General Description

AOZ1358LI-01 is a current-limiting protection switch for USB Type-C PD current-sourcing applications. The input operating voltage range is from 3.8V to 5.5V and the VOUT terminal is rated at 29V absolute maximum to protect the device when used in high voltage PD applications. There is an internal current-limiting circuit to protect the supply from large load currents. The current limit threshold is set with an external resistor. The device also has an internal soft-start circuit to control inrush current due to highly capacitive loads.

AOZ1358LI-01 supports USB PD Fast Role Swap (FRS). When FON pin is high, the device is in fast-turn-on mode to ensure output voltage rises quickly to meet the USB PD specification.

AOZ1358LI-01 features Ideal Diode Reverse-Current Blocking (IDRCB) protection to prevent reverse current flow from VOUT to VIN at any load. This feature complies with the USB PD specification. The device also features fast recovery from reverse blocking to prevent excessive VOUT droop in power swap applications

The device offers other protection features including surge protection, Under-Voltage LockOut (UVLO), Short Circuit Protection (SCP) and Thermal Shut Down (TSD).

AOZ1358LI-01 is available in 2.01mm x 2.05mm WLCSP package with 0.5mm pitch and 16 bumps.

Features

- 29V abs max rating on VOUT pin
- 3.8V to 5.5V operating input voltage
- Typical R_{ON} = 34mΩ
- Supports USB PD Fast Role Swap (FRS)
- Programmable current limit
- Ideal Diode Reverse-Current Blocking (IDRCB)
- Internal soft-start
- Short-Circuit Protection (SCP)
- Input Under-Voltage LockOut (UVLO)
- Thermal shutdown protection
- ±8kV IEC 61000-4-2 on VOUT
- ±4kV HBM rating
- ±1kV CDM rating
- ±80V IEC 61000-4-5 surge protection on VOUT
- IEC 62368-1:2018 Certification Number US-35581-UL

Applications

- USB PD power source switch
- Notebooks, ultrabooks and desktops
- Portable devices, tablets
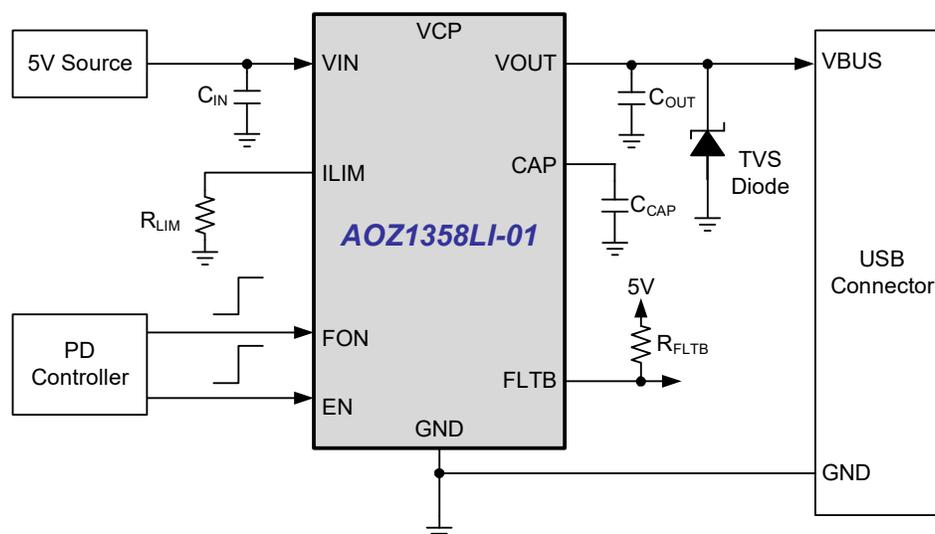
Green Product

Ordering Information

Part Number	Operating Voltage Range	Package	Environmental
AOZ1358LI-01	3.8V to 5.5V	2.01x2.05WLCSP-16L	RoHS

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
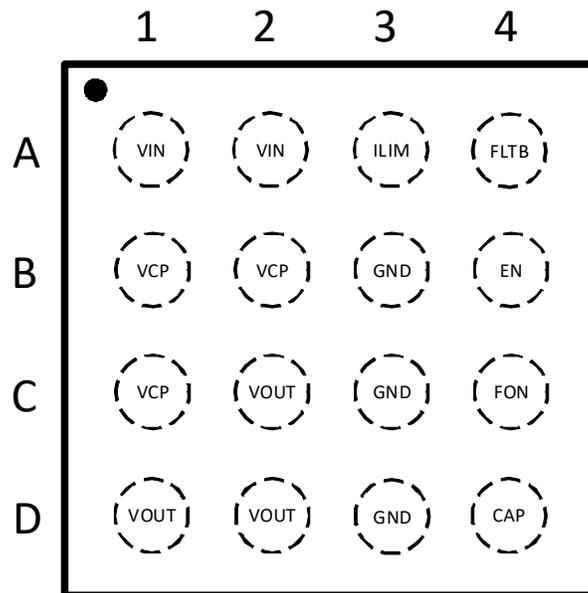
WLCSP-16 2.01mm x 2.05mm 0.5mm pitch
(Top Transparent View)

Pin Description

Pin Number	Pin Name	Pin Function
A1, A2	VIN	Supply input. Connect to output of internal regulator.
B1, B2, C1	VCP	Central point of integrated back-to-back power MOSFETs. These pins should be left floating
C2, D1, D2	VOUT	Power output. For USB Type C, connect to VBUS.
A3	ILIM	Current limit setting pin. Connect a 1% (R_{LIM}) resistor from ILIM to GND to set the current limit.
A4	FLTB	Fault condition indicator, open-drain output.
B4	EN	Enable input. Active High. Internally pulled down to GND with 1MΩ resistor.
B3, C3, D3	GND	Ground.
C4	FON	Fast turn-on. Active High. Pull high to enable fast turn-on mode. Internally pulled down to GND with a 1MΩ resistor.
D4	CAP	Connect a capacitor from CAP to GND.

Absolute Maximum Ratings

Exceeding the Absolute Maximum ratings may damage the device.

