General Description

The AOZ1360 is a member of Alpha and Omega Semiconductor’s high-side load switch family intended for applications that require circuit protection. The device operates from a source voltage between 5.5V and 28V. The internal current limiting circuit protects the input supply voltage from large current load. The current limit can be set with an external resistor. The AOZ1360 provides thermal protection function that limits excessive power dissipation. The device employs internal soft-start circuitry to control in-rush current due to highly capacitive loads associated with hot-plug events. It features low quiescent current of 220 µA and the supply current reduces to less than 1 µA at shutdown.

The AOZ1360 is available in either an SO-8 or a DFN-10 4 mm x 4 mm package which can operate over a -40°C to +85°C temperature range.

Features

- 35mΩ maximum on resistance
- Programmable current limit
- 5.5V to 28V operating input voltage
- Low quiescent current
- Under-voltage lockout
- Thermal shutdown protection
- 2.5kV ESD rating
- Available in SO-8 or DFN-10 package

Applications

- Notebook PCs
- Hot swap supplies

Typical Application

![Typical Application Diagram]
Ordering Information

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Package</th>
<th>Temperature Range</th>
<th>Environmental</th>
</tr>
</thead>
<tbody>
<tr>
<td>AOZ1360AIL</td>
<td>SO-8</td>
<td>-40 °C to +85 °C</td>
<td>Green Product</td>
</tr>
<tr>
<td>AOZ1360DIL</td>
<td>DFN-10 4x4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

AOS Green Products use reduced levels of Halogens, and are also RoHS compliant. Please visit www.aosmd.com/media/AOSGreenPolicy.pdf for additional information.

Pin Configuration

```
IN 1, 2 8  OUT
IN 2 7  OUT
GND 3 6  SET
SS 4 5  EN
```

SO-8 (Top View)

```
IN 1 2  IN
SS 3 4  NC
GND 5 6  GND
OUT 7 8  OUT
```

DFN-10 (Top View)

Pin Description

<table>
<thead>
<tr>
<th>Pin Name</th>
<th>Pin Number</th>
<th>Pin Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>PIN</td>
<td>SO-8 1, 2</td>
<td>P-channel MOSFET source. Connect a 1 µF capacitor from IN to GND.</td>
</tr>
<tr>
<td>GND</td>
<td>3  4</td>
<td>Ground.</td>
</tr>
<tr>
<td>SS</td>
<td>4  5</td>
<td>Soft-Start Pin. Connect a capacitor from SS to GND to set the soft-start time. Connect SS to IN to set to the default soft-start time of 100us.</td>
</tr>
<tr>
<td>EN</td>
<td>5  6</td>
<td>Enable Input.</td>
</tr>
<tr>
<td>SET</td>
<td>6  7</td>
<td>Current Limit Set Pin. Connect a resistor from SET to GND to set the switch current limit.</td>
</tr>
<tr>
<td>NC</td>
<td>3, 8</td>
<td>No Connect</td>
</tr>
<tr>
<td>OUT</td>
<td>7, 8 9, 10</td>
<td>P-channel MOSFET Drain. Connect a capacitor with 0.1 µF or above from OUT to GND.</td>
</tr>
</tbody>
</table>
Functional Block Diagram

![Functional Block Diagram](image)

Figure 1. Functional Block Diagram

Timing Diagram

![Timing Diagram](image)

Figure 2. AOZ1360 Timing Diagram

Absolute Maximum Ratings

*Exceeding the Absolute Maximum Ratings may damage the device.*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>IN to GND</td>
<td>-0.3 V to +30 V</td>
</tr>
<tr>
<td>EN, OUT to GND</td>
<td>-0.3 V to V&lt;sub&gt;IN&lt;/sub&gt; +0.3 V</td>
</tr>
<tr>
<td>SS, SET</td>
<td>-0.3 V to +6 V</td>
</tr>
<tr>
<td>Maximum Junction Temperature (T&lt;sub&gt;J&lt;/sub&gt;)</td>
<td>+150 °C</td>
</tr>
<tr>
<td>ESD Rating (Human Body Model)</td>
<td>2.5 kV</td>
</tr>
</tbody>
</table>

Recommended Operating Conditions

The device is not guaranteed to operate beyond the maximum Recommended Operating Conditions.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Junction Temperature (T&lt;sub&gt;J&lt;/sub&gt;)</td>
<td>-40 °C to +125 °C</td>
</tr>
<tr>
<td>Thermal Resistance</td>
<td></td>
</tr>
<tr>
<td>SO-8 (θ&lt;sub&gt;JA&lt;/sub&gt;)</td>
<td>82 °C/W</td>
</tr>
<tr>
<td>DFN-10 (θ&lt;sub&gt;JA&lt;/sub&gt;)</td>
<td>63 °C/W</td>
</tr>
</tbody>
</table>
## Electrical Characteristics

