

General Description

The AOZ9006DIL is a battery protection IC with integrated dual common-drain N-channel MOSFET. The device includes accurate voltage detectors and delay circuits, and is suitable for protecting single-cell lithium-ion / lithium-polymer rechargeable battery packs from overcharge, over-discharge, and over-current conditions.

The AOZ9006DIL is available in a 2mm x 5mm 6-pin DFN package and is rated over a -40°C to +85°C ambient temperature range.

Features

- Integrated Common-Drain N-Channel MOSFET
 - ▶ 48mΩ (max.) source to source on resistance
- High-accuracy voltage detection circuit
 - ▶ Overcharge detection accuracy ±25mV (+25°C), ±30mV (-5°C to +55°C)
 - ▶ Overcharge release accuracy ±50mV
 - ▶ Over-discharge detection accuracy ±50mV
 - ▶ Over-discharge release accuracy ±100mV
 - ▶ Discharge over-current detection accuracy ±15mV
 - ▶ Load short-circuit detection accuracy ±200mV
- ±20% accurate internal detection delay times (external capacitors are unnecessary)
- Charger connection pin withstands up to 28V
- Wide operating temperature range -40°C to +85°C
- Low current consumption
 - ▶ 3.0μA (typ.), 5.5μA (max.) in operation mode at +25°C
- Small 2mm X 5mm 6-pin DFN package

Applications

- Lithium-ion rechargeable battery packs
- Lithium-polymer rechargeable battery packs



Typical Application

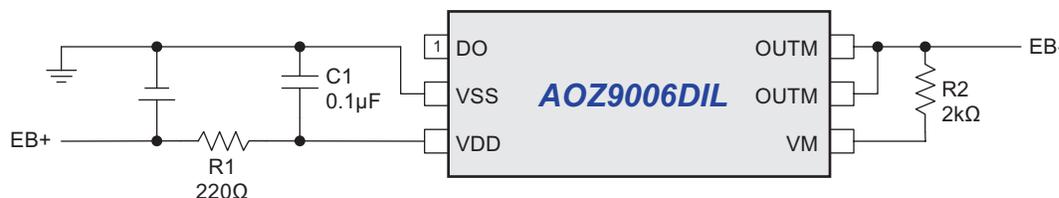


Figure 1. Typical Application

Ordering Information

Part Number	Overcharge Detection Voltage (V _{CU})	Overcharge Release Voltage (V _{CL})	Over-discharge Detection Voltage (V _{DL})	Over-discharge Release Voltage (V _{DU})	Discharge Over-current Threshold (V _{DIOV})*	Load Short-circuiting Detection Voltage (V _{SHORT})	Charge Over-current Threshold (V _{CIOV})*	0V Battery Charge Function	Shutdown Function
AOZ9006DIL	4.275V	4.175V	2.3V	2.4V	0.10V	0.5V	-0.10V	Yes	Yes

*Please refer to page 8 for calculation of charge and discharge current limits.

All AOS products are offered in packages with Pb-free plating and compliant to RoHS standards.

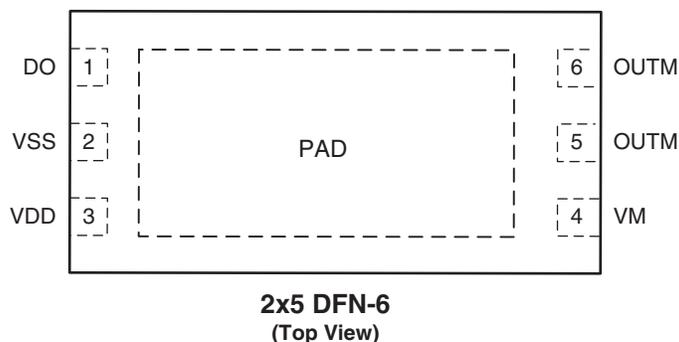
• Parts marked as Green Products (with “L” suffix) use reduced levels of Halogens, and are also RoHS compliant.

Please visit www.aosmd.com/web/quality/rohs_compliant.jsp for additional information.

Table 1. Delay Time Combination

Overcharge Detection Delay Time (t _{CU})	Over-discharge Detection Delay Time (t _{DL})	Discharge Over-current Detection Delay Time (t _{DIOV})	Charge Over-current Detection Delay Time (t _{CIOV})	Load Short-circuiting Detection Delay Time (t _{SHORT})
1.2s	150ms	9ms	9ms	300μs

Pin Configuration



Pin Description

Pin Name	Pin Name	Pin Function
DO	1	Discharge MOSFET Gate. This pad is for test purposes only. Always leave this pad unconnected.
VSS	2	Ground. VSS is the source of the internal Discharge MOSFET. Connect VSS directly to the cathode of lithium-ion/lithium polymer battery cell.
VDD	3	Input supply pin. Connect a 0.1μF capacitor between VDD and VSS.
VM	4	Over-current/Charger Detection Pin. Connect a 2kΩ resistor between VM and the negative terminal of the battery pack.
OUTM	5, 6	Output pin. OUTM is the source of the internal Charge MOSFET. Connect OUTM directly to the negative terminal of the battery pack.
PAD	Drain	MOSFET Common-Drain Connection. This pad is for test purposes only. Always leave this pad unconnected.

