

## Switchmode Single-Cell/Two-Cell Li-ion/Li Polymer Battery Charger

### 1、HB6298A functions

#### 1.1、Features

- High conversion efficiency charger for 1-cell/2-cell Li-ion/Li polymer battery
- 0.5% voltage accuracy
- Full charged voltage trimming by external resistors
- Build-in battery detection
- Integrated power MOSFET
- Soft starting
- 300kHz PWM Oscillator frequency
- Programmable charge current up to 1.5A
- Reverse leakage protection prevents battery drainage
- NTC Thermistor interface for battery temperature monitor
- Status outputs for LED
- Cycle-by-cycle current limit, charge current thermal foldback, short circuit protection
- 18V absolute maximum voltage rating on IN pins
- Ambient temperature range:  $-20^{\circ}\text{C}\sim 70^{\circ}\text{C}$

#### 1.2、Applications

- Handheld devices, include medical handhelds
- Portable-DVD, PDA, cell phones and smart phones
- Portable instruments
- Self-charging battery packs
- Stand-alone chargers

#### 1.3、Introduction

HB6298A is an integrated 1-cell/2-cell Li-ion/Li polymer switch-mode charge management device, targeted at a wide range of portable applications. HB6298A offers integrated power FET, high-accuracy current and voltage regulation, charge preconditioning, charge status, and charge termination, in a small TSSOP20 package. HB6298A charges the battery in three phase: preconditioning, constant current(CC), and constant voltage(CV). The charge current is programmable with an external resistor up to 1.5A. HB6298A features cycle-by-cycle current limit, charge current thermal foldback and short circuit protection to guarantee safe operation. Additional features include NTC thermistor interface to monitor the battery temperature.