$V_{\text{IN}} = 12\,\text{V}, \quad T_A = 25^\circ\text{C}$ unless otherwise stated.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{\text{IN}}$</td>
<td>Input Supply Voltage</td>
<td></td>
<td>5.5</td>
<td>28</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>$V_{\text{UVD}}$</td>
<td>Undervoltage Lockout Threshold IN rising</td>
<td></td>
<td>4.9</td>
<td>5.4</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>$V_{\text{UVDHY}}$</td>
<td>Undervoltage Lockout Hysteresis</td>
<td></td>
<td>400</td>
<td></td>
<td></td>
<td>mV</td>
</tr>
<tr>
<td>$I_{\text{IN_ON}}$</td>
<td>Input Quiescent Current</td>
<td>$EN = \text{IN}, \text{no load}$</td>
<td>220</td>
<td>400</td>
<td></td>
<td>$\mu\text{A}$</td>
</tr>
<tr>
<td>$I_{\text{IN_OFF}}$</td>
<td>Input Shutdown Current</td>
<td>$EN = \text{GND}, \text{no load}$</td>
<td>1</td>
<td></td>
<td></td>
<td>$\mu\text{A}$</td>
</tr>
<tr>
<td>$I_{\text{LEAK}}$</td>
<td>Output Leakage Current</td>
<td>$EN = \text{GND}, \text{no load}$</td>
<td>1</td>
<td></td>
<td></td>
<td>$\mu\text{A}$</td>
</tr>
<tr>
<td>$R_{\text{DS(ON)}}$</td>
<td>Switch On Resistance</td>
<td>$AOZ1360AI \quad V_{\text{IN}} = 12,\text{V}$</td>
<td>22</td>
<td>35</td>
<td></td>
<td>m$\Omega$</td>
</tr>
<tr>
<td>$R_{\text{DS(ON)}}$</td>
<td>Switch On Resistance</td>
<td>$AOZ1360AI \quad V_{\text{IN}} = 5.5,\text{V}$</td>
<td>33</td>
<td>43</td>
<td></td>
<td>m$\Omega$</td>
</tr>
<tr>
<td>$I_{\text{LIM}}$</td>
<td>Current Limit</td>
<td>$R_{\text{SET}} = 84.5,\text{k}$</td>
<td>2</td>
<td>2.7</td>
<td>3.4</td>
<td>A</td>
</tr>
<tr>
<td>$V_{\text{EN_L}}$</td>
<td>Enable Input Low Voltage</td>
<td></td>
<td>0.8</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>$V_{\text{EN_H}}$</td>
<td>Enable Input High Voltage</td>
<td></td>
<td>2.0</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>$I_{\text{EN_BIAS}}$</td>
<td>Enable Input Bias Current</td>
<td></td>
<td>100</td>
<td></td>
<td></td>
<td>mV</td>
</tr>
<tr>
<td>$T_{\text{d} _ \text{on}}$</td>
<td>Turn-On Delay Time EN_50% to OUT_10%</td>
<td>$R_L = 120,\Omega, \quad C_L = 1,\mu$F, SS = Floated</td>
<td>220</td>
<td></td>
<td></td>
<td>$\mu$s</td>
</tr>
<tr>
<td>$T_{\text{on}}$</td>
<td>Turn-On Rise Time OUT_10% to 90%</td>
<td>$R_L = 120,\Omega, \quad C_L = 1,\mu$F, SS = Floated</td>
<td>280</td>
<td></td>
<td></td>
<td>$\mu$s</td>
</tr>
<tr>
<td>$T_{\text{off}}$</td>
<td>Turn-Off Fall Time</td>
<td>$R_L = 120,\Omega, \quad C_L = 1,\mu$F, CSS = 1 nF</td>
<td>360</td>
<td></td>
<td></td>
<td>$\mu$s</td>
</tr>
<tr>
<td>$T_{\text{SD}}$</td>
<td>Thermal Shutdown Threshold</td>
<td></td>
<td>130</td>
<td></td>
<td></td>
<td>$^\circ$C</td>
</tr>
<tr>
<td>$T_{\text{SD} _ \text{HY}}$</td>
<td>Thermal Shutdown Hysteresis</td>
<td></td>
<td>30</td>
<td></td>
<td></td>
<td>$^\circ$C</td>
</tr>
</tbody>
</table>
Typical Performance Characteristics

