Description

The AP22815/615 is a 3A single-channel current-limited high-side power switch with output OVP optimized for USB and other hot-swap applications, which must have overvoltage protection from output to protection the system. The AP22815/615 complies with USB standards and is available with both polarities of Enable input. AP22815 supports fixed current-limited feature, while AP22615 equips adjustable current-limited feature optimized for applications that require precision current limiting support. It supports USB PD3.0 fast role-swap function. The output voltage could recovery to USB valid voltage range within 110µs during USB PD fast role-swap event.

The device has fast short-circuit and output overvoltage response time for improved overall system robustness. Both TSOT25 and TSOT26 packages integrate discharge circuitry inside OUT pin. They provide a complete protection solution for applications subject to heavy capacitive loads and the prospect of short circuit, and offer output overvoltage protection, reverse-current protection, overcurrent, overtemperature and short-circuit protection, as well as controlled rise time and undervoltage lockout functionality. A 7ms deglitch capability on the open-drain flag output prevents false overcurrent, overvoltage, and overtemperature reporting and does not require any external components.
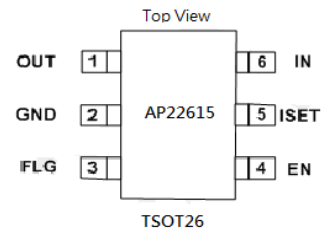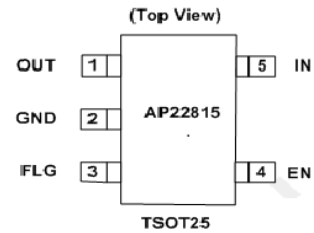
The AP22815 is available in a standard green TSOT25 packages with RoHS compliant. The AP22615 is available in a standard Green TSOT26 packages with RoHS compliant.

Pin Assignments

(Top View)

OUT 1 — AP22815 — 5 IN
GND 2
FLG 3 — 4 EN
TSOT25

Top View

OUT 1 — AP22615 — 6 IN
GND 2 — 5 ISET
FLG 3 — 4 EN
TSOT26

Features

- Input Voltage Range: 3.0V ~ 5.5V
- 40mΩ On-Resistance
- Built-in Soft-Start with 2.1ms Typical Rise Time
- Fault Report (FLG) with Blanking Time (7ms typ)
- Accurate Adjustable Current Limit, 0.4A ~ 4.0A (AP22615 Only)
- ESD Protection: 2KV HBM, 200V MM
- Active Low or Active High Enable
- Protection
  - Output Overvoltage with Auto Recovery
  - Overcurrent with Auto Recovery
  - Short-Circuit with Auto Recovery
  - Overtemperature with Auto Recovery
- Output Reverse Voltage/Current Protection
- Fast Role Swap Function
- Thermally Efficient Low Profile Package
- 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)**

Applications

- Integrated Load Switches in Ultrabook PC
- Power Up/Down Sequencing in Ultrabook PC
- Notebook, Netbook, Tablet PC, Set-Top Box
- SSD (Solid State Drives)
- Consumer Electronics
- USB Charger
- Telecom Systems

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.
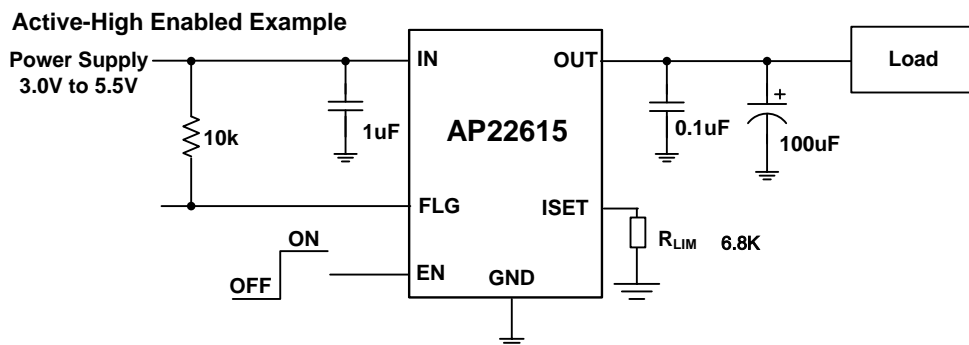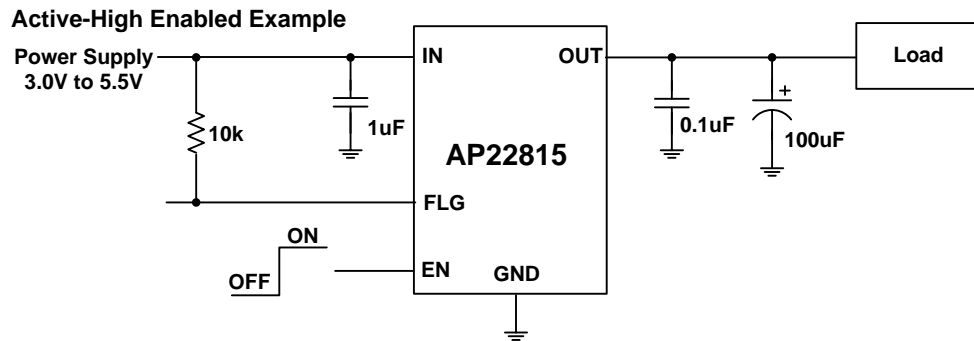
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Typical Applications Circuit
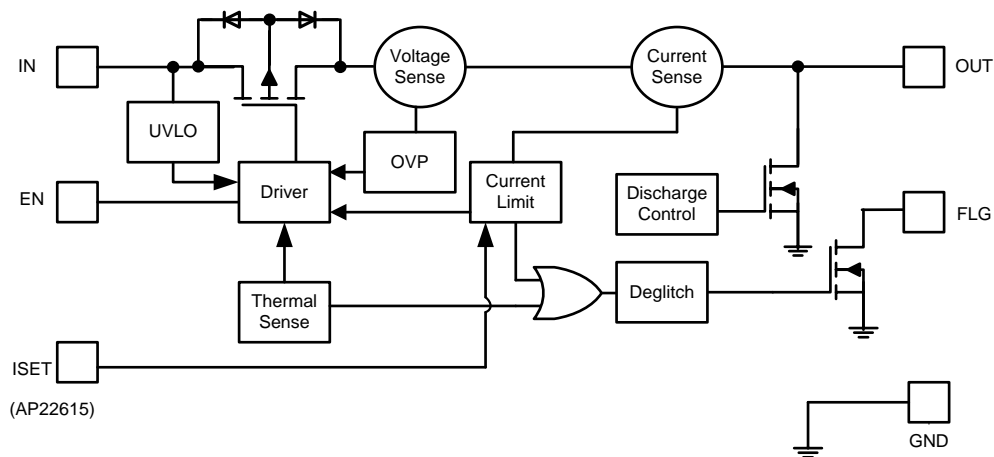
Active-High Enabled Example

Active-High Enabled Example

Note: Applying a 1μF input capacitor leads to a large V_{IN} spike, so it is recommended to use a 10μF capacitor instead.

