

## Li+ Charger Protection IC

### Features

- Provide Input Over-Voltage Protection
- Programmable Over-Current Protection
- Over-Temperature Protection
- High Immunity of False Triggering
- High Accuracy Protection Threshold
- Fault Status Indication
- Available in WLCSP0.74x1.14-5 and TDFN2x2-8 Package
- Lead Free and Green Devices Available (RoHS Compliant)

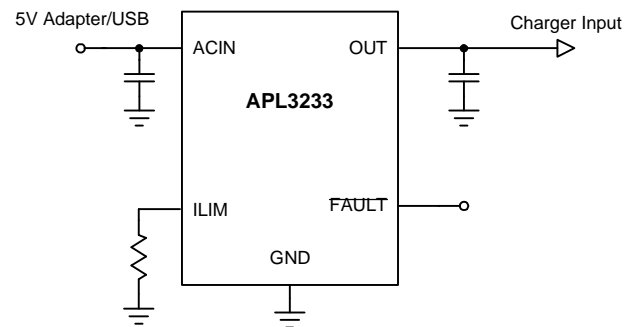
### General Description

The APL3233A/B provides complete Li+ charger protection against input over-voltage, input over-current. The over-current protection is programmed by a resistor connected from ILIM pin to the ground. When any of the monitored parameters are over the threshold, the IC removes the power from the charging system by turning off an internal switch. All protections also have deglitch time against false triggering due to voltage spikes or current transients.

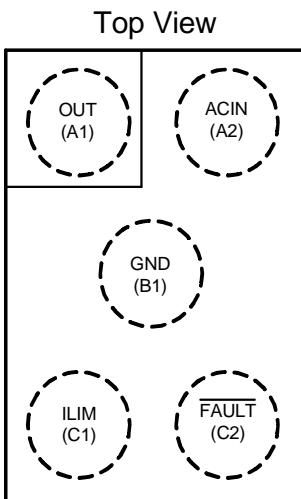
### Applications

- Smart Phones and PDAs
- Digital Still Cameras
- Portable Devices

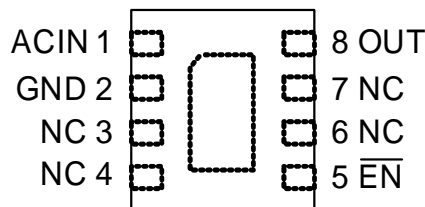
### Simplified Application Circuit



### Pin Configuration



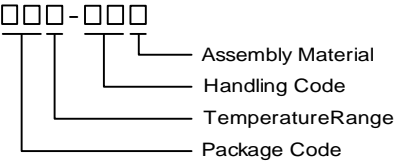
WLCSP 0.74x1.14-5



TDFN2x2-8 (Top View)

ANPEC reserves the right to make changes to improve reliability or manufacturability without notice, and advise customers to obtain the latest version of relevant information to verify before placing orders.

## Ordering and Marking Information

APL3233/A/B <span style="font-family: monospace;">□□□-□□□</span> 	Package Code HA : WLCSP0.74x1.14-5    QB : TDFN2x2-8 Operating Ambient Temperature Range I : -40 to 85°C Handling Code TR : Tape & Reel Assembly Material G : Halogen and Lead Free Device
APL3233A HA: <span style="border: 1px solid black; padding: 2px;">.AX</span>	X - Date Code
APL3233B HA: <span style="border: 1px solid black; padding: 2px;">.BX</span>	X - Date Code
APL3233 QB: <span style="border: 1px solid black; padding: 2px;">L33 X</span>	X - Date Code

Note : ANPEC lead-free products contain molding compounds/die attach materials and 100% matte tin plate termination finish; which are fully compliant with RoHS. ANPEC lead-free products meet or exceed the lead-free requirements of IPC/JEDEC J-STD-020D for MSL classification at lead-free peak reflow temperature. ANPEC defines "Green" to mean lead-free (RoHS compliant) and halogen free (Br or Cl does not exceed 900ppm by weight in homogeneous material and total of Br and Cl does not exceed 1500ppm by weight).

## Absolute Maximum Ratings (Note 1)

Symbol	Parameter	Rating	Unit
$V_{ACIN}$	ACIN Input Voltage (ACIN to GND)	-0.3 ~ 30	V
$V_{FAULT}, V_{ILIM}$	FAULT, ILIM to GND Voltage	-0.3 ~ 7	V
$V_{OUT}$	OUT to GND Voltage	-0.3 ~ 7	V
$T_J$	Maximum Junction Temperature	150	°C
$T_{STG}$	Storage Temperature	-65 ~ 150	°C
$T_{SDR}$	Maximum Lead Soldering Temperature(10 Seconds)	260	°C

Note1: Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

## Thermal Characteristics

Symbol	Parameter	Typical Value	Unit
$\theta_{JA}$	Junction-to-Ambient Resistance in free air <sup>(Note 2)</sup> <div style="display: flex; justify-content: space-between; width: 100%;"> <span>WLCSP0.74x1.14-5</span> <span>100</span> </div> <div style="display: flex; justify-content: space-between; width: 100%;"> <span>TDFN2x2-8</span> <span>75</span> </div>		°C/W

Note 2:  $\theta_{JA}$  is measured with the component mounted on a high effective thermal conductivity test board in free air.

## Recommended Operating Conditions (Note3)

Symbol	Parameter	Range	Unit
$V_{ACIN}$	ACIN Input Voltage	4.5 ~ 5.5	V
$I_{OUT}$	Output Current	0 ~ 2	A
$R_{ILIM}$	Over-current Protection Setting Resistor	10 ~ 31.25	k $\Omega$
$T_A$	Ambient Temperature	-40 ~ 85	$^{\circ}$ C
$T_J$	Junction Temperature	-40 ~ 125	$^{\circ}$ C

Note 3 : Refer th the typical application circuit.

## Electrical Characteristics

Unless otherwise specified, these specifications apply over  $V_{ACIN}=5V$ ,  $T_A = -40\sim 85^{\circ}C$ . Typical values are at  $T_A=25^{\circ}C$ .