- **Input Quiescent Current**
  - Supply Current (μA) vs. \( V_{IN} (V) \)
  - Curves for \( 85°C \), \( 25°C \), and \( -40°C \)

- **Input Shutdown Current**
  - Supply Current (μA) vs. \( V_{IN} (V) \)
  - Curves for \( 85°C \), \( 25°C \), and \( -40°C \)

- **Output Leakage Current**
  - Output Leakage Current (μA) vs. Temperature (°C)
  - Curves for \( V_{IN} = 12V \) and \( V_{IN} = 5.5V \)

- **UVLO Threshold vs. Temperature**
  - Threshold (V) vs. Temperature (°C)
  - Curves for Rising and Falling transitions

- **R\(_{DS(ON)}\) vs. Supply Voltage**
  - R\(_{DS(ON)}\) (mΩ) vs. \( V_{IN} (V) \)
  - Curves for \( V_{IN} = 12V \) and \( V_{IN} = 5.5V \)

- **R\(_{DS(ON)}\) vs. Temperature**
  - R\(_{DS(ON)}\) (mΩ) vs. Temperature (°C)
  - Curves for \( V_{IN} = 12V \) and \( V_{IN} = 5.5V \)
Typical Performance Characteristics (Continued)

Enable Input Threshold (Rising) vs. Temperature

Enable Input Threshold (Falling) vs. Temperature

Current Derating Curve for SO8

Current Derating Curve for DFN-10 4x4

Internal Power MOSFET SOA
Typical Performance Characteristics (Continued)

**Turn-On**
$(V_{IN} = 12V, \ R = 5.6\Omega)$

- $V_{IN}$: 2V/div
- $V_{OUT}$: 2V/div
- $EN$: 1V/div
- $I_{OUT}$: 0.5A/div
- Time: 1ms/div

**Turn-Off**
$(V_{IN} = 12V, \ R = 5.6\Omega)$

- $V_{IN}$: 2V/div
- $V_{OUT}$: 2V/div
- $EN$: 1V/div
- $I_{OUT}$: 0.5A/div
- Time: 20μs/div

**Current Limit**
$(V_{IN} = 12V, \ R = 3.6\Omega)$

- $V_{IN}$: 5V/div
- $V_{OUT}$: 2V/div
- $EN$: 1V/div
- $I_{OUT}$: 0.5A/div
- Time: 5ms/div

**Over Temperature**
$(V_{IN} = 12V, \ R = 3.6\Omega)$

- $V_{IN}$: 2V/div
- $V_{OUT}$: 2V/div
- $EN$: 1V/div
- $I_{OUT}$: 0.5A/div
- Time: 100ms/div
Detailed Description

Introduction
The AOZ1360 is a 35 mΩ P-channel high-side load switch with adjustable soft-start slew-rate control, programmable current limit and thermal shutdown. It operates with an input voltage range from 5.5 V to 28 V.

Enable
The EN pin is the On/Off control for the output switch. It is an active-high input. The EN pin is active after $V_{IN}$ is above the UVLO threshold of 4.9 V. Conversely, the EN pin will be deactivated if the $V_{IN}$ falls below the UVLO of 2.0V. The EN pin must be driven to a logic high or logic low state to guarantee operation. While disabled, the AOZ1360 only draws approximately 1 µA supply current. The EN is a high impedance input with an ESD protection diode to ground and should not be forced below ground. This input level is compatible with most microcontroller outputs and other logic families.

Under-Voltage Lockout (UVLO)
The under-voltage lockout (UVLO) circuit of the AOZ1360 monitors the input voltage and prevents the output MOSFET from turning on until $V_{IN}$ exceeds 4.9 V.

Adjustable Soft-Start Slew-Rate Control
When the EN pin is high, the slew rate control circuitry applies voltage on the gate of the PMOS switch in a manner such that the output voltage and current is ramped up linearly until it reaches the steady-state load current level. The slew rate can be adjusted by an external capacitor connected between the SS pin and ground.

The slew rate rise time, $T_{on}$, can be set using the following equation:

$$T_{on} = \frac{C_{ss} \times V_{IN}}{30 \mu A}$$

Programmable Current Limit
The current limit is programmed by an external resistor connected between the SET pin and ground. This sets a reference voltage to the current limit error amplifier that compares it to a sensed voltage that is generated by passing a small portion of the load current through an internal amplifier. When the sensed load current exceeds the set current limit, the load current is then clamped at the set limit and the $V_{out}$ drops to whatever voltage is necessary to clamp the load current. The AOZ1360 will stay in this condition until the load current no longer exceeds the current limit or if the thermal shutdown protection is engaged.

