Single Cell Li-ion Battery Charger

Features

- High-Accuracy Voltage and Current Regulation
- Charge Voltage Regulation Accuracy:
  ±0.5% (0°C to 50°C)
- Charge Current Accuracy: ±10%
- Maximum 28V Input Voltage Rating with Over-Voltage Protection
- Complete Charge Process with Pre-Charge, Constant Current Charging(CC) and Constant Voltage Charging(CV)
- Programmable CC Charge current
- Wide Range Fast Charge Current: 5mA~1000mA
- Strong Robust Protection: VBUS OVP, Battery OVP, Reverse Leakage Protection, Thermal Protection, NTC Temperature Protection
- Less than 1μA Leakage current from the Battery when Input Power absented or Charger Disabled
- Fully Integrated Dynamic Input Power Management
- ESOP-8L package
- IEC62368-1 Approved-File No.BE-37454

Applications

- Smart Handheld Devices
- Wearable Devices
- Smart Watches
- Fitness Accessories
- Wireless Remote

General Description

The AW32006ZXXX is a highly-integrated Li-Ion/Li-Polymer battery linear charger. The AW32006ZXXX is targeted at space limited portable applications. The chip can take input power from either an AC adaptor or a USB port to charge the battery. The charger accepts an input voltage up to 28V but is disabled when the input voltage exceeds the OVP threshold, typically 6.8V (AW32006L) /13.5V (AW32006H), to prevent excessive power dissipation.

The charge process of AW32006ZXXX includes: Pre-Charge, Constant Current Charging and Constant Voltage Regulation. The charge current is programmable with external resistor. The charge process runs automatically. In all charge phases, an internal control loop monitors the IC junction temperature and reduces the charge current if an internal temperature threshold is exceeded. Additionally, input over voltage protection, input under voltage lockout protection and input headroom voltage detection are integrated for good input source monitor.

AW32006ZXXX support status indication function using the CHG and PPR pin which allow simple interface to a microprocessor or LEDs. The chip consume less than 1μA leakage from battery when Input Power absented or Charger Disabled. It is available ESOP-8L package.

Typical Application Circuit

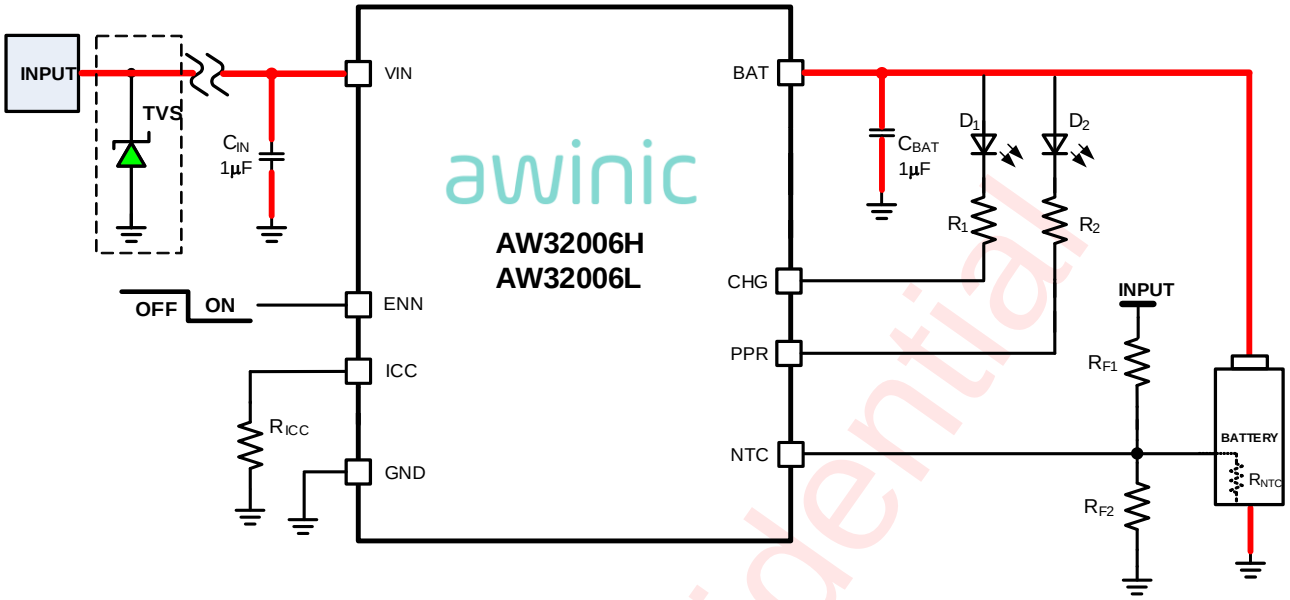
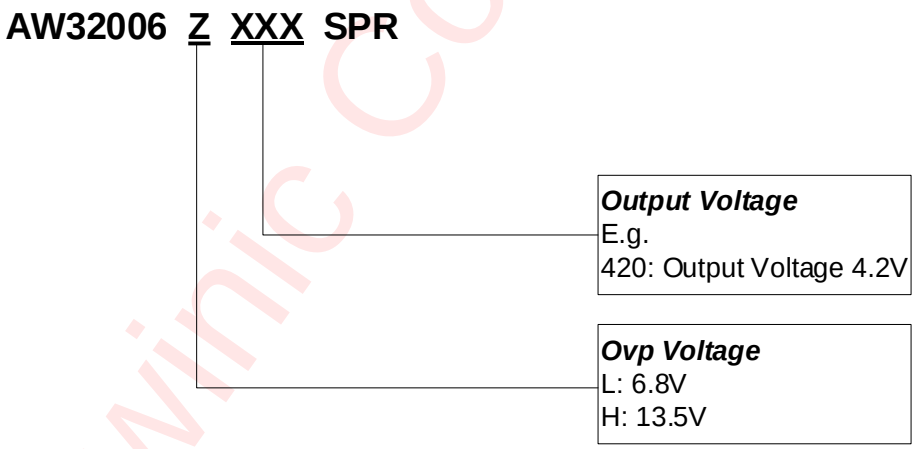


Figure 1 Typical Application Circuit of AW32006H/AW32006L

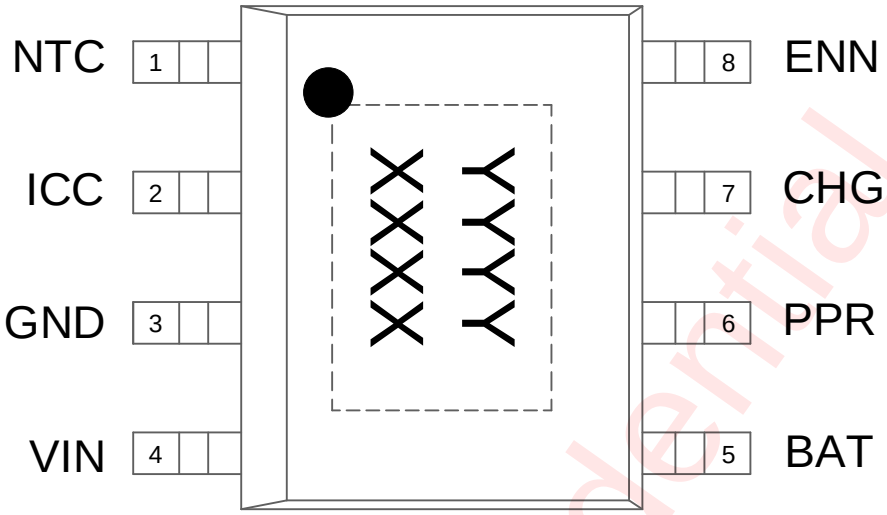
Name Rule



Device Comparison Table

PART No.	OVP VOLTAGE	VBAT VOLTAGE
AW32006L420SPR	6.80 V	4.20 V
AW32006L435SPR	6.80 V	4.35 V
AW32006L440SPR	6.80 V	4.40 V
AW32006L444SPR	6.80 V	4.44 V
AW32006H420SPR	13.5 V	4.20 V
AW32006H435SPR	13.5 V	4.35 V
AW32006H440SPR	13.5 V	4.40 V
AW32006H444SPR	13.5 V	4.44 V