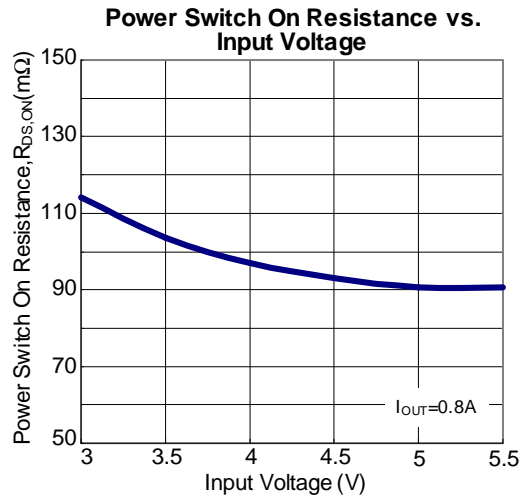
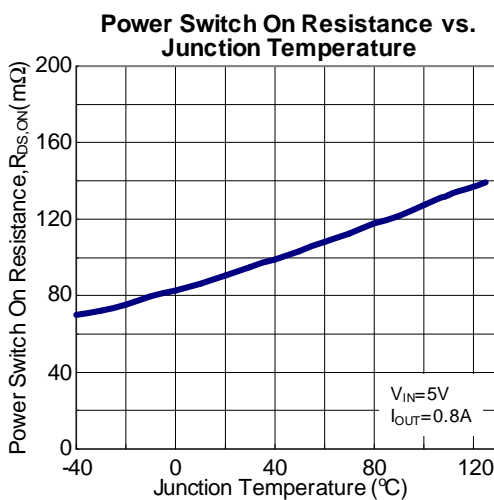
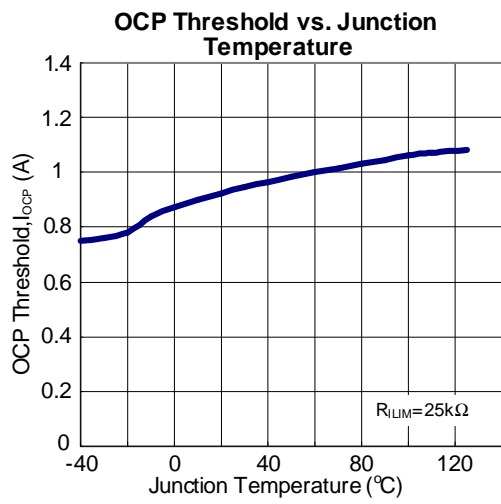
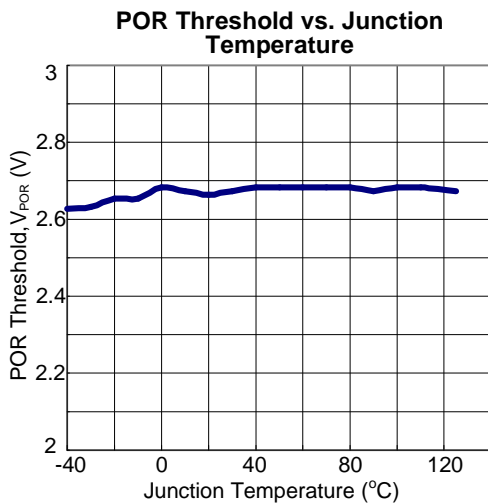
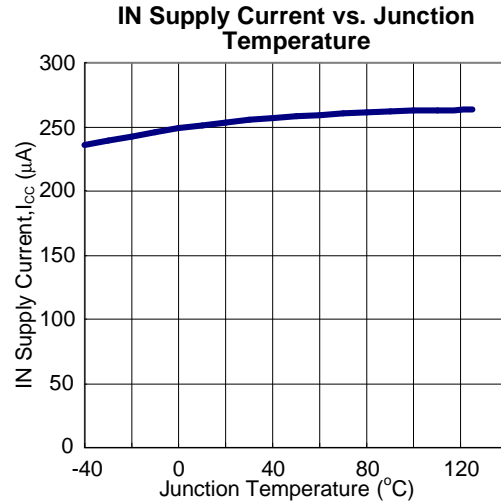
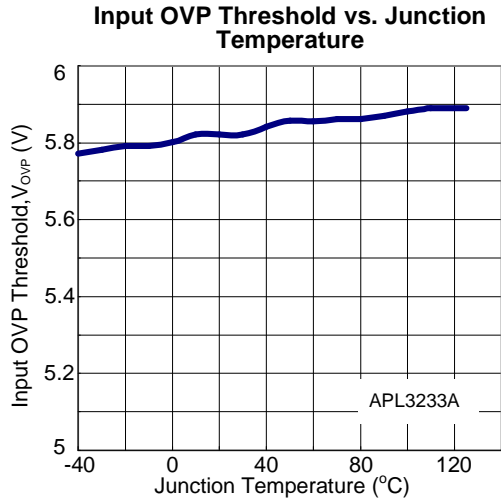
Symbol	Parameter	Test Conditions	APL3233A/B			Unit
			Min	Typ	Max	
<b>ACIN INPUT CURRENT and POWER-ON-RESET (POR)</b>						
$I_{ACIN}$	ACIN Supply Current		-	250	350	$\mu$ A
$V_{ACIN}$	ACIN POR Threshold	$V_{IN}$ rising	2.4	2.6	2.8	V
	ACIN POR Hysteresis		160	250	300	mV
$T_{B(ACIN)}$	ACIN Power-On Blanking Time	$V_{IN}$ rising to $V_{OUT}$ rising, $V_{IN}=4.5\sim 5.5V$		8	16	ms
<b>INTERNAL SWITCH ON RESISTANCE</b>						
$R_{ON}$	Power Switch On Resistance	$I_{OUT} = 0.8A, V_{IN}=5V$	-	90	180	m $\Omega$
	OUT Discharge Resistance	$V_{OUT} = 3V$	400	500	600	$\Omega$
<b>INPUT OVER-VOLTAGE PROTECTION (OVP)</b>						
$V_{OVP}$	Input OVP Threshold	APL3233/A, $T_A = -40 \sim 85^{\circ}C$	5.7	5.85	6.0	V
		APL3233B, $T_A = -40 \sim 85^{\circ}C$	6.6	6.8	7.0	V
	Input OVP Hysteresis	APL3233A	200	250	330	mV
		APL3233B	290	350	410	mV
	Input OVP propagation delay	$V_{ACIN} = 5V$ to $12V$ , $I_{OUT} = 10mA$	-	-	1	$\mu$ s
$T_{ON(OVP)}$	Input OVP recovery time	$V_{IN}=4.5\sim 5.5V$	-	8	16	ms
	ACIN to FAULT Delay Time	$V_{ACIN}$ rising to $V_{FAULT}$ falling, $V_{ACIN} = 0$ to $12V$ .	60	160	260	$\mu$ s
<b>OVER-CURRENT PROTECTION (OCP)</b>						
$I_{OCP}$	OCP Threshold	$R_{ILIM} = 25k\Omega, T_A = -40 \sim 85^{\circ}C, V_{IN}=4.5\sim 5.5V$	900	1000	-	mA
$T_{B(OCP)}$	OCP Blanking Time	$V_{IN}=4.5\sim 5.5V$	155	176	195	$\mu$ s
$T_{ON(OCP)}$	OCP Recovery Time	$V_{IN}=4.5\sim 5.5V$	50	64	80	ms

## Electrical Characteristics

Unless otherwise specified, these specifications apply over  $V_{ACIN}=5V$ ,  $T_A=-40\sim 85^{\circ}C$ . Typical values are at  $T_A=25^{\circ}C$ .

