

General Description

The AOZ1356LI is a current-limiting protection switch targeting applications that require comprehensive protections. For AOZ1356LI-01 and -02 the input operating voltage range is 3.4V to 5.5V, and for AOZ1356LI-05 and -06, the input operating voltage range is between 3.6V and 5.3V. The output terminal is rated 28V absolute maximum. The internal current-limiting circuit protects the supply from large load current. The current limit level is set with an external resistor. The internal soft-start circuit controls inrush current due to highly capacitive loads. The device features very low quiescent current. The supply current reduces to 6 μ A in shut-down. It also has under-voltage lockout (UVLO), over-voltage protection (OVP) and thermal shutdown protection.

The AOZ1356LI has True Reverse-Current Blocking (TRCB) protection to avoid undesired reverse-current from VOUT to VIN.

The AOZ1356LI supports USB PD Fast Role Swap. When FON pin is high, the device is in fast turn-on mode to ensure output voltage rises quickly to meet USB PD spec. The device also features fast recovery to turn on power switch once reverse current blocking protection is de-activated.

The AOZ1356LI is available in 1.31mm x 1.81mm WLCP package with 0.4mm pitch and 12-bumps.

Features

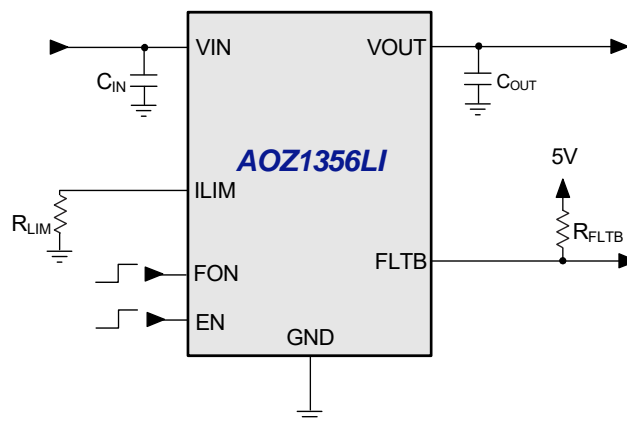
- 28V voltage rating on VOUT pin
- Up to 3.5A current capability
- Typical R_{ON} : 34m Ω
- Supports USB PD Fast Role Swap (FRS)
- Programmable current limit
- True Reverse-Current Blocking (TRCB)
- Fast recovery from TRCB
- 125 μ A quiescent current
- Over-voltage protection
- Short-circuit protection
- Input under-voltage lockout
- Thermal shutdown protection
- \pm 4kV HBM rating
- \pm 1kV CDM rating
- IEC61000-4-5: 45V (No Cap)
- WLCSP-12 1.31mm x 1.81mm 0.4 pitch
- UL Pending

Applications

- USB PD power source switch
- Smartphones and tablets
- Notebooks, ultra books and desktops
- Portable devices



Typical Application



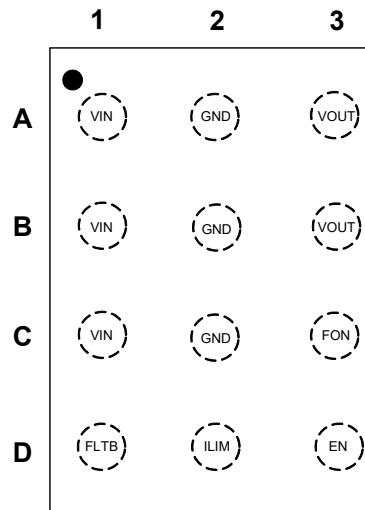
Ordering Information

Part Number	Fault Recovery	Operating Voltage Range	Package	Environmental
AOZ1356LI-01	Auto-Restart	3.4V-5.5V	WLCSP, 12-bumps	RoHS
AOZ1356LI-02	Latch-Off	3.4V-5.5V	WLCSP, 12-bumps	RoHS
AOZ1356LI-05	Auto-Restart	3.6V-5.3V	WLCSP, 12-bumps	RoHS
AOZ1356LI-06	Latch-Off	3.6V-5.3V	WLCSP, 12-bumps	RoHS



All AOS products are offered in packages with Pb-free plating and compliant to RoHS standards. Please visit www.aosmd.com/media/AOSGreenPolicy.pdf for additional information.

Pin Configuration



WLCSP-12 1.31mm x 1.81mm 0.4 pitch
(Top Transparent View)

Pin Description

Pin Number	Pin Name	Pin Function
1A, 1B, 1C	VIN	Supply input. Connected to internal power regulator. They are internally connected together.
1D	FLTB	Fault indicator, open-drain output, active-low when fault condition occurs.
2A, 2B, 2C	GND	Ground.
2D	ILIM	Current limit set pin. Connect a 1% resistor R_{LIM} from ILIM to GND to set the current limit threshold.
3A, 3B	VOUT	Power output. Connect to adapter. They are internally connected together.
3C	FON	Fast-On. Active high. This pin set device into fast turn-on mode. Internally pulled down with a resistor.
3D	EN	Enable input. Active high. Internally pulled down with a resistor.

Absolute Maximum Ratings

Exceeding the Absolute Maximum Ratings may damage the device.

Parameter	Rating
V _{OUT} to GND	-0.3V to +28V
V _{IN} , EN, ILIM, FON, FLTB to GND	0V to +6V
Junction Temperature (T _J)	+150°C
Storage Temperature (T _S)	-65°C to +150°C
ESD Rating HBM/CDM	±4kV / ±1kV

Recommended Operating Ratings

The device is not guaranteed to operate beyond the Maximum Operating Ratings.

Parameter	Rating
V _{IN} to GND	3.4V to 5.5V
FON, EN, FLTB to GND	0V to 5.5V
Switch Current (I _{SW})	0A to 3.5A
ILIM	0V to 2V
Ambient Temperature (T _A)	-40°C to +85°C
Package Thermal Resistance	84°C/W

