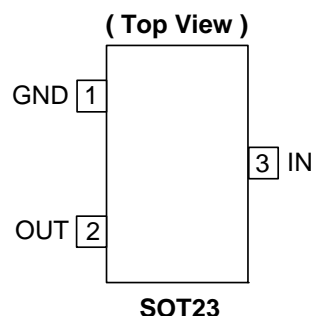


## Description

The AP2337 is single channel current-limited integrated high-side power switches optimized for hot-swap applications. The devices have fast short-circuit response time for improved overall system robustness and provide a complete protection solution for application subject to heavy capacitive loads and the prospect of short circuit. It offers reverse current blocking, over-current, over-temperature and short-circuit protection, as well as controlled rise time and under-voltage lockout functionality.

The device is available in SOT23 package.

## Pin Assignments



## Features

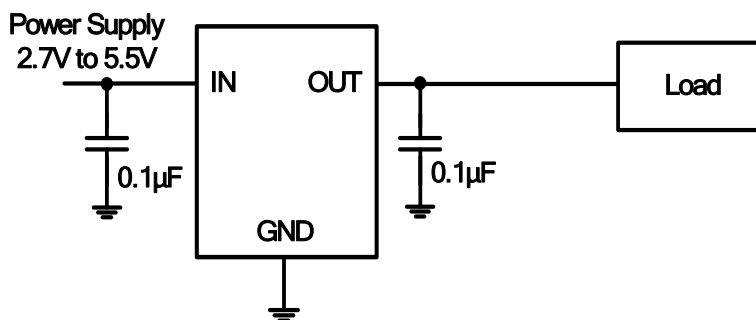
- Input voltage range: 2.7V – 5.5V
- Fast short-circuit response time
- 1.5A accurate current limiting
- 110mΩ on-resistance
- Reverse Current Blocking
- Built-in soft-start with 2.5ms typical turn-on time
- Over Current Protection
- Over Voltage Protection
- Short circuit and thermal protection
- ESD protection: 3KV HBM, 300V MM
- Ambient temperature range: -40°C to 85°C
- Available in “Green” Molding Compound (No Br, Sb)
- Lead Free Finish/ RoHS Compliant (Note 1)
- UL Recognized, File Number E322375 (to be completed)
- IEC60950-1 CB Scheme Certified (to be completed)

## Applications

- LCD TVs & Monitors
- Set-Top-Boxes, Residential Gateways
- Laptops, Desktops, Servers
- Printers, Docking Stations, HUBs
- Smart phones, e-Readers

Notes: 1. EU Directive 2002/95/EC (RoHS). All applicable RoHS exemptions applied. Please visit our website at [http://www.diodes.com/products/lead\\_free.html](http://www.diodes.com/products/lead_free.html).