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Pin Descriptions

AP22815 TSOT25	AP22615 TSOT26	Pin Name	Pin function
1	1	OUT	Voltage Output Pin
2	2	GND	Ground Pin of the Circuitry
3	3	FLG	Overcurrent and Overtemperature Fault Report; Open-Drain Flag is Active Low When Triggered.
4	4	EN	Enable Input. Enable Input (Active Low or Active High).
NC	5	ISET	AP22815 : NC pin AP22615 : Set OCP current by attaching resistor. The current limit: ILIM (A)=6800/RLIM(Ω)
5	6	IN	Voltage Input Pin

Functional Block Diagram

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

Symbol	Parameter		Ratings	Units
ESD HBM	Human Body ESD Protection		2000	V
ESD MM	Machine Model ESD Protection		200	V
V_{IN}	Input Voltage		-0.3 to 6.0	V
V_{OUT}	Output Voltage (V_{OUT} to GND, V_{OUT} to V_{IN})		-0.3 to 28	V
V_{EN}	Enable Voltage		-0.3 to (V_{IN} +0.3)	V
V_{ISET}	ISET Voltage		-0.3 to (V_{IN} +0.3)	V
I_L	Load Current		Internal Limited	A
$T_{J(max)}$	Maximum Junction Temperature		150	°C
T_{ST}	Storage Temperature		-65 to +150	°C
$R_{\Theta JA}$	Thermal Resistance, Junction to Ambient	TSOT25	85	°C/W
		TSOT26	80	
$R_{\Theta JC}$	Thermal Resistance, Junction to Case	TSOT25	32	°C/W
		TSOT26	30	

Note: 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. $R_{\Theta JA}$ and $R_{\Theta JC}$ are measured at TA = 25°C on a high effective thermal conductivity four-layer test board per JEDEC 51-7.

Recommended Operating Conditions   (Note 5)

Symbol	Parameter	Min	Max	Unit
V_{IN}	Input Voltage	3.0	5.5	V
I_{OUT}	Output Current, 4.0V ≤ Vin ≤ 5.5V	0	3	A
	Output Current, 3.0V ≤ Vin < 4.0V	0	1.5	A
V_{IL}	EN Input Logic Low Voltage	0	0.4	V
R_{LIM}	Current-Limit Threshold Resistor Range (1% Initial Tolerance)	1.94	6.8	kΩ
V_{OUT}	Output Voltage	0	23	V
V_{IH}	EN Input Logic High Voltage	1.2	V_{IN}	V
T_A	Operating Ambient Temperature	-40	+85	°C

Note: 5. Refer to the typical application circuit.

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Electrical Characteristics (Vin = 5.0v @ T_A = +25°C, C_{IN} = 1µF, C_L = 100nF, unless otherwise specified.)

Symbol	Parameter	Test Conditions		Min	Typ	Max	Unit
V_{UVLO}	Input UVLO	V_{IN} Rising		2.1	2.5	2.9	V
ΔV_{UVLO}	Input UVLO Hysteresis	V_{IN} Decreasing		—	180	—	mV
I_{SHDN}	Input Shutdown Current	Disabled, OUT = Open (Discharge Current Included)		—	0.1	10	µA
I_Q	Input Quiescent Current	Enabled, OUT = Open		—	300	—	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 OUT		—	0.5	15	µA
		Disabled, V_{IN} = 0V, V_{OUT} = 20V, I_{REV} at OUT		—	0.5	30	µA
$R_{DS(ON)}$	Switch On-Resistance	AP22815	V_{IN} = 5.0V, I_{OUT} = 1A	—	40	50	mΩ
I_{LIMIT}	Overload Current Limit	(AP22815) V_{IN} = 5V, V_{OUT} = 4V		3.1	3.6	4.2	A
		(AP22615) V_{IN} = 5V, V_{OUT} = 4V, R_{LIM} = 1.94K		3.1	3.6	4.2	A
		(AP22615) V_{IN} = 5V, V_{OUT} =4V	R_{LIM} = 6.8K	0.75	1	—	A
I_{SHORT}	Short-Circuit Current Limit	Enabled, Output Short to Ground		—	1	—	A
T_{SHORT}	Short-Circuit Response Time	V_{IN} = 5 V, No Load		—	5	—	µs
V_{IL}	EN Input Logic Low Voltage	V_{IN} = 5V		—	—	0.4	V
V_{IH}	EN Input Logic High Voltage	V_{IN} = 5V		1.2	—	—	V
$I_{LEAK-EN}$	EN Input Leakage	V_{IN} = 5V, V_{EN} = 0V and 5.5V		—	1	2	µA
I_{LEAK-O}	Output Leakage Current	Disabled, V_{OUT} = 0V		—	0.5	1	µA
$T_{D(ON)}$	Output Turn-On Delay Time	C_L = 10µF, R_{LOAD} = 10Ω @ V_{IN} = 5V (Figure 1)		—	2.2	—	ms
T_R	Output Turn-On Rise Time	C_L = 10µF, R_{LOAD} = 10Ω @ V_{IN} = 5V (Figure 1)		1.0	1.9	3.5	ms
$T_{D(OFF)}$	Output Turn-Off Delay Time	C_L = 10µF, R_{LOAD} = 10Ω @ V_{IN} = 5V (Figure 1)		—	0.02	—	ms
T_F	Output Turn-Off Fall Time	C_L = 10µF, R_{LOAD} = 10Ω @ V_{IN} = 5V (Figure 1)		—	0.2	—	ms
R_{FLG}	FLG Output FET On-Resistance	I_{FLG} = 10mA		—	40	60	Ω
I_{FOH}	FLG Off Current	V_{FLG} = 5V		—	0.01	1	µA
T_{Blank}	FLG Blanking Time	Assertion or Deassertion due to Overvoltage, Overcurrent, and Overtemperature Condition		2	7	20	ms
R_{DIS}	Discharge Resistance	V_{IN} = 5V, Disabled, V_{OUT} = 1V		—	100	—	Ω
T_{SHDN}	Thermal Shutdown Threshold	Enabled		—	140	—	°C
T_{HYS}	Thermal Shutdown Hysteresis	—		—	35	—	°C
V_{OV_TRIP}	Output OVP Lockout	V_{OUT} Rising Threshold		5.5	5.7	5.9	V
		V_{OUT} Falling Threshold		—	5.6	—	V
OUT_{HYS}	Output OVP Hysteresis	—		—	0.1	—	V
T_{OVP}	OVP Response Time	I_{OUT}=0.5A, C_L =1µF, V_{OUT} from 5.5V to 6V		—	1	—	µs
V_{RVP}	Reverse-Voltage Comparator Trip Point	V_{OUT} - V_{IN}		—	65	—	mV