Block Diagram

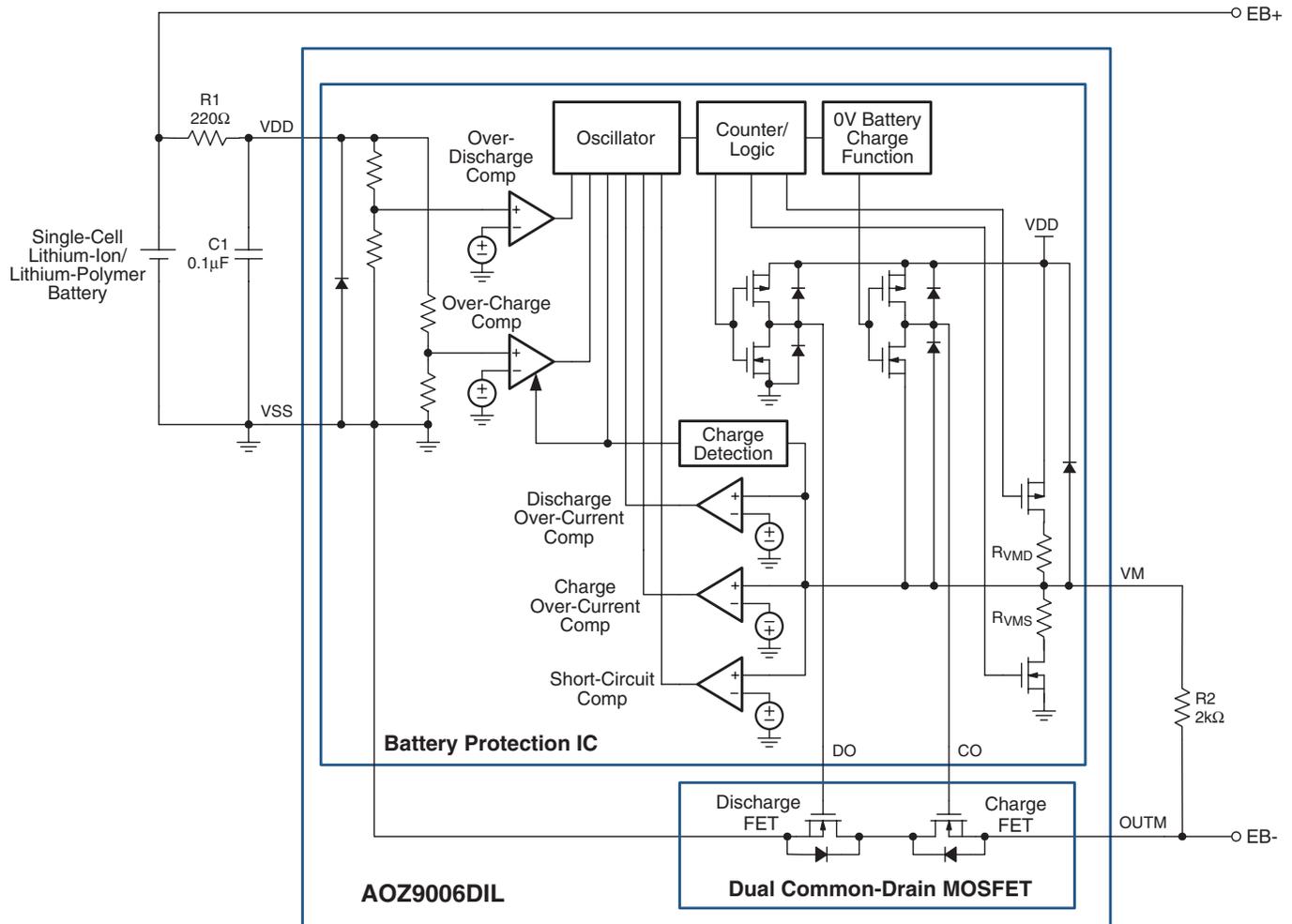


Figure 1. AOZ9006DIL Function Block Diagram

Absolute Maximum Ratings

Exceeding the Absolute Maximum ratings may damage the device.

Symbol	Parameter	Conditions	Ratings		Unit
			Min.	Max.	
V _{DD}	Supply Voltage		-0.3	12	V
V _M	VM Pin Voltage		V _{DD} - 28	V _{DD} + 0.3	V
V _{DSS}	Drain-Source Voltage			30	V
I _D	Drain Current ⁽¹⁾	R _{θJA} = 84°C/W, T _A = 25°C		4.1	A
T _{OPR}	Operating Temperature		-40	85	°C
T _{STD}	Storage Temperature		-55	125	°C
P _D	Total Power Dissipation ⁽¹⁾	R _{θJA} = 84°C/W, T _A = 25°C		1.0	W

Note:

1. The value of R_{θJA} is measured with the device mounted on 1-in² FR-4 board with 2-oz. copper, in a still air environment with T_A = 25°C. The value in any given application depends on the user's specific board design.

Electrical Characteristics

$T_A = 25^\circ\text{C}$ unless otherwise specified. Parameters specified over $T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$ are guaranteed by design only and not production tested.

Control IC

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
DETECTION VOLTAGE						
V_{CU}	Overcharge Detection Voltage	$T_A = 25^\circ\text{C}$	4.250	4.275	4.300	V
		$T_A = -5^\circ\text{C}$ to $+55^\circ\text{C}$	4.245	4.275	4.305	
		$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$	4.215	4.275	4.315	
V_{CL}	Overcharge Release Voltage	$T_A = 25^\circ\text{C}$	4.125	4.175	4.225	V
		$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$	4.095	4.175	4.24	
V_{DL}	Over-Discharge Detection Voltage	$T_A = 25^\circ\text{C}$	2.250	2.300	2.350	V
		$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$	2.190	2.300	2.430	
V_{DU}	Over-Discharge Release Voltage	$T_A = 25^\circ\text{C}$	2.300	2.400	2.500	V
		$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$	2.250	2.400	2.590	
V_{DIOV}	Discharge Over-Current Threshold	$T_A = 25^\circ\text{C}$	0.085	0.100	0.115	V
		$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$	0.079	0.100	0.124	
V_{SHORT}	Load Short-Circuiting Detection Voltage	$T_A = 25^\circ\text{C}$	0.3	0.50	0.7	V
		$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$	0.16	0.50	0.84	
V_{CIOV}	Charge Over-Current Threshold	$T_A = 25^\circ\text{C}$	-0.13	-0.1	-0.07	V
		$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$	-0.14	-0.1	-0.06	
0 V BATTERY CHARGE FUNCTION						
V_{0CHA}	0V battery charge starter battery voltage (0V battery charging function "available")	$T_A = 25^\circ\text{C}$	1.2			V
		$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$	1.7			
INPUT VOLTAGE						
V_{DSOP1}	Operating Voltage Between V_{DD} Pin and V_{SS} Pin	Internal Circuit Operating Voltage	1.5		8	V
V_{DSOP2}	Operating Voltage Between V_{DD} Pin and VM Pin	Internal Circuit Operating Voltage	1.5		28	V
INPUT CURRENT (Shutdown Function)						
I_{OPE}	Current Consumption During Operation	$V_{DD} = 3.5\text{V}$, $V_{VM} = 0\text{V}$, $T_A = 25^\circ\text{C}$	1.0	3.0	5.5	μA
		$V_{DD} = 3.5\text{V}$, $V_{VM} = 0\text{V}$, $T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$	0.7	3.0	6.0	
I_{PDN}	Current Consumption at Shutdown	$V_{DD} = V_{VM} = 1.5\text{V}$, $T_A = 25^\circ\text{C}$			0.2	μA
		$V_{DD} = V_{VM} = 1.5\text{V}$, $T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$			0.3	
Internal Resistance						
R_{VMD}	Resistance Between VM Pin and V_{DD} Pin	$V_{DD} = 1.8\text{V}$, $V_{VM} = 0\text{V}$, $T_A = 25^\circ\text{C}$	100	300	900	$\text{k}\Omega$
		$V_{DD} = 1.8\text{V}$, $V_{VM} = 0\text{V}$, $T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$	78	300	1310	
R_{VMS}	Resistance Between VM Pin and V_{SS} Pin	$V_{DD} = 3.5\text{V}$, $V_{VM} = 1.0\text{V}$, $T_A = 25^\circ\text{C}$	10	20	40	$\text{k}\Omega$
		$V_{DD} = 3.5\text{V}$, $V_{VM} = 1.0\text{V}$, $T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$	7.2	20	44	

Electrical Characteristics (Continued)

$T_A = 25^\circ\text{C}$ unless otherwise specified. Parameters specified over $T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$ are guaranteed by design only and not production tested.

