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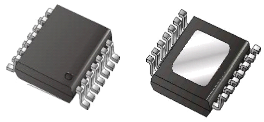
STBC21

LI+ battery charger with thermal regulation

Datasheet — production data

Features

- Programmable charge current up to 1.1 A
- Floating voltage limitation outside the safety temperature range
- PSE fully compatible
- Low battery voltage detection for pre-charge setting
- Automatic recharge
- Two charge status output pins
- Constant current / constant voltage operation
- No external MOSFET, sense resistors or blocking diode required
- Reverse current blocking (50 µA max.)
- Short-circuit protection and thermal shutdown
- Less than 1 mA supply current in standby mode
- Reversed battery polarity protection
- I^2C interface for charging parameters programming
- ESD: HBM ± 2 kV, CDM 500 V on every pin
- HTSSOP-14 (5 x 4.4 mm) package available
- -25 °C to 125 °C operative junction temperature



HTSSOP-14 (5 x 4.4 mm)

Description

The STBC21 is a constant current/constant voltage charger for single cell Li-Ion batteries. Most of the charging parameters, including floating voltage, pre-charge and termination current are programmable in NVM memory. While fast charging current is programmed using an external resistor. The constant current process is split into three phases depending on the battery voltage. If the battery voltage is below 3.0 V, the charging current is set to a programmable value below 200 mA. A timeout of 60 minutes is used in this phase to detect faulty batteries. When the battery voltage goes above 3.0 V, the charger moves to the fast-charge procedure with a current programmable by an external resistor up to 1.1 A. When the battery reaches the value of the floating voltage the charger enters “constant voltage” mode. Even in this mode a protection timer is active to avoid risks due to damaged batteries. The charge cycle is automatically terminated when the current flowing to the battery reaches the value programmed in NVM. There is also a programmable lag time after the termination to maximize the battery charge. An internal block regulates the battery floating voltage when its temperature is outside the safety range between 10 °C and 45 °C, (JEITA/PSE regulation). The floating voltage inside the safety range is set, by default, at 4.2 V. If the external power supply is removed, the STBC21 turns off and a 50 µA (max.) current can flow from the battery to the device. The device also has an undervoltage lockout and automatic recharge capability which can be enabled/disabled by setting a bit in NVM. Two separate status pins allow a lot of information to be gotten based also on flashing frequency and duty cycle. The STBC21 also includes a reversed battery polarity protection to prevent damage due to incorrect battery insertion. The package is a HTSSOP-14 (5 x 4.4).

