



STC4054

800mA Standalone linear Li-Ion Battery charger with thermal regulation

Feature summary

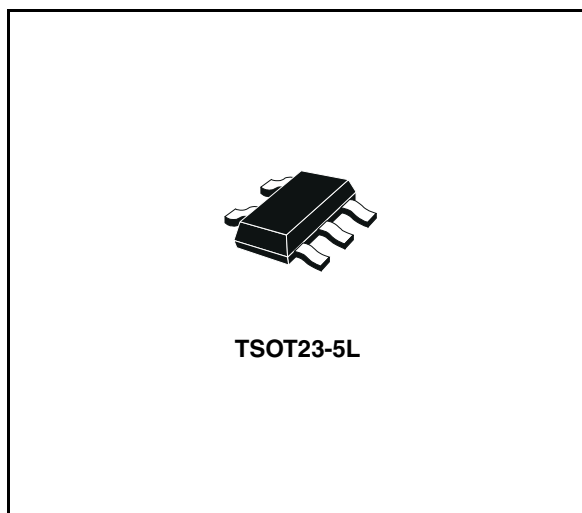
- Programmable charge current up to 800mA
- No external MOSFET, sense resistors or blocking diode required
- Constant current / constant voltage operation with thermal regulation to maximize charge rate without risk of overheating
- Charges single cell li-ion batteries directly from USB port
- Preset 4.2V charge voltage with 1% accuracy
- Automatic recharge
- Single charge status output pin
- Charge current monitor output for gas gauging
- C/10 Charge termination
- 25 μ A supply current in shutdown mode
- Low battery voltage detect for precharge setting
- Soft-start limits inrush current
- TSOT23-5L package

Applications

- Cellular telephones
- PDAs
- Bluetooth applications
- Battery-powered devices

Description

The STC4054 is a constant current/constant voltage charger for single cell Li-Ion batteries. No external sense resistor or blocking diode is



required and its ThinSOT package make it ideally suited for portable applications.

The STC4054 is designed to work within USB power specifications. An internal block regulates the current when the junction temperature increases, in order to protect the device when it operates in high power or high ambient temperature.

The charge voltage is fixed at 4.2V, and the charge current limitation can be programmed using a single resistor connectd between PROG pin and GND. The charge cycle is automatically terminated when the current flowing to the battery is 1/10 of the programmed value. If the external adaptor is removed, the STC4054 turns off and a 2 μ A current can flow from the battery to the device. The device can be put into Shutdown Mode, reducing the supply current to 25 μ A. The device also has a charge current monitor, under voltage lockout, automatic recharge. The device is packaged in TSOT23-5L.

Order code

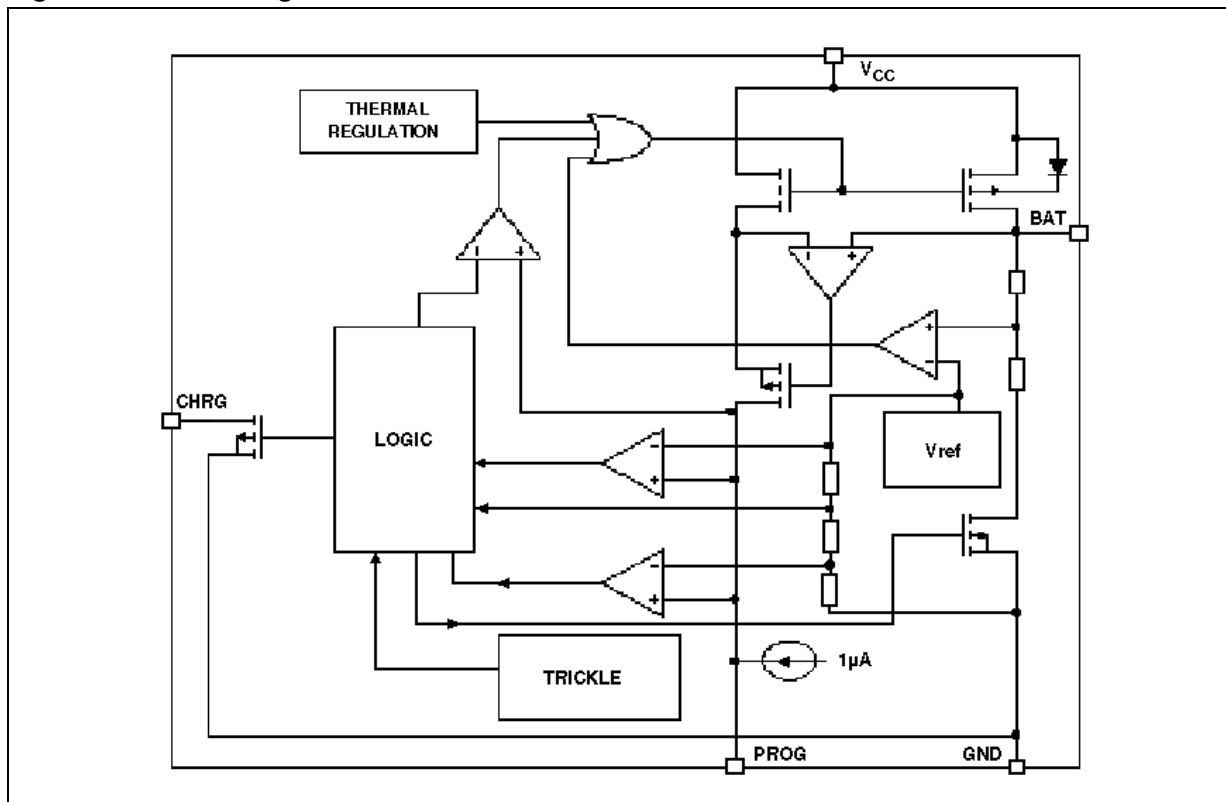
| Part number | Package | Packaging |
|-------------|-----------|---------------------|
| STC4054GR | TSOT23-5L | 3000 parts per reel |

