SKYWORKS

DATA SHEET

AAT4687

Over-Voltage Protection Switch

General Description

The AAT4687 OVPSwitch™ is a member of Skyworks' Application Specific Power MOSFET™ (ASPM™) product family. It is a P-channel MOSFET power switch with precise over-voltage protection control, designed to protect low-voltage systems against high-voltage faults up to +28V. If the input voltage exceeds the programmed over-voltage threshold, the P-channel MOSFET switch will be turned off to prevent the output load circuits from damage. The AAT4687 is available with an internally programmed over-voltage trip point or as an adjustable version programmed by two external resistors.

The AAT4687 includes an under-voltage lockout (UVLO) protection circuit, which will put the device into sleep mode at low input voltages only consuming < 1µA of current. The AAT4687 also includes an enable pin ($\overline{\text{EN}}$) to enable or disable the device and an OVP, OTP fault indicator ($\overline{\text{FLT}}$).

The AAT4687 is offered in a small Pb-free, 10 pin SC70JW package, and is specified for operation over the -40°C to +85°C ambient temperature range.

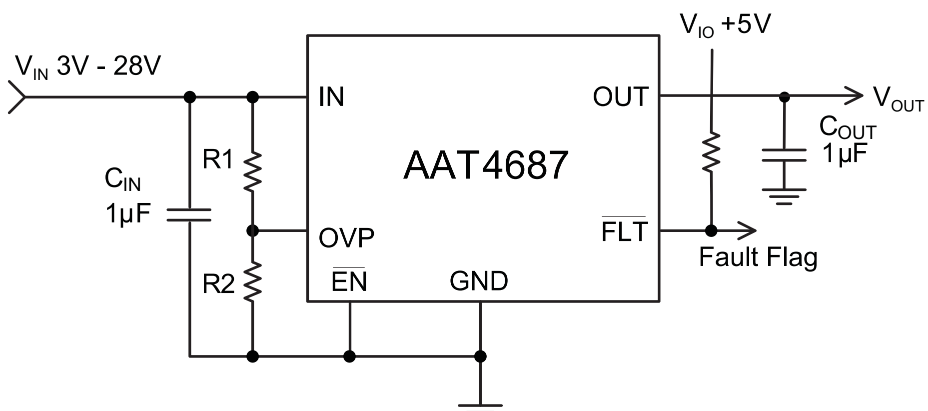
Features

- Over-Voltage Protection up to 28V
- Fixed or Adjustable Over-Voltage Protection Threshold
- 3V Under-Voltage Lockout Threshold
- Fast OVP Response:
  - 0.7µs Typical to Over-Voltage Transient
- Low Operation Quiescent Current
  - 30µA Typical
  - 1µA Max in Shutdown (Disabled)
- Thermal Shutdown Protection
- 100mΩ Typical (130mΩ Max) $R_{DS(ON)}$ at 5V
- OVP, OTP Fault Indicator
- 1.8A Maximum Continuous Current
- Temperature Range: -40°C to 85°C
- Available in SC70JW-10 Package

Applications

- Cell Phones
- Digital Still Cameras
- GPS
- MP3 Players
- Personal Data Assistants (PDA)
- USB Hot Swap/Live Insertion Device

Typical Application (Adjustable Version)

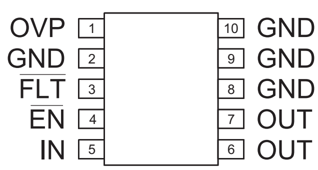


Pin Descriptions

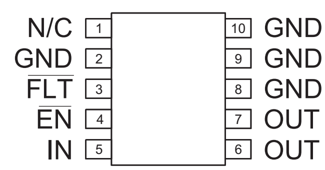
Pin Number		Symbol	Function
Adjustable	Fixed		
1	N/C	OVP	Over-voltage protection threshold input (Adjustable only). In the fixed version, this pin is not connected.
2, 8, 9, 10		GND	Ground connection pin.
3		$\overline{\text{FLT}}$	Over-voltage or over-temperature fault reporting output pin. Open drain. $\overline{\text{FLT}}$ goes low when input voltage exceeds the over-voltage threshold or an over-temperature fault occurs. An external pull up resistor to V_{IO} (6.5V max) should be added.
4		$\overline{\text{EN}}$	Enable input pin, active low. An internal pull-down resistor is connected on this pin. Connect to ground for normal operation. Connect to high (6.5V max) to shut down the device, which then draws less than 1μA of current.
5		IN	Power input pin. Connect 1μF capacitor from IN to GND.
6, 7		OUT	Output. Connect a 0.1μF~47uF capacitor from OUT to GND.

Pin Configuration

SC70JW-10
Adjustable Version
(Top View)



SC70JW-10
Fixed Version
(Top View)



Absolute Maximum Ratings[1]

Symbol	Description	Value	Units
V_{IN}	IN to GND	-0.3 to 30	V
V_{OVP}	OVP to GND	-0.3 to 6.5	V
$V_{\overline{FLT}}$, $V_{\overline{EN}}$	$\overline{FLT}$, $\overline{EN}$ to GND	-0.3 to 6.5	V
V_{OUT}	OUT to GND	-0.3 to V_{IN} + 0.3	V
I_{MAX}	Maximum Continuous Switch Current	1.8	A
T_J	Operating Junction Temperature Range	-40 to 150	°C
T_{STG}	Storage Temperature	-40 to 150	°C
T_{LEAD}	Maximum Soldering Temperature (at Leads)	300	°C

Thermal Characteristics

Symbol	Description	Value	Units
Θ_{JA}	Maximum Thermal Resistance[2]	160	°C/W
P_D	Maximum Power Dissipation[2, 3]	625	mW

1. Stresses above those listed in Absolute Maximum Ratings may cause permanent damage to the device. Functional operation at conditions other than the operating conditions specified is not implied. Only one Absolute Maximum Rating should be applied at any one time.
2. Mounted on a FR4 board.
3. Derate 6.25mW/°C above 25°C.

