Li+ Charger Protection IC with Integrated P-MOSFET

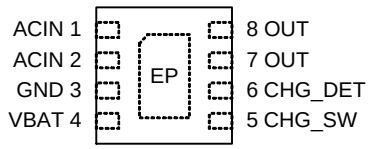
Features

- **Input Over-Voltage Protection**
- **Current-Limit Protection**
- **Battery Over-Voltage Protection**
- **High Immunity of False Triggering**
- **High Accuracy Protection Threshold**
- **A Built-In P-MOSFET**
- **Available with 3 Versions of Charging Current: 450mA, 550mA, 650mA**
- **Thermal Shutdown Protection**
- **Available in TDFN2x2-8 and TSOT-23-6A Packages**
- **"Lithium-Safe" Criteria**
- **Lead Free and Green Devices Available (RoHS Compliant)**

Applications

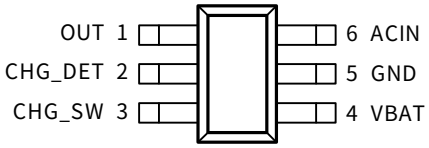
- **Cell Phones for Infineon**

Pin Configuration



TDFN2x2-8
(Top View)

EP = Exposed Pad
(Connected to the ground plane for better heat dissipation)



TSOT-23-6A
(Top View)

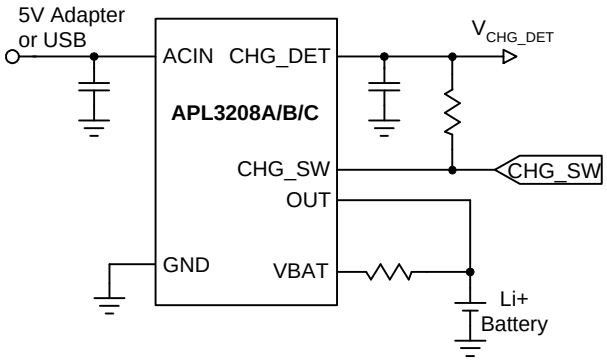
General Description

The APL3208A/B/C provides complete Li+ charger protection against Input over-voltage, battery over-voltage, and the charge current limit. When the input OVP or the battery OVP is over the threshold, the IC removes the power from the charging system by turning off an internal switch. When the current via the internal switch surpasses the current limit threshold, the current will be clamped in a constant level to provide a constant current for battery charging usage. All protections also have deglitch time against false triggering due to voltage spikes or current transients.

The APL3208A/B/C integrates a P-MOSFET with the body diode reverse protection to replace the external power bipolar transistor and Schottky diode for charger function of the Infineon ULC2 mobile phones. When the CHG_DET voltage drops below V_{BAT}+20mV, the internal power select circuit will reverse the body diode's terminal to prevent a reverse current flowing from the battery back to the CHG_DET pin.

The APL3208A/B/C provides complete Li+ charger protections and save the external MOSFET and Schottky diode for the Infineon ULC2 mobile phones. The above features and small package make the APL3208A/B/C an ideal part for cell phones applications.

Simplified Application Circuit



Ordering and Marking Information

APL3208A APL3208B APL3208C □□□-□□□ Assembly Material Handling Code Temperature Range Package Code	Package Code QB : TDFN2x2-8 CT : TSOT-23-6A Operating Ambient Temperature Range I : -40 to 85 °C Handling Code TR : Tape & Reel Assembly Material G : Halogen and Lead Free Device

APL3208A	QB:	L08A X	X - Date Code
APL3208B	QB:	L08B X	X - Date Code
APL3208C	QB:	L08C X	X - Date Code
APL3208A	CT:	L8AX	X - Date Code
APL3208B	CT:	L8BX	X - Date Code
APL3208C	CT:	L8CX	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_{CHG_DET}	CHG_DET to GND Voltage	-0.3 ~ 7	V
V_{CHG_SW}	CHG_SW to GND Voltage	-0.3 ~ V_{CHG_DET}	V
V_{BAT}	VBAT to GND Voltage	-0.3 ~ 7	V
V_{OUT}	OUT to GND Voltage	-0.3 ~ 7	V
I_{OUT}	OUT Output Current	1.5	A
T_J	Maximum Junction Temperature	150	°C
T_{STG}	Storage Temperature	-65 ~ 150	°C
T_{SDR}	Maximum Lead Soldering Temperature, 10 Seconds	260	°C

Note 1: Absolute Maximum Ratings are those values beyond which the life of a device may be impaired. 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 Resistance in Free Air (Note 2)			°C/W
		TDFN2x2-8	80	
		TSOT-23-6A	235	

Note 2: θ_{JA} is measured with the component mounted on a high effective thermal conductivity test board in free air. The exposed pad of TDFN2x2-8 is soldered directly on the PCB.

Recommended Operating Conditions (Note 3)

Symbol	Parameter	Range	Unit
V_{ACIN}	ACIN Input Voltage	4.5 ~ 5.5	V
T_A	Ambient Temperature	-40 ~ 85	°C
T_J	Junction Temperature	-40 ~ 125	°C

Note 3: Refer to the typical application circuit

Electrical Characteristics

Unless otherwise specified, these specifications apply over V_{ACIN}=5V, V_{BAT}=3.8V and T_A= -40 ~ 85 °C. Typical values are at T_A=25°C.

