SINGLE-CHANNEL POWER DISTRIBUTION SWITCH WITH OUTPUT OVP

Description

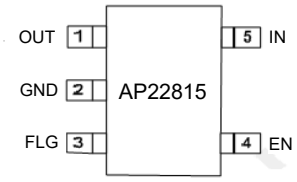
The AP22815 / AP22615 are 3A, single-channel, current-limited, high-side power switches with output overvoltage protection (OVP) optimized for USB and other hot-swap applications. The AP22815 / AP22615 comply with USB standards and are available with both polarities of Enable input. The devices also possess fixed and adjustable current-limited features optimized for applications requiring precise current-limiting support. They have USB PD3.0 fast role-swap functions, and the output voltage recovers to a valid USB voltage range within 110µs during the USB PD fast role-swap event.

The devices have fast short-circuit and output overvoltage response times for improved system robustness. Both the TSOT25 (Type A1) and TSOT26 (Type A1) packages integrate discharge circuitry inside the OUT pin. They provide a complete protection solution for applications subject to heavy capacitive loads and the prospect of short circuits, and offer output overvoltage, reverse-current, 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 (Type A1) package with RoHS compliancy. The AP22615 is available in a standard Green TSOT26 (Type A1) package with RoHS compliancy.

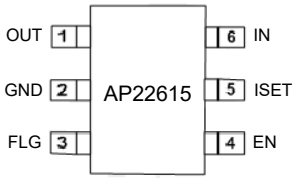
Pin Assignments

(Top View)



TSOT25 (Type A1)

(Top View)



TSOT26 (Type A1)

Features

- Input Voltage Range: 3.0V to 5.5V
- 40mΩ On-Resistance
- Built-In Soft-Start with 2.1ms Typical Rise Time
- Fault Report (FLG) with Blanking Time (7ms Typical)
- Accurate Adjustable Current Limit, 0.4A to 4.0A (AP22615 Only)
- ESD Protection: 2kV HBM, 200V MM
- Active-Low or Active-High Enable
- Protection Functions:
  - 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 # E322375
- IEC 60950-1 CB Scheme Certified
- IEC 62368-1 CB Scheme Certified
- **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/

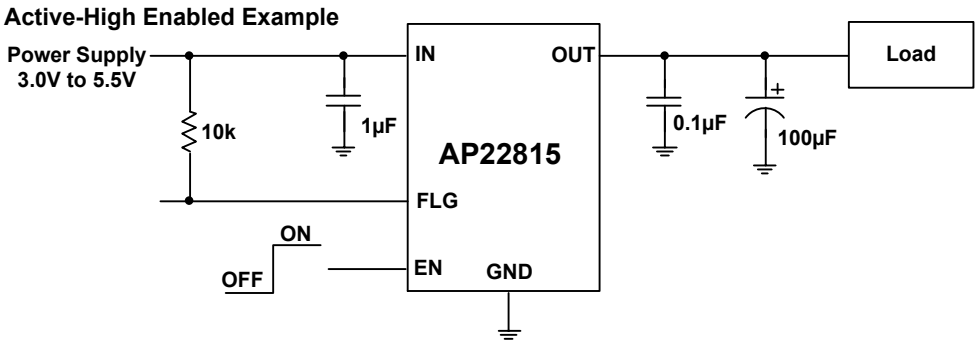
Applications

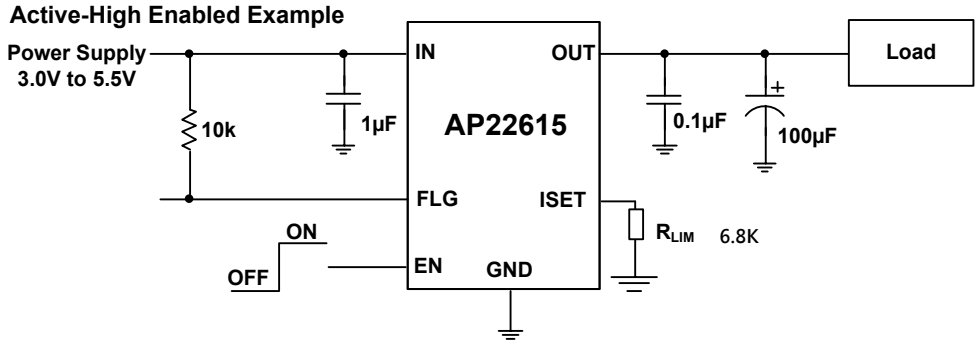
- Integrated load switches in ultrabook PCs
- Power-up/down sequencing in ultrabook PCs
- Notebooks, netbooks, tablet PCs, and set-top boxes
- Solid-state drives (SSDs)
- Consumer electronics
- USB chargers
- Telecom systems

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 (Note 4)





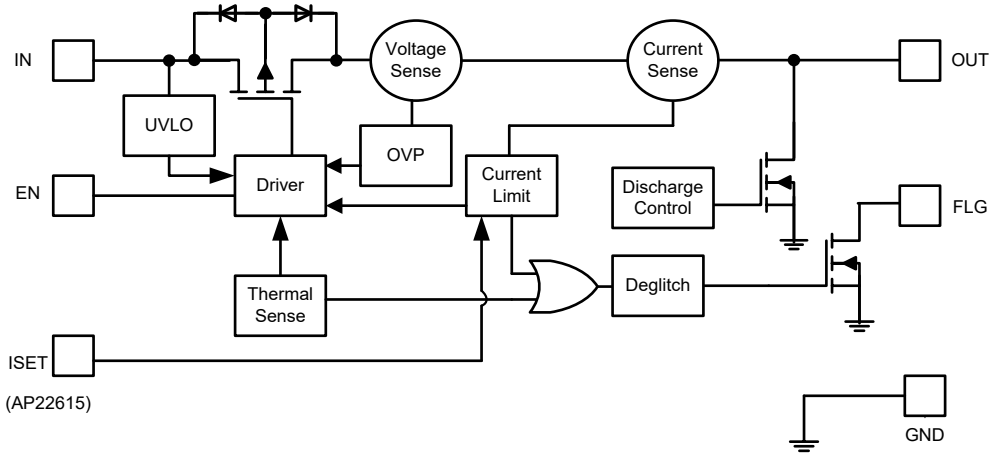
Note: 4. Applying a 1µF input capacitor leads to a large V_{IN} spike, so it is recommended to use a 10µF capacitor instead.