Pin Configuration and Top Mark



YYYY - AW32006ZXXXSPR
XXXX - Production Tracing Code

Figure 2 Pin Configuration and Top Mark

Pin Definition

No.	NAME	DESCRIPTION
1	NTC	Temperature sense input. Connect a negative temperature coefficient thermistor. Program the hot and cold temperature window with resistor dividers from VIN to GND, and NTC is the middle node.
2	ICC	Charge-Current Programming and Monitoring Pin. Connect a resistor between this pin and the GND pin to set the charge current limit determined by the following equation: $I_{CC} = \frac{12000}{R_{ICC}}$ (mA) where R_{ICC} is in kΩ. The resistor should be located very close to this pin. The ICC pin voltage also monitors the actual charge current during the entire charge cycle, including the trickle, constant-current, and constant-voltage phases. When disabled, VICC = 0V.
3	GND	System Ground.
4	VIN	Power Input. The absolute maximum input voltage is 28V. A 1μF or larger value X5R ceramic capacitor is recommended to be placed very close to the input pin for decoupling purpose. Additional capacitance may be required to provide a stable input voltage.
5	BAT	Charger Output Pin. Connect this pin to the battery. A 1μF or larger X5R ceramic capacitor is recommended for decoupling and stability purposes.
6	PPR	Open-Drain Power Presence Indication. The open-drain MOSFET turns on when the input voltage is above the POR threshold and ICC voltage is built, otherwise the MOSFET is off. This pin is capable to sink 15mA current to drive an LED. This pin is independent on the pin input.
7	CHG	Open-Drain Charge Indication. This pin outputs a logic low when a charge cycle starts and turns to high impedance when the full-of-charge (FOC) condition is qualified. This pin is capable to sink 15mA current to drive an LED. When the charger is disabled, the CHG pin outputs high impedance.
8	ENN	Enable Input. This is a logic input pin to disable or enable the charger. Drive high to disable the charger. When this pin is driven to low or left floating, the charger is enabled. This pin has an internal 1.7MΩ pull-down resistor.

Ordering Information

Part Number	Temperature	Package	Marking	Moisture Sensitivity Level	Environmental Information	Delivery Form
AW32006L420SPR	-40°C～85°C	ESOP-8L	EFKH	MSL3	ROHS+HF	2500 units/ Tape and Reel
AW32006L435SPR	-40°C～85°C	ESOP-8L	Y6MY	MSL3	ROHS+HF	2500 units/ Tape and Reel
AW32006L440SPR	-40°C～85°C	ESOP-8L	NHWJ	MSL3	ROHS+HF	2500 units/ Tape and Reel
AW32006L444SPR	-40°C～85°C	ESOP-8L	U4AK	MSL3	ROHS+HF	2500 units/ Tape and Reel
AW32006H420SPR	-40°C～85°C	ESOP-8L	EB62	MSL3	ROHS+HF	2500 units/ Tape and Reel
AW32006H435SPR	-40°C～85°C	ESOP-8L	JLZW	MSL3	ROHS+HF	2500 units/ Tape and Reel
AW32006H440SPR	-40°C～85°C	ESOP-8L	PC7L	MSL3	ROHS+HF	2500 units/ Tape and Reel
AW32006H444SPR	-40°C～85°C	ESOP-8L	B744	MSL3	ROHS+HF	2500 units/ Tape and Reel

Absolute Maximum Ratings(NOTE1)

PARAMETERS		MIN	MAX	UNIT
Input voltage range V_{IN} (with respect to GND)	VIN	-0.5	28	V
Other pins voltage range (with respect to GND)	BAT, PPR, CHG, ICC, ENN, NTC	-0.3	6	V
Operating free-air temperature range		-40	85	°C
Operating junction temperature T_J		-40	150	°C
Storage temperature T_{STG}		-65	150	°C
Lead temperature (Soldering 10 seconds)			260	°C

NOTE1: *Conditions out of those ranges listed in "absolute maximum ratings" may cause permanent damages to the device. In spite of the limits above, functional operation conditions of the device should within the ranges listed in "recommended operating conditions". Exposure to absolute-maximum-rated conditions for prolonged periods may affect device reliability.*

ESD Rating and Latch Up

PARAMETERS	VALUE	UNIT
HBM (Human Body Model) (NOTE 2)	±6	kV
CDM(NOTE 3)	±1.5	kV
Latch-Up(NOTE 4)	+IT：200 -IT：-200	mA

NOTE2: *The human body model is a 100pF capacitor discharged through a 1.5kΩ resistor into each pin. Test method: ESDA/JEDEC JS-001-2017*

NOTE3: Test method: ESDA/JEDEC JS-002-2018

NOTE4: Test method: JESD78E

Recommended Operating Conditions

PARAMETERS	MIN	TYP	MAX	UNIT
Supply voltage range V_{IN} (AW32006LXXX)	4		6.8	V
Supply voltage range V_{IN} (AW32006HXXX)	4		13.5	V
Charge current I_{CHG}	5		1000	mA
Battery regulated voltage V_{BAT_REG}	3.52		4.52	V
Operating junction temperature T_J	-40		125	°C

Thermal Information

PARAMETERS	VALUE	UNIT
Junction-to-ambient thermal resistance θ_{JA}	39.78	°C/W

Electrical Characteristics

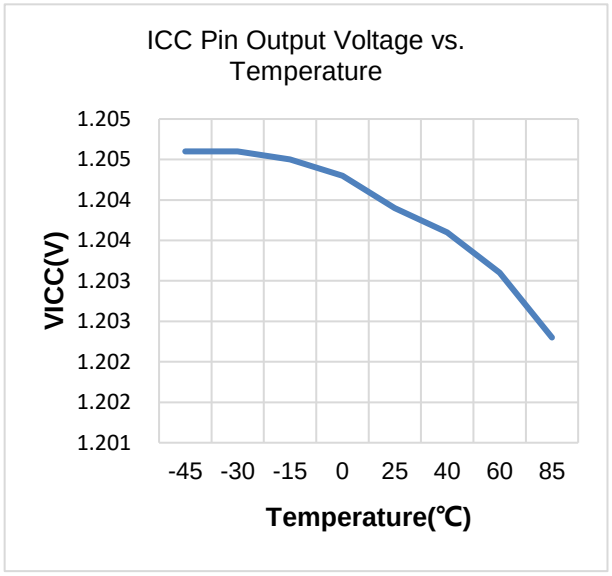
V_{IN}=5V, V_{BAT}=4.35V, T_J=25°C for typical values (unless otherwise noted)

