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Linear Li-Ion/Polymer Charger IC with Integrated FET and Charger Timer

DESCRIPTION

The EUP8010X series are highly integrated single cell Li-Ion/Polymer battery charger IC designed for handheld devices. The EUP8010X integrates internal power FET, current sensor, charge status and reverse current protection in a single monolithic devices.When AC-adapter is applied, an external resistor sets the magnitude of the charge current, which may be programmed up to 1A.

The EUP8010X charges the battery in three phases: conditioning, constant current, and constant voltage. Charge is terminated based on minimum current. An internal charge timer provides a backup safety for charge termination. The EUP8010X automatically re-starts the charge if the battery voltage falls below an internal threshold. The EUP8010X also automatically enters sleep mode when DC supplies are removed. No external sense resistor or blocking diode is required for charging.

FEATURES

- Integrated Power FET and Current Sensor for Up to 1A Charge Applications
- Charge Termination by Minimum Current and Time
- Precharge Conditioning With Safety Timer
- Reverse Leakage Protection Prevents Battery Drainage
- Status Outputs for LED or System Interface Indicates Charge and Fault Conditions
- Optional Battery Temperature Monitoring Before and During Charge
- Automatic Sleep Mode for Low-Power Consumption
- Available in 3mm × 3mm TDFN-10 Package
- RoHS Compliant and 100% Lead (Pb)-Free

APPLICATIONS

- Smartphones
- Digital Cameras
- PDAs/ MP3 Players
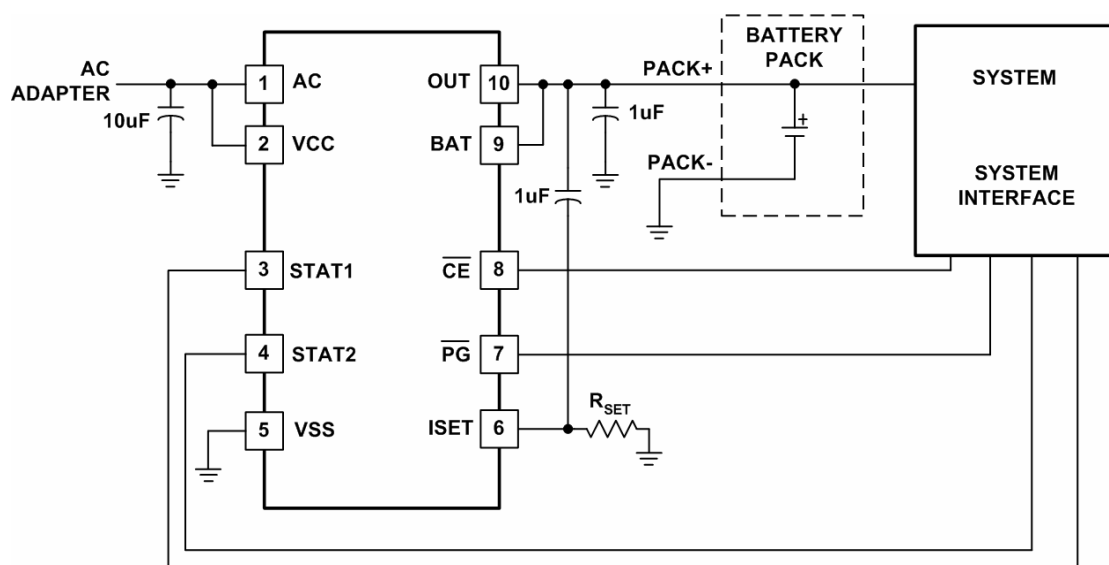- Stand-Alone Chargers