Table 1. Device summary

Order code	Package	Packaging
STBC21FTR	HTSSOP-14	Tape and reel

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1 Block diagram

Figure 1. Block diagram

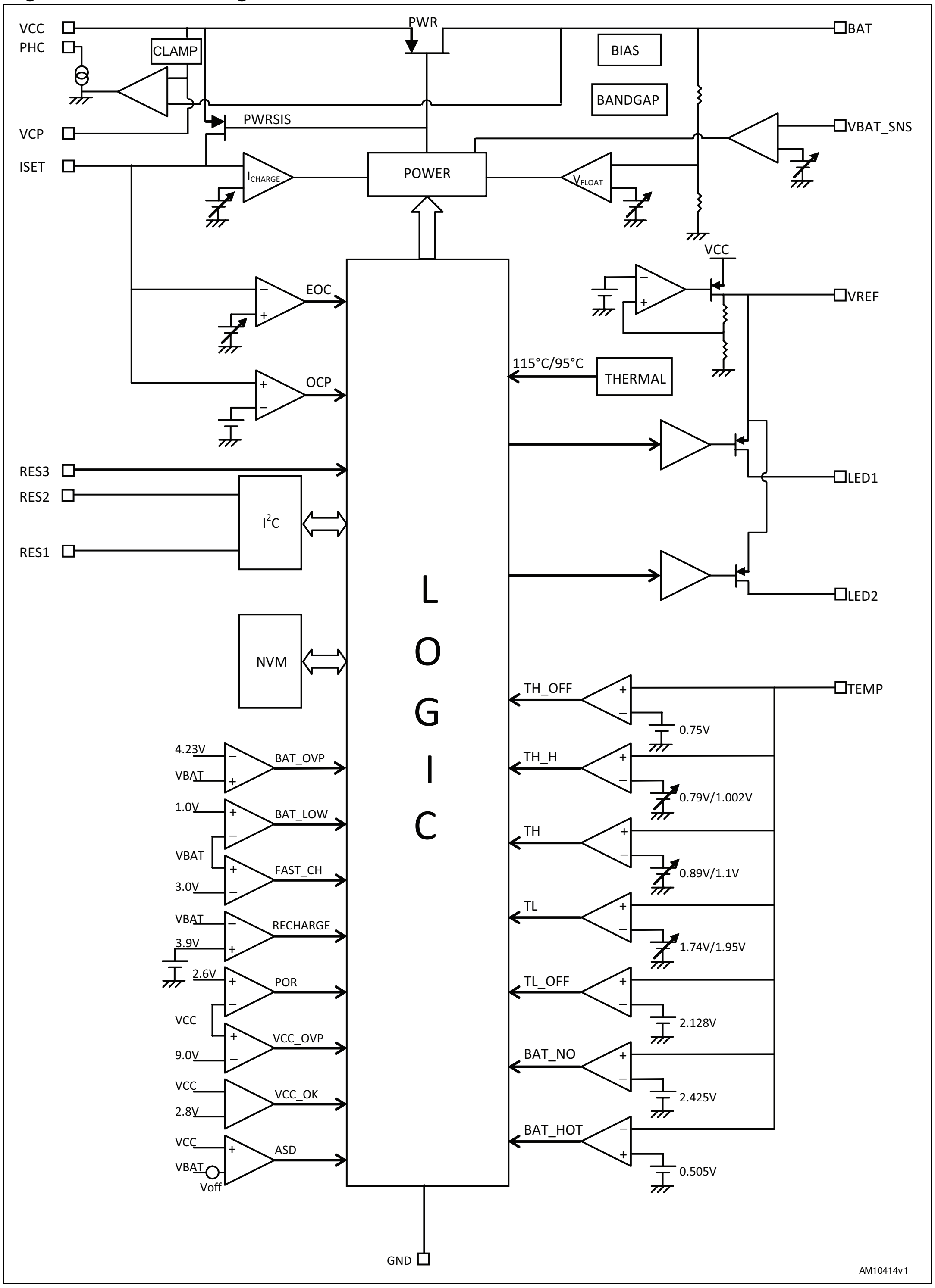


Figure 2. Typical application schematic

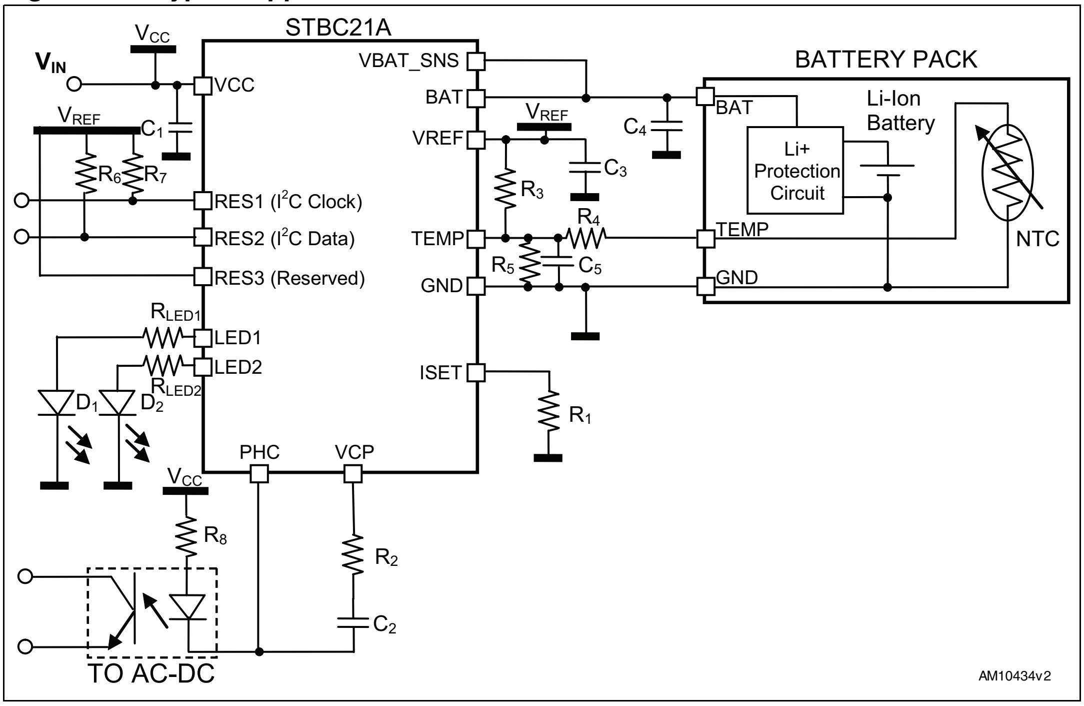


Table 2. External components

Symbol	Parameter	Min.	Typ.	Max.	Unit
C_1	Ceramic capacitor SMD	1		10	µF
C_2	Ceramic capacitor SMD		TBD		µF
C_3	Ceramic capacitor SMD		0.1		µF
C_4	Ceramic capacitor SMD		10		µF
C_5	Ceramic capacitor SMD		TBD (1)		
R_1	Resistor		10 (2)		kΩ
R_2	Resistor		TBD		kΩ
R_3	Resistor		100		kΩ
R_4	Resistor		0		Ω
R_5	Resistor		TBD (1)		
R_6	Resistor		4.7		kΩ
R_7	Resistor		4.7		kΩ
R_8	Resistor		TBD (3)		
R_{LED1}, R_{LED2}	Resistor		90		Ω
D_1	LED Kingbright L-934HD				
D_2	LED Kingbright L-934GD				

1. Time constant R5*C5 must be less than 20 msec.
2. This value refers to a fast-charge current of 100 mA.
3. Time constant must be chosen taking into account compensation loop.

2 Pin configuration

Figure 3. Pin connections (top through view)

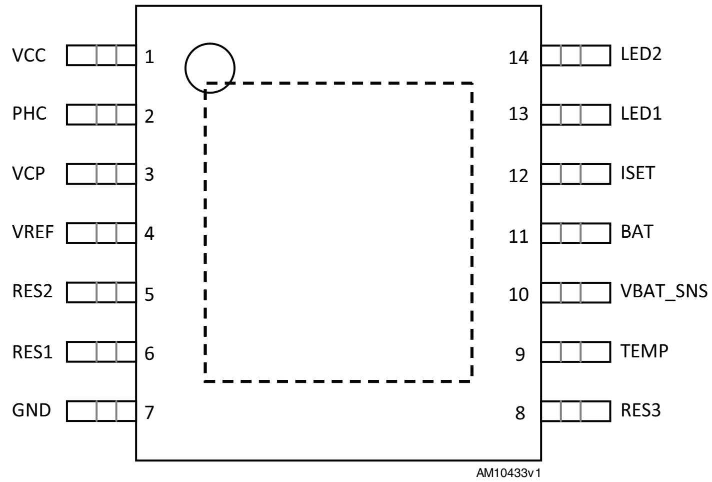


Table 3. Pin description

Pin n°	Symbol	Function
1	VCC	Input supply voltage
2	PHC	Photo coupler driver
3	VCP	Compensation pin
4	VREF	Voltage reference for external NTC
5	RES2	I²C bi-directional data - pulled high
6	RES1	I²C clock - pulled high
7	GND	Ground pin
8	RES3	Reserved
9	TEMP	Input from temperature sensor
10	VBAT_SNS	Battery voltage sensing
11	BAT	This pin provides an accurate output voltage and the charge current following the charging algorithm. Only 50 µA reverse current can flow into the device when in standby mode
12	ISET	Fast-charge current setting
13	LED1	Open drain. See Appendix E & F
14	LED2	Open drain. See Appendix E & F
	EXPOSED PAD	Not connected

3 Maximum ratings

Table 4. Absolute maximum ratings

Symbol	Parameter	Value	Unit
V_{CC}	Input supply voltage	From -0.3 to 10	V
V_{BAT}, V_{BAT_SNS}	Battery voltage	From -6.0 to 6.0	V
V_{PHC}	PHC voltage	From -0.3 to 10	V
V_{VCP}	VCP voltage	From -0.3 to 5.5	V
V_{REF}	REF voltage	From -0.3 to 3.6	V
V_{LV}	TEMP, LED1, LED2, ISET	From -0.3 to V_{REF}+0.3	V
V_{RES}	RES1, RES2, RES3	From -0.3 to 3.6	V
I_{BAT}	Charging battery current	1350	mA
ESD	Electrostatic discharge voltage (according to HBM JESD22-A114D)	±2	kV
	Electrostatic discharge voltage (according to CDM JESD22-C101C)	500	V
T_{STG}	Storage temperature range	–65 to 150	°C
T_J	Junction temperature range	–40 to 125	°C
Lead temperature	(soldering, 10 seconds)	300	°C

Note: Absolute maximum ratings are those values beyond which damage to the device may occur. Functional operation under these conditions is not implied. All values are referred to GND.

Table 5. Thermal data

Symbol	Parameter	Value	Unit
R_{thJA} (1)	Thermal resistance junction-ambient	37.6 (2)	ºC/W

1. Evaluated on 1S2P (1 signal, 2 plane layers) board, 4.4 x 5 mm body size, 3.0 x 3.0 mm pad size, 1.5 W applied power.
2. By 0 velocity (linear feet per minute). This value drops to 30.2 °C/W by 500 velocity.

4 Electrical characteristics

T_J = -25 °C to 85 °C unless otherwise specified. Refer to the typical application circuit. Typical values are referred to T_J = 25 °C.

Table 6. Electrical characteristics (DC)

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
V_{CC}			2.6		9.0	V
V_{CC_USB}	Minimum V_{CC} to enable charging without quasi-pulse			4.5		V
V_{BAT}			3.0		4.25	V
I_{CC}	Supply current (excluding LEDs and battery current)	Fast charge (1) 3.0 V<V_{CC}<9.0 V I_{BAT}=100 mA			750	µA
		Shutdown 2.6 V<V_{CC}<2.85 V			80	µA
		Standby (charge terminated) 2.8 V<V_{CC}<9.0 V			450	µA
I_{STBY}	I_{BAT} standby current (charge terminated)	0 V<V_{CC}<9.0 V V_{BAT}=4.2 V V_{TEMP}=1.2 V			-50	µA
I_{PRE_CH}	Nominal pre-charge / 0V-charge current	2.8 V<V_{CC}<9.0 V	48	60	72	mA
			72	90	108	
			96	120	144	
I_{F_CH}	Nominal fast-charge current	Set by Ext. resistor R_1=1.25 kΩ	744	800	856	mA
I_{TERM}	Charge termination current	10 mA steps from 40 mA to 190 mA 4.5 V<V_{CC}<9.0 V V_{BAT}=4.2 V, TIMER3=0	32	40	48	mA
				...		
			152	190	228	
I_{BAT_OCP}	I_{BAT} overcurrent protection			1.35		A
I_{VREF}	V_{REF} current limit	5.0 V<V_{CC}<9.0 V		30		mA
I_{PHC}	Photo-coupler current	V_{CC}=5.0 V, V_{BAT}=3.0 V		10		mA
I_{Lk_PHC}	Photo-coupler leakage	V_{CC}=5.0 V, V_{BAT}=4.8 V, V_{PHC}=5.0 V		2		µA
I_{SINK}	Sunk current during battery detection	C_{OUT}=10 µF		1		mA
I_{DETECT}	Sunk current during battery detection	C_{OUT}=10 µF		1		mA
I_{LED}	LED current	V_{REF}=2.9 V, VF_{LED}=2 V R_{LED}=90 kΩ		10		mA
V_{CC_POR}	Power-on reset threshold		2.47	2.6	2.73	V