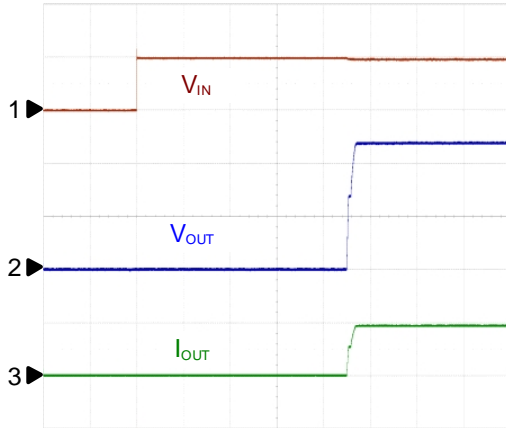
Symbol	Parameter	Test Conditions	APL3233A/B			Unit
			Min	Typ	Max	
<b>FAULT LOGIC LEVELS AND DELAY TIME</b>						
$V_{\overline{FAULT}}$	$\overline{FAULT}$ Output Low Voltage	Sink 5mA current	-	-	0.4	V
	$\overline{FAULT}$ Leakage Current	$V_{\overline{FAULT}} = 5V$	-	-	1	$\mu A$
$T_{F(L)}$	OUT to $\overline{FAULT}$ Delay Time	$V_{OUT}$ falling to $V_{\overline{FAULT}}$ falling, when any protection is detected	1	2	5	$\mu s$
$T_{F(H)}$	$\overline{FAULT}$ to OUT Delay Time	$V_{\overline{FAULT}}$ rising to $V_{OUT}$ rising, when any protection is released.	1	2	5	$\mu s$
<b>Thermal Shutdown Protection</b>						
$T_{OTP}$	Thermal Shutdown Threshold		-	155	-	$^{\circ}C$
	Thermal Shutdown Hysteresis		-	30	-	$^{\circ}C$

### Typical Operating Characteristics



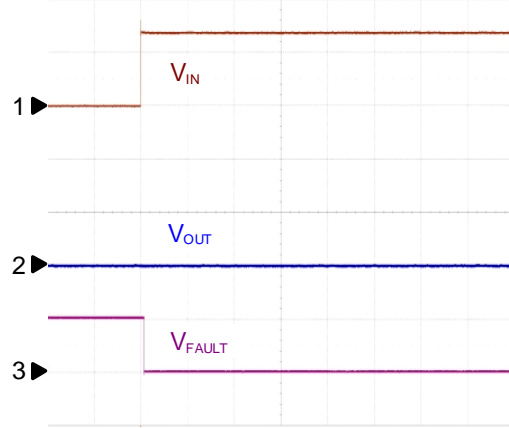
Operating Waveforms

Normal Power On



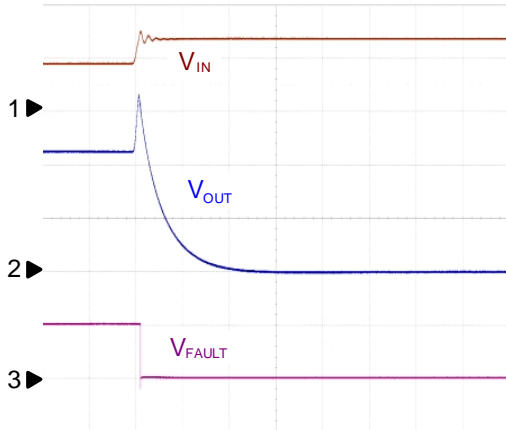
V<sub>IN</sub>=0 to 5V  
 C<sub>OUT</sub>=1μF, C<sub>IN</sub>=1μF, R<sub>OUT</sub>=10Ω  
 CH1: V<sub>IN</sub>, 5V/Div, DC  
 CH2: V<sub>OUT</sub>, 2V/Div, DC  
 CH3: I<sub>OUT</sub>, 0.5A/Div, DC  
 TIME: 2ms/Div

OVP at Power On



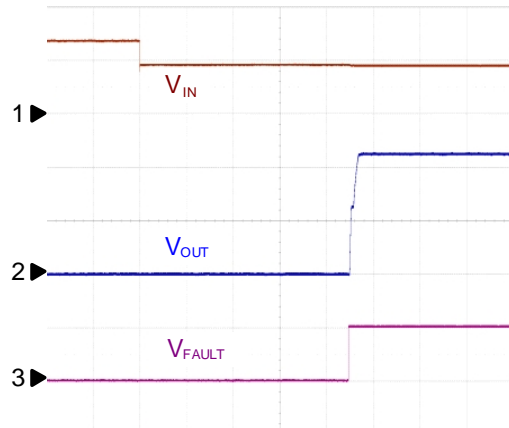
V<sub>IN</sub>=0 to 7V  
 C<sub>OUT</sub>=1μF, C<sub>IN</sub>=1μF, R<sub>OUT</sub>=10Ω  
 CH1: V<sub>IN</sub>, 5V/Div, DC  
 CH2: V<sub>OUT</sub>, 2V/Div, DC  
 CH3: V<sub>FAULT</sub>, 5V/Div, DC  
 TIME: 2ms/Div

Input Over-Voltage Protection



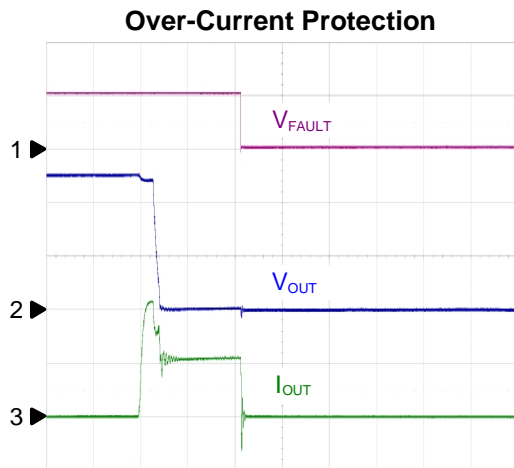
V<sub>IN</sub>=5 to 7V  
 C<sub>OUT</sub>=1μF, C<sub>IN</sub>=1μF, R<sub>OUT</sub>=10Ω  
 CH1: V<sub>IN</sub>, 5V/Div, DC  
 CH2: V<sub>OUT</sub>, 2V/Div, DC  
 CH3: V<sub>FAULT</sub>, 5V/Div, DC  
 TIME: 20μs/Div

Recovery from Input OVP



V<sub>IN</sub>=7V to 5V  
 C<sub>OUT</sub>=1μF, C<sub>IN</sub>=1μF, R<sub>OUT</sub>=10Ω  
 CH1: V<sub>IN</sub>, 5V/Div, DC  
 CH2: V<sub>OUT</sub>, 2V/Div, DC  
 CH3: V<sub>FAULT</sub>, 5V/Div, DC  
 TIME: 2ms/Div