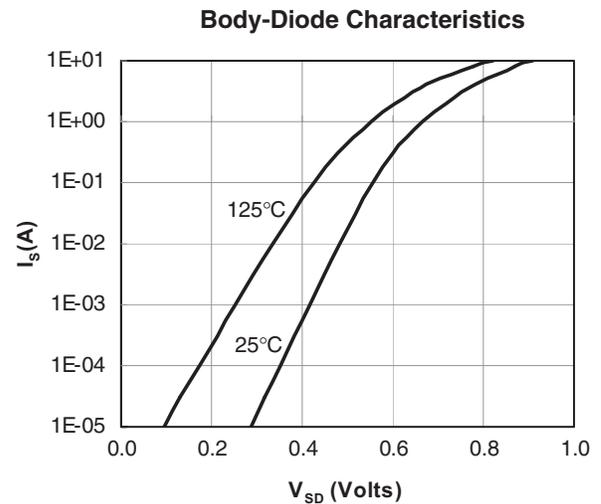
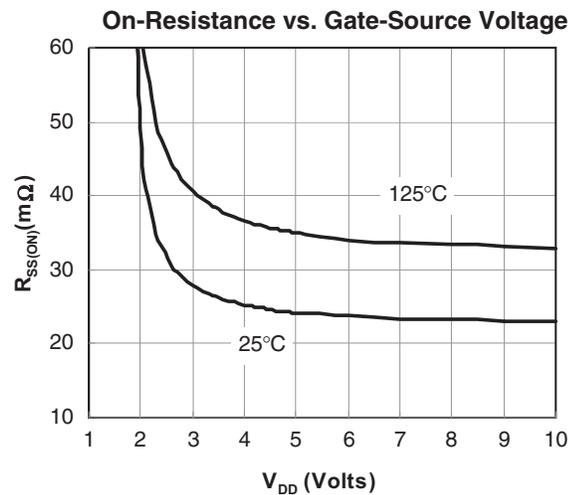
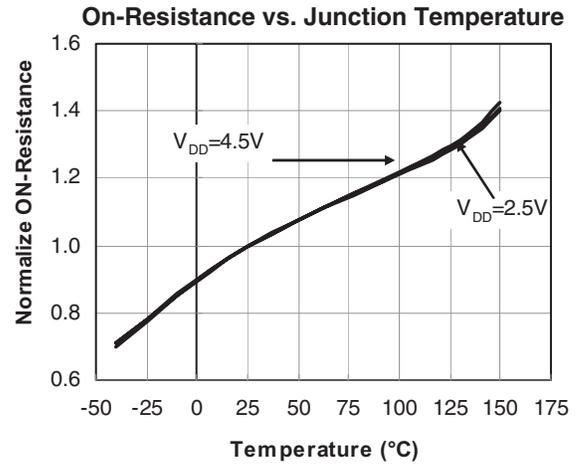
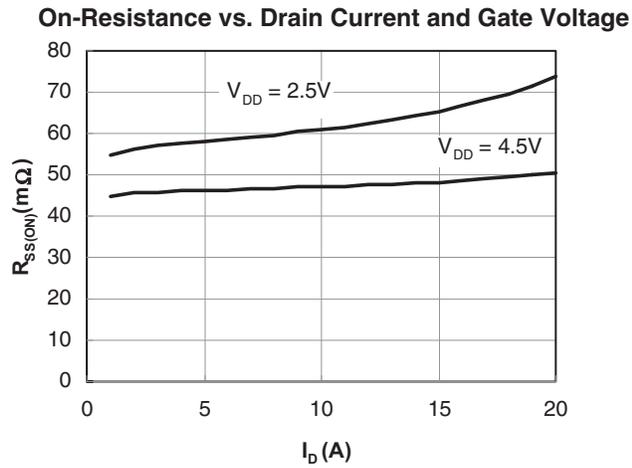
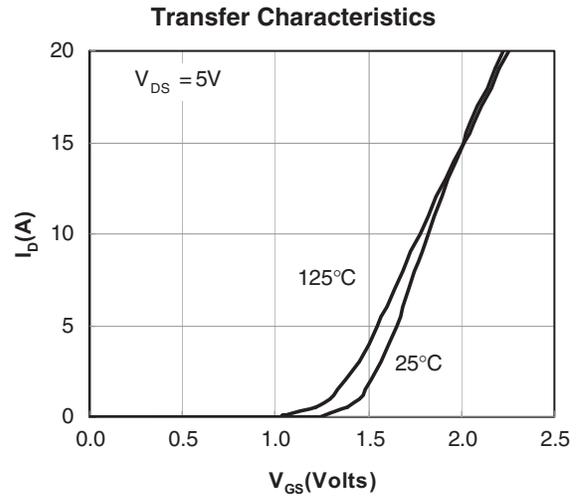
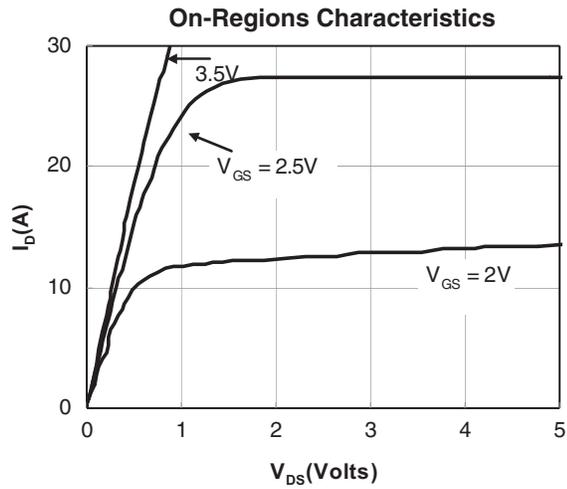
Control IC (Continued)