Table 6. Electrical characteristics (DC) (continued)

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
V_{CC_OK}	Charging start threshold – V_{CC} undervoltage alarm (V_{CC_UVLO})	±5%	2.66	2.8	2.94	V
V_{CC_ASD}	V_{CC}-V_{BAT} threshold			125		mV
V_{CC_OVP}	V_{CC} overvoltage protection		8.55	9.0	9.45	V
IO_{DROP_QP}	Quasi-pulse V_{CC}-V_{BAT} drop	I_{BAT}=100 mA, I_{BAT}=1.0A			0.35	V
V_{0V_HD}	0V-charge threshold	±5%		1		V
V_{PRE_CH}	Pre-charge to fast-charge voltage threshold	V_{CC} = 5.0 V		3.0		V
ΔV_{FLT}	Float voltage range tolerance	V_{FLT} = 4.2 V, I_{BAT} =1 mA T_J = -10 °C to 85 °C	-0.7		0.7	%
V_{FLT_OVP}	Float voltage OVP	5.0 V < V_{CC} < 9.0 V T_{BAT} = 0 °C to 60 °C I_{BAT} = 1.0 mA TIMER-3 = 60 min.	4.21	4.23	4.25	V
V_{CC_QP}	Quasi-pulse minimum supply voltage in pre-charge phase			3.1		V
V_{BAT_QP}	Minimum battery voltage to start quasi-pulse mode			2.8		V
V_{RECH}	Battery recharge threshold voltage	5.0 V < V_{CC} < 9.0 V		3.9		V
V_{TEMP_UN}	NTC voltage threshold for battery unconnected	±2%		2.425		V
V_{TEMP_OT}	NTC voltage threshold for battery overtemperature	±2%		0.505		V
V_{REF}	Reference voltage for NTC / LED drive voltage	±5%		2.9		V
$R_{DS\text{-}ON}$	Power MOS saturation resistance	0 °C < T_J < 85 °C		300		mΩ
T_{RECH}	Battery recharge deglitching time	V_{CC} = 5.0 V		100		ms
T_{FULL}	Full charge detection deglitching time (after termination)	V_{CC} = 5.0 V – TIMER-3 = 0		100		ms
T_{HV}	Battery overvoltage detection deglitching time	V_{CC} = 5.0 V		100		ms
T_{HI}	Overcurrent detection deglitching time	V_{CC} = 5.0 V		100		ms
T_{HOLD_OFF}	Deglitching time on V_{CC} to start charging (V_{CC}=3.0 V)	V_{BAT} = 2.8 V		10		ms
T_{BAT_HOT}	Battery hot detection deglitching time	V_{CC} = 5.0 V		10		ms
T_{BAT_CON}	Battery connection detection deglitching time	V_{CC} = 5.0 V		400		ms
T_{BAT_TLO}	Battery T_{LO} temperature detection deglitching time	V_{CC} = 5.0 V		100		ms

Table 6. Electrical characteristics (DC) (continued)

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
T_{BAT_THO}	Battery T_{HO} temperature detection deglitching time	V_{CC} = 5.0 V		100		ms
T_{BAT_TL}	Battery T_L temperature detection deglitching time	V_{CC} = 5.0 V		100		ms
T_{BAT_TH}	Battery T_H temperature detection deglitching time	V_{CC} = 5.0 V		100		ms
T_{BAT_THH}	Battery T_{HH} temperature detection deglitching time	V_{CC} = 5.0 V		100		ms
T_{SINK}	Duration of battery connection detection	C_{OUT} = 10 µF		100		ms
T_{DETECT}	Duration of battery connection detection	C_{OUT} = 10 µF		300		ms
TIMER-1	Pre-charge timer	± 10% @ 25 °C ±15% in temp range		60		min
TIMER-2	Fast-charge timer (programmable)	± 10% @ 25 °C ±15% in temp range	150		510	min
TIMER-3	Termination timer (programmable)	± 10% @ 25 °C ±15% in temp range	0		60	min
TIMER-4	0 V-charge timer	± 10% @ 25 °C ±15% in temp range		16		sec
T_{J_SH}	Junction shutdown temperature	20 °C hysteresis		115		°C
T_L	Lower limit of safety range	10 °C	1.74		1.95	V
T_H	Upper limit of safety range	45 °C	0.89		1.10	V
T_{HH}	Intermediate safety range	50 °C	0.79		1.002	V
T_{HO}	Upper limit of functional range	60 °C	0.727	0.75	0.776	V
T_{LO}	Lower limit of functional range	-2 °C	2.087	2.128	2.168	V
Hysteresis		2 °C		28		mV
		5 °C		70		mV

5 Detailed description

The STBC21 is designed to charge single-cell lithium-ion batteries using the constant current/constant voltage algorithm. The charger can deliver up to 1.1 A (programmable) of charge current with a final float voltage accuracy of 20 mV.

Once the battery is connected, the normal charge cycle begins when the voltage at the V_{CC} pin rises above the threshold (V_{CC_OK}).

The process generally starts with a pre-charge phase in constant current mode, where a reduced charge current (see *Appendix B*) is supplied to the battery. A programmable timer (TIMER-1) during this phase allows possibly damaged batteries to be spotted in case the voltage doesn't reach the expected value within a given time.

Note that, if the battery voltage is below 1.0 V, the charger first attempts to charge (0 V-charge mode) for 16 seconds (TIMER-4) to test if the battery is dead. After the TIMER-4 has elapsed, in case the voltage doesn't cross the 1.0 V threshold, a battery alarm is flagged. Otherwise the charger keeps on charging.

When the battery voltage reaches 3.0 V, the charging current reaches its maximum value (fast-charge phase) programmable by an external resistor.