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Pin Descriptions

Pin Number		Pin Name	Pin Function
AP22815 TSOT25 (Type A1)	AP22615 TSOT26 (Type A1)		
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 (Active-Low or Active-High)
NC	5	ISET	AP22815: NC Pin AP22615: Set OCP current by attaching resistor. The current limit: I_{LIM} (A) = 6800/R_{LIM} (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 5)

Symbol	Parameter		Value	Unit
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_{STG}	Storage Temperature		-65 to 150	°C
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient (Note 6)	TSOT25 (Type A1)	85	°C/W
		TSOT26 (Type A1)	80	
$R_{\theta JC}$	Thermal Resistance, Junction to Case (Note 6)	TSOT25 (Type A1)	32	°C/W
		TSOT26 (Type A1)	30	

Notes: 5. Stresses greater than those listed under *Absolute Maximum Ratings* can cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions* is not implied. Exposure to *Absolute Maximum Ratings* for extended periods can affect device reliability.

6. $R_{\theta JA}$ and $R_{\theta JC}$ are measured at T_A = +25°C on a high effective thermal conductivity four-layer test board per JEDEC 51-7.

Recommended Operating Conditions (Note 7)

Symbol	Parameter	Min	Max	Unit
V_{IN}	Input Voltage	3.0	5.5	V
I_{OUT}	Output Current, 4.0V ≤ V_{IN} ≤ 5.5V	0	3	A
	Output Current, 3.0V ≤ V_{IN} < 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: 7. Refer to the typical application circuit.

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

Symbol	Parameter	Test Condition	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} = 1.94kΩ	3.1	3.6	4.2	A
		(AP22615) V_{IN} = 5V, V_{OUT} = 4V, R_{LIM} = 6.8kΩ	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} = 5V, 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

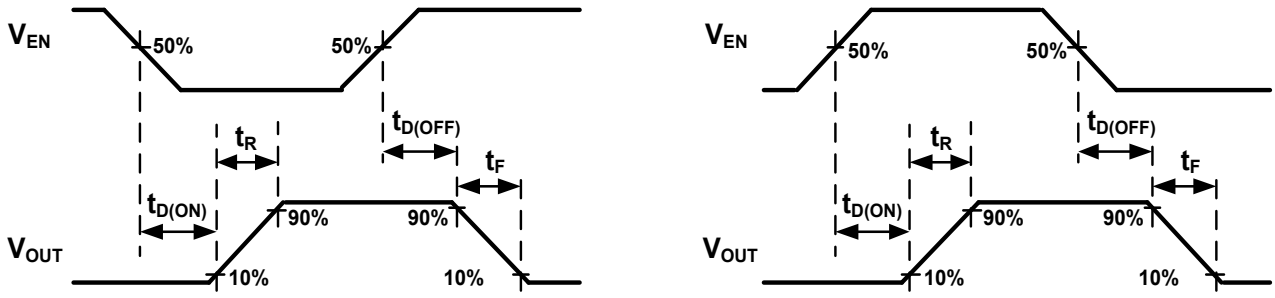
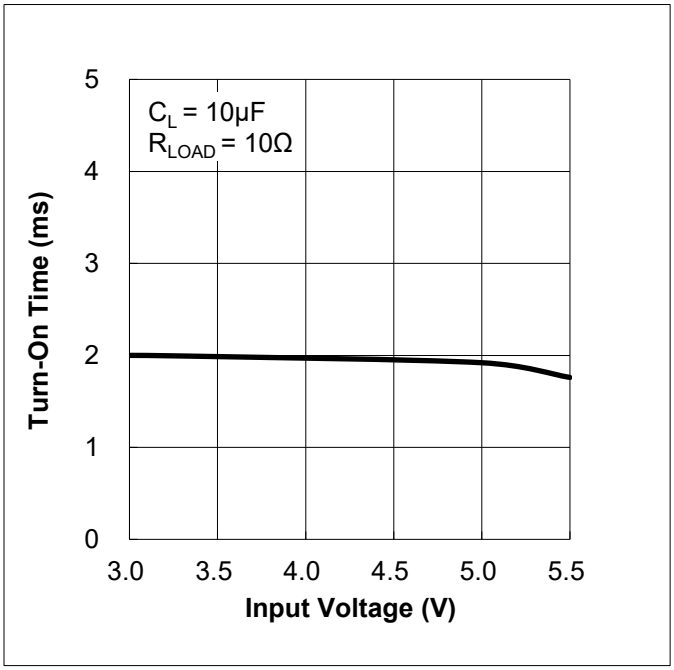


Figure 1. Voltage Waveforms

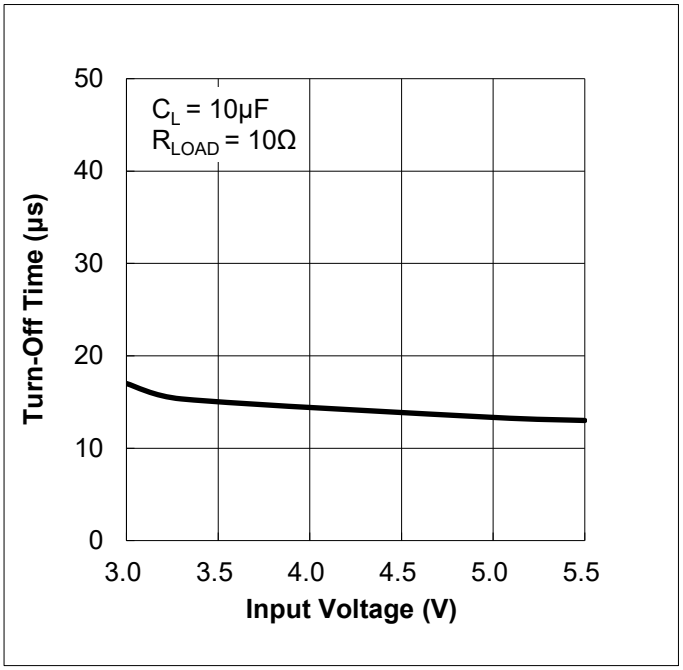
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Typical Performance Characteristics (continued) (T_A = +25°C, V_{IN} = 5V, C_{IN} = 1µF, C_L = 0.1µF, unless otherwise specified.)