Parameter	Rating
VOUT to GND	-0.3V to 29V
VOUT to GND Transient 20us pulse, 1ms period	34V
VIN, EN, FON, ILIM, FLTB, VCP, CAP to GND	-0.3V to 6V
Maximum Junction Temperature (T_J)	+150°C
Storage Temperature (T_S)	-65 °C to +150°C
IEC 61000-4-2 Rating for VOUT	±8kV
ESD Rating for other pins HBM/CDM	±4kV / ±1kV

Recommended Operating Conditions

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

Parameter	Rating
VIN to GND	3.8V to 5.5V
VOUT to GND	0V to 23V
EN, FON, ILIM, FTLB, VCP, CAP to GND	0V to 5.5V
DC Switch Current (I_{SW})	0A to 3.5A
VOUT Capacitance (C_{OUT})	10μF
Ambient Temperature (T_A)	-40°C to +85°C
Package Thermal Resistance	58°C/W

Electrical Characteristics

T_A = 25°C, VIN = 5V, EN = 5V, FON = 0V, R_{LIM} = 47.5kΩ unless otherwise specified.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Units
GENERAL						
V_{IN}	Input Supply Voltage		3.8		5.5	V
V_{UVLO_R}	Under-Voltage Lockout Threshold	VIN rising	3.3	3.6	3.75	V
V_{UVLO_HYS}	Under-Voltage Lockout Hysteresis			250		mV
I_{IN_ON}	Input Quiescent Current	I_{OUT} = 0A		1.3	1.6	mA
I_{IN_FON}	Fast On Ready Quiescent Current	I_{OUT} = 0A, EN = 0V, FON = 5V		180	350	μA
I_{IN_OFF}	Input Shutdown Current	EN = 0V		0.1	1	μA
R_{ON}	Switch ON Resistance	I_{OUT} = 1A, R_{LIM} = 14.3kΩ		34	41	mΩ
		I_{OUT} = 1A, -40°C to +85°C [1]			49	
V_{EN_H}	Enable Input Logic High Threshold	EN rising	1.2			V
V_{EN_L}	Enable Input Logic Low Threshold	EN falling			0.4	V
I_{EN_BIAS}	Enable Input Bias Current	EN = 1.8V		1.8	4	μA
V_{FON_H}	Fast-On Logic High Threshold	FON rising	1.2			V
V_{FON_L}	Fast-On Logic Low Threshold	FON falling			0.4	V
I_{FON_BIAS}	Fast-On Input Bias Current	FON = 1.8V		1.8	4	μA
V_{FLTB_LO}	FLTB Pull-down Voltage	I_{SINK} = 3mA			0.3	V
t_{OCP_FLTB}	Over-Current Flag Delay	From $I_{OUT} \geq I_{LIM}$ to FLTB pulled low		4		ms
t_{SCP_RESP}	Short Circuit Response Time	From (VIN – VOUT) = 500mV to Switch Off		1	5	μs

Electrical Characteristics *(continued)*

T_A = 25°C, VIN = 5V, EN = 5V, FON = 0V, R_{LIM} = 47.5kΩ unless otherwise specified.

| Symbol	Parameter	Conditions	Min.	Typ.	Max.	Units
OVER-CURRENT PROTECTION						
I_{LIM}[1]	Current Limit Threshold	R_{LIM} = 14.3kΩ	3100	3300	3531	mA
		R_{LIM} = 42.2kΩ		1000		
		R_{LIM} = 75kΩ		550		
		ILIM shorted to VIN		210		
FAST REVERSE-CURRENT BLOCKING						
V_{T_FRCB}	FRCB Protection Trip Point	VOUT - VIN		25		mV
t_{FRCB}	FRCB Response Time	VOUT increasing at 300mV/µs		0.5		µs
t_{RCB_OFF}	RCB Recovery Time	Exiting from RCB conditions. C_{OUT} =1µF, R_{OUT} =100Ω			50	µs
THERMAL SHUTDOWN						
T_{SD}	Thermal Shutdown Threshold	Temperature rising		140		°C
T_{SD_HYS}	Thermal Shutdown Hysteresis			20		°C
DYNAMIC						
t_{D_ON}	Turn-On Delay Time	From EN = V_{EN_H} to VOUT = 10% C_{OUT} =1µF, R_{OUT} =100Ω, R_{LIM} = 14.3kΩ		0.9		ms
t_{ON}	Turn-On Time	VOUT from 10% to 90% C_{OUT} =1µF, R_{OUT} =100Ω, R_{LIM} = 14.3kΩ		2		ms
t_{FON}	Fast Role Swap Turn-On Time	From EN = V_{EN_H} to VOUT = 95% FON=5V, C_{OUT} =1µF, R_{OUT} =100Ω, R_{LIM} = 14.3kΩ		60	100	µs
t_{S_FON}	Fast Role Swap Setup Time	From FON = V_{FON_H} to EN = V_{EN_H}	50			µs
t_{H_FON}	Fast Role Swap Hold Time	From EN=V_{EN_H} and FON must be held logic high for the FRS state to be recognized and latched	50			µs

Note:

1. Guaranteed by characterization and design

Functional Block Diagram
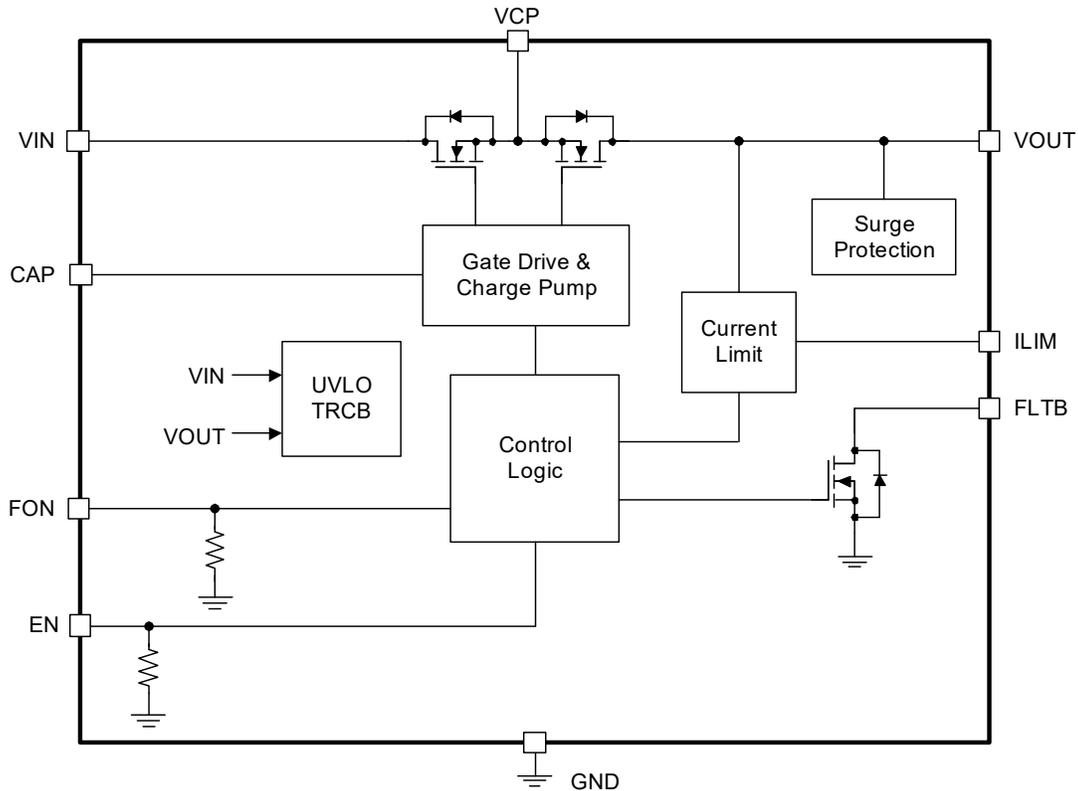
EN	FON	Conditions	FLTB	Power Switch
L	L	VIN: 0V to 5.5V	Hi-Z	Shutdown mode. Switch is off.
H	X	VIN < 3V	Hi-Z	UVLO. Switch is off.
H	L	VIN: 3.8V to 5.5V	Hi-Z	Enabled, Switch turns on with soft-start.
H	H	VIN: 3.8V to 5.5V	Hi-Z	Enabled with Fast switch Turn-On. (Support FRS)
H	X	Over-current; VIN: 3.8V to 5.5V	Low	Device in OCP protection mode. Output current is limited.
H	X	Over-temperature; VIN: 3.8V to 5.5V	Low	Device in Thermal shutdown mode. Switch is OFF.
H	X	VIN: 3.8V to 5.5V; VOUT > VIN	Hi-Z	Device in RCB protection mode. Switch is OFF.
L	H	VIN: 3.8V to 5.5V	Hi-Z	Standby mode.