Electrical Characteristics

T_A = 25°C, V_{IN} = 5V, V_{EN} = 5V, V_{FON} = 0V unless otherwise specified.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Units
General						
V _{IN}	Input Supply Voltage	AOZ1356LI-01 and -02	3.4		5.5	V
		AOZ1356LI-05 and -06	3.6		5.3	V
V _{UVLO_R}	Under-voltage Lockout Threshold	V _{IN} rising AOZ1356LI-01 and -02	3	3.25	3.35	V
		V _{IN} rising AOZ1356LI-05 and -06	3.2	3.45	3.55	V
V _{UVLO_HYS}	Under-voltage Lockout Hysteresis	V _{IN} falling		150		mV
I _{IN_ON}	Input Quiescent Current	I _{OUT} = 0A, FON = 0V, V _{EN} = 5V		125		µA
I _{IN_FON}	FON Standby Current	FON = 5V, V _{EN} = 0V		135		mA
I _{IN_OFF}	Input Shutdown Current	EN = 0V, FON = 0V		6	10	µA
R _{ON}	Switch On Resistance	I _{OUT} = 1A		34		mΩ
V _{EN_H}	Enable Input Logic High Threshold	EN rising	1.4			V
V _{EN_L}	Enable Input Logic Low Threshold	EN falling			0.4	V
I _{EN_BIAS}	Enable Input Bias Current	EN = 1.8V		1	1.5	µA
V _{FON_H}	Fast-On Logic High Threshold	FON rising	1.4			V
V _{FON_L}	Fast-On Logic Low Threshold	FON falling			0.4	V
I _{FON_BIAS}	Fast-On Input Bias Current	V _{FON} = 1.8V		1.5	4.0	µA
V _{FLTB_LO}	FLTB Pull-down Voltage	I _{SINK} = 3mA			0.3	V
Over-Voltage Protection						
V _{OVLO_R}	Over-voltage Lockout Threshold	V _{IN} rising AOZ1356LI-01 and -02	5.6	5.8	6	V
V _{OVLO_F}		V _{IN} rising AOZ1356LI-05 and -06	5.75	5.9		
V _{OVLO_HYS}	Over-voltage Lockout Hysteresis			250		mV
V _{OUT_OVLO}	Output Over-Voltage Lockout Threshold	AOZ1356LI-05 and -06	5.3		5.5	V
T _{DELAY_OVP}	OVP Turn-Off Delay			2		µs

Electrical Characteristics

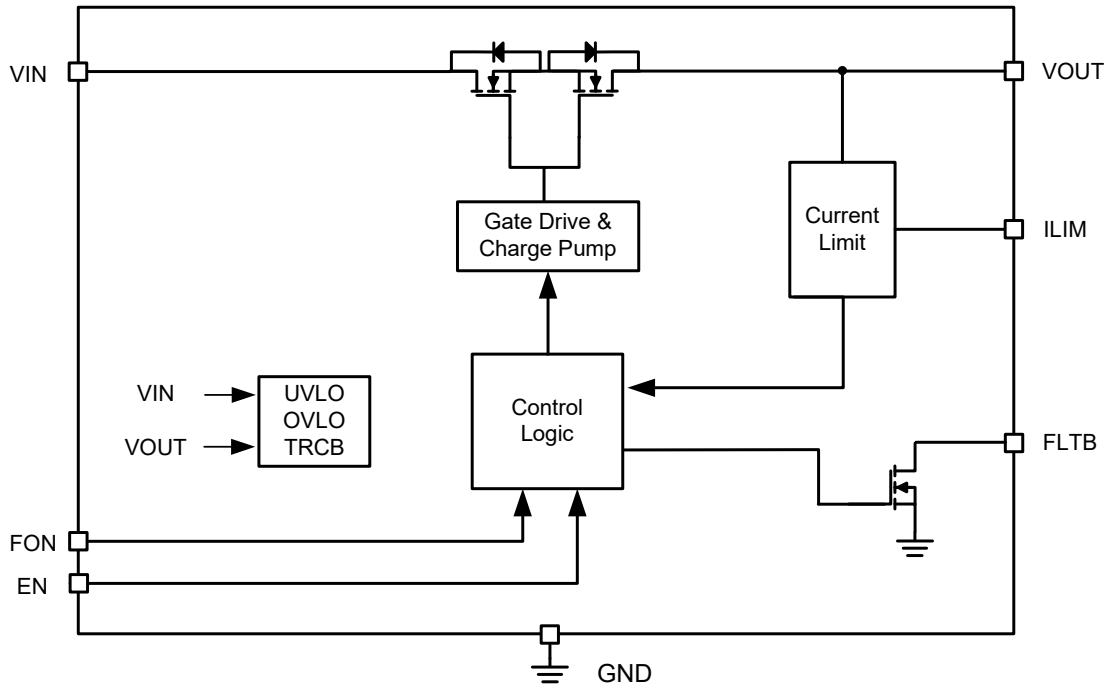
$T_A = 25^\circ\text{C}$, $V_{IN} = 5\text{V}$, $V_{EN} = 5\text{V}$, $V_{FON} = 0\text{V}$ unless otherwise specified.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Units
Over-Current Protection						
I_{LIM}	Current Limit Threshold	$V_{OUT} = 5\text{V}$, $R_{LIM} = 4.02\text{k}\Omega^{(1)}$	3.08	3.5	3.92	A
		$V_{OUT} = 5\text{V}$, $R_{LIM} = 14.3\text{k}\Omega$	0.9	1	1.1	
		$V_{OUT} = 5\text{V}$, $R_{LIM} = 29.4\text{k}\Omega$	0.45	0.5	0.55	
T_{OCP_FLT}	Over-Current Flag Delay	From $I_{OUT} \geq I_{LIM}$ to FLTB pulled low		12		ms
Reverse-Current Blocking						
V_{T_RCB}	RCB Protection Trip Point	$V_{OUT}-V_{IN}$, V_{OUT} rising		25		mV
V_{R_RCB}	RCB Protection Release Trip Point	$V_{IN}-V_{OUT}$, V_{OUT} falling		40		mV
V_{RCB_HYS}	RCB Hysteresis	$V_{T_RCB} + V_{R_RCB}$		65		mV
T_{RCB}	RCB Response Time			600		ns
$T_{RCB_RECOVERY}$	RCB Fast Recovery	$C_{OUT} = 1\mu\text{F}$, $R_L = 100\Omega$		80		μs
Thermal Shutdown						
T_{SD}	Thermal Shutdown Threshold	Temperature rising		140		$^\circ\text{C}$
T_{SD_HYS}	Thermal Shutdown Hysteresis	Temperature falling		20		
Dynamic Characteristics						
T_{D_ON}	Turn-On Delay Time (From V_{EN} 50% to $V_{OUT}=0.5\text{V}$)	$V_{IN} = 5\text{V}$, $R_L = 100\Omega$, $C_{OUT} = 1\mu\text{F}$, $R_{LIM} = 14.3\text{k}\Omega$		2.5		ms
T_{ON}	Turn-ON Time (V_{OUT} from 0.5V to 4.5V)	$V_{IN} = 5\text{V}$, $R_L = 100\Omega$, $C_{OUT} = 1\mu\text{F}$, $R_{LIM} = 14.3\text{k}\Omega$		2		ms
T_{FON}	Fast Turn-On Time (From $V_{EN}=V_{EN_H}$ to $V_{OUT}=4.75\text{V}$)	$V_{IN} = 5\text{V}$, $V_{EN} = 5\text{V}$, $V_{FON} = 5\text{V}$, $R_L = 100\Omega$, $C_{OUT} = 1\mu\text{F}$, $R_{LIM} = 14.3\text{k}\Omega$		50	100	μs
T_{S_FON}	FON Setup Time prior to EN		100			μs
T_{H_FON}	FON Hold Time after EN		40			μs

Note:

1. Guaranteed by design. Not production tested. 1% resistors.

Functional Block Diagram



Timing Diagrams

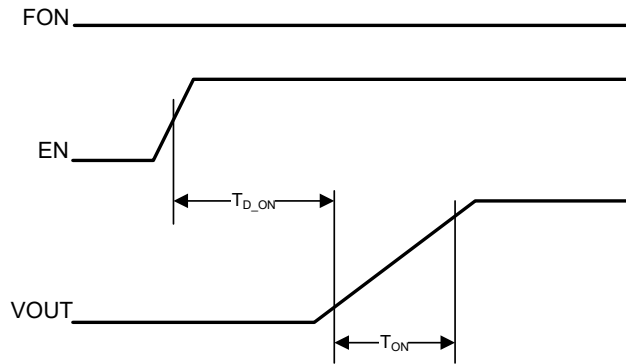


Figure 1. Normal Turn-on Delay and Turn-on Time ($V_{FON}=0V$)

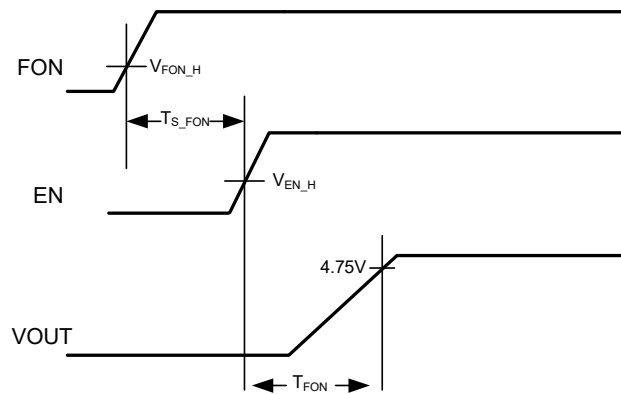


Figure 2. Fast Turn-on Time ($V_{IN}=5V$)

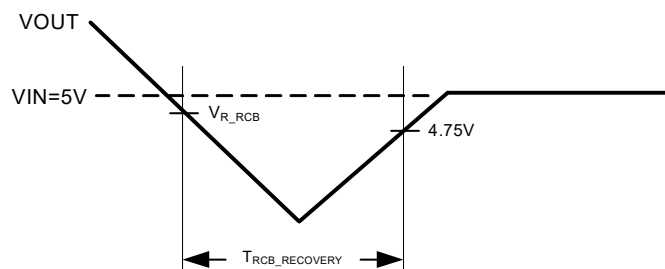


Figure 3. Fast Recovery from RCB

Typical Characteristics

$T_A=25^{\circ}\text{C}$, $V_{IN}=5\text{V}$, FON floating, device option Auto-Restart, $C_{IN}=76\mu\text{F}$ (nominal), $C_{OUT}=9.4\mu\text{F}$ (nominal), $R_{LIM}=4.75\text{k}\Omega$, unless otherwise noted. "Offset" or "ofst" in the scope shots below means vertical position of the channel's ground reference relative to the mid horizontal line.

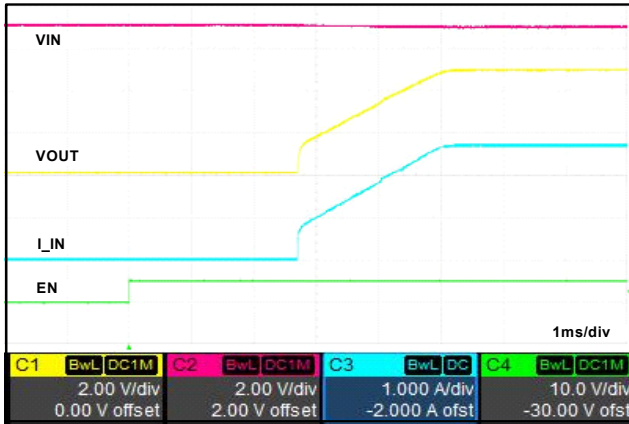


Figure 1. Soft Start (LOAD = 1.9Ω)

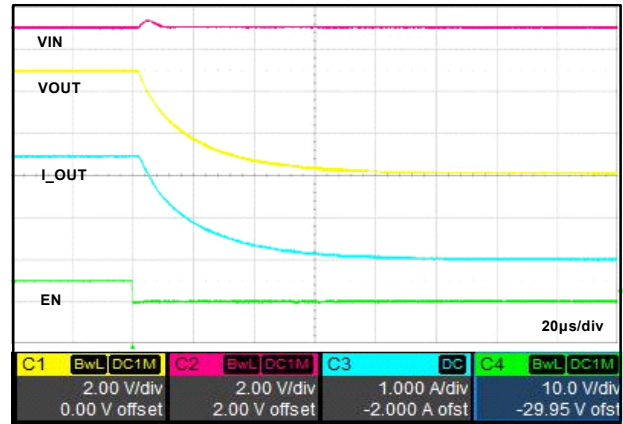


Figure 2. Shutdown by EN (LOAD = 1.9Ω)

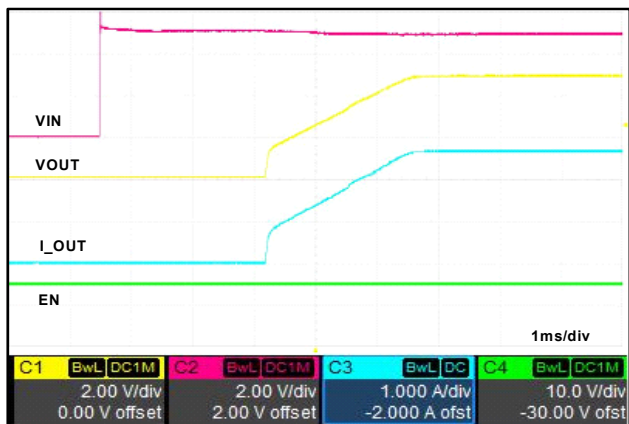


Figure 3. Soft Start by Toggling VIN (LOAD = 1.9Ω)

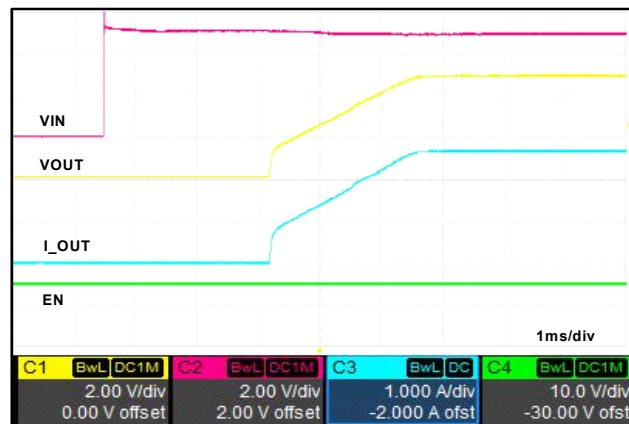


Figure 4. Shutdown by Toggling VIN (LOAD = 1.9Ω)