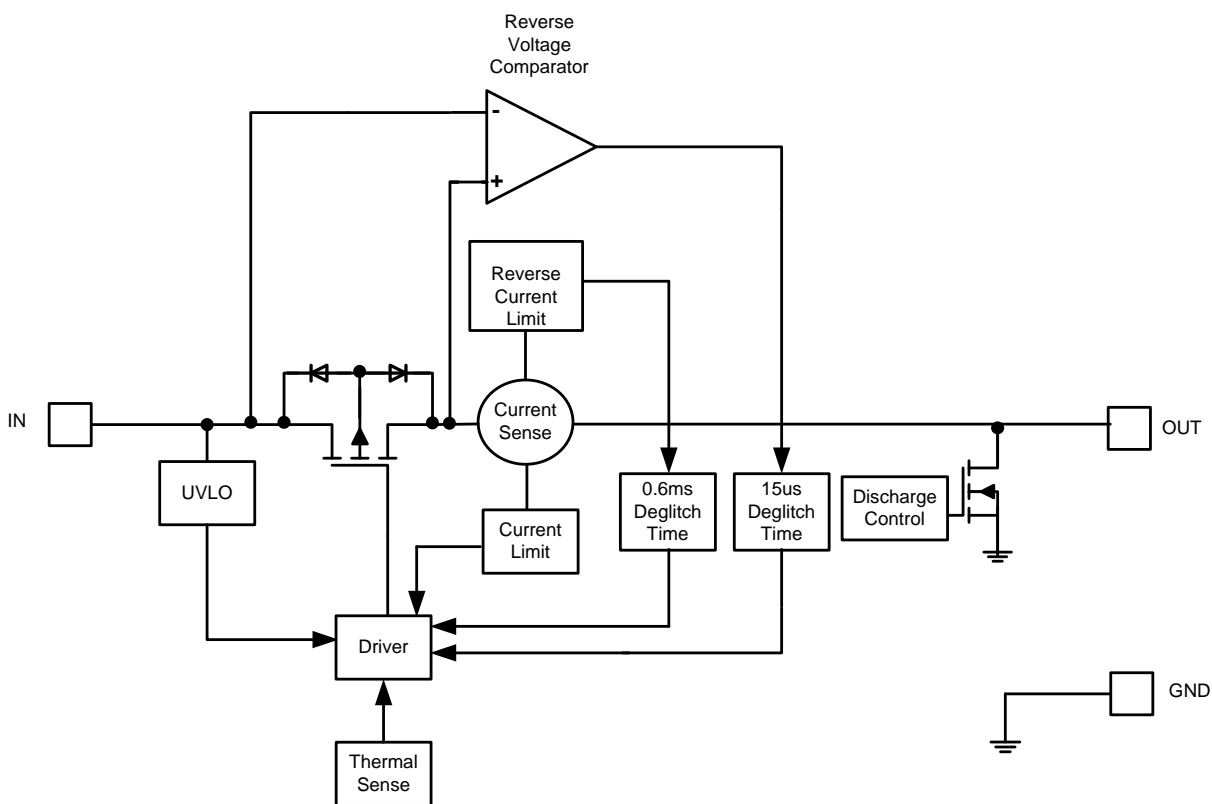
## Typical Application Circuit



**Pin Descriptions**

| Pin Name | Pin Number | Descriptions      |
|----------|------------|-------------------|
| GND      | 1          | Ground            |
| OUT      | 2          | Switch output pin |
| IN       | 3          | Voltage input pin |

**Function Block Diagram**



**Absolute Maximum Ratings**

| Symbol     | Parameter                          | Ratings          | Units |
|------------|------------------------------------|------------------|-------|
| ESD HBM    | Human Body Model ESD Protection    | 3                | KV    |
| ESD MM     | Machine Model ESD Protection       | 300              | V     |
| $V_{IN}$   | Input Voltage                      | 6.5              | V     |
| $V_{OUT}$  | Output Voltage                     | $V_{IN} + 0.3$   | V     |
| $I_{load}$ | Maximum Continuous Load Current    | Internal Limited | A     |
| $T_{Jmax}$ | Maximum Junction Temperature       | 150              | °C    |
| $T_{ST}$   | Storage Temperature Range (Note 2) | -65 to 150       | °C    |

Notes: 2. UL Recognized Rating from -30°C to 70°C (Diodes qualified  $T_{ST}$  from -65°C to 150°C)

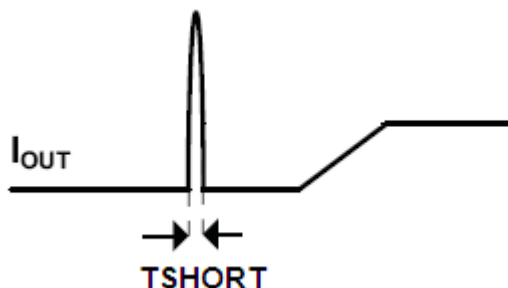
**Recommended Operating Conditions**

| Symbol    | Parameter                     | Min | Max | Units |
|-----------|-------------------------------|-----|-----|-------|
| $V_{IN}$  | Input voltage                 | 2.7 | 5.5 | V     |
| $I_{OUT}$ | Output Current                | 0   | 1.0 | A     |
| $T_A$     | Operating Ambient Temperature | -40 | 85  | °C    |