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1 Block diagram

Figure 1. Block diagram



2 Pin configuration

Figure 2. Pin connections (top view)

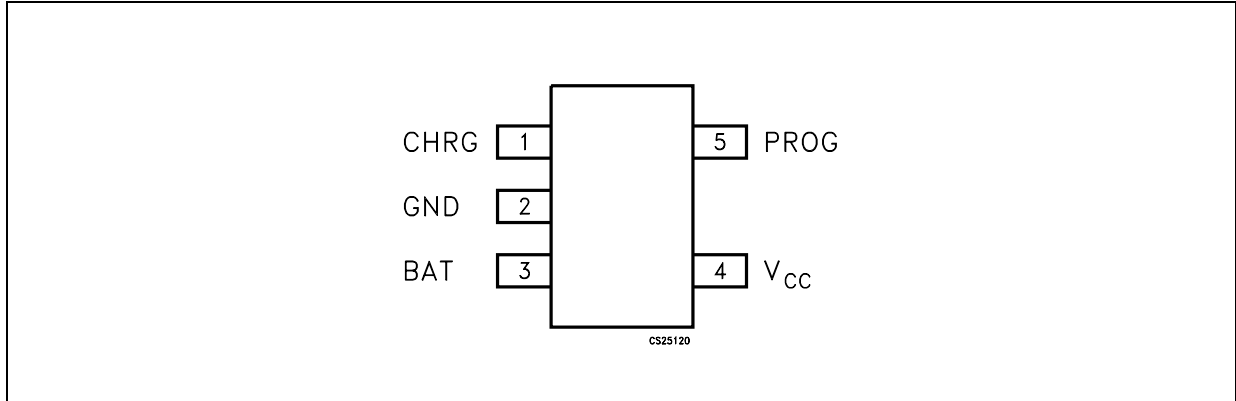
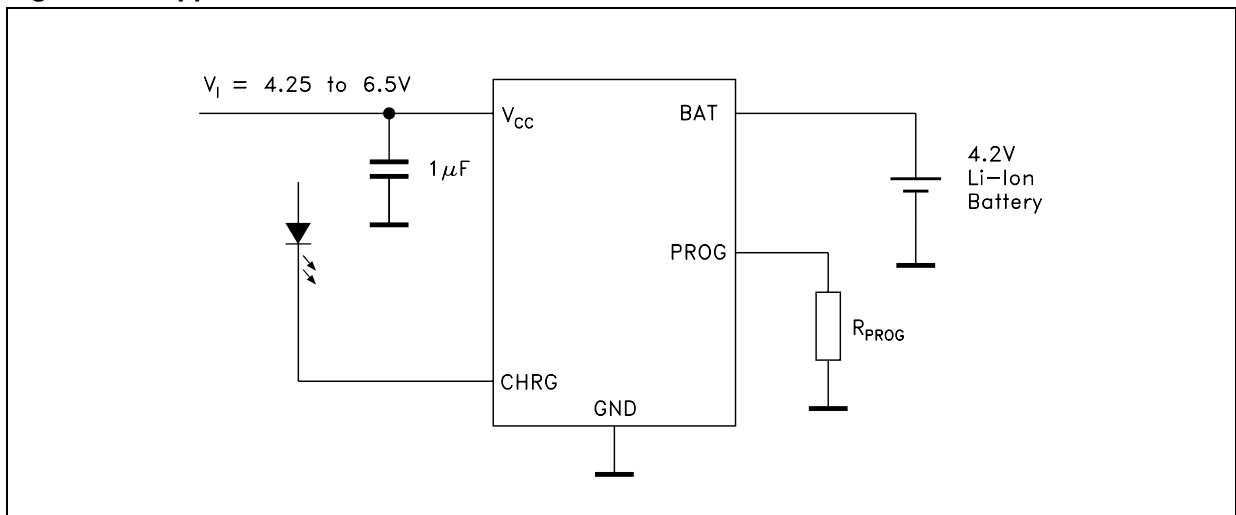


Table 1. Pin description

| Pin N° | Symbol | Note |
|--------|-----------------|--|
| 1 | CHRG | Open Drain. This pin goes in low impedance when the STC4054 is in precharge or charge mode |
| 2 | GND | Ground pin |
| 3 | BAT | This pin provides an accurate 4.2V output voltage and the charge current to the battery. Only 2µA reverse current can flow in to the device when in Shutdown mode |
| 4 | V _{CC} | Input Supply voltage. The input range is from 4.25V to 6.5V. If V _{CC} <V _{BAT} +30mV the device enters Shutdown mode and the sinked I _{BAT} is less than 2µA |
| 5 | PROG | Charge current program. Charge Current monitor and Shutdown pin |

