ALPHA & OMEGA
SEMICONDUCTOR

5V/3A ECPower™ Smart Current Limited Load Switch
with True Reverse-Current Blocking

General Description

The AOZ1353DI is a current-limited load switch targeting applications that require comprehensive protections. The input operating voltage range is between 3.4V and 5.5V. 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 soft-start circuit controls inrush current due to highly capacitive loads. The soft-start time can be optionally adjusted with an external capacitor. The device features very low quiescent current of 80µA. The supply current reduces to less than 1µA in shutdown. It also has under-voltage lockout (UVLO), over-voltage protection (OVP) and thermal shutdown protection.

The AOZ1353DI has True Reverse-Current Blocking (TRCB) protection to avoid undesired reverse-current from VOUT to VIN.

The device features fast recovery to turn on power switch once reverse current blocking protection is de-activated.

The AOZ1353DI is available in 3mm x 3mm DFN-12L package.

Features

- 28V voltage rating on VOUT pin
- 3.4V to 5.5V operating input voltage
- 3.5A current capability
- Typical R_{ON}: 40mΩ
- Programmable current limit
- True Reverse-Current Blocking (TRCB)
- Fast recovery from TRCB
- Adjustable soft-start
- 80µA quiescent current
- Over-voltage protection
- Input under-voltage lockout
- Thermal shutdown protection
- ±4kV HBM rating
- ±1kV CDM Rating
- 3mm x 3mm DFN-12L Package
- UL2367 file no. E326264
- IEC60950 CB Certificate no. US-31249-UL

Applications

- USB PD power source switch
- Smart phone and tablet
- Notebook, ultrabook and desktop
- Portable devices

Typical Application
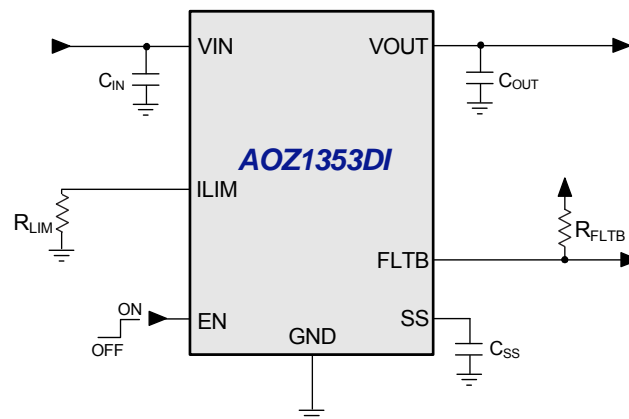
Ordering Information

Part Number	Fault Recovery	Package	Environmental
AOZ1353DI-01	Auto-Restart	3mm x 3mm DFN-12L	RoHS
AOZ1353DI-02	Latch-Off	3mm x 3mm DFN-12L	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
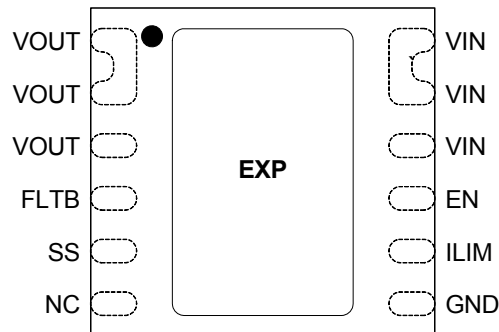
3mm x 3mm DFN-12L
(Top Transparent View)

Pin Description

Pin Number	Pin Name	Pin Function
1, 2, 3	VOUT	Power output. Connect to adaptor. Pin 3 is internally connected to pin 1 and pin 2.
4	FLTB	Fault indicator, open-drain output, active-low when fault condition occurs.
5	SS	Soft-start pin. Connect a capacitor C_{SS} from SS to GND to set the soft-start time or short to GND for fixed-time soft-start.
6	NC	Not connected internally. Can leave it floated or connect to GND.
7	GND	Ground
8	ILIM	Current limit set pin. Connect a 1% resistor R_{LIM} from ILIM to GND to set the current limit threshold.
9	EN	Enable input. Active high.
10, 11, 12	VIN	Supply input. Connected to internal power regulator. Pin 10 is internally connected to pin 11 and pin 12.
EXP	EXP	Exposed pad. Connect to GND.

Absolute Maximum Ratings

Exceeding the Absolute Maximum Ratings may damage the device.

Parameter	Rating
VOUT to GND	-0.3V to +28V
VIN, EN, ILIM, SS, FLTB to GND	-0.3V 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
VIN to GND	3.4V to 5.5V
EN, FLTB to GND	0V to 5.5V
Switch Current (I_{SW})	0A to 3.5A
Ambient Temperature (T_A)	-40°C to +85°C
Package Thermal Resistance	50°C/W