**Electrical Characteristics ( $T_A = 25^\circ\text{C}$ ,  $V_{IN} = +5.0\text{V}$ , unless otherwise stated)**

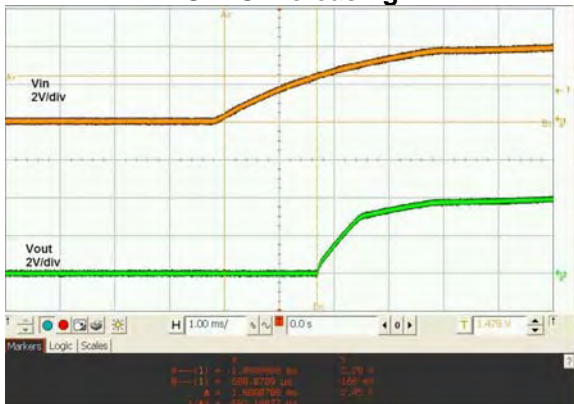
| Symbol        | Parameter  | Test Conditions (Note 3)   | Min  | Typ. | Max  | Unit          |
|---------------|--|--|------|------|------|---------------|
| $V_{UVLO}$    | Input UVLO   | $V_{IN}$ rising  | 2.00 |      | 2.65 | V             |
| $I_Q$         | Input quiescent current  | Above UVLO, $I_{OUT} = 0$  |      | 65   | 110  | $\mu\text{A}$ |
| $I_{REV}$     | Reverse leakage current  | $V_{IN} = 0\text{V}$ , $V_{OUT} = 5\text{V}$ , $I_{REV}$ at $V_{IN}$                               |      | 0.01 | 0.1  | $\mu\text{A}$ |
| $R_{DS(ON)}$  | Switch on-resistance   | $V_{IN} = 5\text{V}$ , $I_{OUT} = 1\text{A}$   |      | 110  | 140  | m $\Omega$    |
|               |  | $V_{IN} = 3.3\text{V}$ , $I_{OUT} = 1\text{A}$   |      | 140  | 170  |               |
| $I_{LIMIT}$   | Over-load current limit  | $V_{IN} = 5\text{V}$ , $V_{OUT} = 4\text{V}$ , $C_L = 10\mu\text{F}$                               | 1.1  | 1.5  | 1.9  | A             |
| $I_{OS}$      | Short-circuit current  | OUT connected to ground, $C_L = 10\mu\text{F}$   | 0.2  | 0.6  | 1.0  | A             |
| $T_{SHORT}$   | Short-circuit response time                                    | From $V_{OUT} < 0.6\text{V}$ to $I_{OUT} = 0\text{A}$ (OUT shorted to GND) (See Figure. 1)(Note 7) |      | 5    |      | $\mu\text{s}$ |
| $I_{ROCP}$    | Reverse current limit  | Above UVLO   | 0.3  | 0.5  | 0.7  | A             |
| $T_{Trig}$    | Deglintch time from reverse current trigger to MOSFET turn off |  |      | 0.6  |      | ms            |
| $V_{OVP}$     | Output over-voltage trip point                                 | Above UVLO (Note 4)  | 110% |      | 120% | $V_{IN}$      |
| $T_{OVP}$     | Debounce time from output over-voltage to MOSFET turn off      |  |      | 15   |      | $\mu\text{s}$ |
| $T_{ON}$      | Output turn-on time (Note 5)                                   | $C_L = 1\mu\text{F}$ , $R_{load} = 5\Omega$ (UVLO to 90% $V_{OUT-NOM}$ )                           | 1    |      | 4    | ms            |
| $T_{DIS}$     | Discharge time   | $C_L = 1\mu\text{F}$ , from UVLO to $V_{OUT} < 0.3\text{V}$  |      | 500  |      | $\mu\text{s}$ |
| $T_{SHDN}$    | Thermal shutdown threshold                                     |  |      | 150  |      | °C            |
| $T_{HYS}$     | Thermal shutdown hysteresis                                    |  |      | 20   |      | °C            |
| $\theta_{JA}$ | Thermal Resistance Junction-to-Ambient                         | (Note 6)   |      | 180  |      | °C/W          |

- Notes:
- Pulse-testing techniques maintain junction temperature close to ambient temperature; thermal effects must be taken into account separately.
  - During output over-voltage protection, the output draws approximately 60 $\mu\text{A}$  current.
  - Since the output turn-on slew rate is dependent on input supply slew rate, this limit is only applicable for input supply slew rate between 5V/0.2ms to 5V/1ms.
  - Device mounted on FR-4 substrate PCB, 2oz copper, with minimum recommended pad layout.
  - Applicable for output voltage slew rate  $\leq 5\text{V}/30\mu\text{s}$ .