### 2、Typical application circuit

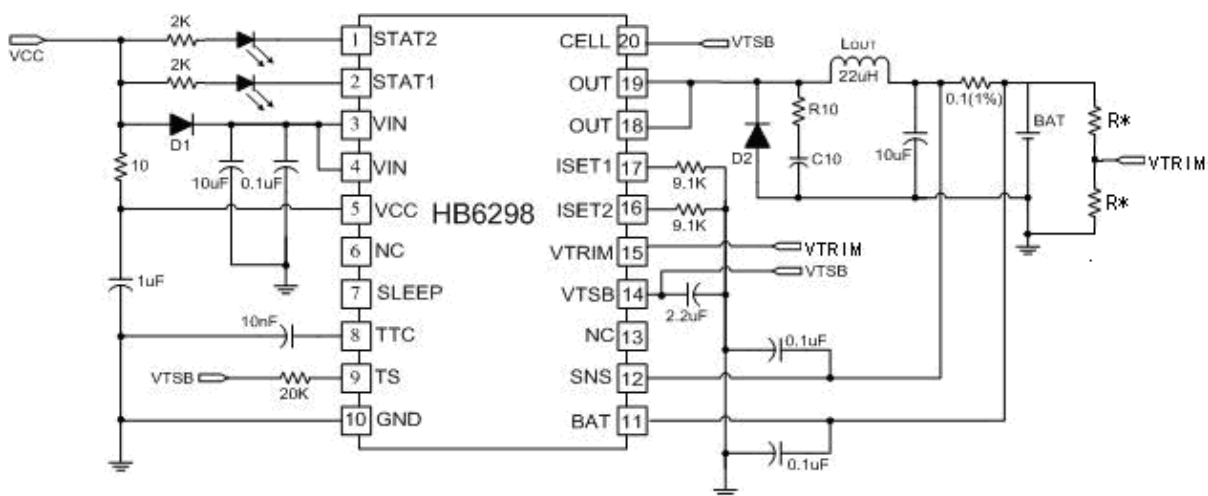


Figure2.1、HB6298A application circuit

3、HB6298A function block

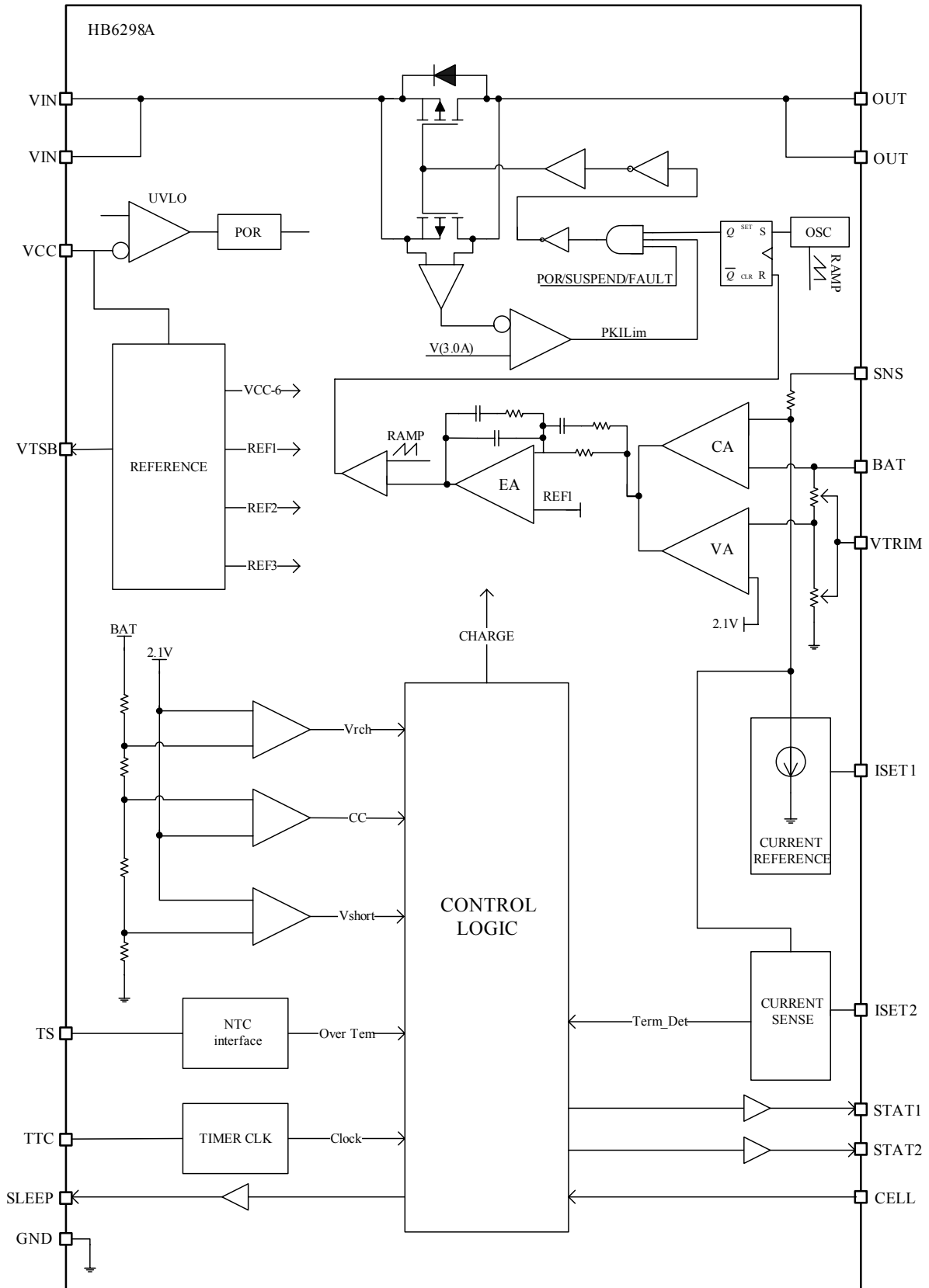


Figure3.1、HB6298A function bock

#### 4、Pin Configuration

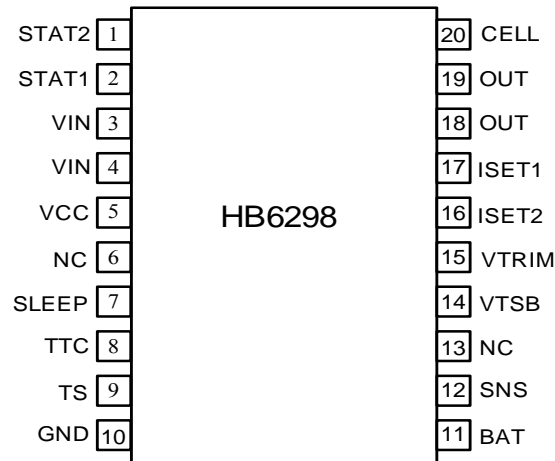


Figure 4.1、HB6298A pin configuration

List 4.1、HB6298A description

NO.	SYMBOL	I/O	DESCRIPTION		
1	STAT2	0	STAT1 (GREEN)	STAT2 (RED)	DISCRIPTION
2	STAT1	0	off	off	Charge suspend, no battery
			off	on	In charge
			on	off	End of charge
			off	PULSE1 (0.5Hz)	FAULT condition
			off	PULSE2 (2.0Hz)	Battery temperature abnormal
3&4	VIN	I	Charger input voltage, bypass it with a 10 $\mu$ F capacitor from VIN to GND		
5	VCC	I	Analog device input, a capacitor to VSS is required		
6	NC	-			
7	SLEEP	0	SLEEP mode output, to control the external power MOSFET		
8	TTC	-	Connect a capacitor from this node to VSS to set the HB6298A timer, when this input is low, the timer and termination detection are disabled		
9	TS	I	Feed back of battery temperature		
10	GND	-	Analog ground input		
11	BAT	I	Battery voltage-sense input		
12	SNS	I	Charge current-sense input		
13	NC	-			
14	VTSB	0	3.2V voltage reference, capable of driving 10mA load, connect a capacitor(2.2 $\mu$ F) between this output and VSS		
15	VTRIM	I	Trimming of full charged voltage with external resistor		
16	ISET2	I	Charge current set point (termination), set by a resistor connected to VSS		
17	ISET1	I	Charge current set point (fast charge and precharge), set by a resistor		
18&19	OUT	0	Power PMOSFET output, inductor connection point		
20	CELL	I	Low: two cell application		
			High: single cell charge		