Symbol	Parameter	Test Conditions	APL3208A/B/C			Unit
			Min.	Typ.	Max.	
ACIN INPUT CURRENT AND POWER-ON-RESET (POR)						
I_{ACIN}	ACIN Supply Current	I_{OUT}=0A, I_{CHG_DET}=0A	-	250	350	μA
V_{ACIN}	ACIN POR Threshold	V_{ACIN} rising	2.4	-	2.8	V
	ACIN POR Hysteresis		200	250	300	mV
$T_{B(ACIN)}$	ACIN Power-On Blanking Time		-	8	-	ms
INTERNAL SWITCH ON RESISTANCE						
	CHG_DET Discharge On Resistance		-	500	-	Ω
INPUT OVER-VOLTAGE PROTECTION (OVP)						
V_{OVP}	Input OVP Threshold	V_{ACIN} rising	6	6.17	6.35	V
	Input OVP Hysteresis		200	300	400	mV
	Input OVP Propagation Delay		-	-	1	μs
$T_{ON(OVP)}$	Input OVP Recovery Time		-	8	-	ms
CURRENT-LIMIT PROTECTION						
I_{LIM}	Current Limit Threshold	APL3208A, T_A=25°C	400	450	500	mA
		APL3208B, T_A=25°C	500	550	600	
		APL3208C, T_A=25°C	600	650	700	
BATTERY OVER-VOLTAGE PROTECTION						
V_{BOVP}	Battery OVP Threshold	V_{BAT} rising	4.32	4.35	4.38	V
	Battery OVP Hysteresis		220	270	320	mV
I_{VBAT}	VBAT Pin Leakage Current	V_{BAT} = 4.4V	-	-	20	nA
$T_{B(BOVP)}$	Battery OVP Blanking Time		-	176	-	μs
INTERNAL P-MOSFET (CHG_DET, OUT AND CHG_SW PINS)						
	V_{CHG_DET}-V_{BAT} Lockout Threshold	V_{CHG_DET} from low to high, P-MOSFET is controlled by CHG_SW	-	120	-	mV
		V_{CHG_DET} from high to low, P-MOSFET is off	-	20	-	
	OUT Input Current	V_{CHG_DET}=0V, V_{OUT}=4.2V, CHG_SW =GND	-	-	1	μA
	CHG_SW Leakage Current	V_{ACIN}=V_{CHG_DET}= V_{OUT}=5V, V_{CHG_SW}=0V	-	7.5	13	μA
	OUT Leakage Current	V_{ACIN}=V_{CHG_DET}= V_{CHG_SW} =5V, V_{OUT}=0V	-	-	1	μA

Electrical Characteristics (Cont.)

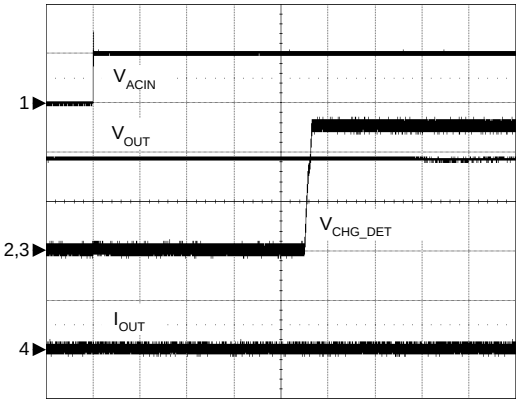
Unless otherwise specified, these specifications apply over V_{ACIN}=5V, V_{BAT}=3.8V and T_A= -40 ~ 85 °C. Typical values are at T_A=25°C.

Symbol	Parameter	Test Conditions	APL3208A/B/C			Unit
			Min.	Typ.	Max.	
INTERNAL P-MOSFET (CHG_DET, OUT AND CHG_SW PINS) (CONT.)						
	P-MOSFET Input Capacitance		-	200	-	pF
	CHG_SW Input Resistance		-	15	-	Ω
OVER-TEMPERATURE PROTECTION (OTP)						
T_{OTP}	Over-Temperature Threshold	T_J rising	-	160	-	°C
	Over-Temperature Hysteresis		-	40	-	°C

Operating Waveforms

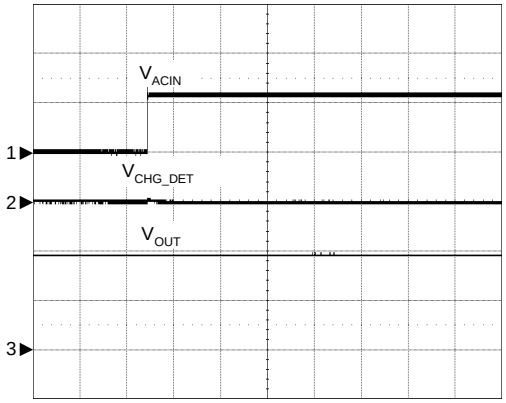
The test condition is V_{ACIN}=5V, V_{BAT}=3.8V, T_A= 25°C unless otherwise specified.

Normal Power On



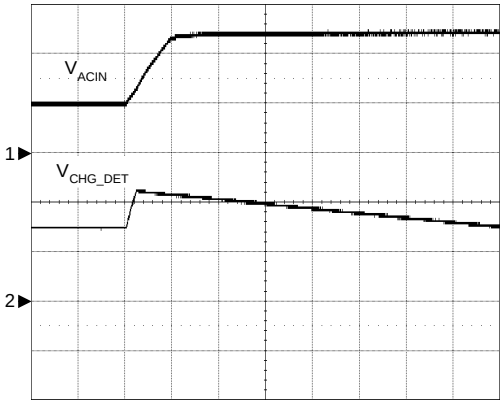
C_{ACIN} =1µF, C_{OUT} =1µF, V_{CHG_SW} = V_{CHG_DET}
CH1: V_{ACIN}, 5V/Div, DC
CH2: V_{OUT}, 2V/Div, DC
CH3: V_{CHG_DET}, 2V/Div, DC
CH4: I_{OUT}, 0.2A/Div, DC
TIME: 2ms/Div