**Figure 1. Short Circuit Response Time**

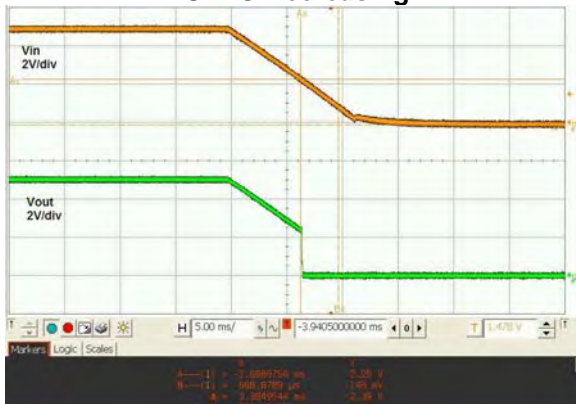
**Typical Performance Characteristics**

**UVLO Increasing**



1ms/div

**UVLO Decreasing**



5ms/div

**Over-Load Current Limit**



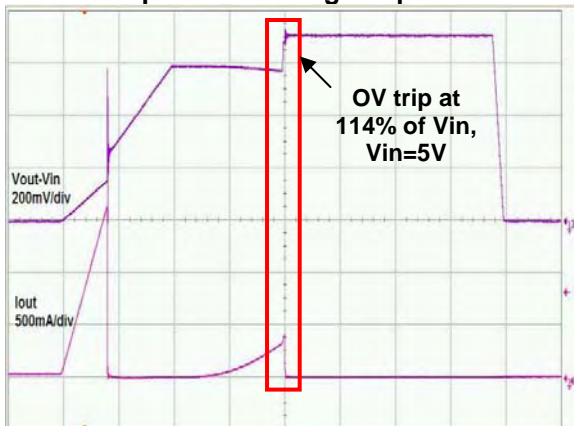
50ms/div

**Short Circuit Current Limit**



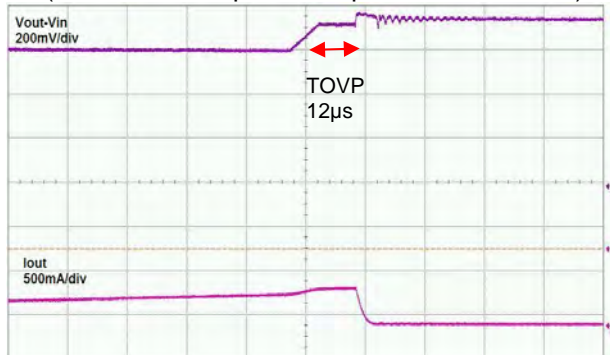
100us/div

**Output Over Voltage Trip Point**



500us/div

**Debounce time from output over-voltage to MOSFET turn off**  
(Zoom in at red portion of previous waveform)