Figure 3. Application circuit



3 Maximum ratings

Table 2. Absolute maximum ratings

| Symbol | Parameter | Value | Unit |
|------------|--------------------------------------|---------------------------|--------------|
| V_{CC} | Input supply voltage | From -0.3 to 10 | V |
| V_{BAT} | BAT pin voltage | From -0.3 to 7 | V |
| V_{PROG} | PROG pin voltage | From -0.3 to $V_{CC}+0.3$ | V |
| V_{CHRG} | CHRG pin voltage | From -0.3 to 7 | V |
| I_{BAT} | BAT pin current | 800 | mA |
| I_{PROG} | PROG pin current | 800 | μ A |
| | BAT short circuit duration | Continuous | |
| P_D | Power dissipation | Internally Limited | mW |
| T_J | Max junction temperature | 125 | $^{\circ}$ C |
| T_{STG} | Storage temperature range | -65 to 125 | $^{\circ}$ C |
| T_{OP} | Operating junction temperature range | -40 to 85 | $^{\circ}$ C |

Table 3. Thermal Data

| Symbol | Parameter | Value | Unit |
|------------|-------------------------------------|-------|----------------|
| R_{thJC} | Thermal resistance junction-case | 81 | $^{\circ}$ C/W |
| R_{thJA} | Thermal resistance junction-ambient | 255 | $^{\circ}$ C/W |

4 Electrical characteristics

Table 4. Electrical characteristics

 ($V_{CC} = 5V$, $C_1 = 1\mu F$, $T_J = -40$ to 85° unless otherwise specified) (*Note 1*).

| Symbol | Parameter | Test | Min. | Typ. | Max. | Unit | |
|---------------------|---|---|--------------------------|---------|---------|---------|----|
| V_{CC} | Supply voltage | | 4.25 | | 6.5 | V | |
| I_{CC} | Supply current (<i>Note 2</i>) | Charge mode, $R_{PROG} = 10K\Omega$, $V_{BAT} = 3.5V$ | | 150 | 500 | μA | |
| | | Standby mode (charge terminated) | | 150 | 300 | | |
| | | Shutdown mode | R_{PROG} not connected | | 21 | | 40 |
| | | | $V_{CC} < V_{BAT}$ | | 17 | | 50 |
| | | $V_{CC} < V_{UV}$ | | 17 | 40 | | |
| V_{BAT} | Termination output voltage | $V_{CC} = 4.3V$ to $6.5V$, $R_{PROG} = 10K\Omega$ | 4.158 | 4.2 | 4.242 | V | |
| I_{BAT} | BAT pin current | Current mode $R_{PROG} = 10K\Omega$ | 90 | 100 | 110 | mA | |
| | | Current mode $R_{PROG} = 2K\Omega$ | 465 | 500 | 535 | mA | |
| | | Standby mode $V_{BAT} = 4.2V$ | 0 | -2.5 | -6 | μA | |
| | | Shutdown mode (R_{PROG} not connected), $T_J = 25^\circ C$ | | ± 1 | ± 2 | μA | |
| | | Sleep mode, $V_{CC} = 0V$, $T_J = 25^\circ C$ | | ± 1 | ± 2 | μA | |
| I_{PRE} | Pre-charge current | $V_{BAT} < 2.8V$ $R_{PROG} = 2K\Omega$ $T_J = 25^\circ C$ | 20 | 45 | 70 | mA | |
| V_{PRE} | Pre-charge threshold | $R_{PROG} = 10K\Omega$ V_{BAT} falling | 2.8 | 2.9 | 3.0 | V | |
| | | Hysteresis $R_{PROG} = 10K\Omega$ | 70 | 100 | 130 | mV | |
| V_{UV} | V_{CC} Undervoltage lockout | V_{CC} Low to High $R_{PROG} = 10K\Omega$ | 3.7 | 3.8 | 3.9 | V | |
| | | Hysteresis $R_{PROG} = 10K\Omega$ | 50 | 180 | 300 | mV | |
| V_{MSD} | Manual shutdown threshold | PROG Pin Rising | 1.15 | 1.21 | 1.30 | V | |
| | | PROG Pin Falling | 0.85 | 0.95 | 1.05 | | |
| V_{ASD} | $V_{CC} - V_{BAT}$ Lockout threshold | V_{CC} Low to High $T_J = 25^\circ C$ $R_{PROG} = 10K\Omega$ | 50 | 85 | 120 | mV | |
| | | V_{CC} High to Low $T_J = 25^\circ C$ $R_{PROG} = 10K\Omega$ | 5 | 30 | 50 | | |
| I_{TERM} | C/10 Termination current threshold (I_{BAT}/I_{BATC10}) (<i>Note 3</i>) | $R_{PROG} = 10K\Omega$ | | 0.1 | | mA/mA | |
| | | $R_{PROG} = 2K\Omega$ | | 0.1 | | | |
| V_{PROG} | PROG pin voltage | Current Mode $R_{PROG} = 10K\Omega$ | 0.93 | 1.0 | 1.07 | V | |
| I_{CHRG} | CHRG Pin current weak pull-down | $V_{CHRG} = 5V$, $V_{BAT} = 4.3V$, $R_{PROG} = 10K\Omega$ | 8 | 20 | 35 | μA | |
| V_{CHRG} | CHRG Pin pull-down voltage | $I_{CHRG} = 5mA$ | | 0.35 | 0.6 | V | |
| ΔV_{RECHRG} | Recharger battery threshold voltage | $V_{FLOAT} - V_{RECHRG}$, $T_J = 25^\circ C$ $R_{PROG} = 10K\Omega$ | | 200 | | mV | |