Electrical Characteristics

T_A = 25°C, V_{IN} = 5V, SS pin is shorted to GND unless otherwise specified.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Units
General						
V_{IN}	Input Supply Voltage		3.4		5.5	V
V_{UVLO_R}	Under-voltage Lockout Threshold	VIN rising	3	3.25	3.35	V
V_{UVLO_HYS}	Under-voltage Lockout Hysteresis	VIN falling		150		mV
I_{IN_ON}	Input Quiescent Current	VIN = 5V, I_{OUT} = 0A, EN = 5V		80		µA
I_{IN_OFF}	Input Shutdown Current	VIN = 5V, EN = 0V		0.1	1	µA
R_{ON}	Switch On Resistance	VIN = 5V, I_{OUT} = 1A		40		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_{FLTB_LO}	FLTB Pull-down Voltage	I_{SINK} = 3mA			0.3	V
Over-Voltage Protection						
V_{OVLO_R}	Over-voltage Lockout Threshold	VIN rising	5.5	5.75	6	V
V_{OVLO_F}		VIN falling		5.5		
V_{OVLO_HYS}	Over-voltage Lockout Hysteresis			250		mV
T_{DELAY_OVP}	OVP Turn-Off Delay	Time between VIN rises from 5V to 6.5V and power switch turns off		2		µs
Over-Current Protection						
I_{LIM}	Current Limit Threshold	VOUT = 5V, R_{LIM} = 4.02kΩ	3.08	3.5	3.92	A
		VOUT = 5V, R_{LIM} = 14.3kΩ	0.9	1	1.1	
		VOUT = 5V, R_{LIM} = 29.4kΩ	0.45	0.5	0.55	
T_{OCP_FLTB}	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	VOUT-VIN, VOUT rising		60		mV
V_{R_RCB}	RCB Protection Release Trip Point	VIN-VOUT, VOUT falling		70		mV
V_{RCB_HYS}	RCB Hysteresis	V_{T_RCB} + V_{R_RCB}		130		mV
T_{RCB}	RCB Response Time			2		µs

Electrical Characteristics

T_A = 25°C, V_{IN} = 5V, SS pin is shorted to GND unless otherwise specified.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Units
Thermal Shutdown						
T_{SD}	Thermal Shutdown Threshold	Temperature rising		140		°C
T_{SD_HYS}	Thermal Shutdown Hysteresis	Temperature falling		20		
Dynamic Characteristics						
T_{D_ON}	Turn-On Delay Time (From VEN 50% to VOUT=0.5V)	VIN = 5V, R_L = 100Ω, C_{OUT} = 1µF, C_{SS} = 1nF, R_{LIM} = 14.3kΩ		2.1		ms
T_{ON}	Turn-ON Time (VOUT from 0.5V to 4.5V)	VIN = 5V, R_L = 100Ω, C_{OUT} = 1µF, SS Pin grounded, R_{LIM} = 14.3kΩ		3.4		ms

Functional Block Diagram
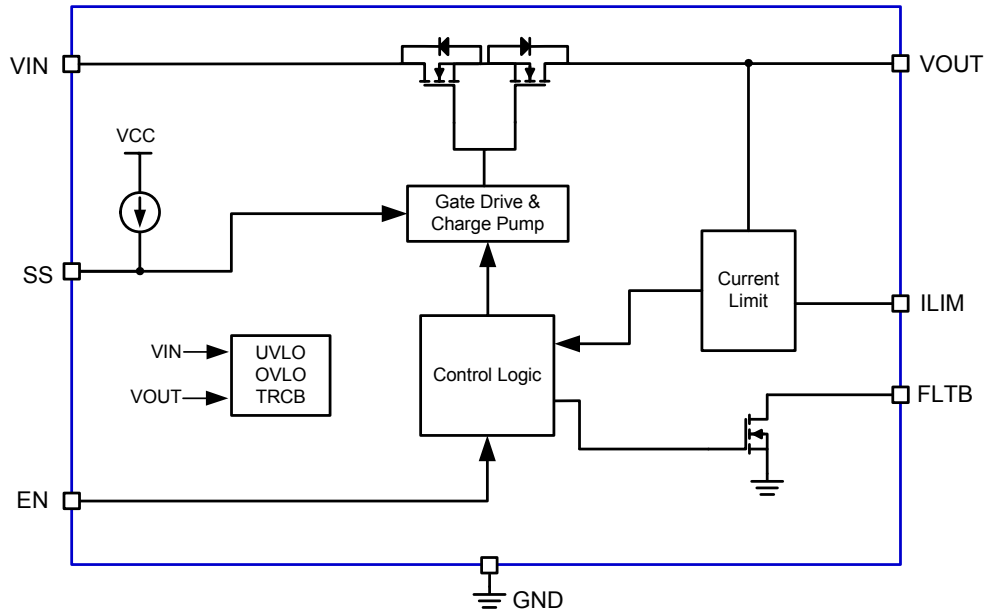
Timing Diagrams
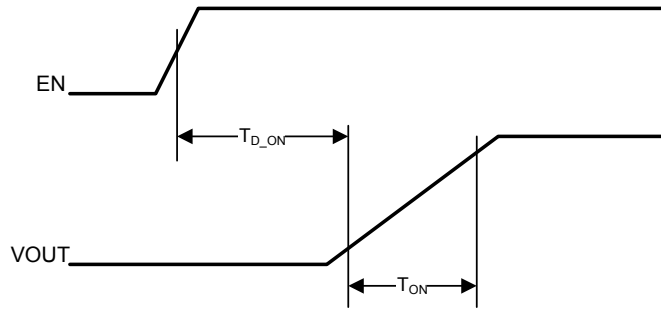
Figure 1. Turn-on Delay and Turn-on Time
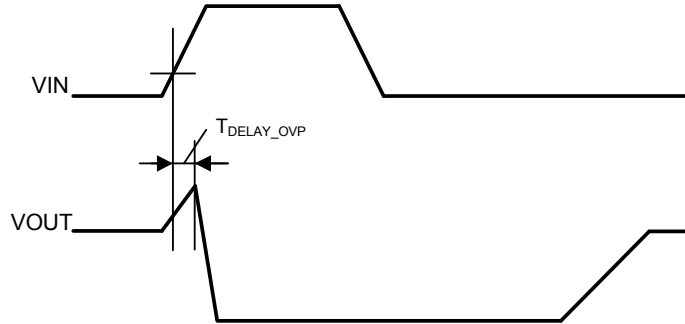
Figure 2. OVP Delay and Recovery

Typical Performance Curves

T_A = 25°C, C_{OUT} = 20μF, R_{LIM} = 4.02kΩ, SS pin shorted to GND unless otherwise specified.