OVP at Power On



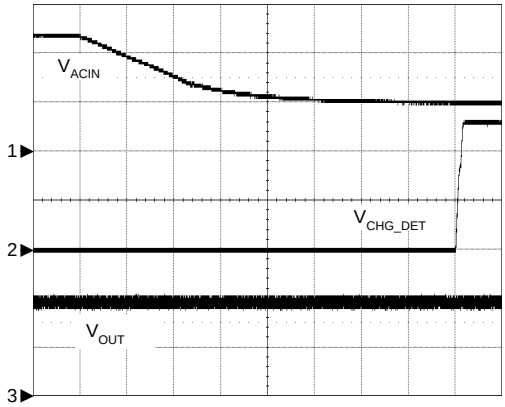
C_{ACIN} =1µF, C_{OUT} =1µF
CH1: V_{ACIN}, 10V/Div, DC
CH2: V_{CHG_DET}, 1V/Div, DC
CH3: V_{OUT}, 2V/Div, DC
TIME: 2ms/Div

Input Over-Voltage Protection



V_{ACIN} =5V to 12V, V_{CHG_SW} = 0V, No Load
C_{ACIN} =1µF, C_{OUT} =1µF
CH1: V_{ACIN}, 5V/Div, AC
CH2: V_{CHG_DET}, 2V/Div, DC
TIME:20µs/Div

Recovery from Input OVP

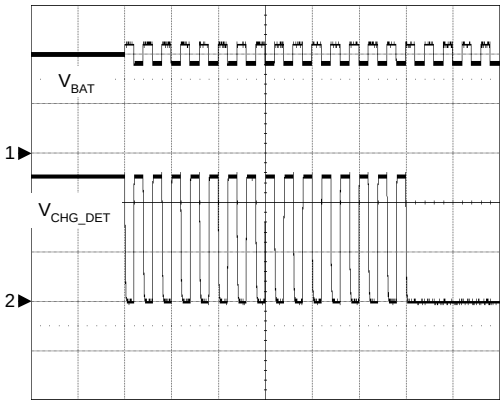


V_{ACIN}= 12V to 5V, V_{CHG_SW} = V_{CHG_DET}
C_{ACIN} =1µF, C_{OUT} =1µF
CH1: V_{ACIN}, 5V/Div, AC
CH2: V_{CHG_DET}, 2V/Div, DC
CH3: V_{OUT}, 2V/Div, DC
TIME: 2ms/Div

Operating Waveforms (Cont.)

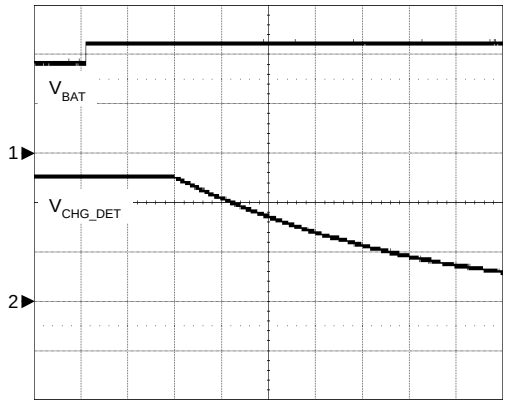
The test condition is V_{ACIN}=5V, V_{BAT}=3.8V, T_A= 25°C unless otherwise specified.

Battery Over-Voltage Protection



V_{BAT} = 3.6V to 4.4V to 3.6V
C_{ACIN} =1µF, C_{OUT} =1µF
CH1: V_{BAT}, 2V/Div, DC
CH2: V_{CHG_DET}, 2V/Div, DC
TIME: 50ms/Div