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Typical Performance Characteristics
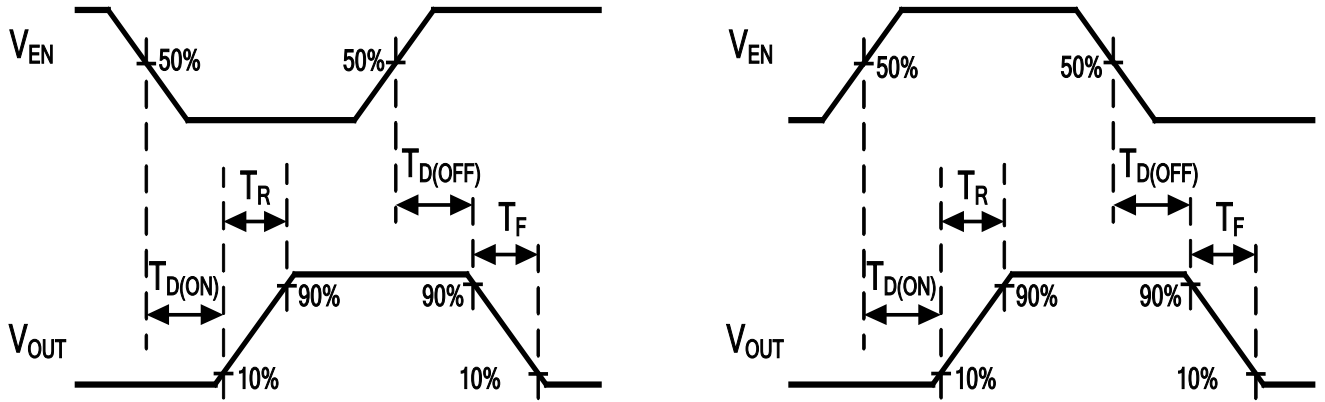
Figure 1 Voltage Waveforms

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Typical Performance Characteristics (cont.) (T$_A$ = +25°C, V$_{IN}$ = 5V, C$_{IN}$ = 1µF, C$_L$ = 0.1µF, unless otherwise specified.)
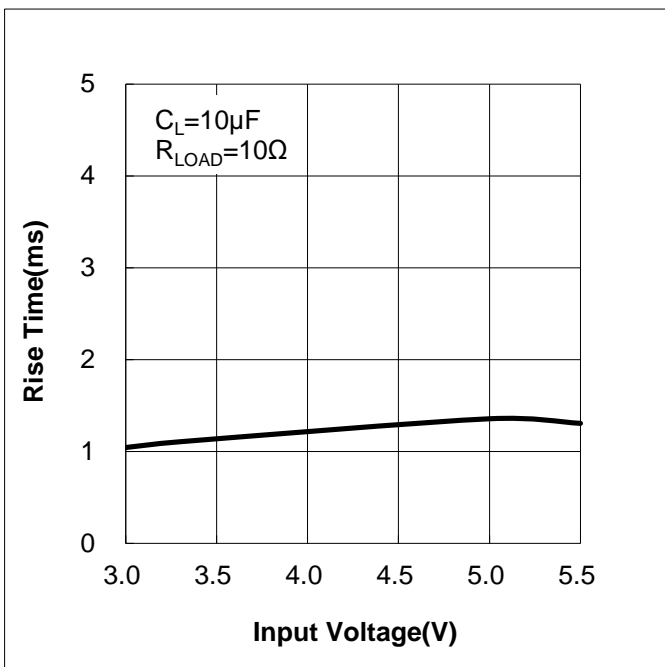
Turn-on Time vs. Input Voltage
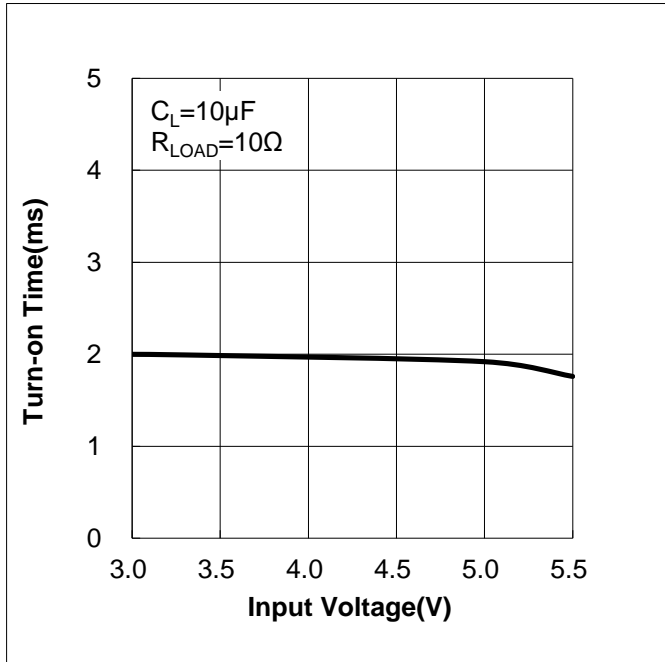
Turn-off Time vs. Input Voltage
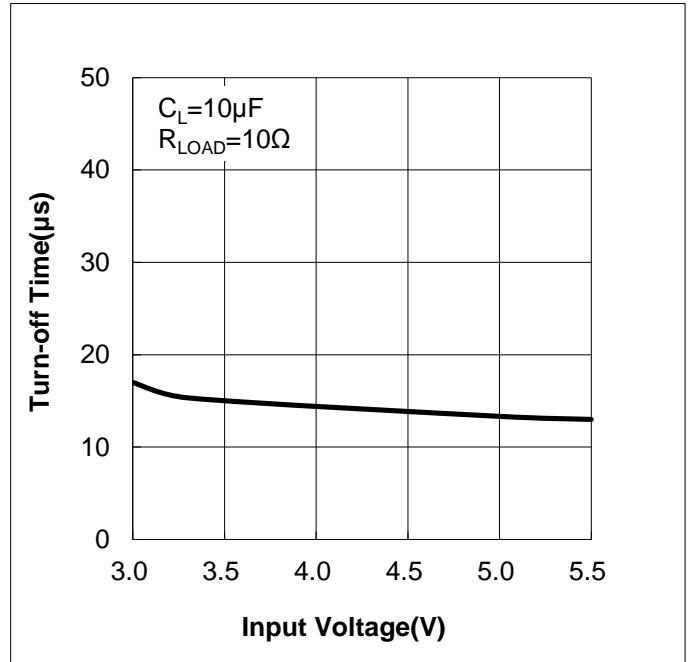
Rise Time vs. Input Voltage

