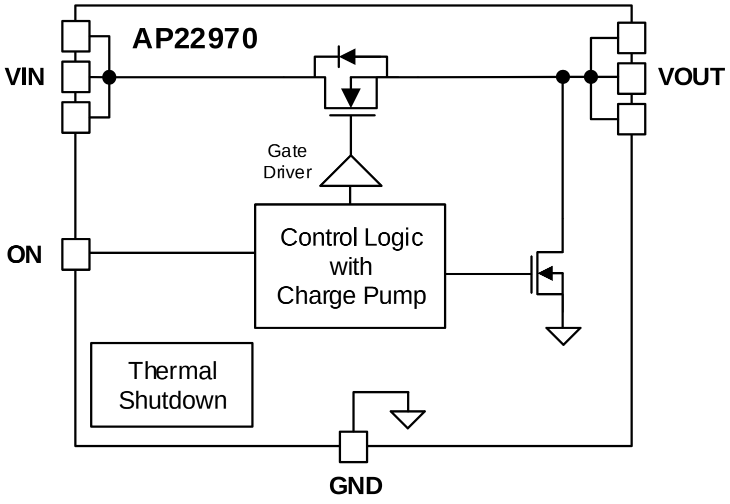
Typical Applications Circuit



Pin Descriptions

Pin Name	Pin Number	Function
VIN	A2, B2, C2	Power Switch Input. Place bypass capacitor to GND.
VOUT	A1, B1, C1	Power Switch Output. Place bypass capacitor to GND.
ON	D2	Active HIGH enable input. Do not leave floating.
GND	D1	Ground

Functional Block Diagram



Absolute Maximum Ratings (@ T_A = +25°C, unless otherwise specified.) (Note 4)

Symbol	Parameter	Ratings	Unit
ESD HBM	Human Body ESD Protection	±2	kV
ESD CDM	Charged Device Model ESD Protection	±1	kV
V_{IN}	Input Voltage at VIN pin	-0.3 to +4	V
V_{OUT}	Output Voltage at VOUT pin	-0.3 to +4	V
V_{ON}	Voltage at ON pin	-0.3 to +4	V
I_L	Load Current	4	A
I_{PLS}	Maximum Pulsed Switch Current, Pulse < 300 µs, 2% duty cycle	6	A
$T_{J(max)}$	Maximum Junction Temperature	Internally Limited	°C
T_{STG}	Storage Temperature	-65 to +150	°C
$R_{θJA}$	Junction-to-ambient thermal resistance (Notes 5)	53.71	°C/W
$R_{θJC(top)}$	Junction-to-Case (Top) Thermal Resistance (Notes 5)	1.12	°C/W
$R_{θJB}$	Junction-to-Board Thermal Resistance (Notes 5)	12.17	°C/W
$Ψ_{JT}$	Junction-to-Top Characterization Parameter (Notes 5)	0.38	°C/W
$Ψ_{JB}$	Junction-to-Board Characterization Parameter (Notes 5)	12.14	°C/W
$R_{θJC(bot)}$	Junction-to-Case (Bot) Thermal Resistance (Notes 5)	8.26	°C/W

Notes: 4. 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.

5. $R_{θJA}$ and $R_{θJC}$ are measured at T_A = 25°C on a high effective thermal conductivity four-layer test board per JEDEC 51-7.

Recommended Operating Conditions (@ T_A = +25°C, unless otherwise specified.) (Note 6)

Symbol	Parameter	Min	Max	Unit
V_{IN}	Input Voltage	0.65	3.6	V
V_{OUT}	Output Voltage	—	V_{IN}	V
T_A	Operating Ambient Temperature	-40	+105	°C
VIH	ON Input Logic HIGH Voltage	0.71	3.6	V
VIL	ON Input Logic LOW Voltage	0	0.46	V

Note: 6. Refer to the typical application circuit

Electrical Characteristics

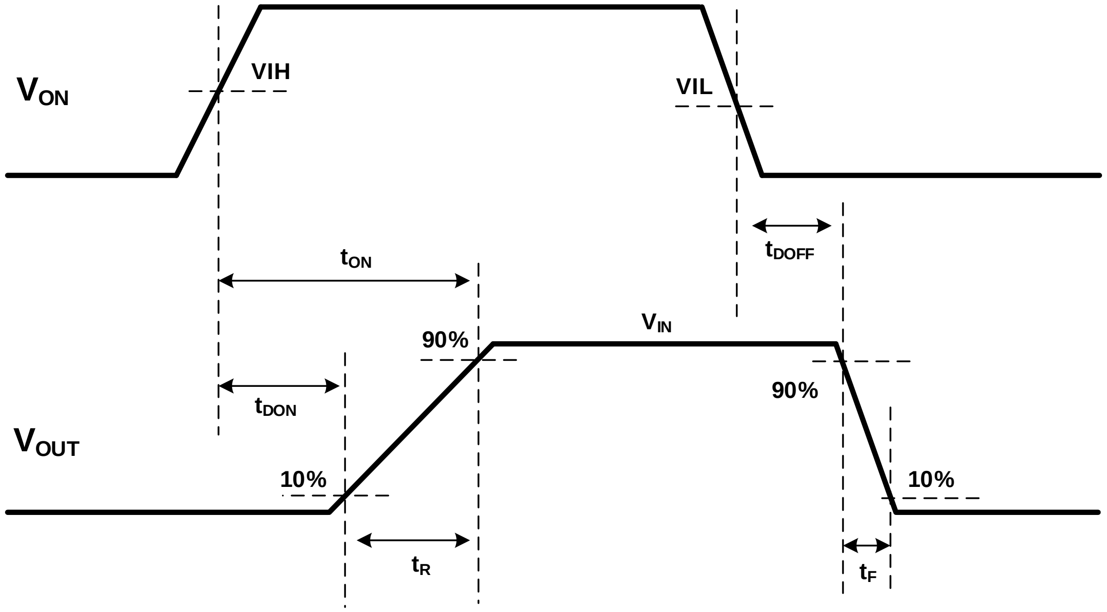
(T_A = -40°C to +105°C, V_{IN} = 0.65 V to 3.6 V, C_{IN} = 1 µF and C_L = 0.1 µF. Typical values are at T_A = +25°C, unless otherwise specified.).