Battery Over-Voltage Protection

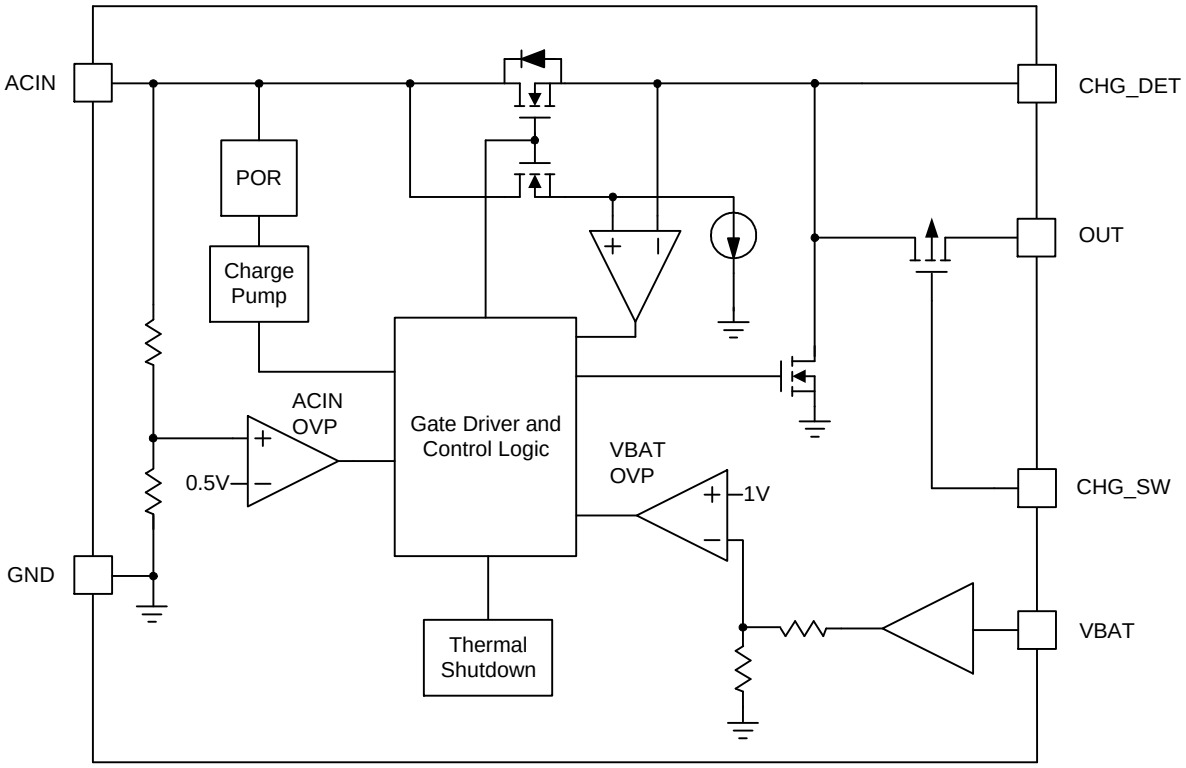


V_{BAT} = 3.6V to 4.4V
C_{ACIN}=1µF, C_{OUT} =1µF
CH1: V_{BAT}, 2V/Div, DC
CH2: V_{CHG_DET}, 2V/Div, DC
TIME: 200µs/Div

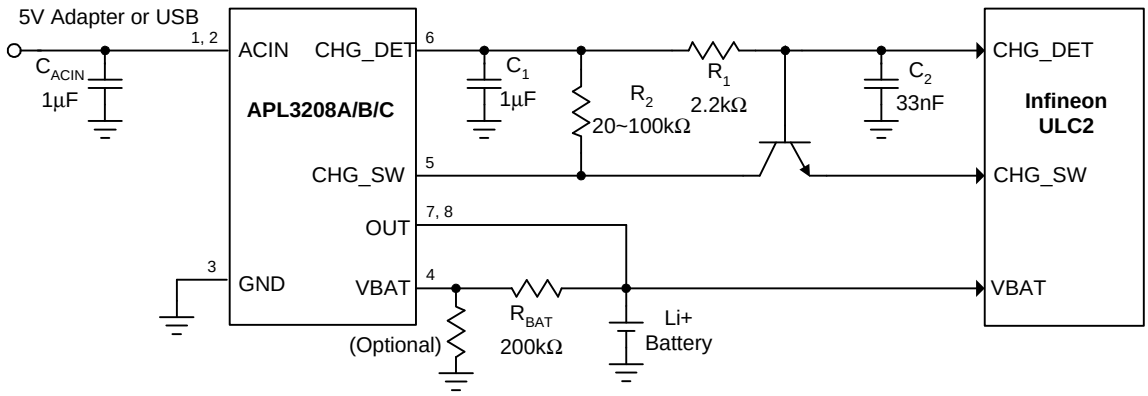
Pin Description

PIN		NAME	FUNCTION
NO.			
TDFN2x2-8	TSOT-23-6A		
1, 2	6	ACIN	Power Supply Input. Connect this pin to external DC supply. Bypass to GND with a 1µF (minimum) ceramic capacitor.
3	5	GND	Ground Terminal.
4	4	VBAT	Battery Voltage Sense Input. Connect this pin to pack positive terminal through a resistor.
5	3	CHG_SW	Internal P-MOSFET Gate Input.
6	2	CHG_DET	Output Pin. This pin provides supply voltage to the Infineon ULC2 input. Bypass to GND with a 1µF (minimum) ceramic capacitor.
7, 8	1	OUT	Output Pins. These pins provide supply source current in series with a resistor to battery.
Exposed Pad	-	EP	Exposed Thermal Pad. Must be electrically connected to the GND pin.

Block Diagram



Typical Application Circuit

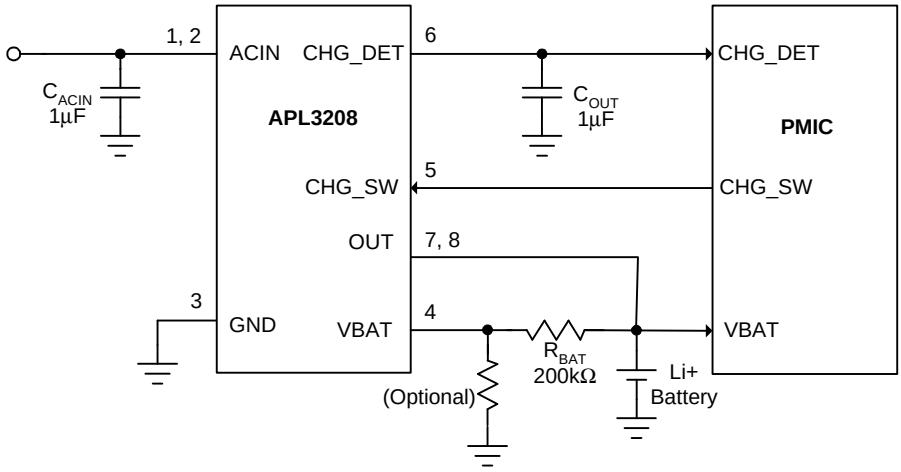


Designation	Description
C_{ACIN}	1µF, 50V, X7R, 0805 Murata GRM21BR71H105K
C_1	1µF, 10V, X7R, 0805 Murata GRM21BR71A105K

Murata website: www.murata.com

Figure 1. Infineon ULC2 Application Circuit

Typical Application Circuit (Cont.)



Designation	Description
C_{ACIN}	1µF, 50V, X7R, 0805 Murata GRM21BR71H105K
C_{OUT}	1µF, 10V, X7R, 0805 Murata GRM21BR71A105K

Murata website: www.murata.com

Figure 2. General Application Circuit

Function Description

ACIN Power-On-Reset (POR)

The APL3208A/B/C has 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 the input voltage exceeds the POR threshold and after 8ms blanking time, the output voltage starts a soft-start to reduce the inrush current.