Figure 3. Startup by EN (R_{Load} = 1.6Ω)
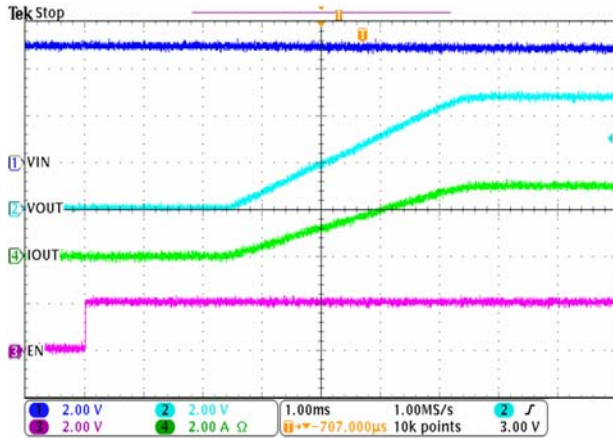
Figure 4. Shutdown by EN (R_{Load} = 1.6Ω)
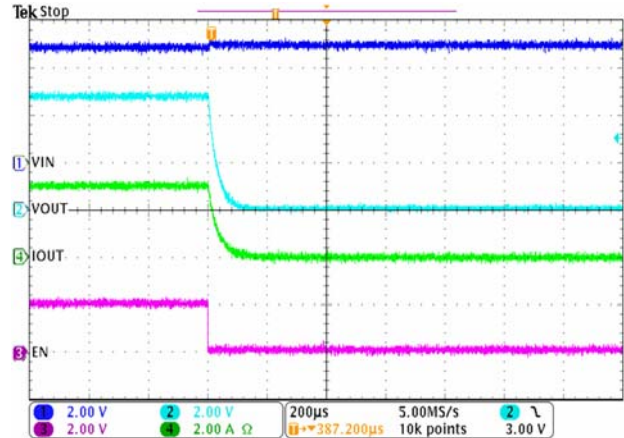
Figure 5. Startup by VIN (R_{Load} = 1.6Ω)
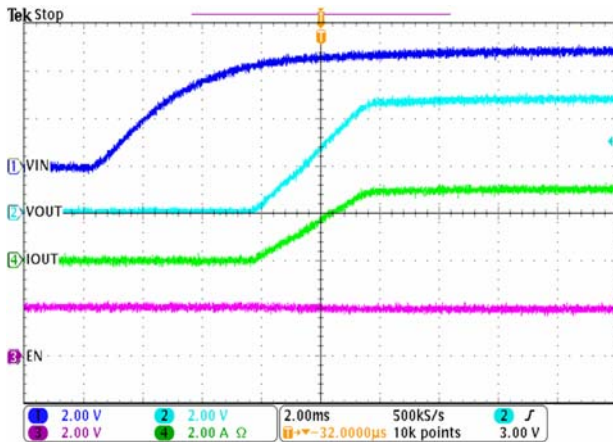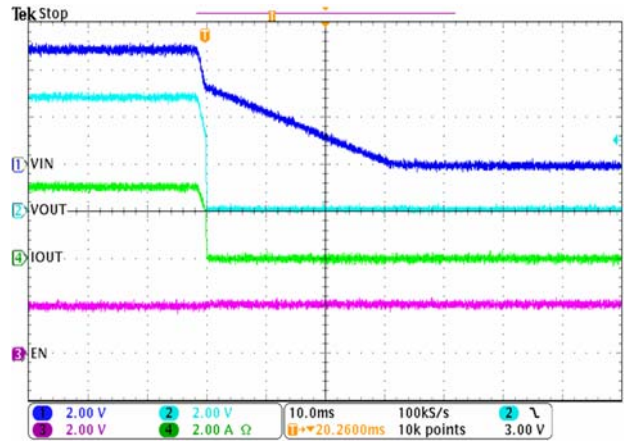

Figure 6. Shutdown by VIN (R_{Load} = 1.6Ω)

Figure 7. Input Over-Voltage Protection and Recovery (R_{LOAD} = 1kΩ, AOZ1353DI-01)
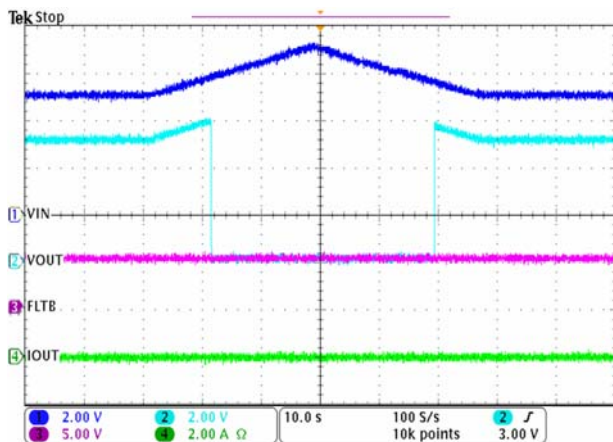
Figure 8. Over-Current Protection (R_{LOAD} = 1Ω, AOZ1353DI-01)
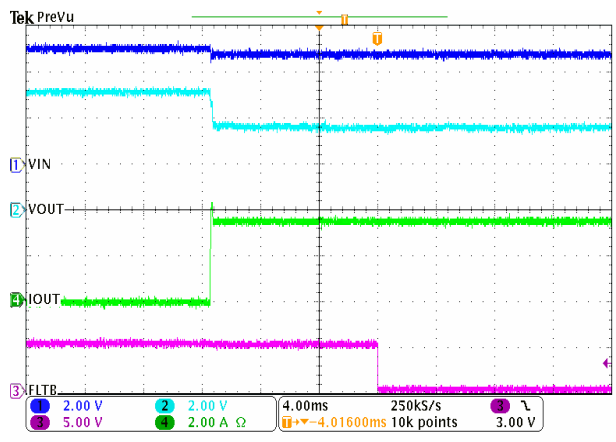
Typical Performance Curves (Continued)

T_A = 25°C, C_{OUT} = 20µF, R_{LIM} = 4.02kΩ, SS pin shorted to GND unless otherwise specified.