## Operating Waveforms

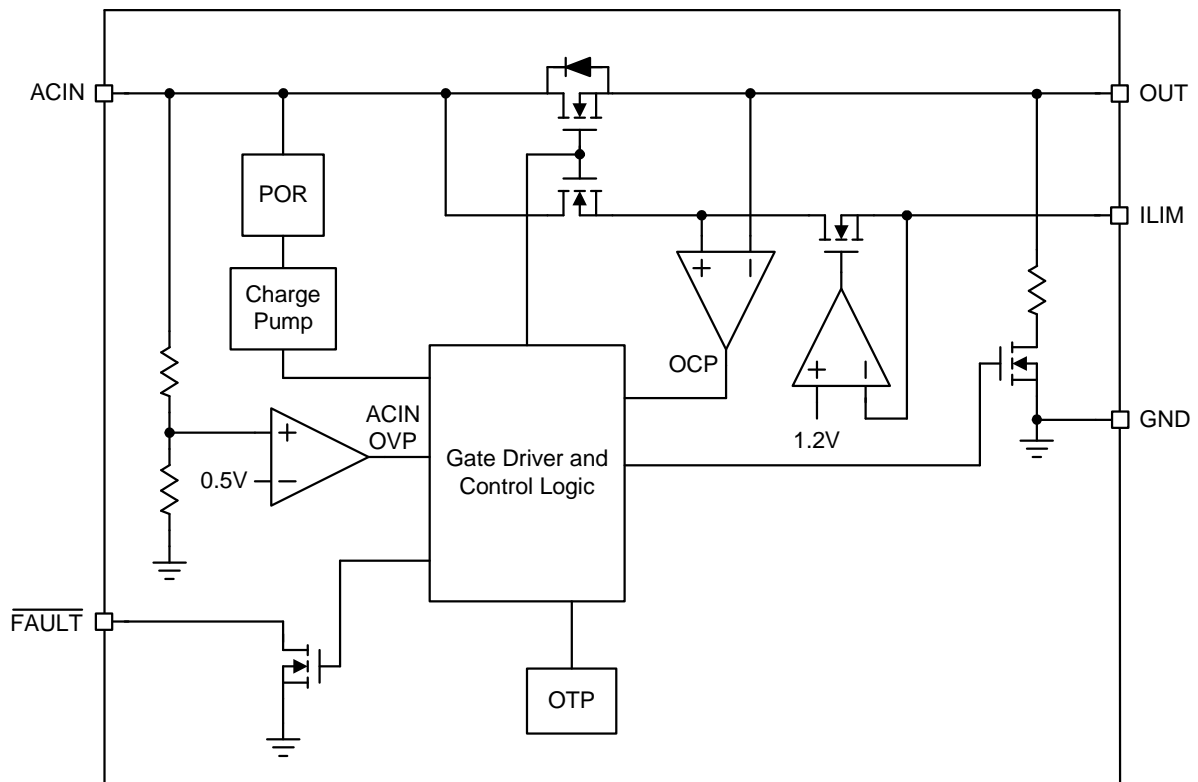


$C_{OUT}=1\mu F, C_{IN}=1\mu F$   
CH1:  $V_{FAULT}$ , 5V/Div, DC  
CH2:  $V_{OUT}$ , 2V/Div, DC  
CH3:  $I_{OUT}$ , 0.5A/Div, DC  
TIME: 100 $\mu$ s/Div

### Pin Description

PIN			Function
TDFN	WLCSP	NAME	
1	A2	ACIN	Power Supply Input, connect to external DC supply. Connect external 1μF ceramic capacitor (minimum) to GND.
2	B1	GND	Ground pin of the circuitry. All voltage levels are measured with respect to this pin.
-	C2	$\overline{\text{FAULT}}$	Fault Indication Pin. This pin goes low when input OVP, OCP is detected.
-	C1	ILIM	Over-current Protection Setting Pin. Connect a resistor ( $R_{ILIM}$ ) to GND to set the over-current threshold. When left open, the internal power FET will be turned off.
8	A1	OUT	Output Pins. Output Voltage Pin. The output voltage follows the input voltage when no fault is detected
5	-	/EN	Enable Input. Pull this pin to high to disable the device and place $\leq 1K\Omega$ pull low resistor to pull this pin to low to enable device.
3,4,6,7	-	NC	NC

### Block Diagram





Typical Application Circuit

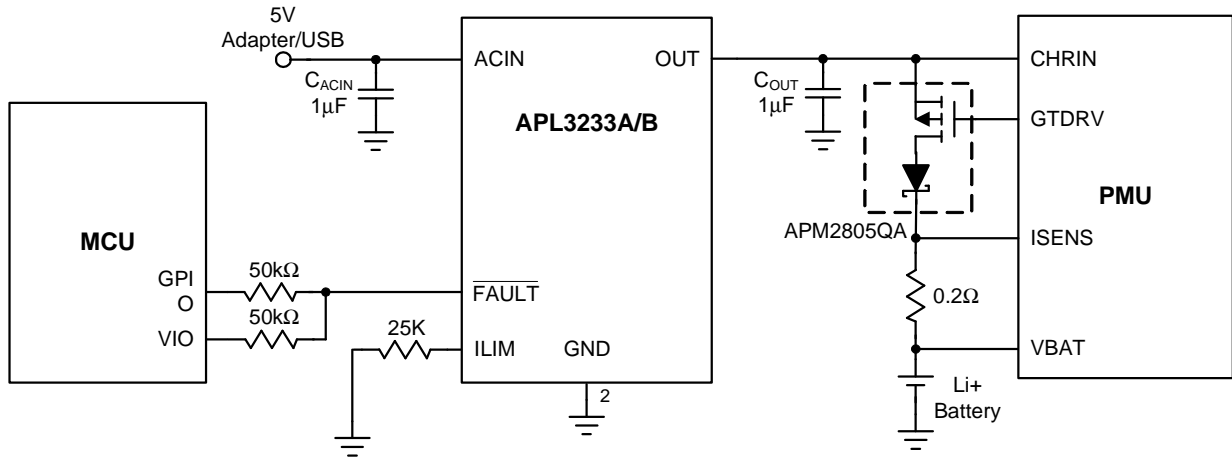


Figure 1. The Typical Protection Circuit for Charger Systems.

Designation	
C <sub>ACIN</sub>	1μF, 25V, X5R, 0603 Murata GRM188R61E105K
C <sub>OUT</sub>	1μF, 10V, X5R, 0603 Murata GRM188R61A105K

Murata website: [www.murata.com](http://www.murata.com)

## Function Description

### ACIN Power-On-Reset (POR)

The APL3233A/B have a built-in power-on-reset circuit to keep the output shutting off until internal circuitry is operating properly. The POR circuit has hysteresis and a de-glitch feature so that it will typically ignore undershoot transients on the input. When input voltage exceeds the POR threshold and after 8ms blanking time, the output voltage starts a soft-start to reduce the inrush current.

