APM8600

SINGLE CELL LINEAR LITHIUM BATTERY CHARGER WITH 28V OVP AND PROGRAMMABLE CHARGE TIMER

NEW PRODUCT

Description

The APM8600 is a linear Li-Ion charger for portable equipment that is optimized for small form-factor applications.

The charge algorithm in the APM8600 covers all the charge requirements for a single Li-Ion battery cell. Included is pre-charging for deeply discharged cells, constant current / constant voltage fast charging and a top-off feature to bring the cell safely to a full-charge level.

The battery is constantly monitored for overvoltage, charge time and cell temperature to ensure safe charging. A fault is triggered once the charge time exceeds a value that is programmable using a single capacitor and the temperature measurement is achieved through a thermistor positioned close to the battery cell.

The APM8600 is packaged in U-DFN3030-14 package with a thermal pad.

Applications

- Handheld Consumer Devices
- Cell Phones, PDAs, MP3 Players
- Handheld Test Equipment
- Digital Still Cameras
- Multimedia players

Pin Assignments

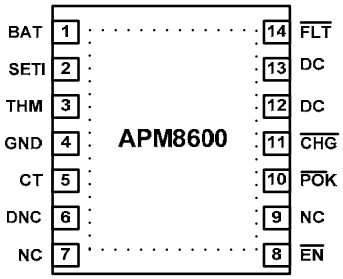


Figure 1 Pin Out

Features

- Linear Lithium Ion / Lithium Polymer charging IC
- Supply input safe up to 28V
- Fast charging with maximum current of 1A
- Resistor-programmable charging current
- Resistor programmable end-of-charge
- Capacitor programmable charge timer
- Three charge indicator pins for a status display
- Thermal protection
- DFN3030-14: Available in “Green” Molding Compound (No Br, Sb)
- Lead Free Finish/ RoHS Compliant (Note 1)

Note: 1. EU Directive 2002/95/EC (RoHS). All applicable RoHS exemptions applied. Please visit our website at http://www.diodes.com/products/lead_free.html.

Typical Application Circuit

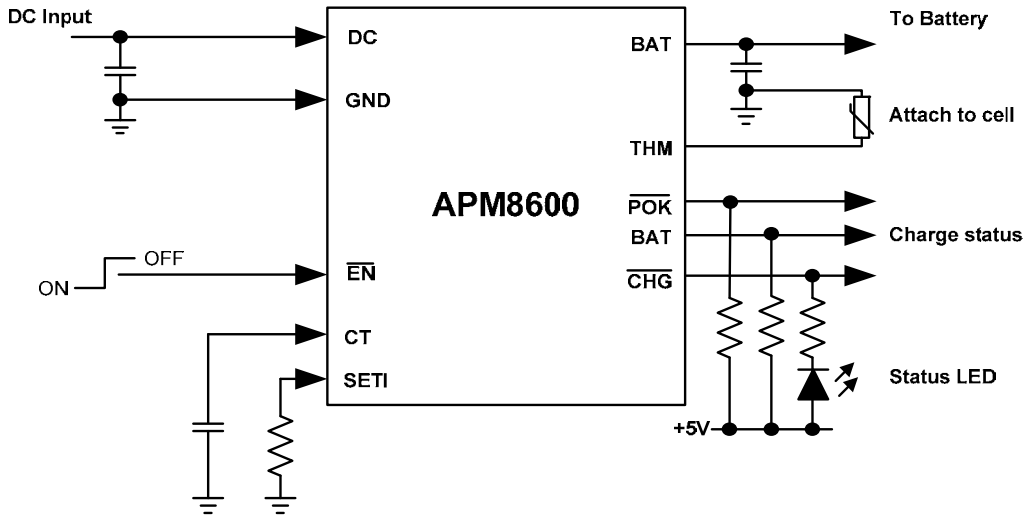
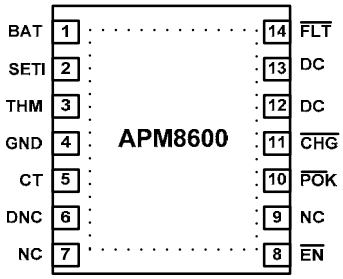