**Figure 9. Output Hard Short and Thermal Shutdown
(AOZ1353DI-01)**
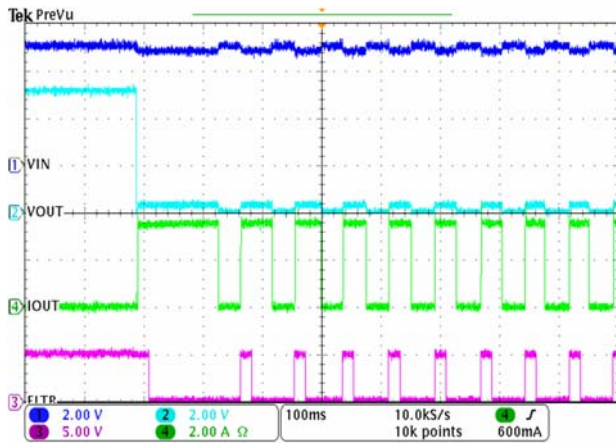
Typical Characteristics

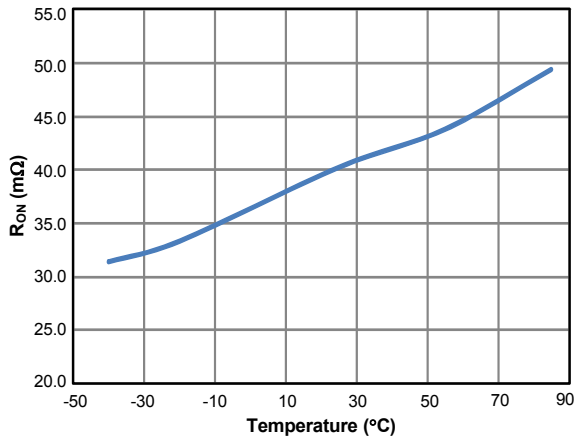T_A = 25°C, V_{IN} = 5V unless otherwise specified.
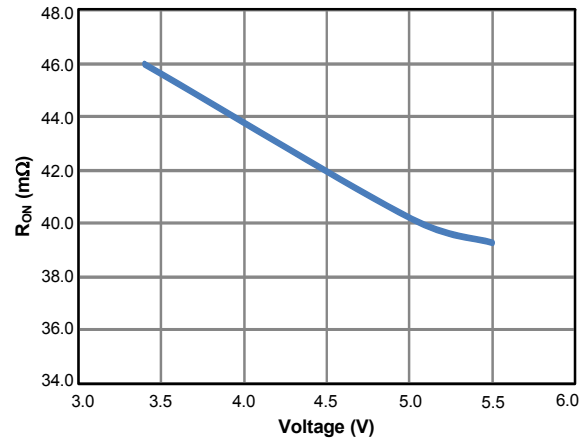

Figure 10. R_{ON} vs. Temperature

Figure 11. R_{ON} vs. Input Voltage

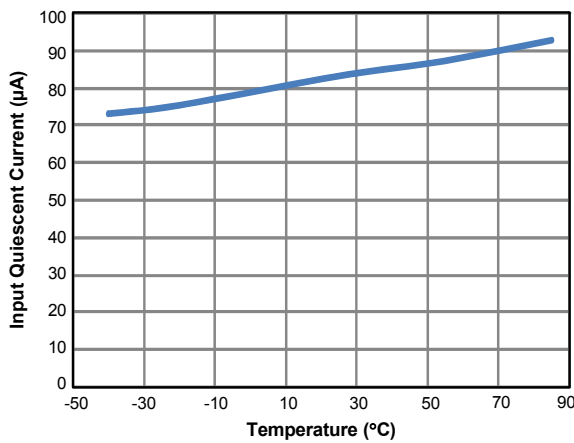Figure 12. Input Quiescent Current vs. Temperature
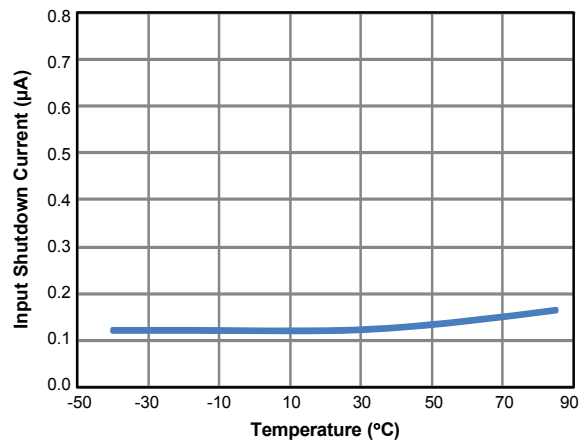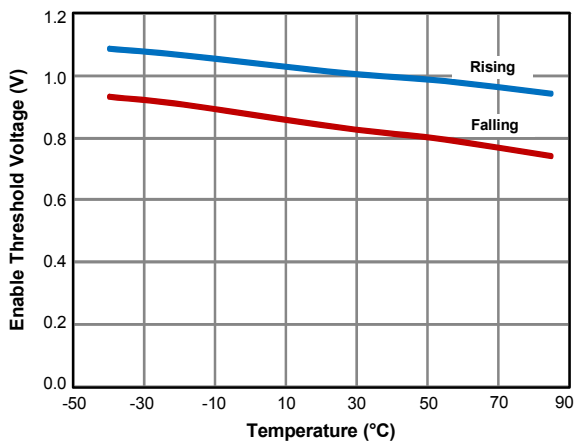