## 5、HB6298A recommended operating condition

List 5.1、HB6298A recommended operating condition

PARAMETER	Min	Typical	Max	Unit	Notes
Supply voltage	4.5	6	18	V	Single cell
Supply voltage	8.8	12	18	V	Two cell
Ambient temperature	-20		70	°C	

## 6、HB6298A electrical specification

List 6.1、HB6298A electrical specification (Ta=25°C)

PARAMETER	SYM	TEST CONDITION	MIN	TYP	MAX	UNITS
<b>INPUT CURRENTS</b>						
VCC supply current	I <sub>VCC</sub>				5	mA
SLEEP mode current	I <sub>SLEEP</sub>	V <sub>I(BAT)</sub> =4.2V		7		uA
		V <sub>I(BAT)</sub> =8.4V		14		
<b>VOLTAGE REGULATION</b>						
Output voltage	V <sub>OREG</sub>	Cells=High	4.158	4.20	4.242	V
		Cells=Low	8.316	8.4	8.484	V
<b>Charge current</b>						
CC charge current	I <sub>CHG</sub>		200		1500	mA
Voltage across R <sub>SNS</sub>	V <sub>IREG</sub>			100		mV
Output current set voltage	V <sub>ISET1</sub>			1		V
Output current set factor	K <sub>ISET1</sub>			1000		V/A
<b>PRECHARGE CURRENT REGULATION</b>						
Precharge to fast charge transition voltage	V <sub>LOWV</sub>	Cells=High		3		V
		Cells=low		6		V
Precharge current range	I <sub>PRECHG</sub>		40		300	mA
Precharge set voltage	V <sub>ISET1</sub>			200		mV
Precharge set factor	K <sub>ISET1</sub>			1000		V/A
<b>CHARGE TERMINATION (CURRENT TAPER) DETECTION</b>						
Termination current range	I <sub>TERM</sub>		20		300	mA
Charge-termination detection set voltage	V <sub>ISET2</sub>			200		mV
Termination current set factor	K <sub>ISET2</sub>			1000		V/A
<b>BATTERY RECHARGE THRESHOLD</b>						
Recharge threshold voltage	V <sub>RGH</sub>			4.1		V/cell
<b>TTC INPUT</b>						
TTC timer multiplier	K <sub>TTC</sub>			4.66		H/10nF
C <sub>TTC</sub> capacitor rang	C <sub>TTC</sub>			10		nF
<b>PWM</b>						

Oscillator frequency				400		KHz
Internal PMOS on-resistor					500	m $\Omega$
Maximum duty cycle	D <sub>MAX</sub>				98%	
Minimum duty cycle	D <sub>MIN</sub>		0%			
<b>BATTERY DETECTION</b>						
Battery detection current during time-out	I <sub>DETECT</sub>			2		mA
Discharge current	I <sub>DISCHARG</sub>			400		$\mu$ A
Discharge time	T <sub>DISCHARG</sub>			1		S
Wake current	I <sub>WAKE</sub>		5			mA
Wake time	T <sub>WAKE</sub>			0.5		S
<b>PROTECTION</b>						
OVP threshold voltage				117		%V <sub>OREG</sub>
Cycle-by-cycle current limit				3		A
Short-circuit voltage				2		V/cell
Short-circuit current				25		mA

