Li+ Charger Protection IC

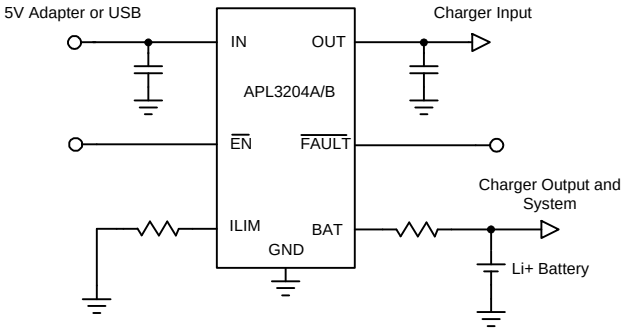
Features

- **Input Over-Voltage Protection**
- **Programmable Input Over-Current Protection**
- **Battery Over-Voltage Protection**
- **Over-Temperature Protection**
- **High Immunity of False Triggering**
- **High Accuracy Protection Thresholds**
- **Fault Status Indication**
- **Enable Input**
- **Available in TDFN4x3-12 Package**
- **Lead Free and Green Devices Available (RoHS Compliant)**

General Description

The APL3204A/B provide complete Li+ charger protections against over-voltage, over-current, and battery over-voltage. The IC is designed to monitor input voltage, input current, and battery voltage. 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. The APL3204A/B also provide over-temperature protection, a $\overline{\text{FAULT}}$ output pin to indicate the fault conditions, and the $\overline{\text{EN}}$ pin to allow the system to disable the IC.

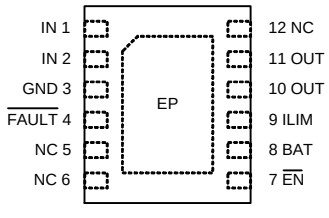
Simplified Application Circuit



Applications

- **Smart Phones and PDAs**
- **Digital Still Cameras**
- **Potable Devices**

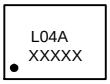
Pin Configuration



TDFN4X3-12 (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

APL3204A □□□-□□□ APL3204B Assembly Material Handling Code Temperature Range Package Code	Package Code QB : TDFN4x3-12 Operating Ambient Temperature Range I : -40 to 85 °C Handling Code TR : Tape & Reel Assembly Material L : Lead Free Device G : Halogen and Lead Free Device
APL3204A QB: 	XXXXX - Date Code
APL3204B QB: 	XXXXX - 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-020C 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_{IN}	IN Input Voltage (IN Pin to GND)	-0.3 to 30	V
V_{OUT}, V_{BAT}	OUT, BAT Pins to GND Voltage	-0.3 to 7	V
V_{ILIM}, $V_{\overline{FAULT}}$, $V_{\overline{EN}}$,	ILIM, $\overline{FAULT}$, $\overline{EN}$, Pins to GND Voltage	-0.3 to 7	V
I_{OUT}	OUT Output Current	2	A
T_J	Maximum Junction Temperature	150	°C
T_{STG}	Storage Temperature Range	-65 to 150	°C
T_{SDR}	Maximum Lead Soldering Temperature,10 Seconds	260	°C

Note 1 : Stresses beyond the absolute maximum rating may damage the device and exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Thermal Characteristics

Symbol	Parameter	Typical Value	Unit
θ_{JA}	Junction to Ambient Thermal Resistance in Free Air TDFN4x3-12	80	°C/W

Recommended Operating Conditions

Symbol	Parameter	Range	Unit
V_{IN}	IN Input Voltage	4.5 to 5.5	V
I_{OUT}	OUT Output Current	0 to 1.5	A
T_J	Junction Temperature	-40 to 125	°C
T_A	Ambient Temperature	-40 to 85	°C

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Electrical Characteristics

Refer to the typical application circuit. These specifications apply over V_{IN}=5V, T_A= -40~85°C, unless otherwise specified. Typical values are at T_A=25°C.

Symbol	Parameter	Test Conditions	APL3204A/B			Unit
			Min.	Typ.	Max.	
POWER-ON-RESET (POR) AND SUPPLY CURRENT						
V_{POR}	IN POR Threshold	V_{IN} rising	2.5	-	2.8	V
	IN POR Hysteresis		-	230	-	mV
I_{CC}	IN Supply Current	$\overline{EN}$ = Low	-	250	350	µA
		$\overline{EN}$ = High	-	100	150	
$T_{B(IN)}$	Input Power-On Blanking Time	V_{IN} rising to V_{OUT} rising	-	8	-	ms
INTERNAL POWER SWITCH AND OUT DISCHARGE RESISTANCE						
	Power Switch On Resistance	I_{OUT} = 0.5A	-	250	450	mΩ
	OUT Discharge Resistance	V_{OUT} = 3V	-	500	-	Ω
INPUT OVER-VOLTAGE PROTECTION (OVP)						
V_{OVP}	Input OVP Threshold	APL3204A, V_{IN} rising	5.67	5.85	6.00	V
		APL3204B, V_{IN} rising	6.60	6.80	7.00	
	Input OVP Recovery Hysteresis		-	200	-	mV
	Input OVP Propagation Delay		-	-	1	µs
$T_{ON(OVP)}$	Input OVP Recovery Time		-	8	-	ms
OVER-CURRENT PROTECTION (OCP)						
I_{OCP}	OCP Threshold	R_{ILIM} = 25kΩ	930	1000	1070	mA
	OCP Threshold Accuracy	I_{OCP} = 300mA to 1500mA	-10	-	+10	%
$T_{B(OCP)}$	OCP Blanking Time		-	176	-	µs
$T_{ON(OCP)}$	OCP Recovery Time		-	64	-	ms
BATTERY OVER-VOLTAGE PROTECTION						
V_{BOVP}	Battery OVP Threshold	V_{BAT} rising	4.30	4.35	4.4	V
	Battery OVP Hysteresis		-	270	-	mV
I_{BAT}	BAT Pin Leakage Current	V_{BAT} = 4.4V	-	-	20	nA
$T_{B(BOVP)}$	Battery OVP Blanking Time		-	176	-	µs
EN LOGIC LEVELS						
	$\overline{EN}$ Input Logic High		1.4	-	-	V
	$\overline{EN}$ Input Logic Low		-	-	0.4	V
	$\overline{EN}$ Internal Pull-Low Resistor		-	500	-	kΩ
FAULT LOGIC LEVELS AND DELAY TIME						
	$\overline{FAULT}$ Output Low Voltage	Sink 5mA current	-	-	0.4	V
	$\overline{FAULT}$ Pin Leakage Current	$V_{\overline{FAULT}}$ = 5V	-	-	1	µA
OVER-TEMPERATURE PROTECTION (OTP)						
T_{OTP}	Over-Temperature Threshold		-	140	-	°C
	Over-Temperature Hysteresis		-	20	-	°C