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
Detection Delay Time						
t_{CU}	Overcharge Detection Delay Time	$T_A = 25^\circ\text{C}$.96	1.2	1.4	s
		$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$	0.7	1.2	2	
t_{DL}	Over-Discharge Detection Delay Time	$T_A = 25^\circ\text{C}$	120	150	180	ms
		$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$	83	150	255	
t_{DIOV}	Discharge Over-Current Detection Delay Time	$T_A = 25^\circ\text{C}$	7.2	9	11	ms
		$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$	5	9	15	
t_{CIOV}	Charge Over-Current Detection Delay Time	$T_A = 25^\circ\text{C}$	7.2	9	11	ms
		$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$	5	9	15	
t_{SHORT}	Load Short-Circuiting Detection Delay Time	$T_A = 25^\circ\text{C}$	240	300	360	ms
		$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$	150	300	540	

Integrated MOSFET:

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
BV_{DS_C}	Charge Control MOSFET Drain-Source Breakdown	$V_{DD} = V_{CU}$	30			V
I_{LEAK_C}	Charge Control MOSFET Leakage	$V_{DD} = V_{CU}$			1	μA
BV_{DS_D}	Discharge Control MOSFET Drain-Source Breakdown Voltage	$V_{DD} = V_{DL}$	30			V
I_{LEAK_D}	Discharge Control MOSFET Leakage Current	$V_{DD} = V_{DL}$			1	μA
R_{SS}	Total Output Resistance (OUTM to VSS)	$V_{DD} = 3.5\text{V}$, $I_{OUT} = 1.5\text{A}$	32	40	48	$\text{m}\Omega$

Typical Performance Characteristics



Theory of Operation

Please refer to the Timing Diagrams for more information.

Normal Status

The AOZ9006DIL monitors the voltage between the VDD pin and VSS pin and the voltage difference between the VM pin and VSS pin to control charging and discharging. Since the device only draws a few microamperes of current during operation and the voltage drop across the low-pass filter R1 is negligible, the voltage between VDD and VSS is equal to the battery voltage. When the battery voltage is in the range between over-discharge detection voltage (V_{DL}) and overcharge detection voltage (V_{CU}), and the VM pin voltage is in the range between the charge over-current detection voltage (V_{CIOV}) and discharge over-current detection voltage (V_{DIOV}), the IC turns both the charging and discharging control FETs on. In this normal status, charging and discharging can be carried out freely.

Caution: Products with “Shut-down Function Available” feature may not enable discharging when the battery is connected for the first time. Connect the charger or short VM pin to VSS can restore the normal status.

Overcharge Status

When the battery voltage rises higher than overcharge detection voltage (V_{CU}) for the overcharge detection delay time (t_{CU}) or longer in the normal status, the AOZ9006DIL turns off the charging control MOSFET to stop charging. This condition is the overcharge status. The resistance (R_{VMD}) between the VM pin and VDD pin, and the resistance (R_{VMS}) between the VM pin and VSS pin are not connected. The overcharge status is released in the following two cases:

1. When the battery voltage falls below overcharge release voltage (V_{CL}) and VM pin voltage is higher than -0.7V (Typ.) (charger is removed), the AOZ9006DIL turns on the charging control MOSFET and returns to the normal status.
2. When a load is connected and battery voltage is below overcharge detection voltage (V_{CU}), the AOZ9006DIL turns on the charging control MOSFET and returns to the normal status.

Caution: When both charger and load are connected after overcharge detection, charging control FET still remains off and a portion of the load current may flow through body diode of charging control FET if the charger can not supply the full load current. This condition may overheat the charging control FET. Please refer to the Typical Characteristics for more information.

Over-Discharge Status

When the battery voltage falls below over-discharge detection voltage (V_{DL}) for the over-discharge detection delay time (t_{DL}) or longer, the IC turns off the discharging control MOSFET to stop discharging. This condition is the over-discharge status. Under the over-discharge status, the VM pin voltage is pulled up by the resistor between the VM pin and VDD pin in the IC (R_{VMD}). The resistance (R_{VMS}) between the VM pin and VSS pin is not connected in the over-discharge status. When voltage difference between the VM pin and VDD pin is 1.3V (Typ.) or lower, the productions with “Shut-down Function Available” feature can enter the shut-down status to save power. At this status, the current consumption is reduced to the shut-down current consumption (I_{PON}). The shut-down status is released when a charger is connected and the voltage difference between the VM pin and VDD pin becomes 1.3V (Typ.) or higher.

When a battery in the over-discharge status is connected to a charger and provides that the VM pin voltage is lower than -0.7V (Typ.), the AOZ9006DIL releases the over-discharge status and turns on the discharging MOSFET when the battery voltage reaches over-discharge detection voltage (V_{DL}) or higher. If VM pin voltage is not lower than -0.7V (Typ.), the AOZ9006DIL releases the over-discharge status and turns on the discharging MOSFET when the battery voltage reaches over-discharge detection voltage (V_{DU}) or higher.

Discharge Over-Current Status (Discharge Over-current, Load Short-circuiting)

When a battery is in the normal status, and the discharge current becomes higher than specified value and the status lasts for the discharge over-current detection delay time (t_{DIOV}), the IC turns off the discharge control MOSFET and stops discharging. This status is the discharge over-current status. In the discharge over-current status, the VM pin and VSS pin are shorted by the resistor between VM pin and VSS pin (R_{VMS}) in the IC. When the load is disconnected, the VM pin returns to the VSS potential. When the impedance between the EB+ pin and EB- pin (Refer to Figure 1) increases and is equal to the impedance that enables automatic restoration and the voltage at the VM pin returns to discharge over-current detection voltage (V_{DIOV}) or lower, the discharge over-current status is restored to the normal status. Even if the connected impedance is smaller than automatic restoration level, the AOZ9006DIL will be restored to the normal status from discharge over-current detection status when the voltage at the VM pin becomes the discharge over-current detection voltage (V_{DIOV}) or lower

by connecting the charger. The resistance (R_{VMD}) between the VM pin and VDD pin is not connected in the discharge over-current detection status.

When a battery is in the normal status, and the discharge current becomes abnormally higher (EB+ pin and EB- pin shorted), and thus the VM pin voltage is equal or higher than load short-circuiting detection voltage (V_{SHORT}) for load short-circuiting detection delay time (t_{SHORT}), the IC turns off the discharge control MOSFET and stops discharging. This status is the load shorting-circuiting status. In the load shorting-circuiting status, the VM pin and VSS pin are shorted by the resistor between VM pin and VSS pin (R_{VMS}) in the IC. When the short-circuiting condition is released, the VM pin returns to the VSS potential. The resistance (R_{VMD}) between the VM pin and VDD pin is not connected in the load shorting-circuiting status.