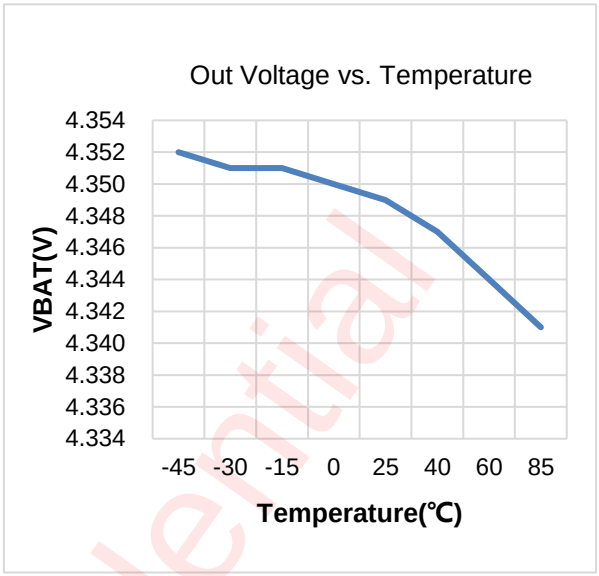
PARAMETER			TEST CONDITION	MIN	TYP	MAX	UNIT
INPUT SOURCE AND BATTERY PROTECTION							
V_{IN_UVLO}	UVLO threshold voltage, entry UVLO		V_{IN} falling	3.5	3.6	3.7	V
	Hysteresis for UVLO		V_{IN} rising		300		mV
	Deglitch time for V_{IN_UVLO}		Exits UVLO		30		ms
V_{IN_OVP}	V_{IN_OVP} threshold voltage	AW32006LXXX	V_{IN} rising	6.6	6.8	7	V
		AW32006HXXX		13.1	13.5	13.9	V
	V_{IN_OVP} hysteresis		V_{IN} falling from above V_{IN_OVP}		350		mV
V_{IN_Clamp}	V_{IN} Clamp voltage		V_{IN} rising	5.25	5.5	5.7	V
			V_{IN} falling	5.05	5.3	5.5	V
V_{HDRM}	Input vs. battery voltage headroom threshold		V_{IN} rising	80	130	170	mV
	Input vs. battery voltage headroom threshold hysteresis		V_{IN} falling		60		mV
CHARGE PROCESS							
V_{OREG}	Output regulation voltage	AW32006Z420SPR	V_{IN}=5V, R_{ICC}=300K	4.18	4.20	4.22	V
		AW32006Z435SPR		4.33	4.35	4.37	V
		AW32006Z444SPR		4.42	4.44	4.46	V
	Output regulation voltage accuracy		T_J=0°C~50°C	-0.5		0.5	%
V_{BAT_OVP}	Battery OVP threshold voltage		V_{BAT} threshold over V_{OREG} to turn off charger during charge	80	130	180	mV
	V_{BAT_OVP} hysteresis				50		mV
V_{BAT_PRE}	Pre charge to fast charge threshold		V_{OREG} <3.56	2.35	2.5		V
			3.60< V_{OREG} <3.88		2.55		V
			3.92< V_{OREG} <4.2		2.6		V
			4.24< V_{OREG} <4.52		2.65	2.75	V
	V_{BAT_PRE} hysteresis		V_{BAT} falling		200		mV
DYNAMIC POWER MANAGEMENT							
V_{IN_DPM}	Dynamic power management clamps V_{IN}			V_{OREG}	V_{OREG} +0.2	V_{OREG} +0.4	V
POWER MOSFET ON-RESISTANCE							
R_{dson}	IN to BAT Power MOS on resistance		Power MOS fully turn on	410	480	550	mΩ

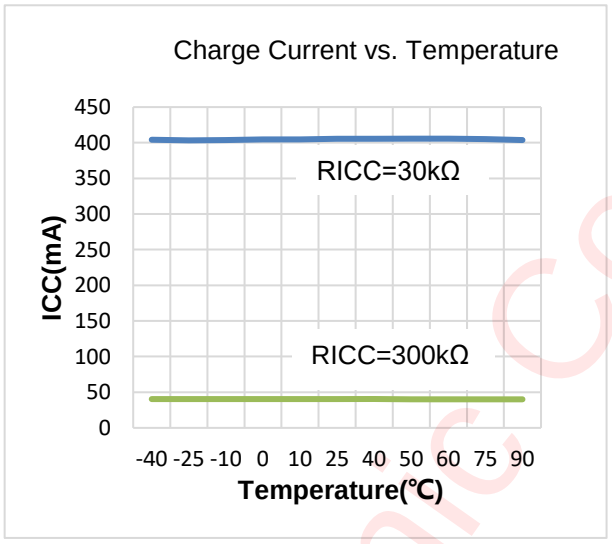
PARAMETER		TEST CONDITION	MIN	TYP	MAX	UNIT
STANDBY CURRENT						
I_{IN_Q}	Input quiescent current	V_{IN}=5V, charge enable, I_{CHG}=8mA;	800	1030	1800	μA
		V_{IN}=5V, charge disabled, I_{CHG}=0;	0.8	1	1.6	μA
		V_{IN}=5V, charge done;	30	55	100	μA
I_{BAT_INOFF}	Battery current when VIN=0	V_{IN}=0V, V_{BAT}=4.2V	-1	0	1	μA
I_{BAT_CHGDN}	Battery charge done current	V_{IN}=5V, charge done, I_{CHG}=0;	0	0.1	1	μA
CHARGE CURRENT						
I_{CHG}	Output charge regulation current programmable range	V_{BAT_PRE}<V_{BAT}<V_{OREG}	5		1000	mA
	Accuracy for charge current regulation	I_{CHG}>98mA & 30mA<I_{CHG}<50mA	-10		10	%
	Accuracy for charge current regulation	I_{CHG}=20mA	17.5	20	22.5	mA
		I_{CHG}=62mA	54.25	62	69.75	mA
		I_{CHG}=74mA	64.75	74	85.2	mA
		I_{CHG}=86mA	75.25	86	98.2	mA
I_{PRE}	Pre-charge current	V_{BAT}< V_{BAT_PRE}		20		%I_{CHG}
I_{TERM}	Termination charge current threshold			2.9		mA
T_{TERM}	Termination deglitch time	I_{CHG}<I_{TERM}		3.2		s
LOGIC INPUT AND OUTPUTS						
R_{CHG}	CHG Pin On-Resistance when LOW	I_{CHG}=5mA	28	35.5	42	Ω
I_{LEAK_CHG}	CHG Pin Leakage Current when High Impendence	V_{CHG}=5.5V			0.1	μA
R_{PPR}	PPR Pin On-Resistance when LOW	I_{PPR}=5mA	28	35.5	42	Ω
I_{LEAK_PPR}	PPR Pin Leakage Current when High Impendence	V_{PPR}=5.5V			0.1	μA
THERMAL PROTECTION						
T_{J_REG}	Junction temperature regulation	Junction temperature rising		120		°C
T_{OTP}	Overheating shutdown protection temperature	Junction temperature rising		150		°C
	Thermal hysteresis for T_{OTP}	Junction temperature falling		20		°C
NTC PROTECTION						
V_{COLD}	NTC cold temp rising threshold	Percent of V_{IN}		30		%
	Hysteresis voltage			70		mV

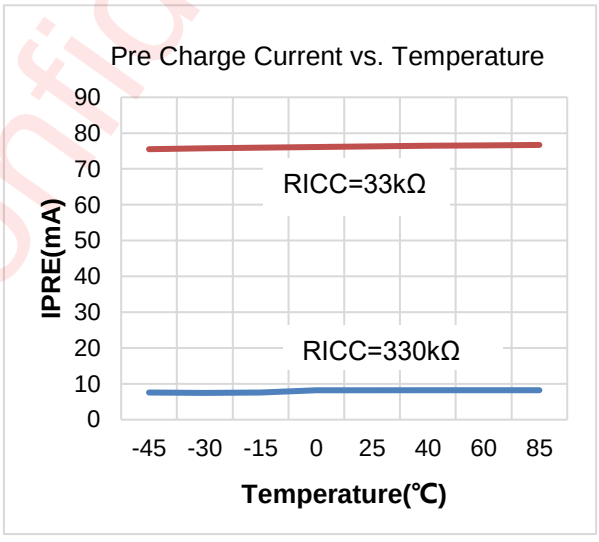
PARAMETER		TEST CONDITION	MIN	TYP	MAX	UNIT
V_{HOT}	NTC hot temp falling threshold	Percent of V_{IN}		15		%
	Hysteresis voltage			70		mV