Typical Application Circuit
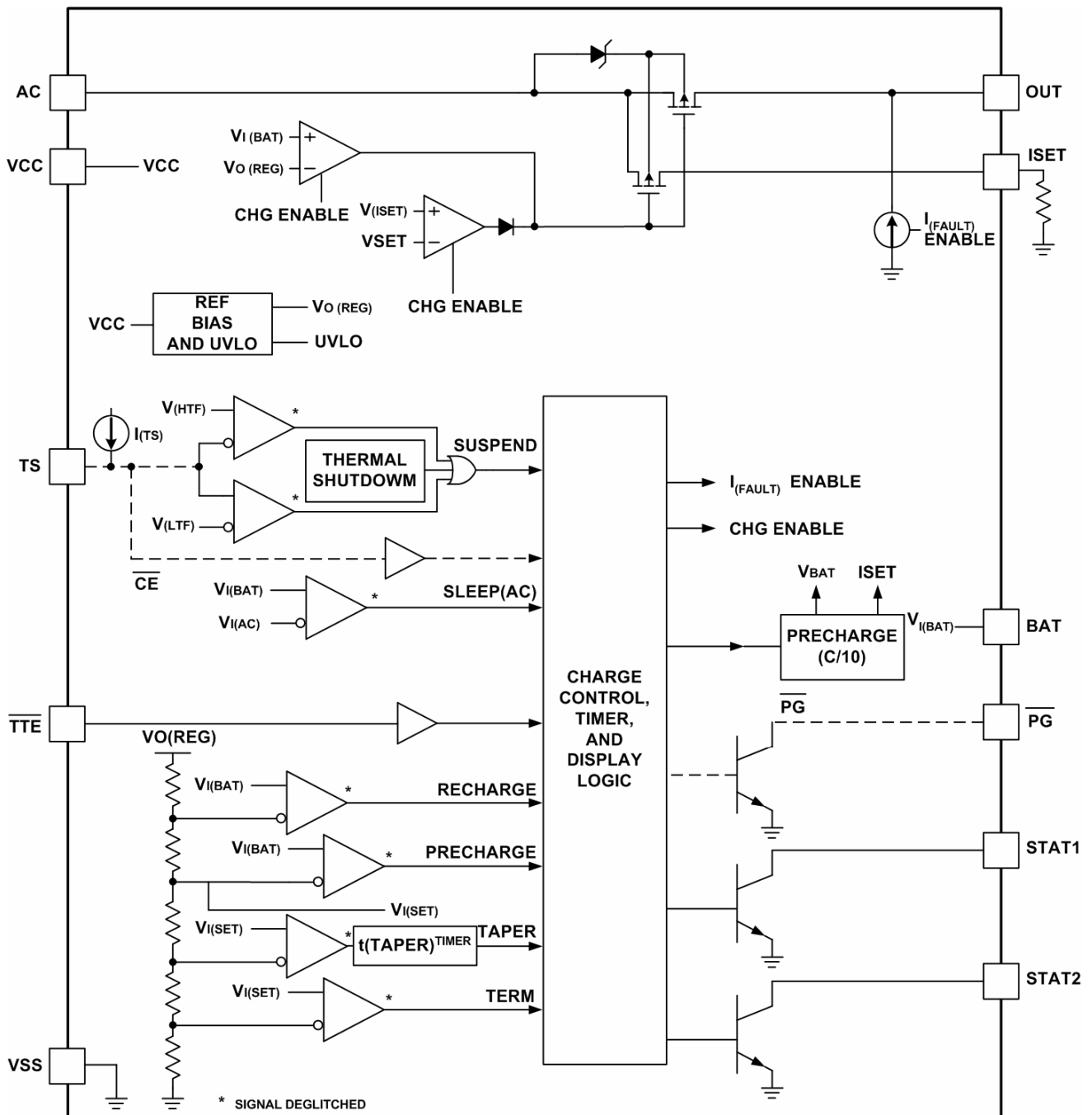

Figure 1. EUP8010B

Block Diagram

Figure 2.

Pin Configurations

Package Type	Pin Configurations	Package Type	Pin Configurations
EUP8010A TDFN-10	AC 1 ● 10 OUT VCC 2 9 BAT STAT1 3 8 TS STAT2 4 7 $\overline{PG}$ VSS 5 6 ISET	EUP8010B TDFN-10	AC 1 ● 10 OUT VCC 2 9 BAT STAT1 3 8 $\overline{CE}$ STAT2 4 7 $\overline{PG}$ VSS 5 6 ISET
EUP8010C TDFN-10	AC 1 ● 10 OUT VCC 2 9 BAT STAT1 3 8 $\overline{TTE}$ STAT2 4 7 $\overline{CE}$ VSS 5 6 ISET	EUP8010D TDFN-10	AC 1 ● 10 OUT VCC 2 9 BAT STAT1 3 8 TS STAT2 4 7 $\overline{CE}$ VSS 5 6 ISET