Figure 2. Typical Application Circuit

© Diodes Incorporated

NEW PRODUCT

Pin Descriptions

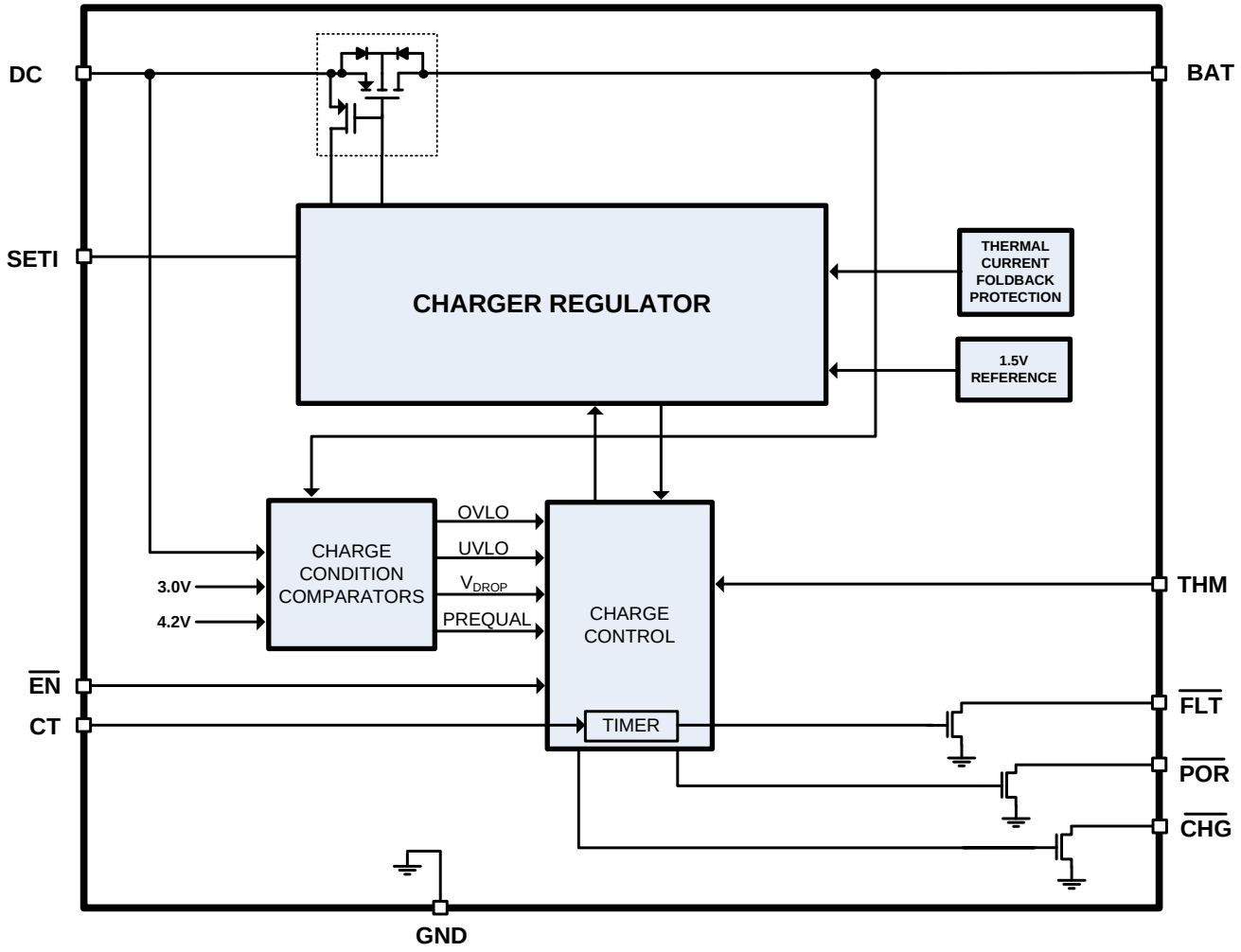


Name	Pin #	Description	
BAT	1, 7	Connection to the Battery	The battery is charged via this pin and the BAT voltage is constantly monitored. Connect a bypass capacitor between BAT and GND (2.2µF).
SETI	2	Charge Current programming	The maximum charge current is programmed using a resistor from SETI to GND. This also determines the prequal current charging level and top-off threshold.
THM	3	Thermistor Input	To monitor the battery temperature, connect a 10kΩ NTC thermistor. Place this thermistor as close as possible to the battery. Connect THM to GND if temperature measurement is not required.
GND	4	Ground	Ground connection.
CT	5	Charge Timing	Connecting a capacitor from CT to GND will set the time-outs for prequal, top-off and fast-charge. Connecting CT direct to GND disables these timers.
$\overline{EN}$	8	Enable (active-low)	The charger is enabled when this input is low. To start the charger connect $\overline{EN}$ to GND. Drive this input high to disable the charger.
$\overline{POK}$	10	Power OK (active-low)	When a valid input source is connected, this open-drain output is pulled low.
$\overline{CHG}$	11	Charge Status (active-low)	Open-drain output that indicates the charging status. It is active only in the fast-charge state and goes high-impedance when the charger is either disabled or in prequal or top-off mode.
DC	12, 13	DC Input	DC supply input. The recommended input voltage is between 4.32V and 7V. This input is capable of withstanding up to 28V. Connect both DC pins together on the PCB. It is recommended to connect a bypass capacitor (1µF) from DC to GND.
$\overline{FLT}$	14	Fault Flag (active-low)	If the prequal or fast-charge timers expire and the charging threshold voltage is not reached, $\overline{FLT}$ (open-drain output) will go low. Remove the fault by cycling power or raise $\overline{EN}$.
	EP	Exposed Pad	For optimal thermal performance connect to copper on PCB (electrically this can be GND).
NC	7,9	Not Connected	Floating pins
DNC	6	Do Not Connect	Must not connect