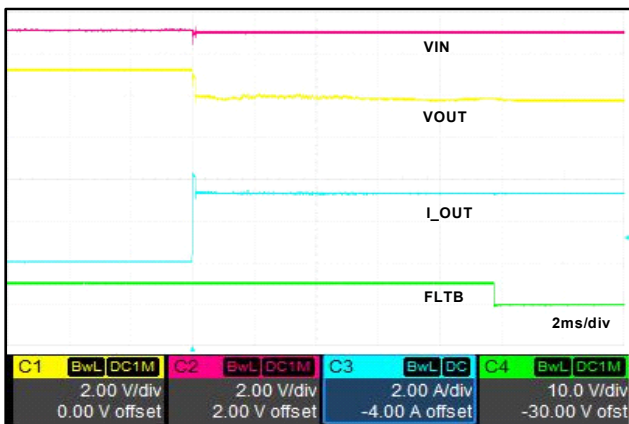


Figure 5. Over Current Protection (LOAD = 1.2Ω Plugged In)

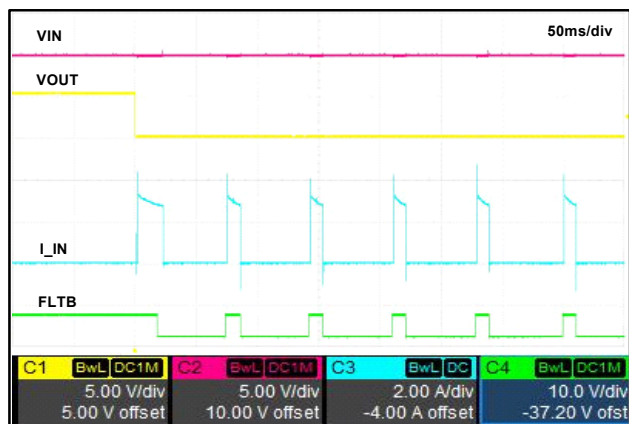


Figure 6. Short Circuit Protection, Thermal Shutdown and Auto Restart

Typical Characteristics (continued)

$T_A=25^{\circ}\text{C}$, $V_{IN}=5\text{V}$, FON floating, device option Auto-Restart, $C_{IN}=76\mu\text{F}$ (nominal), $C_{OUT}=9.4\mu\text{F}$ (nominal), $R_{LIM}=4.75\text{k}\Omega$, unless otherwise noted. "Offset" or "ofst" in the scope shots below means vertical position of the channel's ground reference relative to the mid horizontal line.

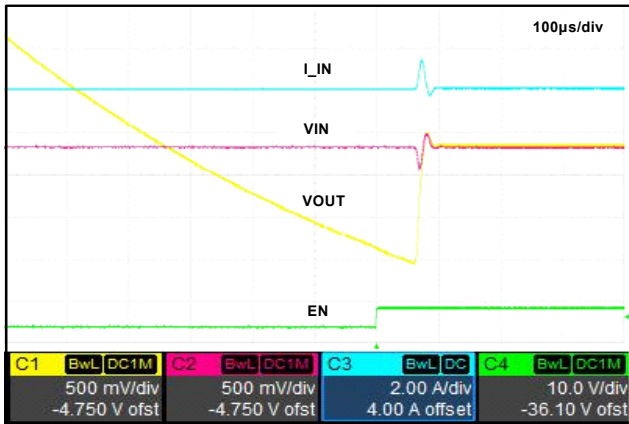


Figure 7. Fast Role Swap

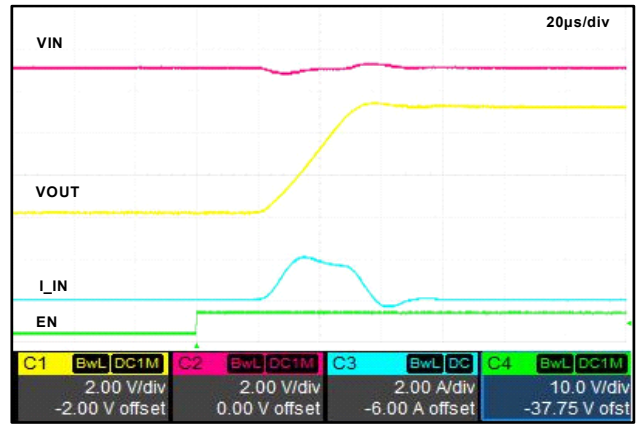


Figure 8. Fast Start Up (FON=5V, No Load)



Figure 9. Starting Up into Shorted Output

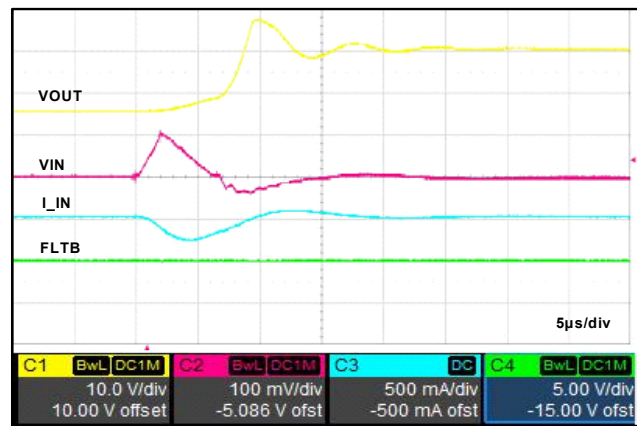


Figure 10. Reverse Current Blocking (VOUT shorted to 20V)

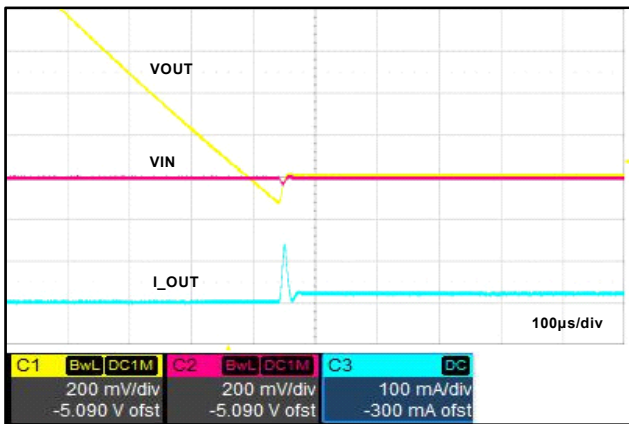


Figure 11. Recovery from Reverse Current Blocking

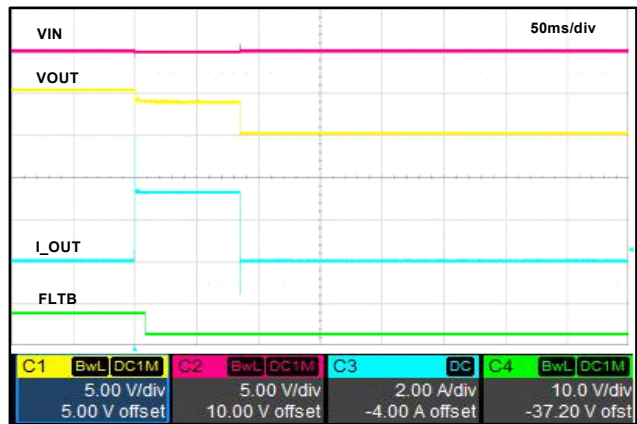


Figure 12. Over Current Protection (Latch-off)

Typical Characteristics (continued)

$T_A=25^{\circ}\text{C}$, $V_{IN}=5\text{V}$, FON floating, device option Auto-Restart, $C_{IN}=76\mu\text{F}$ (nominal), $C_{OUT}=9.4\mu\text{F}$ (nominal), $R_{LIM}=4.75\text{k}\Omega$, unless otherwise noted. "Offset" or "ofst" in the scope shots below means vertical position of the channel's ground reference relative to the mid horizontal line.