Symbol	Parameter	Test Conditions			Min	Typ	Max	Unit
Device								
I_Q	Quiescent Current	V_{OUT} =Open, Switch enabled	$V_{IN} > 1.2V$	T_A=-40°C to 85°C		30	65	µA
				T_A=-40°C to 105°C			75	
			$V_{IN} \le 1.2V$	T_A=-40°C to 85°C		20	50	
				T_A=-40°C to 105°C			55	
I_{SD}	Shutdown Current	V_{OUT} =GND, Switch enabled	$V_{IN} > 1.8V$	T_A=-40°C to 85°C		1	7.5	
				T_A=-40°C to 105°C			18	
			$V_{IN} \le 1.8V$	T_A=-40°C to 85°C		0.9	5	
				T_A=-40°C to 105°C			9.5	
I_{LEAK_ON}	ON Input Leakage	V_{ON} = 0V to 3.6V, T_A=-40°C to 105°C					0.1	µA
R_{DIS}	Output Discharge Resistance	I_{DIS} = 3mA, Switch disabled	V_{IN} = 3.6V	T_A=-40°C to 105°C		150		Ω
			V_{IN} = 0.65V			710		
TSDN	Thermal Shutdown	Threshold				170		°C
		Hysteresis				30		
Power Switch								
R_{ON}	ON Resistance	I_{OUT} = 200mA, T_A = 25°C	$V_{IN} \ge 1.8V$			4.7	8.5	mΩ
			V_{IN} = 1.2V			4.9	9.1	
			V_{IN} = 1.05V			5.1	9.4	
			V_{IN} = 0.65V			6.4	11.5	
		I_{OUT} = 200mA, T_A = -40°C to 85°C	$V_{IN} \ge 1.8V$				9.5	
			V_{IN} = 1.2V				10.1	
			V_{IN} = 1.05V				10.4	
			V_{IN} = 0.65V				12.5	
		I_{OUT} = 200mA, T_A = -40°C to 105°C	$V_{IN} \ge 1.8V$				11.5	
			V_{IN} = 1.2V				12.1	
			V_{IN} = 1.05V				12.4	
			V_{IN} = 0.65V				14.5	

Switching Characteristics

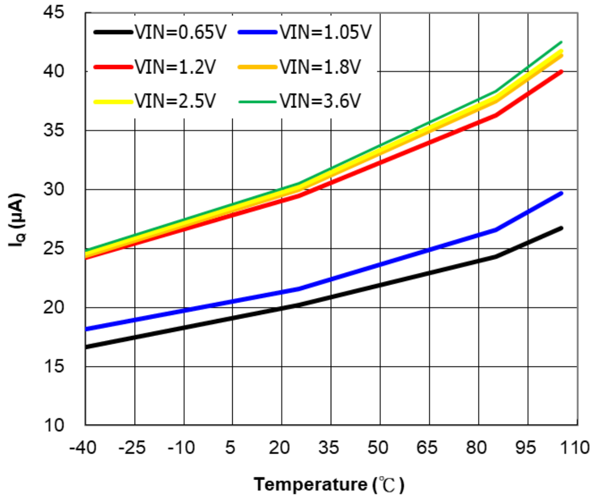
Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit
$V_{IN} = V_{ON} = 3.6V$, $T_A = 25°C$ (Unless otherwise noted)						
t_{ON}	Output Turn ON Time	RL = 10Ω, CL = 0.1µF		1530		µs
t_{DOFF}	OFF Delay Time			3.2		
t_{RISE}	Output Rise Time			985		
t_{FALL}	Output Fall Time			1.8		
t_{DON}	ON Delay Time			550		
$V_{IN} = 1.8V$, $V_{ON} = 3.6V$, $T_A = 25°C$ (Unless otherwise noted)						
t_{ON}	Output Turn ON Time	RL = 10Ω, CL = 0.1µF		1170		µs
t_{DOFF}	OFF Delay Time			4.9		
t_{RISE}	Output Rise Time			645		
t_{FALL}	Output Fall Time			2.2		
t_{DON}	ON Delay Time			525		
$V_{IN} = 0.65V$, $V_{ON} = 3.6V$, $T_A = 25°C$ (Unless otherwise noted)						
t_{ON}	Output Turn ON Time	RL = 10Ω, CL = 0.1µF		815		µs
t_{DOFF}	OFF Delay Time			61		
t_{RISE}	Output Rise Time			320		
t_{FALL}	Output Fall Time			6.3		
t_{DON}	ON Delay Time			495		