Pin Description

PIN	A	B	C	D	I/O	DESCRIPTION
AC	1	1	1	1	I	Charge input voltage. This input must be tied to the VCC pin.
VCC	2	2	2	2	I	VCC supply input
STAT1	3	3	3	3	O	Charge status output 1 (open collector)
STAT2	4	4	4	4	O	Charge status output 2 (open collector)
VSS	5	5	5	5	-	Ground input
ISET	6	6	6	6	O	Charge current set point
$\overline{PG}$	7	7	-	-	O	Power good status output (open collector)
TS	8	-	-	8	I	Temperature sense input
$\overline{CE}$	-	8	7	7	I	Charge enable input (active low)
$\overline{TTE}$	-	-	8	-	I	Timer and termination enable input (active low)
BAT	9	9	9	9	I	Battery voltage sense input
OUT	10	10	10	10	O	Charge current output

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Ordering Information

Order Number	Package Type	Marking	Operating Temperature range
EUP8010A-JIR1	TDFN-10	XXXXX 8010A	-20 °C to 70°C
EUP8010B-JIR1	TDFN-10	XXXXX 8010B	-20 °C to 70°C
EUP8010C-JIR1	TDFN-10	XXXXX 8010C	-20 °C to 70°C
EUP8010D-JIR1	TDFN-10	XXXXX 8010D	-20 °C to 70°C

EUP8010X-

        Lead Free Code
        1: Lead Free   0: Lead

        Packing
        R: Tape& Reel

        Operating temperature range
        I: Industry Standard

        Package Type
        J: TDFN-10
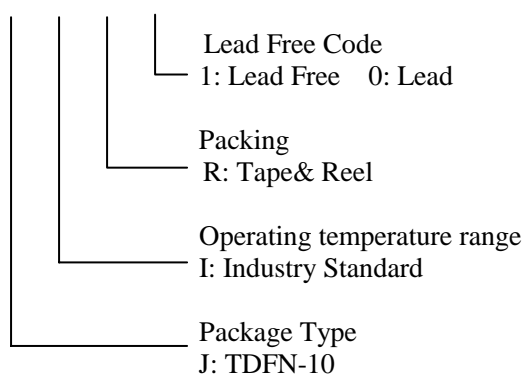
Absolute Maximum Ratings

- Input voltage(AC,VCC, $\overline{CE}$, ISET,OUT,BAT, $\overline{PG}$,STAT1,STAT2, TS, $\overline{TTE}$) -------------------- 0.3V to 6V
- Output sink / source current (STAT1,STAT2, $\overline{PG}$) -- 15mA
- Output current (TS) --- 200μ A
- Output current (OUT) -- 1.5 A
- Junction temperature range, T_J -- 150°C
- Storage temperature range, Tstg -- -65°C to 150°C
- Lead temperature (soldering, 10s) --- 260°C

Dissipation Ratings

Package	JA	T_A < 40°C Power Rating	Derating Factor Above T_A =25°C
TDFN-10	48°C/W	1.5W	0.0208 W/°C

Recommended Operating Conditions (1)

	Min.	Max.	Unit
Supply voltage (from AC input), V_{CC}	4.5	5.5	V
Operating junction temperature range, T_J	-40	125	°C

Electrical Characteristics over Recommended Operating Free-Air Temperature Range

Parameter	Conditions	EUP8010X			Unit
		Min.	Typ.	Max.	
Input Current					
VCC current, $I_{CC}(V_{CC})$	V_{CC} > V_{CC}(min)		0.9	1.5	mA
Sleep current, $I_{CC(SLP)}$	Sum of currents into OUT pin, V_{CC} < $V_{(SLP)}$		1	5	μA
Standby current, $I_{CC(STBY)}$	$\overline{CE}$ = High, 0°C ≤ T_J ≤ 85°C		50	150	
Voltage Regulation					
Output voltage, $V_{O(REG)}$			4.2		V
Voltage regulation accuracy	T_A = 25°C	-0.5%		0.5%	
		-1.5%		1.5%	
AC dropout voltage ($V_{(AC)}$-$V_{(OUT)}$), $V_{(DO)}$	$V_{O(OUT)}$ = $V_{O(REG)}$, $I_{O(OUT)}$ = 1A		400	500	mV
Current Regulation					
AC output current range, $I_{O(OUT)}$ (1)	$V_{I(BAT)}$ >$V_{(LOWV)}$, V_{CC} ≥ 4.5 V	50		1000	mA
Output current set voltage, $V_{(SET)}$	Voltage on ISET pin, V_{CC} ≥ 4.5 V, $V_{I(BAT)}$ > $V_{(LOWV)}$,	2.410	2.460	2.510	V
Output current set factor, $K_{(SET)}$	50 mA ≤ $I_{O(OUT)}$ ≤ 1 A	304	320	336	
	10 mA ≤ $I_{O(OUT)}$ < 50 mA	294	320	346	
	1 mA ≤ $I_{O(OUT)}$ < 10 mA	246	320	416	