Timing Diagrams
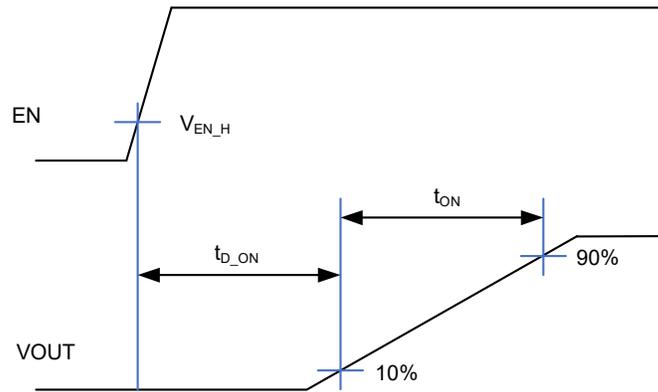
Figure 1. Normal Turn-On Delay and Turn-On Time (FON=0V)
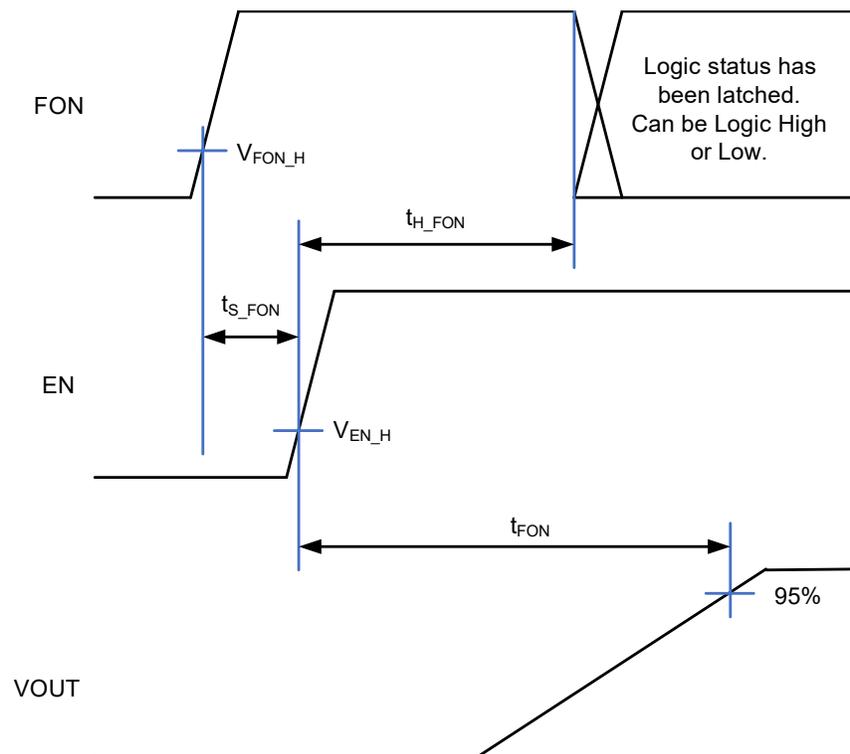
Figure 2. Fast Turn-On Time for Fast Role Swap Function (FON=5V)

Timing Diagrams *(continued)*
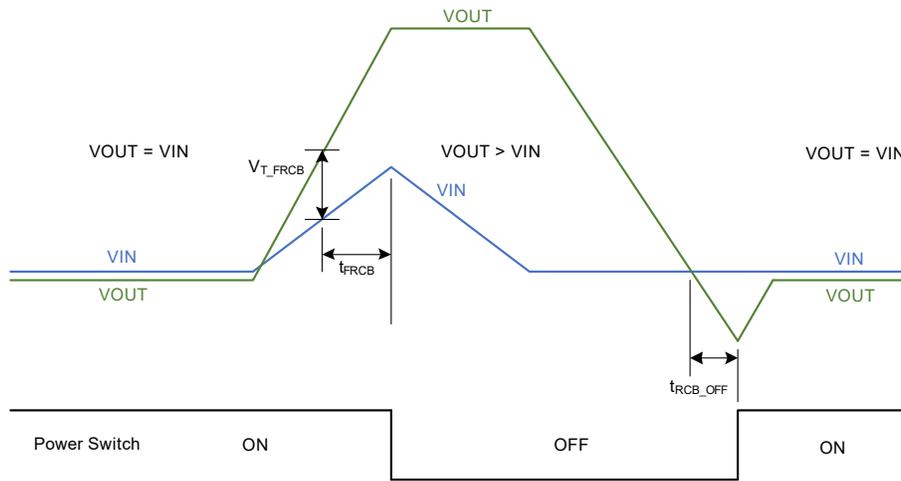
Figure 3. Fast Reverse-Current Blocking (FRCB) Operation