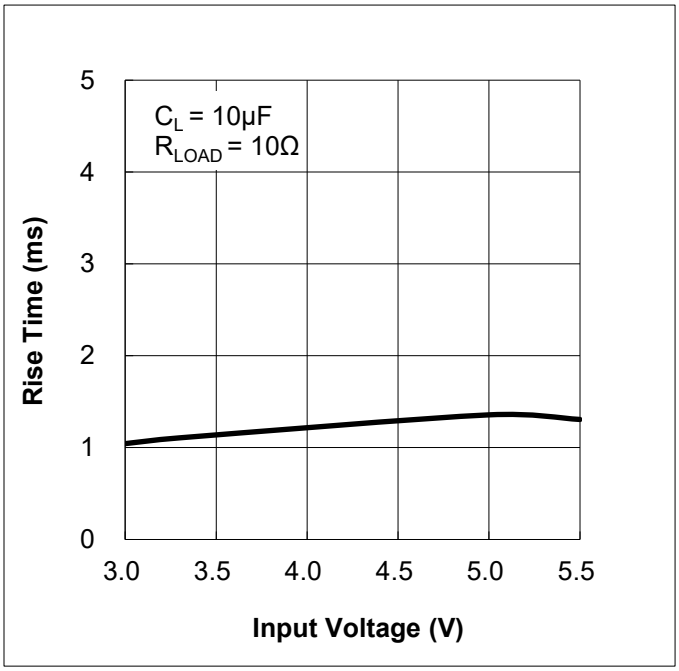
Turn-On Time vs. Input Voltage



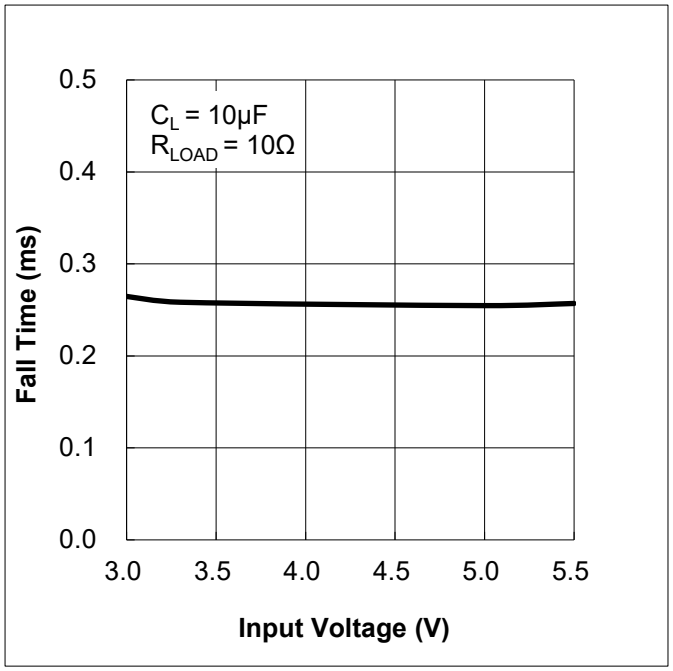
Turn-Off Time vs. Input Voltage



Rise Time vs. Input Voltage



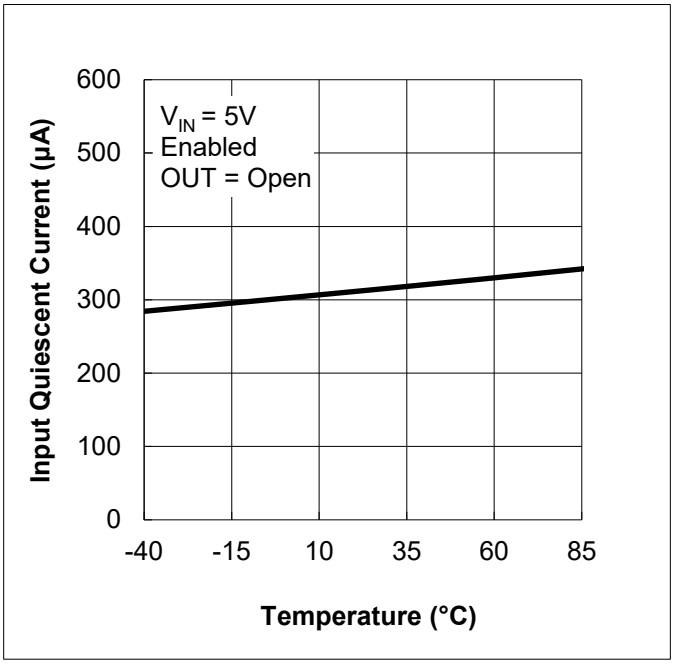
Fall Time vs. Input Voltage



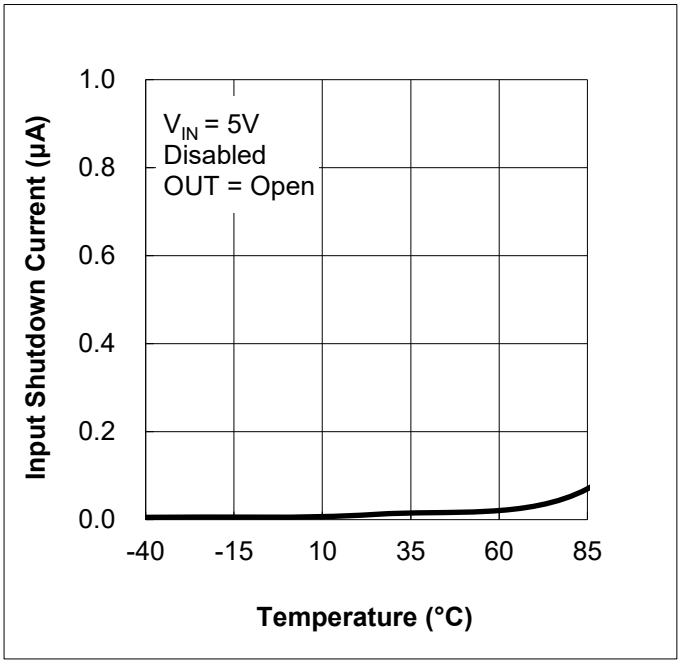
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Typical Performance Characteristics (continued) (T_A = +25°C, V_{IN} = 5V, C_{IN} = 1µF, C_L = 0.1µF, unless otherwise specified.)