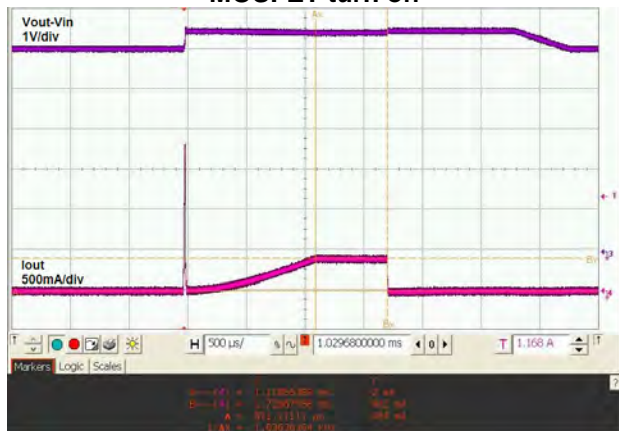


20us/div

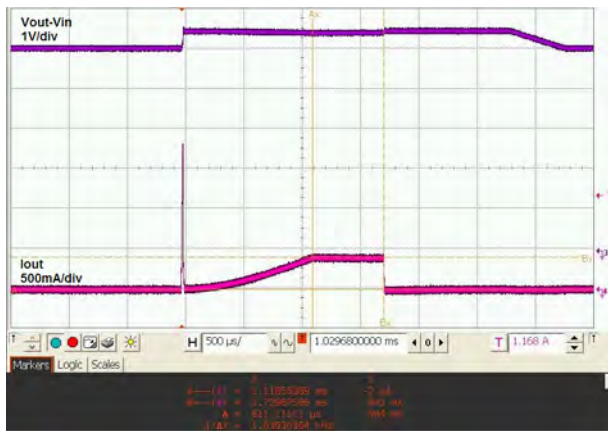
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**Typical Performance Characteristics (cont.)**

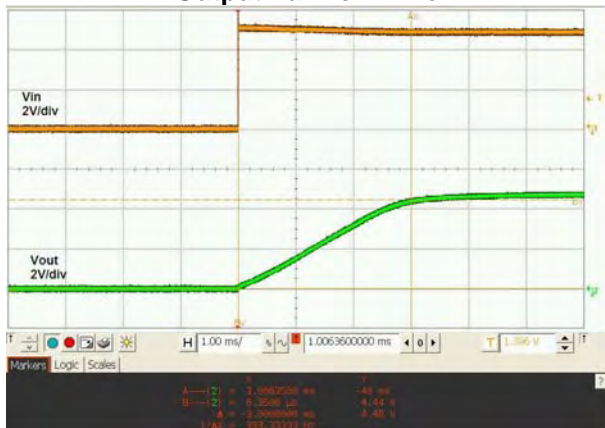
**Deglitch time from reverse current trigger to MOSFET turn off**



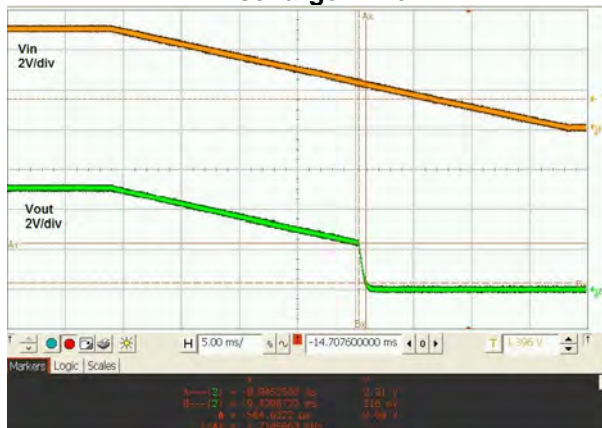
**Reverse Current Limit**



**Output Turn-on Time**



**Discharge Time**



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**Typical Performance Characteristics (cont.)**