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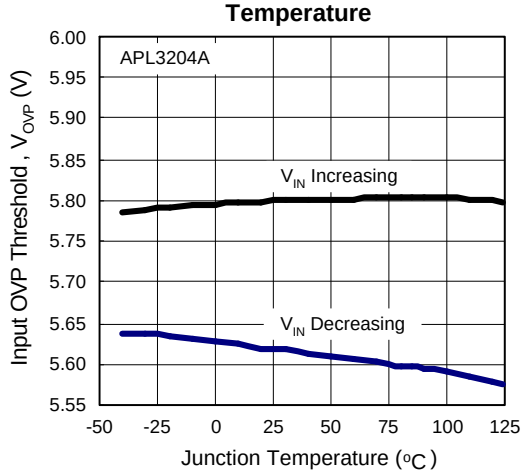
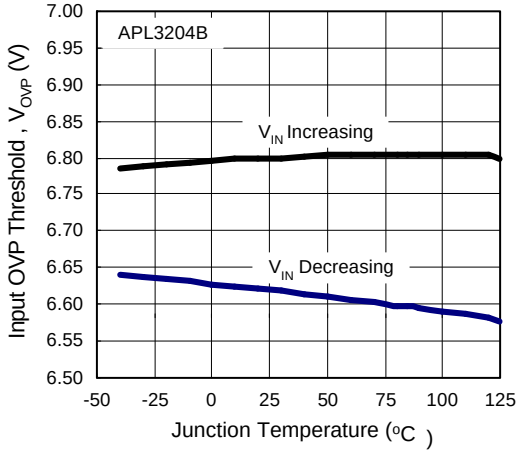
Typical Operating Characteristics

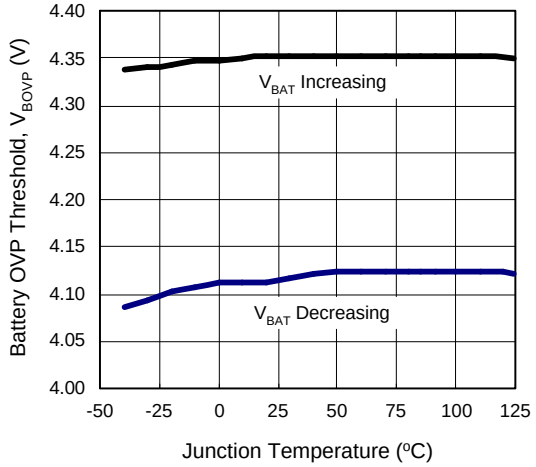
Input OVP Threshold vs. Junction Temperature



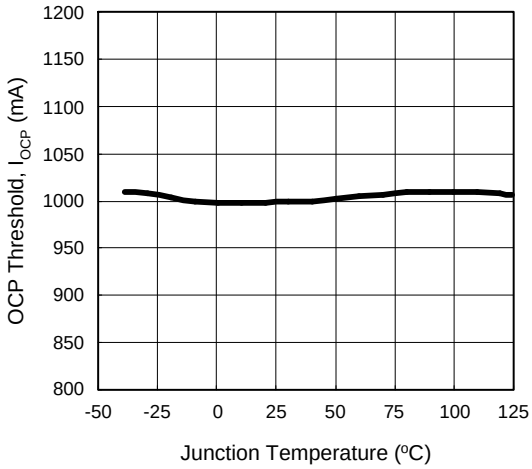
Input OVP Threshold vs. Junction Temperature



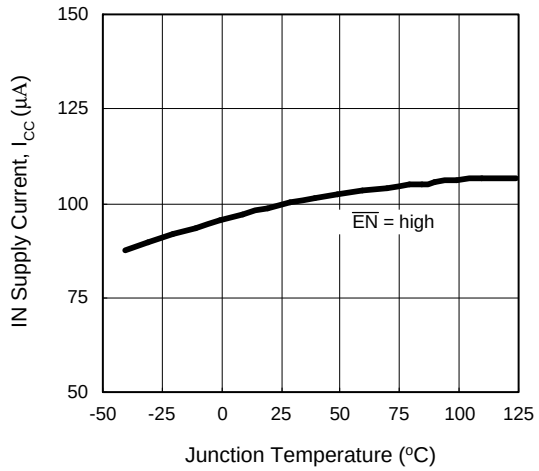
Battery OVP Threshold vs. Junction Temperature