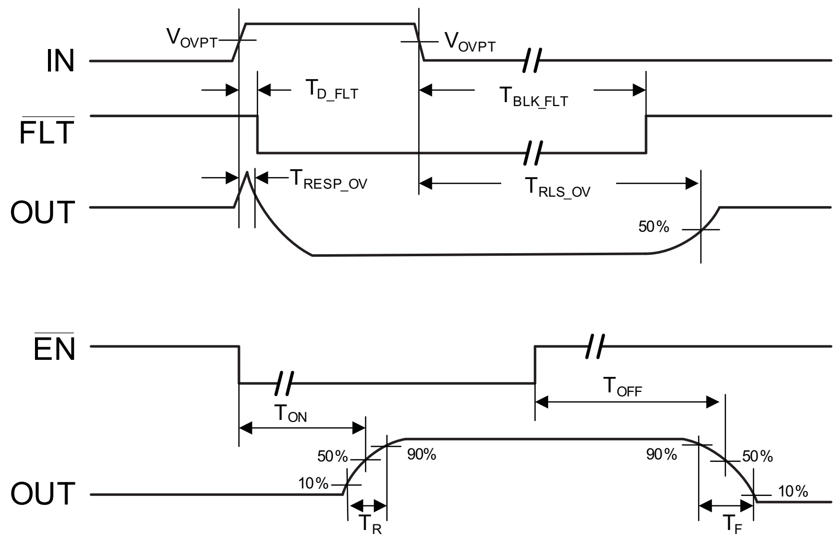
Electrical Characteristics[1]

V_{IN} = 5V, T_A = -40 to 85°C unless otherwise noted. Typical values are at T_A = 25°C.

Symbol	Description	Conditions	Min	Typ	Max	Units
V_{IN_MAX}	Input Over-Voltage Protection Range				28	V
V_{IN}	Normal Operation Voltage Range		3		14	V
I_Q	Operation Quiescent Current	V_{IN} = 5V, $\overline{EN}$ = 0V, I_{OUT} = 0		30	60	μA
$I_{SD(OFF)}$	Shutdown Supply Current	$\overline{EN}$ = V_{IN}, V_{IN} = 5.5V, V_{OUT} = 0V			1	μA
V_{UVLO}	Under-Voltage Lockout Threshold	Rising Edge		3.0	3.3	V
V_{UVLO_HYS}	Under-Voltage Lockout Threshold Hysteresis			0.1		V
Adjustable						
V_{OVP_TH}	Over-Voltage Lockout Threshold, OVP Pin	Rising Edge	1.084	1.1	1.117	V
V_{OVP_HYS}	Over-Voltage Lockout Threshold Hysteresis, OVP Pin			23		mV
Fixed						
V_{OVPT}	Over-Voltage Lockout Threshold, IN Pin	Rising Edge		6.5[1]		V
V_{OVP_HYS}	Over-Voltage Lockout Threshold Hysteresis, IN Pin			2.1		% of V_{OVPT}
MOSFET Switch						
$R_{DS(ON)}$	PMOS On-Resistance	I_{OUT} = 1500mA, T_A = 25°C		100	130	mΩ
$I_{D(OFF)}$	Switch Off-Leakage	$\overline{EN}$ = V_{IN}			1	μA
Logic						
$V_{\overline{EN}(L)}$	$\overline{EN}$ Input Low Voltage				0.4	V
$V_{\overline{EN}(H)}$	$\overline{EN}$ Input High Voltage		1.6			V
$I_{\overline{EN}}$	$\overline{EN}$ Input Leakage	$V_{\overline{EN}}$ = 5.5V or 0V		0.5	2.0	μA
$\overline{FLT}_{OL}$	$\overline{FLT}$ Output Voltage Low	$I_{\overline{FLT}}$ = 1mA			0.4	V
$\overline{FLT}_{IOL}$	$\overline{FLT}$ Output Leakage Current				1	μA
Timing						
T_{BLK_FLT}	$\overline{FLT}$ Blanking Time	From De-assertion of OV	5	10	15	ms
T_{D_FLT}	$\overline{FLT}$ Assertion Delay Time from Over-Voltage (OV)	From Assertion of OV		1		μs
T_{RLS_OV}	Over-Voltage Release Time	V_{IN} = 5V, V_{OVP} fall from 1.13V to 1.07V in 1ns	5	10	15	ms
T_{RESP_OV}	Over-Voltage Response Time	V_{IN} = 5V, V_{OVP} rise from 1.07V to 1.13V in 1ns		0.7		μs
T_{ON}	Turn On Delay Time	V_{IN} = 5V; R_{OUT} = 10Ω; C_{OUT} = 1μF		10		ms
T_R	Turn On Rise Time	V_{IN} = 5V; R_{OUT} = 10Ω; C_{OUT} = 1μF		1		ms
T_{OFF}	Turn Off Delay Time	V_{IN} = 5V; R_{OUT} = 10Ω; C_{OUT} = 1μF		9		ms
T_F	Turn Off Fall Time	V_{IN} = 5V; R_{OUT} = 10Ω; C_{OUT} = 1μF		4.5		ms
Thermal Protection						
T_{SHDN}	Shutdown Temperature			150		°C
T_{HYS}	Over-Temperature Shutdown Hysteresis			20		°C

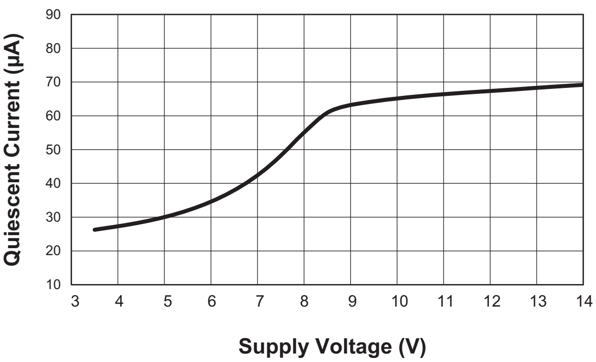
1. Fixed OVP Threshold Voltage Version is available from 5V to 14V at 50mV step.