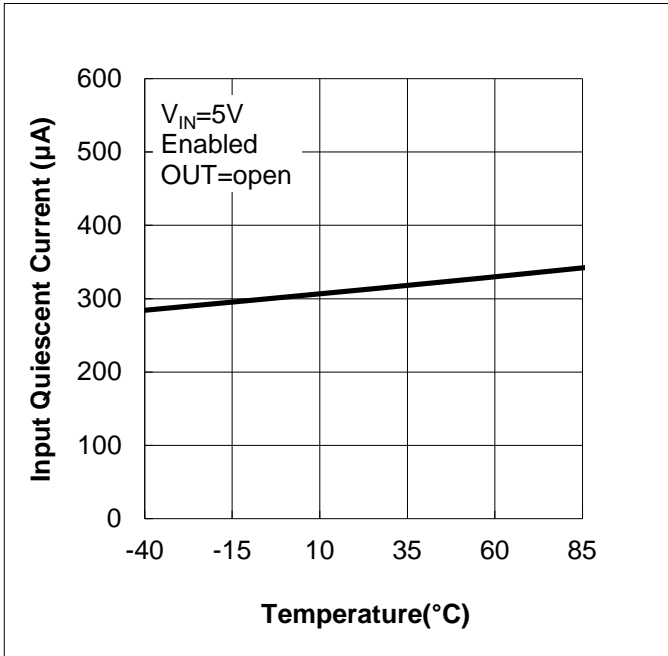**Fall Time vs. Input Voltage**
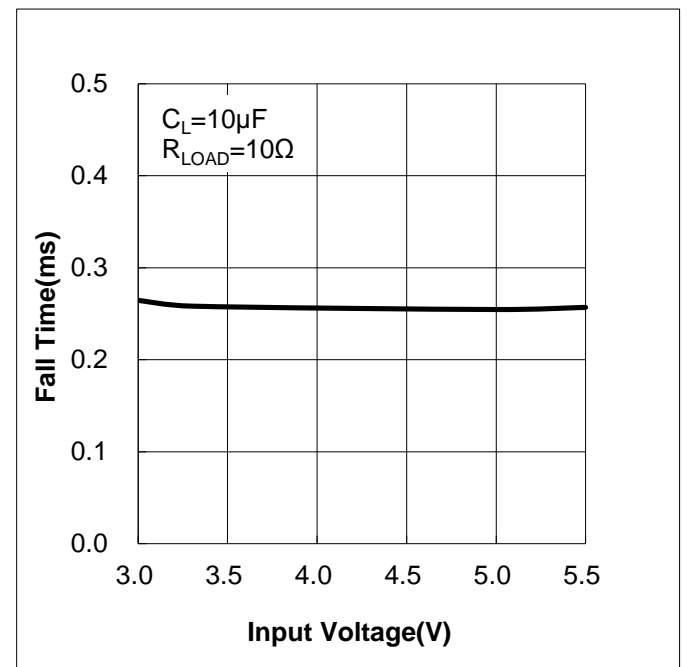
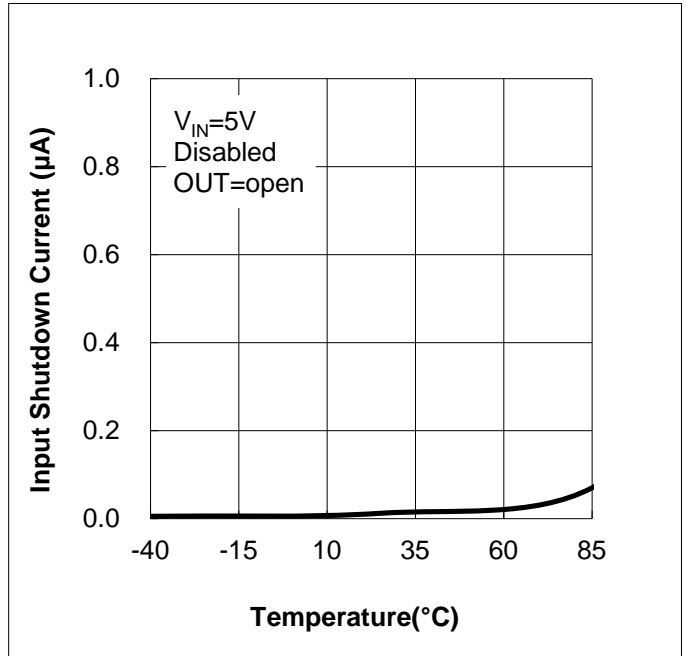AP22815 / AP22615
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Typical Performance Characteristics (cont.) (T$_A$ = +25°C, V$_{IN}$ = 5V, C$_{IN}$ = 1µF, C$_L$ = 0.1µF, unless otherwise specified.)
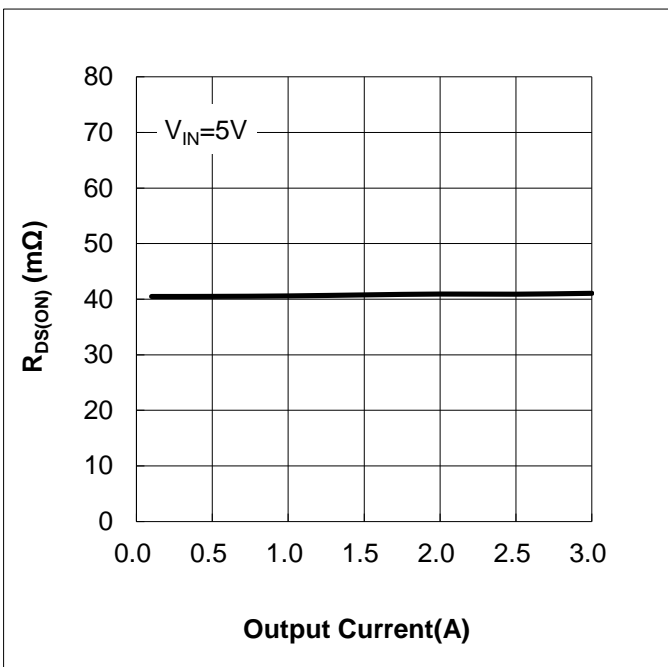
Input Quiescent Current vs. Temperature