Table 4. Electrical characteristics(V_{CC} = 5V, C₁ = 1μF, T_J = -40 to 85° unless otherwise specified) (*Note 1*).

| Symbol | Parameter | Test | Min. | Typ. | Max. | Unit |
|-----------------------|---|--|------|------|------|------|
| T _{LIM} | Junction temperature in constant current mode | | | 120 | | °C |
| R _{ON} | Power Fet "ON" resistance (Between V _{CC} and BAT) | | | 600 | | mΩ |
| t _{SS} | Soft-start time | I _{BAT} =0 to I _{BAT} =1000V/R _{PROG} | | 100 | | μs |
| T _{RECHARGE} | Recharge comparator filter time <i>Note 4</i> | V _{BAT} High to Low | 0.75 | 2 | 4.5 | ms |
| t _{TERM} | Termination comparator filter time <i>Note 4</i> | I _{BAT} Falling Below I _{CHG} /10 | 400 | 1000 | 2500 | μs |
| I _{PROG} | PROG pin pull-up current | | | 1 | | μA |

- Note:*
- 1 The STC4054 was tested using a battery simulator and an output capacitor value about 4.7μF
 - 2 Supply current includes PROG pin current but not include any current delivered to the battery through the V_{BAT} pin
 - 3 I_{TERM} is expressed as a fraction of measured full charge current with indicated PROG resistor
 - 4 Guaranteed by design