© Diodes Incorporated

NEW PRODUCT

Functional Block Diagram



© Diodes Incorporated

NEW PRODUCT

Absolute Maximum Ratings

Symbol	Parameter	Rating	Unit
	DC to GND	-0.3 to 28V	V
	BAT, CT, SETI, THM, $\overline{FLT}$, $\overline{CHG}$, $\overline{POK}$, $\overline{EN}$ to GND	-0.3 to 6V	V
ESD Susceptibility (Note 2)			
HBM	Human Body Model	2	kV
MM	Machine Model	200	V

Note: 2. Semiconductor devices are ESD sensitive and may be damaged by exposure to ESD events. Suitable ESD precautions should be taken when handling and transporting this device.

Thermal Resistance (Note 3)

Symbol	Parameter	Rating	Unit
θ_{JA}	Junction to Ambient	40	°C/W

Note: 3. Test condition for DFN3030-10: Device mounted on FR-4 2-layer board, 2oz copper, with minimum recommended pad on top layer and 6 vias to bottom layer 1.0"x1.5" ground plane.

Recommended Operating Conditions (Note 4)

Symbol	Parameter	Rating	Unit
	Ambient Temperature Range	-40 to +85	°C
	Input Supply Voltage	4.15 to 7.00	V
I_{CHARGE}	Typical Charge Current	0.1 to 1.0	A

Note: 4. The device function is not guaranteed outside of the recommended operating conditions.

© Diodes Incorporated

NEW PRODUCT

Electrical Characteristics

APM8600 is tested at V_{DC} = 5V, V_{BAT} = 4V, $V_{\overline{EN}}$ = 0V, R_{SETI} = 2kΩ, C_{CT} = 68nF, at an ambient temperature of +25°C unless otherwise noted.

Symbol	Parameter	Test Conditions	Min	Typ.	Max	Unit
V_{DC}	Input Voltage Range		0		28	V
V_{DC}	Input Operating Range (Note 5)		4.15		7.00	V
UVLO	Input Undervoltage Lock Out (Note 5)	Input rising, 500mV hysteresis (typ.) V_{BAT} = 3.2V	3.85	4.0	4.15	V
OVLO	Input Overvoltage Lock Out	Input rising, 200mV hysteresis (typ.)	7.2	7.5	7.8	V
I_{DC}	Input Supply Current	I_{BAT} = 0mA, R_{THM} = 10kΩ		750	1200	μA
I_{SHTDWN}	Shutdown Current	$\overline{EN}$ = High, T_A = 25ºC		275	435	μA
R_{DS_ON}	Input to BAT On-Resistance	Input = 3.7V, V_{BAT} = 3.6V		0.5	0.8	Ω
$V_{DROPOUT}$	Input to BAT dropout Voltage	Input falling, 200mV hysteresis (typ.)	5	55	150	mV
V_{BAT_REG}	Battery Voltage Regulation	I_{BAT} = 0mA, T_A = 25ºC	4.179	4.2	4.221	V
BAT_{RSTTH}	Battery Fast-Charge Restart Threshold	From BAT regulation voltage	-230	-175	-110	mV
I_{DC_CHG}	DC Charge Current V_{USB} = 0V	R_{SETI} = 1.5kΩ	950	1000	1140	mA
		R_{SETI} = 2.0kΩ	727	750	870	
		R_{SETI} = 5.0kΩ	280	300	353	
		Prequal, R_{SETI} = 2kΩ, V_{BAT} = 2.5V	60	75	95	
SS	Soft-Start Time	Ramp time to fast-charge		1.2		ms
V_{PREQ_TH}	BAT Prequel Threshold	V_{BAT} rising, 180mV hysteresis (typ.)	2.9	3.0	3.1	V
I_{LEAK}	BAT Leakage Current	V_{DC} = V_{USB} = 0V, V_{BAT} = 4.2V		0.001	5	μA
R_{SETI}	Resistance Range for SETI	Guaranteed by charging current	1.5		5.0	kΩ

Note: 5. Guaranteed by testing of undervoltage- and overvoltage-threshold. To completely charge a battery cell, the input voltage must be greater than 4.32V.

© Diodes Incorporated

NEW PRODUCT

Electrical Characteristics (Continued)

APM8600 is tested at V_{DC} = 5V, V_{BAT} = 4V, $V_{\overline{EN}}$ = 0V, R_{SETI} = 2kΩ, C_{CT} = 68nF, at an ambient temperature of +25°C unless otherwise noted.