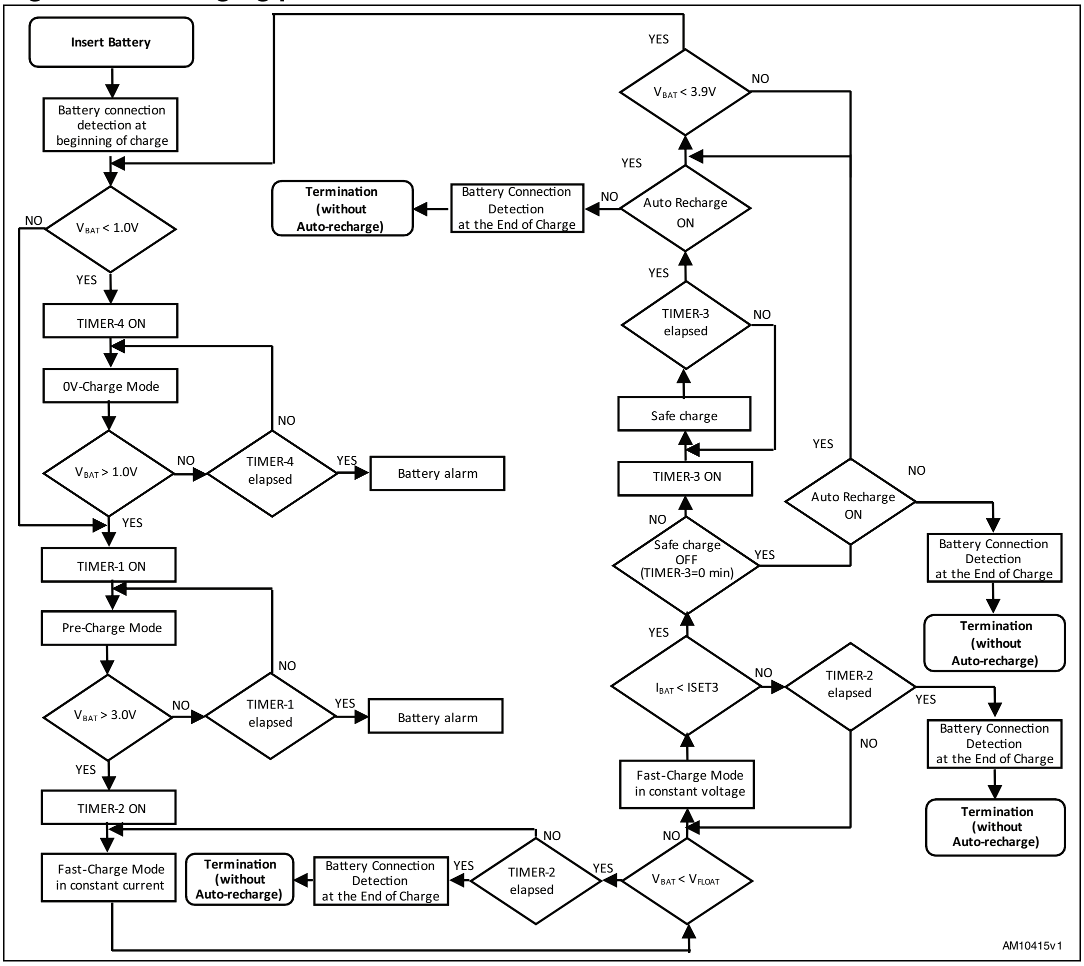
When the battery voltage approaches the final float voltage (programmable, typ. 4.2 V), the STBC21 enters constant voltage mode and the charge current decreases as the battery becomes fully charged. The fast-charge and the following constant voltage phases have a dedicated timer set through bits in NVM to make sure the current reaches its termination value within a given time. If during this phase the battery voltage falls below V_{PRE_CH} or rises above 4.23 V (±20 mV), the operation is stopped and an alarm sounds.

The STBC21 terminates the constant voltage phase when the charging current reaches the termination current threshold (value set in ISET3 register, see *Appendix B*). In addition, a further step (end of charge) can be activated through bits in NVM. In this case, the charging process in constant voltage mode continues for a predefined amount of time (TIMER-3): this behavior is useful to increase the battery duration.

After charge termination the battery may be discharged by the leakage. When the battery voltage reaches V_{RECH} with a lag time of 100 ms the charge automatically restarts. This feature can be disabled setting a bit in NVM.

If, during the charging phase, one of the timeouts elapses, the charge is stopped and a flag is set. See *Appendix B* for more details on timers. The STBC21 charging process works as depicted in *Figure 4*.

Figure 4. Charging process flowchart



Two outputs can be used to detect the status of charge. The functionality of these two pins can be customized in NVM as outlined in *Appendix E* & *Appendix F*. This is to allow the final customer to have different kinds of information depending on whether the output is ON, OFF, or flickering. The flickering frequency is programmable both in frequency and duty cycle (see *Appendix E* & *Appendix F*).

Note: *The device functionality is not guaranteed if the parameters are modified in NVM during the charging cycle.*

5.1 Operation mode

The STBC21 can work in standalone or driven by a microcontroller. If it works in standalone, all device parameters are those stored in NVM. Otherwise, if it works driven by a microcontroller, it is the microcontroller itself to program through I²C (SCL and SDA pins) the device parameters.

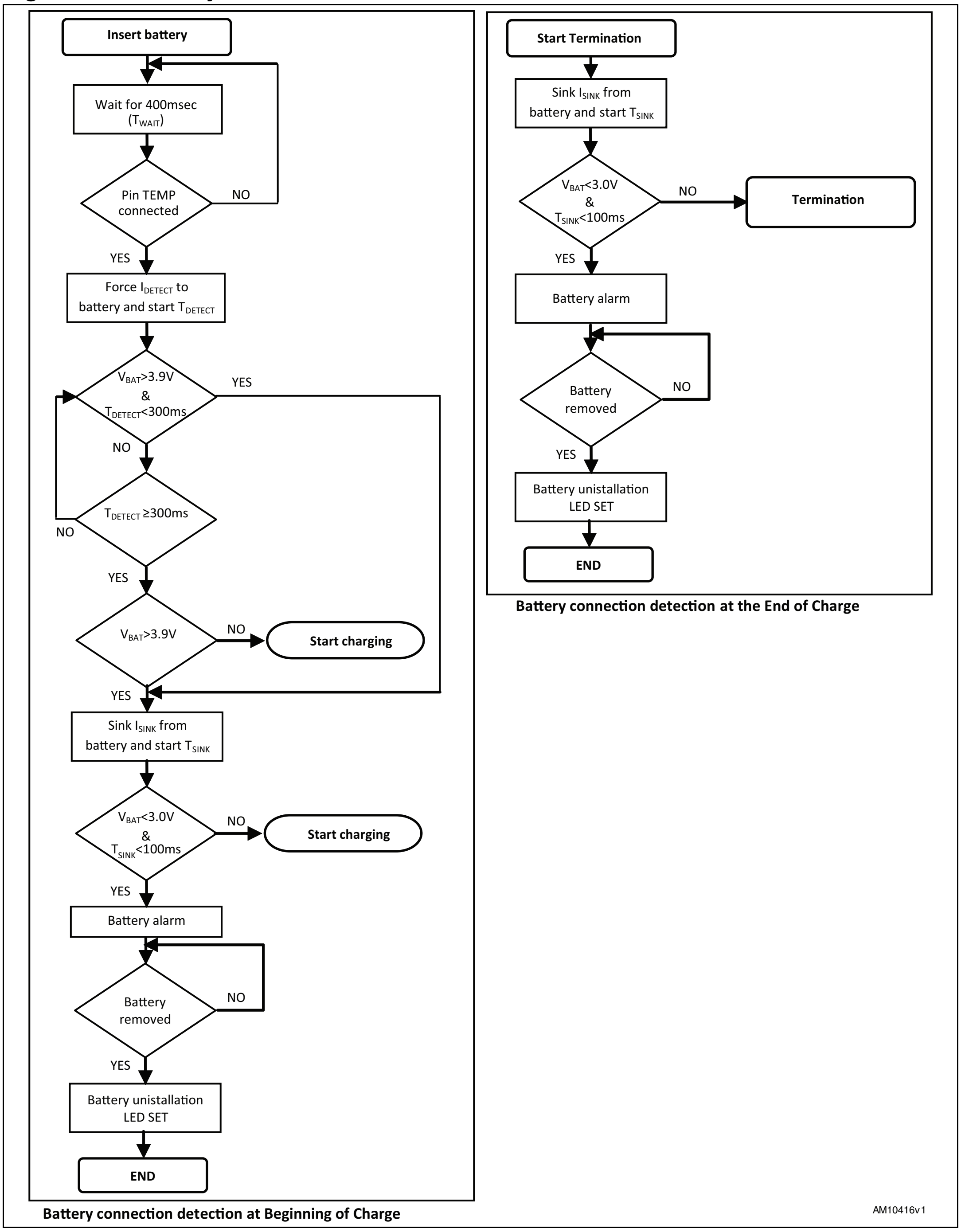
5.2 Battery connection detection

The STBC21 includes a battery detection algorithm to avoid a wrong behavior of the charger due to incorrect pin connection. This control is performed both at the beginning and at the end of charge.

At the beginning of charge, the charger briefly (T_{DETECT}) sources a small current (I_{DETECT}) to the battery: if the voltage remains below V_{RECH}, the battery is definitely connected. Otherwise, if the voltage reaches V_{RECH}, a further control is added to be sure the battery is not connected. The charger briefly sinks (T_{SINK}) a small current (I_{SINK}) from the battery. If voltage falls below V_{PRE_CH}, the battery is certainly absent.