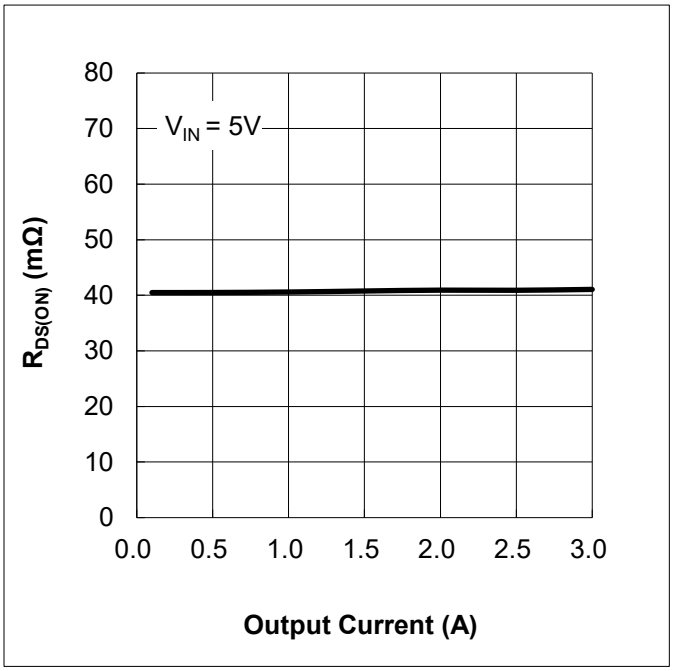
Input Quiescent Current vs. Temperature



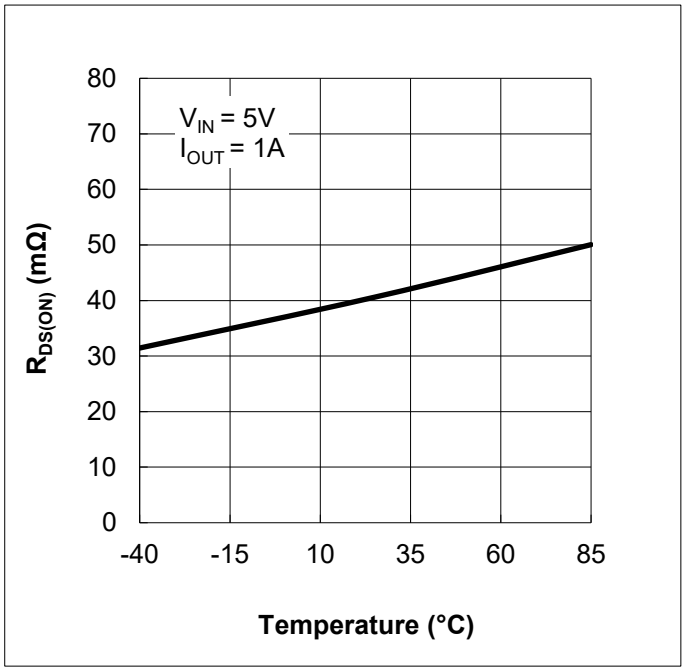
Input Shutdown Current vs. Temperature



$R_{DS(ON)}$ vs. Output Current



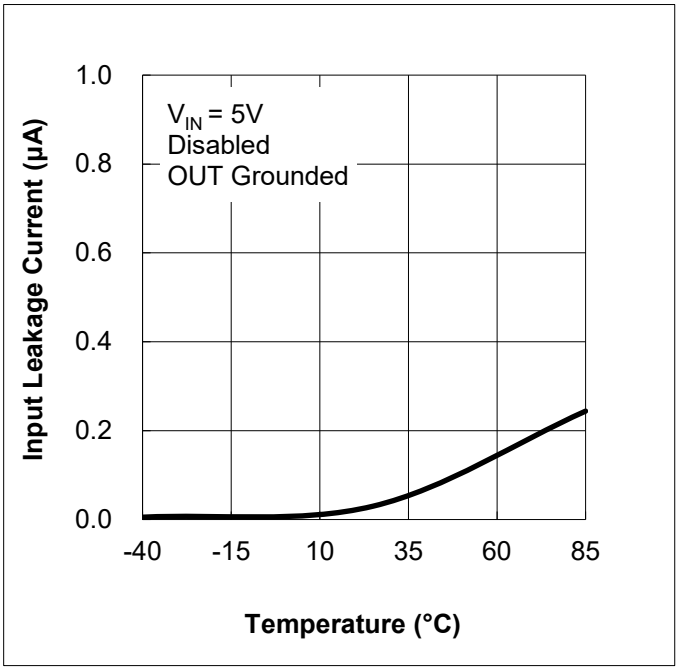
$R_{DS(ON)}$ vs. Temperature



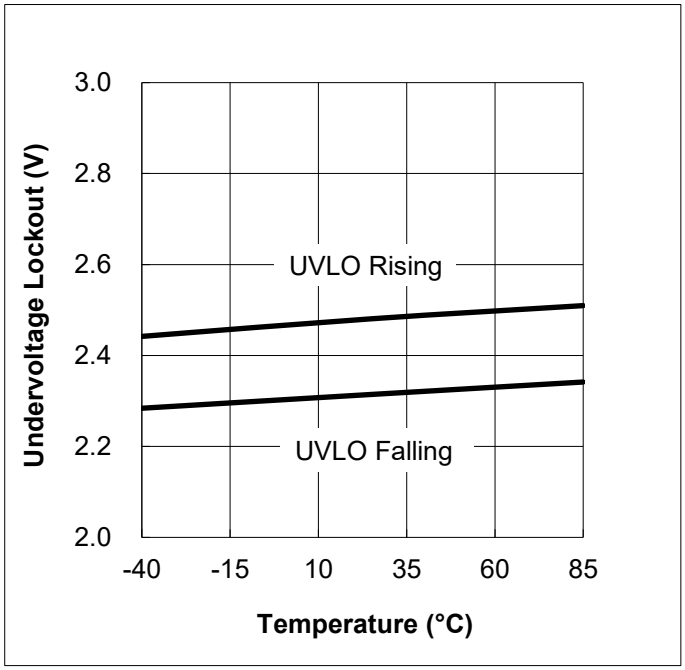
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Typical Performance Characteristics (continued) (T_A = +25°C, V_{IN} = 5V, C_{IN} = 1µF, C_L = 0.1µF, unless otherwise specified.)

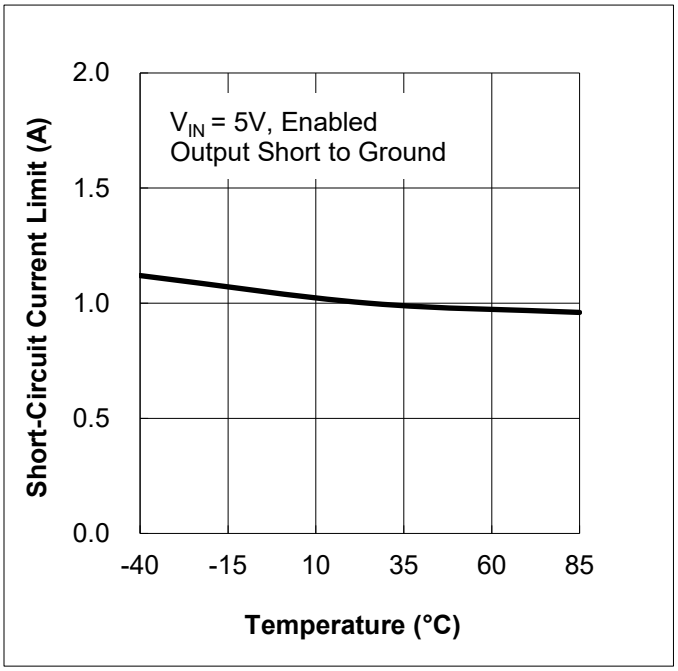
Input Leakage Current vs. Temperature



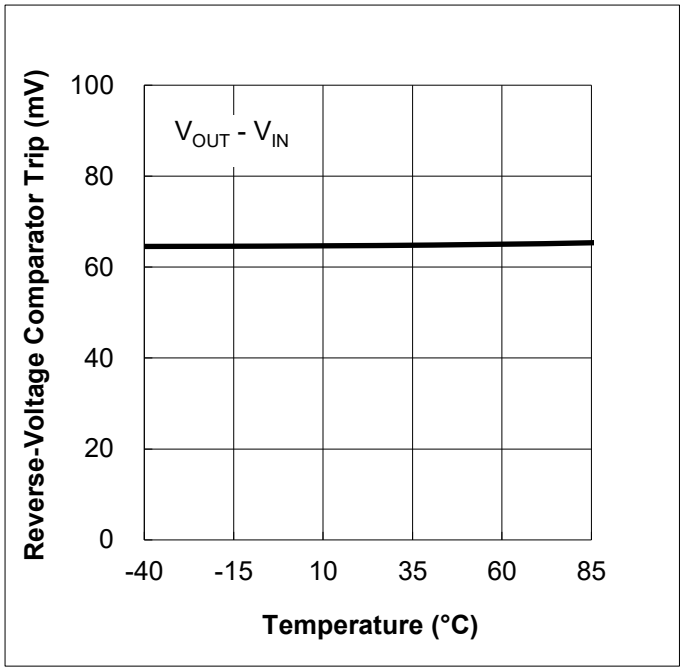
Undervoltage Lockout vs. Temperature



Short-Circuit Output Current vs. Temperature



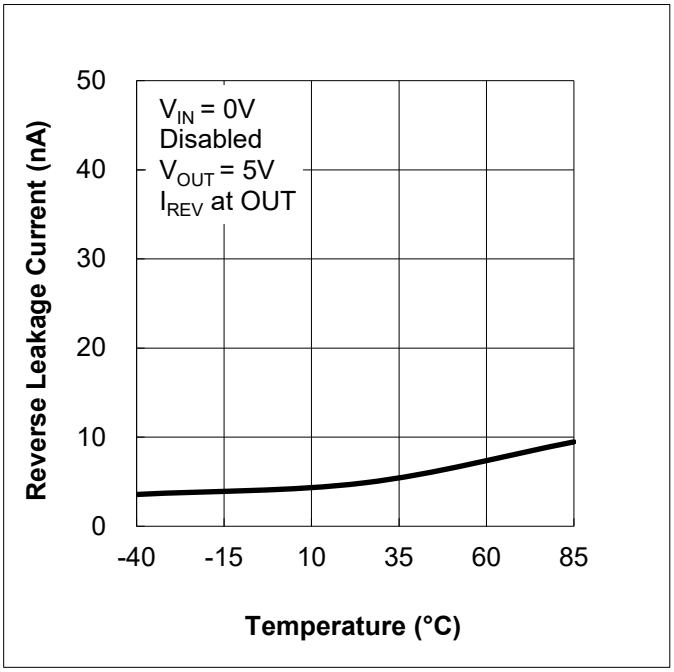
Reverse-Voltage Comparator Trip vs. Temperature