Symbol	Parameter	Test Conditions	Min	Typ.	Max	Unit
$\overline{EN}$						
	Logic Input Thresholds	Rising			1.6	V
		Falling	0.4			
	Logic Input Leakage Current	$V_{\overline{EN}}$ = 0 to 5.5V, T_A = 25ºC		0.001	1	µA
$\overline{POK}$, $\overline{CHG}$, $\overline{FLT}$						
	Logic Output Voltage, Low	$I_{\overline{POK}} = I_{\overline{CHG}} = I_{\overline{FLT}} = 1mA$		12	100	mV
	Logic Output Leakage Current, High	$V_{\overline{POK}} = V_{\overline{CHG}} = V_{\overline{FLT}} = 5.5V$, V_{DC} = V_{USB} = 0V, T_A = +25°C		0.001	1	µA
I_{TOPOFF}	$\overline{CHG}$ / Top-Off Threshold	I_{BAT} falling, battery is charged; R_{SETI} = 1.5kΩ		75		mA
		R_{SETI} = 2.0kΩ	37.5	56.25	75	
		R_{SETI} = 5.0kΩ		22.5		
R_{THM_Pullup}	Internal Pullup Resistance			10		kΩ
R_{THM}	THM Resistance, Hot	R_{THM} falling, 420Ω hyst. (typ.)	3.72	3.94	4.13	kΩ
	THM Resistance, Cold	R_{THM} rising, 2.7kΩ hyst. (typ.)	26.7	28.3	29.7	kΩ
	THM Resistance, Disabled	R_{THM} falling, 230Ω hyst. (typ.)	260	315	370	Ω
CT_{accu}	Charge Timer Accuracy	C_{CT} = 68nF	-20		+20	%
$TL_{Prequal}$	Prequal Time Limit	From entering prequal to $\overline{FLT}$ going low, V_{BAT} < 3V		34.8		min
TL_{CHG}	Charge Time Limit	From entering fast-charge to $\overline{FLT}$ going low, 3V < V_{BAT} < 4.2V		334		min
TL_{Top_off}	Top-Off Time Limit	From $\overline{CHG}$ going high to charger disabled		34.8		min
$THFB_{temp}$	Thermal Foldback Threshold Temperature	Junction temperature beyond which the charge current is reduced, T_J rising		+100		ºC
$THFB_{Gain}$	Thermal Foldback Gain	Reduction of I_{BAT} for increase in T_J (using V_{DC}), R_{SETI} = 1.5kΩ		5		%/ºC