Typical Characteristics

T_A = 25°C, VIN = 5V, EN = 5V, FON floating, C_{IN} = 56µF, C_{OUT} = 10µF, R_{LIM} =14.3kΩ, no load, unless otherwise specified.
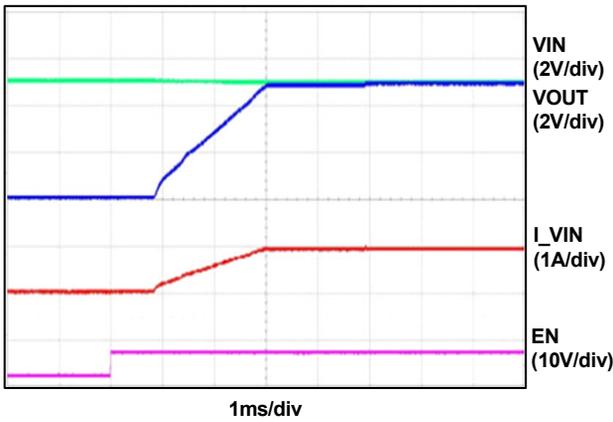
**Figure 4. Soft Start by EN
with 5Ω Load**
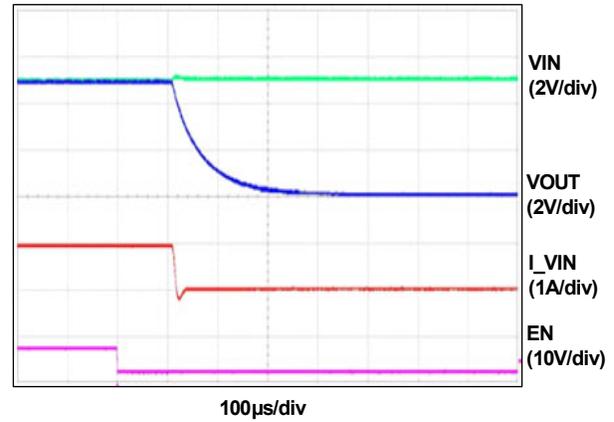
**Figure 5. Shutdown by EN
with 5Ω Load**
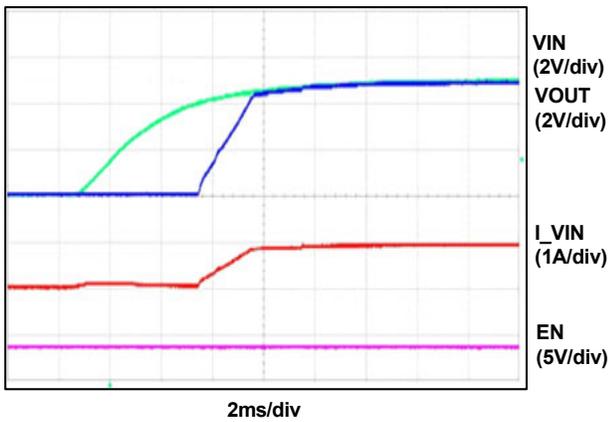
**Figure 6. Soft Start by VIN Ramp
with 5Ω Load**
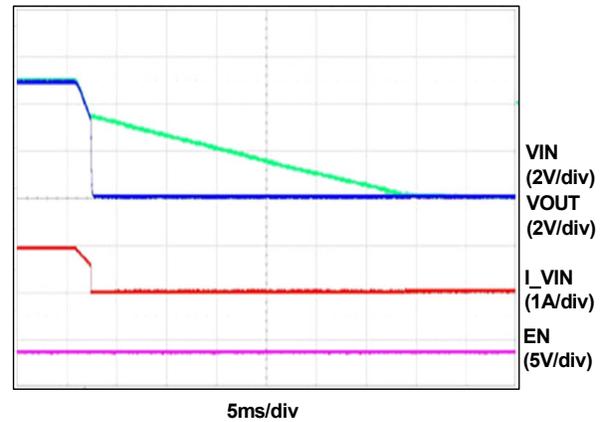
**Figure 7. Shutdown by VIN Ramp
with 5Ω Load**
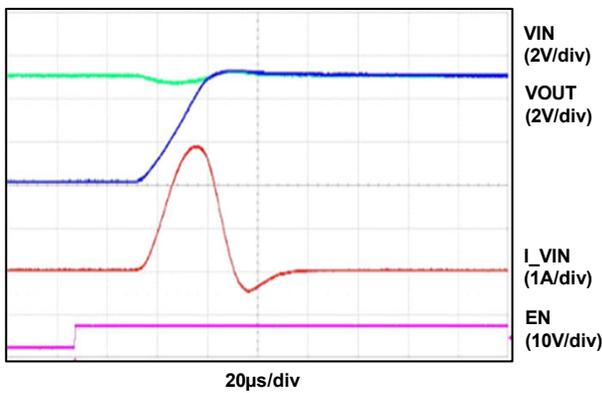
**Figure 8. Fast Start by EN
(FON = 5V)**
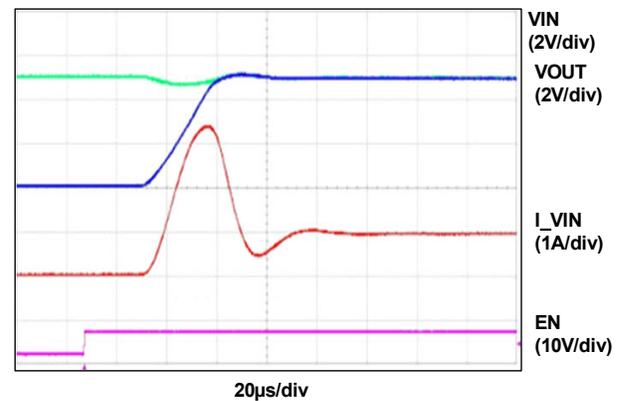
**Figure 9. Fast Start by EN with
5Ω Load (FON = 5V)**