Typical t_{ON}/t_{OFF} Waveforms

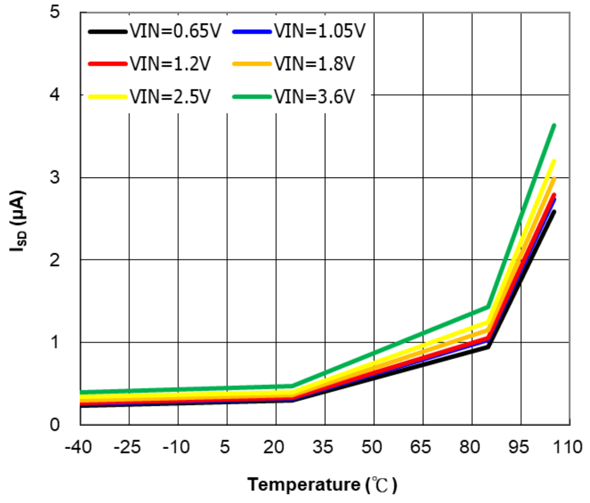


Typical Performance Characteristics

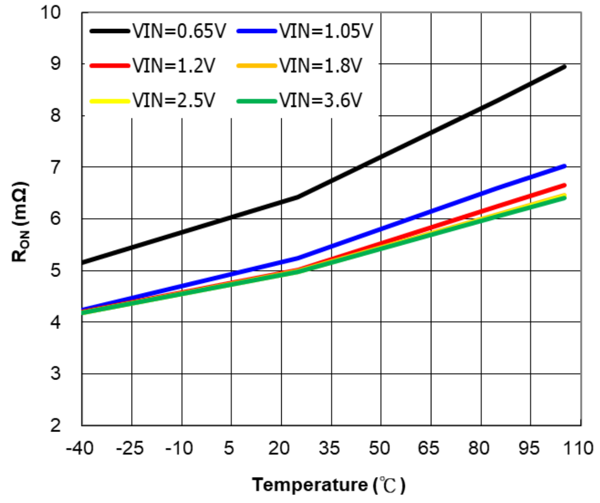
Quiescent Current vs. Temperature



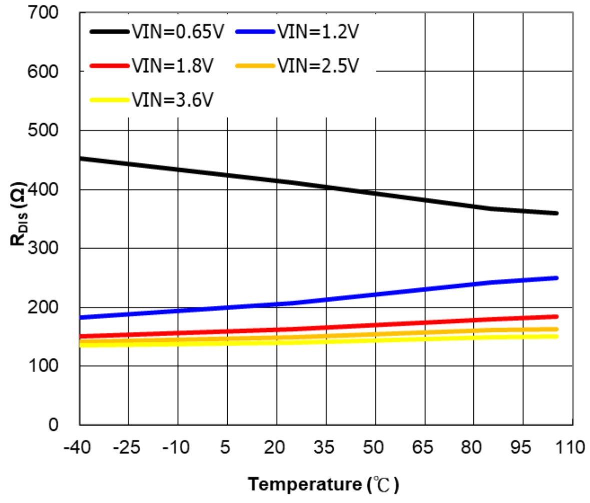
Shutdown Current vs. Temperature



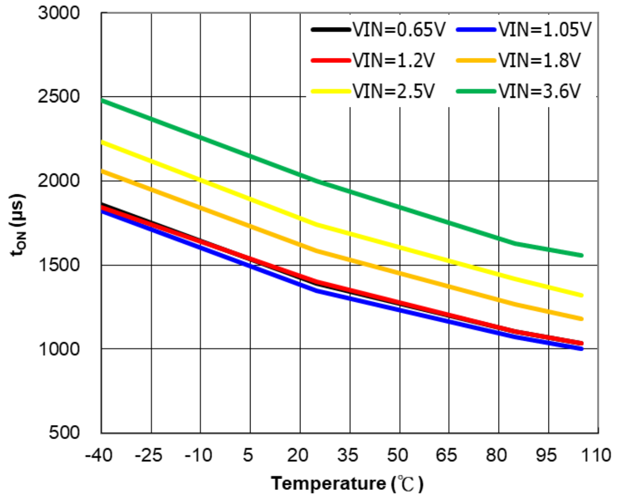
ON Resistance vs. Temperature



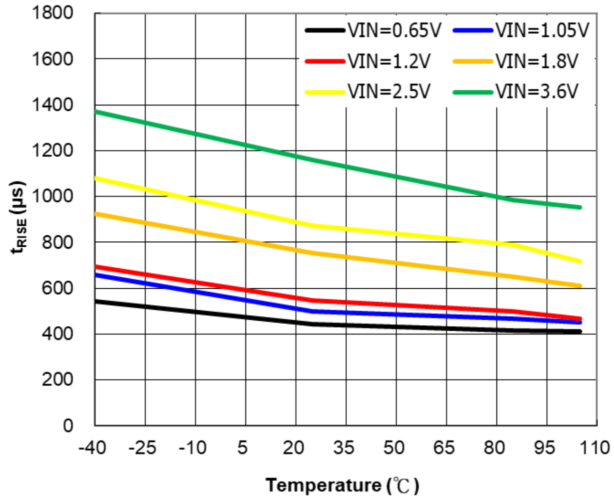
Output Discharge Resistance vs. Temperature