Charge Over-current Status

When a battery in the normal status is in the status, and the charge current is higher than the specified value and the status lasts for the charge over-current detection delay time (t_{CIOV}), the charge control MOSFET is turned off and charging is stopped. This status is the charge over-current status. This IC will be restored to the normal status from the charge over-current status when, the voltage at the VM pin returns to charge over-current detection voltage (V_{CIOV}) or higher by removing the charger. The charge over-current detection function does not work in the over-discharge status. The resistance (R_{VMD}) between the VM pin and VDD pin, and the resistance (R_{VMS}) between the VM pin and VSS pin are not connected in the charge over-current status.

0V Battery Charging Function “Available”

This function is used to recharge a connected battery whose voltage is 0V due to self-discharge. When the 0V battery charge starting charger voltage (V_{0CHA}) or a higher voltage is applied between the EB+ and EB- pins by connecting a charger, the charging control MOSFET gate is fixed to the VDD pin voltage.

When the voltage between the gate and source of the charging control MOSFET becomes equal to or higher than the turn-on voltage due to the charger voltage, the charging control MOSFET is turned on to start charging. At this time, the discharging control MOSFET is off and the charging current flows through the internal parasitic diode in the discharging control MOSFET. When the battery voltage becomes equal to or higher than over-discharge release voltage (V_{DU}), the AOZ9006DIL enters the normal status.

Calculation of Current Limit

The charge and discharge current limit is determined by the charge and discharge over-current threshold voltages (V_{DIOV} and V_{CIOV}), and the total resistance of the internal MOSFET (R_{SS}). Use the following equations to determine the maximum and minimum current limits:

$$I_{DIOV_MAX} = \frac{V_{DIOV_MAX}}{R_{SS_MIN}} ; I_{DIOV_MIN} = \frac{V_{DIOV_MIN}}{R_{SS_MAX}}$$

$$I_{CIOV_MAX} = \frac{V_{CIOV_MAX}}{R_{SS_MIN}} ; I_{CIOV_MIN} = \frac{V_{CIOV_MIN}}{R_{SS_MAX}}$$

Timing Diagrams

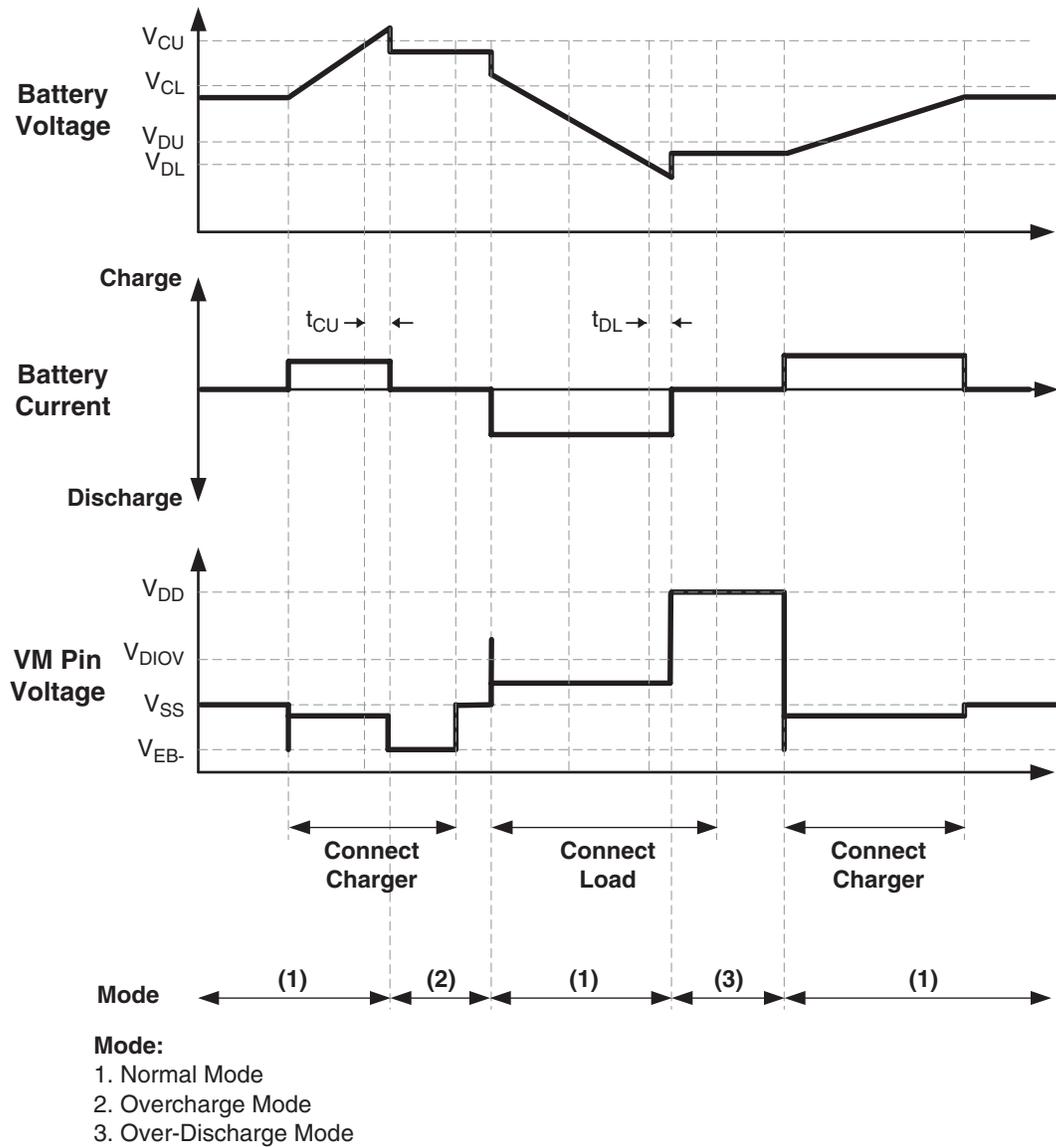


Figure 2. Overcharge and Over-discharge Detection Timing Diagram

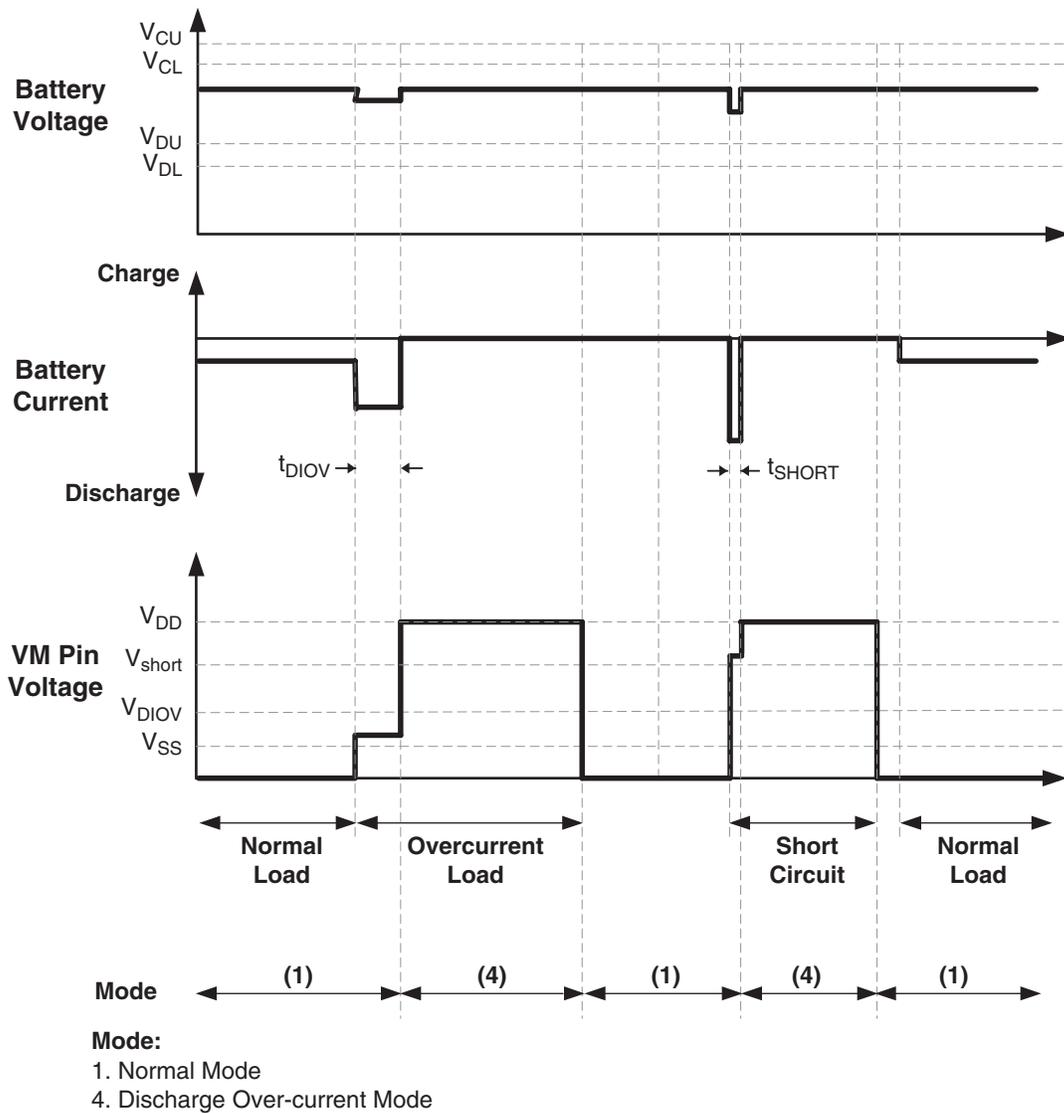


Figure 3. Discharging Over-current Detection Timing Diagram

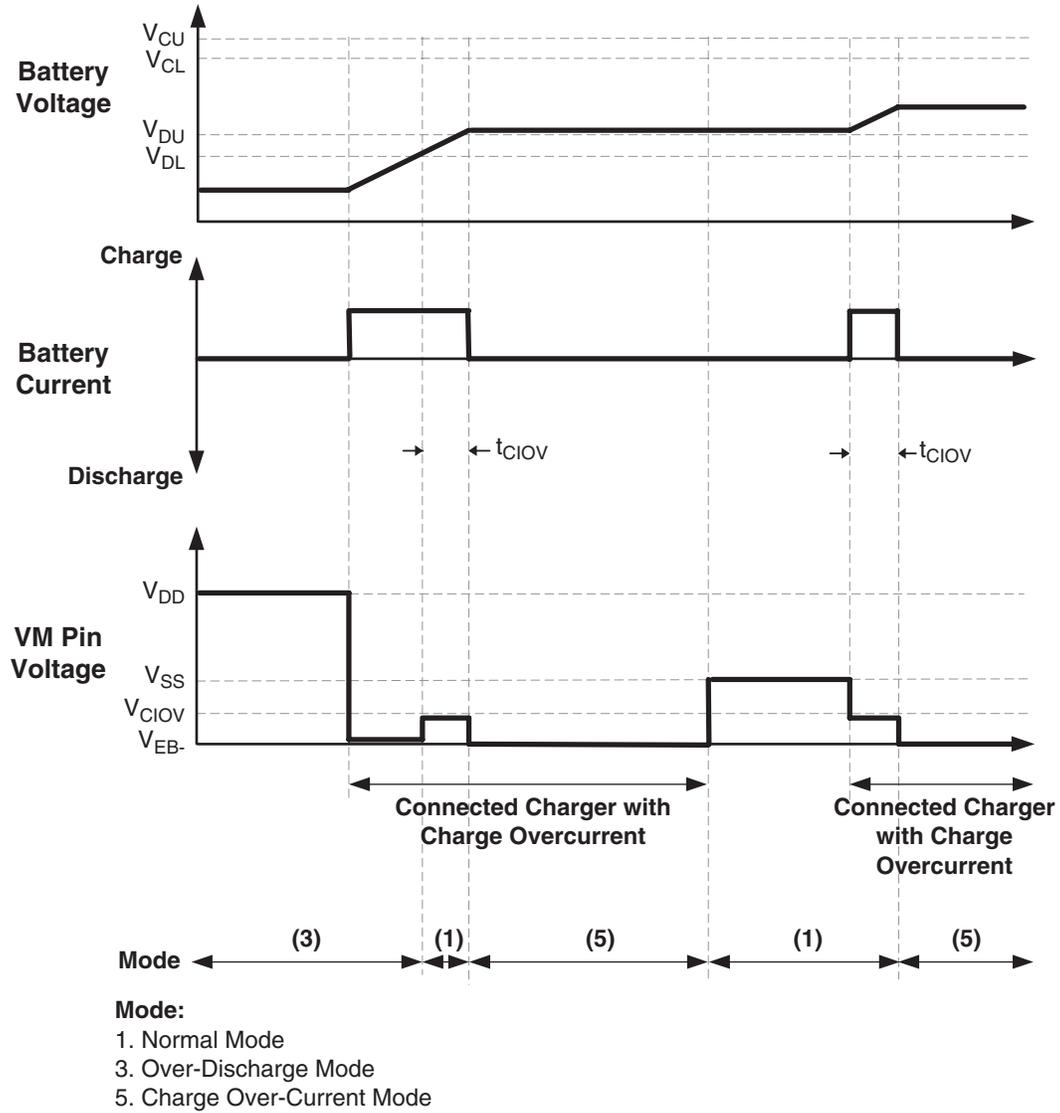


Figure 4. Charging Over-current Detection Timing Diagram

Applications Information

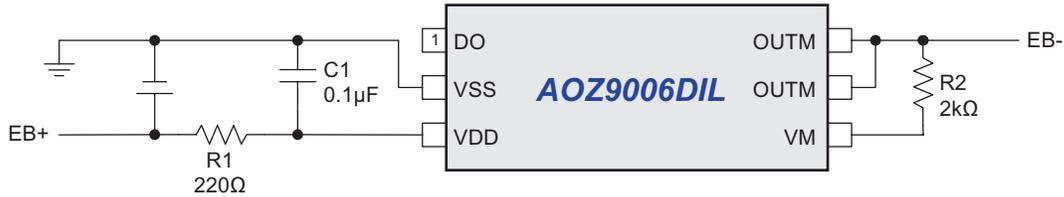


Figure 5. AOZ9006D Applications Circuit

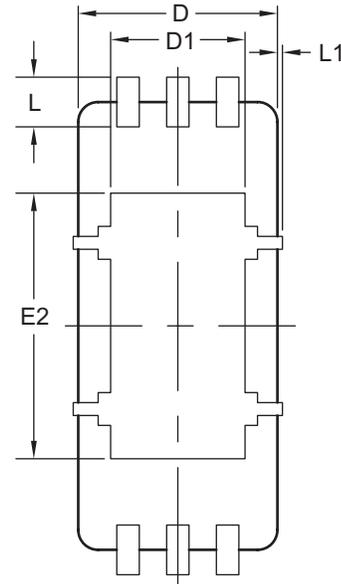
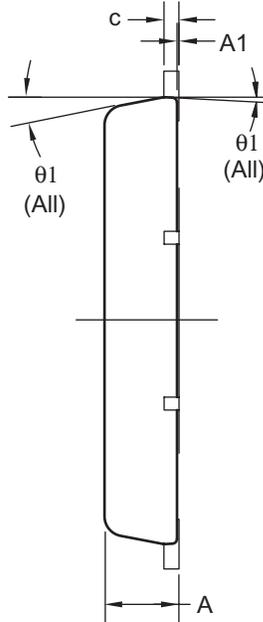
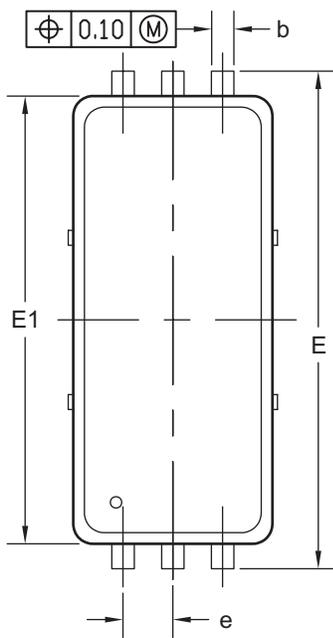
A low-pass filter formed by R1 and C1 reduces supply voltage fluctuation on the VDD pin. R1 also provides ESD protection and serves as a current-limiting resistor in the event of charger reverse connection. The supply current of AOZ9006DIL has to flow through R1, so a small R1 should be chosen to guarantee detection accuracy of VDD voltage. Choose a resistor value between 100Ω and 330Ω for R1. Choose the value of C1 to be 0.022μF or higher. Both R1 and C1 should be placed as close as possible to AOZ9006DIL to minimize parasitic effect.