### Input Over-Voltage Protection (OVP)

The input voltage is monitored by the internal OVP circuit. When the input voltage rises above the input OVP threshold, the internal FET will be turned off within 1 $\mu$ s to protect connected system on OUT pin. When the input voltage returns below the input OVP threshold minus the hysteresis, the FET is turned on again after 8ms recovery time. The input OVP circuit has a 250mV hysteresis and a recovery time of  $T_{ON(OVP)}$  to provide noise immunity against transient conditions.(see Figure 2.)

### Over-Current Protection (OCP)

The output current is monitored by the internal OCP circuit. When the output current reaches the OCP threshold, the device limits the output current at OCP threshold level. If the OCP condition continues for a blanking time of  $T_{B(OCP)}$ , the internal power FET is turned off. After the recovery time of  $T_{ON(OCP)}$ , the FET will be turned on again and the output current is monitored again. The OCP threshold is programmed by a resistor  $R_{ILIM}$  connected from ILIM pin to GND. The OCP threshold is calculated by the following equation:

$$I_{OCP} = \frac{K_{ILIM}}{R_{ILIM}}$$

where

$$K_{ILIM}=25000A\Omega$$

### Over-Temperature Protection

When the junction temperature exceeds 155°C, the internal thermal sense circuit turns off the power FET and allows the device to cool down. When the device's junction temperature cools by 30°C, the internal thermal sense circuit will enable the device, resulting in a pulsed output during continuous thermal protection. Thermal protection is designed to protect the IC in the event of over temperature conditions. For normal operation, the junction temperature cannot exceed  $T_j=+125^\circ\text{C}$ .

### $\overline{\text{FAULT}}$ Output

The APL3233A/B provide an open-drain output to indicate that a fault has occurred. When any of input OVP, OCP is detected, the  $\overline{\text{FAULT}}$  goes low to indicate that a fault has occurred. Since the  $\overline{\text{FAULT}}$  pin is an open-drain output, connecting a resistor to a pull high voltage is necessary.

### ESD Tests

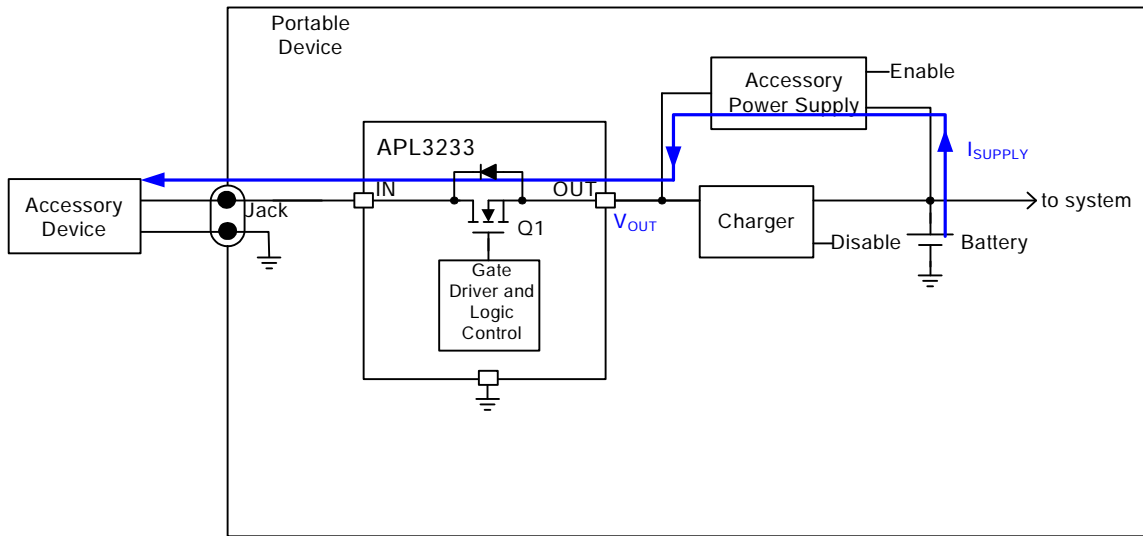
The APL3233A/B VIN input pin fully supports the IEC61000-4-2. That means the VIN pin has immunity of  $\pm 15\text{kV}$  ESD discharge in Air condition, and immunity of  $\pm 8\text{kV}$  ESD discharge in Contact condition.

## Function Description (Cont.)

### Powering an Accessory Device

In some applications, such as USB On-The-Go, users need to power an accessory device by using the portable device's battery through the jack holes of AC adapter. The APL3233A/B provide reverse current flow path from OUT to IN.

If  $V_{OUT} > V_{POR} + 0.7V$ , FET Q1 is turned on, and the reverse current does not flow through the diode but through Q1. Q1 will then remain ON as long as  $V_{OUT} > V_{POR} - V_{POR\_HYS} + R_{DS\_ON} * I_{SUPPLY}$ . Within this voltage range, the reverse current capability is the same as the forward capability, 1.5A. It should be noted that there is no overcurrent protection in this direction.



Function Description (Cont.)