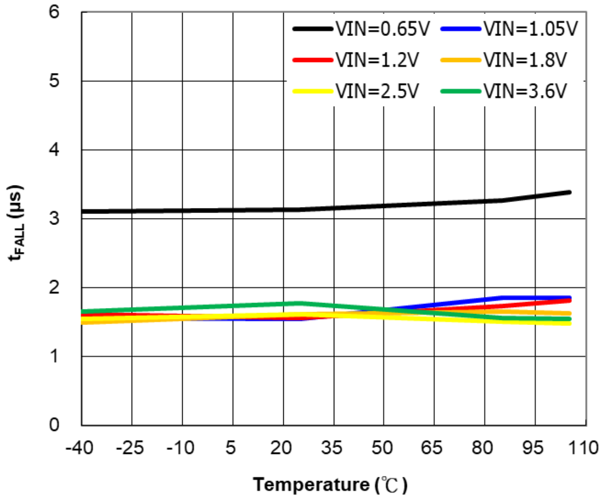
Output Turn ON Time vs. Temperature



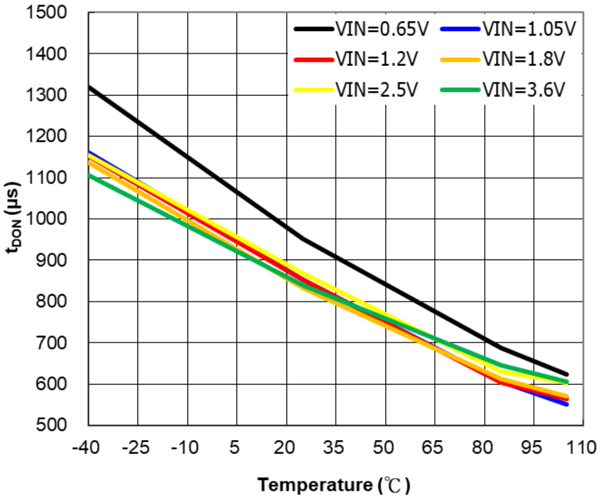
Output Rise Time vs. Temperature



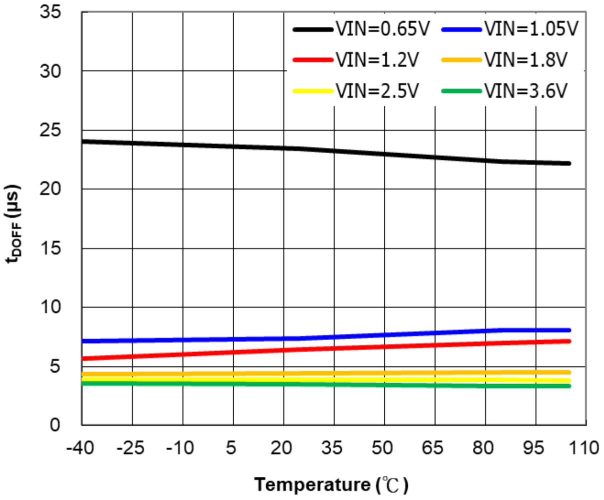
Typical Performance Characteristics



Output Fall Time vs. Temperature



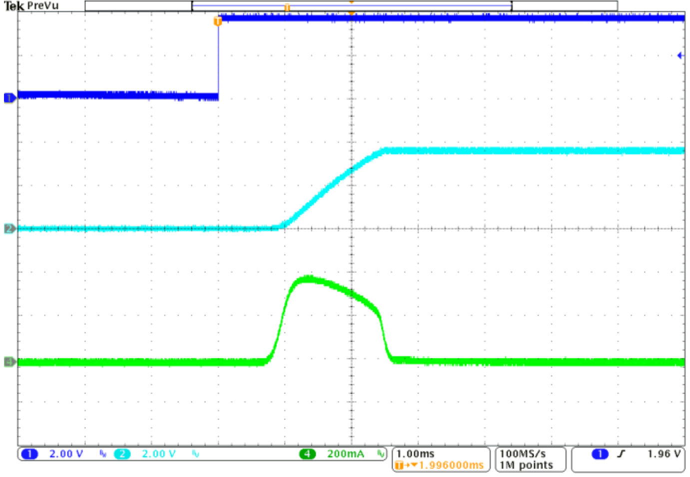
ON Delay Time vs. Temperature



OFF Delay Time vs. Temperature

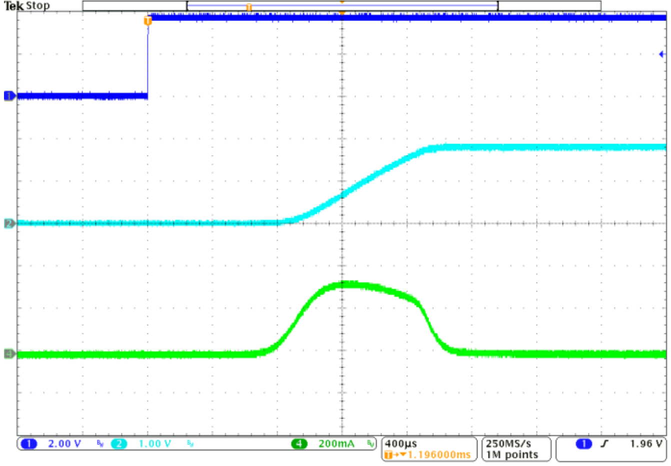
Inrush Current at 3.6 V_{IN}

V_{IN} = 3.6V, C_{IN} = 1μF, C_{OUT} = 147μF, R_L = Open