7. Operational flow chart

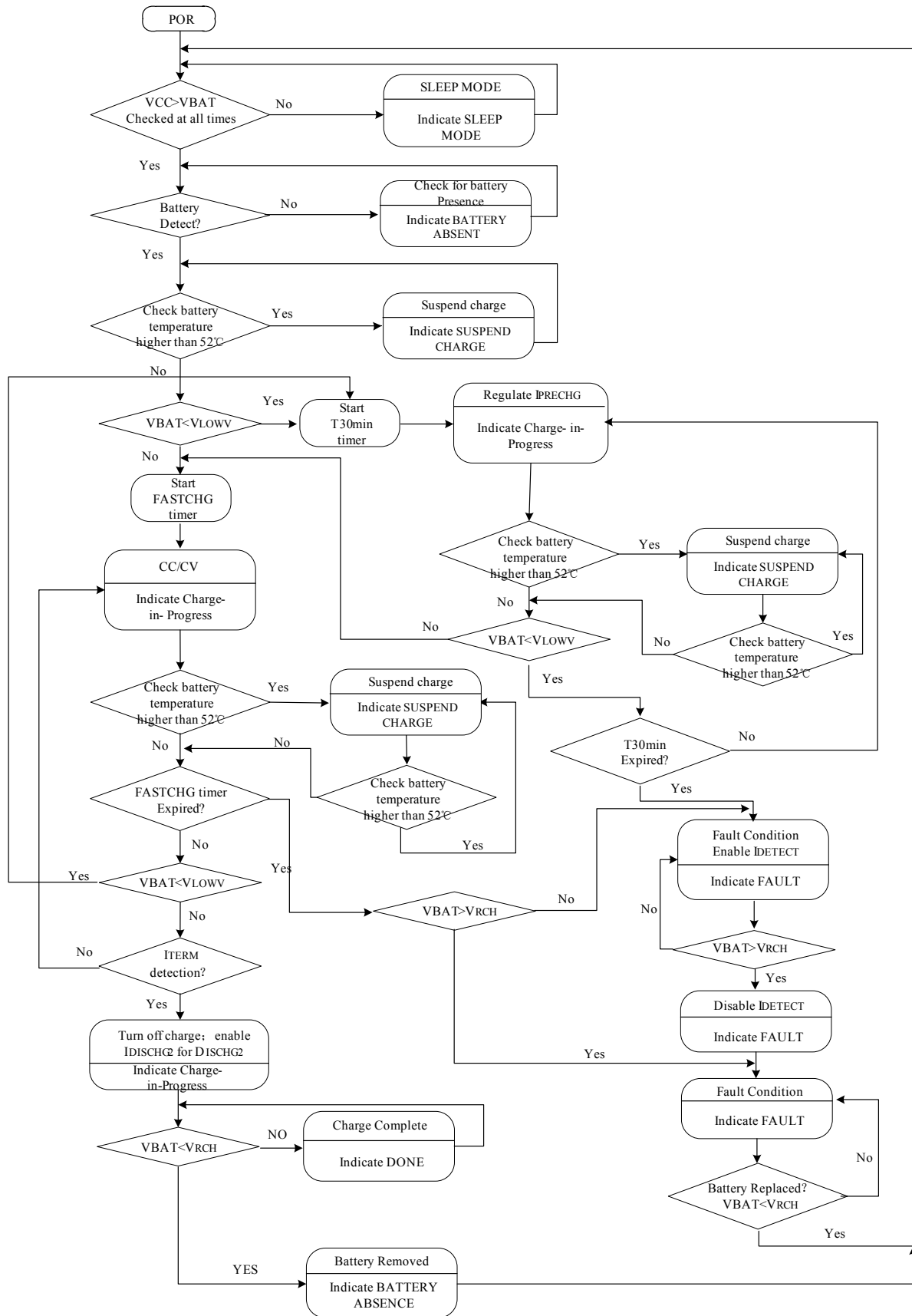


Figure7.1、Operational flow chart

## 8、HB6298A Function introduction

### 8.1、introduction of Li-ion/Li polymer battery charger

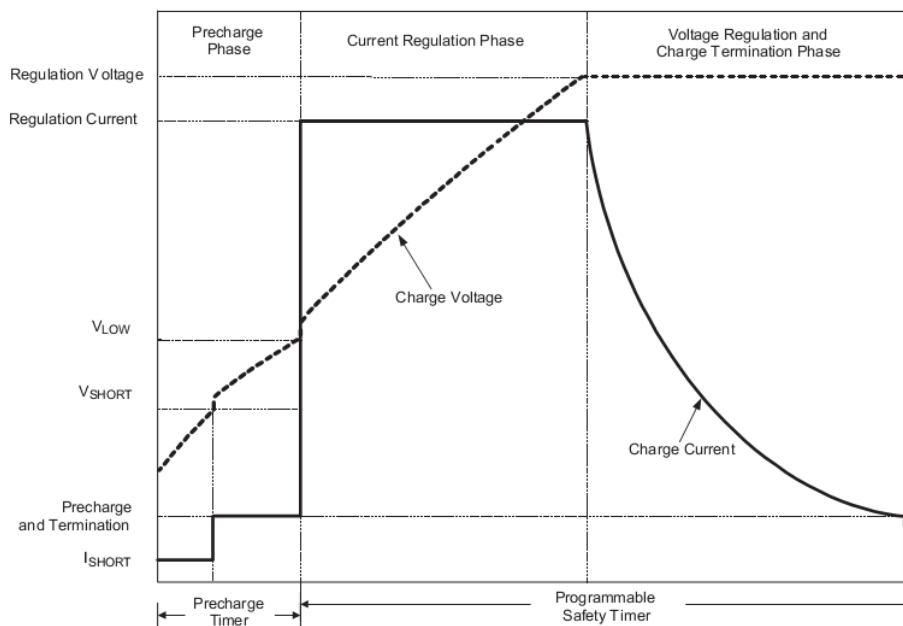


Figure 8.1、diagram of Li-ion/Li polymer battery charge procedure

The complete charge cycle can be divided into three stages, those are precharge, constant current(CC) charge and constant voltage(CV) charge. The charger always preconditions the battery with a small current (1/5 CC charge current) at the beginning of a charge until the battery voltage is verified to be above the minimum fast charge voltage  $V_{LOW}$ , that is precharge stage. During CC stage, the charge current is constant, and the battery voltage keeps on rise. As battery voltage rises up to the set point (normally 4.2V), it goes into CV stage, the charge current will come down continually, until the current is below the end of charge (EOC) current. However, during CV charge stage, battery voltage will increase very slowly.