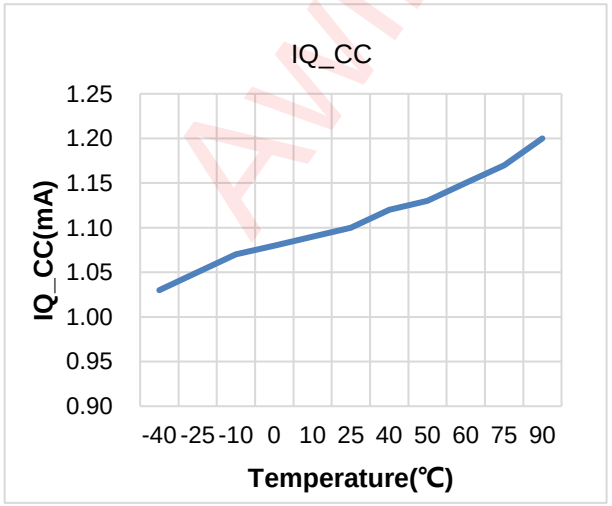
Typical Characteristics

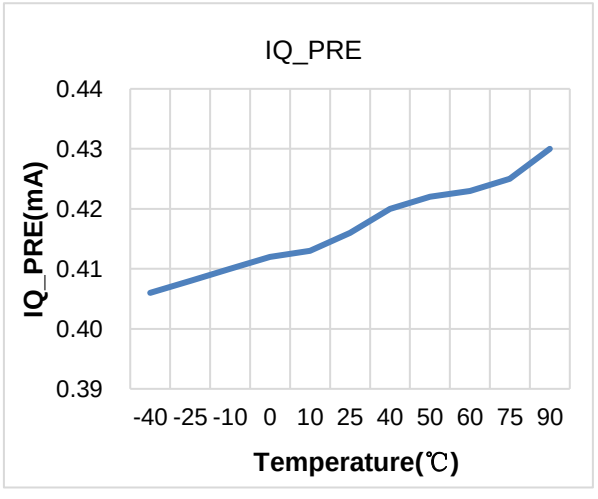












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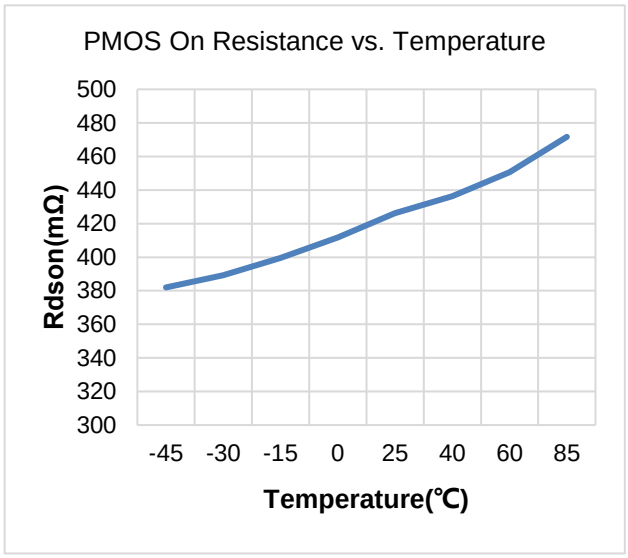