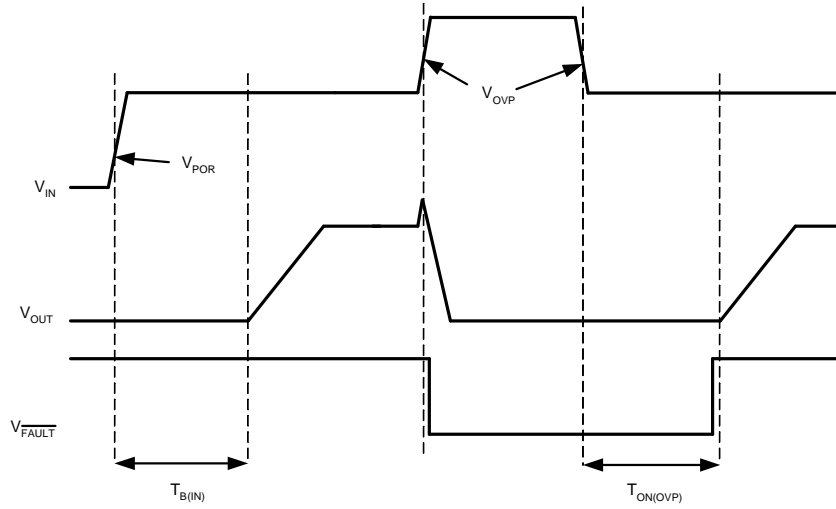


Figure 2. OVP Timing Chart

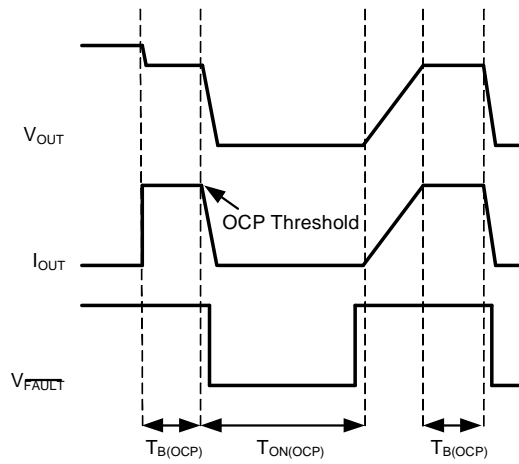


Figure 3. OCP Timing Chart

## Application Information

### FAULT Output

Since the FAULT pin is an open-drain output, connecting a resistor  $R_{UP}$  to a pull high voltage is necessary. It is also recommended that connect the FAULT to the MCU GPIO through a resistor  $R_{FAULT}$ . The  $R_{FAULT}$  prevents damage to the MCU under a failure mode. The recommended value of the resistors should be between 10kΩ to 100kΩ.

### Capacitor Selection

The input capacitor is for decoupling and prevents the input voltage from overshooting to dangerous levels. In the AC adapter hot plug-in applications or load current step-down transient, the input voltage has a transient spike due to the parasitic inductance of the input cable. A 25V, X5R, dielectric ceramic capacitor with a value between 1μF and 4.7μF placed close to the IN pin is recommended.

The output capacitor is for output voltage decoupling, and also can be as the input capacitor of the charging circuit. At least, a 1μF, 10V, X5R capacitor is recommended.

### Layout Consideration

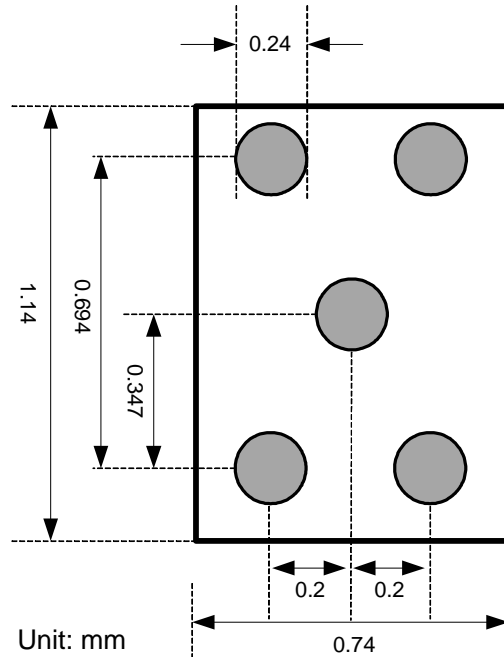
In some failure modes, a high voltage may be applied to the device. Make sure the clearance constraint of the PCB layout must satisfy the design rule for high voltage.

The exposed pad of the WLCSP0.74x1.14-5 performs the function of channeling heat away. It is recommended that connect the exposed pad to a large copper ground plane on the backside of the circuit board through several thermal vias to improve heat dissipation.

The input and output capacitors should be placed close to the IC.  $R_{ILIM}$  also should be placed close to the IC.

The high current traces like input trace and output trace must be wide and short.