R2 provides ESD protection and serve as a current-limiting resistor in the event of charger reverse connection. A large value resistor should be chosen to limit power consumption during this condition. However, an extremely large value of R2, of course, will cause inaccuracy of VM pin voltage detection. Choose a resistor value between 300Ω and 4kΩ for R2.

Table 2. External Components Selection Range

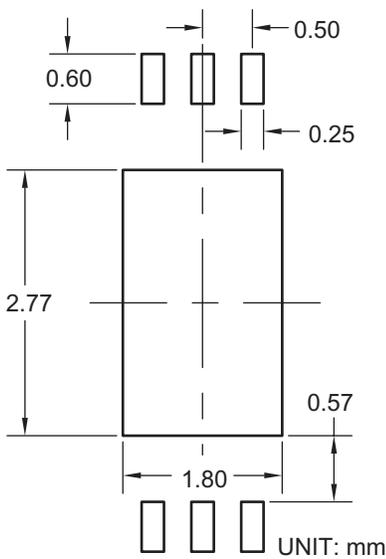
Designator	Purpose	Min.	Typ.	Max.
C1	Reduce supply voltage fluctuation, provide ESD protection, and limit current when a charger is reversely connected	0.022μF	0.1μF	1.0μF
R1	Reduce supply voltage fluctuation	100Ω	220Ω	330Ω
R2	Provide ESD protection and limit current when a charger is reversely connected	300Ω	2kΩ	4kΩ

Package Dimensions, 2x5 6L, EP1_P



BOTTOM VIEW

RECOMMENDED LAND PATTERN



Dimensions in millimeters

Symbols	Min.	Nom.	Max.
A	0.70	0.75	0.80
A1	0.00	—	0.05
b	0.20	0.23	0.30
c	0.10	0.15	0.20
D	2.00 BSC		
D1	1.30	1.35	1.55
E	5.00 BSC		
E1	4.50 BSC		
E2	2.60	2.67	2.95
e	0.50 BSC		
L	0.40	0.50	0.60
L1	0	—	0.10
θ1	0°	10°	12°
θ2	3° BSC		