5 Typical performance characteristics

Figure 4. I_{BAT} vs Supply voltage

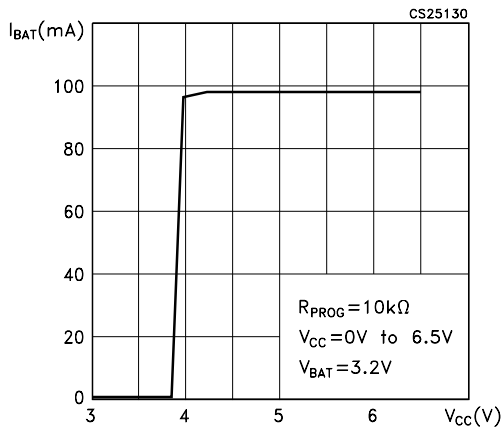


Figure 5. V_{BAT} vs V_{CC}

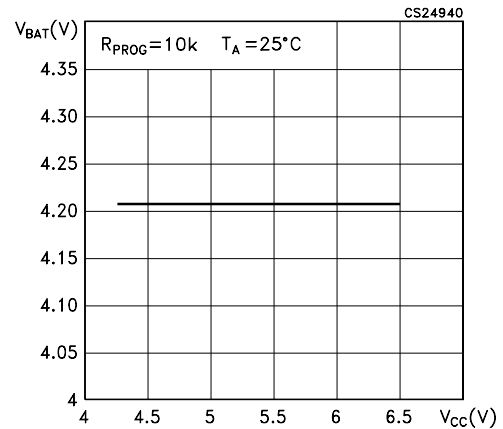


Figure 6. I_{BAT} vs temperature

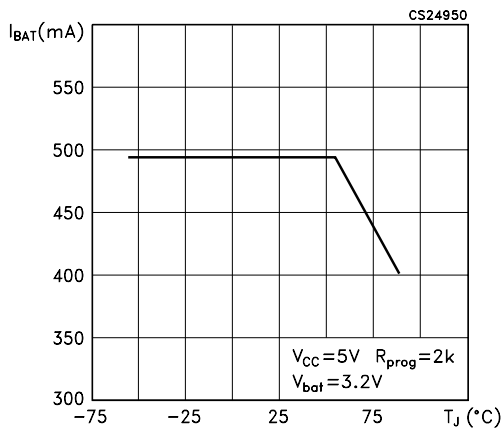


Figure 7. V_{PROG} vs temperature

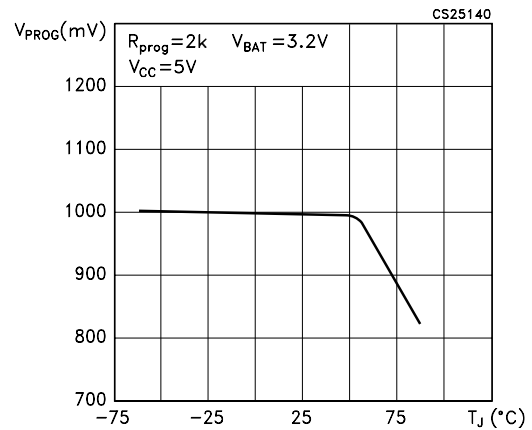


Figure 8. I_{BAT}/I_{PROG} vs temperature

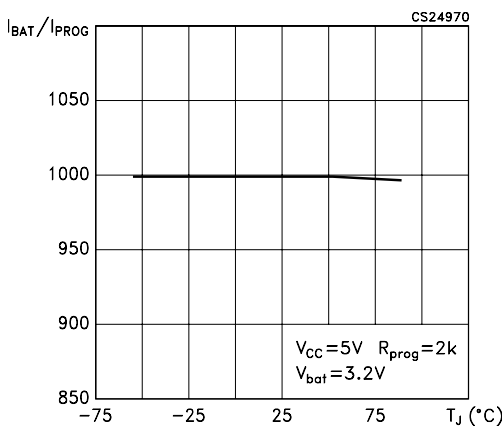


Figure 9. I_{BAT} vs V_{PROG}

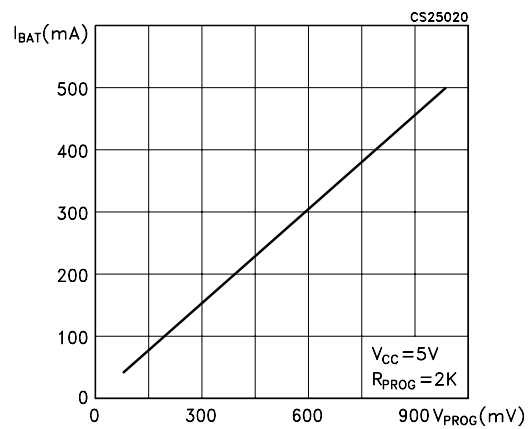


Figure 10. I_{BAT}/I_{PROG} vs V_{CC}

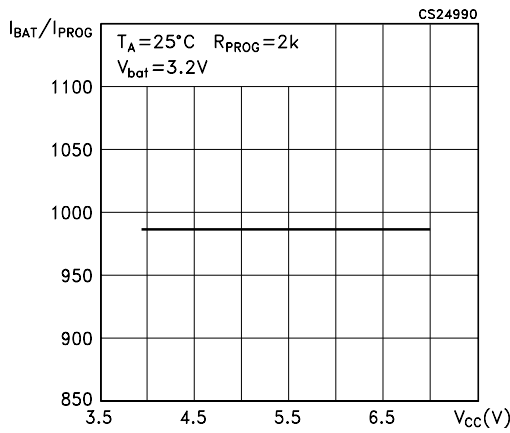


Figure 11. V_{CHRG} vs temperature (CHRG pin output low voltage)

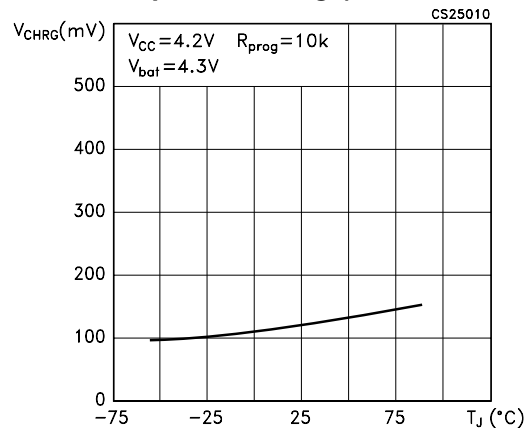


Figure 12. I_{CHRG} vs temperature (CHRG pin weak pull down current)