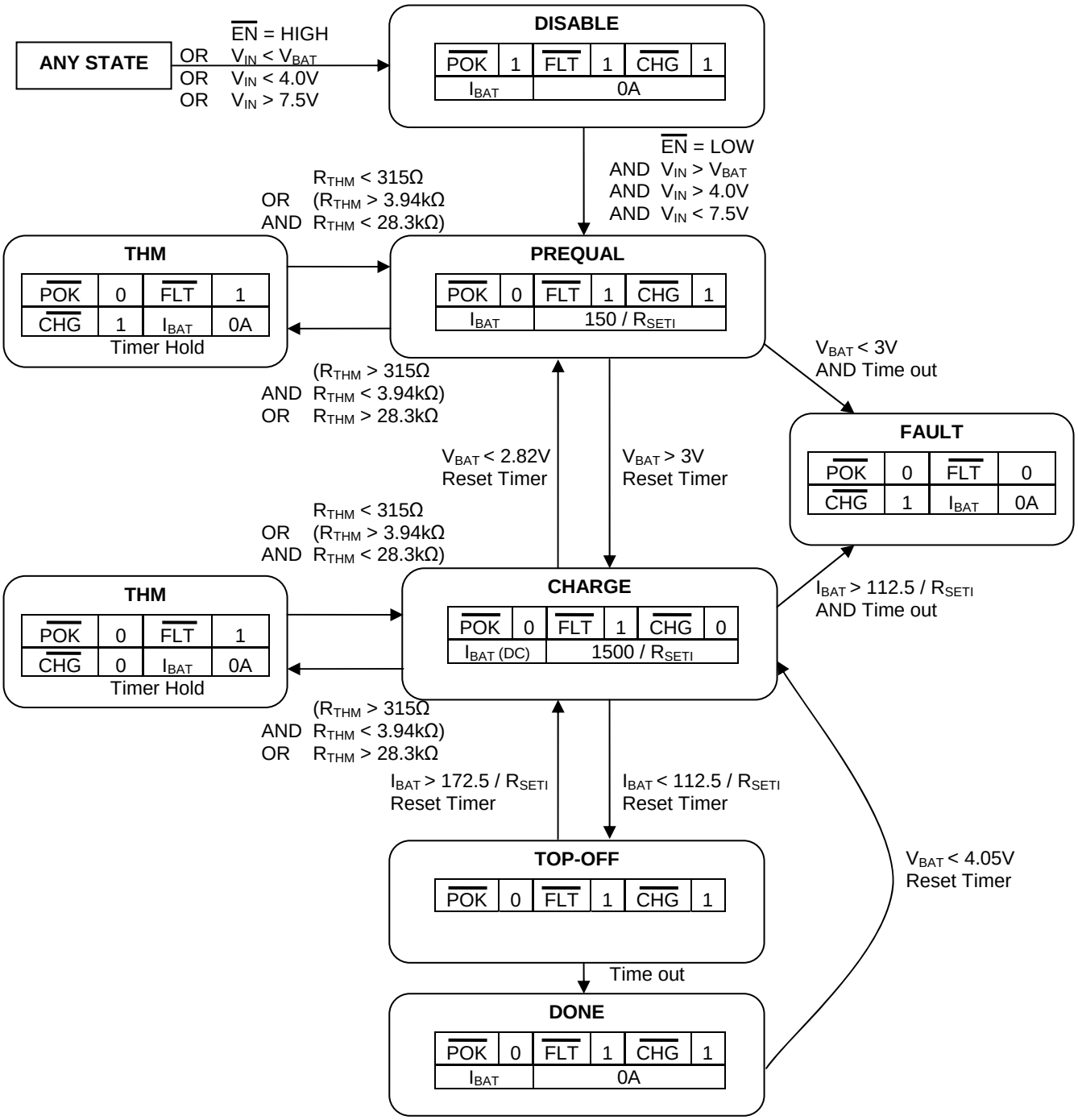
© Diodes Incorporated

NEW PRODUCT

Functional Description

APM8600 is a linear Li-Ion battery charger device for single-cell applications. Charge currents can be programmed with the R_{SETI} resistor. The device also incorporates several safety features, such as charge timers, battery temperature monitoring and internal thermal limiting.

Functional State Diagram



© Diodes Incorporated

NEW PRODUCT

Functional Description (continued)

INPUTS

DC Pins 12 and 13 are the DC input. This input will allow charging from input voltages between 4.15V and 7V, and can withstand up to 28V without device damage although charging is disabled above 7.5V (typ.).

GND System ground connection.

$\overline{EN}$ Pin 8 is the enable pin of the device. When pulled low the device will operate normally. When high, the device will remain in the disabled state. For auto-starting, connect pin 8 directly to GND.

SETI Pin 2 allows the charge currents to be programmed.

$$RSETI = \frac{1500}{ICHARGE}$$

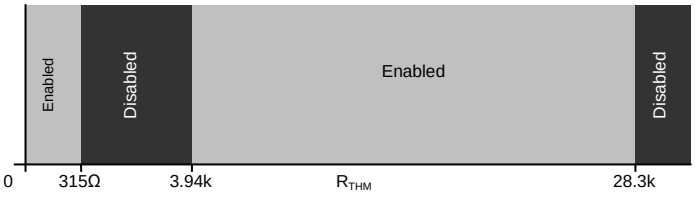
The charge current setting also changes the currents in prequal and top-off modes (being 10% and 7.5% of I_{CHARGE} respectively):

$$IPREQUAL = \frac{150}{RSETI} \qquad ITOPOFF = \frac{112.5}{RSETI}$$

This pin can also be used to monitor the battery charging current:

$$ICHARGE = \frac{VSETI \times 1000}{RSETI}$$

THM The thermistor connection is on pin 3. This allows the battery temperature to be monitored using a 10k NTC thermistor, which should be placed as close as possible to the battery cell. If no thermistor is used then this input should be connected directly to ground. The charger will operate when there is less than 315Ω on this input (i.e., no thermistor connected); will be disabled when there is between 315Ω and 3.94kΩ; enabled when between 3.94kΩ and 28.3kΩ; and disabled above 28.3kΩ.



Thermistor Beta	Resistance in kΩ at 0°C	25°C	50°C	Typical in °C Hot trip	Cold Trip
3000	25.1	10	4.6	55.1	-3.2
3250	27.1	10	4.3	52.6	-1.3
3500	29.3	10	4	50.5	0.5
3750	31.7	10	3.8	48.6	2.0

© Diodes Incorporated

NEW PRODUCT

Functional Description (continued)

CT The Charge Timer input on pin 5 allows selection of how long the system timers for Prequal, Charge and Top-off states last. They are set by selecting the value of capacitor, C_{CT}:

$$TCHARGE = 334\,min \times \left(\frac{CCT}{68nF}\right)$$

$$TPREQUAL = TTOPOFF = 34.8\,min \times \left(\frac{CCT}{68nF}\right)$$

The charge timer will hold its current value if the charging was stopped via the thermistor and continue when the battery is in a valid temperature range for charging.

OUTPUTS

BAT Pin 1 is the current-controlled charging output for the battery cell. It should be connected to the positive terminal of the battery. The chip monitors the voltage on this pin. There should be a 2.2µF capacitor connected from BAT to GND.

$\overline{\text{POK}}$ The $\overline{\text{POK}}$ flag on pin 10 is pulled low when a valid power input is available on DC. It will go high when no valid power is available and the device will enter the Disable state.