Similarly, when the termination current is reached, the charger briefly (T_{SINK}) sinks a small current (I_{SINK}) from the battery. After this period, if the battery voltage is above V_{PRE_CH}, the battery is present. Otherwise the battery is absent. The flowcharts in *Figure 5* better explain this algorithm.

Figure 5. Battery connection detection flowcharts



5.3 Start of charge

The STBC21 start of charge is subject to three variables: input voltage, battery connection and battery temperature. The detection of these variables is filtered with different deglitching as reported in *Table 7*:

Table 7. Start of charge

Item	Delay	Enabling condition
Battery connection detection	400 ms	V_{TEMP} < 2.425 V
V_{CC} voltage detection	10 ms	V_{CC} > 2.8 V
Battery temperature detection	100 ms	0.75 V < V_{TEMP} < 2.128 V

The charge starts if V_{CC} exceeds 2.8 V, the battery is connected and its temperature is in the safety range (see *Section 5.5*).

In addition, the charge cycle starts if the available supply voltage exceeds by $V_{CC\text{-}ASD}$ the BAT pin voltage level.

The start of charge in case of a discharged battery is already described in a previous paragraph. Meanwhile, if a fully charged battery is connected, the charge starts in constant voltage mode with TIMER-2 associated.

5.4 Fast-charge programming

When the battery voltage reaches the pre-charge voltage threshold, the STBC21 starts the fast-charge phase. In this phase, the device charges the battery with a constant current, programmable by an external resistor that sets the charge current. The formula used to select the RPRG is as follows:

Equation 1

$$R_{PRG} = V_{SET} \times \left(\frac{K_{PRG}}{I_{CHG}}\right)$$

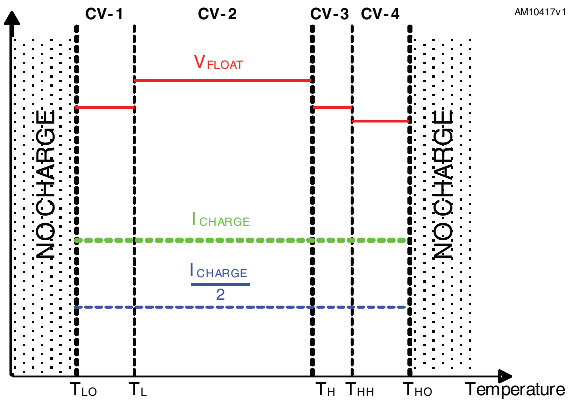
where V_{SET} = 1.0 V and K_{PRG} = 1000. During this phase, the battery voltage increases until it reaches the programmed floating voltage or the safety timer expires and the alarm is activated.

5.5 Charge auto-limitation

The STBC21 includes an auto-limitation algorithm to avoid explosion risks in the Li+ battery. This algorithm makes sure that the battery is never charged at its maximum floating voltage if the temperature is above 45 °C or below 10 °C.

Three more ranges are defined outside the safety range T_L-T_H (10 °C ~ 45 °C) as reported in *Figure 6*.

Figure 6. Temperature ranges compatible with PSE, power safety electrical



The new floating voltage in these ranges can be programmed to be 4.2 V, 4.1 V or 4.05 V (± 30 mV), as reported in *Appendix B*.

Once the reduced floating voltage is reached, the charge terminates only if the battery temperature is in the 10 °C ~ 45 °C range. If the temperature is outside this range, the charger holds and restarts once the temperature decreases.

This function can be enabled/disabled setting a bit in NVM.

There is also the possibility to halve the charging current (see *Figure 6*, blue dashed line) in fast-charge in all temperature ranges.

In addition, all thresholds have an hysteresis: T_{LO} and T_{HO} have a fixed hysteresis of 2 °C, whereas T_L, T_H and T_{HH} have a programmable hysteresis of 2 °C or 5 °C (value set by a bit in NVM).

If the temperature moves above T_H or below T_L, V_{float} is reduced. When the temperature goes back inside the range T_L-T_H (with the associated hysteresis), V_{float} is replaced to its maximum value.

At the beginning of the charge, when the battery pack is inserted, a check of battery temperature is performed: if the temperature is outside the range 0 °C~45 °C, the charger doesn't start charging and waits until the temperature goes back into the range (above 0 °C or below 43 °C) (see *Figure 8*).

Similarly, if auto-recharge is active and battery voltage decreases below 3.9 V, but its temperature is outside the range 0 °C ~ 45 °C, the charge is stopped and restarts only when battery temperature goes into the range 0 °C ~ 43 °C. In this situation, LEDs continue to show “charge completed”.

During charging, if battery temperature goes outside the functional range (-2 °C ~ 60 °C), the charger must stop the operations regardless of the current state. In this case, the LEDs show “Battery temperature alarm” but the timers keep on counting. If the temperature moves back inside the range 0 °C ~ 43 °C, the charger restarts the operations restoring the status it was in before the interruption.

In this case, if temperature goes above 60 °C twice, the charger stops, the LEDs show a “charge completed” and it is necessary to remove the battery to restart the operations (see *Figure 9*). With the battery uninstalled, the LED configuration is like that indicated in *Appendix E*.

In summary, the STBC21 behavior can also be represented as the following V-I characteristic:

Figure 7. V-I characteristics

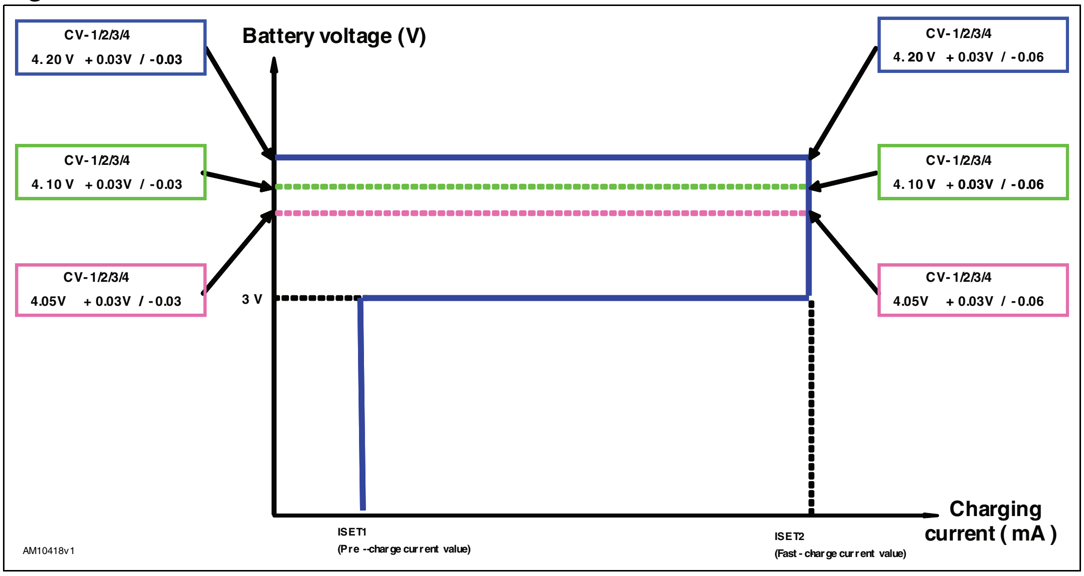


Figure 8. Battery temperature alarm after charging starts (at battery insertion and at recharge) flowchart