Timing Diagram

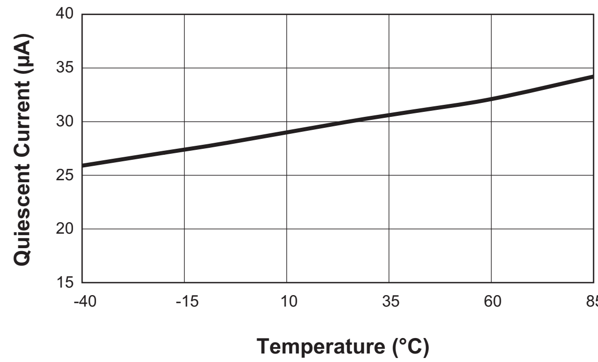


Typical Characteristics

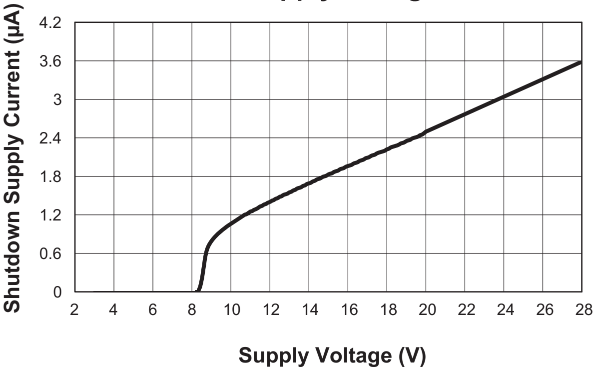
Operation Quiescent Current vs. Supply Voltage



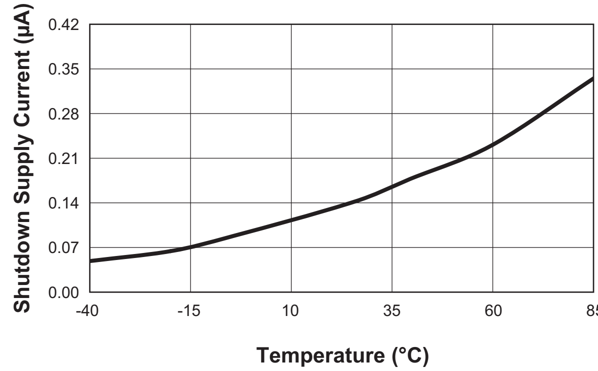
Operation Quiescent Current vs. Temperature
(V_{IN} = 5V; No Load)



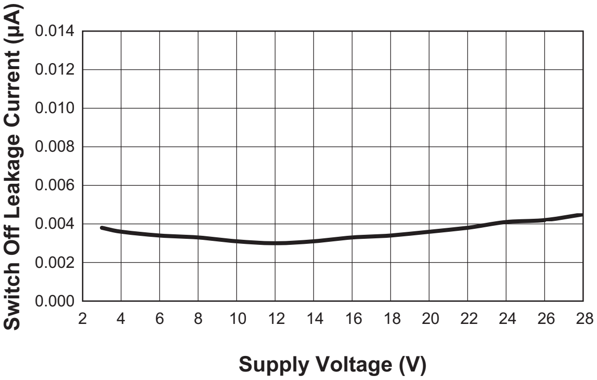
Shutdown Supply Current vs. Supply Voltage



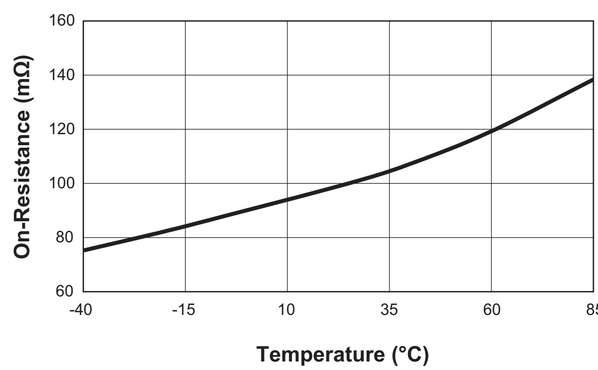
Shutdown Supply Current vs. Temperature
(V_{IN} = 6.5V)



Switch Off Leakage vs. Supply Voltage

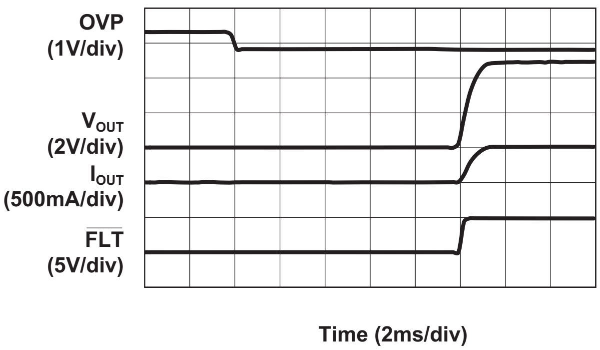


PMOS On-Resistance vs. Temperature
(V_{IN} = 5V, 1A Load)