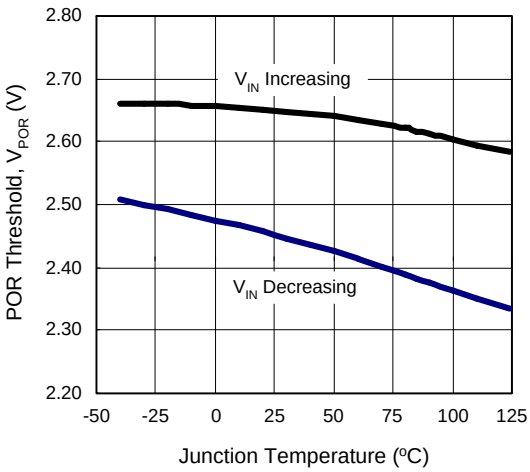
OCP Threshold vs. Junction Temperature



IN Supply Current vs. Junction Temperature



POR Threshold vs. Junction Temperature



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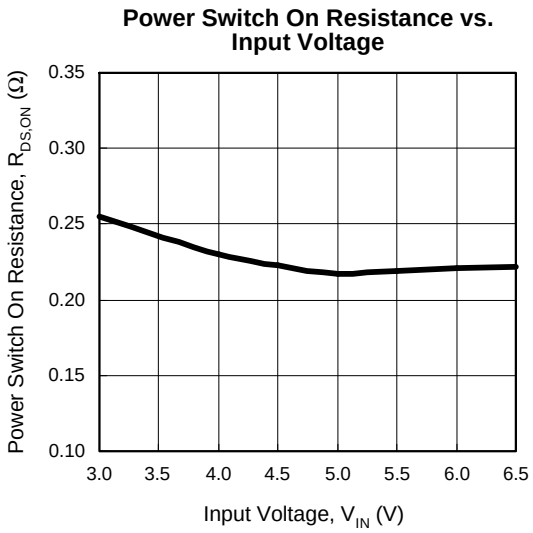
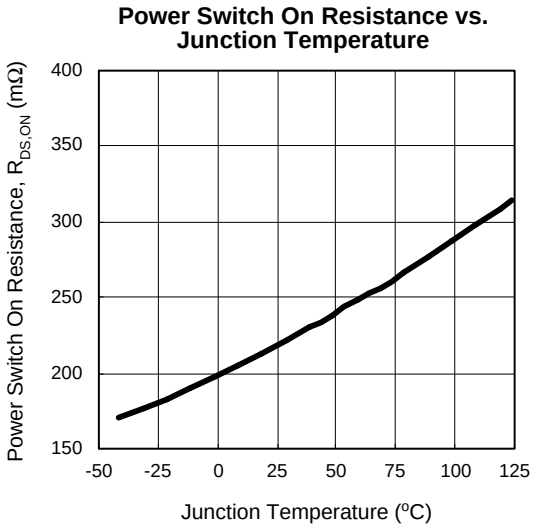
Typical Operating Characteristics (Cont.)

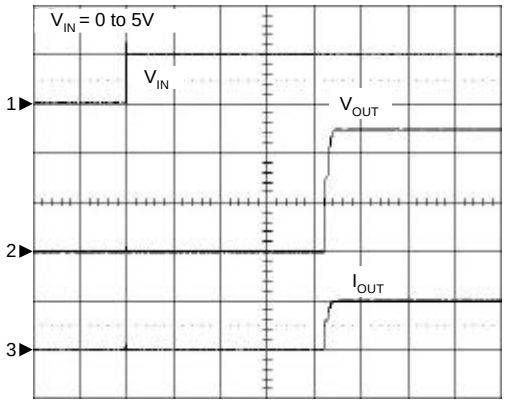




Operating Waveforms

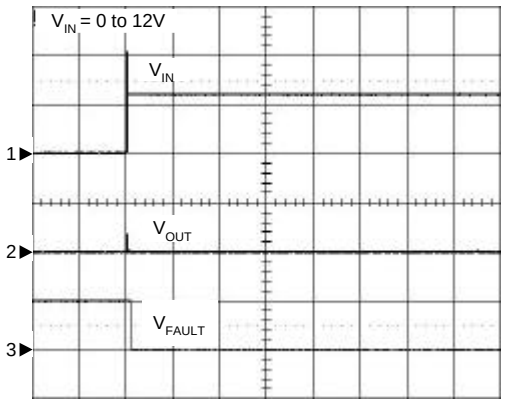
Refer to the typical application circuit. The test condition is V_{IN}=5V, T_A= 25°C unless otherwise specified.

Normal Power On



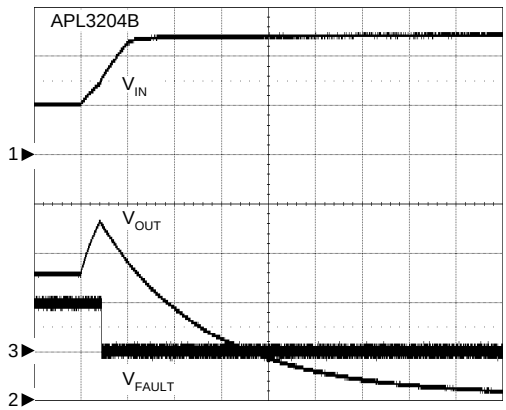
C_{OUT} =1µF, C_{IN} =1µF, R_{OUT} = 10Ω
CH1: V_{IN}, 5V/Div, DC
CH2: V_{OUT}, 2V/Div, DC
CH3: I_{OUT}, 0.5A/Div, DC
TIME: 2ms/Div

OVP at Power On



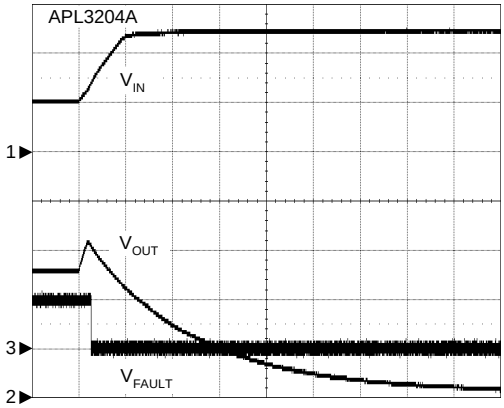
C_{OUT} =1µF, C_{IN} =1µF, R_{OUT} = 10Ω
CH1: V_{IN}, 10V/Div, DC
CH2: V_{OUT}, 2V/Div, DC
CH3: V_{FAULT}, 5V/Div, DC
TIME: 2ms/Div

Input Over-Voltage Pretection



V_{IN} = 5V to 12V
C_{OUT} = 1µF, C_{IN}=1µF, R_{OUT}=50Ω
CH1: V_{IN}, 5V/Div, AC
CH2: V_{OUT}, 2V/Div, DC
CH3: V_{FAULT}, 5V/Div, DC
TIME:20µs/Div

Input Over-Voltage Pretection

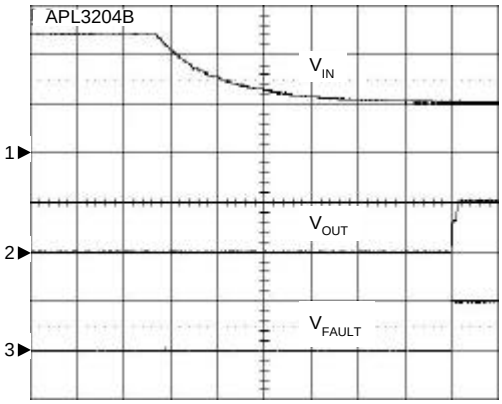


C_{OUT} = 1µF, C_{IN}=1µF, R_{OUT}=50Ω
CH1: V_{IN}, 5V/Div, AC
CH2: V_{OUT}, 2V/Div, DC
CH3: V_{FAULT}, 5V/Div, DC
TIME: 20µs/Div

Operating Waveforms (Cont.)