Typical Characteristics *(continued)*

T_A = 25°C, VIN = 5V, EN = 5V, FON floating, C_{IN} = 56µF, C_{OUT} = 10µF, R_{LIM} =14.3kΩ, no load, unless otherwise specified.
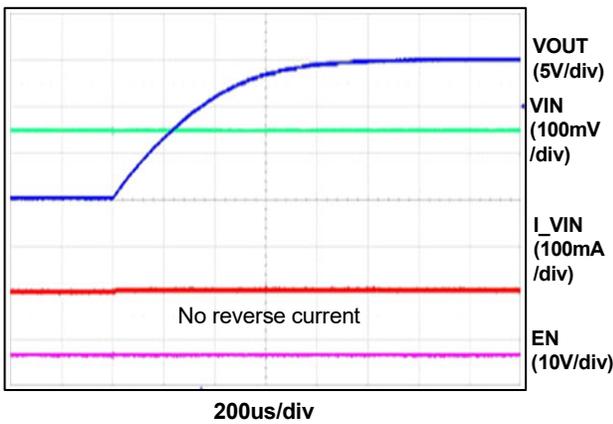
Figure 10. Slow Reverse-Current Blocking
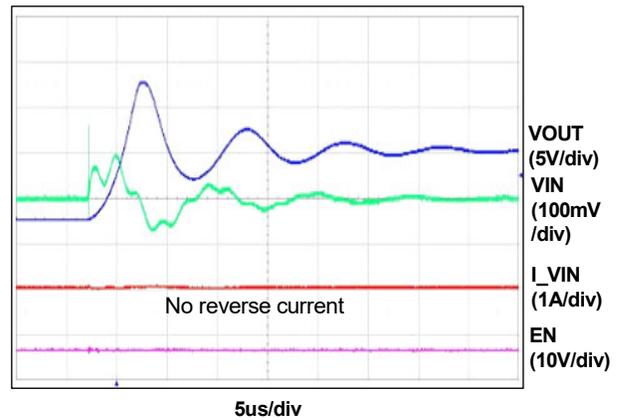
Figure 11. Fast Reverse-Current Blocking
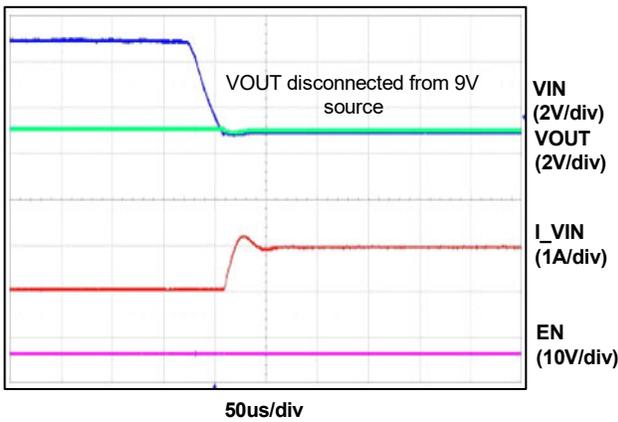
Figure 12. Reverse-Current Blocking Recovery with 5Ω Load
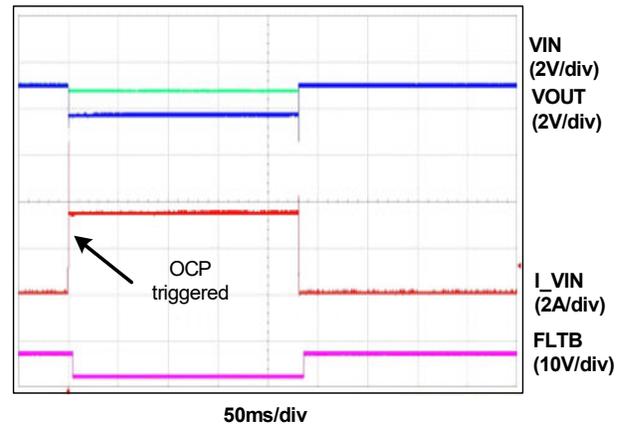
Figure 13. Output Load Step Response
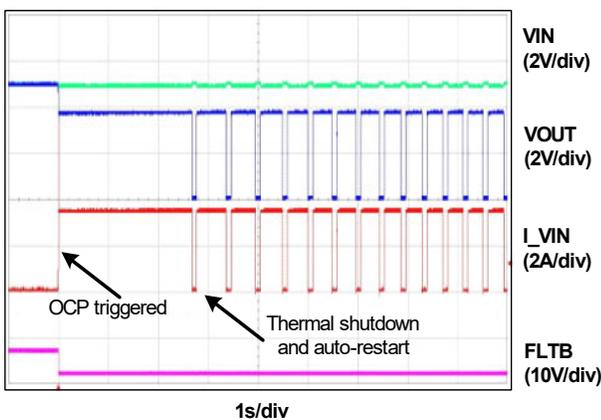
Figure 14. Over-Current FLTB Response
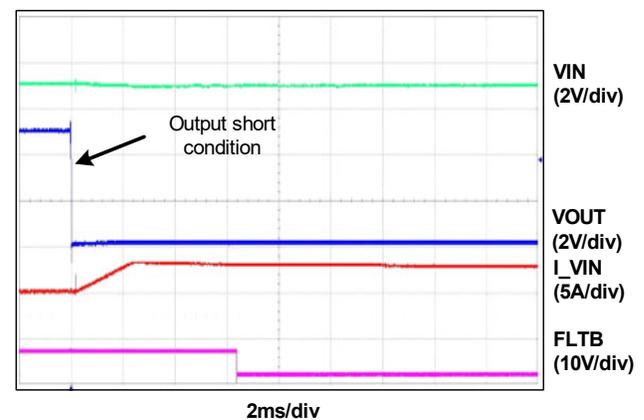
Figure 15. Over-Current and Thermal Shutdown Response

Typical Characteristics *(continued)*

T_A = 25°C, VIN = 5V, EN = 5V, FON floating, C_{IN} = 56µF, C_{OUT} = 10µF, R_{LIM} =14.3kΩ, no load, unless otherwise specified.
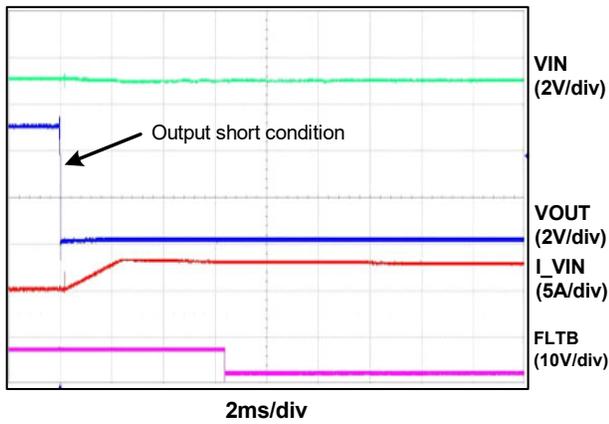
Figure 16. Short-Circuit Response
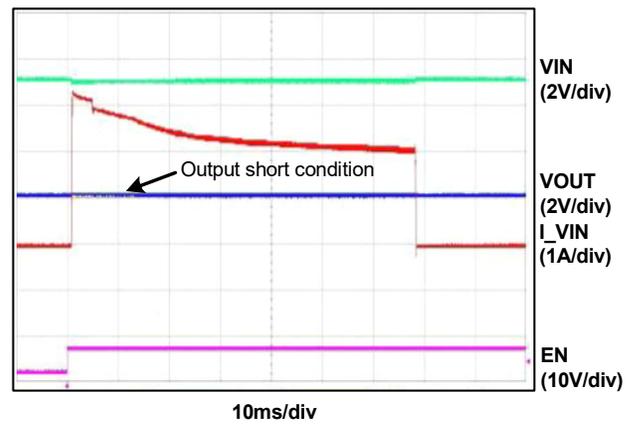
Figure 17. Start Up to Short Circuit Condition with Load Shorted to GND
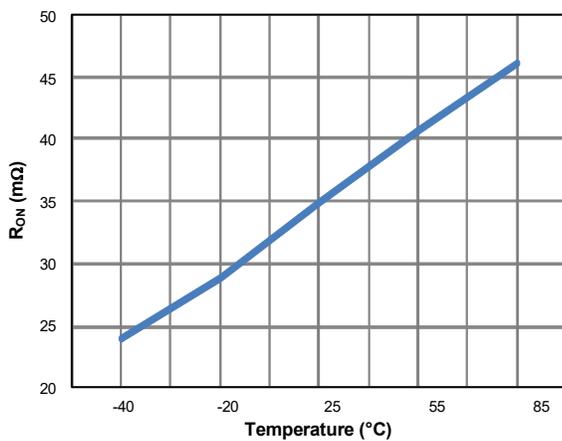
Figure 18. RON vs Temperature
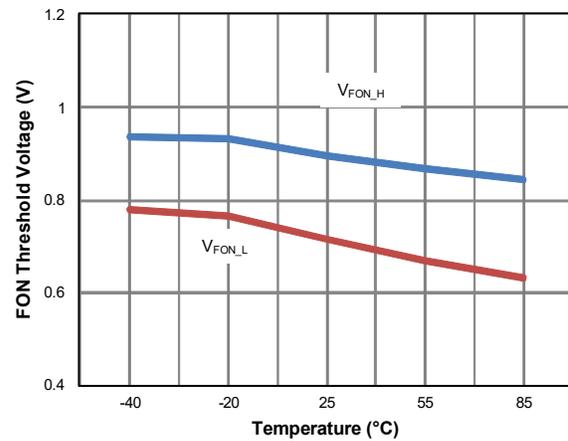
Figure 19. FON Threshold vs Temperature
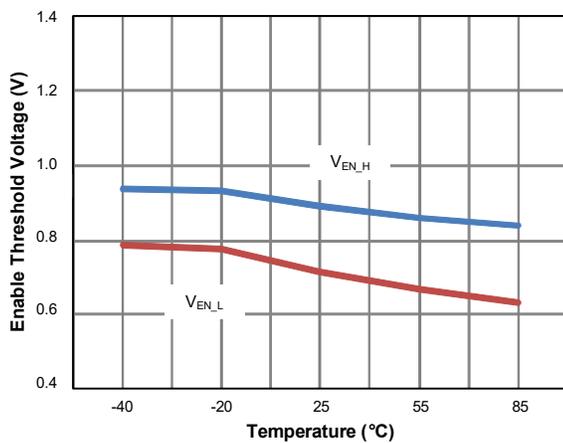
Figure 20. EN Threshold vs Temperature