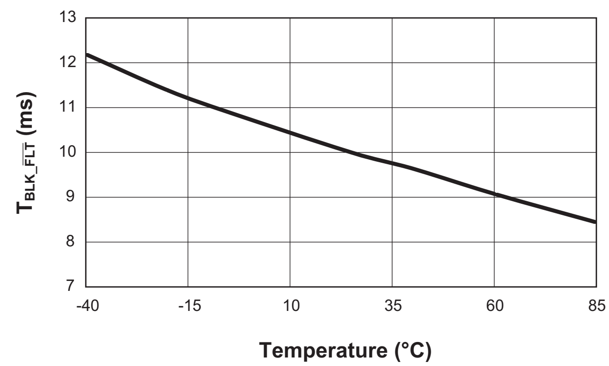


Typical Characteristics

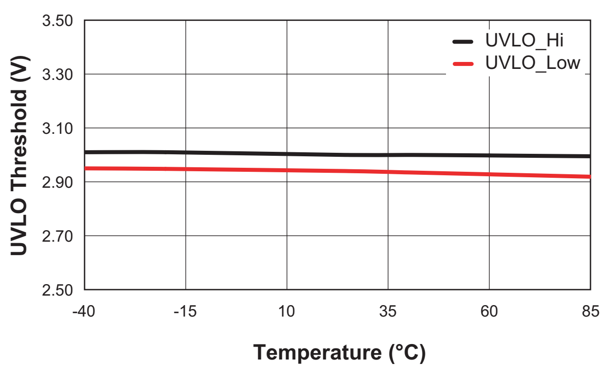
$\overline{FLT}$ Blanking Time
(V_{IN} = 5V, C_{OUT} = 1µF, OVP Transient from 1.2V to 0.8V, R_O = 10Ω)



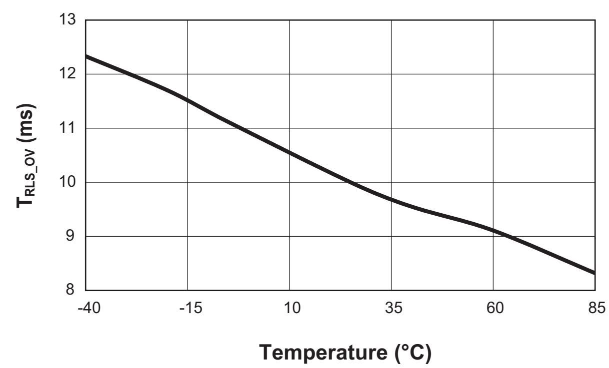
$\overline{FLT}$ Blanking Time vs. Temperature



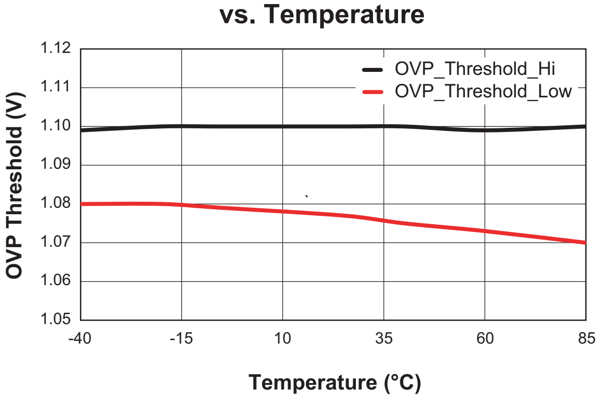
Under-Voltage Lockout Threshold vs. Temperature



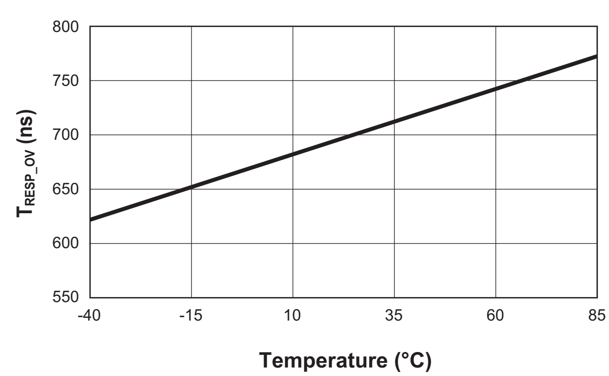
Over-Voltage Release Time vs. Temperature
(V_{IN} = 5V, C_{OUT} = 1µF, R_O = 10Ω)



Over-Voltage Lockout Threshold vs. Temperature

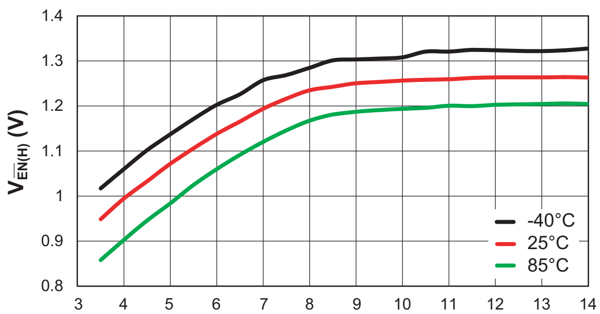


Over-Voltage Response Time vs. Temperature
(V_{IN} = 5V)



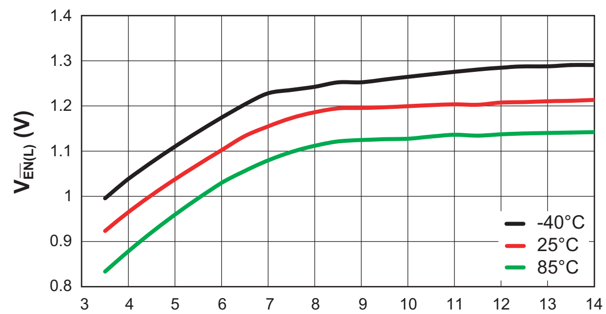
Typical Characteristics

$\overline{EN}$ Input High Voltage vs. Supply Voltage



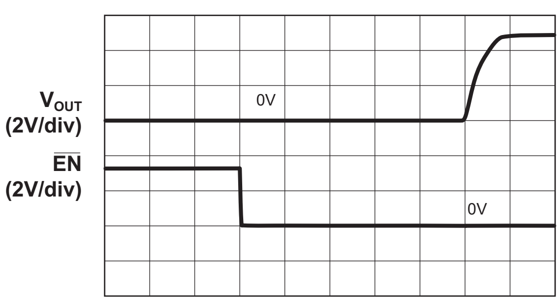
Supply Voltage (V)