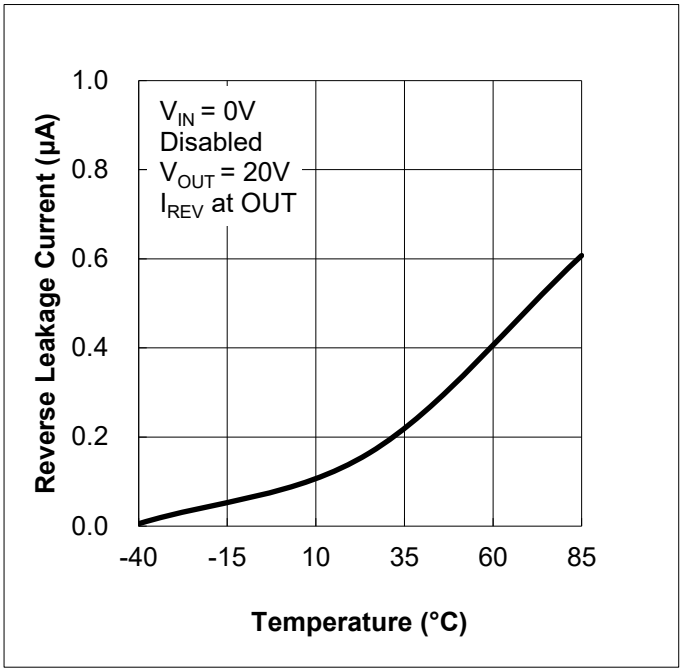
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Typical Performance Characteristics (continued) (T_A = +25°C, V_{IN} = 5V, C_{IN} = 1µF, C_L = 0.1µF, unless otherwise specified.)