#### 8.2、Battery Preconditioning (Precharge)

On power up, if the battery voltage is below the  $V_{LOW}$  threshold, the HB6298A applies a precharge current,  $I_{PRECHG}$ , to the battery. Precharge time ( $T_{PRECHG}$ ) is 1/8 of  $T_{IMEOUT}$ . When TTC is connected to ground, the timer and termination detection are disabled, but  $T_{PRECHG}$  is set to be 40 minute. If the

$V_{LOW}$  threshold is not reached within  $T_{PRECHG}$ , the HB6298A turns off the charger and the LED connected to STATE2 (RED) will blink at a fixed frequency (0.5Hz). Power on reset (POR) and replacing battery are recovery methods to deal with fault conditions.

$$I_{PRECHG} = \frac{K_{ISET1} \times V_{ISET1}}{R_{SNS} \times R_{ISET1}}$$

Where,  $V_{ISET1}$  is the output of the ISET1 pin and not the same in precharge stage and fast charge stage.  $K(ISET1)$  is the A/V gain factor which unit is V/A.  $R_{SNS}$  is the external current-sense resistor.

#### 8.3、Battery Charge Current

The battery charge current  $I_{CHARGE}$ , is established by setting the external sense resistor  $R_{SNS}$  and  $R_{SET1}$  connected to the ISET1 pin. In order to set the current, first choose  $R_{SNS}$ ,  $R_{SNS}$  based on the regulation threshold  $V_{IREG}$  across this resistor. The best accuracy is achieved when the  $V_{IREG}$  is between 100mV and 200mV.

$$R_{SNS} = \frac{V_{IREG}}{I_{CHARGE}}$$

If the results is not a standard sense resistor

value, choose the next larger value. Using the selected standard value, solve for  $V_{I\text{REG}}$ . Once the sense resistor is selected, the ISET1 resistor can be calculated using the following equation:

$$R_{I\text{SET}1} = \frac{K_{I\text{SET}1} \times V_{I\text{SET}1}}{R_{\text{SNS}} \times I_{\text{CHARGE}}}$$

Where,  $V_{I\text{SET}1}$  is the output of the ISET1 pin,  $K(I\text{SET}1)$  is the A/V gain factor, which unit is V/A.

**8.4. Battery Voltage Regulation**

While the battery voltage is below 3.0V (6.0V for two cell), it enters into pre-charge model, the charge current is 1/5 of CC charge current.

The full charged battery voltage is 4.2V for one cell battery, and 8.4V for two cell battery. As the charge is done, if the battery voltage drops below 4.1V(8.2V for two cell battery), the charger will recharge the battery.

**8.5. Charge time limitation**

HB6298A internally limits the total charge time and precharge time. The total charge time is:

$$T_{\text{CHARGE}} = C_{\text{TTC}} \cdot K_{\text{TTC}}$$

Where,  $C_{\text{TTC}}$  is the capacitor connected to the TTC pin,  $K_{\text{TTC}}$  is the multiplier.

When a 10nF is connected, the total charge time is 4.66 hour, and it can be extended by connecting a larger capacitor to TTC pin. The pre-charge mode has a time limit of 1/8  $T_{\text{CHARGE}}$ . The charger has to reach the EOC within  $T_{\text{CHARGE}}$ , otherwise, a TIMEOUT fault is issued, the LED connected to STATE2 (RED) will blink at a fixed frequency(0.5Hz).

**8.6. Charge Termination current**

During the voltage regulation phase, once the termination threshold,  $I_{\text{TERM}}$ , is detected, the HB6298A terminates charge and an internal EOC signal is generated.

$$I_{\text{TERM}} = \frac{K_{I\text{SET}2} \times V_{\text{TERM}}}{R_{\text{SNS}} \times R_{I\text{SET}2}}$$

Where,  $V_{\text{TERM}}$  is the output of the ISET2 pin, the EOC signal is generated when  $V_{\text{TERM}}$  is 0.2V.  $R_{\text{SNS}}$  is the external current-sense resistor.  $K(I\text{SET}2)$  is the A/V gain factor which unit is V/A.

When the charge current falls below twice  $I_{\text{TERM}}$ , a TAPE signal is generated, and charge will terminate after half an hour if charge current does not fall below  $I_{\text{TERM}}$ .

**8.7. BATTERY ABSENT DETECTION**

For applications with removable battery packs, HB6298A provides a battery absent detection.