Figure 13. Input Shutdown Current vs. Temperature
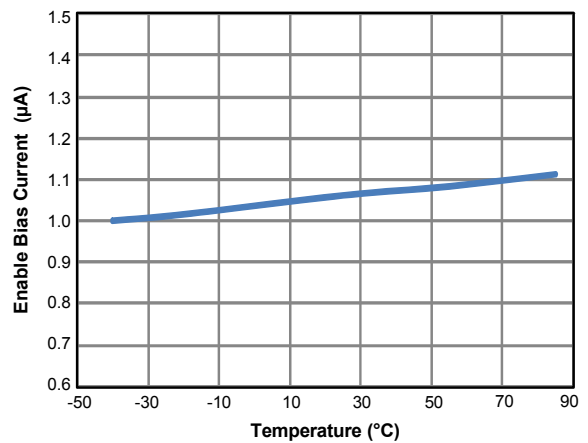

Figure 14. EN Threshold vs. Temperature

Figure 15. EN Bias Current vs. Temperature

Typical Characteristics (Continued)

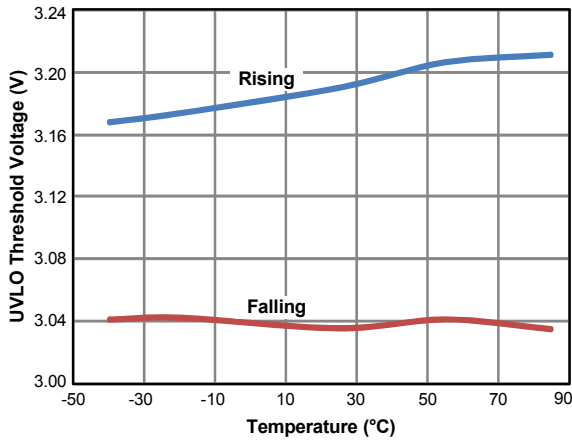$T_A = 25°C$, $V_{IN} = 5V$ unless otherwise specified.

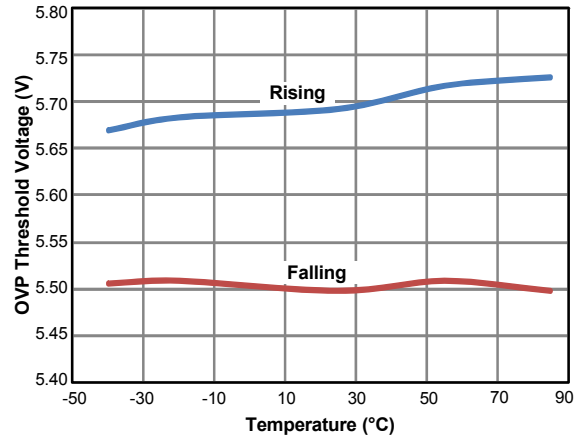**Figure 16. UVLO Threshold vs. Temperature**

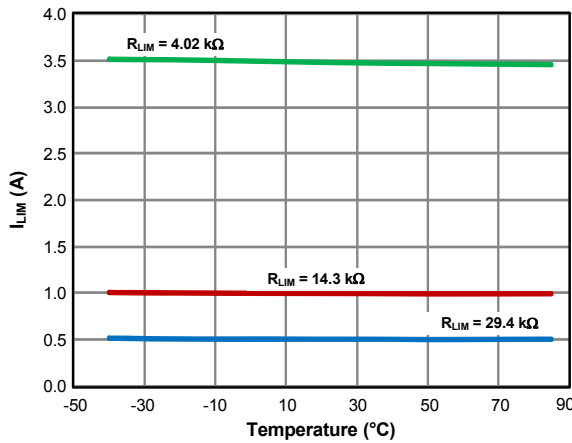**Figure 17. OVP Threshold vs. Temperature**

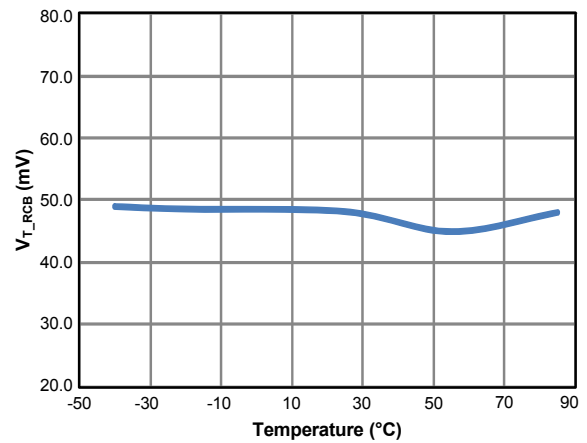**Figure 18. Current Limit Threshold vs. Temperature**

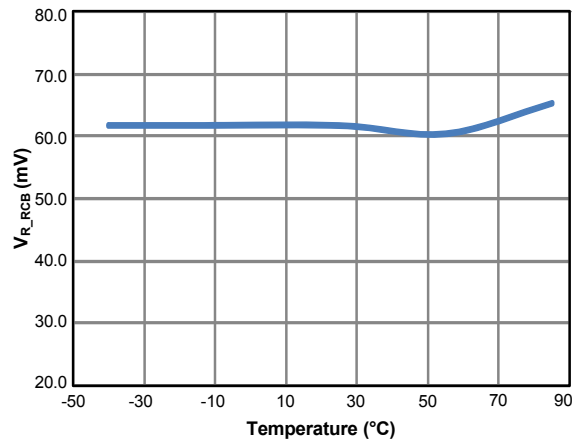**Figure 19. RCB Threshold (Rising) vs. Temperature**