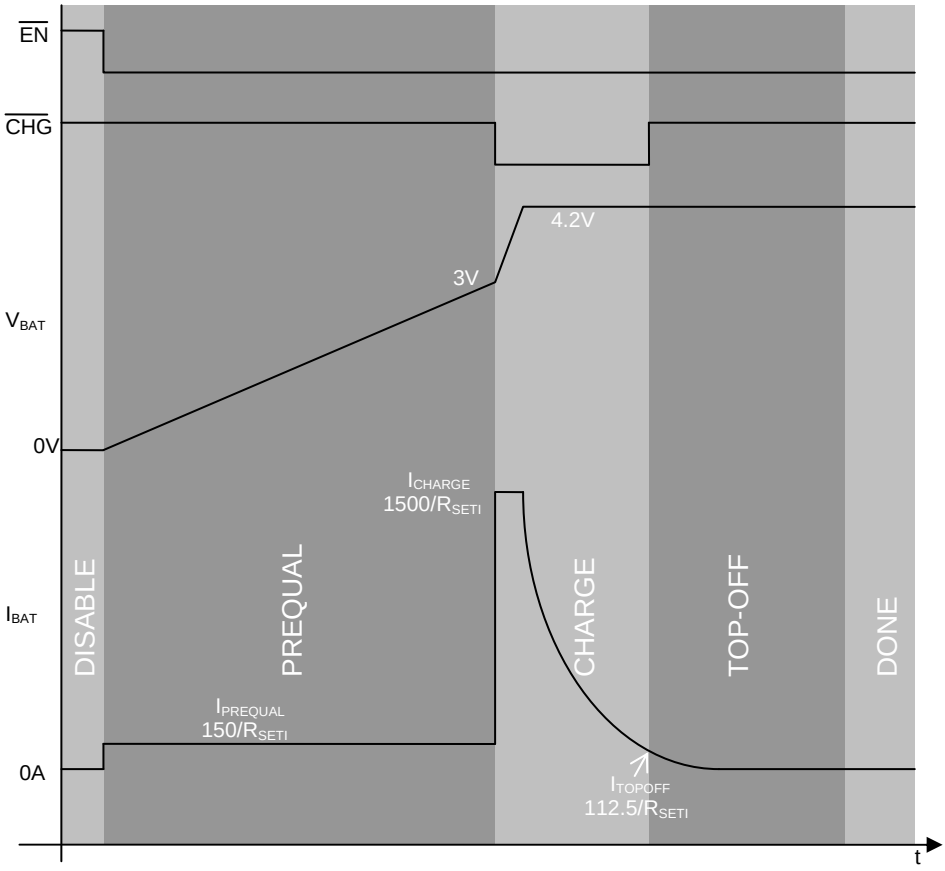
$\overline{\text{CHG}}$ The $\overline{\text{CHG}}$ flag at pin 11 is pulled low when the device is in the Charge state. It will be high in Prequal and Top-off states. If the thermistor trips the circuit into the THM state (from Prequal or Charge states), $\overline{\text{CHG}}$ will hold its previous value.

$\overline{\text{FLT}}$ The $\overline{\text{FLT}}$ flag on pin 14 indicates a battery fault, as determined by a time-out in either the Prequal or Charge states. If the battery voltage does not reach 3V after the prequal timer (default 34.8mins), or does not reduce charging current to 7.5% after the charge timer (default 334mins), this indicates that the battery has failed or is failing and this will trigger the $\overline{\text{FLT}}$ flag. This flag will not automatically reset, and can only be cleared by cycling the power input or the $\overline{\text{EN}}$ pin.

© Diodes Incorporated

NEW PRODUCT

Functional Description (continued)



CHARGING PROCESS DESCRIPTION

The charging process is as follows, working through the state diagram.

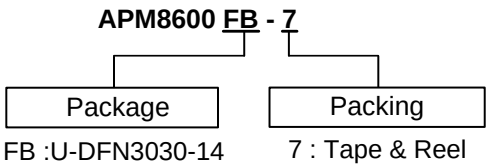
The device will begin in the **Disable** state as the input power supply ramps from 0V. Once the input power supply has got into the valid range (4.15V – 7V), and the device is enabled then it will enter the **Prequal** state. This state allows for slow charging of a severely discharged battery. If the battery is already partially charged then the condition to move into the **Charge** state is met. If it is not then the slow charge will increase the battery voltage until it can enter the **Charge** state, or if the voltage does not rise sufficiently before the charge timer runs out (set using the capacitor on the CT pin) then the device will go into the **Fault** state, indicating that the battery cell may be damaged or has failed and is not taking charge. In the **Prequal** state the battery temperature can be monitored with a 10k NTC thermistor connected to the THM pin, and if the battery temperature goes out of range (above ~50°C or below ~0°C, depending on thermistor choice) then charging will be suspended with the device going into the **THM** state.