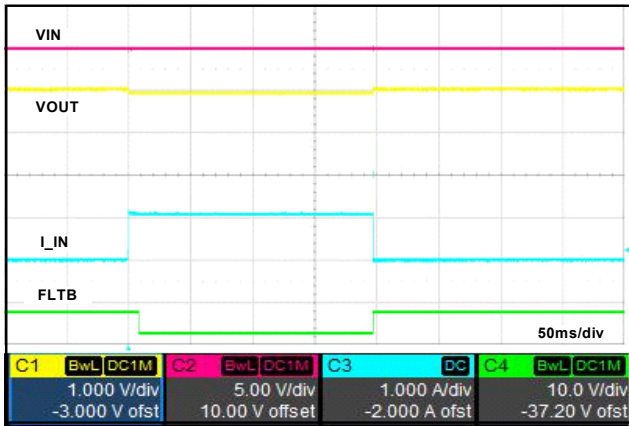


Figure 13. Short Duration Over Current ($R_{LIM}=14.3\text{K}$) (Latch-off)

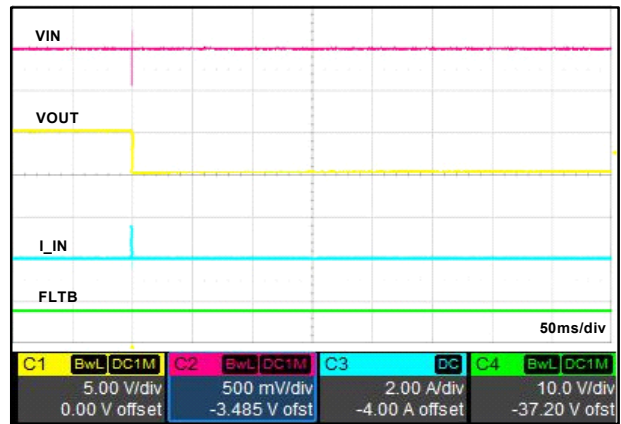


Figure 14. Short Circuit Protection (Latch-off)

Typical Characteristics

$T_A = 25^\circ\text{C}$, $V_{IN} = 5\text{V}$ unless otherwise specified.