$\overline{EN}$ Input Low Voltage vs. Supply Voltage



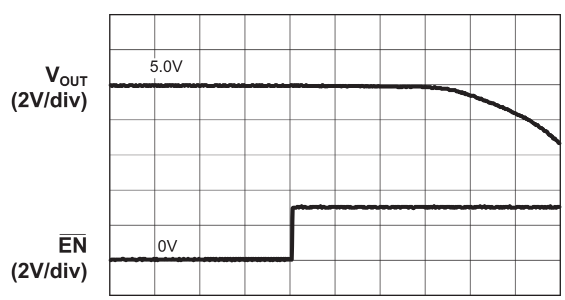
Supply Voltage (V)

Turn On Delay Time
(V_{IN} = 5.0V, R_O = 10Ω)



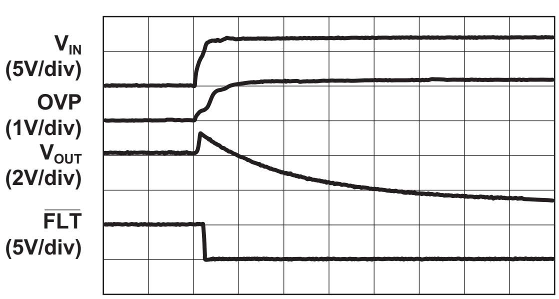
Time (2ms/div)

Turn Off Delay Time
(V_{IN} = 5.0V, R_O = 10Ω)



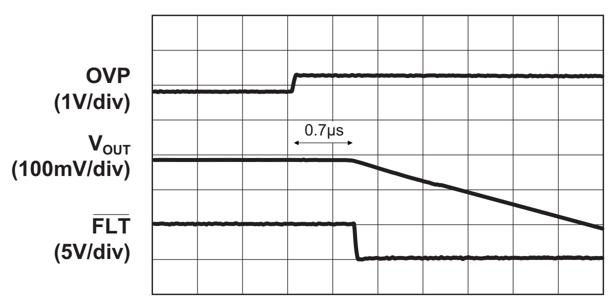
Time (2ms/div)

Over-Voltage Protection Response



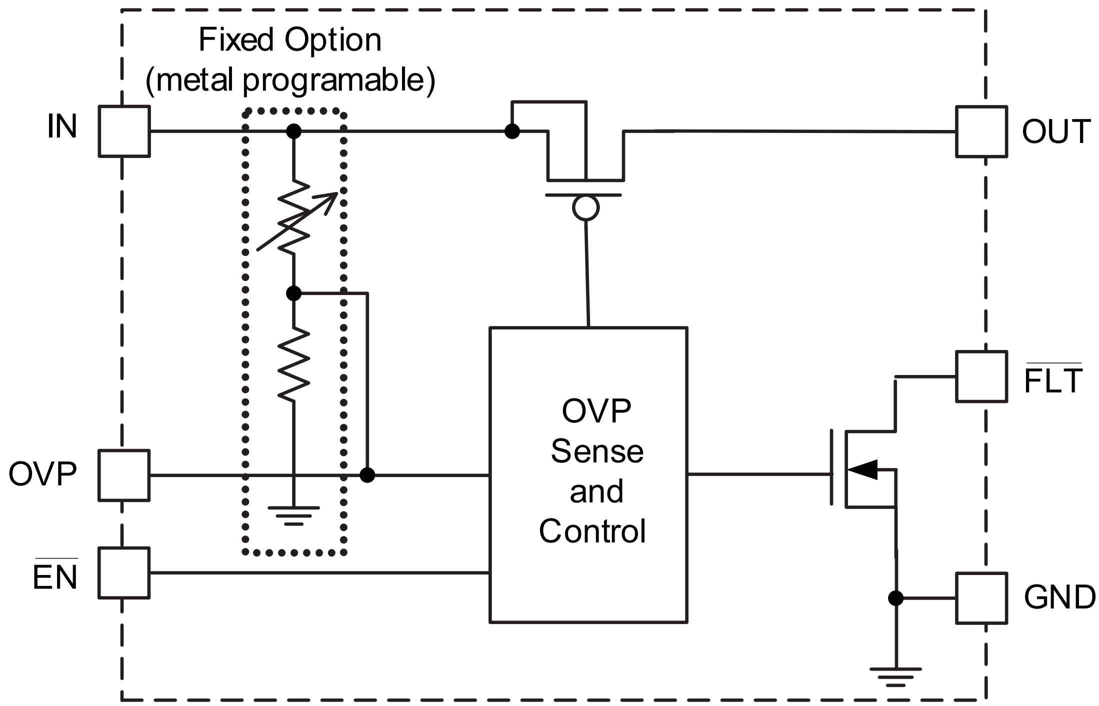
Time (5µs/div)

Over-Voltage Response Time
(V_{IN} = 5V, OVP Transient from 0.8V to 1.2V)



Time (500ns/div)

Functional Block Diagram



Functional Description

The AAT4687 provides up to 28V over-voltage protection when powering low-voltage systems such as cell phones, MP3, and PDAs or when charging Lithium-Ion batteries from a poorly regulated supply. The AAT4687 is inserted between the power supply or charger source and the load to be protected. The AAT4687 IC includes a low resistance P-channel MOSFET, under-voltage lockout protection, over-voltage monitor, fast shut-down circuitry, and a fault output flag.

In normal operation the P-channel MOSFET acts as a slew-rate controlled load switch, connecting and disconnecting the power supply from IN to OUT. A low resistance MOSFET is used to minimize the voltage drop between the voltage source and the load and to reduce power dissipation. When the voltage on the input exceeds the over-voltage protection trip voltage (internally set in the fixed voltage version or externally by a voltage divider to the OVP pin for the adjustable version), the device immediately turns off the internal P-channel FET, disconnecting the load from the input and preventing damage to downstream components. Simultaneously, the fault flag is raised, alerting the system to a problem.

If an over-voltage condition is applied at the time of the device enable, then the switch will remain OFF.