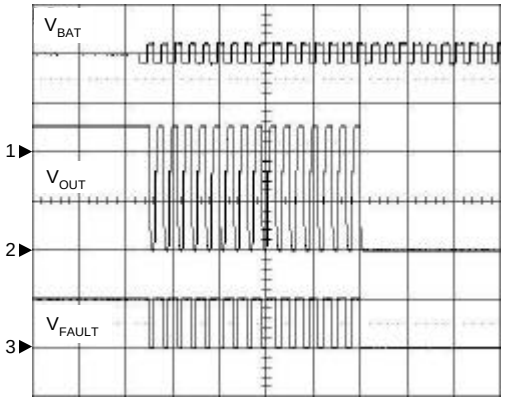
Refer to the typical application circuit. The test condition is V_{IN}=5V, T_A= 25°C unless otherwise specified.

Recovery from Input OVP



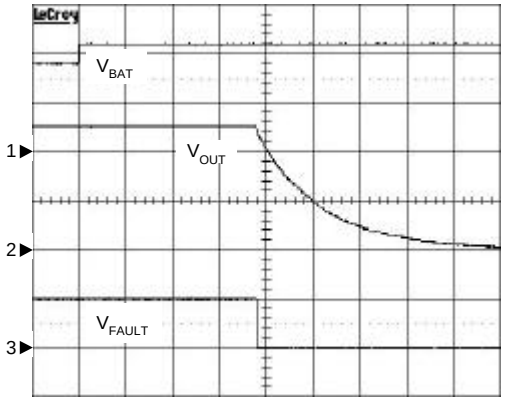
V_{IN} = 12V to 5V
C_{OUT} = 1µF, C_{IN}=1µF, R_{OUT}=50Ω
CH1: V_{IN}, 5V/Div, AC
CH2: V_{OUT}, 5V/Div, DC
CH3: V_{FAULT}, 5V/Div, DC
TIME: 2ms/Div

Battery Over-Voltage Pretection



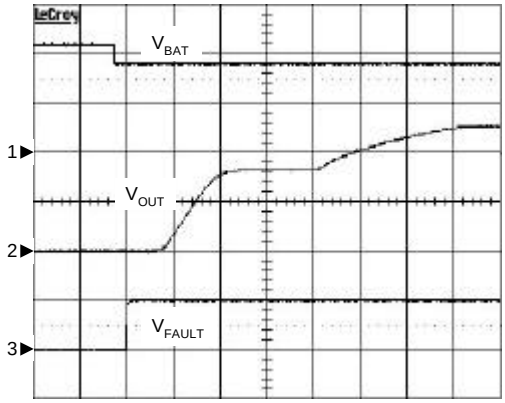
V_{BAT} = 3.6V to 4.4V to 3.6V, R_{OUT}=33.3Ω
C_{OUT} =1µF, C_{IN} =1µF
CH1: V_{BAT}, 2V/Div, DC
CH2: V_{OUT}, 2V/Div, DC
CH3: V_{FAULT}, 5V/Div, DC
TIME: 5ms/Div

Battery Over-Voltage Pretection



V_{BAT} = 3.6V to 4.4V, R_{OUT}=33.3Ω
C_{OUT} =1µF, C_{IN} =1µF
CH1: V_{BAT}, 2V/Div, DC
CH2: V_{OUT}, 2V/Div, DC
CH3: V_{FAULT}, 5V/Div, DC
TIME: 50µs/Div

Recovery from Battery OVP



V_{BAT} = 4.4V to 3.6V, R_{OUT}=33.3Ω
C_{OUT} =1µF, C_{IN} =1µF
CH1: V_{BAT}, 2V/Div, DC
CH2: V_{OUT}, 2V/Div, DC
CH3: V_{FAULT}, 5V/Div, DC
TIME: 50µs/Div

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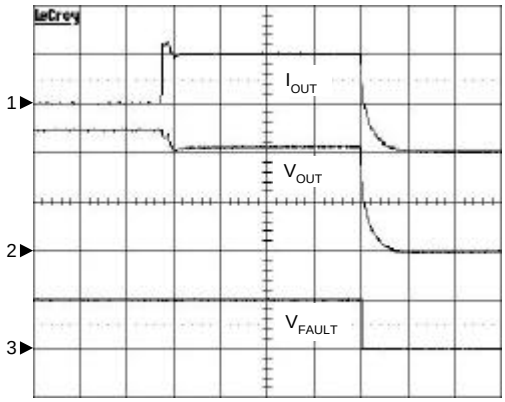
Operating Waveforms (Cont.)

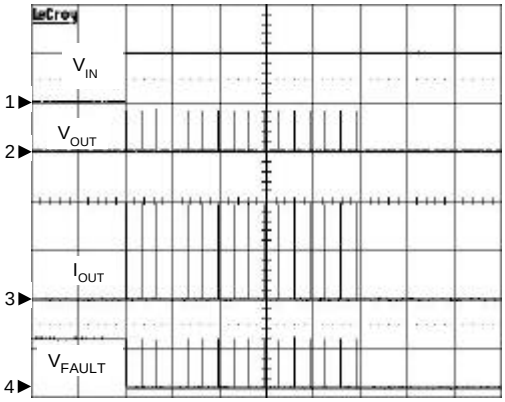
Refer to the typical application circuit. The test condition is V_{IN}=5V, T_A= 25°C unless otherwise specified.