Thermal-Shutdown Protection
During current limit or short circuit conditions, the PMOS resistance is increased to clamp the load current. This increases the power dissipation in the chip causing the die temperature to rise. When the die temperature reaches 130 °C the thermal shutdown circuitry will shutdown the device. There is a 30 °C hysteresis after which the device will turn back on and go through soft start. The thermal shutdown will cycle repeatedly until the short circuit condition is resolved or the enable pin is pulled LOW externally.
Application Information

Input Capacitor Selection
The input capacitor prevents large voltage transients from appearing at the input and provides the instantaneous current needed each time the switch turns on. The input capacitor also limits input voltage drop and prevents high-frequency noise on the power line from passing through the output of the power side. The choice of input capacitor is based on its ripple current and voltage ratings rather than the actual capacitance value. The input capacitor should be located as close to VIN as possible. A 1 µF ceramic cap is recommended. However, higher capacitor values will further reduce the voltage drop at the input.

Output Capacitor Selection
The output capacitor acts in a similar way. A small 0.1 µF capacitor prevents high-frequency noise from going into the system. Also, the output capacitor has to supply enough current for any large load that may occur during system transients. This bulk capacitor must be large enough to supply fast transient load in order to prevent the output from dropping.

Current Limit Setting
The current limit is set by an external resistor connected to the SET pin. Refer to Figure 3 for current limit settings.

Slew Rate Setting
Slew rate is set by changing the capacitor value on the SS pin of the device. A capacitor connected between the SS pin and ground will reduce the output slew-rate. The capacitive range is 0.001 µF to 0.1 µF. Refer to Figure 4.

Power Dissipation Calculation
Calculate the power dissipation for normal load condition using the following equation:

\[ P_D = R_{ON} \times (I_{OUT})^2 \]

The worst case power dissipation occurs when the load current hits the current limit due to over-current or short circuit faults. The power dissipation under these conditions can be calculated using the following equation:

\[ P_D = (V_{IN} - V_{OUT}) \times I_{LIMIT} \]
Layout Guidelines

Proper PCB layout is important for improving the thermal and overall performance of the AOZ1360. To optimize the switch response time for outputting short-circuit conditions, keep all traces as short as possible. This will also reduce the effect of unwanted parasitic inductance.

Place the input and output bypass capacitors as close as possible to the IN and OUT pins. The input and output PCB traces should be as wide as possible for the given PCB space. Use a ground plane to enhance the power dissipation capability of the device.
Package Dimensions, SO-8L

Notes:
1. All dimensions are in millimeters.
2. Dimensions are inclusive of plating.
3. Package body sizes exclude mold flash and gate burrs. Mold flash at the non-lead sides should be less than 6 mils.
4. Dimension L is measured in gauge plane.
5. Controlling dimension is millimeter, converted inch dimensions are not necessarily exact.
Tape and Reel Dimensions, SO-8

### Carrier Tape

![Diagram of Carrier Tape]

UNIT: mm

<table>
<thead>
<tr>
<th>Package</th>
<th>A0</th>
<th>B0</th>
<th>K0</th>
<th>D0</th>
<th>D1</th>
<th>E</th>
<th>E1</th>
<th>E2</th>
<th>P0</th>
<th>P1</th>
<th>P2</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO-8 (12mm)</td>
<td>6.40</td>
<td>5.20</td>
<td>2.10</td>
<td>1.60</td>
<td>1.50</td>
<td>12.00</td>
<td>1.75</td>
<td>5.50</td>
<td>8.00</td>
<td>4.00</td>
<td>2.00</td>
<td>0.25</td>
</tr>
</tbody>
</table>

### Reel

![Diagram of Reel]

UNIT: mm

<table>
<thead>
<tr>
<th>Tape Size</th>
<th>Reel Size</th>
<th>M</th>
<th>N</th>
<th>W</th>
<th>W1</th>
<th>H</th>
<th>K</th>
<th>S</th>
<th>G</th>
<th>R</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>12mm</td>
<td>Ø330</td>
<td>Ø330.00</td>
<td>Ø97.00</td>
<td>13.00</td>
<td>17.40</td>
<td>Ø13.00</td>
<td>10.60</td>
<td>2.00</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

### Leader/Trailer and Orientation

![Diagram of Leader/Trailer and Orientation]