Under-Voltage Lockout (UVLO)

The AAT4687 has a fixed 3.0V under-voltage lockout level (UVLO). When the input voltage is less than the UVLO level, the MOSFET is turned off. 100mV of hysteresis is included to ensure circuit stability.

Over-Voltage Protection (OVP)

The AAT4687 adjustable version has a 1.1V ±1.5% over-voltage trip threshold on the OVP pin. With a resistor divider on the OVP pin from IN to GND, the over-voltage trip point can be adjusted anywhere within the input voltage range (see Table 1). Once the over-voltage trip level is triggered, the PMOS switch controller will turn off the PMOS in less than 0.7µs.

The AAT4687 fixed version is also available, in which the resistor divider is internally integrated with the input voltage trip point at 6.5V. The fixed version of the AAT4687 does not have a connection to the internal OVP circuitry and Pin 1 is designed to be left unconnected.

Over-Temperature Protection (OTP)

If the ambient temperature of the device exceeds T_{SHDN}, the OVP switch is turned off, and the pin is driven low. The OVP switch will recover automatically when the junction temperature falls below T_{SHDN} - 20°C.

Fault Indicator ($\overline{FLT}$)

The output is an active-low open-drain fault reporting output. A pull-up resistor should be connected from $\overline{FLT}$ to the logic I/O voltage of the host system. $\overline{FLT}$ will be asserted immediately if an over-voltage or over-temperature fault occurs.

Enable Control ($\overline{EN}$)

$\overline{EN}$ is an active-low enable input. $\overline{EN}$ is driven low, connected to ground, or left floating for normal device operation. Taking the $\overline{EN}$ high turns off the MOSFET. In case of an over-voltage or UVLO condition, toggling the $\overline{EN}$ will not override the fault condition and the switch will remain off.

Device Operation

On initial power-up, if $V_{IN} < V_{UVLO}$ or if $V_{OVP} > V_{OVP\_TH}$ (1.1V), the PMOS is held off. If $V_{UVLO} < V_{IN}$, $V_{OVP} < V_{OVP\_TH}$, and $\overline{EN}$ is low, the device enters startup after a 10ms internal delay.

Application Information

Over-Voltage Protection

The AAT4687 over-voltage protection circuit provides fast protection against transient voltage spikes and short duration spikes of high voltage from the power supply lines. The AAT4687 can quickly disconnect the input supply from the load and avoid damage to sensitive components.

In portable product applications, if the user removes the battery pack during charging, this action can create large transients and a high voltage spike can occur which can damage other electronic components in the product such as the battery charger. A "hot plug" of the AC/DC wall adapter into the AC outlet can create and release a voltage spike from the transformer. As a result, some sensitive components within the product can be damaged. With the AAT4687 placed between the power lines and the sensitive devices, they are insulated from the voltage spike and the input supply is disconnected in 0.7µs.

Figure 2 shows the over-voltage protection response time of the test circuit (Figure 1) with R1 = 487kΩ, R2 = 110kΩ, C_{OUT} = 1µF and R_{OUT} = 10Ω. The input voltage is rapidly increased from 5V to 12V by a voltage surge or voltage spike. The voltage at the OVP pin is also increased until it reaches the over-voltage trip point. At this point, the $\overline{FLT}$ pin is pulled low and the output voltage starts to fall. Figure 3 shows a zoom-in scope capture of the OVP response time; the output is disconnected from the input in as little as 0.7µs.

Adjustable Version - Over-Voltage Protection Resistors

The over-voltage protection threshold is programmed with two resistors, R1 and R2. To limit current flow through the external resistor string while maintaining good noise immunity, use smaller resistor values, such as 10kΩ for R2. Using a larger value will further reduce system current, but will also increase the impedance of the OVP node, making it more sensitive to external noise and interference. A suggested value for R2 is 110kΩ. In the case of R2 = 110kΩ and V_{OVP_TH} = 1.1V, R1 can be approximated by the following formula:

$$R_1 = \left(\frac{V_{OVPT}}{V_{OVP\_TH}} - 1\right) \cdot R_2 = \left(\frac{V_{OVPT}}{1.1} - 1\right) \cdot 110$$

(Voltage in V, Resistance in kΩ)

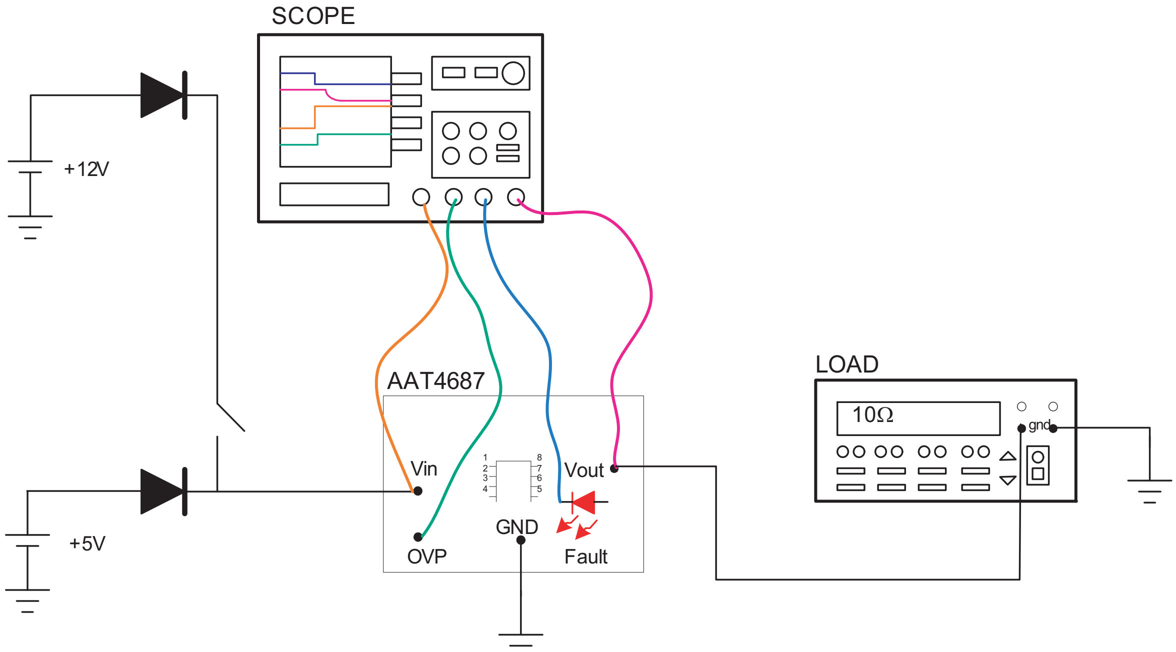


Figure 1: Over-Voltage Protection Response Time Test Circuit.