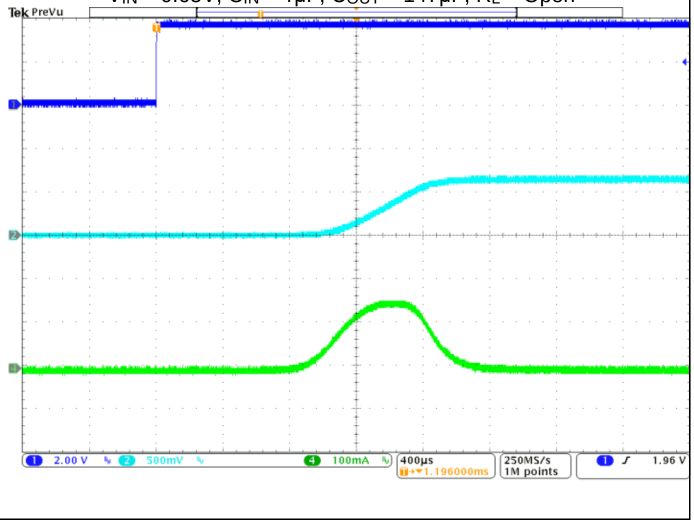
Inrush Current at 1.8 V_{IN}

V_{IN} = 1.8V, C_{IN} = 1μF, C_{OUT} = 147μF, R_L = Open



Inrush Current at 0.65 V_{IN}

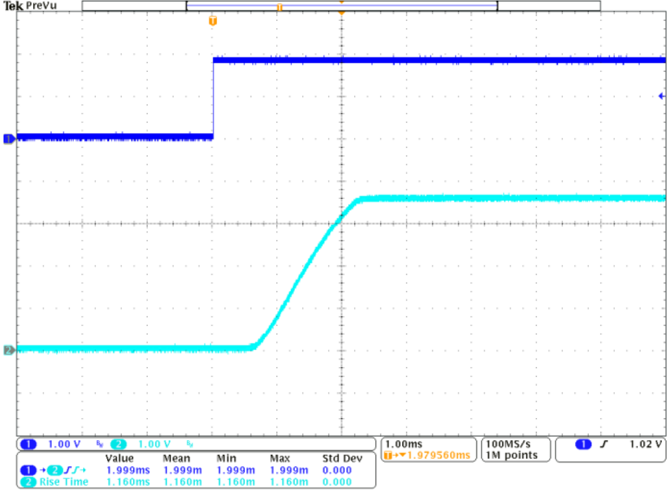
V_{IN} = 0.65V, C_{IN} = 1μF, C_{OUT} = 147μF, R_L = Open



Typical Performance Characteristics

Output Turn On Response

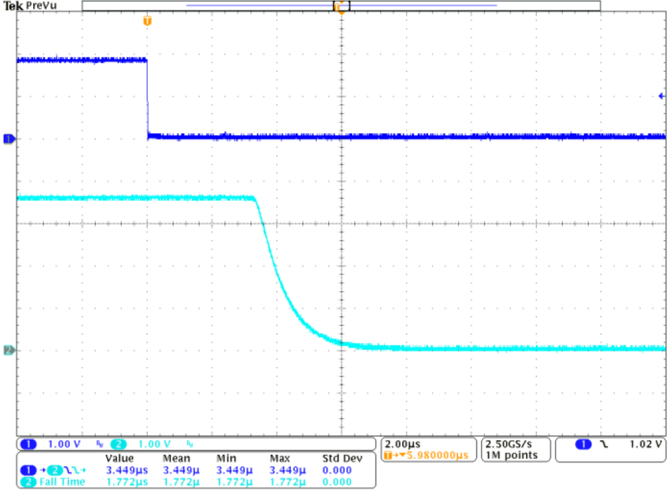
V_{IN} = 3.6V, C_{IN} = 1µF, C_{OUT} = 0.1µF, R_L = 10Ω



	Value	Mean	Min	Max	Std Dev
1 → 2	1.999ms	1.999m	1.999m	1.999m	0.000
2 Rise Time	1.160ms	1.160m	1.160m	1.160m	0.000