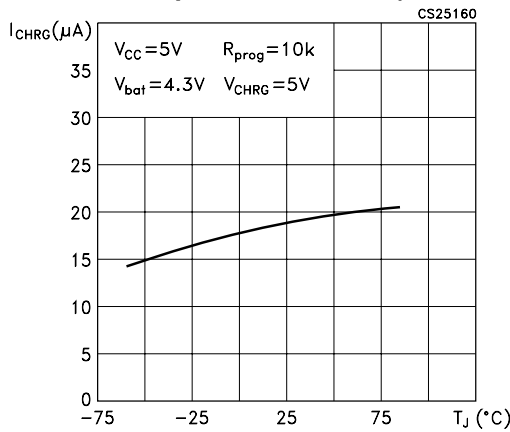


Figure 13. Power FET "ON" resistance

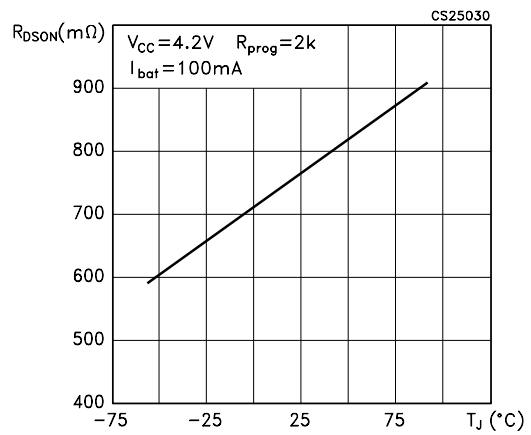


Figure 14. I_{BAT} vs V_{BAT}

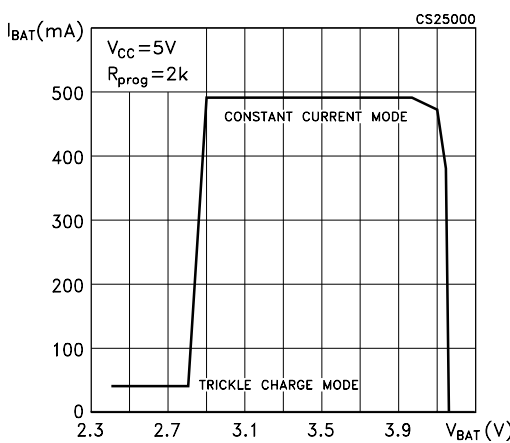
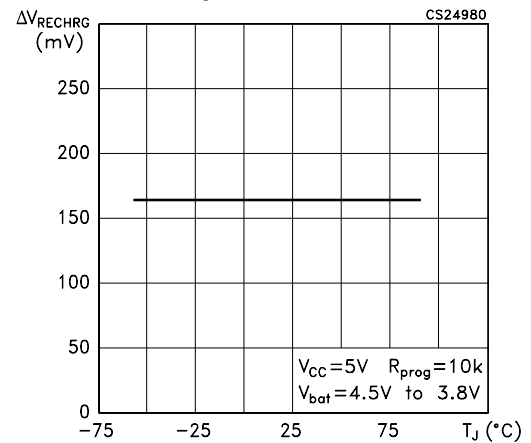


Figure 15. Recharge battery threshold voltage vs. temperature



6 Application information

The STC4054 uses an internal P-Channel MOSFET to work in constant current and constant voltage method. It is able to provide up to 800mA with a final regulated output voltage of $4.2V \pm 1\%$ in full temperature range. No blocking diode and sensing resistor are required. It is also possible to use an USB port as power supply voltage.

6.1 Charge cycle

A charge cycle begins when the voltage at the V_{CC} pin rises above the UVLO threshold level, the R_{PROG} program resistor of 1% is connected between the PROG pin to GND pin and when a battery is connected to the charger output. If the battery voltage is below 2.9V, the charger enters in Trickle Charge mode. In this condition, the device supplies 1/10 of the programmed charge current to bring the battery voltage up to safe level otherwise the life of a battery is reduced. If the BAT pin voltage is higher than 2.9V the charger enters in Constant Current Mode. When the BAT pin voltage is close to the final float voltage (4.2V) the device enters in Constant Voltage Mode and the charge current begins to decrease. The charge cycle is terminated when the current drops to 1/10 of the programmed value.

6.2 V_{CC} Pin

Input Supply Voltage. This pin is used to supply the device in the range from 4.25V to 6.5V voltage. A bypass capacitor of 1 μ F is recommended for use. When V_{CC} value drops of 30mV of the BAT pin voltage, the device enters in Shutdown Mode, dropping I_{BAT} to less than 2 μ A.

6.3 CHRG pin

This is a flag open drain. It indicates three different status of the output. When the charge is in progress this pin is pulled low instead at the end of the charge cycle, a weak pull down of approximately 20 μ A is connected to the CHRG pin, indicating a present supply power; if the flag is forced high impedance an under voltage condition is detected.

6.4 PROG pin

Charge Current Program, Charge Current Monitor and Shutdown Pin. The charge current is programmed by connecting a 1% resistor, R_{PROG} , to ground. When the device is charging in constant current, the value of voltage on this pin is 1.0V. In other conditions, the voltage on this pin can be used to measure the charge current using the following formula:

$$I_{BAT} = (V_{PROG}/R_{PROG}) * 1000$$

The PROG pin is used to shut down the device, disconnecting the program resistor from ground a 1 μ A current flows to pull the PROG pin high. If the value of this Pin is 1.21V (shutdown threshold voltage), the device enters Shutdown mode and the input supply current drops to 25 μ A. Driving this pin to voltage beyond 2.4V a current of 35 μ A flows into the device from PROG pin.

6.5 Programming charge current

The R_{PROG} resistor is used to set the charge current value. The battery charge current is 1000 times the Prog pin current value. The program resistor and the charge current are calculated using the following formula:

$$R_{\text{PROG}} = 1000 \cdot V_{\text{PROG}} / I_{\text{BAT}}$$

The charge current out of the BAT pin can be monitored through the PROG pin voltage using the following equation:

$$I_{\text{BAT}} = (V_{\text{PROG}} / R_{\text{PROG}}) \times 1000$$

6.6 Charge status indicator (CHRG)

The charge status output has three different states: Strong pull-down ($\sim 10\text{mA}$), weak pull-down ($20\mu\text{A}$) and high impedance. The strong pull-down indicates that the device is charging the battery. Weak pull-down indicates that V_{CC} meets the UVLO conditions and the device is ready to charge. The last status high impedance indicates an insufficient voltage is applied to the V_{CC} pin or the voltage on V_{CC} is less than 100mV above the BAT pin voltage.

6.7 BAT pin

Charge Current Output pin. It provides charge current to the battery and regulates the final float voltage to 4.2V. An internal precision resistor is used as a feedback loop to compare the V_{O} with the reference.

6.8 Charge termination

A charge cycle is terminated when the final float voltage is reached consequently the charge current falls to 1/10th of the programmed value. The charge is over when the PROG pin voltage falls below 100mV for longer time than t_{TERM} ($\sim 1\text{ms}$). The charge current is latched off, the device enters in standby mode and the input supply current drops to $200\mu\text{A}$.

6.9 Automatic recharge

The device restarts the charge cycle when the battery voltage falls below 4.05V to maintain the battery capacity value higher than 80%. During the recharge time, the CHRG pin goes low state.

6.10 Soft start

When a charge cycle starts, a internal soft start circuit minimizes the inrush current. At starting phase, the charge current ramps from zero to the full scale in a $100\mu\text{s}$ period time.