Once the battery has charged to a level of 3V, the device enters the **Charge** state, allowing faster charging of the battery in its normal voltage range, with 10 times the current used in the **Prequal** state. For information on setting the charge currents, see the functional description of the SETI pin. Again, the battery temperature is monitored and charging will be suspended if the temperature goes out of range. The **Charge** state will last until the current drawn by the battery drops to 7.5% of the full charge current. The device will then enter the **Top-Off** state, maintaining battery voltage and providing top-off charging current for the time defined by the C_T value. Once that timer completes, the device will enter the **Done** state, with zero battery current. If the battery voltage falls below 4.05V then the device will automatically return to the **Charge** state.

© Diodes Incorporated

NEW PRODUCT

Ordering Information

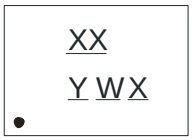


Device	Package Code	Packaging (Note 6)	7" Tape and Reel	
			Quantity	Part Number Suffix
APM8600FB-7	FB	U-DFN3030-14	3000/Tape & Reel	-7

Note: 6. Pad layout as shown on Diodes Inc. suggested pad layout document AP02001, which can be found on our website at http://www.diodes.com/datasheets/ap02001.pdf.

Marking Information

(Top View)



XX : P3 : APM8600
Y : Year : 0~9
W : Week : A~Z : 1~26 week;
a~z : 27~52 week;
z : represents 52 and 53
X : A~Z : Internal Code

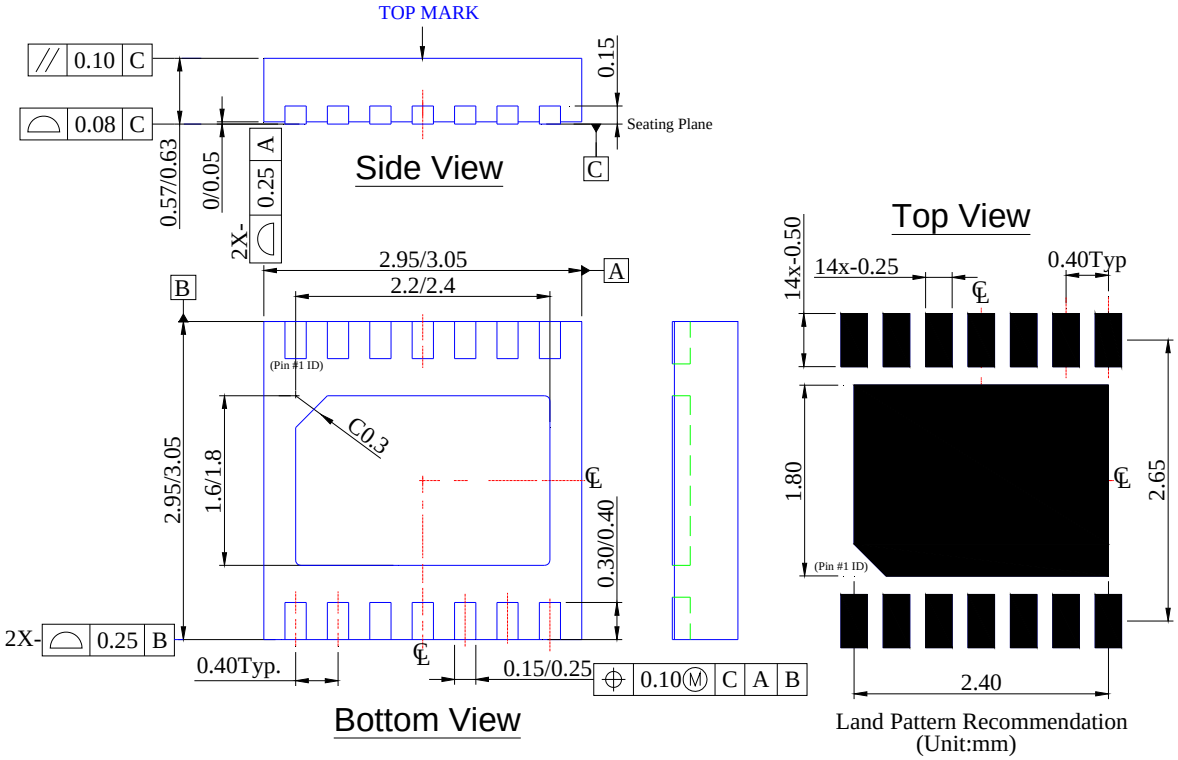
Part Number	Package	Identification Code
APM8600FB-7	U-DFN3030-14	P3

© Diodes Incorporated

NEW PRODUCT

Package Outline Dimensions (All Dimensions in mm)