### Recommended Minimum Footprint

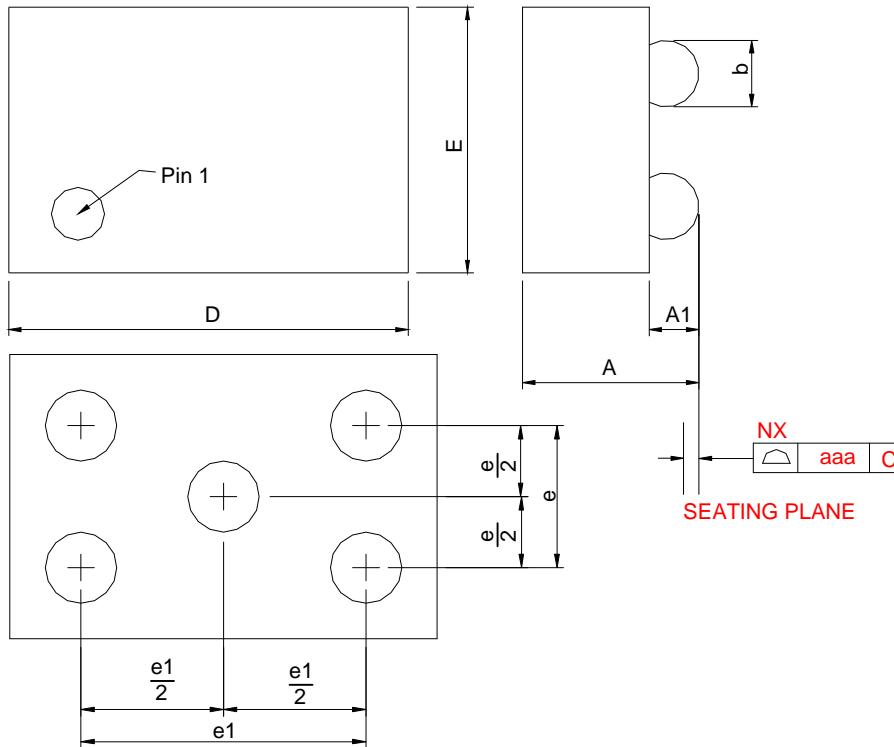


Unit: mm

WLCSP0.74x1.14-5

Package Information

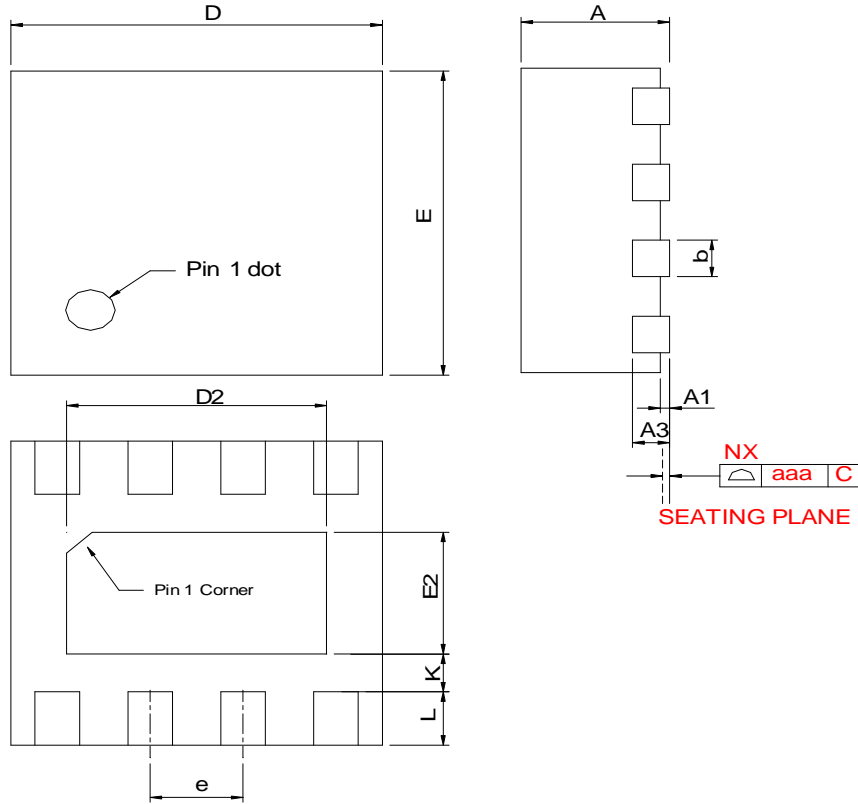
WLCSP0.74x1.14-5



S Y M B O L	WLCSP0.74*1.14-5			
	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A		0.60		0.024
A1	0.14	0.18	0.006	0.007
b	0.18	0.25	0.007	0.010
D	1.14	1.20	0.045	0.047
E	0.74	0.80	0.029	0.032
e	0.40 BSC		0.016 BSC	
e1	0.694 BSC		0.027 BSC	
aaa	0.08		0.003	

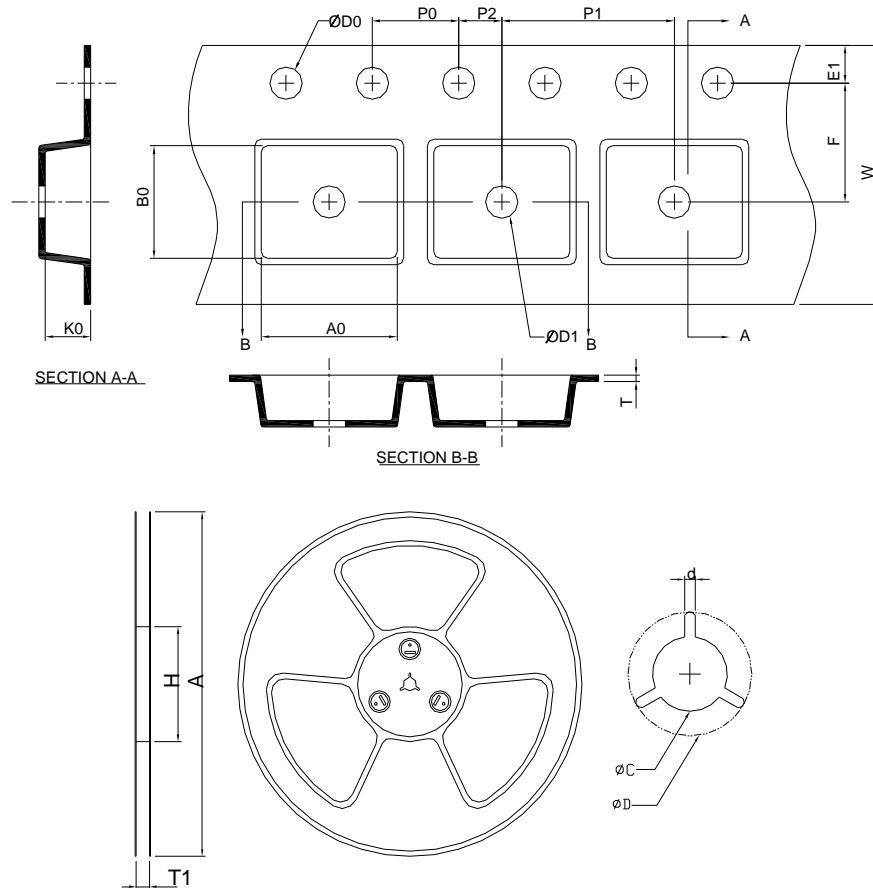
Package Information (Cont.)

TDFN2x2-8



SYMBOL	TDFN2*2-8			
	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A	0.70	0.80	0.028	0.031
A1	0.00	0.05	0.000	0.002
A3	0.20 REF		0.008 REF	
b	0.18	0.30	0.007	0.012
D	1.90	2.10	0.075	0.083
D2	1.00	1.60	0.039	0.063
E	1.90	2.10	0.075	0.083
E2	0.60	1.00	0.024	0.039
e	0.50 BSC		0.020 BSC	
L	0.30	0.45	0.012	0.018
K	0.20		0.008	
aaa	0.08		0.003	

### Carrier Tape & Reel Dimensions



Application	A	H	T1	C	d	D	W	E1	F
WLCSP (0.74x1.14)	178.0±2.00	50 MIN.	8.4+2.00 -0.00	13.0+0.50 -0.20	1.5 MIN.	20.2 MIN.	8.0±0.30	1.75±0.10	3.5±0.05
	P0	P1	P2	D0	D1	T	A0	B0	K0
	4.0±0.10	4.0±0.10	2.0±0.05	1.5+0.10 -0.00	0.5 MIN.	0.6+0.00 -0.40	0.85±0.05	1.25±0.05	0.56±0.05
Application	A	H	T1	C	d	D	W	E1	F
TDFN (2x2)	178.0±2.00	50 MIN.	8.4+2.00 -0.00	13.0+0.50 -0.20	1.5 MIN.	20.2 MIN.	8.0±0.20	1.75±0.10	3.5±0.05
	P0	P1	P2	D0	D1	T	A0	B0	K0
	4.0±0.10	4.0±0.10	2.0±0.05	1.5+0.10 -0.00	1.5 MIN.	0.6+0.00 -0.40	2.35±0.20	2.35±0.20	1.00±0.20

(mm)

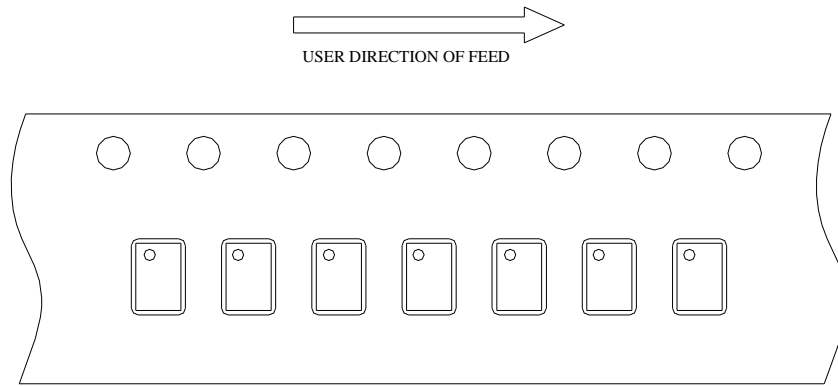
### Devices Per Unit

Package Type	Unit	Quantity
WLCSP(0.74x1.14)	Tape & Reel	3000
Package Type	Packing	Quantity
TDFN(2x2)	Tape & Reel	3000