Output Turn Off Response

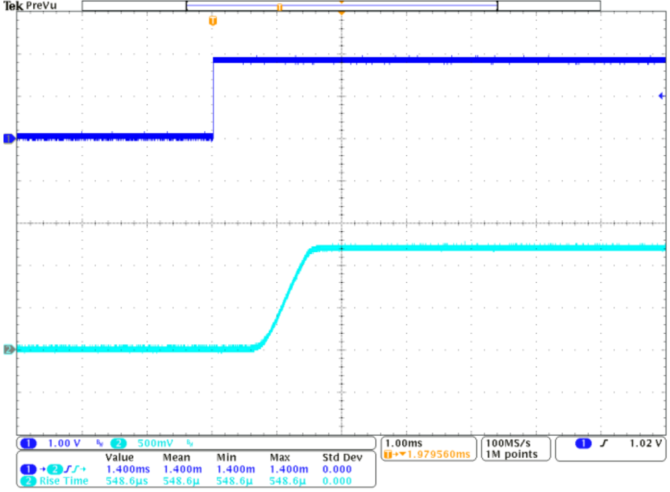
V_{IN} = 3.6V, C_{IN} = 1µF, C_{OUT} = 0.1µF, R_L = 10Ω



	Value	Mean	Min	Max	Std Dev
1 → 2	3.449µs	3.449µ	3.449µ	3.449µ	0.000
2 Fall Time	1.772µs	1.772µ	1.772µ	1.772µ	0.000

Output Turn On Response

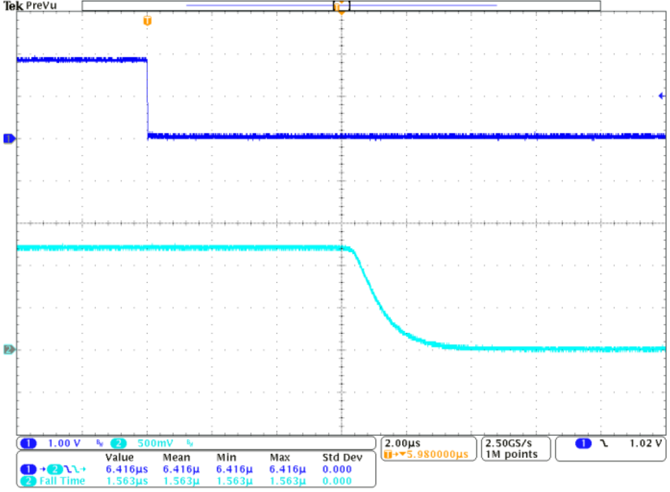
V_{IN} = 1.2V, C_{IN} = 1µF, C_{OUT} = 0.1µF, R_L = 10Ω



	Value	Mean	Min	Max	Std Dev
1 → 2	1.400ms	1.400m	1.400m	1.400m	0.000
2 Rise Time	548.6µs	548.6µ	548.6µ	548.6µ	0.000

Output Turn Off Response

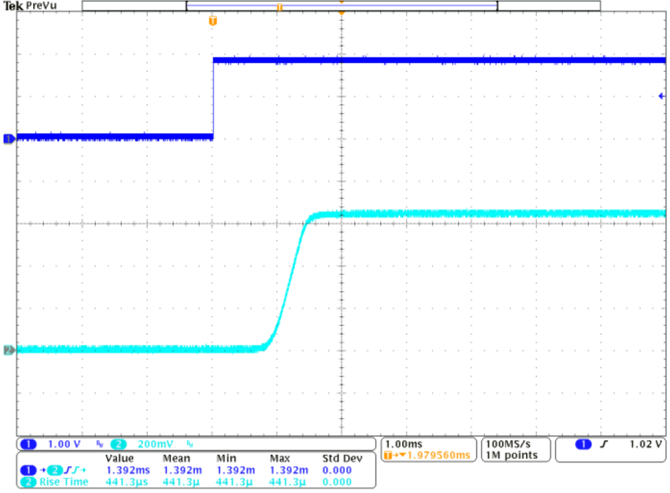
V_{IN} = 1.2V, C_{IN} = 1µF, C_{OUT} = 0.1µF, R_L = 10Ω



	Value	Mean	Min	Max	Std Dev
1 → 2	6.416µs	6.416µ	6.416µ	6.416µ	0.000
2 Fall Time	1.563µs	1.563µ	1.563µ	1.563µ	0.000

Output Turn On Response

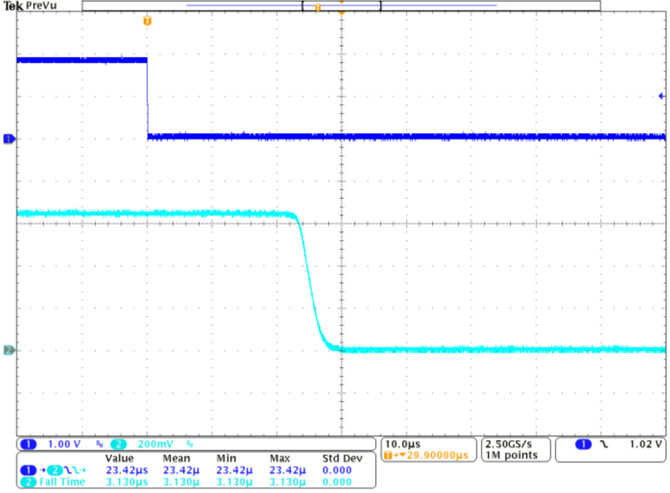
V_{IN} = 0.65V, C_{IN} = 1µF, C_{OUT} = 0.1µF, R_L = 10Ω



	Value	Mean	Min	Max	Std Dev
1 → 2	1.392ms	1.392m	1.392m	1.392m	0.000
2 Rise Time	441.3µs	441.3µ	441.3µ	441.3µ	0.000

Output Turn Off Response

V_{IN} = 0.65V, C_{IN} = 1µF, C_{OUT} = 0.1µF, R_L = 10Ω



	Value	Mean	Min	Max	Std Dev
1 → 2	23.42µs	23.42µ	23.42µ	23.42µ	0.000
2 Fall Time	3.130µs	3.130µ	3.130µ	3.130µ	0.000

Application Information

Enable/Disable CONTROL

The ON pin controls the state of the power switch. The AP22970 is enabled when the ON pin is asserted high, and disabled when the ON pin is asserted low. The ON input is compatible with both TTL and CMOS logic. This pin cannot be left floating and must be tied either high or low for proper functionality.