Over-Current Pretection



C_{OUT} =1µF, C_{IN} =1µF, I_{OUT} = 0.5A to 1.2A
CH1: I_{OUT}, 0.5A/Div, DC
CH2: V_{OUT}, 2V/Div, DC
CH3: V_{FAULT}, 5V/Div, DC
TIME: 50µs/Div

Over-Current Pretection



C_{OUT} =1µF, C_{IN} =1µF, R_{OUT} = 2.5Ω
CH1: V_{IN}, 5V/Div, DC
CH2: V_{OUT}, 5V/Div, DC
CH3: I_{OUT}, 0.5A/Div, DC
CH4: V_{FAULT}, 5V/Div, DC
TIME: 200ms/Div

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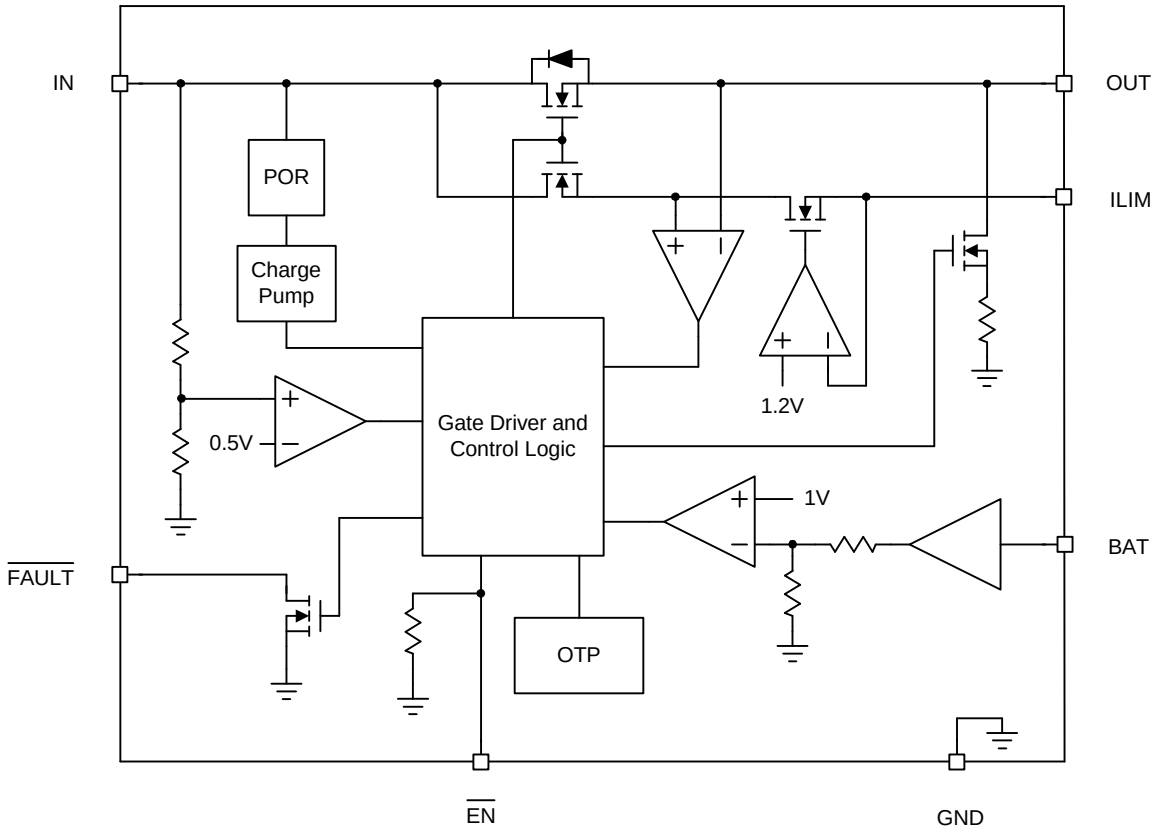
Pin Description

PIN		FUNCTION
NO.	NAME	
1,2	IN	Power Supply Input.
3	GND	Ground.
5,6,12	NC	No Connection.
4	$\overline{\text{FAULT}}$	Fault Indication Pin. This pin goes low when input OVP, OCP, or battery OVP is detected.
7	$\overline{\text{EN}}$	Enable Input. Pull this pin to high to disable the device and pull this pin to low to enable device.
8	BAT	Battery OVP Sense Pin. Connect to positive terminal of battery through a resistor.
9	ILIM	Over-current Protection Setting Pin. Connect a resistor to GND to set the over-current threshold.
10,11	OUT	Output Voltage Pin. The output voltage follows the input voltage when no fault is detected.
-	EP	Exposed Thermal Pad. Must be electrically connected to the GND pin.

Block Diagram



Typical Application Circuit

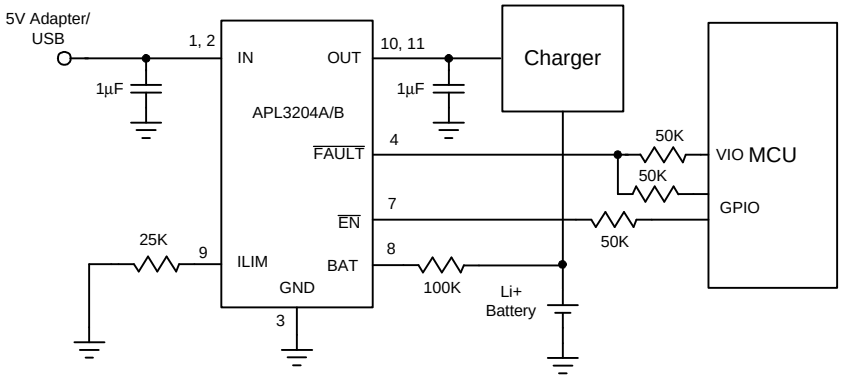


Figure 1. The Typical Protection Circuit for Charger Systems.

Function Description

Power-Up

The APL3204A/B have a built-in power-on-reset circuit to keep the output shuting off until internal circuitry is operating properly. The POR circuit has hysteresis and a deglitch 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 1µs 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 200mV hysteresis and a recovery time of $T_{ON(OVP)}$ to provide noise immunity against transient conditions.