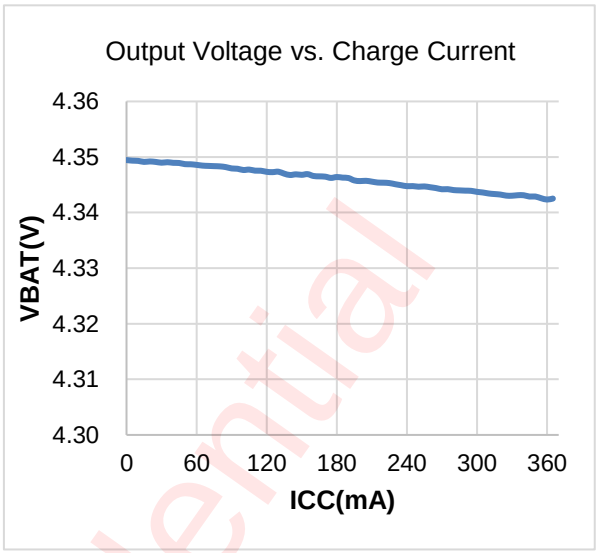

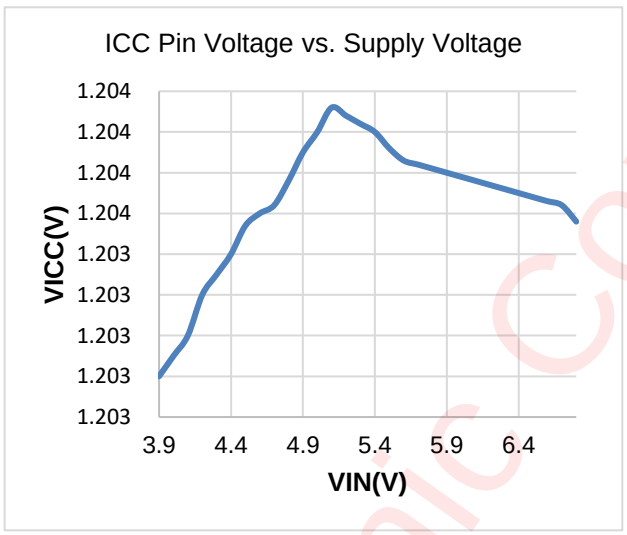

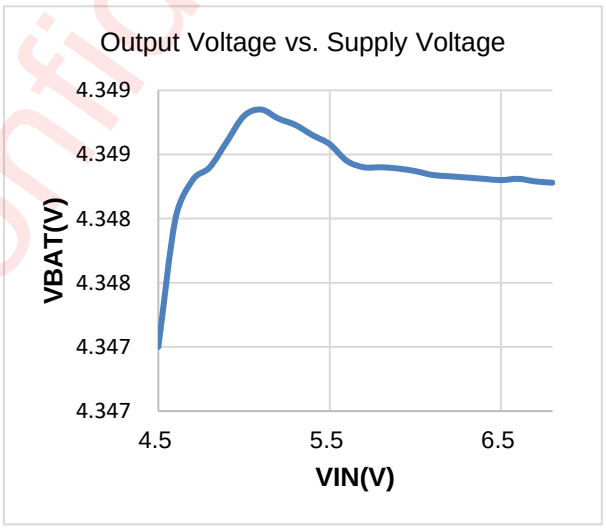

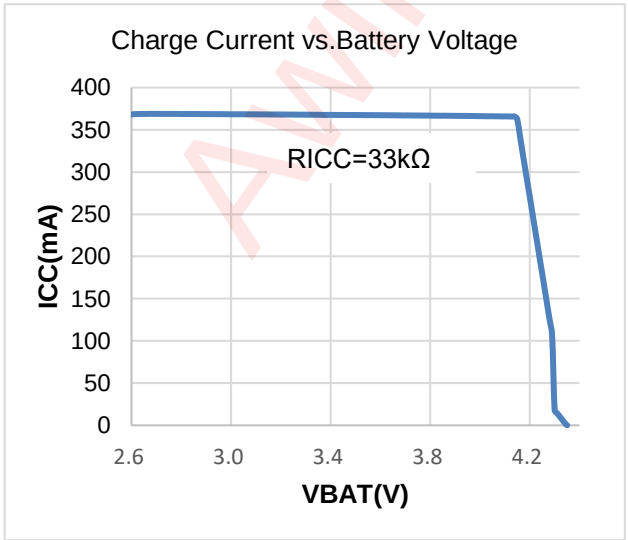

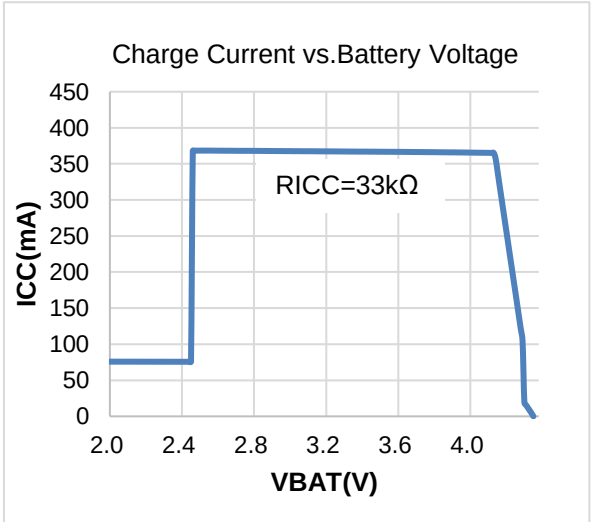

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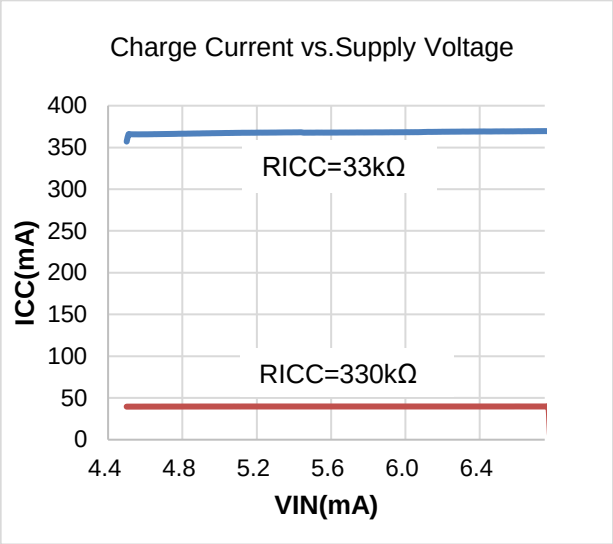
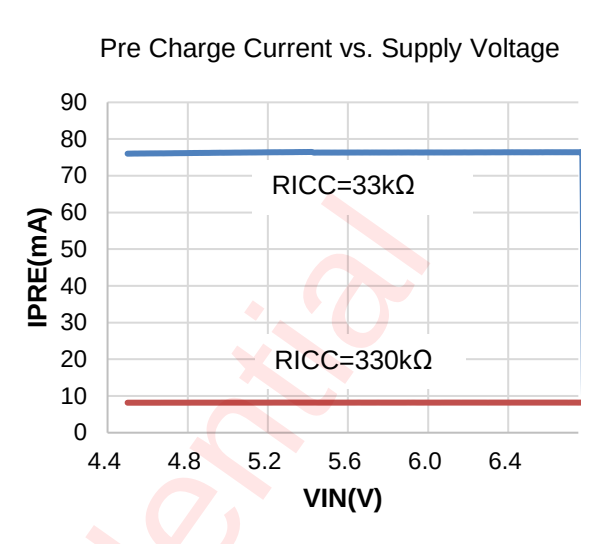
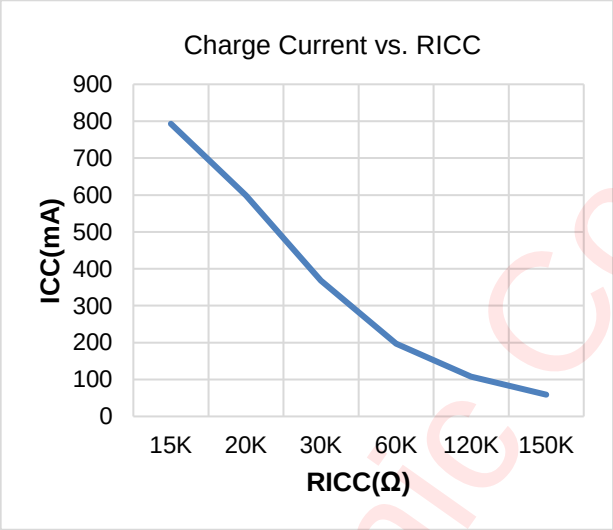
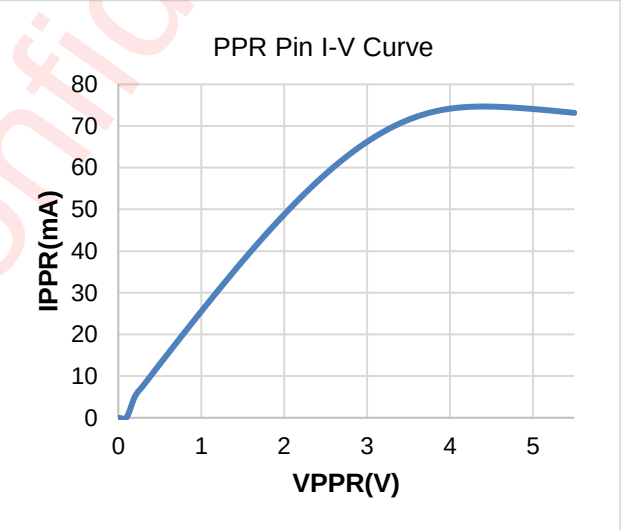
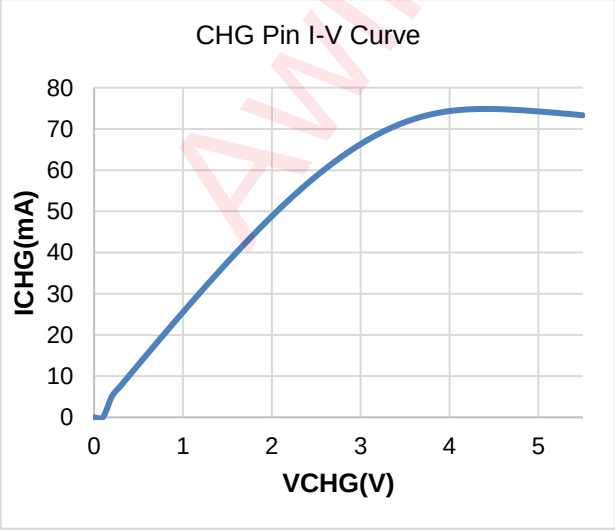
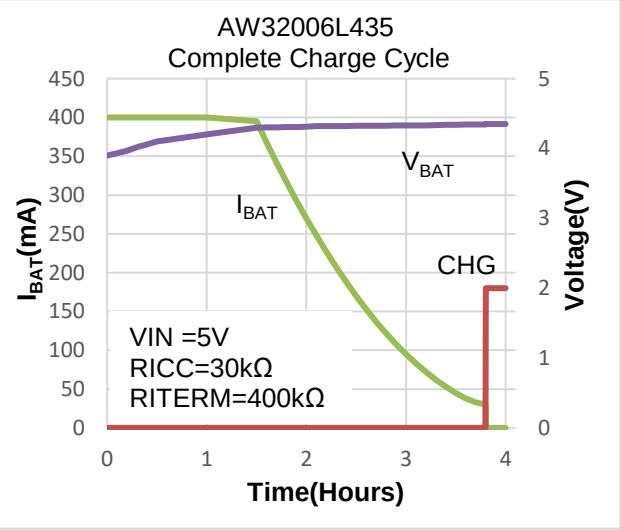