Application Information

The AOZ1358LI-01 is a current-limited power switch with over-voltage, over-current, and reverse-current blocking as well as thermal shutdown protections. The VOUT pin is rated at 29V absolute maximum. The operating input voltage ranges from 3.8V to 5.5V.

The device has an Ideal Diode Reverse-Current Blocking (IDRCB) feature that will prevent undesired current flow from the output port to the input port in either enabled or disabled state.

Fast Role Swap Function (FON = Logic High)

The device supports the USB PD Fast Role Swap (FRS) function. FRS assures that the device will transition the USB VBUS from sinking power to sourcing power within 150µs in order to prevent any power interruption to the external system connected through the USB port.

In order to perform the FRS in <150µs, FON must be logic high for 50µs (t_{S_FON}) before EN goes to logic high. Also, FON must remain logic high for 100µs (t_{H_FON}) after EN is logic high. AOZ1358LI-01 can achieve $\overline{FRS}$ in 100µs because the FON function has already gone through internal setup by the time EN goes logic high.

If FON and EN are tied together, the FRS function will complete in 150µs.

Normal Soft Start (FON = Logic Low)

AOZ1358LI-01 will soft start normally when EN is logic high while FON is held at logic low. Typical soft start time is internally controlled and it is set at 2ms.

Enable

The EN pin is the ON/OFF control for the power switch. The device is enabled when EN pin is logic high and VIN is above the under-voltage lockout threshold (V_{UVLO_R}). The EN pin must be driven to a logic high or logic low state to guarantee operation. When the part is disabled and FON is logic low, it draws less than 1µA from power supply.

Input Under-Voltage Lockout (UVLO)

The under-voltage lockout (UVLO) circuit monitors the VIN input voltage. The power switch is only allowed to turn on when input voltage is higher than UVLO threshold (V_{UVLO_R}) even if EN is logic high.

Programmable Current Limit and Over-Current Protection (OCP)

The AOZ1358LI-01 current limit feature ensures that the current through the switch does not exceed the current limit threshold set by the external resistor R_{LIM}.

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

$$I_{LIM} = \frac{47200}{R_{LIM}}$$

I_{LIM} unit: Ampere

R_{LIM} unit: Ohm

For example, for 3.3A current limit threshold, a 14.3kΩ R_{LIM} resistor should be selected. A 1% resistor is recommended for R_{LIM}.

AOZ1358LI-01 continuously limits the output current when output is overloaded. During current limiting, FLTB will be pulled low after blanking delay time (t_{OCP_FLTB}). Severe overload will generate excessive power dissipation and die temperature will increase and it may trigger thermal shutdown.

AOZ1358LI-01 allows 2x current limit set by the R_{LIM} for the first 150µs after the initial current limit threshold is exceeded. The current limit will decrease linearly from 2X to 1X threshold within this 150us time period as shown in Figure 21. The device will limit the current to the value set by R_{LIM} after the first 150µs is expired. This is to avoid current limit and possible shutdown due to transient over current during plug-in.

If VOUT < 3V under heavy load condition, current limit will foldback by 12% to maintain current sense linearity and reduce power dissipation.
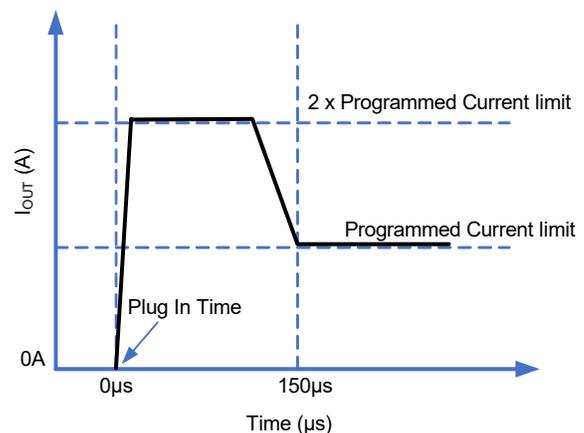

Figure 21. I_{LIM} vs Time Upon Initial OCP Condition

Ideal Diode Reverse-Current Blocking Protection (IDRCB)

AOZ1358LI-01 uses an ideal diode gate control loop to implement the reverse-current blocking function. The device regulates the VOUT output voltage to 70mV below VCP.

When the load current is high enough that the voltage drop from VCP to VOUT is greater than 70mV, the ideal diode gate control loop will fully turn on the power MOSFET and R_{ON} is at the lowest. If the load is reducing, the gate control loop will increase the R_{ON} to prevent the (VCP – VOUT) to drop below 70mV. Once (VCP – VOUT) drops below the 70mV threshold the power MOSFET turns off and prevents current flow in the reverse voltage condition.

In fast reverse-current conditions, the ideal diode might not be quick enough to block the current. AOZ1358LI-01 has integrated a fast comparator to quickly turn off the power MOSFET when fast RCB event happens.

If VOUT voltage is higher than VIN when the device is enabled, the power MOSFET will not turn on. The part will always check (VOUT–VIN) condition before switching on the power MOSFET.

When the device is enabled and VOUT drops below VIN, the device will exit the RCB and turn on the power MOSFET within 50µs (t_{RCB_OFF}).