Figure 20. RCB Threshold (Falling) vs. Temperature
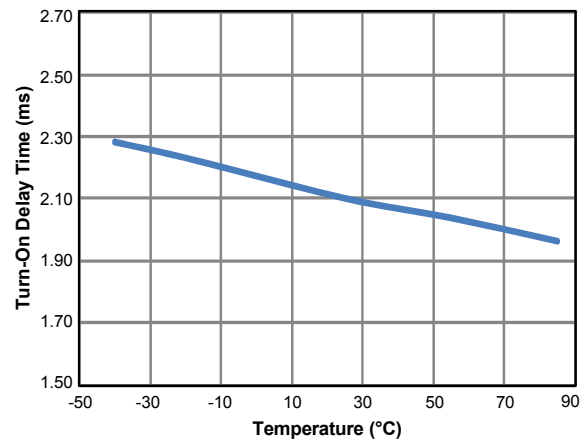

Figure 21. Turn-On Delay vs. Temperature

Typical Characteristics (Continued)

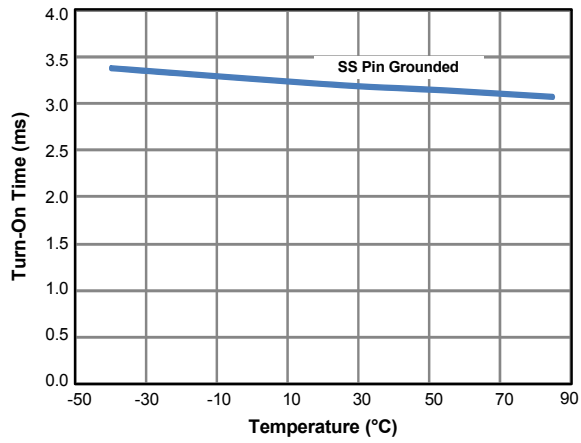T_A = 25°C, V_{IN} = 5V unless otherwise specified.
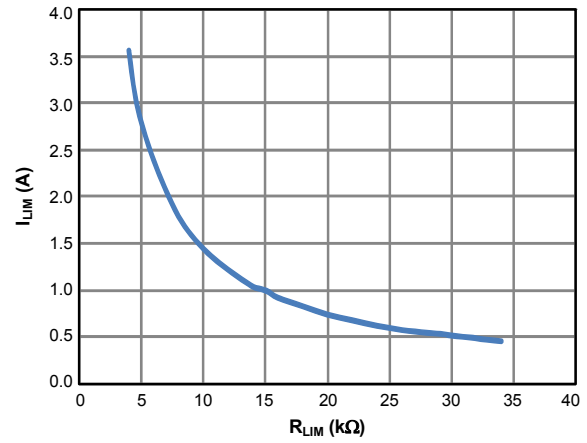

Figure 22. Turn-On Time vs. Temperature

Figure 23. Current Limit vs. R_{LIM}

Functional Description

The AOZ1353DI is a current limited power switch with over-voltage, over-current, reverse-current and thermal shutdown protections. The VOUT pin is rated 28V. The operating input voltage ranges from 3.4V to 5.5V. 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 AOZ1353DI draws less than 1μA from supply.

For AOZ1353DI-02, 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 (V_{OVLO_R}), the power switch is either turned off immediately or kept off, depending on its initial state. AOZ1353DI-01 can restart when VIN drops below V_{OVLO_F}.

Programmable Current Limit and Over-Current Protection (OCP)

The AOZ1353DI implemented current limit to ensure that the current through the switch does not exceed current limit threshold set by the external resistor R_{LIM}.

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

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

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

AOZ1353DI continuously limits the output current when output is overloaded, Under current-limiting, FLTB is pulled low after delay (T_{OCP_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 70mV.

Fast Recovery (For AOZ1353DI-01 only)

Once RCB event is removed, power switch turns on again quickly. The recovery time is less than 100μs.

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 AOZ1353DI-01 power switch is allowed to turn on again if die temperature drops below approximately 120°C.

Soft Start

The AOZ1353DI has soft-start circuitry to limit in-rush current due to large capacitive load. By default the turn-on time is 3.4ms when SS pin is connected to GND.

Fast turn-on time can be set by adding an external capacitor C_{SS} between SS pin and ground. The capacitor value is selected using Table 1.

Table 1. Turn-On Time Settings by C_{ss}

C_{ss} (nF)	Turn-On Time (ms)
1	0.3
1.2	0.4
2.2	0.8
3.3	1.2
4.7	1.7
5.6	1.9
6.8	2.4
8.2	2.8
10	3.2
12	3.4
SS pin short to GND	3.4

Startup

The device is enabled when EN ≥ V_{EN_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

AOZ1353DI 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 is pulled high once fault is removed.

In case of output overload, FLTB pin is pulled low about 12ms (T_{OCP_FLTB}) after device is in current- limiting. For AOZ1353DI-02 power switch is then turned off after another 12ms.

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

Auto-restart or Latch-off

AOZ1353DI-01 (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.

AOZ1353DI-02 (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 is also to prevent 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 10µF 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 AOZ1353DI 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.