Dimensions in inches

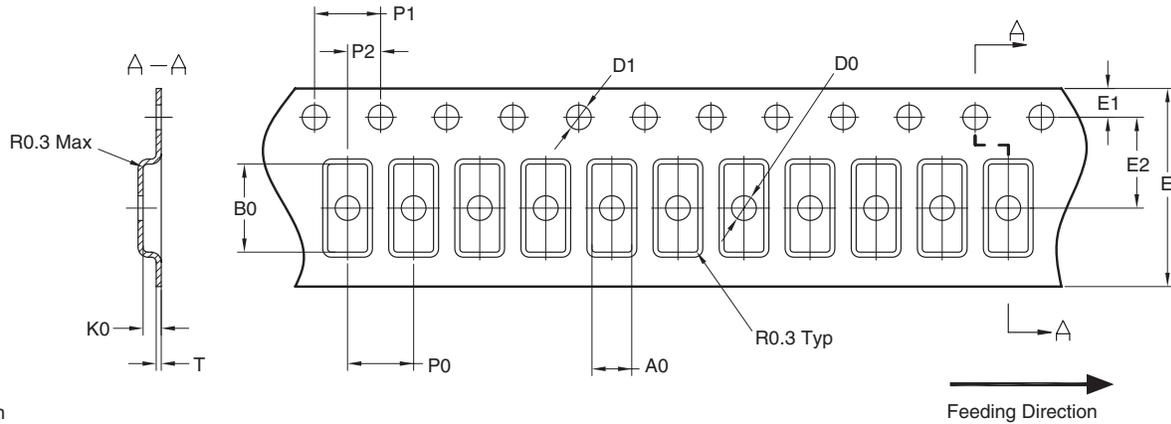
Symbols	Min.	Nom.	Max.
A	0.028	0.030	0.031
A1	0.000	—	0.002
b	0.008	0.009	0.012
c	0.004	0.006	0.008
D	0.079 BSC		
D1	0.051	0.053	0.061
E	0.197 BSC		
E1	0.177 BSC		
E2	0.102	0.105	0.116
e	0.020 BSC		
L	0.016	0.020	0.024
L1	0	—	0.004
θ1	0°	10°	12°
θ2	3° BSC		

Notes:

1. Package body sizes exclude mold flash and gate burrs. Mold flash at the non-lead sides should be less than 6 mils.
2. Controlling dimension is millimeter, converted inch dimensions are not necessarily exact.

Tape and Reel Dimensions, DFN 2 x 5

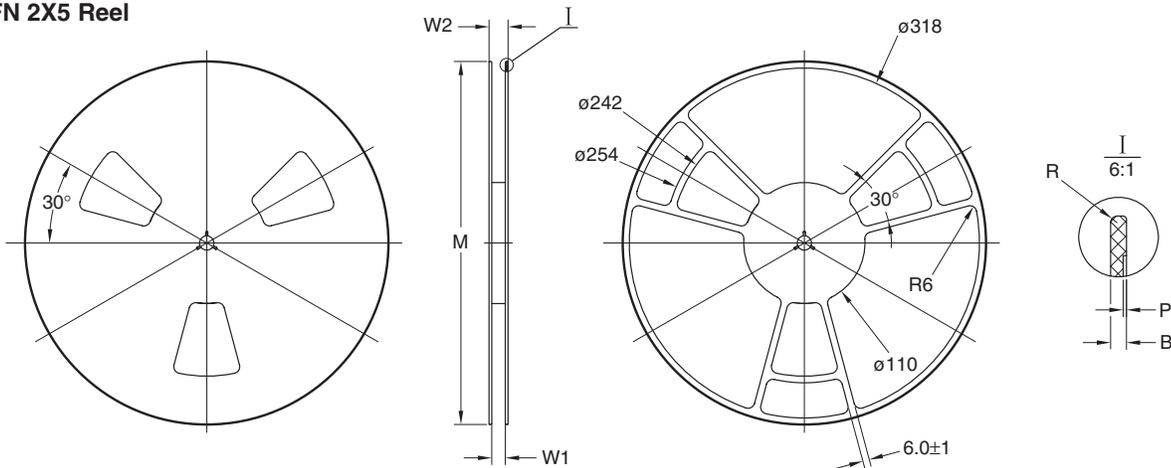
DFN2X5 Carrier Tape



Unit: mm

Package	A0	B0	K0	D0	D1	E	E1	E2	P0	P1	P2	T
DFN 2X5	2.41 ±0.10	5.34 ±0.10	1.10 ±0.10	1.50 +0.1/-0	1.50 +0.1/-0	12.00 ±0.10	1.75 ±0.10	5.50 ±0.10	4.00 ±0.10	4.00 ±0.10	2.00 ±0.10	0.30 ±0.10

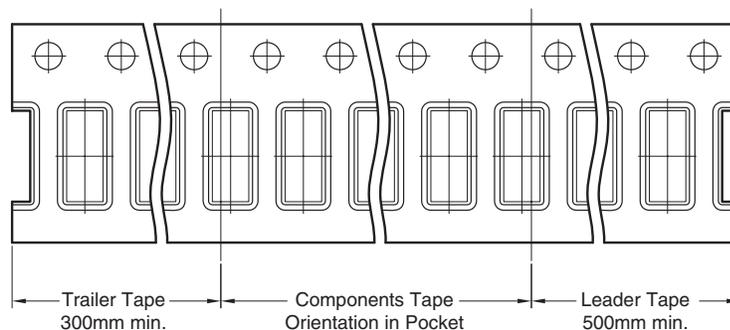
DFN 2X5 Reel



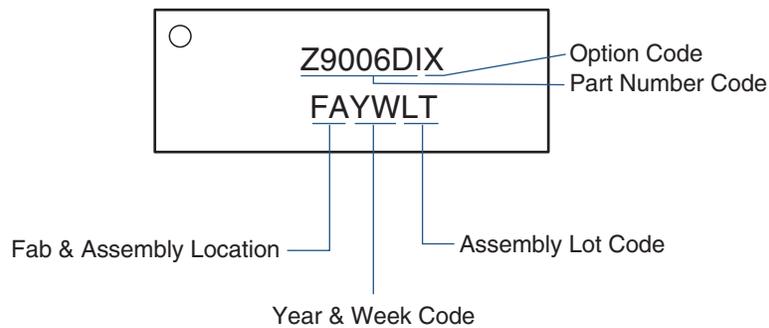
Tape Size	Reel Size	M	W1	W2	B	P	R
12mm	ø330	ø330.00 +0.3/-0.4	12.40 +2.0/-0.0	18.40 Max	2.40 ±0.3	0.5	1

DFN2X5 Tape

Leader/Trailer
& Orientation



AOZ9006D Package Marking



This datasheet contains preliminary data; supplementary data may be published at a later date. Alpha & Omega Semiconductor reserves the right to make changes at any time without notice.

LIFE SUPPORT POLICY

ALPHA & 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.