ACIN 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 1ms to protect the 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.

Battery Over-Voltage Protection

The APL3208A/B/C monitors the VBAT pin voltage for battery over-voltage protection. The battery OVP threshold is internally set to 4.35V. When the VBAT pin voltage exceeds the battery OVP threshold for a blanking time of $T_{B(BOVP)}$, the internal power FET is turned off. When the VBAT voltage returns below the battery OVP threshold minus the hysteresis, the FET is turned on again. The APL3208A/B/C has a built-in counter. When the total count of battery OVP fault reaches 16, the FET is turned off permanently, requiring a V_{ACIN} POR again to restart.

Current-Limit Protection

The APL3208A/B/C provides a current-limit protection function. When the current via the internal switch surpasses the current limit threshold, the current will be clamped to a constant level to provide external battery charging current.

Over-Temperature Protection

When the junction temperature exceeds 160°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 40°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.

Internal P-MOSFET

The APL3208A/B/C integrates a P-channel MOSFET with the body diode reverse protection to replace the external power bipolar transistor and Schottky diode for the Infineon ULC2 mobile. The body diode reverse protection prevents a reverse current flowing from the battery back to the CHG_DET pin. During power-on, when CHG_DET voltage rises above the VBAT voltage by more than 120mV, the body diode of the P-channel MOSFET is forward biased from OUT to CHG_DET, and P-MOSFET is controlled by the external CHG_SW voltage. When the CHG_DET voltage drops below V_{BAT}+20mV, the body diode of the P-channel MOSFET is forward biased from CHG_DET to OUT and P-channel MOSFET is turned off. When any of input OVP, battery OVP, is detected,the internal P-channel MOSFET is also turned off.

Function Description (Cont.)