Input Shutdown Current vs. Temperature
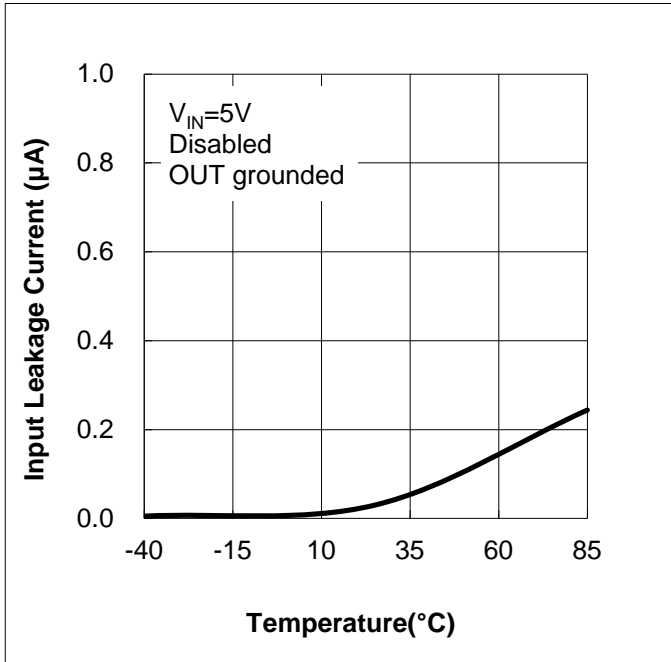

R$_{DS(ON)}$ vs. Output Current
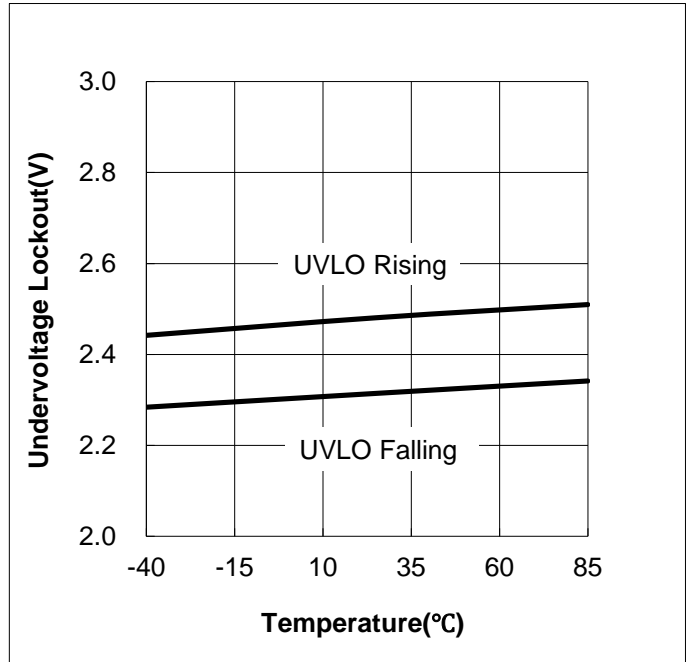

R$_{DS(ON)}$ vs. Temperature
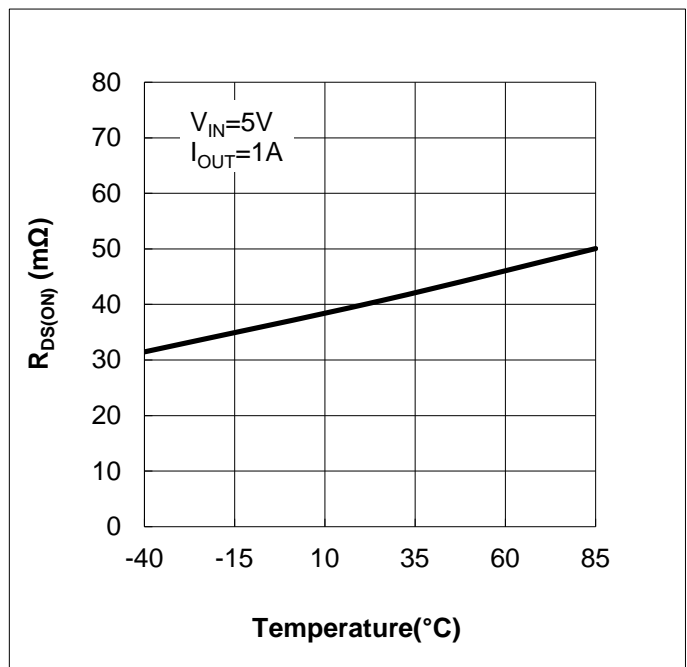
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Typical Performance Characteristics (cont.) (T$_A$ = +25°C, V$_{IN}$ = 5V, C$_{IN}$ = 1μF, C$_L$ = 0.1μF, unless otherwise specified.)

Input Leakage Current vs. Temperature

V$_{IN}$=5V
Disabled
OUT grounded

Under Voltage Lockout vs. Temperature

UVLO Rising

UVLO Falling

Short-Circuit Output Current vs. Temperature

V$_{IN}$=5V, Enabled
Output short to ground
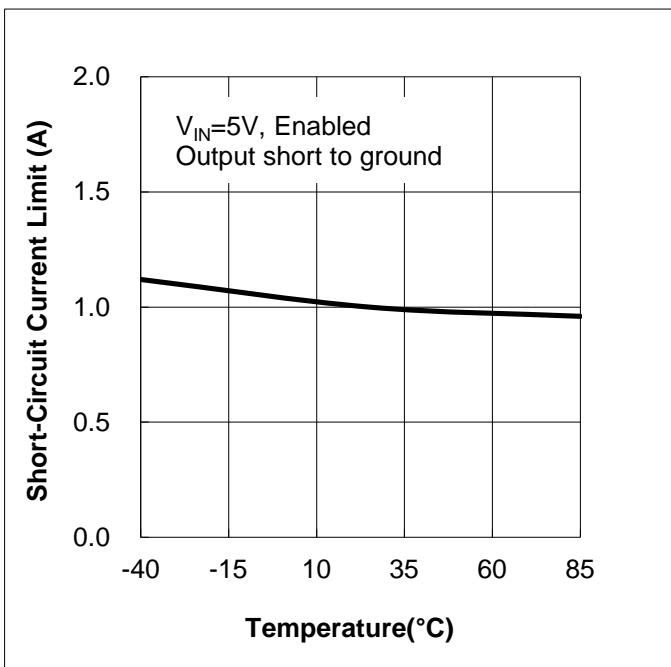
Reverse-Voltage Comparator Trip vs. Temperature
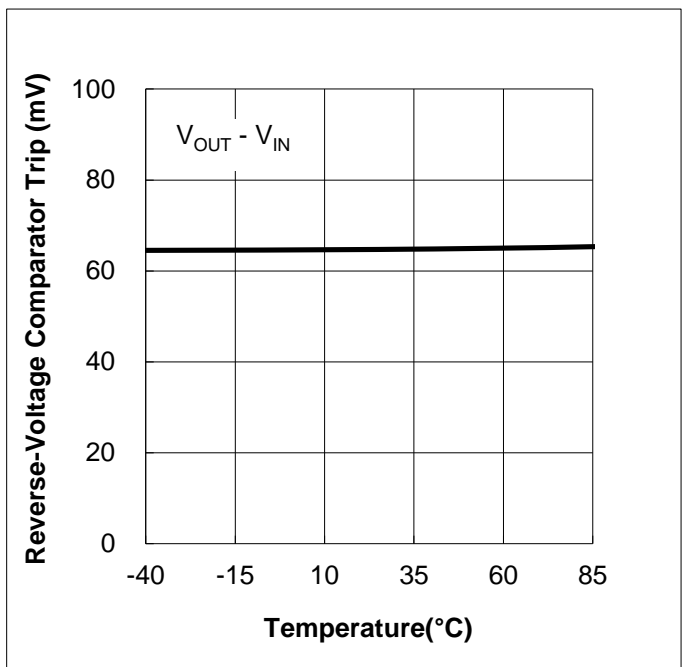
V$_{OUT}$ - V$_{IN}$

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Typical Performance Characteristics (cont.) (T_A = +25°C, V_{IN} = 5V, C_{IN} = 1μF, C_L = 0.1μF, unless otherwise specified.)