- Trailer Tape: 300mm min. or 75 empty pockets
- Components Tape: Orientation in Pocket
- Leader Tape: 500mm min. or 125 empty pockets
Package Dimensions, DFN-10L, 4x4

Notes:
1. All dimensions are in millimeters.
2. The dimensions with * are just for reference.
3. The location of the terminal #1 identifier and terminal numbering convention conforms to JEDEC publication 95 SPP-002.
4. Dimension b applies to metallized terminal and is measured between 0.15mm and 0.30mm from the terminal tip. If the terminal has the optional radius on the other end of the terminal, then dimension b should not be measured in that radius area.
5. Coplanarity applies to the terminals and all other bottom surface metallization.
6. Drawings shown are for illustration only.
Tape and Reel Dimensions, DFN-10L, 4x4

Carrier Tape

Reel

Leader/Trailer and Orientation

<table>
<thead>
<tr>
<th>Tape Size</th>
<th>Reel Size</th>
<th>M</th>
<th>N</th>
<th>W</th>
<th>W1</th>
<th>H</th>
<th>K</th>
<th>S</th>
<th>G</th>
<th>R</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 mm</td>
<td>ø330</td>
<td>ø330.0</td>
<td>ø79.0</td>
<td>12.4</td>
<td>17.0</td>
<td>ø13.0</td>
<td>10.5</td>
<td>2.0</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

UNIT: MM

<table>
<thead>
<tr>
<th>Package</th>
<th>A0</th>
<th>B0</th>
<th>K0</th>
<th>D0</th>
<th>D1</th>
<th>E</th>
<th>E1</th>
<th>E2</th>
<th>P0</th>
<th>P1</th>
<th>P2</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
<td>DFN 4x4 (12mm)</td>
<td>4.35</td>
<td>4.35</td>
<td>1.10</td>
<td>1.50</td>
<td>1.50</td>
<td>12.0</td>
<td>1.75</td>
<td>5.50</td>
<td>8.00</td>
<td>4.00</td>
<td>2.00</td>
<td>0.30</td>
</tr>
</tbody>
</table>

UNIT: MM

<table>
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<tr>
<th>Carrier Tape: DFN 4x4 (12mm)</th>
<th>A0</th>
<th>B0</th>
<th>K0</th>
<th>D0</th>
<th>D1</th>
<th>E</th>
<th>E1</th>
<th>E2</th>
<th>P0</th>
<th>P1</th>
<th>P2</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
<td>±0.10</td>
<td>±0.10</td>
<td>±0.10</td>
<td>±0.10</td>
<td>±0.10</td>
<td>±0.10</td>
<td>±0.10</td>
<td>±0.10</td>
<td>±0.10</td>
<td>±0.10</td>
<td>±0.10</td>
<td>±0.10</td>
<td>±0.10</td>
</tr>
</tbody>
</table>

UNIT:  MM

<table>
<thead>
<tr>
<th>Reel: ø330</th>
<th>ø330.0</th>
<th>ø79.0</th>
<th>12.4</th>
<th>17.0</th>
<th>ø13.0</th>
<th>10.5</th>
<th>2.0</th>
<th>—</th>
<th>—</th>
<th>—</th>
</tr>
</thead>
<tbody>
<tr>
<td>±2.0</td>
<td>±1.0</td>
<td>+2.0/-0.0</td>
<td>+2.6/-0.0</td>
<td>±0.5</td>
<td>±0.2</td>
<td>±0.5</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

UNIT: MM

Carrier Tape: DFN 4x4 (12mm)

<table>
<thead>
<tr>
<th>Leaders/Trailer and Orientation</th>
<th>Trailer Tape</th>
<th>Components Tape</th>
<th>Leader Tape</th>
</tr>
</thead>
<tbody>
<tr>
<td>300mm min. or 75 empty pockets</td>
<td>Orientation in Pocket</td>
<td>500mm min. or 125 empty pockets</td>
<td></td>
</tr>
</tbody>
</table>
Part Marking

SO-8

Part Number Code

Underscore Indicates
Green Product

Fab & Assembly Location

Year & Week Code

Assembly Lot Code

DFN-10

Part Number Code

Underscore Indicates
Green Product

Fab & Assembly Location

Year & Week Code

Assembly Lot Code
As used herein:

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2. A critical component in any component of a life support, device, or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

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ALPHA AND OMEGA SEMICONDUCTOR PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS.

As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body or (b) support or sustain life, and (c) whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury of the user.

2. A critical component in any component of a life support, device, or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.