INPUT CAPACITOR

A capacitor needs to be placed between VIN and GND to limit the voltage drop on the input supply when the switch turns on into a discharged load capacitor (resulting in a transient inrush current). Use a 1µF capacitor or a larger value for high-current applications. Place the capacitor close to the VIN pins.

OUTPUT CAPACITOR

Because of the integrated body diode in the NMOS switch, a C_{IN} greater than C_{OUT} is highly recommended. A C_{OUT} that is greater than C_{IN} can cause the VOUT to exceed VIN when the system supply is removed. This may result in current flow through the body diode from VOUT to VIN. A C_{IN} to C_{OUT} ratio of 10 to 1 is recommended for minimizing VIN dip caused by inrush currents during startup; however, a 10 to 1 ratio for capacitance is not required for proper functionality of the device. A ratio smaller than 10 to 1 (such as 1 to 1) may cause slightly more VIN dip upon turn-on because of inrush currents.

OUTPUT DISAHRGE

The AP22970 includes a QOD feature. When the switch is disabled, an internal discharge resistance is connected between VOUT and GND to remove the remaining charge from the output. This resistance has a typical value of 150Ω and prevents the output from floating while the switch is disabled.

THERMAL CONSIDERATOIN

The maximum junction temperature should be restricted to +125°C under normal operating conditions. The maximum allowable power dissipation, $P_{D(MAX)}$, can be calculated as:

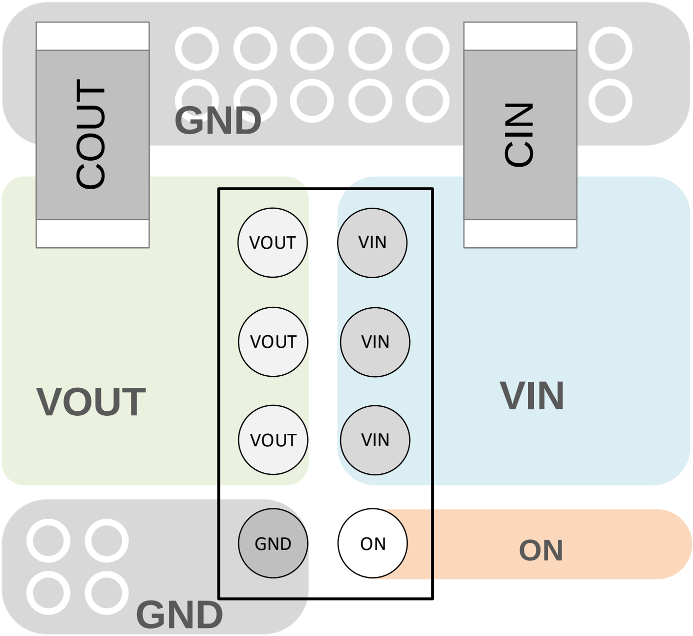
$$P_{D(MAX)} = (T_{J(MAX)} - T_A) / \theta_{JA}$$

Where,

$T_{J(MAX)}$ is the maximum operating junction temperature.
T_A is the ambient temperature of the device
Θ_{JA} is the junction-to-air thermal impedance

BOARD LAYOUT

A good PCB layout is important for improving the thermal performance of the device. All trace lengths should be kept as short as possible. Place the input and output capacitors close to the device to minimize the effects of parasitic inductance. The input and output PCB traces should be as wide as possible.



Ordering Information

AP22970 XXX - X

Package
GD8 : X1-WLB1909-8

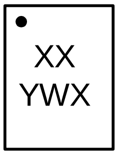
Packing
7 : Tape & Reel

Orderable Part Number	QOD	Package Code	Package	Packing		
				Quantity	**Carrier**	**Part Number Suffix**
AP22970	YES	GD8	X1-WLB1909-8	3,000	7” Tape and Reel	-7

Marking Information

X1-WLB1909-8

(Top View)