Electrical Characteristics Over Recommended Operating Free-Air Temperature Range

Parameter	Conditions	EUP8010X			Unit
		Min.	Typ.	Max.	
Precharge and Short-Circuit Current Regulation					
Precharge to fast-charge transition threshold, $V_{(LOWV)}$	Voltage on OUT pin	2.8	3.0	3.2	V
Deglitch time for fast-charge to precharge transition		250	375	500	ms
Precharge range, $I_{O(PRECHG)}$ (2)	$0\,V < V_{I(BAT)} < V_{(LOWV)}$	5		100	mA
Precharge set voltage, $V_{(PRECHG)}$	Voltage on I_{SET} pin, $0\,V < V_{I(BAT)} > V_{(LOWV)}$	230	245	260	mV
Charge Taper and Termination Detection					
Charge taper detection range, $I_{(TAPER)}$ (3)	$V_{I(BAT)} > V_{(RCH)}$	5		100	mA
Charge taper detection set voltage, $V_{(TAPER)}$	Voltage on ISET pin, $V_{O(REG)} = 4.2V$, $V_{I(BAT)} > V_{(RCH)}$	235	250	265	mV
Charge termination detection set voltage, $V_{(TERM)}$ (4)	Voltage on ISET pin, $V_{O(REG)} = 4.2V$, $V_{I(BAT)} > V_{(RCH)}$	11	18	25	
Deglitch time for TAPER detection, tTPRDET		250	375	500	ms
Deglitch time for termination detection, tTRMDET		250	375	500	
Temperature Sense Comparator					
Low-voltage threshold, $V_{(LTF)}$		2.49	2.515	2.54	V
High-voltage threshold, $V_{(HTF)}$		0.495	0.510	0.525	
Current source, $I_{(TS)}$		102	112	122	μA
Deglitch time for temperature fault, t(DEGL)		250	375	500	ms
Battery Recharge Threshold					
Recharge threshold, VRCH		$V_{O(REG)}$ -0.150	$V_{O(REG)}$ -0.10	$V_{O(REG)}$ -0.050	V
Deglitch time for recharge detect, t(DEGL)		250	375	500	ms
STAT1, STAT2, and PG Outputs					
Low-level output saturation voltage, V_{OL}	$I_O = 5\ mA$			0.25	V

$$ (1)\ \ I_{O(OUT)} = \left(\frac{K_{(SET)} \times V_{(SET)}}{R_{SET}} \right) \qquad (2)\ \ I_{O(PRECHG)} = \left(\frac{K_{(SET)} \times V_{(PRECHG)}}{R_{SET}} \right) $$

$$ (3)\ \ I_{O(TAPER)} = \left(\frac{K_{(SET)} \times V_{(TAPER)}}{R_{SET}} \right) \qquad (4)\ \ I_{O(TERM)} = \left(\frac{K_{(SET)} \times V_{(TERM)}}{R_{SET}} \right) $$