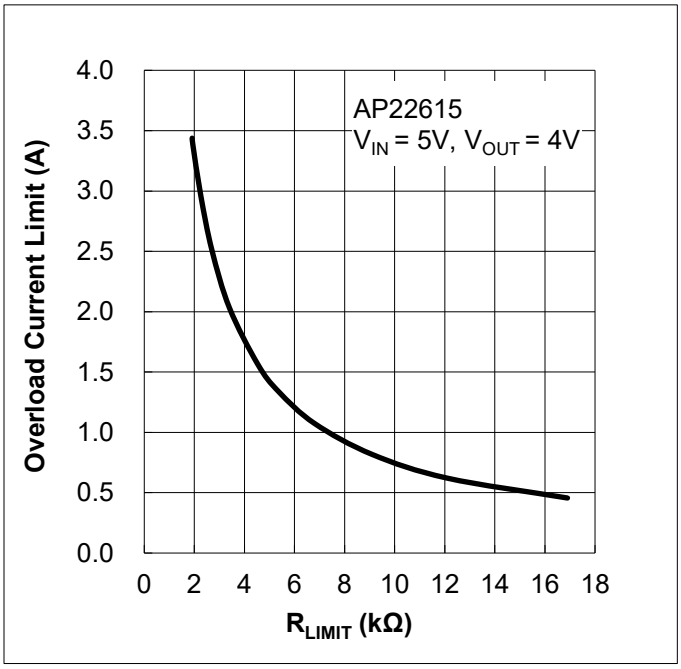
Reverse Leakage Current vs. Temperature



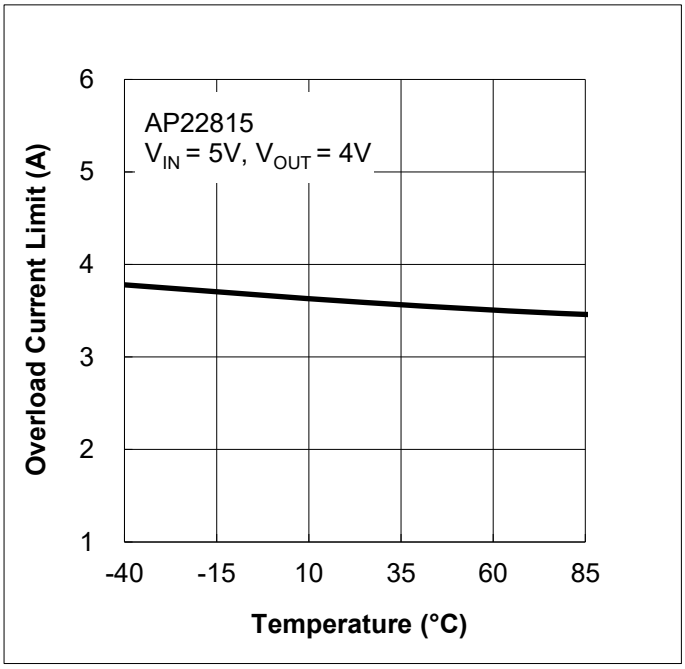
Reverse Leakage Current vs. Temperature



Overload Current Limit vs. R_{LIMIT}



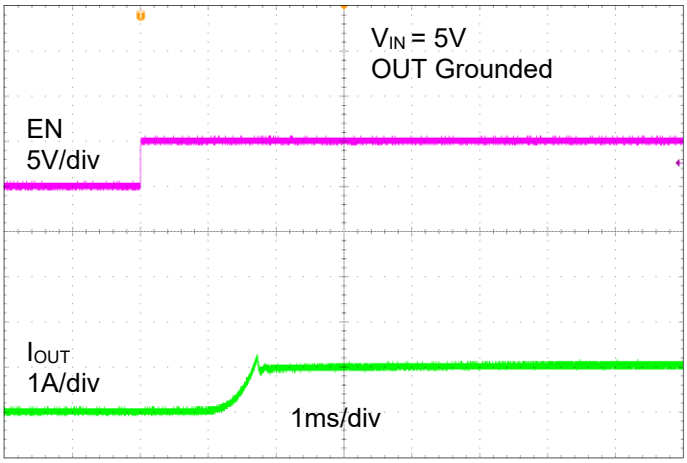
Overload Current Limit vs. Temperature



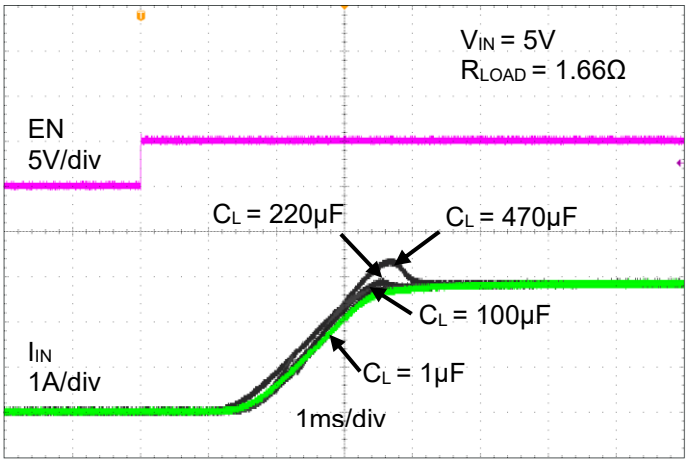
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Typical Performance Characteristics (continued) (T_A = +25°C, V_{IN} = 5V, C_{IN} = 1µF, C_L = 0.1µF, unless otherwise specified.)

Device Enabled Into Short-Circuit



Inrush Current



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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 the 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 conditions happen, these capacitors can also reduce output negative voltage due to parasitic inductive effects 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 if the duration is short.

FLG Response

When an overcurrent, overtemperature, or 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 overcurrent, overtemperature, or 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 are designed to eliminate false overcurrent reporting without the need for external components, removing unwanted pulses.

When V_{IN} operates below 4V, the lower V_{IN} voltage results in higher equivalent R_{ON} 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 sense the short circuit and immediately clamp the output current to a certain safe level.

In the second condition, an output short or overload occurs while the device is enabled. At the instance that 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 the 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 are 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 implement 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 V_{IN} operates below 4V, the lower V_{IN} voltage results in higher equivalent R_{ON} 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 are 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 and AP22815 integrate fast role-swap function, which makes the V_{OUT} recover to 4.75V within 150µs when the V_{OUT} drops from high voltage to low. When EN is high, V_{IN} is valid, and V_{OUT} is higher than V_{IN} by 65 mV; the device works at reverse-block mode, and the power FET turns off and stands by for FRS. Once V_{OUT} drops lower than V_{IN}, the 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 currents. 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, to 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

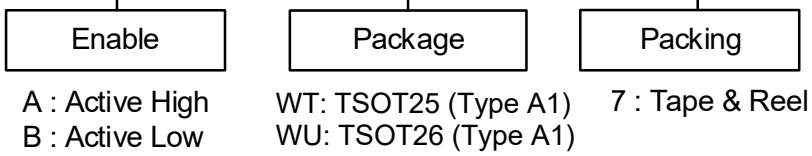
Board Layout Instruction

Place input and output capacitors, 1µF and 0.1µF+100µF respectively, close to the device pins. This 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 (Note 8)

AP22815X XX - X
AP22615X XX - X



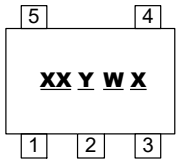
Orderable Part Number	Package Code	Package	Packing		
			Quantity	Carrier	Part Number Suffix
AP22815AWT-7	WT	TSOT25 (Type A1)	3,000	7" Tape & Reel	-7
AP22815BWT-7	WT	TSOT25 (Type A1)	3,000	7" Tape & Reel	-7
AP22615AWU-7	WU	TSOT26 (Type A1)	3,000	7" Tape & Reel	-7
AP22615BWU-7	WU	TSOT26 (Type A1)	3,000	7" Tape & Reel	-7

Note: 8. For packaging details, go to our website at https://www.diodes.com/design/support/packaging/diodes-packaging/.

Marking Information

(1) TSOT25 (Type A1)

(Top View)

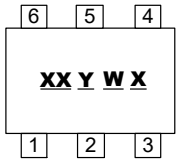


XX : Identification code
Y : Year 0~9
W : Week : A~Z : 1~26 week;
a~z : 27~52 week; z represents
52 and 53 week
X : A~Z : Green

Orderable Part Number	Package Type	Identification Code
AP22815AWT-7	TSOT25 (Type A1)	P5
AP22815BWT-7	TSOT25 (Type A1)	P6

(2) TSOT26 (Type A1)

(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 : A~Z : Green

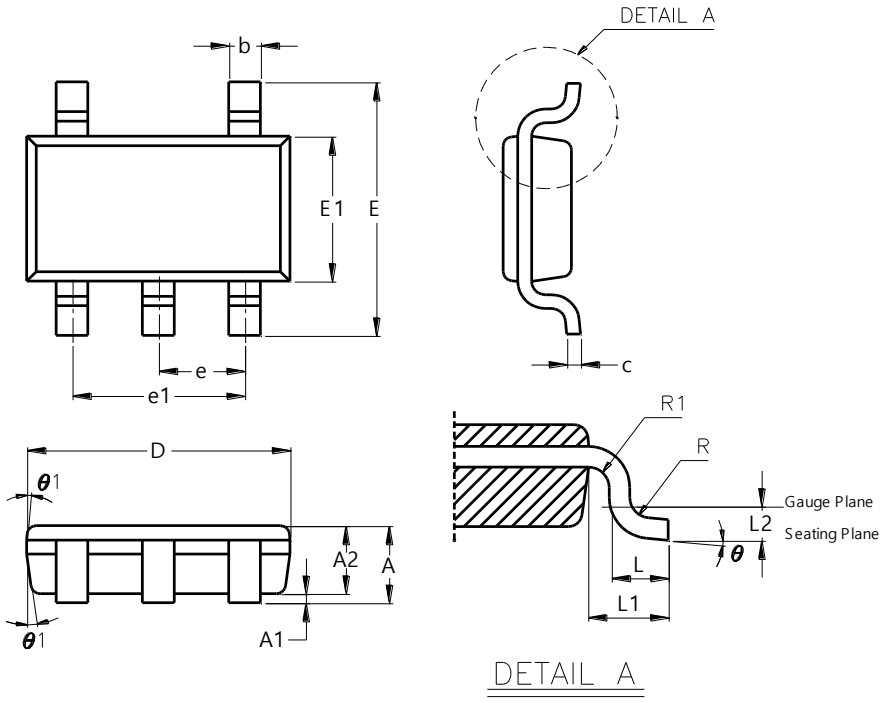
Orderable Part Number	Package Type	Identification Code
AP22615AWU-7	TSOT26 (Type A1)	P7
AP22615BWU-7	TSOT26 (Type A1)	P8