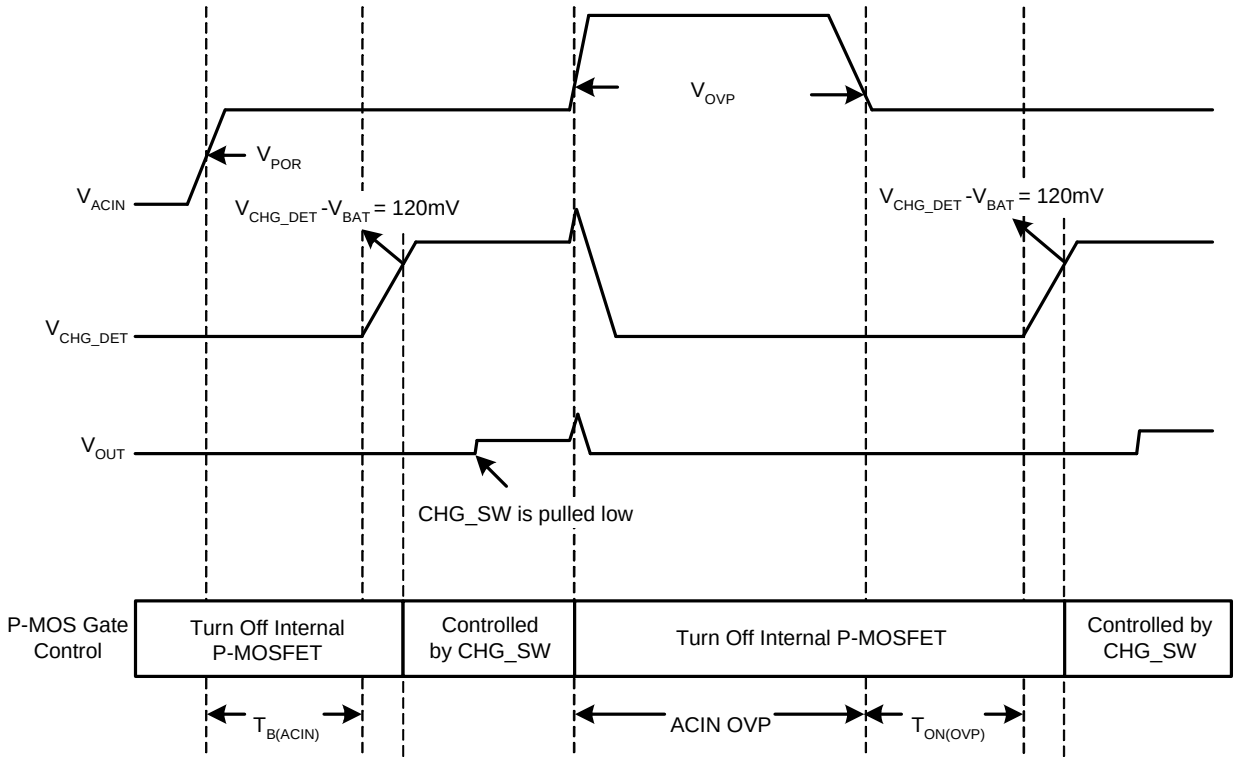


Figure 3. OVP Timing Diagram

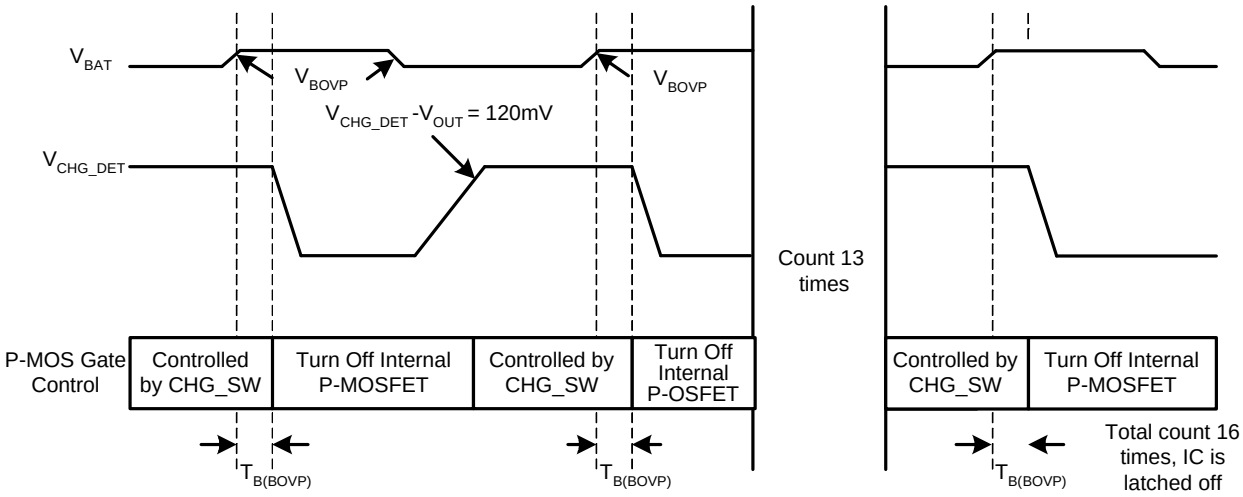


Figure 4. Battery OVP Timing Diagram

Application Information

R_{BAT} Selection

Connect the VBAT pin to the positive terminal of battery through a resistor R_{BAT} for battery OVP function. The R_{BAT} limits the current flowing from VBAT to battery in case of VBAT pin is shortened to ACIN pin under a failure mode. The recommended value of R_{BAT} is 200kΩ. In the worse case of an IC failure, the current flowing from the VBAT pin to the battery is:

(30V-3V)/ 200kΩ =135μA

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

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 50V, X7R, dielectric ceramic capacitor with a value between 1μF and 4.7μF placed close to the ACIN pin is recommended.

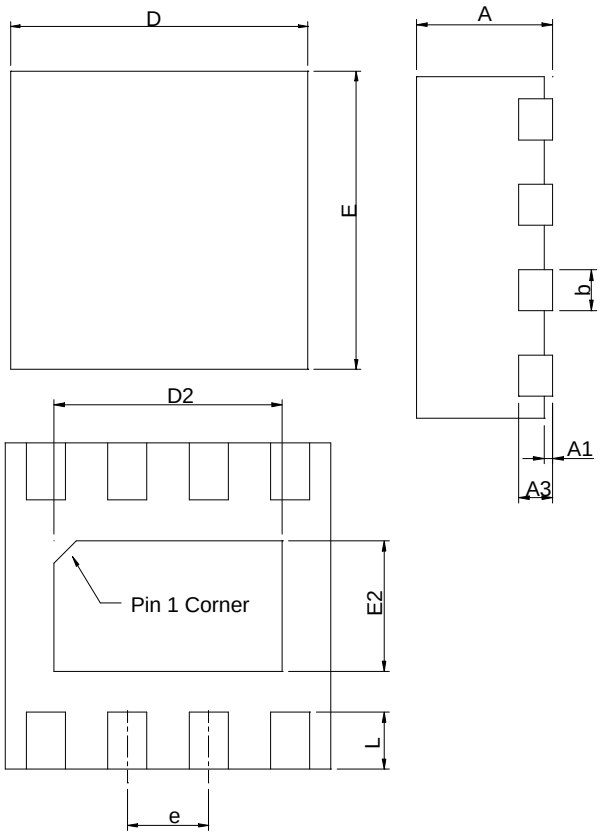
The output capacitor of CHG_DET is for CHG_DET voltage decoupling. And also can be as the input capacitor of the charging circuit. At least, a 1μF, 10V, X7R capacitor is recommended.

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 TDFN2x2-8 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. The high current traces like input trace and output trace must be wide and short.