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 APL3204A/B have a built-in counter. When the total count of OCP fault reaches 16, the FET is turned off permanently, requiring either a V_{IN} POR or $\overline{EN}$ re-enable again to restart. 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}=25000AΩ

Battery Over-Voltage-Protection

The APL3204A/B monitor the BAT pin voltage for battery over-voltage protection. The battery OVP threshold is internally set to 4.35V. When the BAT pin voltage exceeds the battery OVP threshold for a blanking time of $T_{B(BOVP)}$, the internal power FET is turned off. When the BP voltage returns below the battery OVP threshold minus the hysteresis, the FET is turned on again. The APL3204A/B have a built-in counter. When the total count of battery OVP fault reaches 16, the FET is turned off permanently, requiring either a V_{IN} POR or $\overline{EN}$ re-enable again to restart.

Over-Temperature Protection

When the junction temperature exceeds 140°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 20°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 °C.

$\overline{FAULT}$ Output

The APL3204A/B provide an open-drain output to indicate that a fault has occurred. When any of input OVP, OCP, battery OVP, is detected, the $\overline{FAULT}$ goes low to indicate that a fault has occurred. Since the $\overline{FAULT}$ pin is an open-drain output, connecting a resistor to a pull high voltage is necessary.

Enable/Shutdown

Pull the $\overline{EN}$ pin voltage above 1.4V to disable the device and pull $\overline{EN}$ pin voltage below 0.4V to enable the device. The $\overline{EN}$ pin has an internal pull-down resistor and can be left floating. When the IC is latched off due to the total count of OCP or battery OVP reaches 16, disable and re-enable the device with the $\overline{EN}$ pin can clear the counter.

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Function Description (Cont.)

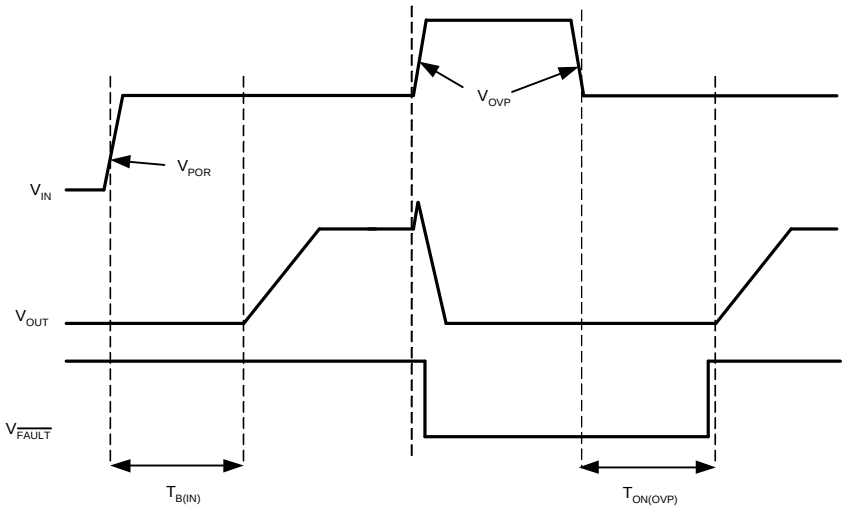

Figure2. OVP Timing Chart

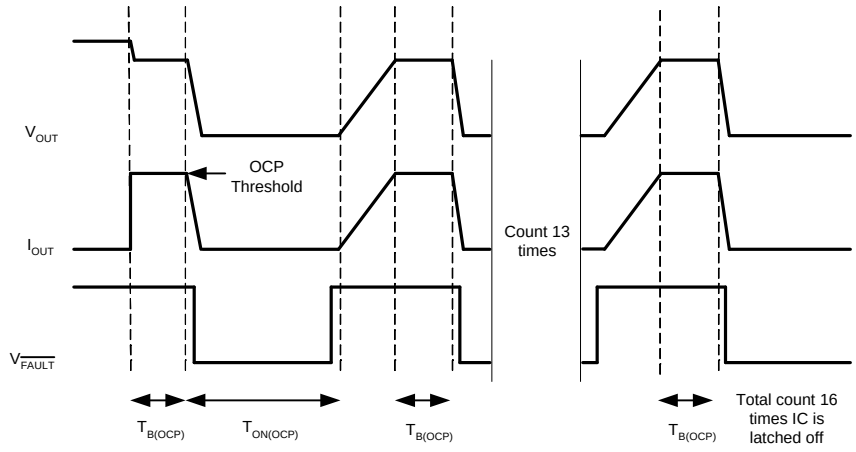

Figure 3 OCP Timing Chart

Function Description (Cont.)

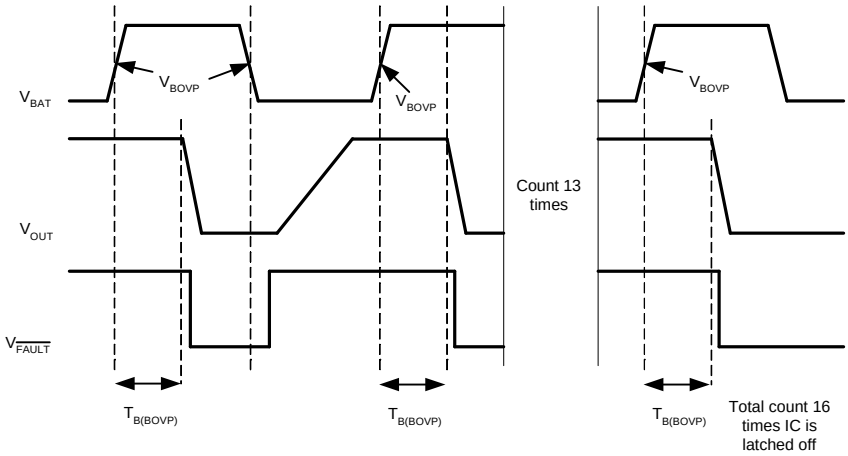

Figure 4. Battery OVP Timing Chart

Application Information

R_{BAT} Selection

Connect the BAT pin to the positive terminal of battery through a resistor R_{BAT} for battery OVP function. The R_{BAT} limits the current flowing from BAT to battery in case of BAT pin is shorted to VIN pin under a failure mode. The recommended value of R_{BAT} is 100kΩ. In the worse case of an IC failure, the current flowing from the BAT pin to the battery is:

(30V-3V)/ 100kΩ =270μA

where the 30V is the maximum IN voltage and the 3V is the minimum battery voltage. The current is so small and can be absorbed by the charger system.