Parameter	Conditions	EUP8010X			Unit
		Min.	Typ.	Max.	
Charge Enable ($\overline{CE}$), Timer and Termination Enable ($\overline{TTE}$) Inputs					
Low-level input voltage, V_{IL}	I_{IL} = 10 μA	0		0.4	V
High-level input voltage, V_{IH}	I_{IL} = 20 μA	1.4			
$\overline{CE}$ or $\overline{TTE}$ low-level input current, I_{IL}		-1			μA
$\overline{CE}$ or $\overline{TTE}$ high-level input current, I_{IH}				1	
Timers					
Precharge time, $t_{(PRECHG)}$		1,650	1,940	2,230	s
Taper time, $t_{(TAPER)}$	8010A,8010B,8010C,8010D	1,650	1,940	2,230	
Charge time, $t_{(CHG)}$	8010A,8010B,8010C,8010D	16,500	19,400	22,300	
Timer fault recovery current, $I_{(FAULT)}$			200		μA
Sleep Comparator					
Sleep-mode entry threshold voltage, $V_{(SLP)}$	$2.3\ V \leq V_{I(BAT)} \leq V_{O(REG)}$	$V_{CC} \leq V_{I(BAT)}$ +100 mV			V
Sleep mode exit threshold voltage, $V_{(SLPEXIT)}$	$2.3\ V \leq V_{I(BAT)} \leq V_{O(REG)}$	$V_{CC} \geq V_{I(BAT)}$ +190mV			
Sleep mode deglitch time		250	375	500	ms
Thermal Shutdown Thresholds					
Thermal trip threshold, $T_{(SHTDWN)}$			165		°C
Thermal hysteresis			30		
Undervoltage Lockout					
Undervoltage lockout $V_{(UVLO)}$	Decreasing V_{CC}	2.2	2.4	2.6	V
Hysteresis			20		mV

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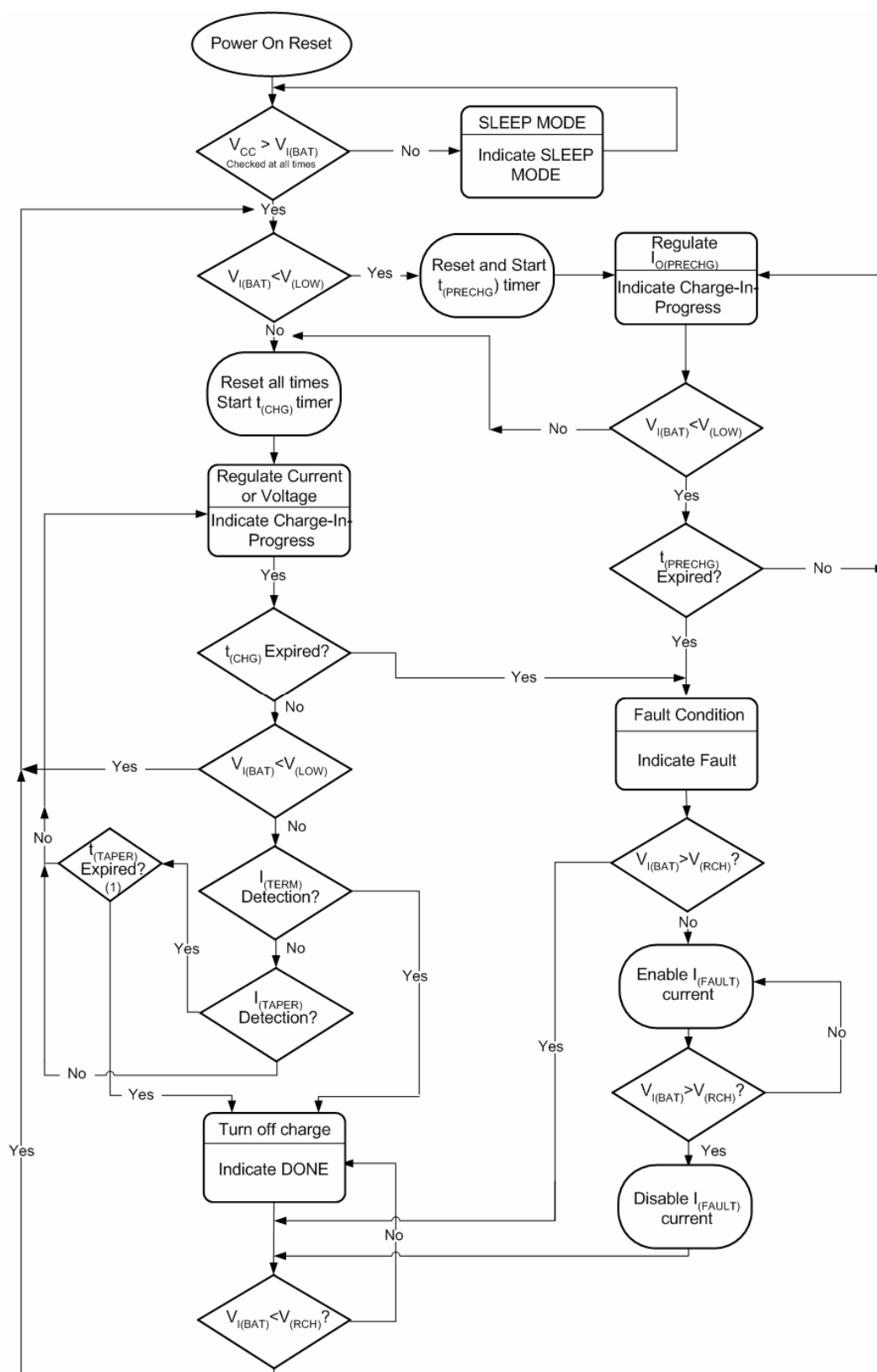MICROELECTRONICS