Package Information

TDFN2x2-8

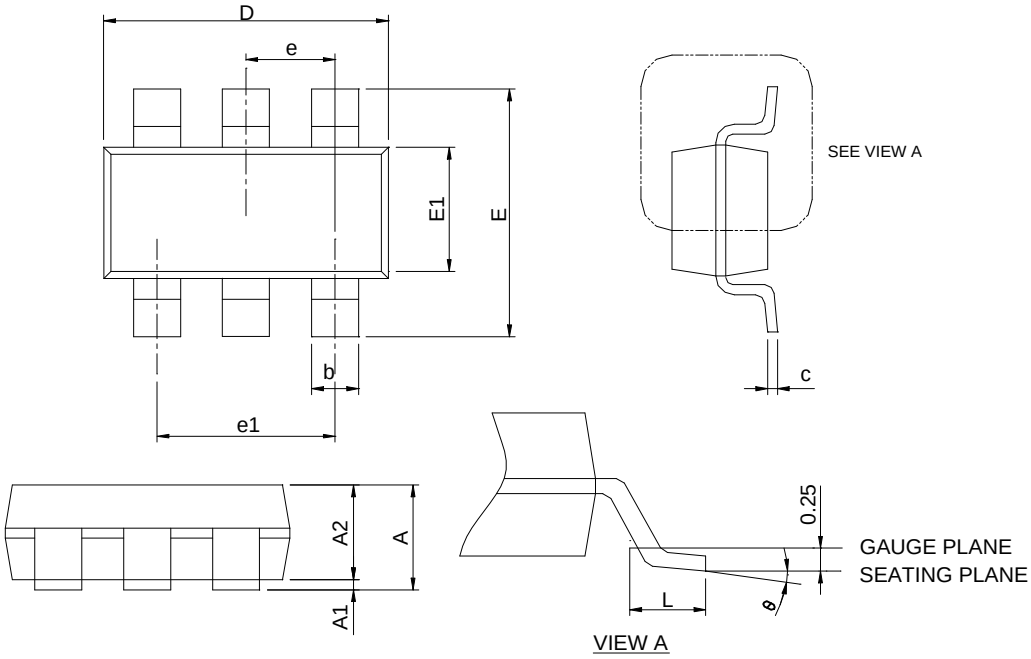


SYMBOL	TDFN2x2-8			
	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A	0.70	0.80	0.028	0.031
A1	0.00	0.05	0.000	0.002
A3	0.20 REF		0.008 REF	
b	0.18	0.30	0.007	0.012
D	1.90	2.10	0.075	0.083
D2	1.00	1.60	0.039	0.063
E	1.90	2.10	0.075	0.083
E2	0.60	1.00	0.024	0.039
e	0.50 BSC		0.020 BSC	
L	0.30	0.45	0.012	0.018

Note : 1. Follow from JEDEC MO-229 WCCD-3.

Package Information

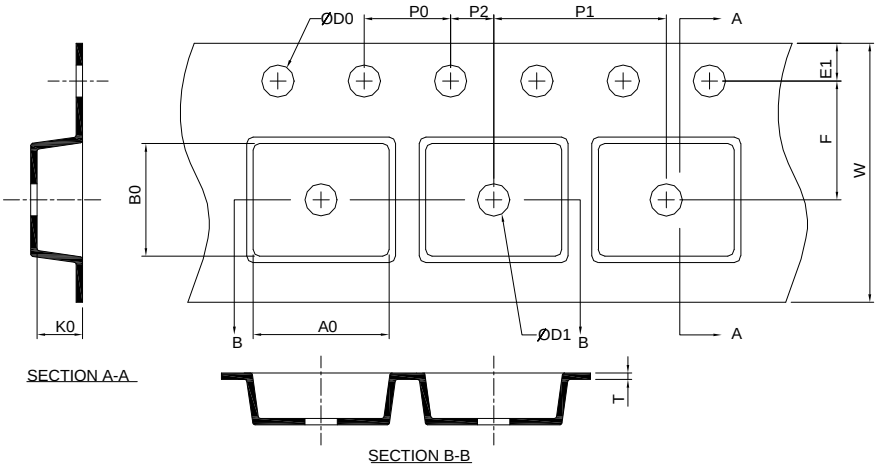
TSOT-23-6A

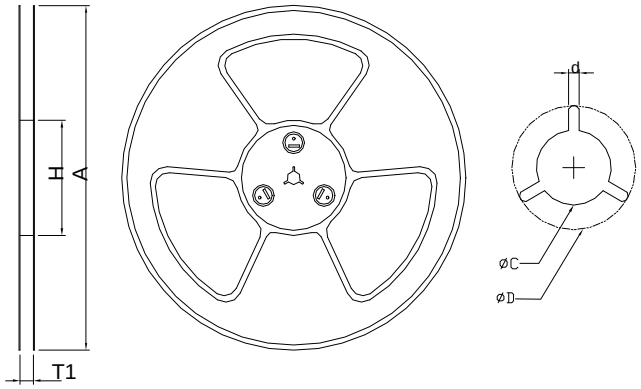


SYMBOL	TSOT-23-6A			
	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A	0.70	1.00	0.028	0.039
A1	0.01	0.10	0.000	0.004
A2	0.70	0.90	0.028	0.035
b	0.30	0.50	0.012	0.020
c	0.08	0.20	0.003	0.008
D	2.70	3.10	0.106	0.122
E	2.60	3.00	0.102	0.118
E1	1.40	1.80	0.055	0.071
e	0.95 BSC		0.037 BSC	
e1	1.90 BSC		0.075 BSC	
L	0.30	0.60	0.012	0.024
θ	0°	8°	0°	8°

Note : Dimension D and E1 do not include mold flash, protrusions or gate burrs. Mold flash, protrusion or gate burrs shall not exceed 10 mil per side.

Carrier Tape & Reel Dimensions





Application	A	H	T1	C	d	D	W	E1	F
TDFN2x2-8	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	3.50±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 -0.4	3.35 MIN	3.35 MIN	1.30±0.20
Application	**A**	**H**	**T1**	**C**	**d**	**D**	**W**	**E1**	**F**
TSOT-23-6A	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	1.0 MIN.	0.6+0.00 -0.40	3.20±0.20	3.10±0.20	1.50±0.20

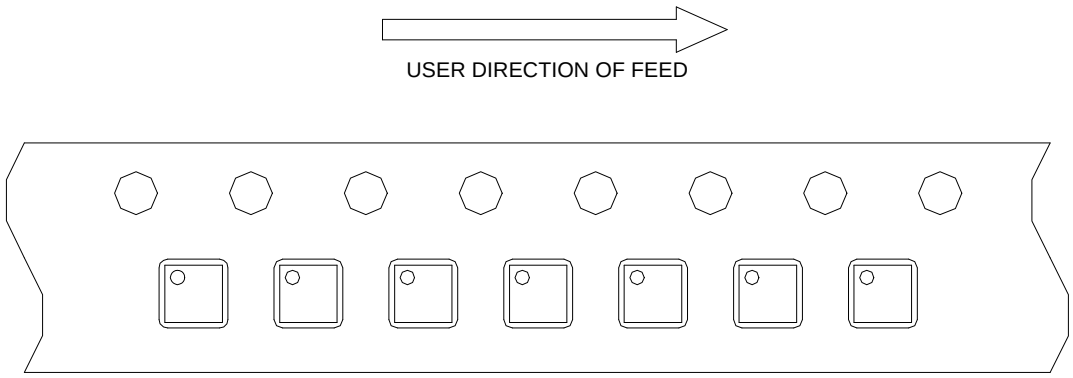
(mm)