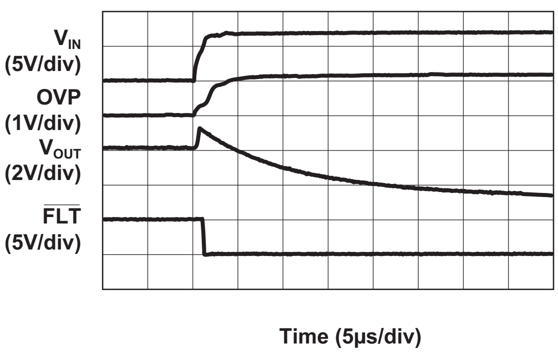


Figure 2: Typical Over-Voltage Response Time.

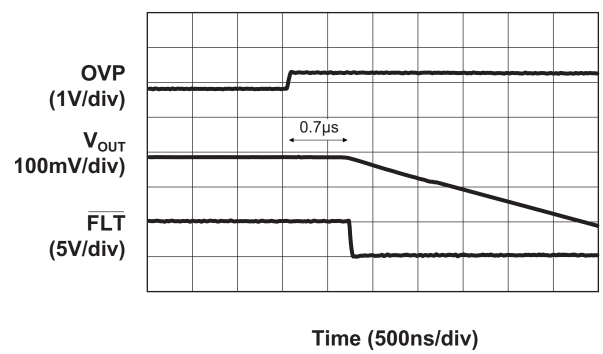


Figure 3: Typical Over-Voltage Response Time (Zoom View).

Table 1 summarizes resistor values for various over-voltage settings. Use 1% tolerance metal film resistors for programming the desired OVP setting.

R2 (kΩ)	R1 (kΩ)	V_{OVPT} Setting (V)
110	387	5.0
110	487	6.0
110	536	6.5
110	787	9.0
110	1000	11.0
110	1300	14.0
110	1540	16.5
110	1780	19.0
110	2050	21.5
110	2320	24.0
110	2550	26.5

Table 1: Recommended OVP Setting for AAT4687 Adjustable Version.

Input Capacitor

A 1µF or larger capacitor is typically recommended for C_{IN}. C_{IN} should be located as close to the device VIN pin as practically possible. Ceramic, tantalum, or aluminum electrolytic capacitors may be selected for C_{IN}. There is no specific capacitor equivalent series resistance (ESR) requirement for C_{IN}. However, for higher current operation, ceramic capacitors are recommended for C_{IN} due to their inherent capability over tantalum capacitors to withstand input current surges from low impedance sources such as batteries in portable devices.

Capacitors are typically manufactured in different voltage ratings. If the maximum possible surge voltage is known, select capacitors with a voltage rating at least 5V higher than the maximum possible surge voltage. Otherwise, 50V rated capacitors are generally good for most OVP applications to prevent any surge voltage.

Output Capacitor

A 0.1µF~47µF output capacitor is required at the output. Likewise, with the output capacitor, there is no specific capacitor ESR requirement. C_{OUT} may be increased to accommodate any load transient condition.

Thermal Considerations and Maximum Output Current

The AAT4687 is designed to deliver a continuous output load current. The limiting characteristic for maximum safe operating output load current is package power dissipation. In order to obtain high operating currents, careful device layout and circuit operating conditions must be taken into account. The following discussions will assume the load switch is mounted on a printed circuit board utilizing the minimum recommended footprint as stated in the "Printed Circuit Board Layout Recommendations" section of this datasheet. At any given ambient temperature (T_A), the maximum package power dissipation can be determined by the following equation:

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

Constants for the AAT4687 are maximum junction temperature ($T_{J(MAX)}$ = 125°C) and package thermal resistance (θ_{JA} = 160°C/W). Worst-case conditions are calculated at the maximum operating temperature, T_A = 85°C. Typical conditions are calculated under normal ambient conditions where T_A = 25°C. At T_A = 85°C, $P_{D(MAX)}$ = 250mW. At T_A = 25°C, $P_{D(MAX)}$ = 625mW.

The maximum continuous output current for the AAT4687 is a function of the package power dissipation and the R_{DS} of the MOSFET at $T_{J(MAX)}$. The maximum R_{DS} of the MOSFET at $T_{J(MAX)}$ is calculated by increasing the maximum room temperature.

For maximum current, refer to the following equation:

$$I_{OUT(MAX)} = \sqrt{\frac{P_{D(MAX)}}{R_{DS}}}$$

The maximum allowable output current for the AAT4687 is 1.8A. If the output current exceeds 1.8A, the device will be damaged.

Printed Circuit Board Layout Recommendations

For proper thermal management and to take advantage of the low $R_{DS(ON)}$ of the AAT4687, certain circuit board layout rules should be followed: V_{IN} and V_{OUT} should be routed using wider than normal traces, and GND should be connected to a ground plane. To maximize package thermal dissipation and power handling capacity of the AAT4687 SC70JW-10 package, the ground plane area connected to the ground pins should be as large as possible. For best performance, C_{IN} and C_{OUT} should be placed close to the package pins, as shown in Figures 5 and 6.