Application Information

Figure 3. Operational Flow Chart

Functional Description

Temperature Qualification (8010A,8010D Only)

The EUP8010X continuously monitors battery temperature by measuring the voltage between the TS and VSS pins.

An internal current source provides the bias for most common 10-k negative-temperature coefficient thermistors (NTC) (see Figure 4). The device compares the voltage on the TS pin against the internal $V_{(LTF)}$ and $V_{(HTF)}$ thresholds to determine if charging is allowed. Once a temperature outside the $V_{(LTF)}$ and $V_{(HTF)}$ thresholds is detected the device immediately suspend the charge. The device suspend charge by turning off the power FET and holding the timer value (i.e. timers are NOT reset). Charge is resumed when the temperature returns to the normal range.

However the user may modify these thresholds by adding two external resistors. See Figure 5.

Battery Pre-Conditioning

During a charge cycle if the battery voltage is below the $V_{(LOWV)}$ threshold, the EUP8010X applies a precharge current, $I_{O(PRECHG)}$, to the battery. This feature revives deeply discharged cells. The resistor connected between the ISET and V_{SS}, R_{SET}, determines the precharge rate. The $V_{(PRECHG)}$ and $K_{(SET)}$ parameters are specified in the specifications table.

$$I_{O(PRECHG)} = \frac{V_{(PRECGH)} \times K_{(SET)}}{R_{SET}} \text{ ----------- (1)}$$

The EUP8010X activates a safety timer, $t_{(PRECHG)}$, during the conditioning phase. If $V_{(LOWV)}$ threshold is not reached within the timer period, the EUP8010X turns off the charger and enunciates FAULT on the STATx pins. Please refer to the Timer Fault Recovery section for additional details.
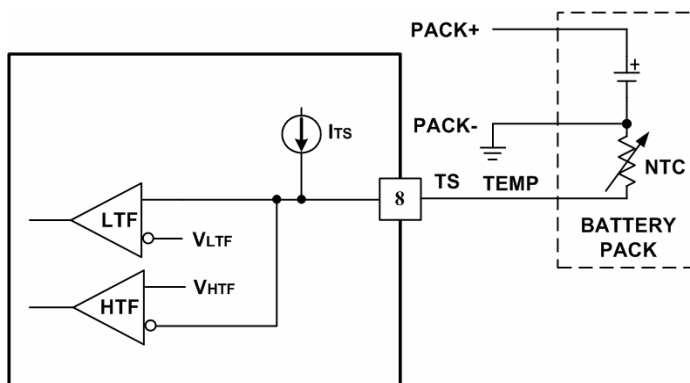
Figure 4. Temperature Sensing Configuration
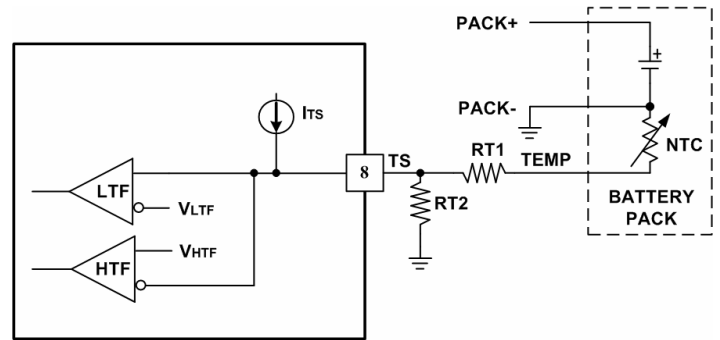
Figure 5. Temperature Sensing Thresholds