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

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:

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

Layout Guidelines

Good PCB layout is important for improving the thermal and overall performance of AOZ1353DI. 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.
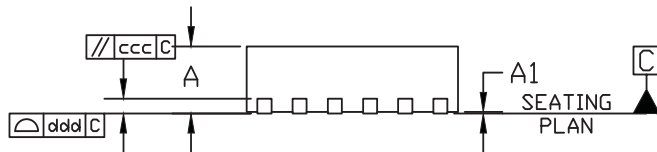
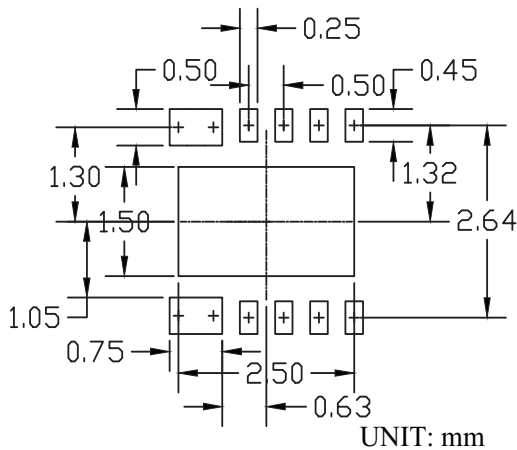## Package Dimensions, DFN3x3B_12L, EP1_S
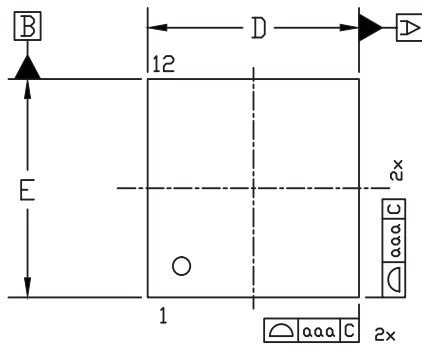
TOP VIEW
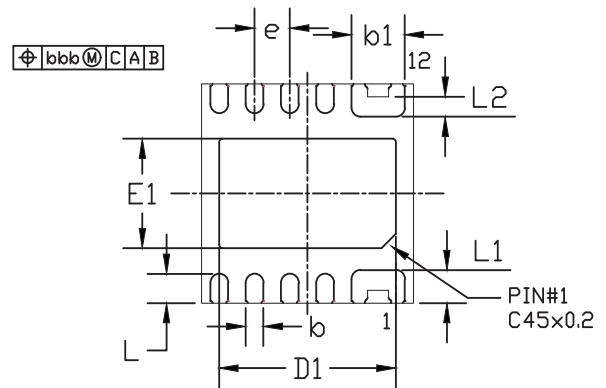
BOTTOM VIEW



SIDE VIEW

RECOMMENDED LAND PATTERN

UNIT: mm

SYMBOLS	DIMENSIONS IN MILLIMETERS			DIMENSIONS IN INCHES		
	MIN	NOM	MAX	MIN	NOM	MAX
A	0.80	0.90	1.00	0.031	0.035	0.039
A1	0.00	0.02	0.05	0.000	0.001	0.002
b	0.20	0.25	0.30	0.008	0.010	0.012
b1	0.70	0.75	0.80	0.028	0.030	0.032
c	0.195	0.203	0.211	0.008	0.008	0.008
D	2.90	3.00	3.10	0.116	0.118	0.120
D1	2.40	2.50	2.60	0.094	0.098	0.102
E	2.90	3.00	3.10	0.116	0.118	0.120
E1	1.40	1.50	1.60	0.055	0.059	0.063
e	0.50BSC			0.020BSC		
L	0.30	0.40	0.50	0.012	0.016	0.020
L1	0.35	0.45	0.55	0.014	0.018	0.022
L2	0.22	0.27	0.32	0.009	0.011	0.013
aaa	0.15			0.006		
bbb	0.10			0.004		
ccc	0.10			0.004		
ddd	0.08			0.003		

NOTE
1. DIMENSIONING AND TOLERANCING CONFORM TO ASME Y14.5M-1994.
2. CONTROLLING DIMENSION IS MILLIMETER.
   CONVERTED INCH DIMENSIONS ARE NOT NECESSARILY EXACT.
3. 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, THE DIMENSION b SHOULD NOT BE
   MEASURED IN THAT RADIUS AREA.
4. COPLANARITY ddd APPLIERS TO THE TERMINALS AND ALL OTHER BOTTOM SURFACE
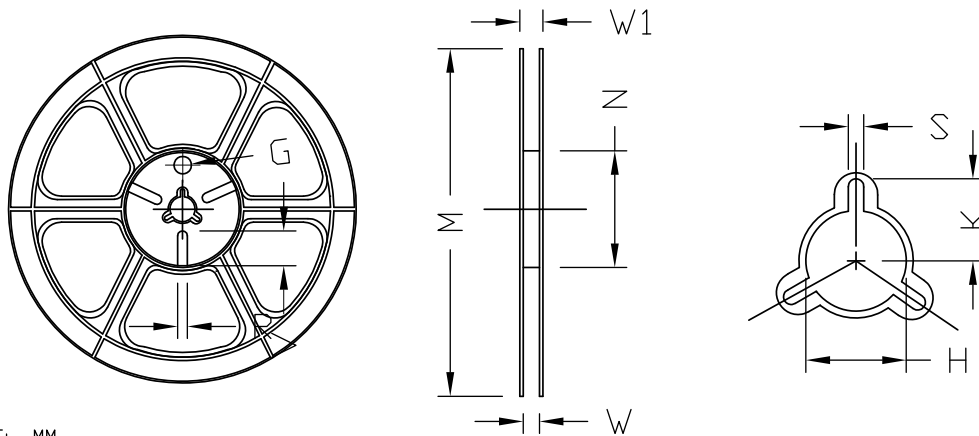   METALLIZATION.