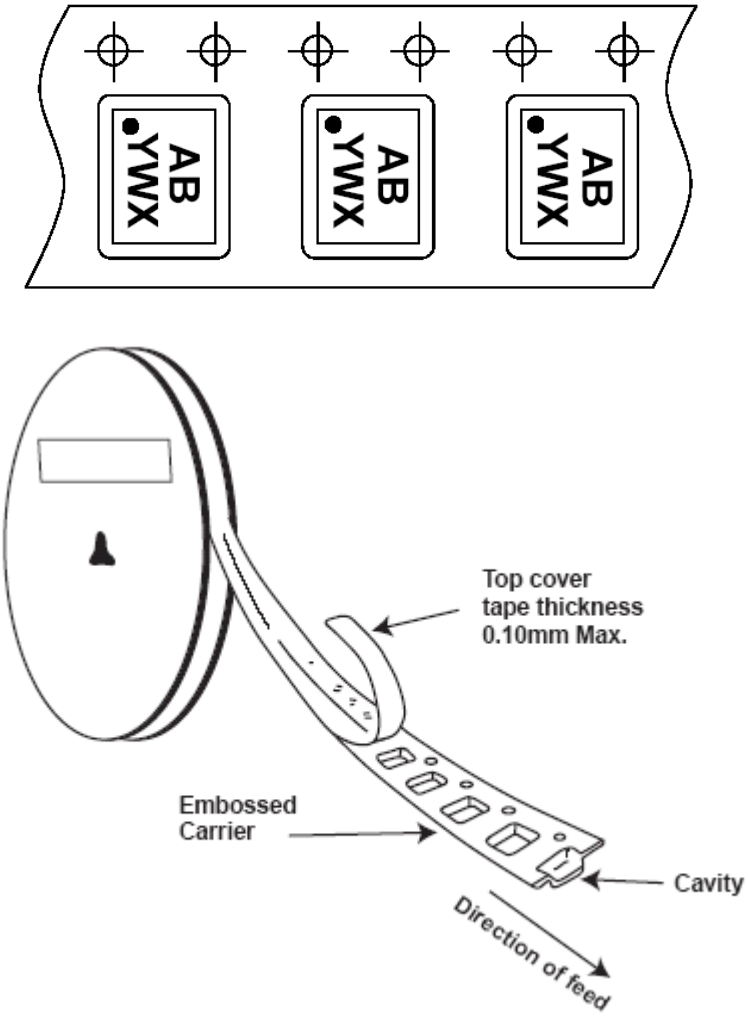
U-DFN3030-14



© Diodes Incorporated

NEW PRODUCT

Taping Orientation (Note 6)



Note: 6. The taping orientation of the other package type can be found on our website at http://www.diodes.com/datasheets/ap02007.pdf

© Diodes Incorporated

NEW PRODUCT

IMPORTANT NOTICE

DIODES INCORPORATED MAKES NO WARRANTY OF ANY KIND, EXPRESS OR IMPLIED, WITH REGARDS TO THIS DOCUMENT, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE (AND THEIR EQUIVALENTS UNDER THE LAWS OF ANY JURISDICTION).

Diodes Incorporated and its subsidiaries reserve the right to make modifications, enhancements, improvements, corrections or other changes without further notice to this document and any product described herein. Diodes Incorporated does not assume any liability arising out of the application or use of this document or any product described herein; neither does Diodes Incorporated convey any license under its patent or trademark rights, nor the rights of others. Any Customer or user of this document or products described herein in such applications shall assume all risks of such use and will agree to hold Diodes Incorporated and all the companies whose products are represented on Diodes Incorporated website, harmless against all damages.

Diodes Incorporated does not warrant or accept any liability whatsoever in respect of any products purchased through unauthorized sales channel.
Should Customers purchase or use Diodes Incorporated products for any unintended or unauthorized application, Customers shall indemnify and hold Diodes Incorporated and its representatives harmless against all claims, damages, expenses, and attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized application.

Products described herein may be covered by one or more United States, international or foreign patents pending. Product names and markings noted herein may also be covered by one or more United States, international or foreign trademarks.

LIFE SUPPORT

Diodes Incorporated products are specifically not authorized for use as critical components in life support devices or systems without the express written approval of the Chief Executive Officer of Diodes Incorporated. As used herein:

A. Life support devices or systems are devices or systems which:

1. are intended to implant into the body, or

2. support or sustain life and whose failure to perform when properly used in accordance with instructions for use provided in the labeling can be reasonably expected to result in significant injury to the user.

B. A critical component is any component in a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or to affect its safety or effectiveness.

Customers represent that they have all necessary expertise in the safety and regulatory ramifications of their life support devices or systems, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of Diodes Incorporated products in such safety-critical, life support devices or systems, notwithstanding any devices- or systems-related information or support that may be provided by Diodes Incorporated. Further, Customers must fully indemnify Diodes Incorporated and its representatives against any damages arising out of the use of Diodes Incorporated products in such safety-critical, life support devices or systems.

Copyright © 2010, Diodes Incorporated

www.diodes.com