The disadvantage with the large R_{BAT} is that the error of the battery OVP threshold will be increased. The additional error is the voltage drop across the R_{BAT} because of the BAT bias current. When R_{BAT} is 100kΩ, the worse-case additional error is 100kΩx20nA=2mV, which is acceptable in most applications.

R_{EN} Selection

For the same reason as the BAT pin case, the EN pin should be connected to the MCU GPIO pin through a resistor. The value of the R_{EN} is dependent on the IO voltage of the MCU.

Since the IO voltage is divided by R_{EN} and $\overline{EN}$ internal pull low resistor for $\overline{EN}$ voltage. It has to be ensured that the $\overline{EN}$ voltage is above the $\overline{EN}$ logic high voltage when the GPIO output of the MCU is high.

$\overline{FAULT}$ 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 $\overline{FAULT}$ 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.

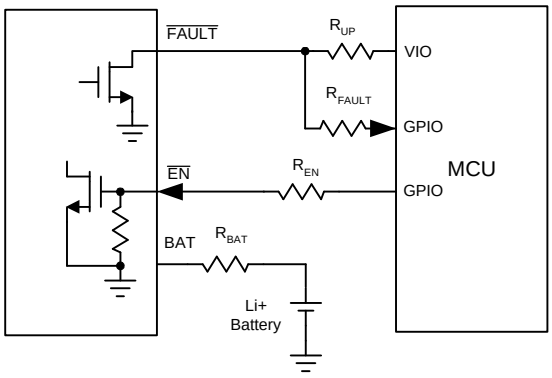

Figure 5. R_{UP}, R_{FAULT}, R_{EN} and R_{BAT}

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 TDFN4x3-12 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.

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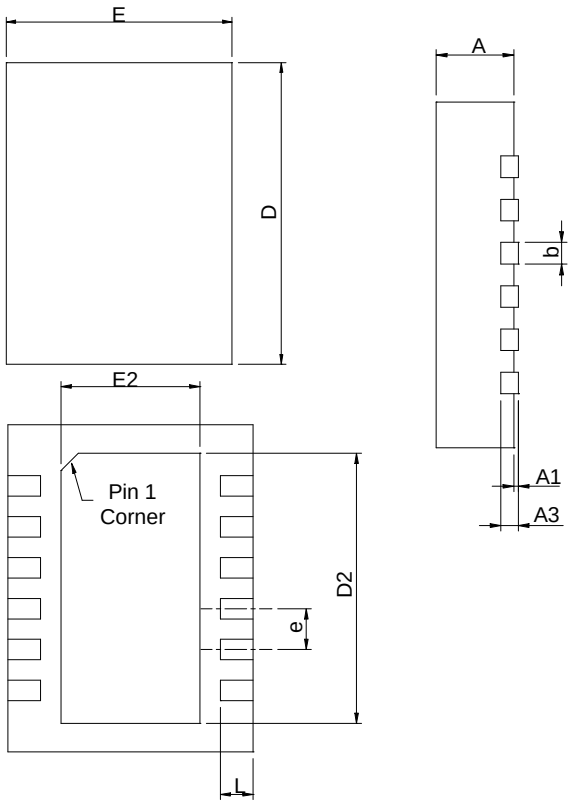
Package Information

TDFN4x3-12



SYMBOL	TDFN4x3-12			
	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	4.00 BSC		0.157 BSC	
D2	3.00	3.70	0.118	0.146
E	3.00 BSC		0.118 BSC	
E2	1.40	1.80	0.055	0.071
e	0.50 BSC		0.020 BSC	
L	0.30	0.50	0.012	0.020
K	0.20		0.008	

Note : Follow JEDEC MO-229 WGED-4.

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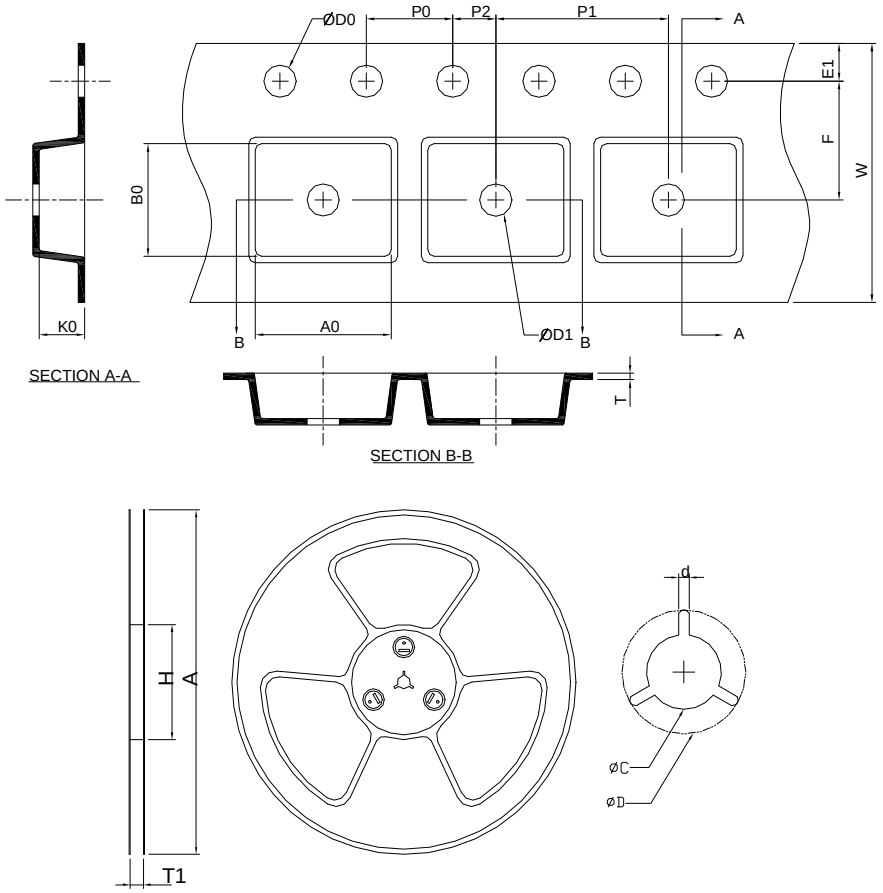
Carrier Tape & Reel Dimensions