Evaluation Board Schematic

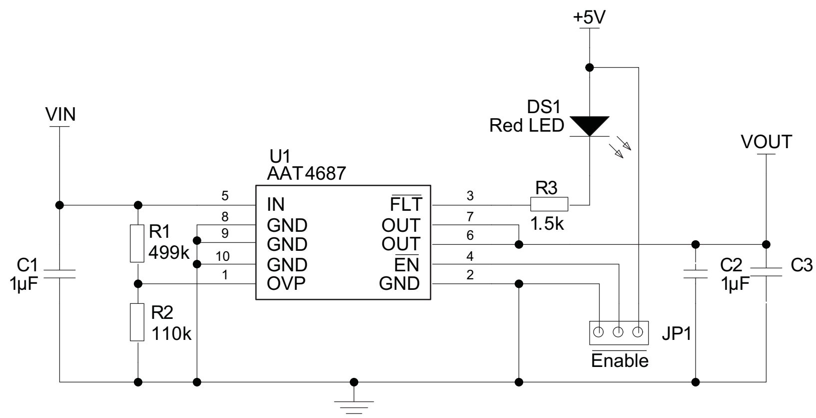


Figure 4: AAT4687 Evaluation Board Schematic.

Component	Part Number	Description	Manufacturer
U1	AAT4687	Over-Voltage Protection Switch	Skyworks
R1	RC0603FR-07499KL	RES 499KΩ 1/10W 1% 0603 SMD	
R2	RC0603FR-07110KL	RES 110KΩ 1/10W 1% 0603 SMD	Yageo
R3	RC0603FR-071K5L	RES 1.5KΩ 1/10W 1% 0603 SMD	
C1	GRM31MR71H105K	Cap Ceramic 1µF 1206 X7R 50V 10%	Murata
C2	GRM21BR71C105K	Cap Ceramic 1µF 0805 X7R 16V 10%	
C3	Not populated		
D1	0805KRCT	Red LED 0805	HB

Table 2: AAT4687 Evaluation Board Bill of Materials.

Evaluation Board Layout

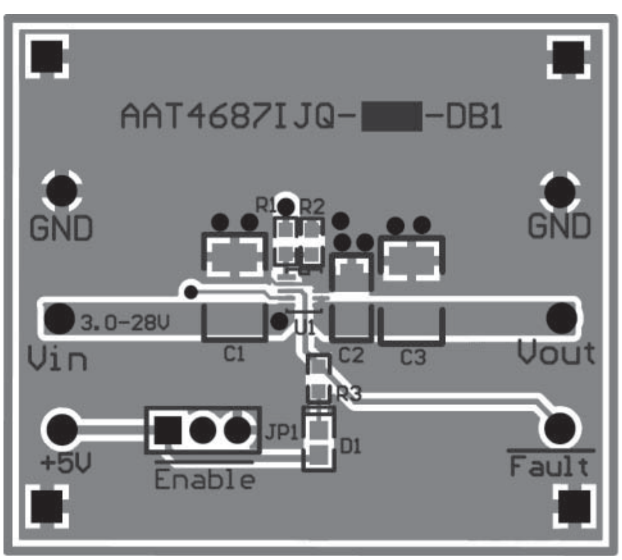


Figure 5: AAT4687 Evaluation Board Component Side Layout.

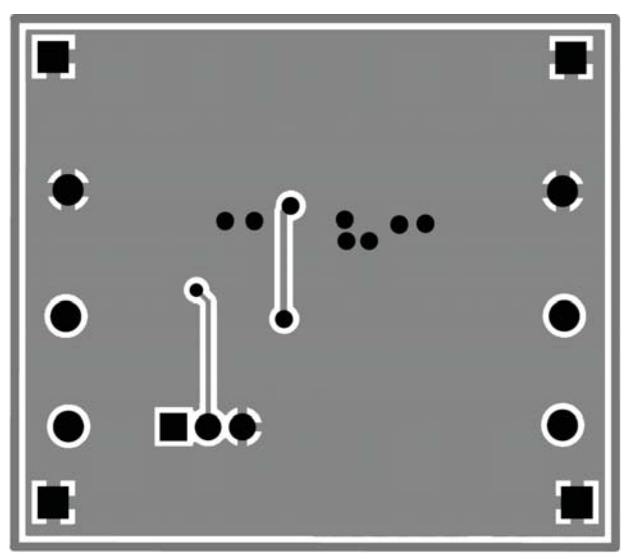


Figure 6: AAT4687 Evaluation Board Solder Side Layout.

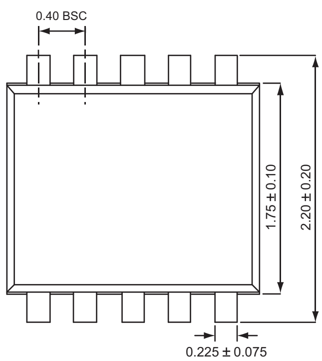
Ordering Information

Package	OVP Trip Voltage	Marking[4]	Part Number (Tape and Reel)[5]
SC70JW-10	Adjustable	7QXYY	**AAT4687IJQ-T1**
SC70JW-10	6.5V		AAT4687IJQ-6.5-T1

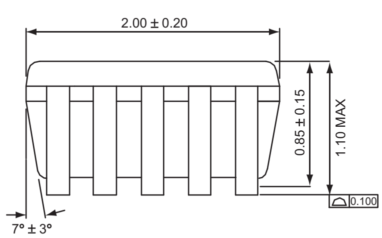
Skyworks Green™ products are compliant with all applicable legislation and are halogen-free. For additional information, refer to *Skyworks Definition of Green™*, document number SQ04-0074.

Package Information

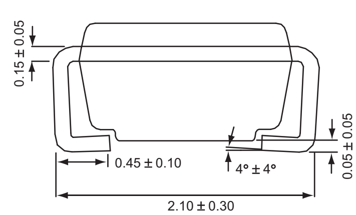
SC70JW-10



Top View



Side View



End View

All dimensions in millimeters.

1. XYY = assembly and date code.
2. Sample stock is generally held on part numbers listed in **BOLD**.