Battery Charge Current

The EUP8010X offers on-chip current regulation with programmable set point. The resistor connected between the ISET and V_{SS}, R_{SET}, determines the AC charge rate. The $V_{(SET)}$ and $K_{(SET)}$ parameters are specified in the specifications table.

$$I_{O(OUT)} = \frac{V_{(SET)} \times K_{(SET)}}{R_{SET}} \text{ -------------------- (2)}$$

Battery Voltage Regulation

The voltage regulation feedback is through the OUT pin. This input is tied directly to the positive side of the battery pack. The EUP8010X monitors the battery pack voltage between the OUT and VSS pins. When the battery voltage rises to $V_{O(REG)}$ threshold, the voltage regulation phase begins and the charging current begins to taper down.

As a safety backup, the EUP8010X also monitors the charge time in the charge mode. If charge is not terminated within this time period, $t_{(CHG)}$, the EUP8010X turns off the charger and enunciates FAULT on the STATx pins. Please refer to the Timer Fault Recovery section for additional details.

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Charge Taper Detection, Termination and Recharge

The EUP8010X monitors the charging current during the voltage regulation phase. Once the taper threshold, $I_{(TAPER)}$, is detected the EUP8010X initiates the taper timer, $t_{(TAPER)}$. Charge is terminated after the timer expires. The resistor connected between the ISET and V_{SS}, R_{SET}, determines the taper detection level. The $V_{(TAPER)}$ and $K_{(SET)}$ parameters are specified in the specifications table.

$$I_{(TAPER)} = \frac{V_{(TAPER)} \times K_{(SET)}}{R_{SET}} \text{----------------- (3)}$$

The EUP8010X resets the taper timer in the event that the charge current returns above the taper threshold, $I_{(TAPER)}$.

In addition to the taper current detection, the EUP8010X terminates charge in the event that the charge current falls below the $I_{(TERM)}$ threshold. This feature allows for quick recognition of a battery removal condition or insertion of a fully charged battery. Note that charge timer and taper timer are bypassed for this feature. The resistor connected between the ISET and V_{SS}, R_{SET}, determines the taper detection level. The $V_{(TERM)}$ and $K_{(SET)}$ parameters are specified in the specifications table.

$$I_{(TERM)} = \frac{V_{(TERM)} \times K_{(SET)}}{R_{SET}} \text{------------------- (4)}$$

After charge termination, the EUP8010X re-starts the charge once the voltage on the OUT pin falls below the $V_{(RCH)}$ threshold. This feature keeps the battery at full capacity at all times.

Sleep Mode

The EUP8010X enters the low-power sleep mode if AC-adapter is removed from the circuit. This feature prevents draining the battery during the absence of input supply.

Charge Status Outputs

The open-drain STAT1 and STAT2 outputs indicate various charger operations as shown in the following table. These status pins can be used to drive LEDs or communicate to the host processor. Note that OFF indicates the open-drain transistor is turned off.

Table 1. Status Pins Summary

CHARGE STATE	STAT1	STAT2
Precharge in progress	ON	ON
Fast charge in progress	ON	OFF
Charge done	OFF	ON
Charge suspend (temperature)	OFF	OFF
Timer fault	OFF	OFF
Sleep mode	OFF	OFF

OFF means the open-drain output transistor on the STAT1 and STAT2 pins is in an off state.

$\overline{PG}$ Output

The open-drain $\overline{PG}$ (Power Good) indicates when the AC adapter is present. The output turns ON when a valid voltage is detected. This output is turned off in the sleep mode. The $\overline{PG}$ pin can be used to drive an LED or communicate to the host processor.

$\overline{CE}$ Input (Charge Enable)

The $\overline{CE}$ digital input is used to disable or enable the charge process. A low-level signal on this pin enables the charge and a high-level signal disables the charge and places the device in a low-power mode. A high-to-low transition on this pin also resets all timers and timer fault conditions.

$\overline{TTE}$ Input (Timer and Termination Enable)

The $\overline{TTE}$ digital input is used to disable or enable the fast-charge timer and charge taper detection. A low-level signal on this pin enables the fast-charge timer and taper timer and a high-level signal disables this feature.

Thermal shutdown and Protection

The EUP8010X monitors the junction temperature, T_J, of the die and suspends charging if T_J exceeds $T_{(SHTDWN)}$. Charging resumes when T_J falls below $T_{(SHTDWN)}$ by approximately 30 .