The fast recovery of the power MOSFET is assisted by the external boost capacitor at CAP pin. The boost capacitor will be charged whenever EN is set to logic high.

AOZ1358LI-01 protects VIN voltage from rising due to reverse current both in cases of slowly rising output or hot plug-in.

Soft-Start

The AOZ1358LI-01 has internal soft-start circuitry to limit in- rush current due to large capacitive load. The soft start time is internally set at 2ms (t_{ON}) nominal.

Thermal Shutdown Protection

Thermal shutdown protects device from excessive temperature. The power MOSFET is turned off when the die temperature reaches thermal shutdown threshold of 140°C. After a 20°C hysteresis, the power MOSFET turns on again.

Startup

The device is enabled when EN ≥ V_{EN_H} and VIN > V_{ULVO_R}. The device first checks if any fault condition exists. If no fault exists, the power MOSFET is turned on and the output is started to ramp up. The power MOSFET will be kept off if any fault condition is detected.

Fault Reporting

AOZ1358LI-01 protects itself and its load from the following fault condition: Over-Current and Over-Temperature.

The FLTB pin is an open drain fault flag output. It is asserted low when either over-current and/or over-temperature condition is detected. The FLTB pin becomes high impedance when the fault conditions are removed. A pull-up resistor (R_{FLTB}) must be used.

When thermal shutdown is activated, FLTB is pulled low immediately to report the fault condition to host. FLTB becomes high impedance again once the fault is removed. In case of an output overload, the FLTB pin is pulled low 4ms (t_{OCP_FLTB}) after device is in current limiting.

FLTB will remain low if the device exits thermal shut-down but still in current-limiting.

There is no fault reporting for UVLO or IDRCB events. The power MOSFET is turned on immediately after a IDRCB event is removed.

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 value of 1µF of ceramic capacitors should be used. However, a higher capacitor value is strongly recommended to further reduce the transient voltage drop at the input.

Output Capacitor Selection

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 loads in order to prevent the output from dropping.

Power Dissipation Calculation

The power dissipation for normal load condition can be calculated using the following equation:

$$Power\ Dissipated = (VIN - VOUT) \times I_{OUT}$$

PCB Layout Guidelines

Good PCB layout is important for improving the thermal and overall performance of AOZ1358LI-01. 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. It is recommended to place the input C_{IN} and output C_{OUT} 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, WLCSP 2.01mm x 2.05mm - 16 Bump Array

TOP VIEW

BOTTOM VIEW

SIDE VIEW

RECOMMENDED LAND PATTERN
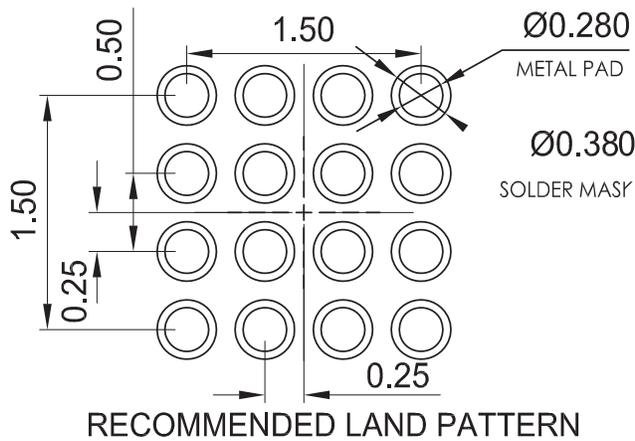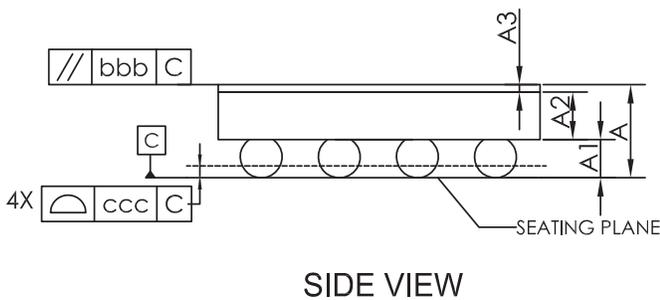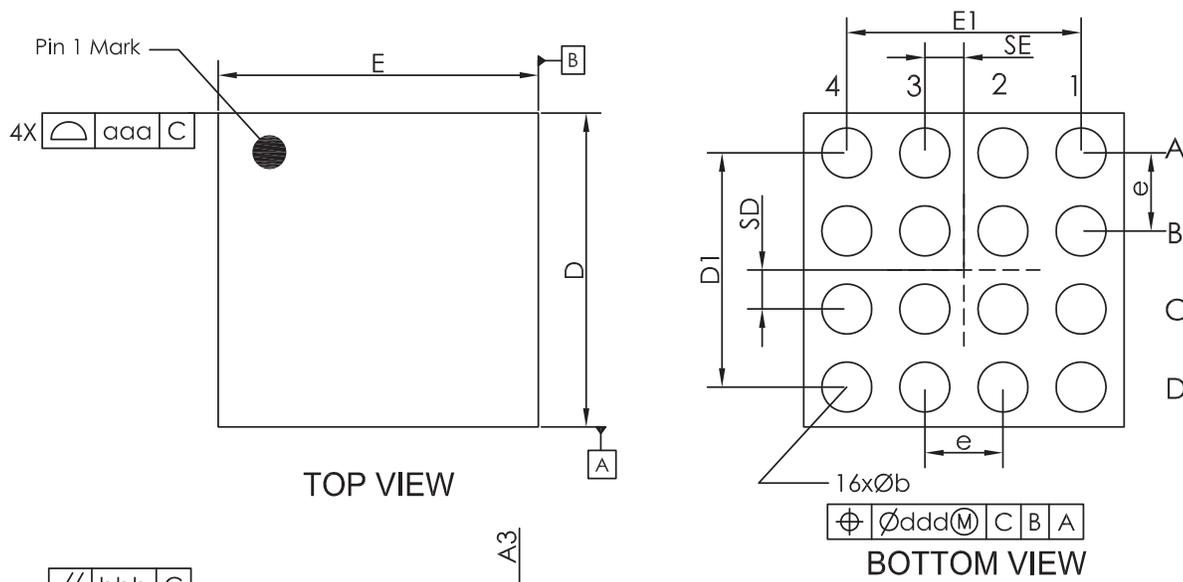
SYMBOL	DIMENSION IN MM			DIMENSION IN INCH		
	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.
A	0.505	0.555	0.605	0.0199	0.0219	0.0238
A1	0.210	0.230	0.250	0.0083	0.0091	0.0098
A2	0.275	0.300	0.325	0.0108	0.0118	0.0128
A3	0.020	0.025	0.030	0.0008	0.0010	0.0012
D	1.985	2.010	2.035	0.0781	0.0791	0.0801
D1	1.450	1.500	1.550	0.0571	0.0591	0.0610
E	2.025	2.050	2.075	0.0797	0.0807	0.0817
E1	1.450	1.500	1.550	0.0571	0.0591	0.0610
b	0.290	0.320	0.350	0.0114	0.0126	0.0138
e	0.500 BSC.			0.0157 BSC.		
SD	0.250 BSC.			0.0079 BSC.		
SE	0.250 BSC.			0.0000 BSC.		
Tol. of Form&Position				Tol. of Form&Position		
aaa	0.05			0.0020		
bbb	0.05			0.0020		
ccc	0.05			0.0020		
ddd	0.05			0.0020		

NOTES:
1.CONTROLLED DIMENSIONS ARE IN MILLIMETERS.
2.TOP VIEW IS THE VIEW OF TOP SURFACE OF THE PART HAVING INDEX AND PART NUMBER MARKING.