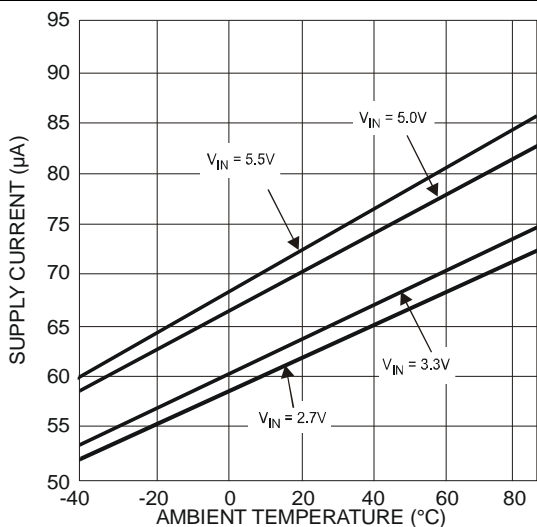


Fig. 1 Quiescent Supply Current vs. Ambient Temperature

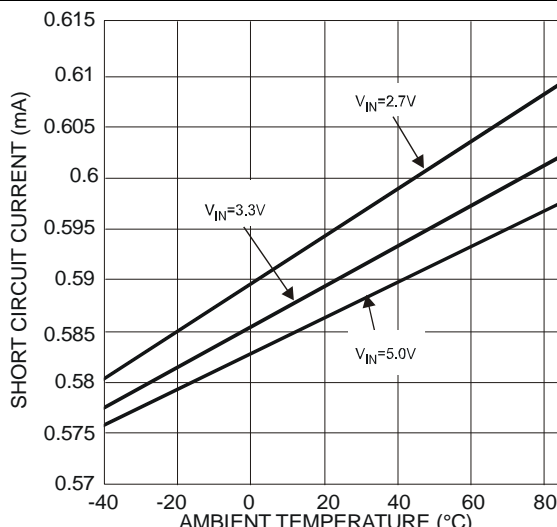


Fig. 2 Short Circuit Output Current vs. Ambient Temperature

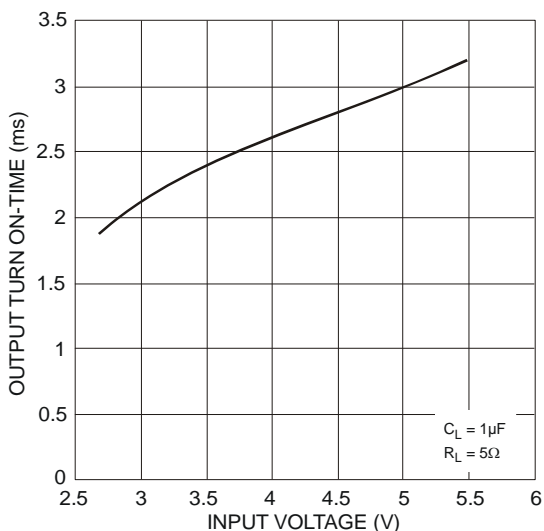


Fig. 3 Output Turn On-Time vs. Input Voltage

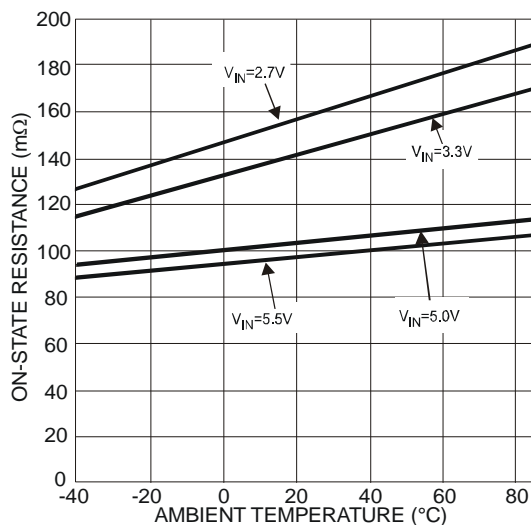


Fig. 4 Switch On-Resistance vs. Ambient Temperature

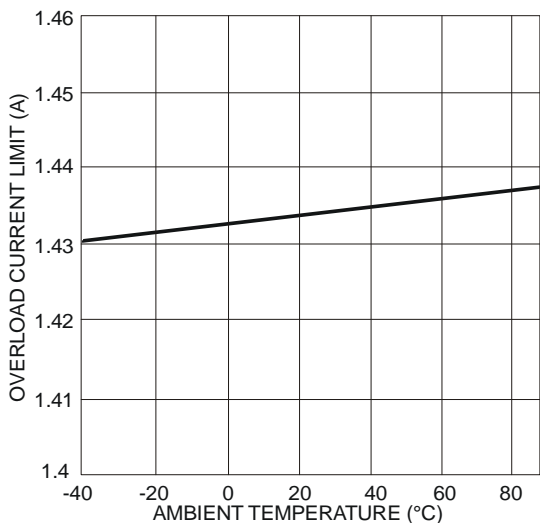


Fig. 5 Current Limit Trip Threshold vs. Ambient Temperature

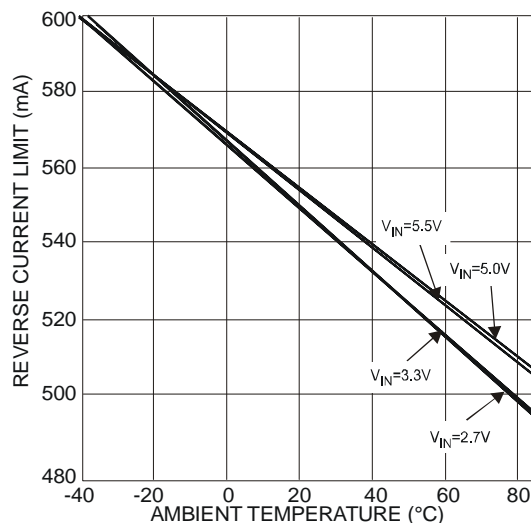


Fig. 6 Reverse Current Limit vs. Ambient Temperature

### Application Note

#### Protection Features:

##### Under-voltage Lockout (UVLO)

Whenever the input voltage falls below UVLO threshold (~2.5V), the power switch is 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.

##### Over-current and Short Circuit Protection

An internal sensing FET is employed to check for over-current 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.

The different overload conditions and the corresponding response of the AP2337 are outlined below:

| NO | Conditions   | Explanation   | Behavior of the AP2337  |
|----|--|---|---|
| 1  | Short circuit condition at start-up                            | Output is shorted before input voltage is applied or before the part is powered up.         | The IC senses the short circuit and immediately clamps output current to a certain safe level namely $I_{short}$  |
| 2  | Short-circuit or Overcurrent condition                         | Short-Circuit or Overload condition that occurs when the part is powered up and above UVLO. | <ul style="list-style-type: none"> <li>At the instance the overload occurs, higher current may flow for a very short period of time before the current limit function can react.</li> <li>After the current limit function has tripped (reached the over-current trip threshold), the device switches into current limiting mode and the current is clamped at <math>I_{short} / I_{LIMIT}</math>.</li> </ul> |
| 3  | Gradual increase from nominal operating current to $I_{LIMIT}$ | Load increases gradually until the current-limit threshold.                                 | The current rises until $I_{LIMIT}$ . Once the threshold has been reached, the device switches into its current limiting mode and is clamped at $I_{LIMIT}$ .   |