Tape and Reel Drawing DFN3x3 EP

Carrier Tape

UNIT: MM   FEEDING DIRECTION
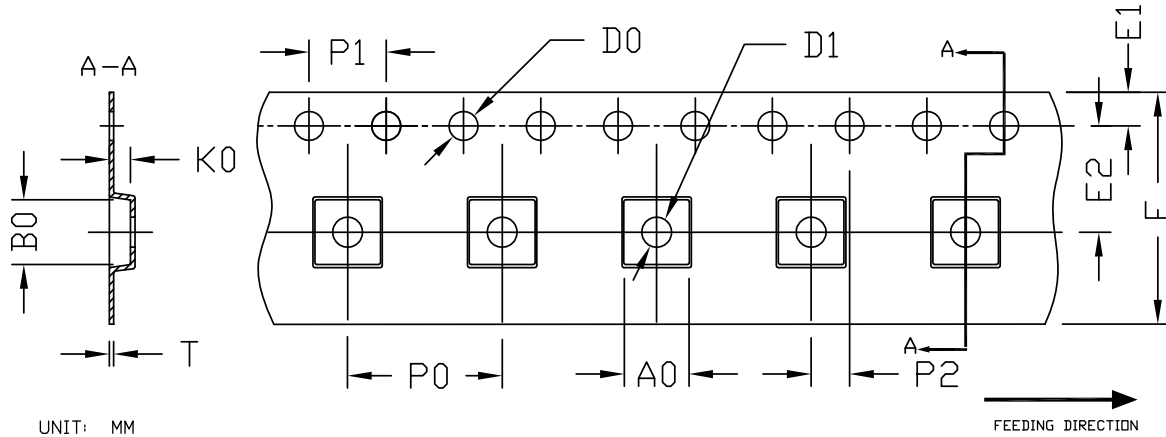
PACKAGE	A0	B0	K0	D0	D1	E	E1	E2	P0	P1	P2	T
DFN3x3_EP	3.40 ±0.10	3.35 ±0.10	1.10 ±0.10	1.50 +0.10 −0	1.50 +0.10 −0	12.00 ±0.30	1.75 ±0.10	5.50 ±0.05	8.00 ±0.10	4.00 ±0.10	2.00 ±0.05	0.30 ±0.05

Reel

UNIT: MM

TAPE SIZE	REEL SIZE	M	N	W	W1	H	K	S	G	R	V
12 mm	Ø330	Ø330.00 ±0.50	Ø97.00 ±0.10	13.00 ±0.30	17.40 ±1.00	Ø13.00 +0.50 −0.20	10.60	2.00 ±0.50	---	---	---

DFN3x3 EP TAPE
Leader / Trailer & Orientation

Unit Per Reel:
5000pcs

| TRAILER TAPE | COMPONENTS TAPE | LEADER TAPE |
| 300mm MIN. | ORIENTATION IN POCKET | 500mm MIN. |

Part Marking

AOZ1353DI
(DFN3x3)

AG00

YWLT

Option Code
Special Code
Part Number Code

Year Code
Week Code
Assembly lot Code
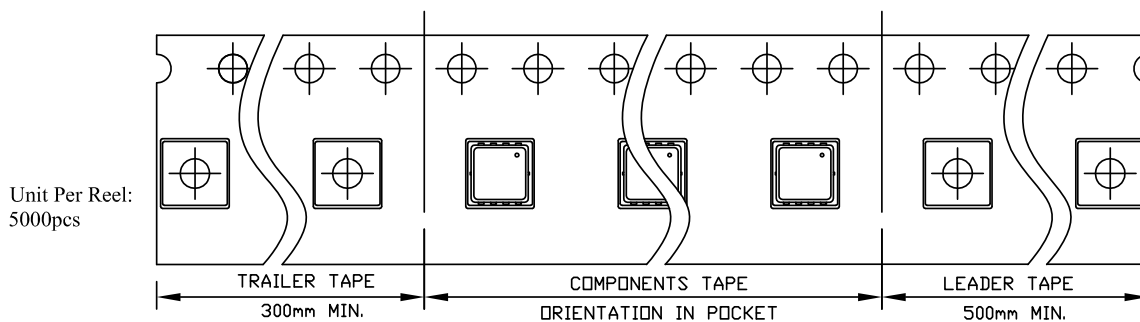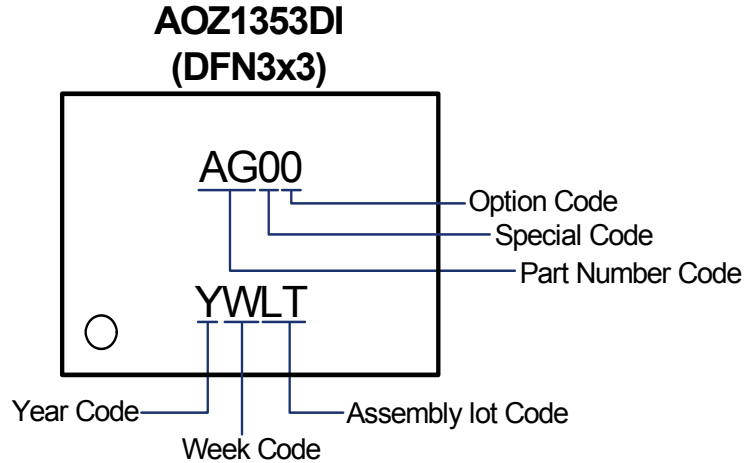
Part Number	Description	Code
AOZ1353DI-01	Green Product	AG01
AOZ1353DI-02	Green Product	AG02