Tape and Reel Drawing, WLCSP 2.01mm x 2.05mm - 16 Bump Array

WLCSP2.05x2.01_16 Carrier Tape
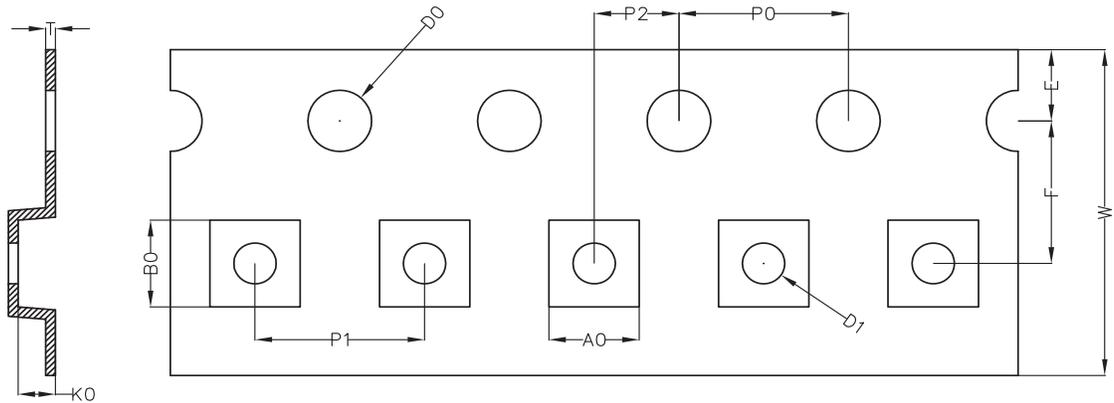
UNIT: MM

| PACKAGE	A0	B0	K0	D0	D1	W	E	F	P0	P1	P2	T
WLCS2.05x2.01_16	2.13 ±0.05	2.13 ±0.05	0.88 ±0.05	1.50 +0.10 −0.00	1.00 ±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	0.23 ±0.02

WLCSP2.05x2.01_16 REEL

EIAJ
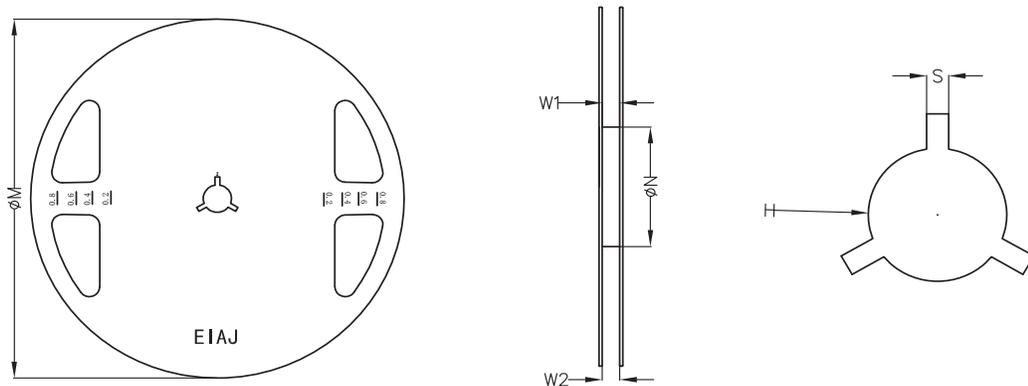
UNIT: MM

TAPE SIZE	REEL SIZE	M	N	W1	W2	H	S
8	Ø180	Ø180.0 ±2.0	Ø60.0 ±1.0	9.0 +0.0 −1.0	9.0 +1.5 −0.0	Ø13.0 ±0.20	2.00 ±0.50

WLCSP2.05x2.01_16 TAPE

Leader / Trailer
& Orientation

Unit Per Reel:
3000pcs

TRAILER TAPE
300mm MIN.

COMPONENTS TAPE
ORIENTATION IN POCKET

LEADER TAPE
500mm MIN.

Feeding Direction

Part Marking

AOZ1358LI-01
(WLCSP)

PYWLT

Part Number Code ——————— ┌┐ ┌┐ ┌───— Assembly Lot Code

●

Year Code ——————— └┘ └——— Week Code
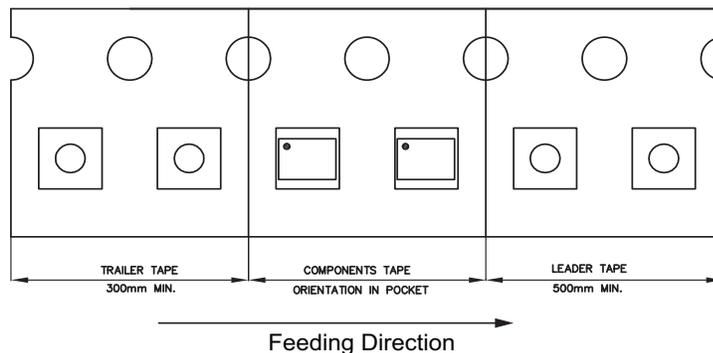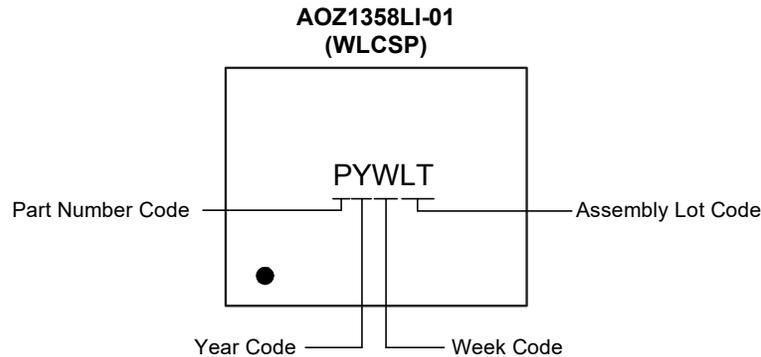
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1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body or (b) support or sustain life, and (c) whose failure to perform when properly used in accordance with instructions for use provided 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.