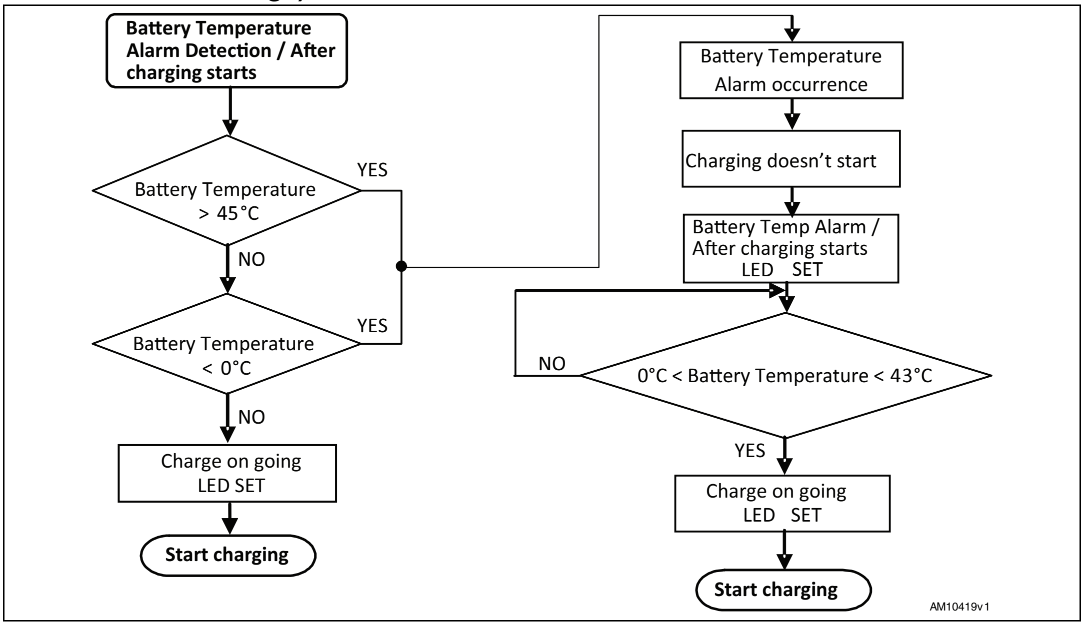
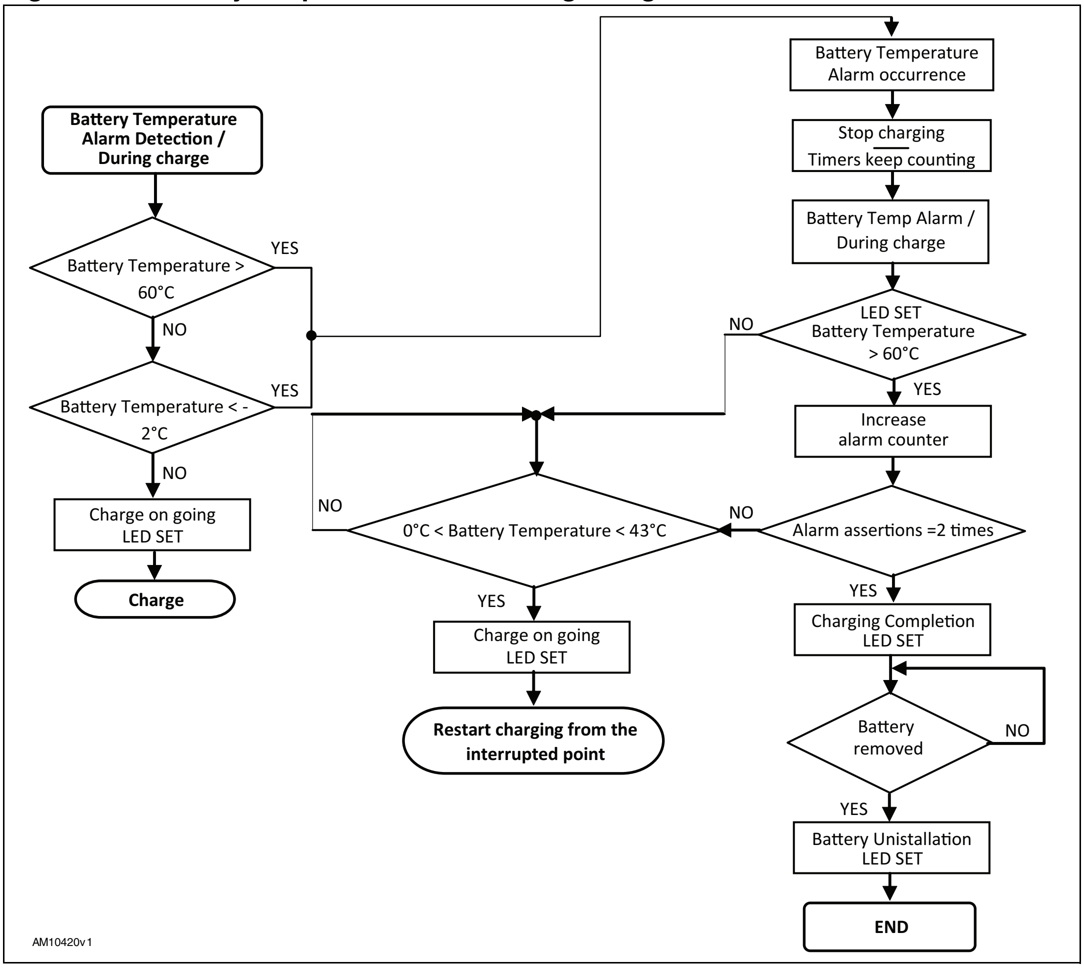


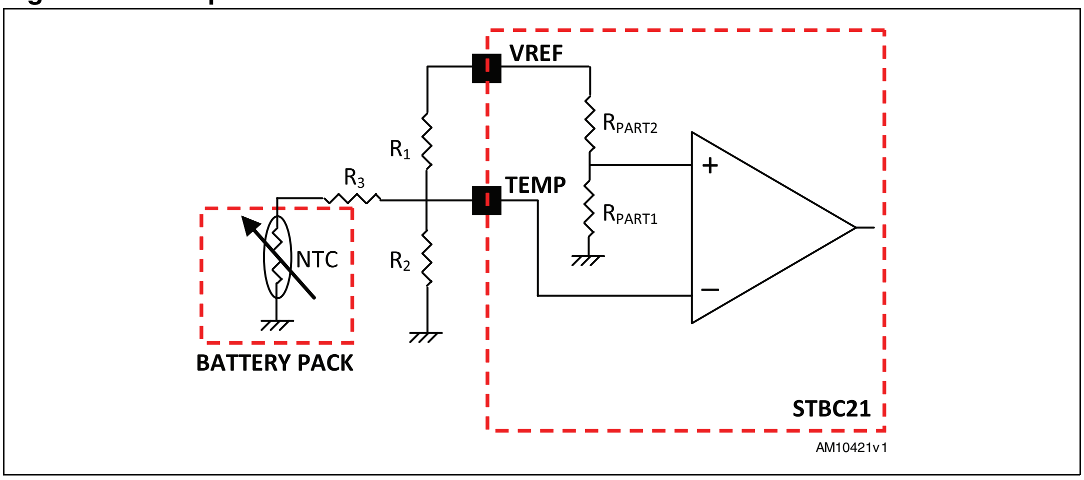
Figure 9. Battery temperature alarm during charge flowchart



The chip also includes an NVM to allow the temperature thresholds above to be programmable few times by the battery manufacturer.

The temperature thresholds are sensed by the NTC inside the battery pack. A reference voltage is properly partitioned to translate the variable resistance in a variable voltage as shown in *Figure 10*.

Figure 10. Temperature detector schematic



Using an integrated resistor partition and a very low-offset comparator, it's possible to detect a battery temperature value that doesn't depend on reference voltage, but is affected by an internal resistor divider matching only.

As regards NTC, the components suggested are:

1. NTC1 PANASONIC R_{25} = 100 kΩ ±1% $B_{25/85}$=4700 K ±1% (code ERTJ0EV104F)
2. NTC2 PANASONIC R_{25} = 10 kΩ ±1% $B_{25/85}$=3435 K ±1% (code ERTJ0EG103FA)

Two resistor networks are proposed to implement linearization of these two NTCs, as written below.