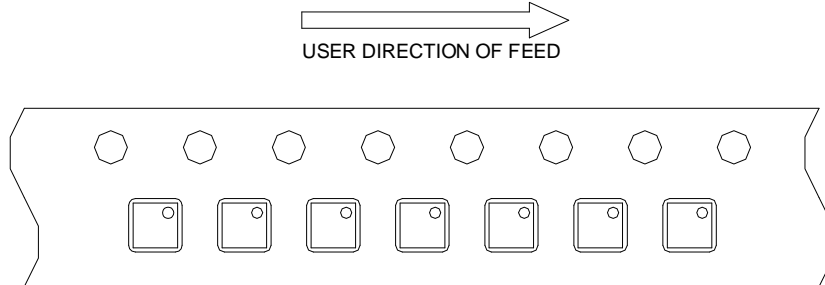


### Taping Direction Information

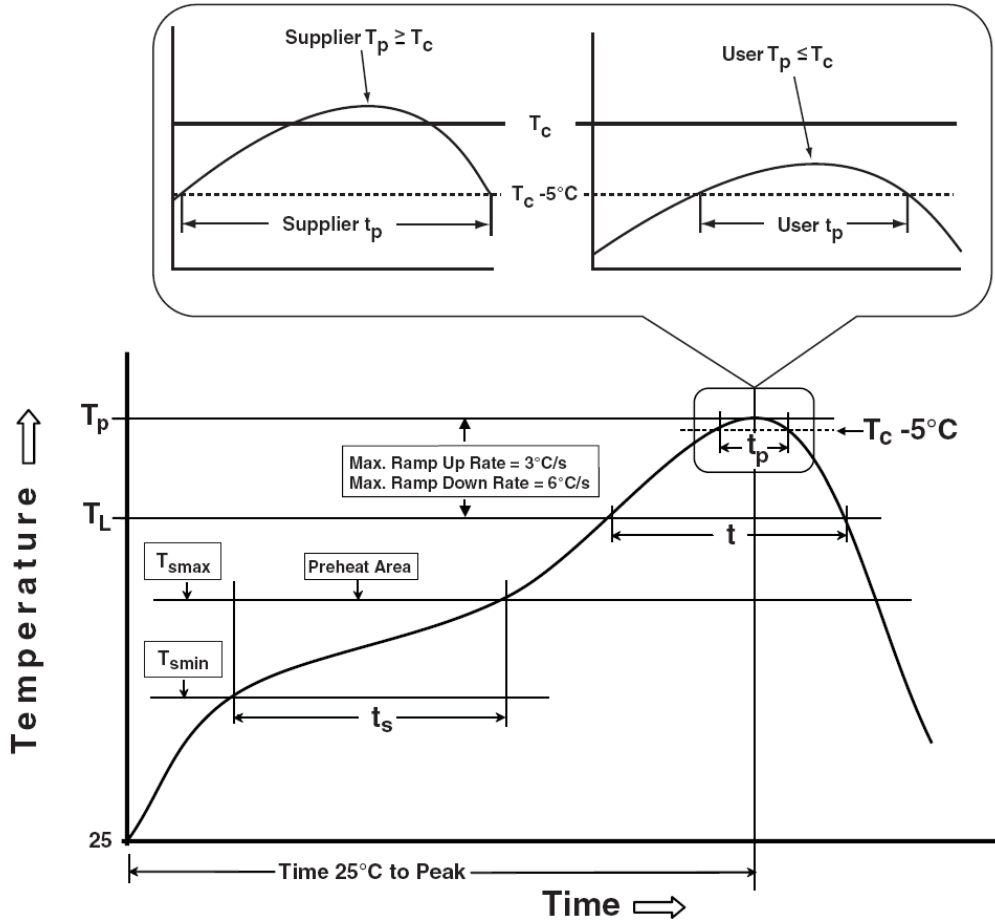
WLCSP0.74x1.14



TDFN2x2-8



Classification Profile



### Classification Reflow Profiles

Profile Feature	Sn-Pb Eutectic Assembly	Pb-Free Assembly
<b>Preheat &amp; Soak</b>		
Temperature min ( $T_{smin}$ )	100 °C	150 °C
Temperature max ( $T_{smax}$ )	150 °C	200 °C
Time ( $T_{smin}$ to $T_{smax}$ ) ( $t_s$ )	60-120 seconds	60-120 seconds
Average ramp-up rate ( $T_{smax}$ to $T_p$ )	3 °C/second max.	3°C/second max.
Liquidous temperature ( $T_L$ )	183 °C	217 °C
Time at liquidous ( $t_L$ )	60-150 seconds	60-150 seconds
Peak package body Temperature ( $T_p$ )*	See Classification Temp in table 1	See Classification Temp in table 2
Time ( $t_p$ )** within 5°C of the specified classification temperature ( $T_c$ )	20** seconds	30** seconds
Average ramp-down rate ( $T_p$ to $T_{smax}$ )	6 °C/second max.	6 °C/second max.
Time 25°C to peak temperature	6 minutes max.	8 minutes max.
* Tolerance for peak profile Temperature ( $T_p$ ) is defined as a supplier minimum and a user maximum.		
** Tolerance for time at peak profile temperature ( $t_p$ ) is defined as a supplier minimum and a user maximum.		

Table 1. SnPb Eutectic Process – Classification Temperatures ( $T_c$ )

Package Thickness	Volume mm <sup>3</sup> <350	Volume mm <sup>3</sup> ≥350
<2.5 mm	235 °C	220 °C
≥2.5 mm	220 °C	220 °C

Table 2. Pb-free Process – Classification Temperatures ( $T_c$ )

Package Thickness	Volume mm <sup>3</sup> <350	Volume mm <sup>3</sup> 350-2000	Volume mm <sup>3</sup> >2000
<1.6 mm	260 °C	260 °C	260 °C
1.6 mm – 2.5 mm	260 °C	250 °C	245 °C
≥2.5 mm	250 °C	245 °C	245 °C

### Reliability Test Program

Test item	Method	Description
SOLDERABILITY	JESD-22, B102	5 Sec, 245°C
HOLT	JESD-22, A108	1000 Hrs, Bias @ 125°C
PCT	JESD-22, A102	168 Hrs, 100%RH, 2atm, 121°C
TCT	JESD-22, A104	500 Cycles, -65°C~150°C
HBM	MIL-STD-883-3015.7	VHBM ≥ 2KV
MM	JESD-22, A115	VMM ≥ 200V
Latch-Up	JESD 78	10ms, $1_{tr} \geq 100mA$

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