Application	A	H	T1	C	d	D	W	E1	F
TDFN3x4-12	330.0±2.00	50 MIN.	12.4+2.00 -0.00	13.0+0.50 -0.20	1.5 MIN.	20.2 MIN.	12.0±0.30	1.75±0.10	5.5±0.05
	P0	**P1**	**P2**	**D0**	**D1**	**T**	**A0**	**B0**	**K0**
	4.0±0.20	8.0±0.10	2.0±0.05	1.5+0.10 -0.00	1.5 MIN.	0.6+0.00 -0.40	3.7±0.20	4.7±0.20	1.30±0.20

(mm)

Devices Per Unit

Package Type	Unit	Quantity
TDFN4x3-12	Tape & Reel	3000

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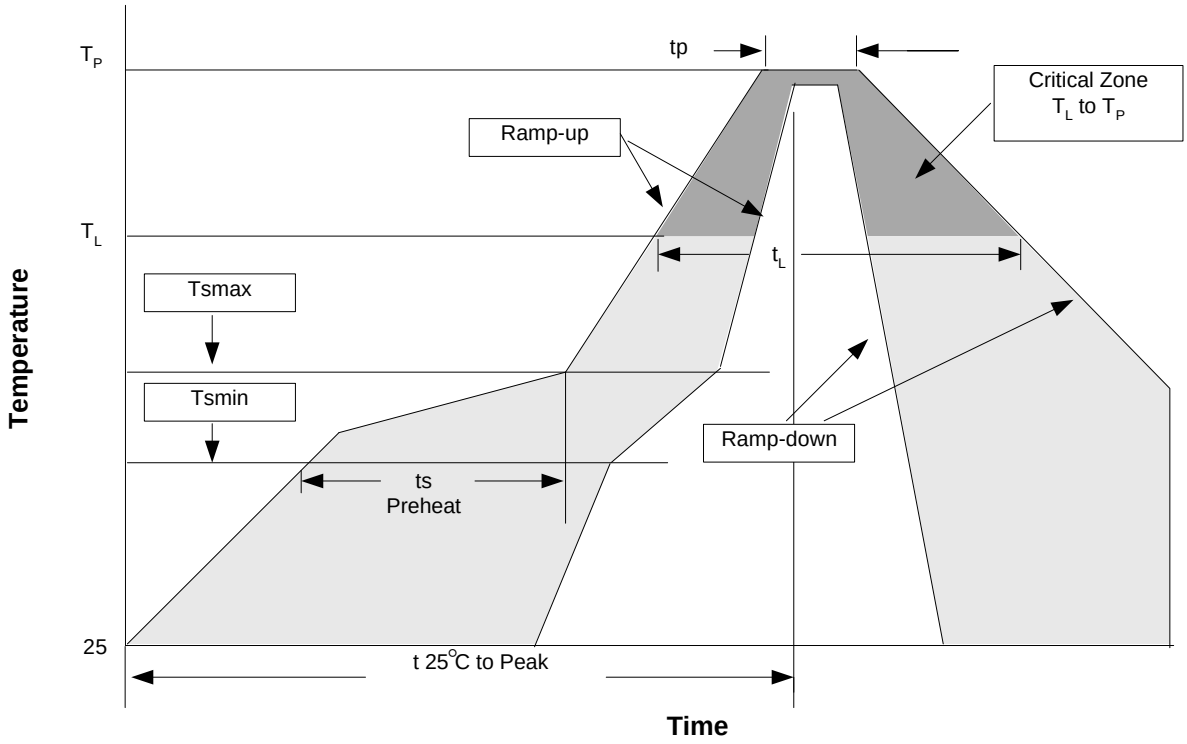
Reflow Condition (IR/Convection or VPR Reflow)



Reliability Test Program

Test item	Method	Description
SOLDERABILITY	MIL-STD-883D-2003	245°C, 5 sec
HOLT	MIL-STD-883D-1005.7	1000 Hrs Bias @125°C
PCT	JESD-22-B,A102	168 Hrs, 100%RH, 121°C
TST	MIL-STD-883D-1011.9	-65°C~150°C, 200 Cycles
ESD	MIL-STD-883D-3015.7	VHBM > 2KV, VMM > 200V
Latch-Up	JESD 78	10ms, 1_{tr} > 100mA

Classification Reflow Profiles

Profile Feature	Sn-Pb Eutectic Assembly	Pb-Free Assembly
Average ramp-up rate (T_L to T_P)	3°C/second max.	3°C/second max.
Preheat - Temperature Min (Tsmin) - Temperature Max (Tsmax) - Time (min to max) (ts)	100°C 150°C 60-120 seconds	150°C 200°C 60-180 seconds
Time maintained above: - Temperature (T_L) - Time (t_L)	183°C 60-150 seconds	217°C 60-150 seconds
Peak/Classification Temperature (Tp)	See table 1	See table 2
Time within 5°C of actual Peak Temperature (tp)	10-30 seconds	20-40 seconds
Ramp-down Rate	6°C/second max.	6°C/second max.
Time 25°C to Peak Temperature	6 minutes max.	8 minutes max.

Note: All temperatures refer to topside of the package. Measured on the body surface.

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Classification Reflow Profiles (Cont.)

Table 1. SnPb Eutectic Process – Package Peak Reflow Temperatures

Package Thickness	Volume mm^3 <350	Volume mm^3 ³350
<2.5 mm	240 +0/-5°C	225 +0/-5°C
≥2.5 mm	225 +0/-5°C	225 +0/-5°C

Table 2. Pb-free Process – Package Classification Reflow Temperatures

Package Thickness	Volume mm^3 <350	Volume mm^3 350-2000	Volume mm^3 >2000
<1.6 mm	260 +0°C*	260 +0°C*	260 +0°C*
1.6 mm – 2.5 mm	260 +0°C*	250 +0°C*	245 +0°C*
≥2.5 mm	250 +0°C*	245 +0°C*	245 +0°C*
* Tolerance: The device manufacturer/supplier **shall** assure process compatibility up to and including the stated classification temperature (this means Peak reflow temperature +0°C. For example 260°C+0°C) at the rated MSL level.			

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