6.11 Thermal regulation

An internal thermal feedback loop reduces the output current if the die temperature attempts to rise above a present value of approximately 120°C. This feature protects the device from excessive temperature and allows the user to push the limits of the power handling capability of a given circuit board without risk of damaging the device.

6.12 Power dissipation

It is very important to use a good thermal PC board layout to maximize the available output current. The thermal path for the heat generated by the IC is from the die to the copper lead frame through the package leads and exposed pad to the PC board copper. The PC board copper is the heat sink. The footprint copper pads should be as wide as possible and expand out to larger copper areas to spread and dissipate the heat to the surrounding ambient. Feed through vias to inner or backside copper layers are also useful in improving the overall thermal performance of the device. Other heat sources on the board, not related to the device, must also be considered when designing a PC board layout because they will affect overall temperature rise and the maximum output current.

6.13 Stability considerations

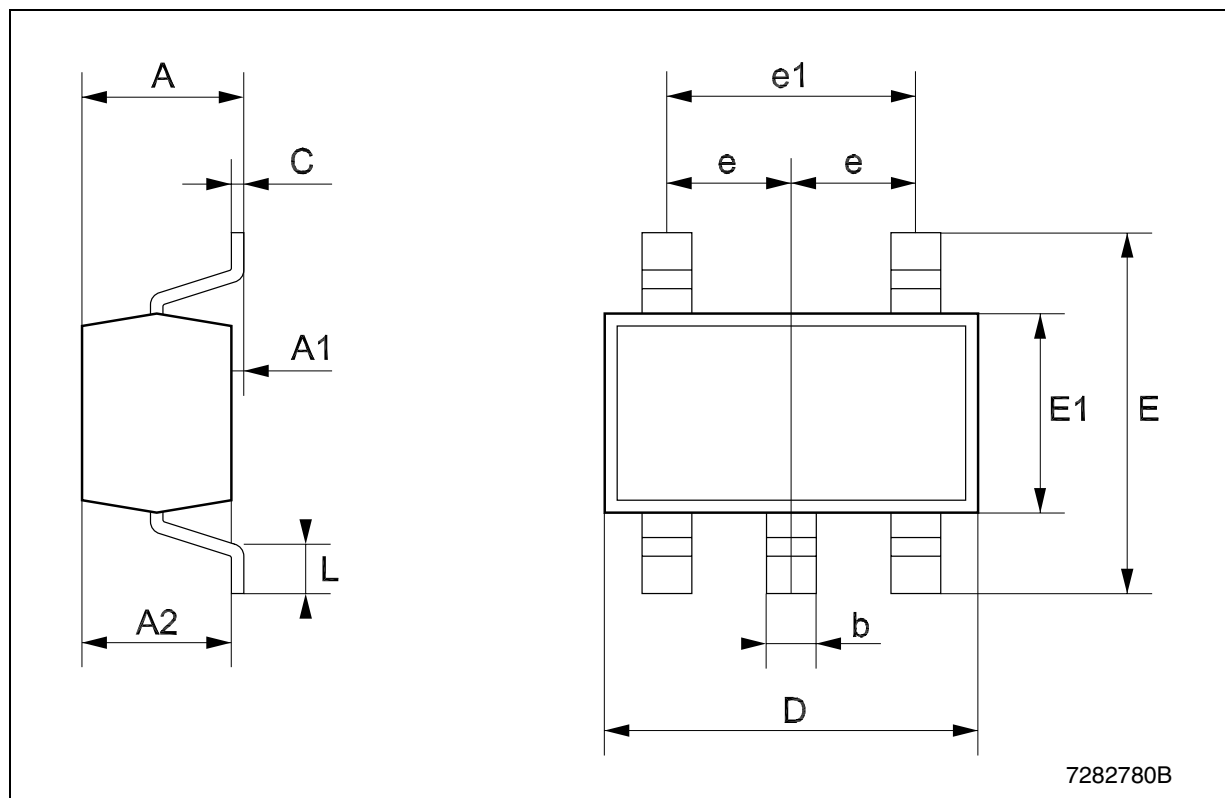
The STC4054 contains two control loops: constant voltage and constant current. The constant-voltage loop is stable without any compensation when a battery is connected with low impedance leads. Excessive lead length, however, may add enough series inductance to require a bypass capacitor of at least 1µF from BAT to GND. Furthermore, a 4.7µF capacitor with a 0.2Ω to 1Ω series resistor from BAT to GND is required to keep ripple voltage low when the battery is disconnected.

7 Package mechanical data

In order to meet environmental requirements, ST offers these devices in ECOPACK® packages. These packages have a Lead-free second level interconnect. The category of second Level Interconnect is marked on the package and on the inner box label, in compliance with JEDEC Standard JESD97. The maximum ratings related to soldering conditions are also marked on the inner box label. ECOPACK is an ST trademark. ECOPACK specifications are available at: www.st.com.