Functional Diagram

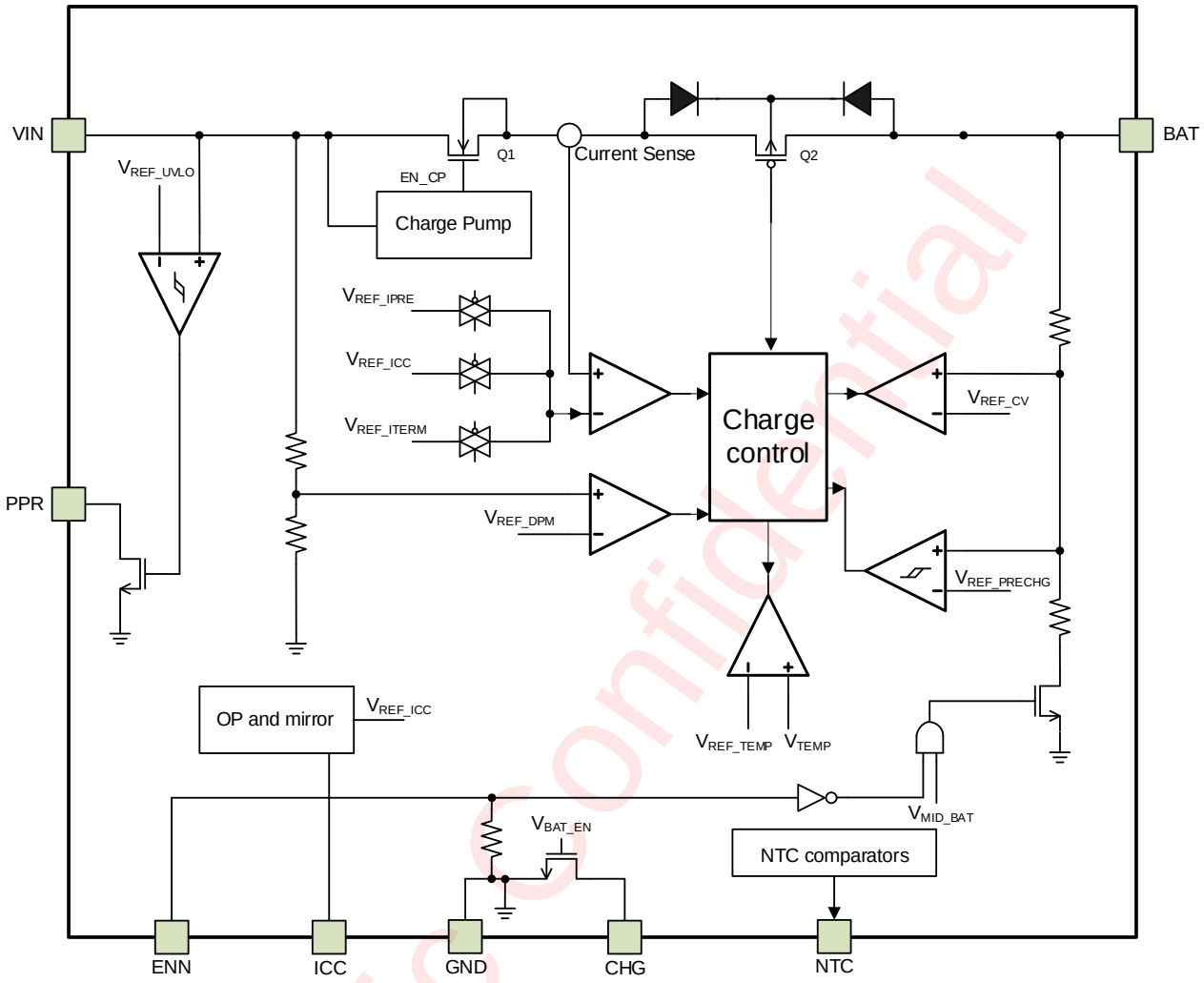


Figure 3 Functional Block Diagram

Detailed Functional Description

The AW32006ZXXX is a highly integrated linear battery charger. The full-charge process of AW32006ZXXX not only includes pre-charge, constant-current fast charge (CC) and constant voltage (CV) regulation, but also includes charge termination, etc. When the input power is limited by input current or voltage, the charge current will decease automatically.

The charge current is programmable with external resistors. The charge process runs automatically. In all charge phases, an internal control loop monitors the IC junction temperature and reduces the charge current if an internal temperature threshold is exceeded. Additionally, input over voltage protection, input under voltage lockout protection and input headroom voltage detection are integrated for good input source monitor.

Operation

When AW32006ZXXX operates in Charge Mode, the input Voltage DPM, thermal regulation and other functions are available.

Enable

AW32006ZXXX is enabled by pulling ENN pin low, and system shuts down when the ENN pin pull high. When ENN pin is floating, the chip is enable. ENN pin has a 1.7MΩ internal pull-down resistance.

Input Voltage Power Regulation

The input voltage DPM(dynamic power management) function is built in AW32006ZXXX. When the load is over the input power capacity, the input voltage also can be regulated to V_{IN_DPM} for the input voltage-based DPM regulation. Once the current load above the input power capacity, input voltage decreases below the DPM threshold V_{IN_DPM}, which triggers the DPM control loop. Then VIN-BAT path current is regulated and decreases, until the input voltage stops falling and holds on almost DPM threshold voltage. If the load decreases below the input power capacity, the input voltage will rise over the DPM threshold and the device will exit DPM control loop.

Battery Charge flow

The AW32006ZXXX has three main charging processes: pre-charge, fast-current charge, and constant-voltage charge:

- Pre-charge: In the pre-charge process, the IC charges the deeply depleted battery safely with small current until the battery voltage rises to the pre-charge threshold(V_{BAT_PRE}), in which the chip enters the fast-charge process. The pre-charge current is 20% of Fast charge current programmed by ICC pin. If the V_{BAT} is not exceeding V_{BAT_PRE} before the pre-charge timer expires (1 hour), the charge cycle stops, and a corresponding timeout fault signal is asserted. Only power on from VIN or Enable can trigger recharge form charge timer expires fault.
- Fast charge: When V_{BAT} exceeds V_{BAT_PRE}, the AW32006ZXXX enters the fast charge process. The fast-charge current is programmed by external resistance.
- Constant-voltage charge: The charge mode changes from CC mode to CV mode when the V_{BAT} rises to the battery-full voltage (V_{BAT_REG}) . At the same time, the charge current starts decreasing in CV charge process. When the charge current is smaller than termination current threshold I_{TERM} for 3.2s in CV process, the charge cycle will be completed, and the charge status is updated to charge done. If the V_{BAT} is not increasing to V_{BAT_REG} before the CC-charge timer expires (4 hours), the charge cycle stops, and a corresponding timeout fault signal is asserted. Only power on from VIN or Enable can trigger recharge form charge timer expires fault.

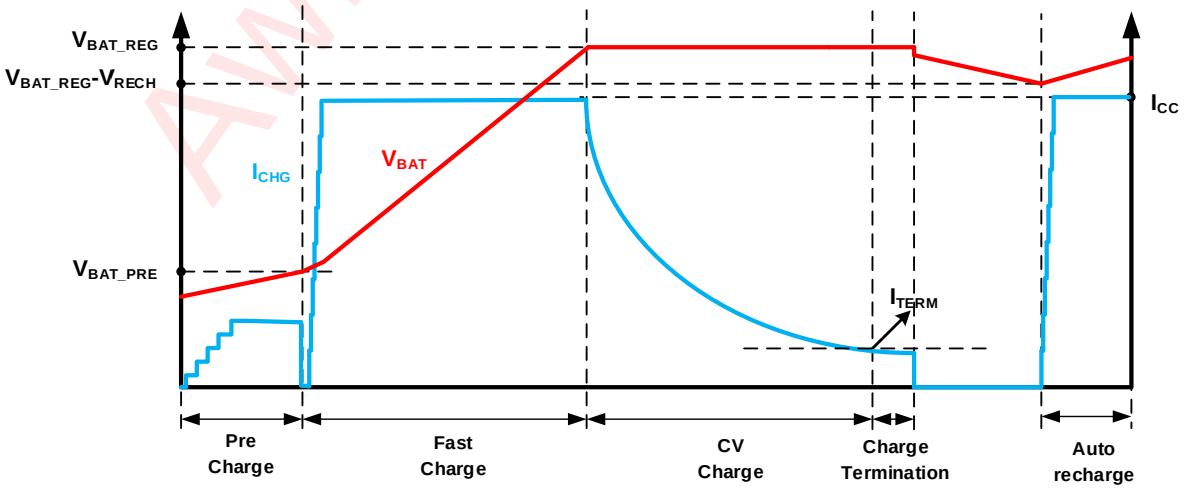


Figure 4 Battery Charge Profile

Automatic Recharge

After the charge process is completed and charging cycle is terminated, the system's consumption or battery self-discharge may cause the battery voltage decreasing. When the battery voltage falls below the recharge threshold and V_{IN} is still in the operating range, another new charging cycle will be start automatically.

Thermal Regulation

The AW32006ZXXX build-in thermal regulation function to avoid overheating the chip and maximize power delivery. When the internal junction temperature rising and reaches the preset limit T_{J_REG} (120°C), the charge current starts reducing to prevent dangerous high power dissipation. The charge current decreases continually when the temperature falling.

Protection Operation

The AW32006ZXXX has input OVP, UVLO, battery OVP and other functions to protect its normal operation. Additionally, NTC function is integrated to prevent battery from high temperature danger.

Input OVP and UVLO

The AW32006ZXXX has an input UVLO and over-voltage protection (OVP) threshold. The Q1 is turned off immediately when the input voltage is out of its operating range.

The input over-voltage protection is integrated to prevent the device and other components from damage caused by the high input voltage (Voltage from V_{IN} to GND). If the voltage at V_{IN} pin exceeds V_{IN_OVP} threshold(6.8V typical)，the chip will turn off Q1 and send out a fault pulse. When V_{IN} drops lower than the input overvoltage exit threshold (6.5V typical), Q1 will be turned on again.

When V_{IN} falls below V_{UVLO}, the Q1 is also turned off and the input to system loop controller is shut down. Once V_{IN} rises above V_{UVLO}+300mV, the Q1 is turned on and relative circuits start working.