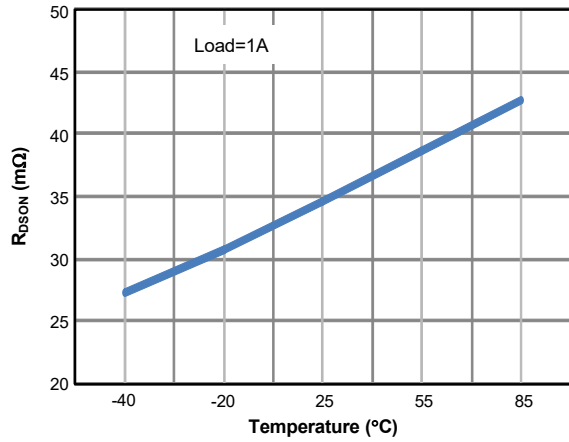


Figure 15. R_{DSON} vs. Temperature

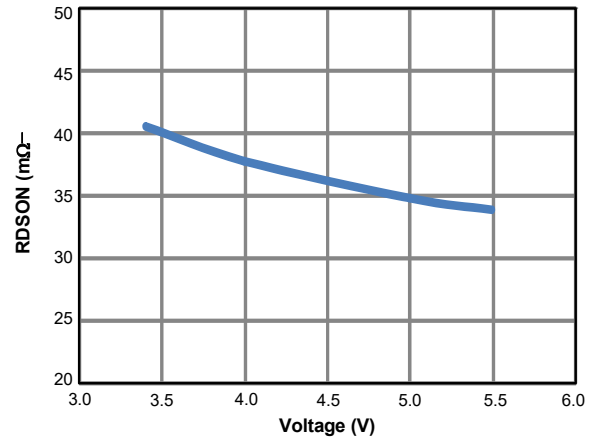


Figure 16. R_{DSON} vs. Input Voltage

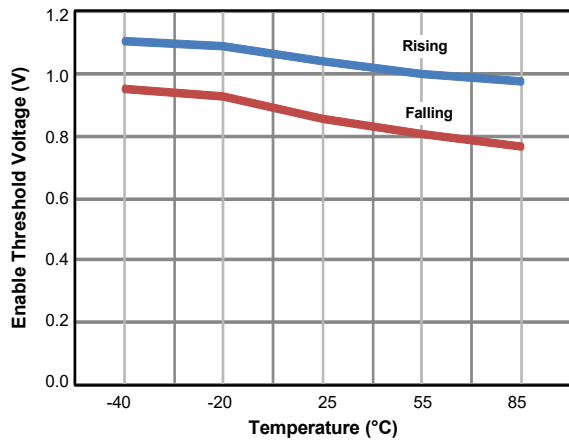


Figure 17. EN Threshold vs. Temperature

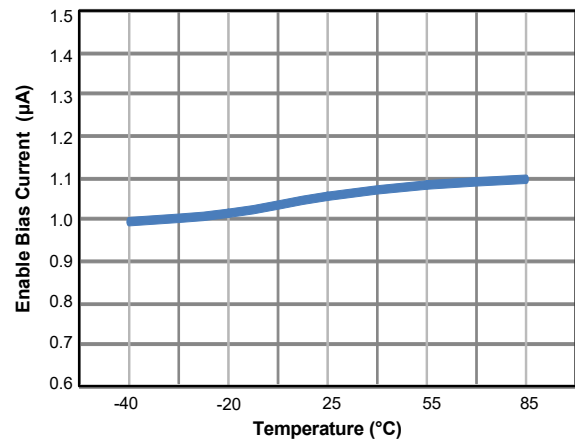


Figure 18. EN Bias Current vs. Temperature

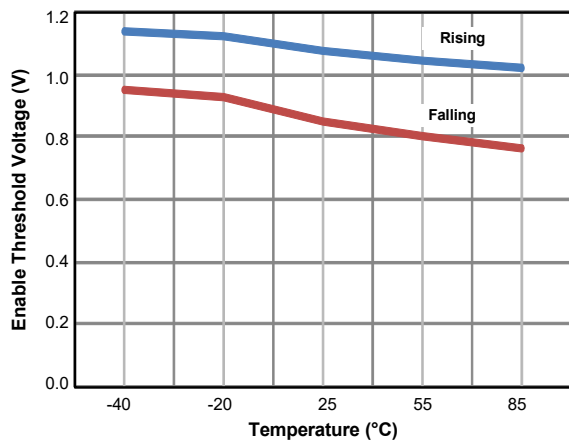


Figure 19. FON Threshold vs. Temperature

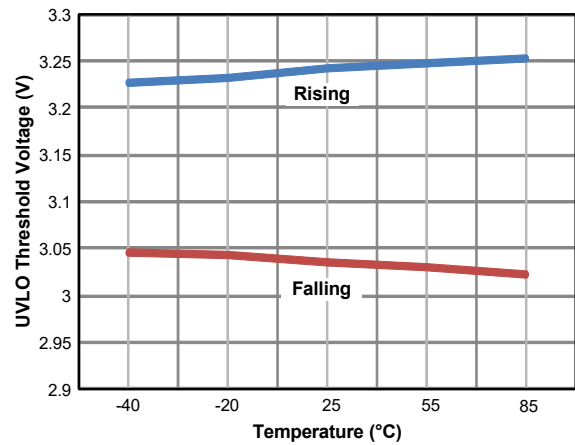


Figure 20. UVLO Threshold vs. Temperature (AOZ1356LI-01, -02)

Typical Characteristics (Continued)

$T_A = 25^\circ\text{C}$, $V_{IN} = 5\text{V}$ unless otherwise specified.

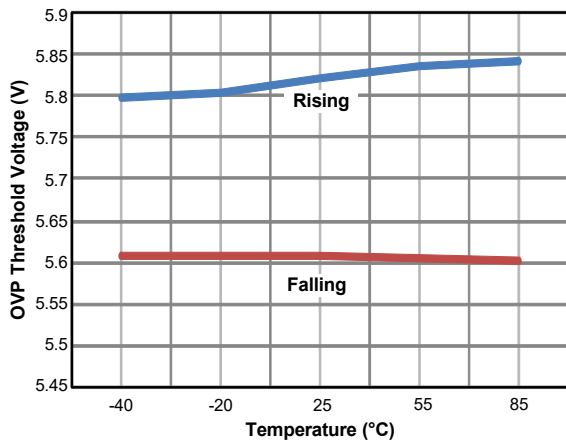


Figure 21. OVP Threshold vs. Temperature (AOZ1356LI-01, -02)

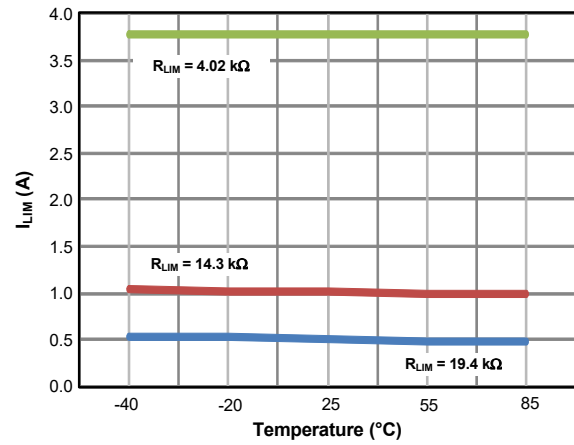


Figure 22. Current Limit Threshold vs. Temperature

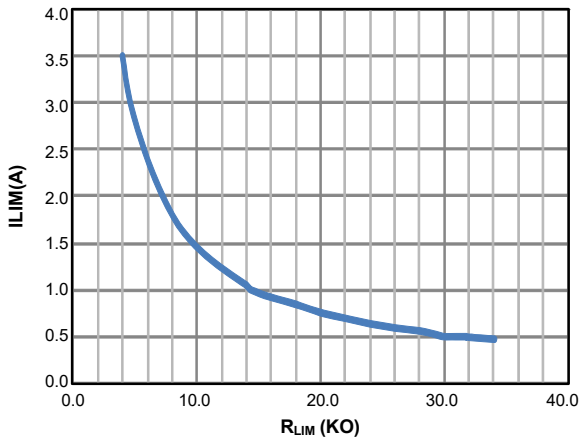


Figure 23. Current Limit vs. R_{LIM}

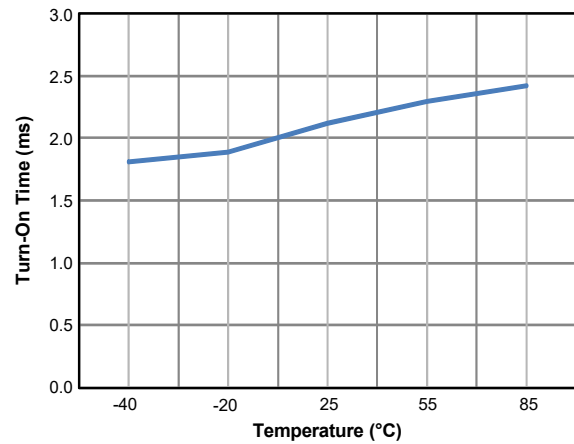


Figure 24. Turn-On Time (TON) vs. Temperature

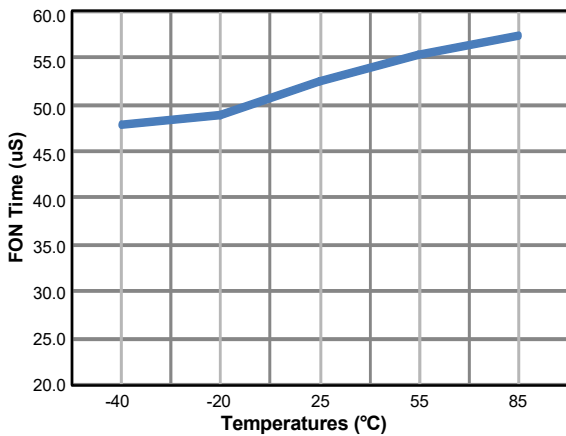


Figure 23. Current Limit vs. R_{LIM}

Functional Description

The AOZ1356LI is a current limited power switch with over-voltage, over-current, reverse-current and thermal shutdown protections. The VOUT pin is rated 28V. The switch current is rated up to 3.5A.

The device has true reverse-current blocking features that will prevent undesired current flow from output to its input in either enabled or disabled state.

Enable

The EN pin is the ON/OFF control for the power switch. The device is enabled when EN pin is high and not in under-voltage lockout state. The EN pin must be driven to a logic high or logic low state to guarantee operation. While disabled, the AOZ1356LI draws 6 μ A from supply.

For AOZ1356LI-02, -06 toggle EN pin to restart the device and clear fault flag after device latches off due to fault.

Input Under-Voltage Lockout (UVLO)

The under-voltage lockout (UVLO) circuit monitors the input voltage. The power switch is only allowed to turn on when input voltage is higher than UVLO threshold. Otherwise the switch is off.