Timer Fault Recovery
As shown in Figure 3, EUP8010X provides a recovery method to deal with timer fault conditions. The following summarizes this method:

Condition #1: Charge voltage above recharge threshold ($V_{(RCH)}$) and timeout fault occurs
Recovery method: EUP8010X waits for the battery voltage to fall below the recharge threshold. This could happen as a result of a load on the battery, self-discharge or battery removal. Once the battery falls below the recharge threshold, the EUP8010X clears the fault and starts a new charge cycle. A POR or $\overline{CE}$ or $\overline{TTE}$ toggle also clears the fault.

Condition #2: Charge voltage below recharge threshold ($V_{(RCH)}$) and timeout fault occurs
Recovery method: Under this scenario, the EUP8010X applies the $I_{(FAULT)}$ current. This small current is used to detect a battery removal condition and remains on as long as the battery voltage stays below the recharge threshold. If the battery voltage goes above the recharge threshold, then the EUP8010X disables the $I_{(FAULT)}$ current and executes the recovery method described for condition #1. Once the battery falls below the recharge threshold, the EUP8010X clears the fault and starts a new charge cycle.
A POR or $\overline{CE}$ or $\overline{TTE}$ toggle also clears the fault.

Packaging Information

TDFN-10

DETAIL A
Thermal Pad Option
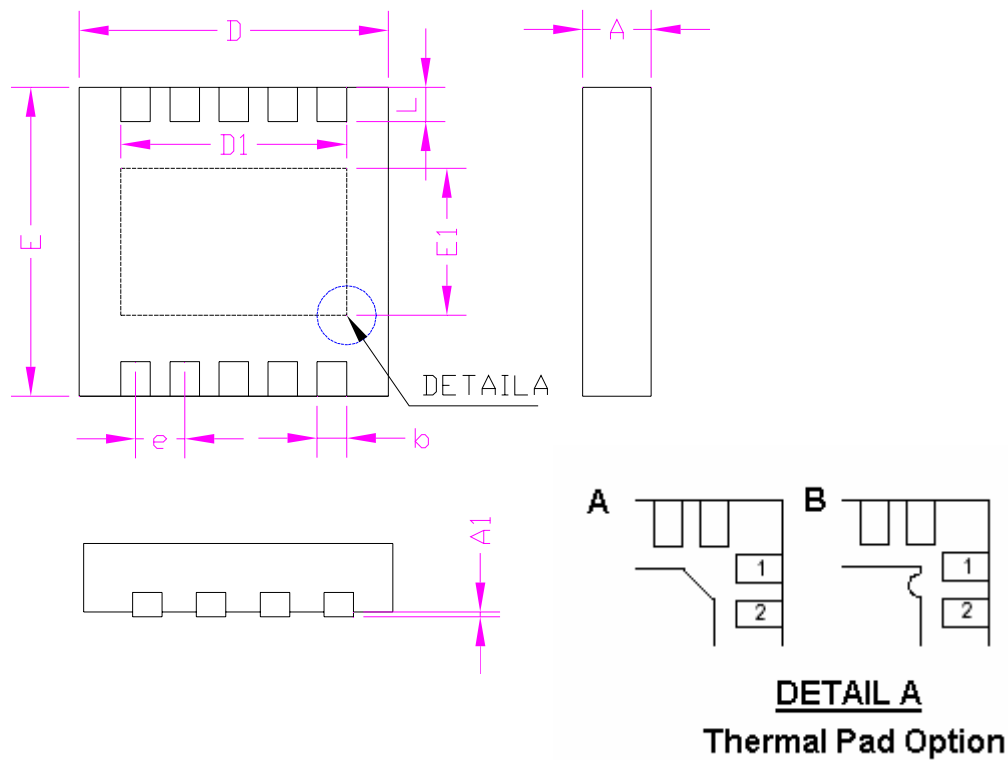
SYMBOLS	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A	0.70	0.80	0.028	0.031
A1	0.00	0.05	0.000	0.002
D	2.90	3.10	0.114	0.122
E1	1.70		0.067	
E	2.90	3.10	0.114	0.122
L	0.30	0.50	0.012	0.020
b	0.18	0.30	0.007	0.012
e	0.50		0.020	
D1	2.40		0.094	

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