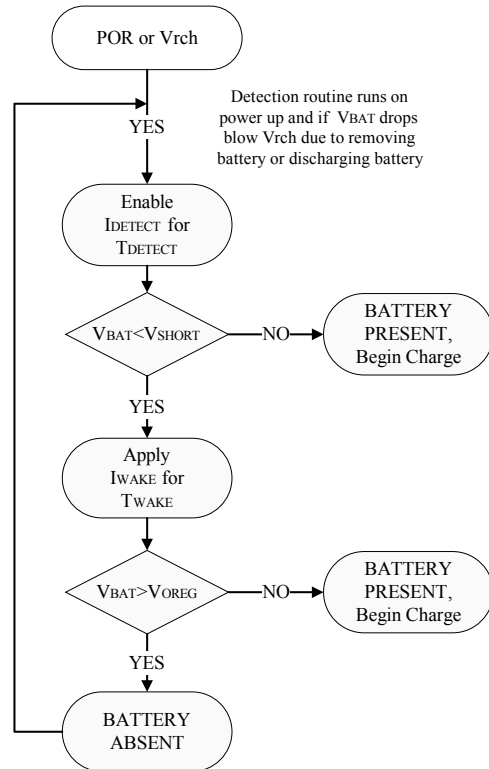


Figure 8.2. Battery detection flow chart

The voltage at the BAT pin is held above the battery recharge threshold  $V_{\text{RCH}}$ , by the charged battery following fast charging. When the voltage at the BAT pin falls to the recharge threshold, either by a load on the battery or due to battery removal, the HB6298A begins a battery absent detection test. This test involves enabling a detection current,  $I_{\text{DISCHARGE}}$ , for a period of  $I_{\text{DISCHARGE}}$  and checking to see if the battery voltage is below the short circuit threshold,  $V_{\text{SHORT}}$ . Following this, the wake current,  $I_{\text{WAKE}}$  is applied for a period of  $T_{\text{WAKE}}$  and the battery voltage is checked again to ensure that it is above the recharge threshold. Passing both of the discharge and charge tests



indicates a battery absent. Failure of either test indicates a battery present and starts a new charge cycle.

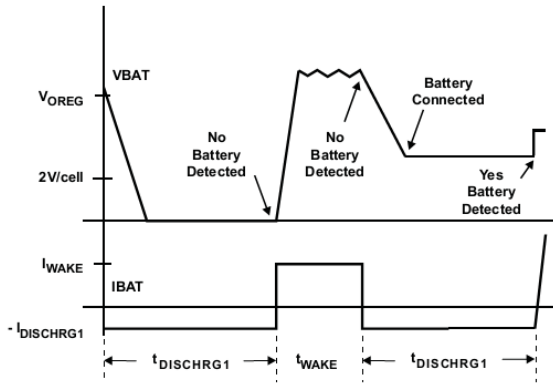


Figure 8.3. Battery detect wave

Figure 8.3 is the battery detecting wave,  $T_{DISCHARGE}$  is 1 second,  $T_{WAKE}$  is 0.5 second.

**8.8、CYCLE-BY-CYCLE current limit**

Cycle-by-cycle current limit is sensed through the internal high-side sense FET. The threshold is set to a nominal 3A peak current. Cycle-by-cycle

**8.11、Charge Status Outputs**

(STAT1) GREEN	(STAT2) RED	DISCRIPTION
Off	Off	Charge suspend, no battery
Off	On	In charge
On	Off	End of charge
Off	PULSE1(0.5HZ)	FAULT condition(Total timer fault, precharge timer fault)
Off	PULSE2(2.0HZ)	Battery temperature abnormal

**8.12、Temperature Qualification**

The HB6298A uses NTC thermistor to detect the battery temperature. The value of NTC resistor will change with the temperature. Connect the NTC thermistor series with a resistor. The feed back voltage from TEMP will change with the change of the NTC resistance. As showing in figure 8.4, the value of R6 is 20.5 times as the value of NTC resistor at 52°C. As the temperature of the battery pack is higher than 52°C, a temperature abnormal indication signal is generated, and the LED connected to STATE2 (RED) will blink at a

current limit can protect against over current and short circuit.

**8.9、Sleep Mode**

When VCC is blow the battery voltage, HB6298A enter sleep mode, this feature prevents draining the battery during the absence of VCC.

**8.10、Reference voltage**

HB6298A provides a 3.2V voltage(pin VTSB, connected a capacitor greater than 1uF) biasing the internal control and logic circuit. This voltage is also available for external circuits. The maximum allowed external load is 10mA.

fixed frequency(2.0Hz). If over temperature detection is not necessary, just replace the NTC thermistor with a normal resistor R2. The value of R2 can be 1/2 that of R6.

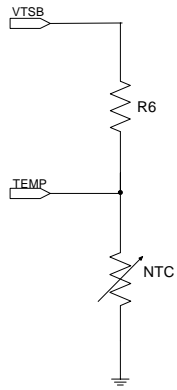
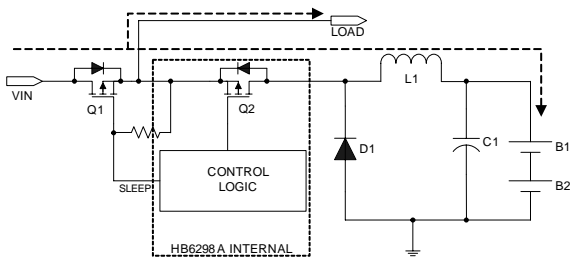