NTC1: R_1 = 100 kΩ - R_2 = 700 kΩ - R_3 = 17.8 kΩ

NTC2: R_1 = 9.1 kΩ - R_2 = 160 kΩ - R_3 = 0.22 kΩ

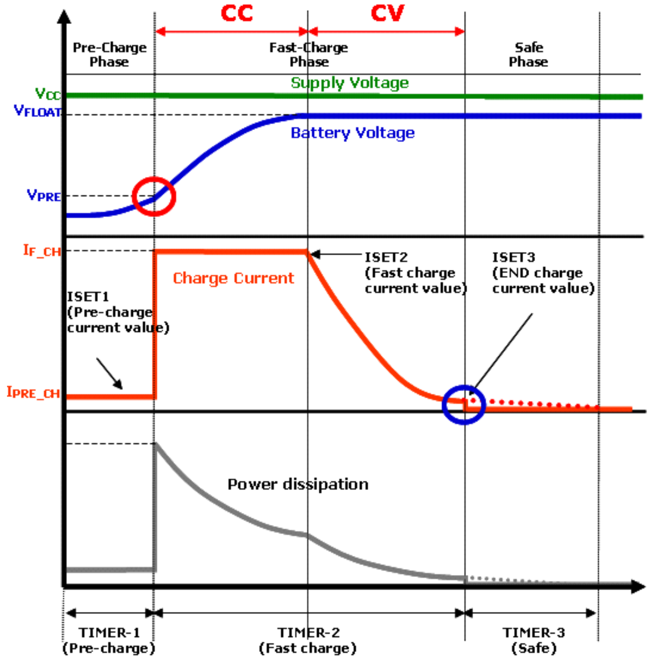
In this way, voltage thresholds of similar value for both NTCs are obtained. The STBC21 automatically recognizes these voltage thresholds.

T_{LO} (-2 °C)	T_L (10 °C)	T_H (45 °C)	T_{HH} (50 °C)	T_{HO} (60 °C)
2.128 V	1.74 V - 1.95 V	0.89 V - 1.1 V	0.79 V - 1.002 V	0.75 V

5.6 PHC pin functionality

The time diagram of the charging process can be summarized in the image below:

Figure 11. Charging process diagram



As shown, in fast-charge phase the power dissipation can be important and supposing V_{IN} = 9.0 V and I_{BAT} = 1.1 A:

Equation 2

$$P = (V_{IN} - V_{OUT}) \times I_{BAT} = 6.6W$$

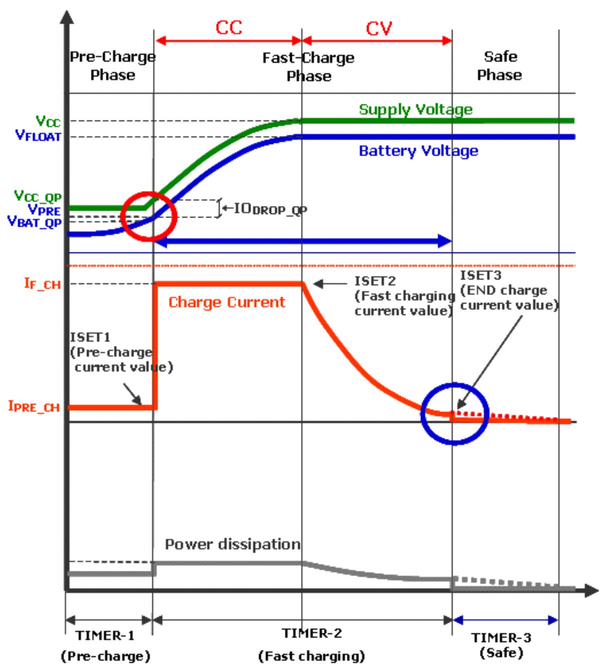
which is not compatible with the thermal specifications of the package used. In this situation either the charging current must be reduced (increasing the charging time) or the STBC21 enters into thermal shutdown.

This effect can be seen even in pre-charge but is less critical because this phase generally last few minutes and the current is lower but can become longer in case the chip goes into thermal shutdown.

To allow a higher current capability during charging, the power dissipation must be reduced acting on the voltage drop between input and output. To keep this difference at a minimum value the STBC21 provides a pin to drive a controller downstream so that the input voltage depends on the battery voltage.

The input voltage waveform is shaped as reported in *Figure 12*.

Figure 12. Charging process diagram



During pre-charge, until V_{BAT} reaches 2.8 V (V_{BAT_QP} threshold), the input voltage must be regulated at V_{CC_QP}. When V_{BAT} goes over 2.8 V, V_{CC} starts to increase, keeping a constant voltage difference with V_{BAT} (I_{ODROP_QP}).

5.7 Alarms

The STBC21 implements four kinds of alarms: battery alarm, charger alarm, ASD (automatic shutdown) alarm and device temperature alarm.

Battery alarm occurs when:

- TIMER-1 during pre-charge phase elapses;
- TIMER-4 during 0V-charge phase elapses;
- Overvoltage on the BAT pin occurs (V_{BAT} > 4.23 V ± 20 mV, infringement of JEITA/PSE regulation);
- Undervoltage, during fast-charge or end of charge, on the BAT pin occurs (V_{BAT} < 3.0 V);
- Undervoltage on the TEMP pin occurs (V_{TEMP} < 0.505 V, battery overheating);
- Battery connection detection error occurs.

In all these cases the charge stops, the LEDs show a “Battery alarm” and a battery removal is required to reset the charger. The battery removal is spotted because the voltage on the TEMP pin rises above 2.425 V.

The battery alarm's flowchart is presented in *Figure 13*.

Charger alarm occurs when:

- Overvoltage on the V_{CC} pin occurs (V_{CC} > 9.0 V);
- Undervoltage on the V_{CC} pin occurs (V_{CC} < 2.8 V, except for the power-up transition when the charger is switched on);
- Current increases over 1.1 A.

In these cases the charge is stopped, LEDs show a “charger alarm” and it's kept in this state even if the battery is removed. A V_{CC} removal is required to reset the charger.

The charger alarm's flowchart is depicted in *Figure 14*.

Other alarms occur when:

- V_{CC} and V_{BATT} are very close (V_{CC_ASD} is lower than threshold);
- Die temperature increases over 115 °C (thermal shutdown).

In these cases the battery charge is stopped, the LEDs continue to show “charge ongoing” if the charger was in charge, and “end of charge” if the charger was in the termination phase and the timers keep on counting. Once the alarm condition is removed, the charger restarts the operations restoring the status it was in before the interruption.

During this phase, all other alarms (battery alarms and charger alarms) are active.