Reverse Leakage Current vs. Temperature

Reverse Leakage Current (nA) vs. Temperature(°C)
V_{IN}=0V
Disabled
V_{OUT}=5V
I_{REV} at OUT

Reverse Leakage Current vs. Temperature

Reverse Leakage Current (μA) vs. Temperature(°C)
V_{IN}=0V
Disabled
V_{OUT}=20V
I_{REV} at OUT
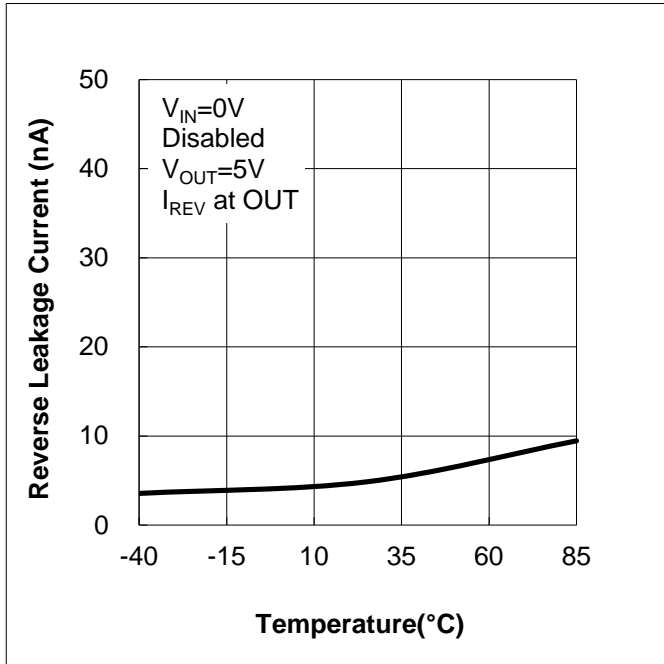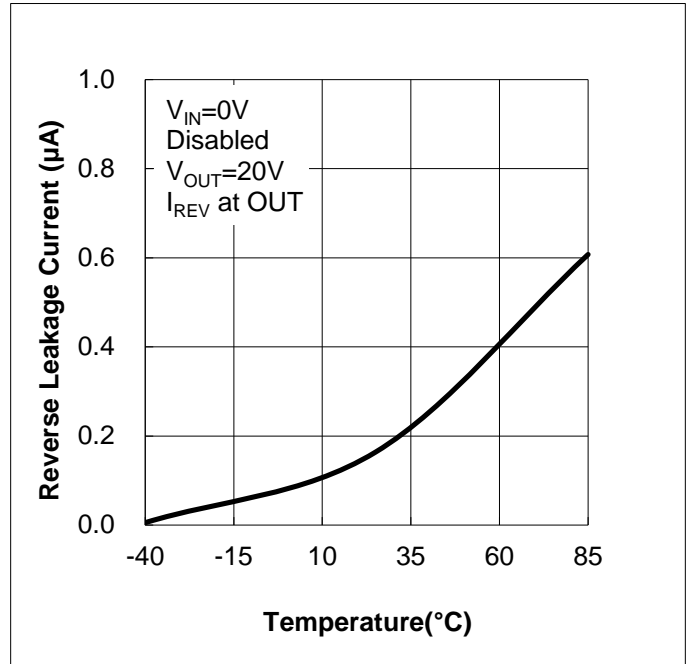
R_{LIMIT} vs. Over Load Current Limit

Over Load Current Limit (A) vs. R_{LIMIT} (kΩ)
AP22615
V_{IN}=5V, V_{OUT}=4V
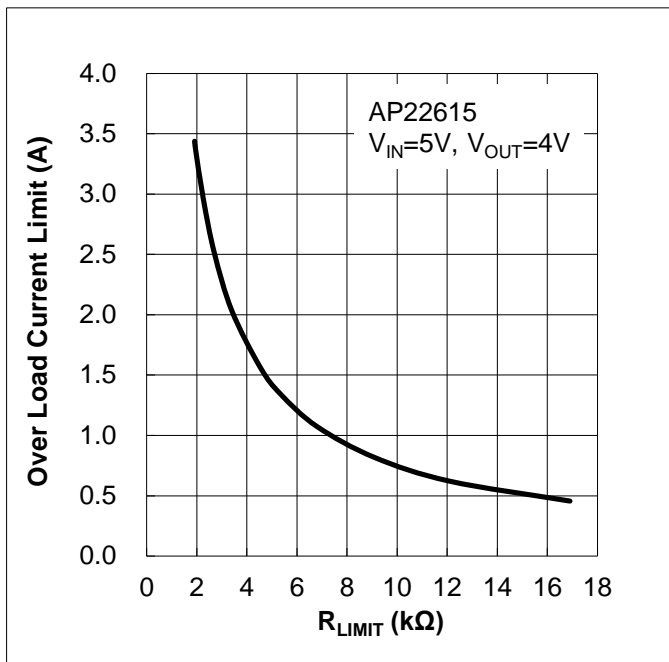
Over Load Current Limit vs. Temperature
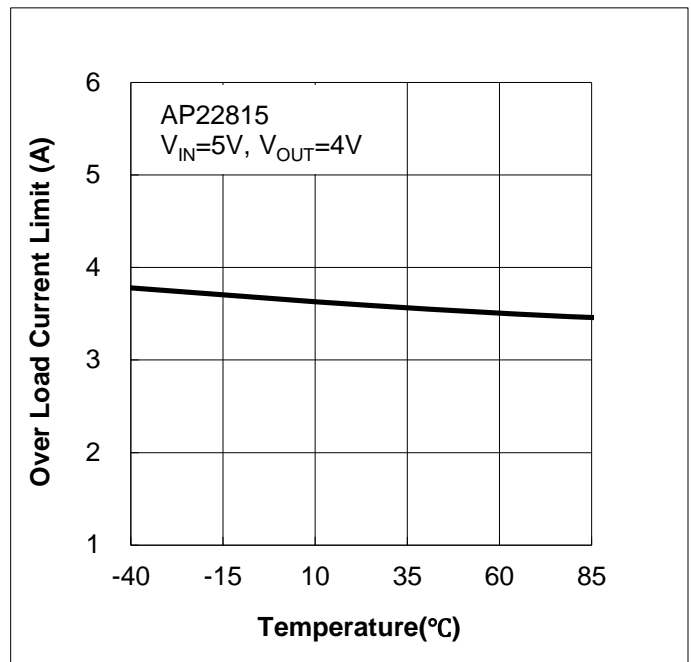
Over Load Current Limit (A) vs. Temperature(°C)
AP22815
V_{IN}=5V, V_{OUT}=4V

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Typical Performance Characteristics (cont.) (T_A = +25°C, V_{IN} = 5V, C_{IN} = 1µF, C_L = 0.1µF, unless otherwise specified.)