Over-Voltage Protection (OVP)

The voltages at VIN terminal is constantly monitored once the device is enabled. In case input voltage exceeds the over-voltage lockout threshold (VOVLO_R), the power switch is either turned off immediately or kept off, depending on its initial state. AOZ1356LI-01, -05 can restart when VIN drops below VOVLO_F.

Programmable Current Limit and Over-Current Protection (OCP)

The AOZ1356LI implemented current limit to ensure that the current through the switch does not exceed current limit threshold set by the external resistor RLIM.

The current limit threshold can be estimated using the equation below:

$$I_{LIM} = 14300/R_{LIM} \text{ (A)}$$

For example, for 1A current limit threshold, a 14.3k Ω RLIM resistor should be selected. 1% resistor is recommended for RLIM.

AOZ1356LI continuously limits the output current when output is overloaded. Under current-limiting, FLTB is pulled low after delay (TOCP_FLTB). Severe overload causes power dissipation and die temperature to increase and may trigger thermal shutdown.

True Reverse-Current Blocking Protection (TRCB)

True reverse-current blocking prevents undesired current flow from output to input when power switch is in either on or off state. When device is enabled, power switch is quickly turned off whenever output voltage is higher than input voltage. The power switch is turned on again when output voltage falls below input by 40mV.

Soft Start

The AOZ1356LI has internal soft-start circuitry to limit in-rush current due to large capacitive load. The turn-on (TON) time is 2ms.

Fast Turn-On

The FON pin allows the power switch to turn-on quickly. FON should be inserted before device is enabled.

If VIN>VOUT, the power switch turns on quickly by minimizing turn on delay and disables over-current protection.

Fast Recovery from RCB

Once RCB event is removed, power switch turns on again quickly. The recovery time is 80 μ s Typ.

Fast Role Swap (FRS) Support

The Fast Turn-On and Fast Recovery from RCB allows AOZ1356LI to support Fast Role Swap operation defined in USB Power Delivery Specification Rev 3.0. It allows system to change its role from power consumer to power provider and recover VOUT voltage to >4.75V in 80 μ s Typ.

Thermal Shutdown Protection

Thermal shutdown protects device from excessive temperature. The power switch is turned off when the die temperature reaches thermal shutdown threshold of 140°C. There is a 20°C hysteresis. For AOZ1356LI-01, -05 power switch is allowed to turn on again if die temperature drops below approximately 120°C.

Startup

The device is enabled when EN \geq VEN_H and input voltage is above UVLO threshold. The device first checks if any fault condition exists. When no fault exists, the power switch is turned on and the output is then ramped up. Power switch is kept off if fault condition was detected.

Fault Reporting

AOZ1356LI protects itself and load from the following fault condition: over-voltage, over-current, reverse-current, and over-temperature.

The FLTB pin is an open drain output. It is asserted low when either an over-current, or over-temperature condition occurs. The FLTB pin becomes high impedance when the fault conditions are removed. A pull-up resistor

(R_{FLTB}) must be connected between FLTB to 5V to provide a logic signal.

When thermal shutdown is activated, FLTB is pulled low immediately to report fault condition to host. FLTB become impedance again once fault is removed.

In case of output overload, FLTB pin is pulled low about 12ms (TOCP_FLTB) after device is in current-limiting.

There is no fault reporting for UVLO, OVP and RCB event.

Auto-restart or Latch-off

AOZ1356LI-01, -05 (auto-restart version): The device will try to restart 24ms after the power switch is turned off and when OVP or thermal shutdown fault is removed.

Power switch is turned on immediately after a RCB event is removed.

AOZ1356LI-02, -06 (latch-off version): The device keeps off even after the fault condition is removed. Power switch can only be turned on again by either toggle EN pin or recycle the input supply.

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 to charge output capacitors and to limit input voltage drop. It also prevents high-frequency noise on the power line from passing through to the output. The input capacitor should be located as close to the pin as possible. A minimum of 10 μ F ceramic capacitor should be used. However, higher capacitor value is strongly recommended to further reduce the transient voltage drop at the input.

Output Capacitor Selection

The output capacitor acts in a similar way. Also, the output capacitor has to supply enough current for a large load that it may encounter during system transient. This bulk capacitor must be large enough to supply fast transient load in order to prevent the output from dropping.

There is an upper limit for output capacitor for AOZ1356LI to ensure the output capacitor can be charged fully during start-up. This upper limit is set by the current limit level and soft-start time.

$$C_{out} = I_{LIM} \times (T_{ON} / V_{IN})$$

Power Dissipation Calculation

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

$$Power\ Dissipated = R_{ON} \times (I_{OUT})^2$$

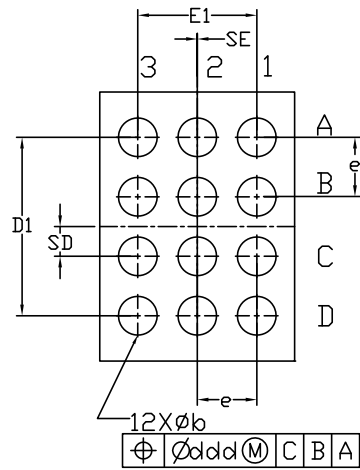
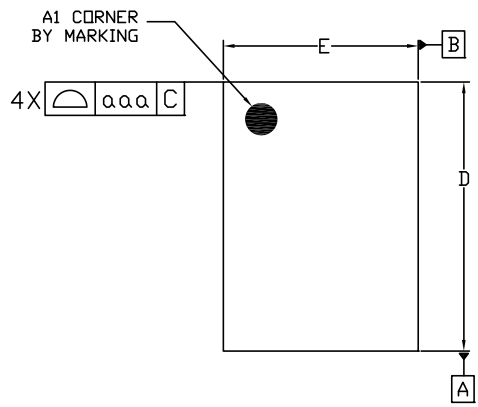
The worst case power dissipation occurs when the load current hits the current limit due to over-current. The power dissipation can be calculated using the following equation:

$$Power\ Dissipated = (V_{IN} - V_{OUT}) \times I_{LIM}$$

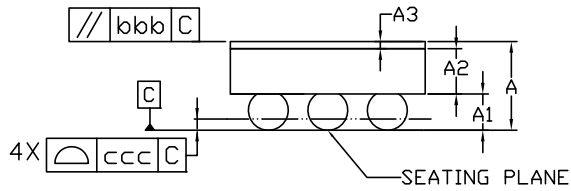
Layout Guidelines

Good PCB layout is important for improving the thermal and overall performance of AOZ1356LI. To optimize the switch response time to output short-circuit conditions, keep all traces as short as possible to reduce the effect of unwanted parasitic inductance. Place the input and output bypass capacitors as close as possible to the VIN and VOUT 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, 1.81x1.31-12, Array WLCSP