##### Reverse Current Protection

The USB specification does not allow an output device to source current back into the USB port. In a normal MOSFET switch, current will flow in reverse direction (from the output side to the input side) when the output side voltage is higher than the input side. A **reverse current limit** feature is implemented in the AP2337 to limit such back currents. This circuit is activated by the difference between the output voltage and the input voltage (100mV TYP). After the reverse current circuit has tripped (reached the reverse current trip threshold), the current rises until  $I_{ROCP}$  level. When the fault exists for more than 600us, output device is disabled and shutdown. This is called the "Deglitch time from reverse current trigger to MOSFET turn off". Recovery from IROCP occurs when the output voltage falls to 101% of input voltage.

##### Over-Voltage Protection

The device has an **output over-voltage** protection that triggers when the output voltage reaches 114% (TYP) of input voltage. When this fault condition stays on for longer than 15us (This is called the "Debounce time from output over-voltage to MOSFET turn off" ) output device is disabled and shutdown. Recovery from ROVP occurs when the output voltage falls to 101% of input voltage.

**Application Note (cont.)**

**Thermal Protection**

Thermal protection prevents the IC from damage when the die temperature exceeds safe margins. This mainly occurs when heavy-overload or short-circuit faults are present for extended periods of time. The AP2337 implements a thermal sensing to monitor the operating junction temperature of the power distribution switch. Once the die temperature rises to approximately 150°C, the Thermal protection feature gets activated as follows: The internal thermal sense circuitry turns the power switch off thus preventing the power switch from damage. Hysteresis in the thermal sense circuit allows the device to cool down to approximately 20°C before the output is turned back on. This built-in thermal hysteresis feature is an excellent feature, as it avoids undesirable oscillations of the thermal protection circuit. The switch continues to cycle in this manner until the load fault is removed, resulting in a pulsed output.