Device Enabled Into Short-Circuit

V_{IN}=5V
OUT grounded

EN
5V/div

I_{OUT}
1A/div

1ms/div

Inrush Current

V_{IN}=5V
R_{LOAD}=1.66Ω

EN
5V/div

C_I =220µF

C_L=470µF

C_I =100µF

C_L=1µF

I_{IN}
1A/div

1ms/div

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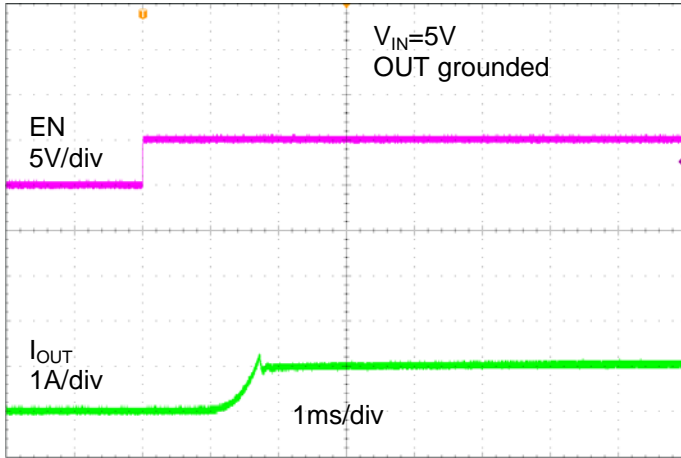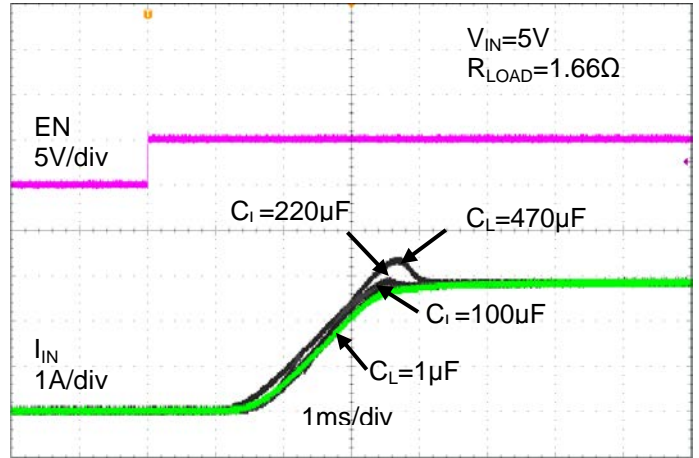
Application Information

Input and Output Capacitors

It is required to place a 1µF X7R or X5R ceramic bypass capacitor between IN and GND—close to the device. It is recommended to place a high-value capacitor (10µF or 47µF) close to input pin when the output transient load is heavy. This precaution reduces power-supply transients that can cause ringing on the input.

Connecting a minimum 100µF low ESR electrolytic or tantalum capacitor (or 22µF MLCC) between OUT and GND is also required for hot-plug applications, which is required to bypass the output with a 0.1µF ceramic capacitor that improves the immunity of the device to short-circuit transients. The bulky 100µF or larger capacitors help reduce output droop voltage when a device is plugged in. When abnormal short-circuit condition happens, these capacitors can also reduce output negative voltage due to parasitic inductive effect and avoid device damage.

Note that without the bypass capacitors, an output short can cause ringing on the input. If the voltage is over the maximum voltage rating, it will destroy the internal control circuitry even the duration is short.

FLG Response

When an overcurrent, overtemperature, or out overvoltage shutdown condition is encountered, the FLG open-drain output goes active low after a nominal 7ms deglitch timeout. The FLG output remains low until both overcurrent and overtemperature or out overvoltage 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 7ms deglitch timeout. The AP22815/AP22615 is designed to eliminate false overcurrent reporting without the requirement of external components to remove unwanted pulses.

When Vin operates below 4V, the lower Vin voltage results in higher equivalent Ron and can potentially cause the FLG signal to be triggered at a higher output current.

Overcurrent and Short-Circuit Protection

An internal-sensing FET is employed to check for overcurrent 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 AP22815/AP22615 senses the short-circuit and immediately clamps output current to a certain safe level.

In the second condition, an output short or an overload occurs while the device is enabled. At the instance the overload occurs, higher current can flow for a very short period of time before the current limit function can react. After the current limit function has tripped, the device switches into current limiting mode, and the current is clamped at I_{LIMIT} or I_{SHORT}.

In the third condition, the load is 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 AP22815/AP22615 is capable of delivering current up to the current-limit threshold without damaging the device. Once the threshold is reached, the device switches into its current limiting mode and is set at I_{LIMIT}.

Thermal Protection

Thermal protection prevents the IC from damage when heavy-overload or short-circuit faults are present for extended periods of time. The AP22815/AP22615 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 +35°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 overtemperature shutdown or overcurrent occurs with 7ms deglitch.

When Vin operates below 4V, the lower Vin voltage results in higher equivalent Ron and might potentially cause the chip to enter thermal cycling condition by higher output current.

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Application Information (continued)

ON/OFF Input Operator

The EN input allows the output current to be switched on and off using a GPIO compatible input. The high signal (switch on) must be at least 1.2V and the low signal (switch off) no higher than 0.4V. This pin should *not* be left floating. It is advisable to hold the EN signal low when applying or removing power.

Undervoltage Lockout (UVLO)

Undervoltage lockout function (UVLO) keeps the internal power switch from being turned on until the power supply has reached at least 2.5V, even if the switch is enabled. Whenever the input voltage falls below approximately 2.3V, the power switch is quickly turned off. This facilitates the design of hot-insertion systems where it is not possible to turn off the power switch before input power is removed.

Discharge Function

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

Output Reverse-Voltage/Current Protection

The output reverse-voltage protection turns off the MOSFET switch whenever the output voltage is higher than the input voltage by 65mV, and the MOSFET switch turns on when output reverse-voltage conditions is removed. When reverse-voltage is lower than 65mV, the reverse current is regulated at approximately 350mA. When the reverse current continuously increases and the reverse voltage is larger than 65mV, the reverse-voltage protection is triggered.

Fast Role-Swap Function

The AP22615 & AP22815 integrate the fast role-swap function, which makes Vout recovery to 4.75V within 150µs during Vout drops from high voltage to low. When EN is high, Vin is valid, and Vout is higher than Vin by 65 mV, the device works at reverse block mode, power FET is off and standby for FRS. Once Vout drops lower than Vin, power FET is turned on in 150µs.

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

Board Layout Instruction

Placing input and output capacitors, 1µF and 0.1µF+100µF respectively, close and next to the device pins must be implemented to minimize the effects of parasitic inductance. For best performance, all trace lengths must be kept as short as possible. The input and output PCB traces must be as wide as possible. Use a ground plane to enhance the power dissipation capability of the device.