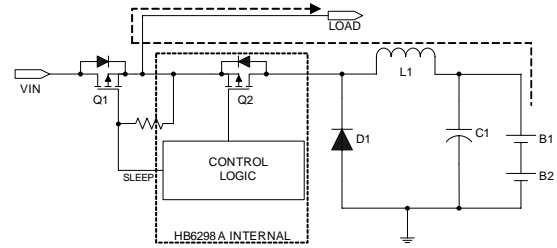
Figure 8.4、NTC application

**8.13、Charge and discharge function**

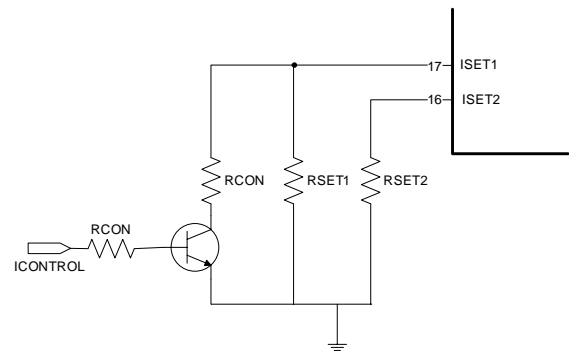
Charge and discharge function means that the input power supply charges batteries and supply power for the load(discharge) at the same time, as the dashed line showing in figure8.5(1). At the moment, Q1 is always on, Q2 is the switch MOSFET of a buck circuit which charges the batteries. Commonly, for the power limitation of the input supply, when charge and discharge at the same time, the charge current is smaller than the charge current when input supply just charges the battery but does not supply power for the load. Charge current could be set by a control signal I<sub>CONTROL</sub> showing figure8.5(1). When there is no input supply or the input voltage is lower than the battery voltage, Q1 is off, Q2 is on, the batteries supply power for the load through L1 and Q2, showing figure8.5(2). Commonly, for the load, the operation voltage is 9~12V, current is 1A.



(1)Charge and discharge function diagram



(2) batteries supply the load function diagram



(3) Large current and small current setting

Figure8.5、Charge and discharge function diagram

**8.14、Timer fault recovery**

As shown in Figure 7.1 (Operational flow chart), HB6298A provides a recovery method to deal with timer fault conditions. The following summarizes this method.

**Condition 1:** V<sub>BAT</sub> above recharge threshold and timeout fault occurs.

Recovery method: HB6298A 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 HB6298A clears the fault and enters the battery absent detection routine. A POR also clears the fault.

**Condition 2:** Charge voltage below recharge threshold and timeout fault occurs.

Recovery method: Under this scenario, the HB6298A applies the I<sub>DETECT</sub> 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 HB6298A disables the I<sub>DETECT</sub> current and executes the recovery method described in Condition 1. Once the battery falls below the recharge threshold, the HB6298A clears the fault and enters the battery absent detection routine. A POR also clears the fault.

### 8.15、Output overvoltage protection

HB6298A provides a built-in overvoltage protection to protect the device and other components against damages if the battery voltage gets too high, as when the battery is suddenly removed. When an overvoltage condition is detected, this feature turns off the PWM and STAT2 pins. The fault is cleared once VIBAT drops to the recharge threshold.

### 8.16、Inductor selection guideline

To insure the stability of the loop, in precharge and fast charge stages, the control loop works in continuous current conduction mode (CCM). The current ripple formula:

$$\Delta I = \frac{1}{L \times FS} \left( \frac{V_{IN} - V_{BAT}}{V_{IN}} \right) \times V_{BAT}$$

Where,  $\Delta I$  is inductor ripple current, FS is PWM oscillator frequency. To insure the control loop works in CCM mode, set  $\Delta I$  to precharge current, which is 1/5 of fast charge current. The inductor value can be calculate from input voltage.

### 8.17、Output capacitor selection guidelines

To insure the stability of the control loop, as inductor value is determined, determine the minimum output capacitor value using the following equation:

$$L \times C \geq 100 \times 10^{-12}$$

where, L, C are the values of inductor and output capacitor.

### 8.18、Application advice

1、For better EMI performance, connect a resistor and a capacitor in series between pin OUT and pin GND, as R10, C10 in figure 2.1. The resistor is 10 $\Omega$  to 30 $\Omega$ , the capacitor is less than 1nF.

2、Connect capacitors between VTRIM and GND, between VTRIM and BAT, the value recommended is 0.22 $\mu$ F, to suppress the noise which affect the feedback voltage.

3、Pin CELL is connected to VTSB when charging one cell battery.

4、Select a schottky diode which reverse leakage current is small for blocking diode D1, because the diode leakage current affecting battery self-discharge. In high voltage application, select a normal power diode.

5、The capacitors should be placed as close as possible to HB6298A;

6、VTRIM is a sensitive signal, should be routed away from the periodical high current paths.

### 8.19、Full charged battery voltage trimming

#### (1) One cell application

Firstly, measure the full charged battery voltage  $V_{CV}$ , define  $V_{CV} = 4.200V \pm \Delta V$ . Determine trimming resistor value using the following equation:

$$R_{TRIM} = \left( \frac{2.100}{\Delta V} - 0.5 \right) R$$

(where R=80k)

To change  $V_{CV}$  lower, connect the trimming resistor between pin BAT and pin VTRIM; to change  $V_{CV}$  higher, connect the trimming resistor between pin VTRIM and pin GND.