Devices Per Unit

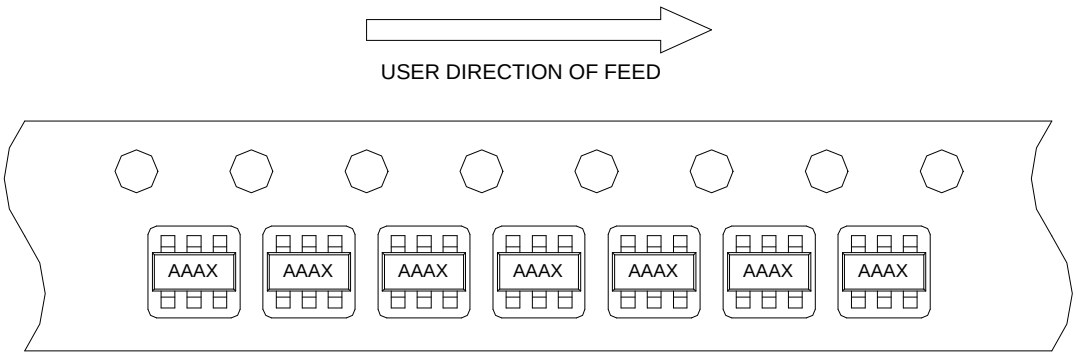
Package Type	Unit	Quantity
TDFN2x2-8	Tape & Reel	3000
TSOT-23-6A	Tape & Reel	3000

Taping Direction Information

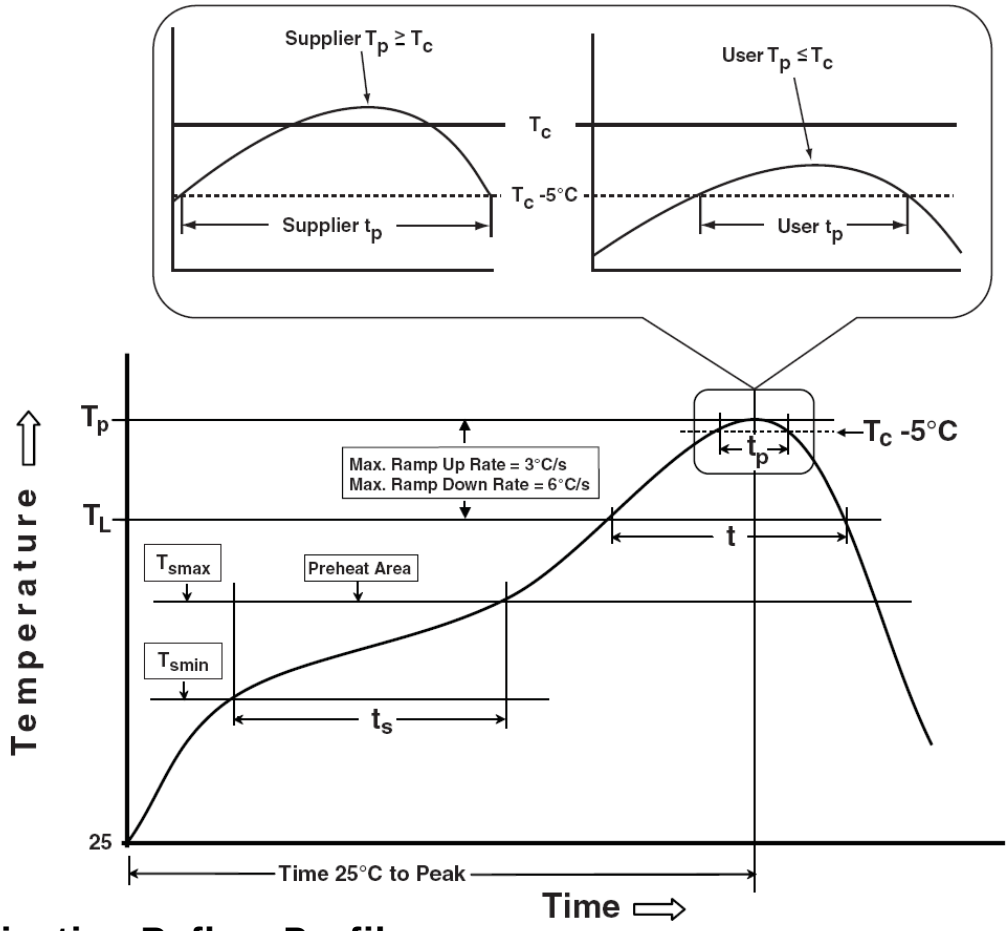
TDFN2x2-8



TSOT-23-6A



Classification Profile



Classification Reflow Profiles

Profile Feature	Sn-Pb Eutectic Assembly	Pb-Free Assembly
Preheat & Soak Temperature min (T_{smin}) Temperature max (T_{smax}) Time (T_{smin} to T_{smax}) (t_s)	100 °C 150 °C 60-120 seconds	150 °C 200 °C 60-120 seconds
Average ramp-up rate (T_{smax} to T_P)	3 °C/second max.	3°C/second max.
Liquidous temperature (T_L) Time at liquidous (t_L)	183 °C 60-150 seconds	217 °C 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.		

Classification Reflow Profiles (Cont.)

Table 1. SnPb Eutectic Process – Classification Temperatures (Tc)

Package Thickness	Volume mm^3 <350	Volume mm^3 ³350
<2.5 mm	235 °C	220 °C
≥2.5 mm	220 °C	220 °C

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

Package Thickness	Volume mm^3 <350	Volume mm^3 350-2000	Volume mm^3 >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}≧100mA

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