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Package Outline Dimensions

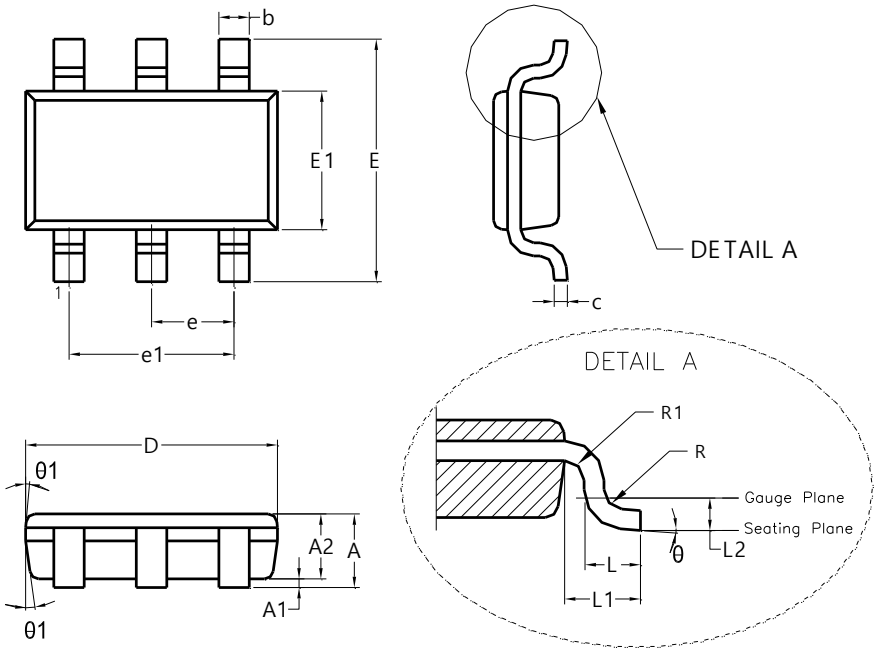
Please see http://www.diodes.com/package-outlines.html for the latest version.

(1) TSOT25 (Type A1)



TSOT25 (Type A1)			
Dim	**Min**	**Max**	**Typ**
A	0.750	0.800	--
A1	0.00	0.050	--
A2	0.700	0.775	0.750
b	0.350	0.500	--
c	0.100	0.200	--
D	2.800	3.000	2.900
E	2.600	3.000	2.800
E1	1.500	1.700	1.600
e	0.950 BSC		
e1	1.900 BSC		
L	0.370	0.600	0.450
L1	0.600 REF		
L2	0.250 BSC		
R	0.100	--	--
R1	0.100	--	--
θ	0°	8°	4°
θ1	4°	12°	10°
All Dimensions in mm			

(2) TSOT26 (Type A1)



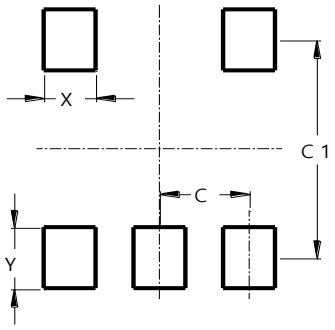
TSOT26 (Type A1)			
Dim	**Min**	**Max**	**Typ**
A	0.700	0.825	--
A1	0.000	0.050	--
A2	0.700	0.775	0.750
b	0.350	0.500	--
c	0.100	0.200	--
D	2.800	3.000	2.900
E	2.600	3.000	2.800
E1	1.500	1.700	1.600
e	0.95 BSC		
e1	1.900 BSC		
L	0.370	0.600	0.450
L1	0.600 REF		
L2	0.250 BSC		
R	0.100	--	--
R1	0.100	0.250	--
θ	0°	8°	4°
θ1	4°	12°	10°
All Dimensions in mm			

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Suggested Pad Layout

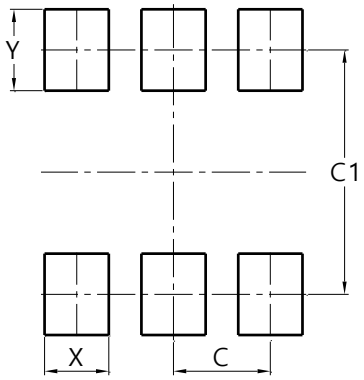
Please see http://www.diodes.com/package-outlines.html for the latest version.

(1) TSOT25 (Type A1)



Dimensions	Value (in mm)
C	0.95
C1	2.50
X	0.55
Y	0.70

(2) TSOT26 (Type A1)



Dimensions	Value (in mm)
C	0.950
C1	2.400
X	0.630
Y	0.800

Mechanical Data

- Moisture Sensitivity: Level 1 per J-STD-020
- Terminals: Finish – Matte Tin Plated Leads, Solderable per MIL-STD-202, Method 208 e3
- Weight: 0.013 grams (Approximate)

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