Figure 13. Battery alarm flowchart

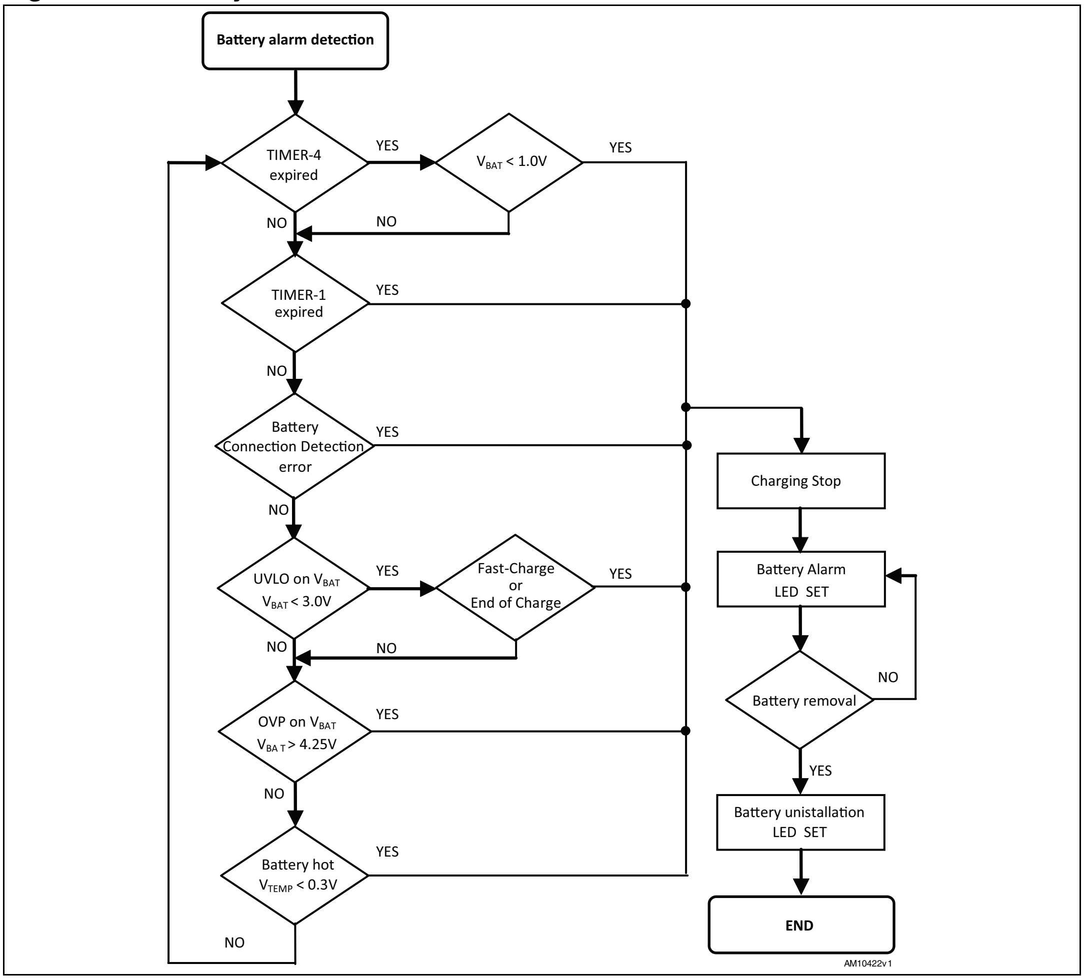
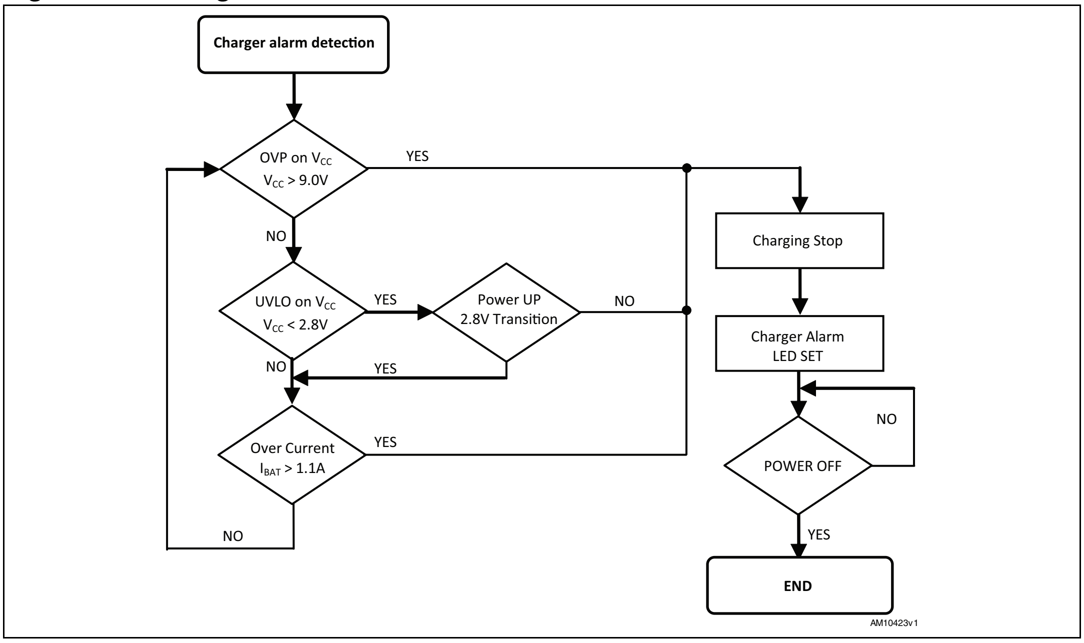
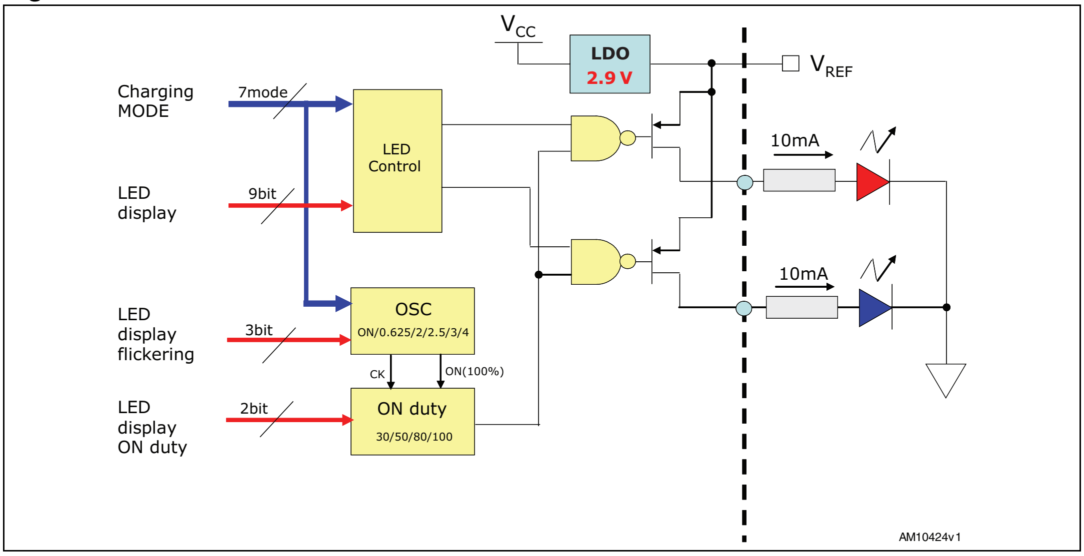


Figure 14. Charger alarm flowchart



The alarms are reported by two different LEDs driven from the high side with 10 mA current capability, as reported in *Figure 15*. The LED current is not internally limited.

Figure 15. LEDs control circuit



See *Appendix E* for possible LED configurations.

As regards R_{LED} calculation, taking into account I_{LED} = 10 mA and V_{FLED} = 2 V, we obtain:

Equation 3

$$R_{LED} = \frac{(V_{REF} - VF_{LED})}{I_{LED}} = \frac{(2.9 - 2)}{0.01} = 90\,\Omega$$

5.8 Reversed battery polarity protection

The STBC21 includes a reversed battery polarity protection to prevent damage due to an incorrect insertion of the battery in the cradle.

If the battery is able to supply 2 mA, charge doesn't start and no alarm is set.

If the battery is protected against overvoltage, undervoltage, etc. and it is in protection mode (represented as an open circuit) it is not able to supply 2 mA. In this condition, the battery connection detection alarm is set. Even in this case the charge does not start.

If the battery is not protected against overvoltage, undervoltage, etc. and battery voltage is below 1.0 V, battery connection detection is unable to start. In this case, for a time corresponding to TIMER-4 (16 sec), the battery is discharged with a pre-charge current. But when TIMER-4 elapses the battery alarm is flagged and the discharge is stopped.

5.9 Temperature protection

The STBC21 has a further protection when the dye temperature reaches 115 °C. In this condition the charge is stopped and restarts after the temperature decreases to 95 °C. During this “idle” state, LEDs continue to show “charge ongoing” if the charger was in charge, “end of charge” if the charger was in termination phase and the timers keep on