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Ordering Information

AP22815X XX-X
AP22615X XX-X

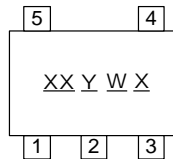| Enable	Package	Packing

A : Active High
B : Active Low

WT: TSOT25
WU: TSOT26
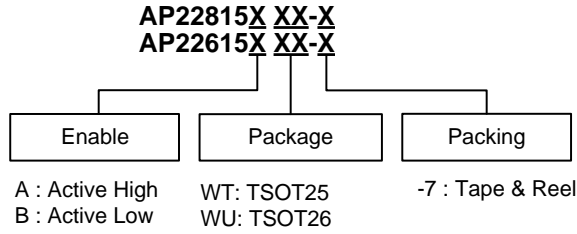
-7 : Tape & Reel

Part Number	Package Code	Packaging	7" Tape and Reel	
			Quantity	Part Number Suffix
AP22815A	WT	TSOT25	3000/Tape & Reel	-7
AP22815B	WT	TSOT25	3000/Tape & Reel	-7
AP22615A	WU	TSOT26	3000/Tape & Reel	-7
AP22615B	WU	TSOT26	3000/Tape & Reel	-7

Marking Information

(1)   TSOT25

(Top View)

$\underline{XX}$: Identification code
$\underline{Y}$: Year 0~9
$\underline{W}$: Week : A~Z : 1~26 week;
     a~z : 27~52 week; z represents
     52 and 53 week
$\underline{X}$: A~Z : Green

Part Number	Package Type	Identification Code
AP22815AWT-7	TSOT25	P5
AP22815BWT-7	TSOT25	P6

(2)   TSOT26

(Top View)
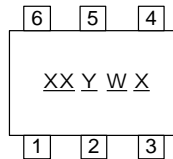
$\underline{XX}$: Identification code
$\underline{Y}$: Year 0~9
$\underline{W}$: Week : A~Z : 1~26 week;
     a~z : 27~52 week; z represents
     52 and 53 week
$\underline{X}$: A~Z : Green

Part Number	Package Type	Identification Code
AP22615AWU-7	TSOT26	P7
AP22615BWU-7	TSOT26	P8

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Package Outline Dimensions (All dimensions in mm.)

Please see http://www.diodes.com/package-outlines.html for the latest version.
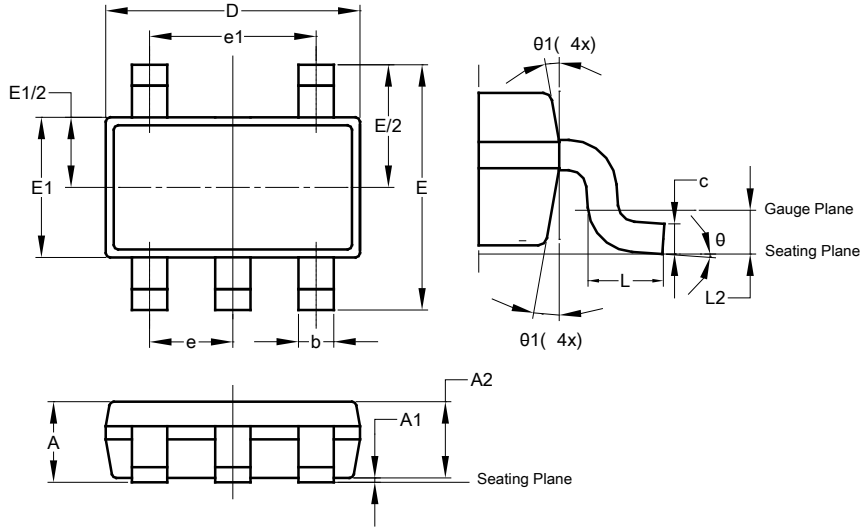
(1)   TSOT25

TSOT25			
Dim	**Min**	**Max**	**Typ**
A	—	1.00	—
A1	0.01	0.10	—
A2	0.84	0.90	—
b	0.30	0.45	—
c	0.12	0.20	—
D	—	—	2.90
E	—	—	2.80
E1	—	—	1.60
e	0.95 BSC		
e1	1.90 BSC		
L	0.30	0.50	—
L2	0.25 BSC		
θ	0°	8°	4°
θ1	4°	12°	—
All Dimensions in mm			

(2)   TSOT26
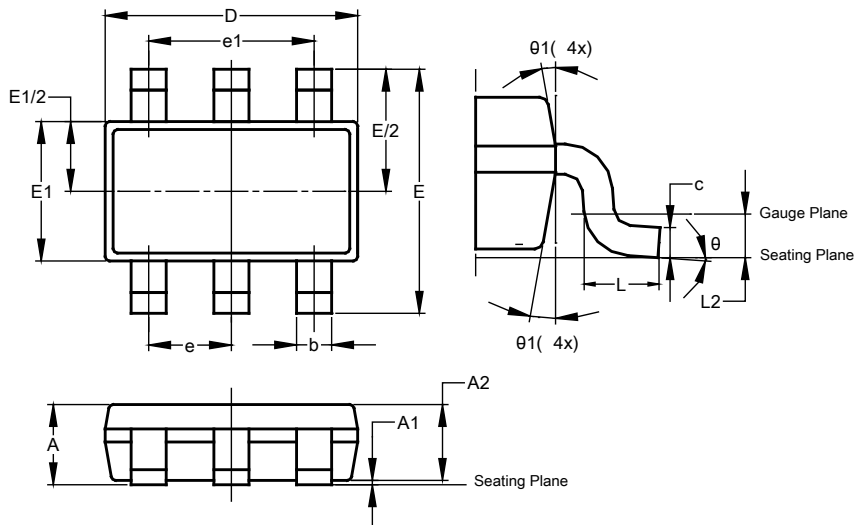
TSOT26			
Dim	**Min**	**Max**	**Typ**
A	—	1.00	—
A1	0.010	0.100	—
A2	0.840	0.900	—
D	2.800	3.000	2.900
E	2.800 BSC		
E1	1.500	1.700	1.600
b	0.300	0.450	—
c	0.120	0.200	—
e	0.950 BSC		
e1	1.900 BSC		
L	0.30	0.50	—
L2	0.250 BSC		
θ	0°	8°	4°
θ1	4°	12°	—
All Dimensions in mm			

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Suggested Pad Layout

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

(1)   TSOT25
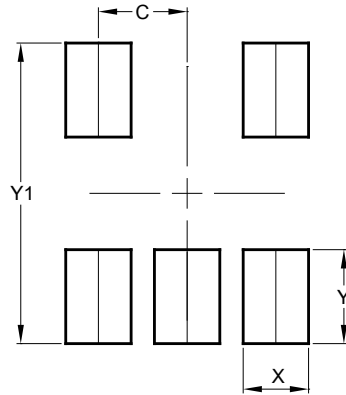
Dimensions	Value (in mm)
C	0.950
X	0.700
Y	1.000
Y1	3.199

(2)   TSOT26

Dimensions	Value (in mm)
C	0.950
X	0.700
Y	1.000
Y1	3.199

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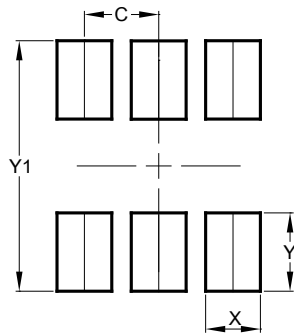
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