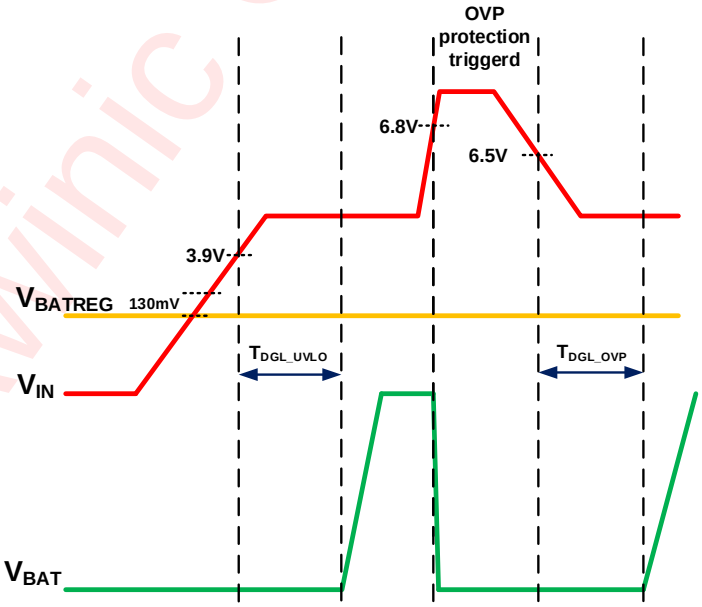


Figure 5 Input Power Detection Operation

Battery OVP

The AW32006ZXXX has battery over-voltage protection (BOVP) function (about 130mV higher than V_{BAT_REG}). When the battery OVP event occurs, AW32006ZXXX will stop the current charging cycle immediately and asserts a fault.

PPR Indication

The PPR pin is an open-drain output to indicate the presence of input power. The PPR open-drain circuit is on when the input voltage is above the POR threshold and the ICC voltage is built, otherwise the PPR open-drain circuit is off. This pin is capable to sink 15mA current to drive an LED. The maximum voltage rating for this pin is 6V.

CHG Indication

CHG pin is an Open-Drain Charge Indication. This pin outputs a logic low when a charge cycle starts and turns to high impedance when the full-of-charge (FOC) condition is qualified. This pin is capable to sink 15mA current to drive an LED. When the charger is disabled, the CHG pin outputs high impedance.

Negative Temperature Coefficient (NTC) Temperature Sensor

The AW32006ZXXX is able to use NTC to sense the battery temperature. By monitoring the thermistor (usually available in the battery pack), the battery is guaranteed to operate in safe environment.

Appropriately valued NTC divider resistors connected among VIN, NTC and GND are demanded for NTC function. At the same time, connect a thermistor from the NTC pin to ground. The NTC voltage is determined by the resistor divider and thermistor, and the divide ratio depends on the temperature of thermistor. The upper and lower bound of NTC voltage is pre-determined in AW32006ZXXX.

The NTC function works only in charge mode. Once the temperature is outside of the safe operating range, the IC stops charging state. When the temperature comes back to the safe range, the charge process resumes automatically.

Over temperature Protection(OTP)

The internal junction temperature is monitored continuously to avoid destroy by abnormal high temperature . When the internal junction temperature reaches 150°C, the Q1 and Q2 will turn off and charge procedure is stopped. The chip will recover from OTP status when the temperature falls below the low threshold 130°C.

Short Circuit Protection(SCP)

The AW32006ZXXX supports SCP function for ICC pin, BAT pin. When ICC pin is shorted to GND, system stops charging until the abnormity is removed. When BAT pin to GND short circuit happening, charge current is about 17mA.

Safety timer

In consideration of the abnormal battery conditions, a pre-charge and fast-charge safety timer is designed in the AW32006ZXXX to prevent an extra-long time charging cycle. The pre-charge safety timer is 1hour, and the fast-charge safety timer is 5 hours. Once the battery enters fast-charge mode, The fast charge safety timer starts.

Application Information

NTC FUNCTION

NTC pin is connected to the thermistor paralleled with a resistor R_{F2} to ground. Another resistor R_{F1} is connected to the VIN which is the chip's internal power supply voltage. The high temperature limit and low temperature limit can be varied by using different R_{F1} and R_{F2}. Illustrated in Figure 6, the off chip resistors must be connected as the blue part demonstrated. The resistance of R_{F1} and R_{F2} can be calculated by Equation (1) and Equation (2):

$$R_{F2} = \frac{(V_{COLD} - V_{HOT}) \times R_{NTCH} \times R_{NTCL}}{(V_{HOT} - V_{COLD} \times V_{HOT}) \times R_{NTCL} - (V_{COLD} - V_{COLD} \times V_{HOT}) \times R_{NTCH}} \quad (1)$$

$$R_{F1} = \frac{1 - V_{COLD}}{V_{COLD}} \times (R_{F2} // R_{NTCL}) \quad (2)$$

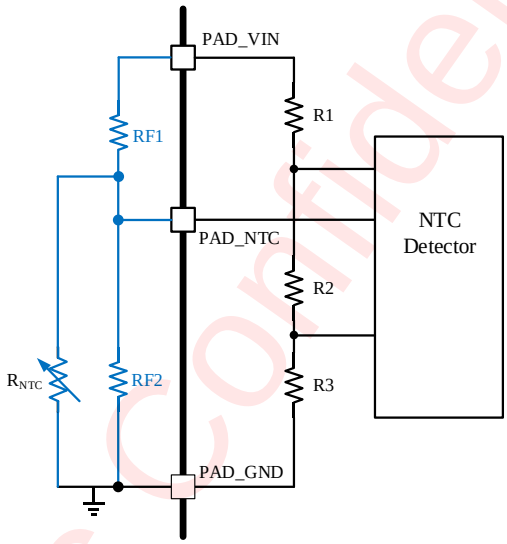


Figure 6 NTC Function

Where R_{NTCH} is the value of the NTC resistor at the high limit temperature, while the R_{NTCL} is the value of the NTC resistor at a low temperature limit.

External Capacitor

The external capacitor cannot be absent for the operation of AW32006ZXXX. Carefully selecting suitable capacitor is important to guarantee the AW32006ZXXX working perfectly on the space limited board.

A 1μF ceramic capacitor with high level voltage endurance (at least 30V) between IN and GND is recommended. This capacitor rejects input power supply ripple and enhance the stability of DPM loop.

A least 1μF ceramic capacitor is also needed between BAT and GND for some application.

PCB Layout Consideration

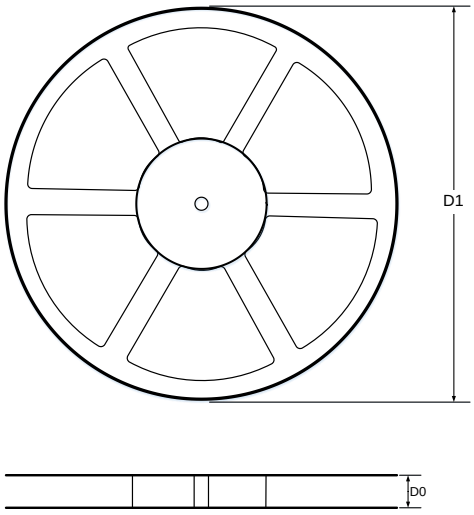
To obtain the optimal performance, PCB layout should be considered carefully. Guidelines below should be obeyed,

1. All peripherals components should be placed as close to the chip as possible. C_{IN} and C_{BAT} should be close to VIN and BAT pins respectively.

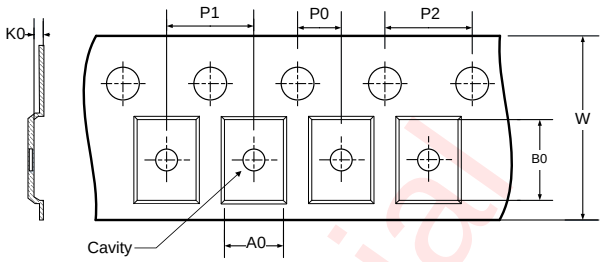
2. IN and BAT pins are input and output of the chip with large current. Make sure the routes of VIN, BAT and GND are sufficient wide and short to flow large charging current.
3. The exposed pad of the chip and GND pin must be well connected to the GND of the PCB and add as many thermal vias as possible on the PCB for the integrity of the GND and heat conductivity.