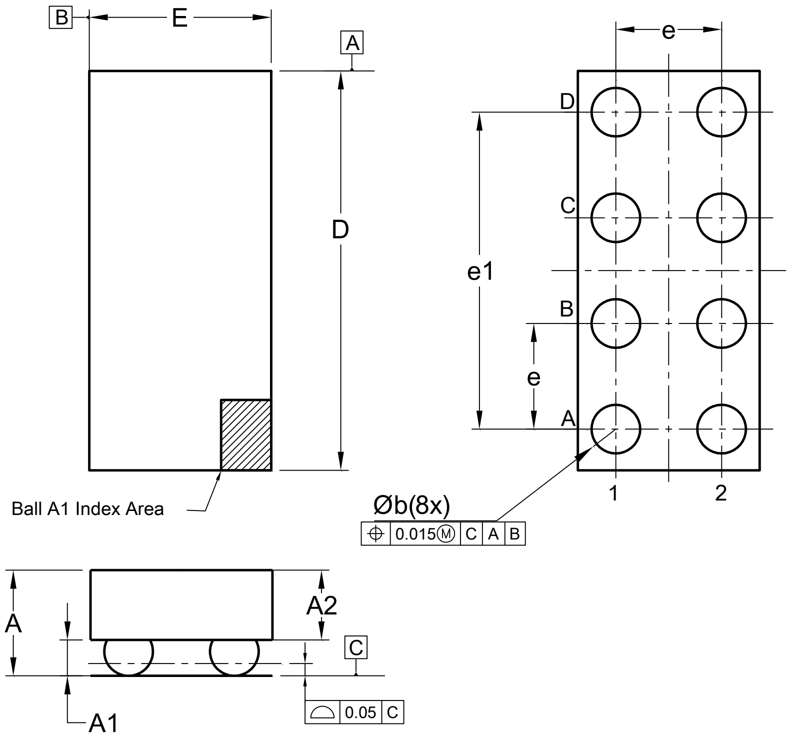
XX : Identification Code
Y : Year : 0~9
W : Week : A~Z : week 1~26;
a~z : week 27~52 ; z represents
week 52 and 53
X : Internal Code

Part Number	Package	Identification Code
AP22970GD8-7	X1-WLB1909-8	H7

Package Outline Dimensions

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

X1-WLB1909-8

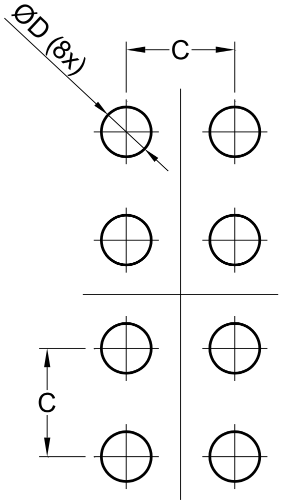


X1-WLB1909-8			
Dim	**Min**	**Max**	**Typ**
A	0.430	0.500	0.465
A1	0.15	0.19	0.17
A2	0.275	0.315	0.295
b	0.21	0.25	0.23
D	1.85	1.91	1.88
E	0.85	0.91	0.88
e	--	--	0.50
e1	--	--	1.50
All Dimensions in mm			

Suggested Pad Layout

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

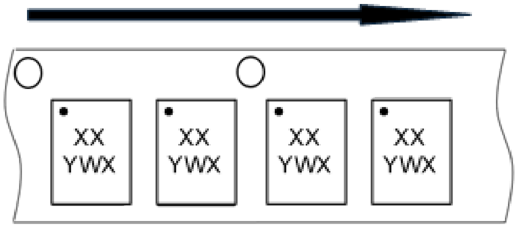
X1-WLB1909-8

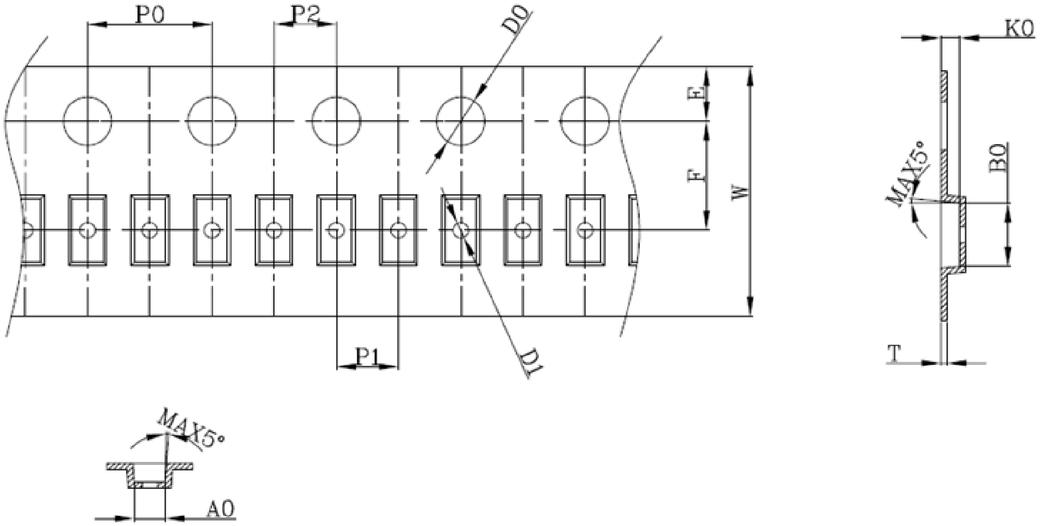


Dimensions	Value (in mm)
C	0.500
D	0.230

Taping Orientation

Package Type: X1-WLB1909-8
Orientation: Top Left Pin1 Orientation





Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width (mm)	Carrier Tape	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	P1 (mm)	P2 (mm)	W (mm)	Pin1 Quadrant
X1-WLB1909-8	CPC000223	8	3000	178.0	8.4	Haolin WLB1909	1.0	2.04	0.60	4.0	2.0	2.0	8.0	Q1

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