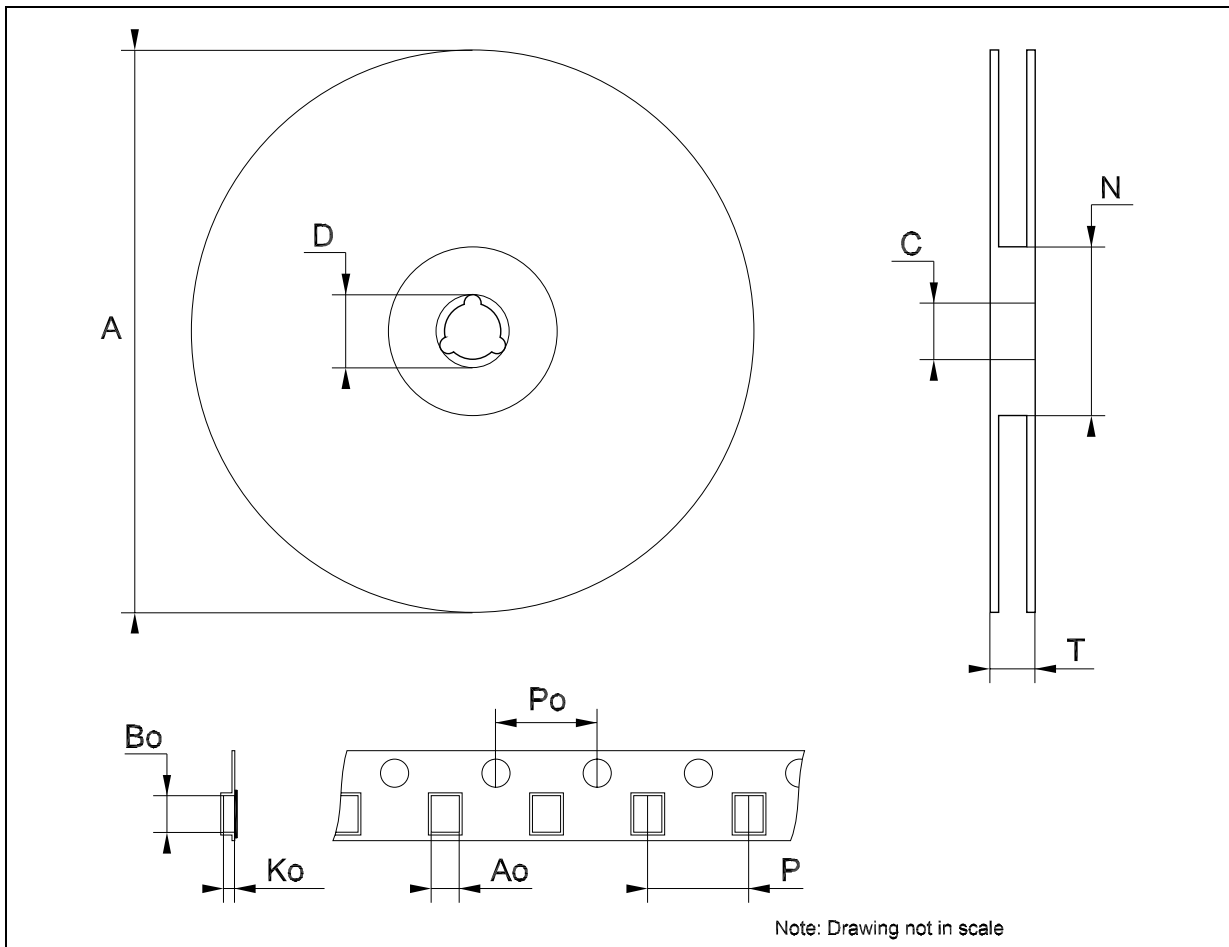
TSOT23-5L MECHANICAL DATA

| DIM. | mm. | | | mils | | |
|------|------|------|------|------|-------|------|
| | MIN. | TYP | MAX. | MIN. | TYP. | MAX. |
| A | | | 1.1 | | | 43.3 |
| A1 | 0 | | 0.1 | | | 3.9 |
| A2 | 0.7 | | 1.0 | 27.6 | | 39.4 |
| b | 0.3 | | 0.5 | 11.8 | | 19.7 |
| C | 0.08 | | 0.2 | 3.1 | | 7.9 |
| D | | 2.9 | | | 114.2 | |
| E | | 2.8 | | | 110.2 | |
| E1 | | 1.6 | | | 63.0 | |
| e | | 0.95 | | | 37.4 | |
| e1 | | 1.9 | | | 74.8 | |
| L | 0.3 | | 0.6 | 11.8 | | 23.6 |



Tape & Reel SOT23-xL MECHANICAL DATA

| DIM. | mm. | | | inch | | |
|------|------|------|------|-------|-------|-------|
| | MIN. | TYP | MAX. | MIN. | TYP. | MAX. |
| A | | | 180 | | | 7.086 |
| C | 12.8 | 13.0 | 13.2 | 0.504 | 0.512 | 0.519 |
| D | 20.2 | | | 0.795 | | |
| N | 60 | | | 2.362 | | |
| T | | | 14.4 | | | 0.567 |
| Ao | 3.13 | 3.23 | 3.33 | 0.123 | 0.127 | 0.131 |
| Bo | 3.07 | 3.17 | 3.27 | 0.120 | 0.124 | 0.128 |
| Ko | 1.27 | 1.37 | 1.47 | 0.050 | 0.054 | 0.058 |
| Po | 3.9 | 4.0 | 4.1 | 0.153 | 0.157 | 0.161 |
| P | 3.9 | 4.0 | 4.1 | 0.153 | 0.157 | 0.161 |



8 Revision history

Table 5. Revision history

| Date | Revision | Changes |
|-------------|----------|------------------|
| 04-Sep-2006 | 1 | Initial release. |

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