Dimensional Ref.			
REF.	Min.	Nom.	Max.
A	0.445	0.495	0.545
A1	0.188	0.208	0.228
A2	0.240	0.265	0.290
A3	0.012	0.022	0.032
D	1.785	1.810	1.835
E	1.285	1.310	1.335
D1	1.150	1.200	1.250
E1	0.750	0.800	0.850
b	0.230	0.260	0.290
e	0.40 BSC		
SD	0.20 BSC		
SE	0.00 BSC		
Tol. of Form&Position			
aaa	0.05		
bbb	0.05		
ccc	0.05		
ddd	0.05		

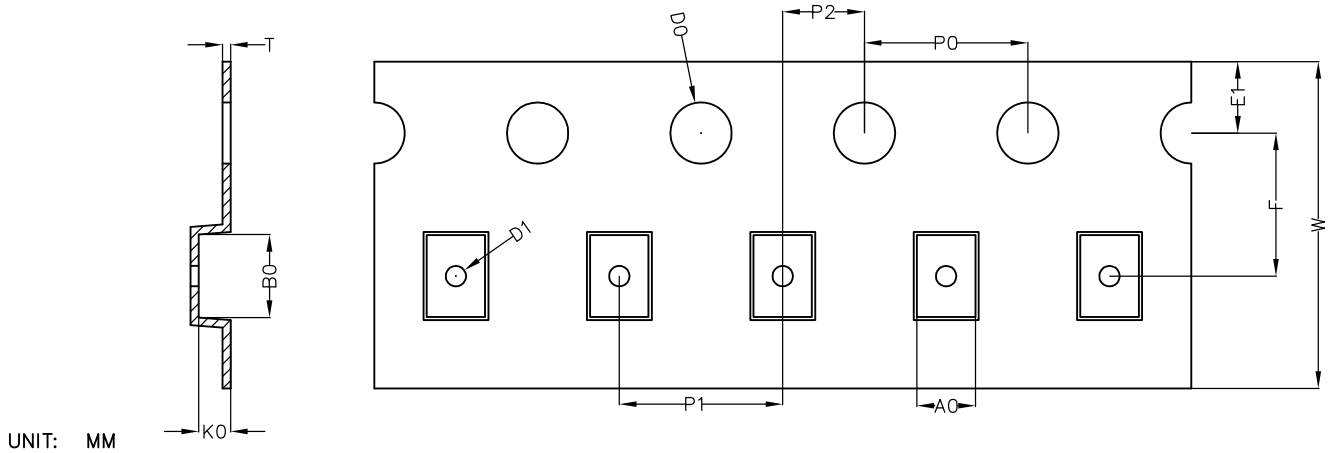


Notes

1. ALL DIMENSIONS ARE IN MILLIMETERS (ANGLES IN DEGREES).
2. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M-1994.

Tape and Reel Drawing, 1.81x1.31-12, Array WLCSP

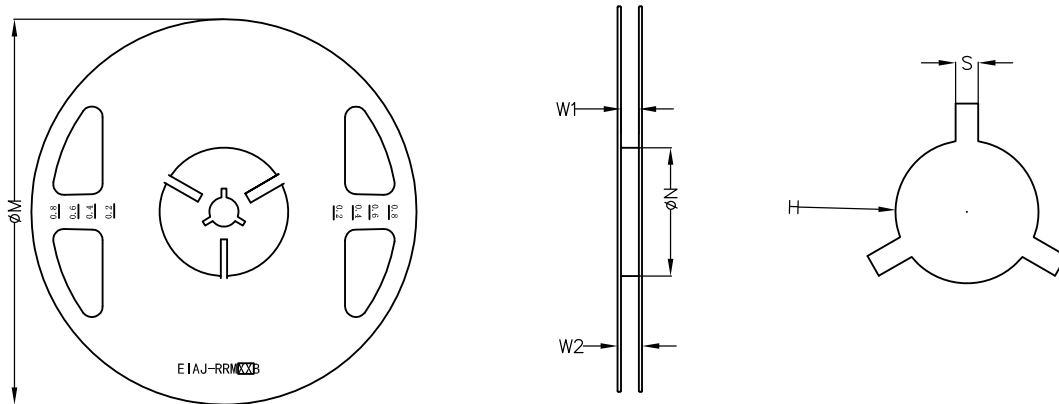
WLCSP1.81x1.31_12 Carrier Tape



UNIT: MM

A0	B0	K0	D0	D1	W	E1	F	P0	P1	P2	T
1.43 ±0.05	2.00 ±0.05	0.78 ±0.05	1.50 +0.10 -0.00	0.50 ±0.05	8.00 +0.30 -0.10	1.75 ±0.10	3.50 ±0.05	4.00 ±0.10	4.00 ±0.10	2.00 ±0.05	0.20 ±0.02

WLCSP1.81x1.31_12 REEL



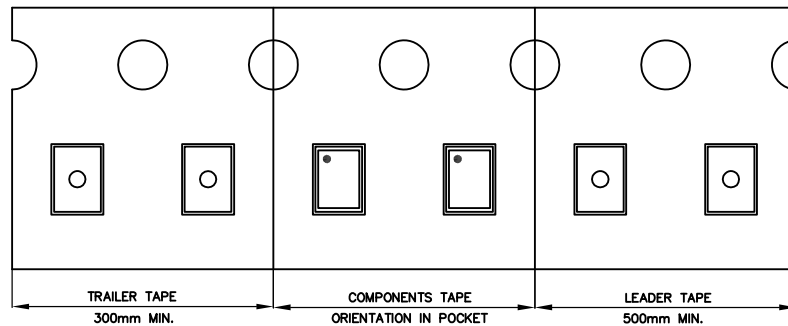
UNIT: MM

TAPE SIZE	REEL SIZE	M	N	W1	W2	H	S
8	ø180	ø180.0 +0.0 -1.0	ø60.0 +1.0 -0.0	9.0 +1.0 -0.0	11.4 +1.0 -0.0	ø13.0 ±0.2	2.0 ±0.5

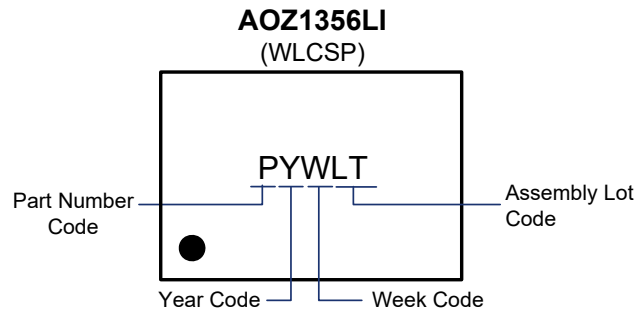
WLCSP1.81x1.31_12 TAPE

Leader / Trailer
& Orientation

Unit Per Reel:
3000pcs



Part Marking



Part Number	Description	Code
AOZ1356LI-01	Green Product	K
AOZ1356LI-02	Green Product	F
AOZ1356LI-05	Green Product	L
AOZ1356LI-06	Green Product	N

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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.