**Discharge Function**

When input voltage is pulled, the discharge function is active. The output capacitor is discharged through an internal NMOS that has a discharge resistance of 100Ω. Hence, the output voltage drops down to zero. The time taken for discharge is dependent on the RC time constant of the resistance and the output capacitor. Discharge time is calculated when UVLO falling threshold is reached to output voltage reaching 300mV.

**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<sub>A</sub>) and R<sub>DS(ON)</sub>, the power dissipation can be calculated by:

$$P_D = R_{DS(ON)} \times I^2$$

Finally, calculate the junction temperature:

$$T_J = P_D \times R_{\theta JA} + T_A$$

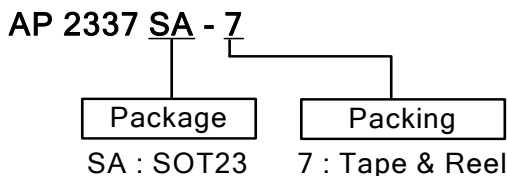
Where:

T<sub>A</sub> = Ambient temperature °C

R<sub>θJA</sub> = Thermal resistance

P<sub>D</sub> = Total power dissipation

**Ordering Information**



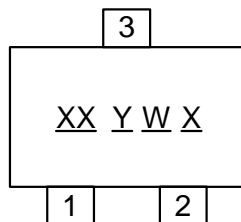
| Device     | Package Code | Packaging<br>(Note 7) | 7" Tape and Reel |                    |
|------------|--------------|-----------------------|------------------|--------------------|
|            |              |                       | Quantity         | Part Number Suffix |
| AP2337SA-7 | SA           | SOT23                 | 3000/Tape & Reel | -7                 |

Notes: 7. Pad layout as shown on Diodes Inc. suggested pad layout document AP02001, which can be found on our website at <http://www.diodes.com/datasheets/ap02001.pdf>.



**Marking Information**

( Top View )

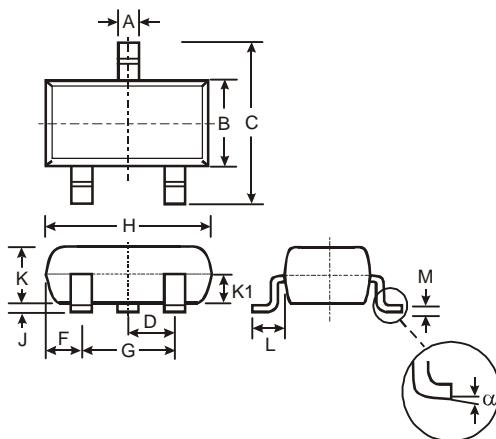


XX : Identification code  
Y : Year 0~9  
W : Week : A~Z : 1~26 week;  
a~z : 27~52 week; z represents  
52 and 53 week  
X : A~Z : Internal code

| Device     | Package | Identification Code |
|------------|---------|---------------------|
| AP2337SA-7 | SOT23   | KM                  |

**Package Outline Dimensions**

SOT23



| SOT23    |       |      |       |
|----------|-------|------|-------|
| Dim      | Min   | Max  | Typ   |
| A        | 0.37  | 0.51 | 0.40  |
| B        | 1.20  | 1.40 | 1.30  |
| C        | 2.30  | 2.50 | 2.40  |
| D        | 0.89  | 1.03 | 0.915 |
| F        | 0.45  | 0.60 | 0.535 |
| G        | 1.78  | 2.05 | 1.83  |
| H        | 2.80  | 3.00 | 2.90  |
| J        | 0.013 | 0.10 | 0.05  |
| K        | 0.903 | 1.10 | 1.00  |
| K1       | -     | -    | 0.400 |
| L        | 0.45  | 0.61 | 0.55  |
| M        | 0.085 | 0.18 | 0.11  |
| $\alpha$ | 0°    | 8°   | -     |

All Dimensions in mm

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