#### (2) Two cell application

Firstly, measure the full charged battery voltage  $V_{CV}$ , define  $V_{CV} = 8.400V \pm \Delta V$ .

To change  $V_{CV}$  higher, connect the trimming resistor between pin VTRIM and pin GND. Determine trimming resistor value using the following equation:

$$R_{TRIM} = \left( \frac{2.100}{\Delta V} - 0.5 \right) R$$

(其中 R=80 k $\Omega$ )

To change  $V_{CV}$  lower, connect the trimming resistor between pin VTRIM and pin BAT. Determine trimming resistor value using following equation:

$$R_{TRIM} = \left( \frac{6.300}{\Delta V} - 1 \right) R$$

(其中 R=80 k $\Omega$ )

9、Package

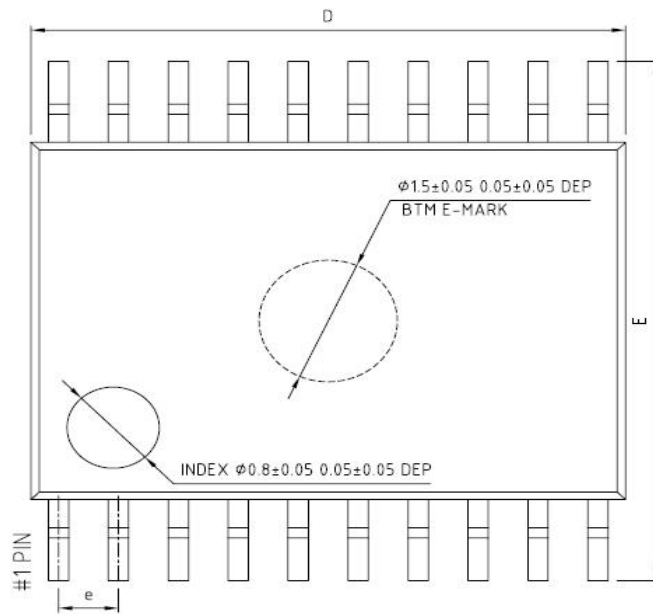


Figure 9.1、TSSOP-20 package diagram(1)

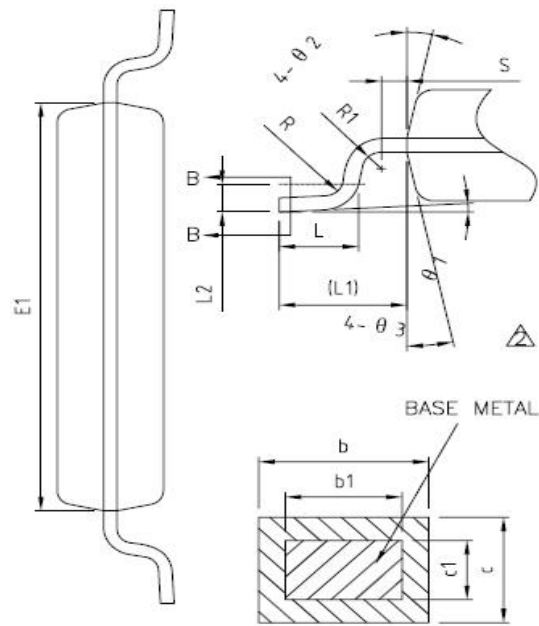


Figure 9.2、TSSOP-20 package diagram(2)

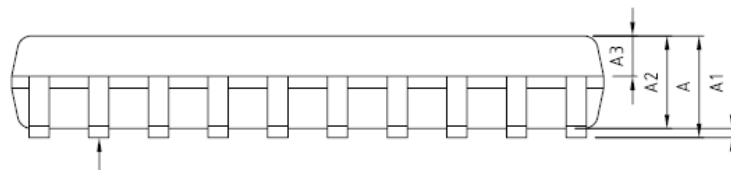


Figure 9.3、TSSOP-20 package diagram(3)

COMMON DIMENSIONS  
(UNITS OF MEASURE=MILLIMETER)

SYMBOL	MIN	NOM	MAX
A	—	—	1.20
A1	0.05	—	0.15
A2	0.90	1.00	1.05
A3	0.34	0.44	0.54
b	0.20	—	0.28
b1	0.20	0.22	0.24
c	0.10	—	0.19
c1	0.10	0.13	0.15
D	6.40	6.50	6.60
E	6.20	6.40	6.60
E1	4.30	4.40	4.50
e	0.65BSC		
L	0.45	0.60	0.75
L1	1.00REF		
L2	0.25BSC		
R	0.09	—	—
R1	0.09	—	—
S	0.20	—	—
$\theta_1$	0°	—	8°
$\theta_2$	10°	12°	14°
$\theta_3$	10°	12°	14°

Figure 9.4. TSSOP-20 dimensions