Tape and Reel Information

REEL DIMENSIONS

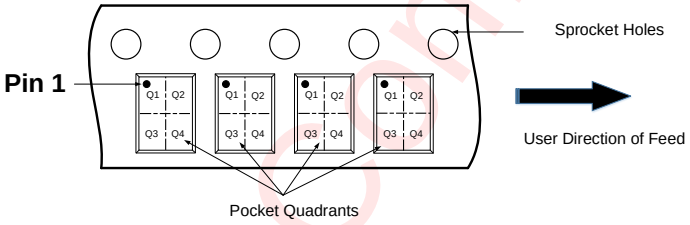


TAPE DIMENSIONS



A0：Dimension designed to accommodate the component width
B0：Dimension designed to accommodate the component length
K0：Dimension designed to accommodate the component thickness
W：Overall width of the carrier tape
P0：Pitch between successive cavity centers and sprocket hole
P1：Pitch between successive cavity centers
P2：Pitch between sprocket hole
D1：Reel Diameter
D0：Reel Width

QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



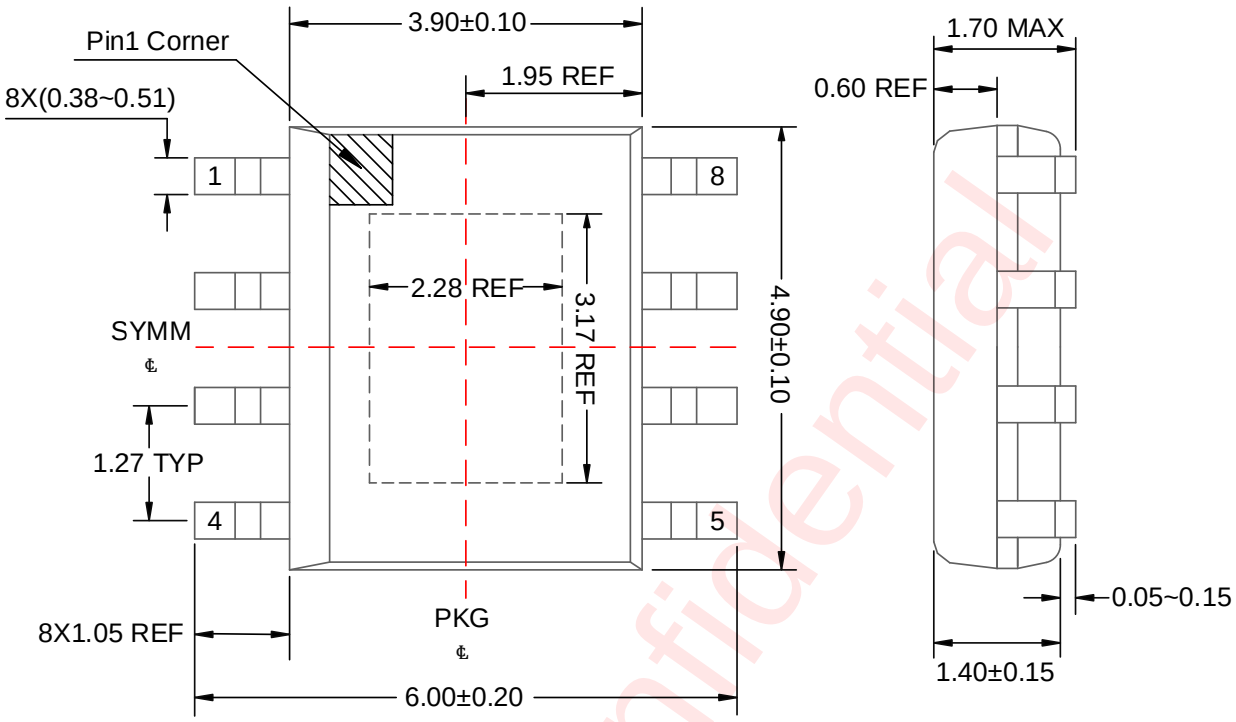
Note：The above picture is for reference only. Please refer to the value in the table below for the actual size

DIMENSIONS AND PIN1 ORIENTATION

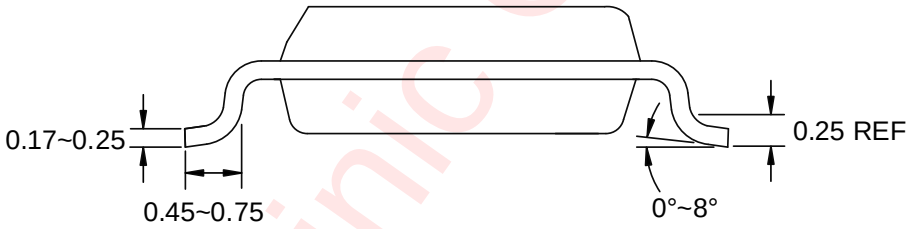
D1 (mm)	D0 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	P1 (mm)	P2 (mm)	W (mm)	Pin1 Quadrant
330	12.5	6.4	5.35	2	2	8	4	12	Q1

All dimensions are nominal

Package Description(POD)



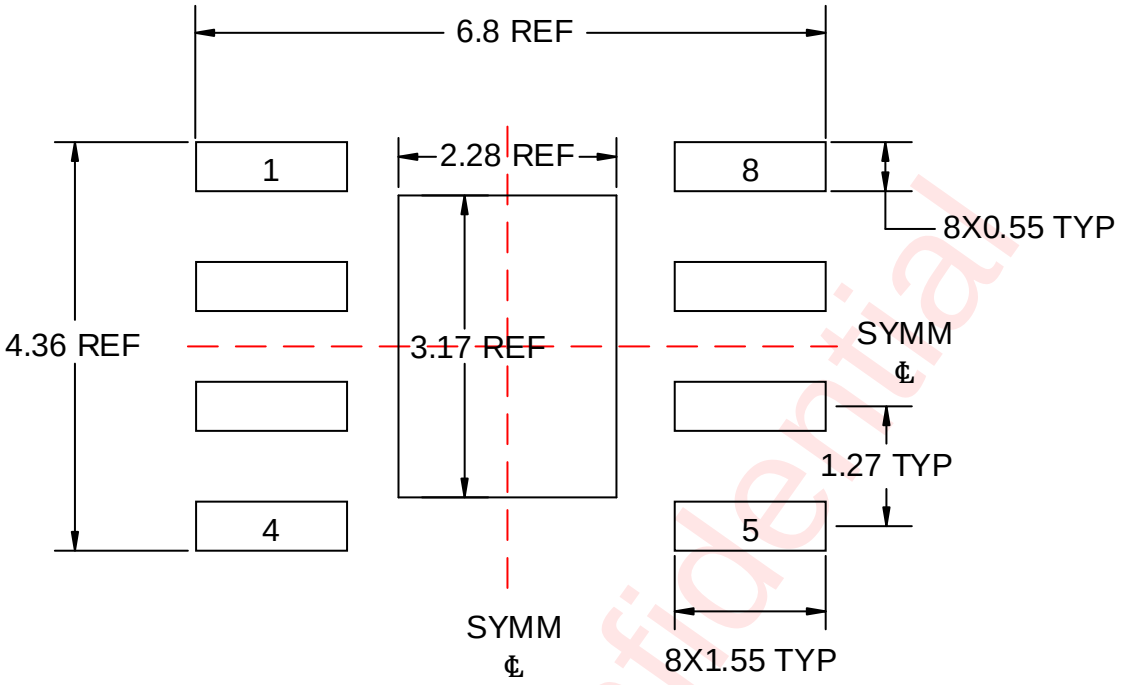
Top View **Side View**



Side View

Unit: mm

Land Pattern Data



NON SOLDER MASK DEFINED

SOLDER MASK DEFINED

Unit：mm

Revision History

Version	Date	Change Record
V1.0	Mar. 2023	Official Released
V1.1	Aug. 2023	Revised the maximum value of the ICHG at 74mA and 86mA
V1.2	Apr. 2024	Revised the ITERM and safety timer values

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